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**Technologies for Sustainable Development**
**European IPPC Bureau**

# Integrated Pollution Prevention and Control

# Draft Reference Document on Best Available Techniques in the Food, Drink and Milk Industry

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# EXECUTIVE SUMMARY

# PREFACE

## 1. Status of this document

Unless otherwise stated, references to “the Directive” in this document means the Council Directive 96/61/EC on integrated pollution prevention and control (IPPC).
This document is a working draft of the European IPPC Bureau. It is not an official publication of the European Communities and does not necessarily reflect the position of the European Commission.

## 2. Relevant legal obligations of the IPPC Directive and the definition of BAT

In order to help the reader understand the legal context in which this document has been drafted, some of the most relevant provisions of the IPPC Directive, including the definition of the term “best available techniques”, are described in this preface. This description is inevitably incomplete and is given for information only. It has no legal value and does not in any way alter or prejudice the actual provisions of the Directive.

The purpose of the Directive is to achieve integrated prevention and control of pollution arising from the activities listed in its Annex I, leading to a high level of protection of the environment as a whole. The legal basis of the Directive relates to environmental protection. Its implementation should also take account of other Community objectives such as the competitiveness of the Community’s industry thereby contributing to sustainable development.

More specifically, it provides for a permitting system for certain categories of industrial installations requiring both operators and regulators to take an integrated, overall look at the polluting and consuming potential of the installation. The overall aim of such an integrated approach must be to improve the management and control of industrial processes so as to ensure a high level of protection for the environment as a whole. Central to this approach is the general principle given in Article 3 that operators should take all appropriate preventative measures against pollution, in particular through the application of best available techniques enabling them to improve their environmental performance.

The term “best available techniques” is defined in Article 2(11) of the Directive as “the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.” Article 2(11) goes on to clarify further this definition as follows:

“techniques” includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

“available” techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

“best” means most effective in achieving a high general level of protection of the environment as a whole.

Furthermore, Annex IV of the Directive contains a list of “considerations to be taken into account generally or in specific cases when determining best available techniques ... bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention”. These considerations include the information published by the Commission pursuant to Article 16(2).

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. According to Article 9(4) of the Directive, these emission limit values, equivalent parameters and technical measures must, without prejudice to compliance with environmental quality standards, be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In all circumstances, the conditions of the permit must include provisions on the minimisation of long-distance or transboundary pollution and must ensure a high level of protection for the environment as a whole.

Member States have the obligation, according to Article 11 of the Directive, to ensure that competent authorities follow or are informed of developments in best available techniques.

## 3. Objective of this Document

Article 16(2) of the Directive requires the Commission to organise “an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them”, and to publish the results of the exchange.

The purpose of the information exchange is given in recital 25 of the Directive, which states that “the development and exchange of information at Community level about best available techniques will help to redress the technological imbalances in the Community, will promote the world-wide dissemination of limit values and techniques used in the Community and will help the Member States in the efficient implementation of this Directive.”

The Commission (Environment DG) established an information exchange forum (IEF) to assist the work under Article 16(2) and a number of technical working groups have been established under the umbrella of the IEF. Both IEF and the technical working groups include representation from Member States and industry as required in Article 16(2).

The aim of this series of documents is to reflect accurately the exchange of information which has taken place as required by Article 16(2) and to provide reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques, these documents should act as valuable tools to drive environmental performance.

## 4. Information Sources

This document represents a summary of information collected from a number of sources, including in particular the expertise of the groups established to assist the Commission in its work, and verified by the Commission services. All contributions are gratefully acknowledged.

## 5. How to understand and use this document

The information provided in this document is intended to be used as an input to the determination of BAT in specific cases. When determining BAT and setting BAT-based permit conditions, account should always be taken of the overall goal to achieve a high level of protection for the environment as a whole.

The rest of this section describes the type of information that is provided in each section of the document.

Chapters 1 and 2 provide general information on the industrial sector concerned and on the industrial processes used within the sector. Chapter 3 provides data and information concerning current emission and consumption levels reflecting the situation in existing installations at the time of writing.

Chapter 4 describes in more detail the emission reduction and other techniques that are considered to be most relevant for determining BAT and BAT-based permit conditions. This information includes the consumption and emission levels considered achievable by using the technique, some idea of the costs and the cross-media issues associated with the technique, and the extent to which the technique is applicable to the range of installations requiring IPPC permits, for example new, existing, large or small installations. Techniques that are generally seen as obsolete are not included.

Chapter 5 presents the techniques and the emission and consumption levels that are considered to be compatible with BAT in a general sense. The purpose is thus to provide general indications regarding the emission and consumption levels that can be considered as an appropriate reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9(8). It should be stressed, however, that this document does not propose emission limit values. The determination of appropriate permit conditions will involve taking account of local, site-specific factors such as the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In the case of existing installations, the economic and technical viability of upgrading them also needs to be taken into account. Even the single objective of ensuring a high level of protection for the environment as a whole will often involve making trade-off judgements between different types of environmental impact, and these judgements will often be influenced by local considerations.

Although an attempt is made to address some of these issues, it is not possible for them to be considered fully in this document. The techniques and levels presented in chapter 5 will therefore not necessarily be appropriate for all installations. On the other hand, the obligation to ensure a high level of environmental protection including the minimisation of long-distance or transboundary pollution implies that permit conditions cannot be set on the basis of purely local considerations. It is therefore of the utmost importance that the information contained in this document is fully taken into account by permitting authorities.

Since the best available techniques change over time, this document will be reviewed and updated as appropriate. All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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# Best Available Techniques Reference Document on Food, Drink and Milk

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# SCOPE

The food, drink and milk best available techniques (BAT) reference document (BREF) is made for the activities listed in Annex 1 parts 6.4. (b) and (c) of Council Directive 96/61/EC of 24 September 1996 on integrated pollution prevention and control (IPPC Directive), i.e.,

“**6.4. (b) Treatment and processing intended for the production of food products from:**

- **animal raw materials (other than milk) with a finished product production capacity greater than 75 tonnes per day**
- **vegetable raw materials with a finished product production capacity greater than 300 tonnes per day (average value on a quarterly basis)**

**(c) Treatment and processing of milk, the quantity of milk received being greater than 200 tonnes per day (average value on an annual basis)”**

The intention is to cover the whole range of activities that may be found in European installations with capacities exceeding the above threshold values.

The BREF does not cover small scale activities, such as catering or activities in restaurants.
Also, food industrial activities that do not use animal or vegetable raw materials are not covered, except as associated activities, e.g. mineral water processing and production of salt.

Agriculture, hunting and the slaughtering of animals are excluded. The manufacture of products other than food, e.g. soap, candles, cosmetics pharmaceuticals; manufacture of gelatine and glue from hides, skin and bones are also excluded.

Generally packaging is not included but the packing of food and drink products on the premises is included.

Animal feed of animal and vegetable origin are also covered.

# 1 GENERAL INFORMATION

## 1.1 Description, turnover, growth, employment

The food and drink industry is the leading sector of industrial activity in the EU, with a total production value amounting to EUR 572 billion in 1999.

The industry produces both finished products destined for consumption and intermediate products destined for further processing. A sectoral breakdown in the EU shows that for most food and drink product categories production exceeds consumption.

Average real annual growth rates of consumption and production are slow; a typical trend of mature markets, e.g. growth during 1997 was less than 2 %.

In employment terms, the food-processing sector employs a workforce of 2.6 million. This represents 11 % of the industrial workforce in Europe.

Data of some European countries are presented in Table 1.1 and in Table 1.2.

| 1998 | Turnover (billion EUR) | Number of employees | Number of companies | Exports (billion EUR) | Imports (billion EUR) |
|---|---|---|---|---|---|
| Austria | 8 | 60579 | 1386 | | |
| Belgium | 22.7 | 86797 | 6776 | 10.7 | 9.42 |
| United Kingdom | 100.5 | 490000 | 2412 | 14 | 26.1 |
| Czech Republic | | 142000 | 947 | 1 | 1.52 |
| Denmark | 14 | 81115 | 312 | - | - |
| The Netherlands | 34 | 108000 | 887 | - | - |
| Estonia | 0.61 | 21125 | 138 | 0.228 | 0.4 |
| Finland | 8.16 | 49000 | 713 | 0.84 | 1.24 |
| France | 122.4 | 403000 | 4250 | 18 | 8.3 |
| Germany | 116.6 | 545000 | 6134 | 19.07 | 23.06 |
| Greece | 5 | 49000 | 524 | - | - |
| Hungary | 8.24 | 131000 | 4215 | 1.846 | 0.774 |
| Ireland | 14 | 47000 | 694 | - | - |
| Italy | | 350000 | 30000 | 10.3 | 7.2 |
| Poland | 19.65 | | | 1.18 | 1.27 |
| Portugal | 10 | 107000 | 2098 | - | - |
| Spain | 52.59 | 398000 | 3200 | 4.53 | 4.7 |
| Sweden | 13.51 | 60841 | 830 | 2.11 | 4.5 |
| **Total** | **549.96** | **3129457** | **65516** | **83.804** | **88.484** |

**Table 1.1: Structure / production by countries**
**[1, CIAA, 2002]**

| 1998 | Production | | Added value | | Employed persons | |
|---|---|---|---|---|---|---|
| | billion EUR | % | billion EUR | % | 1000 | % |
| Processed meat | 102 | 18.7 | 19 | 15.4 | 536 | 20.9 |
| Fish products | 12 | 2.2 | 3 | 2.4 | 84 | 3.3 |
| Processed fruit and vegetables | 32 | 5.9 | 8 | 6.5 | 165 | 6.4 |
| Oils and fats | 29 | 5.3 | 3 | 2.4 | 48 | 1.9 |
| Dairy products | 88 | 16.1 | 14 | 11.4 | 285 | 11.1 |
| Flour and starch products | 20 | 3.7 | 4 | 3.3 | 62 | 2.4 |
| Animal feed | 35 | 6.4 | 5 | 4.1 | 87 | 3.4 |
| Other food products | 134 | 24.6 | 42 | 34.1 | 985 | 38.4 |
| Beverages | 93 | 17.1 | 25 | 20.3 | 312 | 12.2 |
| **Total** | **545** | **100** | **123** | **100** | **2.564** | **100** |

**Table 1.2: Structure / production by sector**
**[1, CIAA, 2002]**

## 1.2 Industry structure

Available statistics show that the EU food and drink industry comprises close to 26000 companies, most of which have over 20 employees.

The EU food and drink industry is exceptionally diverse compared to many other industrial sectors. It is diverse in terms of the size and nature of companies throughout the EU; the range of raw materials, products and processes and the countless combinations of each; the demands of consumers, both for homogenised global products and demands for numerous specialist or traditional products on national and even regional scales; and is subject to very diverse local economic, social and environmental conditions.

The EU food and drink industry is quite fragmented with a high incidence (ca. 92 %) of small and medium sized companies, although there are some sectors, such as sugar manufacturing, which have very large plants. This fragmentation and diversity makes it difficult to ascertain exact figures for the industry as a whole. Also although it is certain that the concentration of the industry remains weak in contrast to other sectors, it remains difficult to ascertain exact figures due to divergent data collection systems in individual States.

The industry is spread all over Europe. Food industrial plants can be found in very industrialised regions but they are also present in rural areas. Traditionally, industrial production has been closely related to primary food production, so that natural resources (land, water) and climate has always influenced its structure and geographical distribution. Although this kind of dependence is being reduced, differences still exist. Some sectors are concentrated in special regions, e.g. fish processing is usually found in countries (or regions) which have direct access to the sea and traditions of fishing; olive oil is mainly manufactured in the Mediterranean countries, especially in Andalucía in Spain, whilst other activities such as sugar production/refining, grain milling or dairy industries are found in all countries. Those food industrial activities which have special requirements for natural resources, especially water, are normally situated near to those resources, e.g. sugar plants, refineries, fruit and vegetable preservation plants are normally situated near to water.

## 1.3 Trade

For many European enterprises, non-European exports constitute an important strategic activity. In 1999, food and drink industry exports amounted to EUR 37 billion (79 % of European global exports of agricultural and food products). This is a slight decrease over 1998 figures.

The main destination for European food products remains the United States, but the Swiss, Japanese and even Russian markets are also significant.

| 1998 | million EUR | % |
|---|---|---|
| Algeria | 769 | 2.0 |
| Australia | 533 | 1.4 |
| Brazil | 541 | 1.4 |
| Canada | 1027 | 2.7 |
| Czech Republic | 576 | 1.5 |
| Israel | 455 | 1.2 |
| Japan | 2977 | 7.8 |
| Mexico | 333 | 0.9 |
| Norway | 860 | 2.3 |
| Poland | 1114 | 2.9 |
| Russia | 3241 | 8.5 |
| Switzerland | 2194 | 5.8 |
| Turkey | 4254 | 1.1 |
| United States | 6345 | 16.7 |
| **Total** | **38069** | **100** |

**Table 1.3: Main export destinations**
**[1, CIAA, 2002]**

| Sectors | % |
|---|---|
| Dairy products | 11.2 |
| Flour and starch products | 4.7 |
| Oils and fats | 7.7 |
| Processed meat | 10.6 |
| Fish products | 2.1 |
| Animal feed | 4.9 |
| Beverages | 25.1 |
| Fruit and vegetables | 5.8 |
| Other food products | 27.9 |

**Table 1.4: Export by sector 1998**
**[1, CIAA, 2002]**

# 1.4 Food and drink in figures

## 1.4.1 Statistical data of some European countries

As examples, some data is presented.

- Details were provided for the **Belgian fruit and vegetable industry**.

| NACE-Bel Code | Description | Flanders | Wallonia | Brussels | Belgium |
|---|---|---|---|---|---|
| 15.31 | Processing and preserving of potatoes | 23 | 5 | 0 | 28 |
| 15.32 | Manufacture of fruit and vegetable juices | 6 | 2 | 2 | 10 |
| 15.33 | Processing and preserving of fruit and vegetables | 54 | 10 | 1 | 65 |
| *Source: Social Security Administration statistics 1996, NIS* | | | | | |

**Table 1.5: Number of fruit and vegetable firms in Belgium**

| Number of employees | Potatoes Nace-Bel 15.31 | Juices Nace-Bel 15.32 | Fruit and vegetables Nace-Bel 15.33 |
|---|---|---|---|
| 1 - 4 | 12 | 2 | 17 |
| 5 - 9 | 3 | 2 | 5 |
| 10 - 19 | 1 | 0 | 4 |
| 20 - 49 | 2 | 0 | 9 |
| 50 - 99 | 2 | 0 | 11 |
| 100 - 199 | 2 | 2 | 5 |
| 200 - 499 | 0 | 0 | 3 |
| >500 | 1 | 0 | 0 |
| Total | 23 | 6 | 54 |
| *Source: Social Security Administration statistics 1996, NIS* | | | |

**Table 1.6: Company size distribution in Flanders in fruit and vegetable industry**

The majority of firms operating in this sector are mainly small and medium-sized firms. In the potato sector, half the firms shown in these statistics have fewer than five employees (mainly preserves companies), and there is only one large company with over 500 employees (a potatoes processor). In vegetable processing, the number of firms with fewer than five employees is limited to one-third, while the genuine processors (deep frozen and preserves) are typically medium-sized firms.

- **Finland** provided information how many of the total number of food industrial plants are considered to be covered by IPPC Directive:

| Sector | No. of plants | | Size (Range) | Production capacity |
|---|---|---|---|---|
| | Total | Connected to sewer | | |
| 1.Dairies | | | | |
| Milk | | | | |
| Powdered milk production | 7 | | | 25 900 t |
| Cheese production | 27 | | | 92 400 t |
| Butter, butterfat production | 10 | | | 59 700 t |
| Yoghurt production | 3 | | | 203 000 t |
| Casein, whey, lactose production | 1 | | | |
| 2.Ice cream | 3 | | | 61700 |
| 3. Oil | | | | |
| Processing of oilseeds | 4 | Yes | 2 IPPC plants | |
| Processing of olives | | | | |
| Margarine, reduced fat and low fat spreads | 1 | 1 | | |
| 4. Cocoa, chocolate, fine bakery wares, sugar confectionery, bakery products | | | | |
| Cocoa, chocolate | 4 | yes | | |
| Caramels, sweets, etc. | 6 | yes | | |
| Cakes and flour confectionery, etc. | 500 | yes | | |
| Bakery products | 500 | yes | | |
| 5. Potato processing (excluding starch production) | 8+ appr. 50 peeling plants | no | 1 IPPC plant | |
| 6. Fruits and vegetables processing (excluding potato processing) | | | | |
| Jams, jellies, marmalades, etc. production of fruit | 5+ appr. 10 small | yes | | |
| Canned, frozen products; ready made food products of vegetables | 2+ some small | yes | | |
| 7. Sugar production | | | | |
| Sugar beet processing | 2 | No | 2 IPPC size | |
| Sugar refining | 1 | No | IPPC size | |
| 8. Starch production | | | | |
| Production of starch from potato or cereals (mainly wheat and maize) | 3 | No | IPPC size | |
| Production of dried and liquid sugars from starch hydrolisates | 1 | yes | | |
| 9.Production of coffee and chicory extract | 3 | yes | | |
| 10. Grain milling | 5 + small | | 5 IPPC plants | |
| 11. (Breakfast) Cereals processing | 2 | yes | | |
| 13. Meat processing | | | | |
| Fresh meat | Approx.40 | most, yes | 4-5 IPPC | 454 000 t/yr |
| Preserved products (sausages …) | 49 | | | |
| Cooked meat, pies, burgers, ready m. | Approx.20 | | | |
| Canned, frozen, dried products | 3 | | | |
| 14. Animal feed production | 2 | | 2 IPPC | |
| 15. Fish processing (Fish & see food) | | | | |
| Frozen fish production | Approx. 5 | No | | |
| Dried, salted or smoked fish prod. | Approx.30 | No | | |
| Prepared or preserved /ready to eat/ | Approx. 5 | | | |
| 16. Malt production | 2 | yes | | |
| 17. Beer production | 8 | Yes | 5 IPPC | 96000 t/yr |

| | | | | |
|---|---|---|---|---|
| 18. Spirits production | | | | |
| Alcohol fermentation + distillation | 2 | 1 | 1 IPPC | |
| Yeast fermentation | 1 | No | | |
| Vinegar fermentation | 1 | | | |
| Production of whiskies, vodka, rum, gin, brandy | 2 see above | | | |
| Production of punch & cocktails, liqueurs, etc. | 4 | | | |
| 19. Wine production | | | | |
| Wine (of grape) | | | | |
| Sparkling, fortified (liquor) wine | 1 | | | |
| Cider & fruit wine | 6 + small | most | | |
| 20. Non-alcoholic beverages | | | | |
| Beverages (juices and concentrates) | 5+ small | yes | | |
| Water based drinks | 3 | yes | | |

**Table 1.7: Number and size of food industrial plants in Finland**
**[78, Finland, 2001]**

- Germany provided detailed information regarding production breakdown and trends in several sectors. The number of food industrial plants in some sectors is presented in Table 1.8.

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|
| Dairies | | | 365 | | | |
| Fresh milk | | | 220 | | | |
| Condensed and dried milk | | | 64 | | | |
| Butter | | | 157 | | | |
| Cheese | | | 217 | | | |
| Vegetable oils and fats | 12 | | | | | 12 |
| Sugar plants | | 39 | 36 | 34 | 34 | 32 |
| Starch manufacturing | | | | | | 15 |
| Coffee processing | | | | | | |
| Grain mills | | | | | | 465 |
| Meat processing | | | | | | 1139 |
| Malt production | | | | | | 30 - 32 |
| Beer production | 1282 | 1276 | 1273 | 1285 | 1279 | 1270 |
| Distilleries | | | | 100 | 93 | 91 |
| Sparkling wine | | | | | | 1401 |
| Soft drinks (water based + juices) | | | | | | 229+116 |

**Table 1.8: The number of food industrial plants in Germany for 1995 - 2000**
**[65, Germany, 2002]**

- **Greece** provided the summary of a Greek study. Different food industrial facilities were listed and a comprehensive analysis of the Greek food industrial situation was given in the summary of the study. [Panagopoulos J.; Malliaros C., 2001 #74; Panagopoulos, 2000 #29]

| Sector | Number of plants under IPPC | Total number of plants |
|---|---|---|
| Dairies | 6 | 809 |
| Vegetable oil and fat | 1 | 94 |
| Fruits and vegetable | 26 | |
| Sugar production | 5 | |
| Grain milling | 4 | 46 |
| Fish processing | 0 | 13 |
| Distillery, brewery, other drinks (159.0) | 7 | 109 |
| Bread and other products (158.1 - 158.7) | 0 | 143 |

**Table 1.9: Number of Greek food industrial plants falling under IPPC compared to total number of plants in that sector in Greece**
**[Panagopoulos J.; Malliaros C., 2001 #74]**

- **Italy** provided information on several sectors, data on the dairy industry is presented as one example.

The Italian dairy industry represents about 12 % of the turnover and about 14 % of the total workforce of the Italian manufacturing sector. The number of companies is large but because of unification is decreasing, i.e. in 1997 there were 2041 plants in Italy, which is 14.8 % less than the previous year. The average amount of milk collected was 7624 tonnes in 1997, this is much less than the EU average of above 20000 tonnes/unit. The number units receiving more than 73000 tonnes of milk a year is 15.

| | |
|---|---|
| NUMBER OF WORKERS | 29500<br>-25 % in the last 10 years with unchanged production |
| TURNOVER | EUR 11935 million<br>0.91 % increase compared to 1998 |
| EXPORTS | EUR 820 million |
| IMPORTS | EUR 2450 million |
| TRADE SURPLUS | EUR -1610 million |
| PRODUCTION PRICES | + 1 % compared to 1998 |

**Table 1.10: Macro-economical figures of Italian dairy industry**
**[79, Italy, 2001]**

- Data on **Dutch** dairy industry were given by CIAA [1, **CIAA**, 2002]

| | Production (million kg) | Export (million kg) | Import (million kg) | Consumption (kg/capita) |
|---|---|---|---|---|
| Cheese | 646 | 482 | 105 | 14.3 |
| Butter | 140 | 121 | 59 | 3.3 |
| Condensed milk[1] | 281 | 231 | 163 | |
| Non-skimmed milk powder | 110 | 190 | 102 | |
| Skimmed milk powder | 59 | 68 | 231 | |
| Whole milk[2] and cream | 186 | 206 | 268 | |

[1] incl. coffee milk
[2] raw milk without condensation with 1 - 6 % fat content

**Table 1.11: Dutch dairy industry; 1999 key figures**
**[1, CIAA, 2002]**

- **Portugal** provided data on several sectors:

| Sector | No. of plants | | Size (Range) | Production capacity (t/yr) |
|---|---|---|---|---|
| | Total | Connected to sewer | | |
| 1.Dairies (Total<br>IPPC) | 294<br>7 IPPC | 25 - 30 %<br>3 IPPC | 0 - 100 t/d: 279 | 2200000 |
| 2.Ice cream | | | | |
| 3. Oil | | | | |
| Processing of oilseeds | 18<br>2 IPPC | 3<br>0 IPPC | 0 - 75:8<br>75 - 150:7 | 1000000 |
| Margarine, reduced fat and low fat spreads | 3<br>0 IPPC | 2 | 75 - 150:2<br>150 - 300:1 | 60000 |
| 6. Fruits and vegetables processing (excluding potato processing) | | | | |
| Vegetable soups, juices,… | 13<br>3 IPPC | 0 | 150 - 300 t/d :10 | |
| 7. Sugar production | | | | |
| Sugar beet processing | 2<br>1 IPPC | 0 | -75 t/d:1<br>300+: 1 | 70000 |
| Sugar refining | 2<br>2 IPPC | 2 | 300+ : 2 | 300000 |
| 8. Starch production | | | | |
| Production of dried and liquid sugars from starch hydrolisates | 1<br>0 IPPC | - | 150 - 300 t/d: 1 | - |
| 10. Grain milling | 28<br>4 IPPC | 28 | 0 - 75:2<br>75 - 150:5<br>150 - 300:2 | 640000 |
| 11. (Breakfast) Cereals processing | 11<br>0 IPPC | 11 | -100: 8<br>100 - 200:3 | 300000<br>(actual:50%) |
| 13. Meat processing | 757<br>5 IPPC | ?<br>3 | 0 - 75: 752 | |
| 14. Animal feed production | 61<br>43 IPPC | 33 % | 150 - 300:18<br>300+: 43 | 9500000 |
| 16. Malt production | 2<br>0 IPPC | | 150 - 300: 2 | |
| 17. Beer production | 5<br>2 IPPC | 0 | 0 - 75: 2<br>-300:1 | 700000 |

**Table 1.12: Number and size of food industrial plants in Portugal**
**[80, Portugal, 2001]**

## 1.4.2 Key figures of some sectors

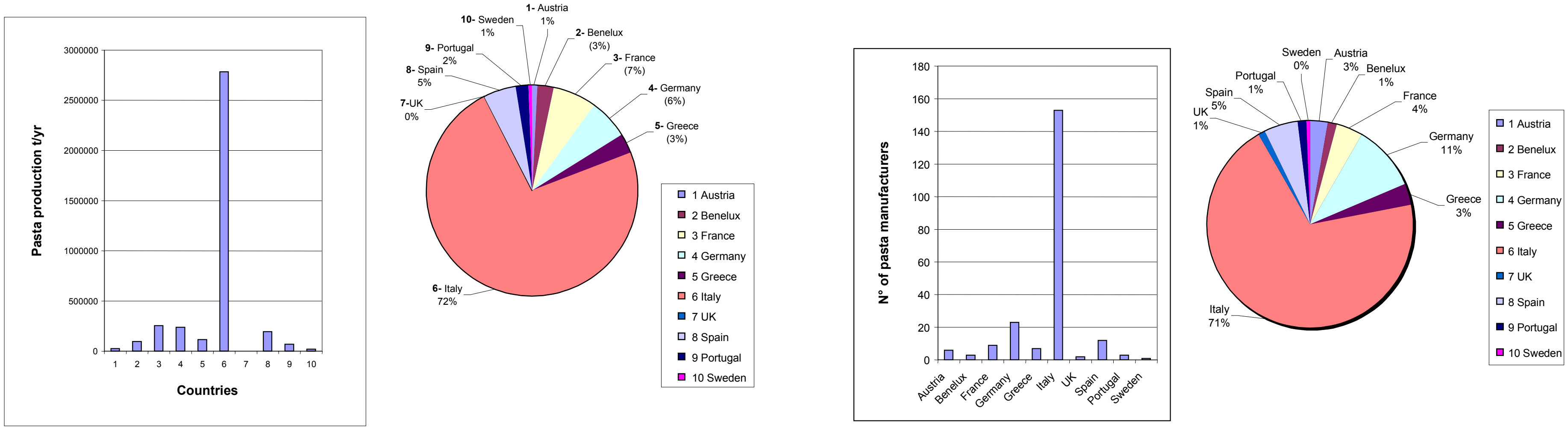


**Figure 1.1: European pasta industry; 1999 key figures**
**[1, CIAA, 2002]**

| | 1998 | 1997/98 Variations |
|---|---|---|
| Total Production (1000 hl) | 314967 | - 2.1 % |
| Number of employees | 120297 | - 6.7 % |
| Number of companies | 1729 | + 0.1 % |
| Exports (1000 hl) | 39582 | - 0.8 % |
| Imports (1000 hl) | 29399 | + 5.6 % |

**Table 1.13: European brewery industry; 1998 key figures**
**[1, CIAA, 2002]**

| | 1998 | 1997/98 Variations |
|---|---|---|
| Turnover | | |
| Number of employees | 3000 | |
| Number of companies | 212 | |
| Exports | 120000 t | |
| Imports | 1200000 t of Durum Wheat | |

**Table 1.14: European durum wheat semolina industry; 1998 key figures**
**[1, CIAA, 2002]**

| | 1998 | 1997/98 Variations |
|---|---|---|
| Turnover | EUR 42 billion | |
| Number of employees | 284641 | |
| Number of companies | 1854 | |
| Exports | EUR 3141 million | |
| Imports | EUR 602 million | |
| Share of exports in turnover | +/- 8 % | |

**Table 1.15: European industry of chocolate, biscuits and confectionery; 1998 key figures**
**[1, CIAA, 2002]**

## 1.5 Market forces: demand, distribution and competition

**Demand**
An ever increasing number of social and economic factors are affecting food and drink consumption patterns throughout the EU. These have led to some diversification from traditional consumption and purchasing models. However, although consumers have developed greater homogeneity of lifestyles, which is reflected in consumption and purchasing patterns for a growing variety of goods, food still retains, albeit with some exceptions, elements of cultural specificity linked to national tradition. Although consumers want to be able to purchase the same items and quality of foodstuffs throughout the whole of the EU they also demand different foodstuffs linked to their traditional culture; this demand can be for foodstuffs of a national, regional and even more local level and also varies for specific times throughout the year.

**Distribution**
In general, cost control activities (e.g. labour saving technologies, improvement of logistics and distribution channels, resource saving practices) have become a necessity in order to preserve producers' profit margins in highly competitive markets. In particular, distributors are squeezing producers' margins to their advantage by introducing private label goods.

In general, most food and drink products tend to be distributed to the major retail chains, although substantial differences persist within EU countries.

**Competition**
As is the case with most mature markets, the food and drink sector is facing sharp competitive pressure and progressive market concentration. In fact, even if great fragmentation persists in most EU countries, the size and the corresponding economic strength of companies is becoming crucial in balancing the increasing bargaining power of retailers and achieving the minimal “critical mass” in terms of production volumes.

## 1.6 The importance of food safety in the food and drink industry

The mission of the food and drink industry is to provide consumers with safe, high quality and wholesome foodstuffs. Food safety is the prime concern and must remain an absolute and non-negotiable priority for all food businesses at every stage of the food supply chain.

Consumers in a single market are entitled to expect and receive common standards of hygiene and safety in comparable circumstances within and between Member States, regardless of where they purchase their food or where it has been produced.

As a matter of principle, all food businesses, regardless of their size, geographical location or point in the chain (from primary production to sale to the final consumer, including all catering outlets) must meet the highest food safety standards. To ensure that the overall burden of legislative requirements on smaller businesses remains proportionate to the risk to food safety, it is vital that this 'integrated' whole chain approach is coupled with the appropriate application and enforcement of the law based on sound HACCP (Hazard Analysis Critical Control Points) principles.

The responsibility for ensuring food safety is maintained at every stage of the food chain but can only be ensured if all players collaborate closely. The food and drink industry has identified five key areas that can ensure day-to-day food safety:

1. Improving food safety systems:
   Full quality assurance systems are available but must be regularly updated according to technological and scientific progress. Today, companies are putting in place procedures to further improve these systems. HACCP methodology, is now the accepted standard in food hygiene. It constitutes the international standard in Codex Alimentarius and is included in EU legislation.
2. Traceability:
   Traceability systems, were originally developed as a tool to deal with product liability, but have been significantly improved over time. Traceability is a fundamental requirement of all Quality Management Systems. ISO 9000 certification requires documented procedures which can ensure product identification, from purchasing of the starting materials through the whole production process and through shipment to the retailer/consumer.
3. Crisis management:
   Procedures are being further improved both at company and at association level. CIAA is developing a crisis management manual.
4. Risk identification:
   The industry participates actively in the processes of identification, evaluation and tracking of the changes of existing, and any sign of new risks in food. Here, industry has a key role to play in providing data and a platform for the discussion and evaluation of data.
5. Communication:
   The industry recognises that communication is an important factor but that it is also difficult to implement. Several initiatives are being undertaken to improve communication and thereby the understanding of the general public.

## 1.7 Legislative framework for food and drink products

The protection of the consumer and of the environment, as well as the elimination of obstacles to the free movement of goods are among the main concerns of EU legislation related to food and drink. The EU legislative framework is based on horizontal measures across product categories as well as on commodity-specific so-called vertical measures, derived from the agricultural policy or the agri-monetary system.

The food and drink industry is controlled by very detailed and comprehensive legislation starting at the farm gate and ending on the dinner plate. This legislation covers the following main areas:

- food safety (contaminants, pesticide residues, quality of water intended for food consumption, official control of foodstuffs, materials in contact with foodstuffs)
- food hygiene (general rules, health rules concerning foodstuffs of animal origin)
- food composition (additives, flavourings, processing aids, GMOs)
- consumer information (general labelling rules, quantitative ingredient declaration, lot identification, unit pricing)
- nutrition
- ionisation
- organic production
- others.

For more detailed information **on food legislation of the European Union,** see CIAA status report, issue of April 2001 [CIAA, 2002 #3], enclosed here in **Annex 1**. Section 17 includes some selected legislation on the environment. Obviously, other pieces of environmental legislation are also valid for the industry (e.g. 98/83/EC Directive on the quality of water for human consumption).
In the relevant chapters, some specific EU legislation and national legislation are also discussed (e.g. legislation on odour control). **Annex 1** also includes some information about national legislation provided by countries in English.

## 1.8 The Food and drink industry and the environment

Food production depends on the quality of natural resources, especially that of land and water. Therefore, for the food and drink industry, preserving the environment in which the raw materials are grown has always been of significant importance.

**Figure 1.2: Need for clean environment to have healthy raw material**

Emissions from the food and drink industry are mostly readily biodegradable organic matter. Although, at the same time, pollution in waste water and waste produced by the industry may represent a very significant load in some countries or regions.

Traditionally the industry has not been heavily regulated with environmental legislation as emissions have been considered as relatively benign compared to many other industrial sectors. The impetus for the industry to improve environmental performance has therefore traditionally been based on improving efficiency, i.e. maximising the utilisation of materials, which subsequently leads to a minimisation of waste.

Today, companies are focusing on proactive environmental management systems, natural resource conservation and waste minimisation techniques performance.

To ensure sustainability the effects of the raw material supply, food processing, transport, distribution, preparation and disposal must be considered and controlled.

Both primary food production and food processing are critically dependent upon reliable water supplies and adequate water quality.

Energy input for food processing is relatively low compared to other industrial sectors. The product energy requirement however, does not end with the manufacturers and retailers. German and Swedish studies have shown that about 20 % of the total energy input is used in home preparation by the consumer.

Packaging and packaging-waste is an issue which has affected the entire consumer goods industry for many years and where great progress in terms of prevention and recovery has already been achieved. Packaging is essential for foodstuffs as it preserves and protects them against handling, spoilage and contamination during production, distribution and sale. It is also an essential communication tool conveying essential information (ingredients, nutritional information, serving and storage instructions) to the consumer. For the producer it is also an essential marketing and sales tool.

Environmental demands for less packaging are coming up against wider trends, such as smaller households and increased demands for convenience foods, which makes packaging reductions difficult to achieve.

The food and drink industry is playing a full role in the efficient management of packaging and packaging waste but others (farmers, retailers, consumers) also have a role to play. In this context, the CEN standards on packaging are very useful. These standards provide guidelines to economic operators to enable them to comply with the essential requirements laid down by the EU Packaging Directive. They offer the required flexibility to encourage innovation and enable packaging to be adapted to consumer needs. They also fit the environmental and quality management systems within companies.

Environmental management systems help to continuously improve environmental performance. This is partly achieved through the consolidation of organisational and technical measures into these systems.

# 2 APPLIED PROCESSES AND TECHNIQUES

The most commonly used processing techniques and unit operations in the food and drink industry are given in Table 2.1 below. The raw materials used by the food and drink industry are natural products, which may vary from season to season and from year to year. It may therefore be necessary to adapt production processes to accommodate the changes in characteristics of the raw materials. This list of processing techniques is clearly not exhaustive.

## 2.1 Overview of processing techniques and unit operations

| **A. Raw materials, reception and preparation** | |
|---|---|
| A.1 | Materials handling, unpacking, storage |
| A.2 | Sorting, screening, grading, dehulling, trimming |
| A.3 | Peeling |
| A.4 | Washing |
| **B. Size reduction, mixing, forming** | |
| B.1 | Cutting, slicing, chopping, mincing, pulping |
| B.2 | Mixing, blending, conching, homogenisation |
| B.3 | Grinding, milling |
| B.4 | Forming, moulding, extruding |
| **C. Separation techniques** | |
| C.1 | Extraction |
| C.2 | Deionisation |
| C.3 | Fining |
| C.4 | Centrifugation/sedimentation |
| C.5 | Filtration |
| C.6 | Membrane separation |
| C.7 | Crystallisation |
| C.8 | Neutralisation (removal of fatty acids) |
| C.9 | Bleaching |
| C.10 | Deodorisation by stream stripping |
| C.11 | Decolourisation |
| C.12 | Distillation |
| **D. Product processing technology** | |
| D.1 | Soaking |
| D.2 | Dissolving |
| D.3 | Solubilisation (alkalising) |
| D.4 | Fermentation |
| D.5 | Coagulation |
| D.6 | Germination |
| D.7 | Brining, curing |
| D.8 | Smoking |
| D.9 | Hardening |
| D.10 | Sulphitation |
| D.11 | Carbonatation |
| D.12 | Carbonation |
| D.13 | Coating, spraying, enrobing, agglomerisation, encapsulation |
| D.14 | Ageing |
| **E. Heat processing** | |
| E.1 | Melting |
| E.2 | Blanching |
| E.3 | Cooking, boiling |
| E.4 | Baking |
| E.5 | Roasting |
| E.6 | Frying |
| E.7 | Tempering |
| E.8 | Pasteurisation, sterilisation, UHT |

| F. Concentration by heat | |
|---|---|
| F.1 | Evaporation (liquid to liquid) |
| F.2 | Drying (liquid to solid) |
| F.3 | Dehydration (solid to solid) |
| **G. Processing by removal of heat** | |
| G.1 | Cooling, chilling |
| G.2 | Freezing |
| G.3 | Freeze drying, lyophilization |
| **H. Post processing operations** | |
| H.1 | Packing, filling |
| H.2 | Gas flushing |
| **U. Utility processes** | |
| U.1 | Cleaning/sanitisation |
| U.2 | Energy generation/consumption |
| U.3 | Water treatment (incoming process water) |
| U.4 | Vacuum generation |
| U.5 | Refrigeration |
| U.6 | Compressed air generation |

**Table 2.1: Overview of processing techniques**

## 2.2 Description of processing techniques and environmental impacts

To process a raw material into a product normally involves a range of processing techniques linked together into a production line. In this chapter, where relevant and possible, examples of data on process conditions are included. It is quite difficult to give quantitative data on environmental aspects of the individual processing techniques due to a lack of reliable data and due to natural variations (seasonal etc.) in many of the raw materials. The seasonal variability often leads to changes in the processing techniques applied. It must be made clear that the ranges in the quantitative data will necessarily be very large due to the very wide variation in individual process applications. Often better quantitative information on the environmental aspects of the whole production line is available than is available on individual processing techniques. In this document (Chapter 3), examples will also be given of the environmental aspects (qualitative, quantitative) of typical production lines. In the description of the environmental aspects of the various processing techniques, ‘solid output’ covers both by-products from the process which can be valorised as well as waste which cannot be valorised. As an example, some by-products from the food industry may be used as animal feed, complying fully with applicable legislation.

### 2.2.1 RAW MATERIALS, RECEPTION AND PREPARATION (A.)

#### 2.2.1.1 Materials handling, unpacking, storage (A.1)

Objective
Materials handling applies to the receipt, storage and internal conveying of raw materials, intermediate products and final products.

Field of application
All sectors.

Description of techniques, methods and equipment

a) **Solid materials**

Solid materials are commonly delivered in bags on pallets or in mini-bulk containers. They are transported with forklift trucks and stored in a store. Larger amounts of solid raw materials and powders are mostly delivered in bulk. These are off-loaded directly for processing or stored in silos for future use. Solid raw materials can be conveyed by water (vegetables, roots, tubers), by air (solid particles, powder) or by conveyer belts and elevators.

b) **Liquids**

Liquid raw materials are delivered in bulk tankers and then pumped into storage tanks. The internal transport of liquid is achieved by pumping the liquid through piping systems. At times the piping system can be extensive and complex. Smaller quantities of liquids are also delivered in mini-bulk containers or in drums. These are then transported with forklift trucks and kept in an appropriate store.

c) **Gases**

Gases like $N_2$, $CO_2$ and $SO_2$ are delivered and stored in special pressurised containers. When they are required they are connected to the system concerned and transported through the piping system by pressure differences. Examples of gas use are $SO_2$ in the processing of sugar and in wine making, and $N_2$ and $CO_2$ in packaging and chilling.

Environmental issues

Accidental releases and cleaning of floor and equipment.

#### 2.2.1.2 Sorting, screening, grading, dehulling, trimming (A.2)

Objective

Most raw materials contain some components which are inedible or have variable physical characteristics. Processing techniques such as sorting, grading, screening, dehulling and trimming are necessary to obtain the required uniformity of the raw material for further processing.

Field of application

These processing techniques are widely used as a first step in the processing of fruits and vegetables (legumes), but are also used for meat, eggs and fish. Screening of grain is, for example, applied in the malting industry to select even sized grains for the malting process. Besides dry screening/sorting, wet screening of slurries is also widely used in the food industry to separate different components.

Description of techniques, methods and equipment

a) **Sorting, screening**

Sorting and/or screening (dry and wet) are/is the separation of raw materials and/or food slurries into categories on the basis of shape, size, weight, image and colour. Size sorting and dry cleaning of agricultural raw materials separates solids into two or more fractions on the basis of different sizes, usually by sieving or screening. Size sorting is especially important for food products which have to be heated or cooled as large differences in size could cause over-processing or under-processing.

For size sorting, various types of screens and sieves, with fixed or variable apertures, can be used. The screens may be stationary, rotating or vibrating.
Shape sorting can be accomplished manually or mechanically with, for example, a belt- or roller-sorter.

Weight sorting is a very accurate method and is therefore used for more valuable foods (cut meats, eggs, tropical fruits, certain vegetables).
Image processing is used to sort foods on the basis of length, diameter, and appearance, i.e. surface defects and orientation of food on a conveyor.
Colour sorting can be applied at high rates using microprocessor controlled colour sorters.

### b) **Grading**

Grading is the assessment of a number of characteristics of a food to obtain an indication of its overall quality. Many characteristics cannot be examined automatically and trained operators are employed to simultaneously assess several characteristics in order to produce a uniform high-quality product. Grading is more expensive than sorting (which looks at only one characteristic) due to the high costs of the skilled personnel required.

### c) **Dehulling**

Dehulling is mainly associated with the removal of hulls from legumes and the shells from cocoa beans.
The ease of dehulling of legumes depends on the thickness of the seed coat and can be achieved via wet or dry methods. The wet method involves soaking the legumes in water for a few hours, draining, drying, milling and then blowing with air to remove the seed coat. In the dry method, oil is mixed with the seeds by passing them through emery-coated rollers to abrade the surface. This is common practice for legumes with particularly tough seed coats.
To remove the shells from cocoa beans, the beans are first broken between adjustable toothed rollers. The broken pieces are subsequently separated in fractions by sieving. Each fraction is treated with a stream of air that carries the light shell pieces away. This breaking and fanning process is often referred to as “winnowing”.

### d) **Trimming**

Trimming is used for the removal of either inedible parts or parts with defects, or for cutting the raw material to a size that is suitable for further processing. Trimming can be carried out manually or by rotating knives.

Environmental issues
Solid and liquid waste can be produced, as can air pollution (particulates).

## 2.2.1.3 Peeling (A.3)

Objective
The objective of peeling is to remove unwanted or inedible material from vegetable raw materials. This improves the appearance and taste of the final product. During peeling, peeling losses need to be minimised by removing as little of the underlying food as possible but still achieving a clean peeled surface.

Field of application
Peeling is applied on an industrial scale to fruits, vegetables, roots, tubers and potatoes.

Description of techniques, methods and equipment
Various methods for peeling exist: flash steam peeling, knife peeling, abrasion peeling, caustic peeling and flame peeling.

### a) **Steam peeling**

Steam peeling is a batch-wise process. The raw materials (roots, tubers) are treated in a pressure vessel and exposed to high-pressure steam (180°C to 200°C). The high temperature causes a rapid heating and cooking of the surface layer (within 15 to 30 s). The pressure is then instantly released, which causes flashing-off of the cooked skin. Most of the peeled material is discharged with the steam. Any remaining traces are sprayed off with water.

b) **Knife peeling**

The materials to be peeled (fruits or vegetables) are placed onto a rotating disc and pressed against stationary or rotating blades to remove the skin. Knife peeling is mostly used for citrus fruits, as the citrus skin is easily removed and the fruit suffers little damage.

c) **Abrasion peeling**

The material to be peeled is fed onto abrasive rollers or fed into a rotating bowl which is lined with abrasive. The abrasive surface removes the skin, which is then washed away with water. The process is normally carried out at ambient temperature.

d) **Caustic peeling**

The material to be peeled is passed through a dilute solution (1 to 2 %) of sodium hydroxide. This treatment softens the skin, which can then be removed by high-pressure water sprays.
A new development in caustic peeling is dry caustic peeling. The material is dipped in a 10 % sodium hydroxide solution. The softened skin is then removed by rubber discs or rollers. A drawback of caustic peeling is that it causes decolourisation of the product.

e) **Flame peeling**

A flame peeler utilises a conveyer belt, which transports and rotates the material through a furnace heated to temperatures above 1000°C. The skin (paper shell, root hairs) is burned off and then removed by high-pressure water sprays. Flame peeling is used, for example, for peeling onions.

Environmental issues
Waste water, dust and odour. Solid outputs are normally used in animal breeding.

### 2.2.1.4 Washing (A.4)

Objective
This section applies to washing the product only, not washing the process plant. The objective of washing is to remove and separate unwanted components (dirt or residual peel) from the food in order to ensure that the surface of the food is in a suitable condition for further processing. Unwanted components can include soil, micro-organisms, pesticide residues, etc.

Field of application
Washing is widely applied as a first processing step to root crops, potatoes, fruits and vegetables.

Description of techniques, methods and equipment
There are many types of machines and systems that have been adapted for the material to be cleaned. Washing can be carried out by vigorous spraying with water, or by immersion with the aid of brushes or by shaking and stirring. Sometimes cleaning substances are added.
Warm water may be used but this may accelerate chemical and microbiological spoilage unless careful control on the washing time and process is carried out.
The dirt, once loosened, usually differs so greatly from the product that the actual separation of dirt and product is normally straightforward (for example by sedimentation).

Environmental issues
Disposal of waste water, sediment.

## 2.2.2 SIZE REDUCTION, MIXING, FORMING (B.)

### 2.2.2.1 Cutting, slicing, chopping, mincing, pulping (B.1)

Objective
The objective of cutting, slicing, chopping, mincing and pulping is to reduce the size of material either for further processing or to improve the eating quality or suitability of foods for direct consumption.

Field of application
These operations are very widely applied in the food industry, for example in the processing of meat, fish, cheese, vegetables, fruits, potatoes, and various crops (sugar beet).

Description of techniques, methods and equipment
A large variety of equipment for cutting, slicing, chopping, mincing and pulping is available, normally adapted to the product to be processed. Equipment can be power- or hand-operated, depending on the size of the operations.

a) **Cutting**

Cutting is used for the size reduction of large to medium sized parts of food material; knives, blades, cleavers or saws are usually used.
Cutting is an important operation in meat and fish processing. Cutting of meat is used post slaughtering to dress and split carcases, to remove offal and to remove appendages and, where required, excess fat and bones. Carcases are further reduced into retail cuts of joints by removal of bone, skin and fat. Meat prepared for further processing into ham, bacon, sausage etc., will be treated initially in a similar manner to fresh meat, and will then be subject to further processing operations. These may include further deboning, derinding, defatting, slicing, comminuting, emulsifying, etc. The cutting equipment used in meat processing includes power operated cleavers, circular or straight saws for splitting carcases, and band saws for further reduction of the carcases. These are all electrically operated. Special derinding machines are used for separating rind and fat from pork carcases.
The cutting of potatoes for the production of french fries often involves the use of hydro cutters (where the potatoes are conveyed by water at high speed over fixed blades).

b) **Slicing**

In slicing, regular pieces of material are obtained. Slicing equipment consists of rotating or reciprocating blades which cut the food when it passes beneath. Sometimes the material is pressed against the blades by centrifugal force. In other cases, i.e. for slicing meat products, the material is held on a carriage as it travels across the blade. Hard fruits, such as apples, are simultaneously sliced and de-cored as they are forced over stationary knives inside a tube.
In the sugar industry sugar beets are cut into thin slices, called “cossettes”.
A variant of slicing is dicing (applied to vegetables, fruits and meats), where the food is first sliced and then cut into strips by rotating blades. The strips are passed on to a second set of rotating knives, which operate at right angles to the first set, and cut the strips into cubes.

c) **Chopping**

Many products require the breaking down of raw materials into small particles (comminution). This can be achieved by chopping. Chopping into a coarse pulp is applied to meat, fruits and vegetables.

In chopping, the material is placed in a slowly rotating bowl and subjected to a set of blades rotating at high speed. This technique, normally called bowl chopping, is widely used in the production of sausages and similar products. In bowl chopping, the degree of comminution can be varied depending on knife-speed and cutting time, and in extreme cases the material can be reduced to an emulsion if required.

d) **Mincing**

Mincing is mainly used for the size reduction and homogenisation of meat. A meat grinder is used to mince the meat. This is a lightly constructed screw press with a cutting plate or rotating knives at its outlet. The process is a combination of cutting and extrusion (where the meat is passed through a plate with orifices).

e) **Pulping**

Pulping is mainly used for the size reduction and homogenisation of fruit and vegetables. A moving rough surface ruptures the fruits (vegetables) and squeezes the material through a gap producing an homogenised mass. The most common pulpers are drum pulpers and disc pulpers. Sometimes the pulping process is used for juice extraction.

Environmental issues
Disposal of waste water; solid wastes are normally re-used.

### 2.2.2.2 Mixing, blending, conching, homogenisation (B.2)

Objective
The aim of this group of operations is to obtain a uniform mixture from two or more components or to obtain an even particle size distribution in a food material. This can also result in improved characteristics and eating quality.

Field of application
These operations are widely applied in almost all sectors of the food industry.

Description of techniques, methods and equipment
a) **Mixing, blending**

Mixing (blending) is the combination of different materials. In mixing, the spatial distribution of the separate components are reduced to obtain a certain degree of homogeneity. Various mixing operations can be distinguished in the food industry:

- solid/solid mixing, carried out during the production of animal feed, blends of tea and coffee, dried soup, cake mixes, custard, ice-cream mixes, etc.
- solid/liquid mixing, carried out during the production of canned foods, dairy products, etc. It is also used in the production of chocolates and sweets where the ingredients are mixed in a more or less liquid state and solidify on cooling
- liquid/liquid mixing, used during the production of emulsions like mayonnaise, margarine and mixtures of solutions
- liquid/gas mixing, used, for example, in making ice-cream, whipped-cream and some sweets. During spray drying the liquid-phase is mixed in a stream of gas.

Mixers which are commonly used for solid/solid mixing are: rotating drums, rotary mixers and mixing screws in cylindrical or cone-shaped vessels. Generally in solid/solid mixing, cyclones are used as an integral part of the process to recover the particulate matter (dust) in extracted air. The recovered material is then reprocessed.
For viscous solid/liquid mixing, kneading machines are used. For low viscous solid/liquid mixtures and liquid/liquid mixtures various types of stirrers, impellers and agitators are applied.

For liquid/gas mixing, atomisers are used to produce small liquid droplets, which are brought into contact with a stream of gas. In making ice-cream, whipped-cream or a foam, small gas bubbles are fed into a liquid.

b) **Homogenisation**

The aim of homogenisation is to attain a more even particle size or a more homogeneous blend of materials. It is, for example, applied to whole milk to reduce the size of fat globules so that they stay evenly divided in the milk, thereby preventing skimming of the fat. The liquid (whole milk) is pressed under high pressure (200 - 300 bar) through a small orifice.

c) **Conching**

Conching is a special method of kneading used in the chocolate industry. The molten chocolate mass is placed in a special trough-shaped vessel and is kneaded by a granite roller moving slowly back and forth. The aim of conching is to reduce the viscosity of the mass and to improve flavour and texture.

Environmental issues
Energy and noise.

### 2.2.2.3 Grinding / milling (B.3)

Objective
Grinding / milling is used for the size reduction of solid dry material. It may also improve the eating quality and/or suitability for further processing.

Field of application
Grinding / milling is applied in sectors in the food industry where dry solid materials are processed, for example, the animal feed industry, flour milling industry, breweries, sugar industry, dairy industry (milk powder, lactose), etc.

Description of processing techniques, methods and equipment
A whole range of grinding / milling techniques and equipment are available for application with specific types of food. Grinding / milling can be carried out dry or wet. In wet grinding / milling smaller particle sizes can be attained. Often dry grinding (milling) is combined with sieving or air classification, this results in particle size fractions with upper and lower limits being obtained. Generally cyclones are used as an integral part of the process to recover the particulate matter (dust) in extracted air. The recovered material is then reprocessed.

Common types of mills used in the food industry are:

a) **Hammer mills**

A hammer mill consists of a horizontal cylindrical chamber lined with a steel breaker plate and containing a high-speed rotor fitted with hammers along its length. The material is disintegrated by impact forces as the hammers drive it against the breaker plate.

b) **Ball mills**

The mill consists of a slowly rotating, horizontal steel cylinder, which is half filled with steel balls (2.5 – 15 cm in diameter). The end particle size depends on the speed and size of the balls.

c) **Roller mills**

The mill consists of two or more steel rollers which revolve towards each other and pull particles of the food material through the space between the rollers (the nip). The size of the nip can be adjusted for different food materials

d) **Disc mills**

Disc mills consist of either a single rotatory disc in a stationary casing or of two discs which rotate in opposite directions. The food material passes through the adjustable gap between the disc and casing or between the discs. Pin and disc mills have intermeshing pins fixed on the discs and casing. This improves the effectiveness of milling.

Environmental issues
Dust (air emission), significant energy consumption.

#### 2.2.2.4 Forming / moulding, extruding (B.4)

Objective
Forming / moulding and extruding are operations to achieve a certain shape of solid materials

Field of application
Forming / moulding is an operation widely applied in the production of chocolate, bread, biscuits, confectionery and pies. Moulding is also an important process step in cheese making.

Extrusion is widely used in the production of meat sausages, confectionery products and starch-based snack foods.

Description of techniques, methods and equipment
a) **Forming/moulding**

The material to be moulded is in a viscous form and fed into the appropriate mould. As the moulding process progresses the material becomes firmer and solidifies up to the point that it becomes a fixed shape.

b) **Extrusion**

Extrusion can be seen as a continuous process of shaping. The material is kneaded under high pressure and pressed continuously through openings of the required shape. In cooking extruders, the material is also heat-treated (cooked), i.e. to solubilise starches. Extruders can contain one or two screws. The rotation of the screws transports and mixes the material and produces pressure build-up.

Environmental issues
Energy consumption and odour may be issues.

### 2.2.3 SEPARATION TECHNIQUES (C.)

#### 2.2.3.1 Extraction (C.1)

Objective
The objective of extraction is to recover valuable soluble components from raw materials by dissolving them in a liquid solvent.

Field of application

Extraction is applied to a wide variety of food products. Typical examples are:

- the extraction of sugar from sugar-beets or sugar-cane
- the extraction of oil from oilseeds
- the extraction of coffee extract from coffee beans
- the extraction of caffeine from coffee beans
- the extraction of various other compounds such as proteins, pectins, vitamins, pigments, essential oils, aroma compounds, flavour compounds etc. from many different materials.

Description of techniques, methods and equipment

Extraction works under the principle that soluble components can be separated from insoluble or less soluble components by dissolving them in a suitable solvent. Raw materials that are suitable for extraction may contain either solids only, solids and a solution, or solids and a liquid. Solid/liquid extraction is sometimes called leaching.

When the soluble component is incorporated in a liquid, liquid/liquid extraction may be applied to recover the valuable soluble component.

Commonly the extract is the product or intermediate product and the residue is a waste or by-product. It is not always the objective to recover one particular compound in pure form from a raw material. Sometimes extraction is intended to separate all the soluble compounds from the residue; an example of this is the extraction of coffee.

The efficiency of the extraction process depends on the selectivity of the solvent. Common solvents are:

- water
- organic solvents like hexane, methylene chloride, ethyl acetate
- alcohol
- supercritical $CO_2$.

Raw materials are usually pretreated in order to ensure efficient extraction of the desired compounds. For example, sugar beets and sugar cane are cut into thin slices, nuts and seeds are ground or flaked, coffee beans are roasted and ground, and tea leaves are dried and ground.

Methods and equipment

The simplest extraction method is repeated extraction with fresh solvent (lateral flow extraction). However, this is rarely used because of the costs and because it results in an extract of very low concentration. The most common method used is counter-current extraction, either batch or continuous process.

Batch-wise counter-current extraction is normally only used for the processing of small amounts of material.

In continuously operating extractors the solid material and the liquid (solvent) flow counter-currently.

In principle, many different methods of transport are possible. Examples of transport systems include:

- perforated trays connected to endless chains and moving horizontally or vertically
- screw conveyors, which transport the solid material in counter-current flow vertically or upwards under an incline slope. The screws are perforated in order to obtain a uniform flow of liquid
- endless perforated belt; the solvent is circulated by a pump and sprayed on top of the solid material.

One difficulty with extraction is the recovery of the extracted material from the solvent. This can be carried out by evaporation, crystallisation, distillation, steam stripping, etc.

Some typical examples of extraction are given below:

### a) Horizontal diffusers

These are large revolving drums, separated into "cells" by a helix attached to the interior surface. As the drum and helix revolve, the juice, which stays at the bottom of the vessel, is transported counter-currently to the solvent, i.e. the juice leaves the diffuser at the end where the fresh solvent enters.

### b) Vertical diffusers

The extractor is composed of two main and distinct parts: the counter-current mixer and the extraction tower. The tower is a 14 to 20m high cylinder. Inside the tower a tubular shaft rotates slowly. Special steel pieces of helicoidal shape, or flights, are fitted on the shaft and move the cossettes upwards. The juice and the cossettes move counter-currently.

Extraction of sugar from sugar-beets and sugar cane (sugar diffusion)
The beets, cut into thin slices called cossettes, pass into a water-based counter-current extraction apparatus (diffuser) and emerge as impure sugar juice and pulp. The fresh water used in the extraction process is condensed water from the subsequent evaporation steps and recirculated water from the pulp pressing. The temperature of the water used is 60 to 72°C.

### c) Extraction of oil from oilseeds

The production of crude vegetable oil from oilseeds (e.g. soybeans, sunflower seeds or rapeseed) is a two-step process.
The first process step involves the cleaning, preparation (i.e. drying), dehulling, flaking, conditioning and pressing of the oilseeds. Pressing takes place in one or two steps resulting in crude pressed oil and a cake which has an oil content of 12 - 25 %. When no further hexane extraction (pressing only) is carried out the cake oil content is lower, i.e. at 6 - 12 %.
Beans (with 20 % oil or less) are not pressed, because of their lower fat content, but are extracted directly after cleaning and preparation.
The second process step is the extraction of oil from the pressed cake or flaked beans with hexane. Extraction takes place in counter-current flow.
The mixture of hexane and oil, called miscella, is further processed in a distillation process to recover the hexane from the vegetable oil. The solvent is passed through a hexane/water separator and then re-used in the extraction process.
The remaining hexane in the cake is recovered by a stripping process, using steam. This desolventising-toasting process also reduces the enzyme- and micro-organism activity in the meal.
The hexane/steam vapours are used in the miscella-distillation process for solvent and heat recovery.
The meal is dried and cooled by air before storage in silos or before loading.

### d) Extraction of coffee for the production of soluble coffee

In this process, water is the extracting solvent. The coarsely ground coffee is extracted in a battery of batch percolating columns. The process is operated semi-continuously with water in counter-current flow to the coffee from the most extracted cell to the one just filled with fresh roast and ground coffee.

The extract is recovered from the fresh or least-extracted cell.
A consequence of the use of high temperatures is that the system must be kept under pressure and the individual cells and associated piping must be designed accordingly.
Once a batch of solids has been extracted, the exhausted cell is isolated from the train and the spent grounds are discharged. At the same time, a cell containing fresh roast and ground coffee is added to the train.
The extraction yield is expressed as the recovered water-soluble dry solid content of roasted coffee as a percentage of roasted coffee (dry weight). Yields of 40 to 56 % are obtainable.

### e) Decaffeination of coffee and tea

Decaffeination is carried out by extraction with decaffeinating agents, such as water or another solvent such as methylene chloride, coffee oils, ethyl acetate or supercritical $CO_2$.
Extraction yields of 97 % of the caffeine can be obtained.
Two main extraction methods for decaffeination can be distinguished:

### f) Solvent decaffeination (direct method)

In this method solvents, such as methylene chloride, coffee oils, ethyl acetate or supercritical $CO_2$ are used. The process can be described as follows:

| Action | Effect |
|---|---|
| Green beans are soaked with water and steam | Beans swell by 30 – 40 %. |
| Decaffeinating agent is added to the wet beans | The agent solubilises the caffeine from the beans |
| Agent is drained or steamed away. | Agent and 97 % of caffeine are removed from the beans |
| Hot air or vacuum drying. | Beans are dried and ready for roasting |

The main process parameters are temperature and time. They vary depending on the type of coffee and the type of solvent. For example, when coffee oil is used as the agent the process may take 6 - 9 hours at 95 – 105 °C, while $CO_2$ is used under high pressure at 40 – 80 °C for 5 – 30 hours.

### g) Water decaffeination (indirect method)

In this method water is used as the extraction solvent. The process can be described as follows:

| Action | Effect |
|---|---|
| Green beans are soaked with water and steam | The water extracts the caffeine, but also some soluble coffee solids |
| Beans are separated from the aqueous solution. | Water extract containing caffeine and coffee solids is isolated. |
| Water extract is passed over an activated charcoal bed. A solvent, e.g. methylene chloride, may be used in place of activated carbon | The caffeine is removed from the solution by activated carbon filtration or methylene chloride. The coffee solids remain in the aqueous solution |
| The decaffeinated extract is concentrated and added back to the pre-dried decaffeinated beans. | Beans and coffee solids without the caffeine, which are ready for roasting. |

Environmental issues
If water is used, water consumption and waste water production are issues. If solvents are used, VOC emissions may be an issue.

## 2.2.3.2 Deionisation (C.2)

Objective
Deionisation (ion exchange) is used to remove unwanted organic and/or inorganic constituents from water and food products.

Field of application
In the dairy industry deionisation is applied in whey processing. For the application of whey solids in human food and infant formulae, low levels of mineral constituents are required.

Deionisation is also widely used in the food industry for the treatment of boiler feed water for power and steam generation and for the production of deionised process water.
Deionisation is also applied for removal of minor ionised organic substances from food.

Description of techniques, methods and equipment
Deionisation is normally carried out by passing the product through a column containing ion exchange resin beads. The beads contain a large number of active sites which are capable of holding a wide variety of inorganic molecules (metals and non-metals) and ionised organic constituents. The columns are operated batch-wise and need to be regenerated when the beads are exhausted (or saturated). This is normally carried out by treatment with a variety of chemicals which remove the impurities and regenerate the active sites.

Environmental issues
Waste water and spent ion exchange resins.

### 2.2.3.3 Centrifugation/sedimentation (C.3)

Objective
Sedimentation and centrifugation are used to separate immiscible liquids and solids from liquids by the application of either natural gravity or centrifugal forces.

Field of application
Centrifugation is typically used in the dairy industry in the clarification of milk, skimming of milk and whey, the concentration of cream, butter oil production, production and the recovery of casein, in the cheese industry, and in lactose and whey protein processing, etc. This processing technique is also used in beverage technology, vegetable and fruit juices, coffee, tea, beer, wine, soy milk, oil and fat processing/recovery, cocoa butter, and sugar manufacturing etc.

Description of techniques
Centrifugation is used to separate mixtures of two or more phases, one of which is a continuous phase. The driving force for separation is the difference in density between the phases. By using centrifugal forces the separation process is accelerated. The necessary centrifugal forces are generated by rotating the materials. The force generated depends on the speed and radius of rotation. In raw milk for example, the skimmed milk is the continuous phase, the fat phase is a discontinuous phase formed of fat globules with diameters of some microns, and a third phase consists of solid particles, hairs, udder cells, straw etc.
When the differences in density are large and time is not a limiting factor separation can take place by gravity (known as sedimentation and skimming).
In beer production, clarification of the hot wort is carried out in order to remove particles (hot trub) to get a clear wort. The commonly used equipment for wort clarification is the whirlpool, here wort trub particles are separated in tangential flow.

a) **Separation by gravity**

- Batch-wise: this occurs in a vessel containing a dispersion of solid particles with a higher density than the liquid. With time these heavier particles fall to the bottom of the vessel. If the height of the vessel is shortened and the surface increased, the sedimentation time is reduced.
- Continuous: the liquid containing the slurried particles is introduced at one end and flows towards an overflow. The sedimentation capacity of such a vessel can be increased by adding baffle plates (horizontal or inclined).

b) **Separation by centrifugal force**

Centrifuges are classified into three groups:

- tubular / disc bowl centrifuges for separation of immiscible liquids
- solid bowl / nozzle, valve discharge centrifuges for clarification of liquids by removal of small amounts of solids
- conveyor bowl / reciprocating conveyor centrifuges for dewatering sludges (high solids content).

### c) Tubular/disc bowl centrifuges

A tubular bowl centrifuge consists of vertical cylinder, which rotates between 15000 – 50000 rpm inside a stationary casing. It is used to separate immiscible liquids, e.g. vegetable oil and water. The two liquids are separated into annular layers, the denser liquid nearer to the bowl wall, which are then discharged separately.

Typically, the disc bowl centrifuge is more widely used in the food industry as it achieves better separation due to the thinner layers of liquid formed. With the disc bowl centrifuge, the cylindrical bowl contains inverted cones or discs. The liquids have only a short distance to travel to achieve separation. These centrifuges operate at 2000 – 7000 rpm and have capacities of up to 150000 l/h. Disc bowl centrifuges are used to separate cream from milk, and to clarify oils, coffee extracts and juices.

### d) Solid bowl nozzle or valve type centrifuges

A solid bowl centrifuge is the simplest solids / liquid centrifuge and is useful when small amounts of solids must be removed from large volumes of liquid. It consists of a rotating cylindrical bowl. Liquor is fed into the bowl; the solids settle out against the bowl wall whilst the liquid spills over the top of the bowl. Periodically the centrifuge has to be stopped to enable the cake to be removed.

Liquors containing higher levels of solids, i.e. > 3 % w/w, can be separated using nozzle or valve discharge centrifuges. These centrifuges are a modified disc bowl centrifuge with a double conical bowl and enable the discharge of solids automatically.

These types of centrifuges are used to treat oils, juices, beer and starches to recover yeast cells. They have capacities of up to 300000 l/h.

A special type is the “bactofuge”, which is specially designed to separate micro-organisms from milk. Bacteria and particularly spores have a higher density than milk and this sludge is called bactofugate.

### e) Conveyor Bowl / reciprocating conveyor / basket centrifuges

These centrifuges are used when the feed contains high levels of solids (sludges). They are used, for example, to recover animal and vegetable proteins (i.e. precipitated casein from skimmed milk), to separate coffee, cocoa and tea slurries and to desludge oils.

In the conveyor bowl centrifuge (decanter), the solid bowl rotates at 25 rpm faster than the screw conveyor. This causes the solids to be conveyed to one end of the centrifuge whereas the liquid fraction moves to the other larger-diameter end.

The reciprocating conveyor centrifuge is used to separate fragile solids (e.g. crystals from liquor). Feed enters a rotating basket through a funnel, which rotates at the same speed. This gradually accelerates the liquid to the bowl speed and thus minimises shear forces. Liquid passes through perforations in the bowl wall. When the layer of cake has built up it is pushed forward by a reciprocating arm.

The basket centrifuge has a perforated basket lined with a filtering medium, which rotates at 2000 rpm. Separation occurs in cycles, which last from 5 – 30 minutes. In the three stages of the cycle the feed liquor first enters the slowly rotating bowl, the speed is then increased and separation takes place, finally the speed of the bowl is reduced and the cake discharged through the base. Capacities for this group of centrifuges are up to 90000 l/h.

<u>Environmental issues</u>

Energy, noise, solid waste are issues.

### 2.2.3.4 Filtration(C.4)

Objective

Filtration is the separation of solids from a suspension in a liquid by means of a porous medium, screen or filter cloth, which retains the solids and allows the liquid to pass through.

Field of application

Filtration is used in the food and drink industry to fulfil the following functions:

- to clarify liquid products, by the removal of small amounts of solid particles (e.g. wine, beer oils and syrups). The objective is to recover the filtrate in this operation
- to separate a liquid from a significant quantity of solid material, where obtaining the filtrate or cake, or both, is the overall objective of the operation (e.g. fruit juices, beer).

Description of techniques, methods and equipment

Filtration equipment operates either by the application of pressure (pressure filtration) to the feed side or by the application of a vacuum (vacuum filtration) to the filtrate side.

The two main types of pressure filtration are; plate and frame filter press and leaf filter

a) **Plate and frame filter press**

This type of filter consists of plates and frames arranged alternatively and supported on a pair of rails. The hollow frame is separated from the plate by the filter cloth. The slurry is pumped through a port in each frame and the filtrate passes through the cloth and flows down the grooved surfaces of the plates and is drained through an outlet channel in the base of each plate. The filter operates at a pressure between 250 to 800 kPa. The filter press is operated batch wise; the optimum time cycle depends on the resistance offered by the filter cake and the time taken to dismantle and refit the press.

A special type of “plate and frame” filter press is the “membrane” filter press. A membrane is mounted on the plate which can be pressurised with air or water. Due to the higher pressure (up to 20 bar) on the filter cake, more liquid is recovered resulting in a dryer filter cake. Filter presses can be obtained where the dismantling, emptying and refitting of the press are carried out in a semi–automatic manner. Sometimes, filter aids (perlite or diatomaceous earth) are used as a pre-coat or body feed to improve filtration.

The equipment is reliable and easily maintained and is widely used, particularly for the production of apple juice and cider and in edible oil refining (bleaching).

b) **Leaf filter**

The need to develop much larger capacity units was met by the introduction of the leaf filters. It consists of mesh “leaves” which are coated in filter medium and supported on a hollow frame, which forms the outlet channel for the filtrate. The leaves can be stacked horizontally or vertically. Feed liquor is pumped into the shell at a pressure of approximately 400 kPa. When the filtration is completed, the cake is blown or washed from the leaves.

c) **Vacuum filtration**

Vacuum filters are normally operated continuously. Liquor is sucked through the filter plate/cloth and a cake of solids is deposited on the cloth. The pressure difference on the downstream side of the filter plate is normally limited to 100 kPa due the cost of vacuum generation. Two common types of vacuum filter are the rotary drum filter and the rotary disc filter. Sometimes, filter aids are used as a pre-coat or body feed to improve filtration. In these cases, a knife is used to scrape off the cake.

Rotary drum filters consist of a slowly rotating cylinder, which is divided into compartments, which are covered with a filter cloth and connected to a central vacuum pump. As the drum rotates it dips into a bath of liquor. Filtrate flows though the filter cloth of the immersed

compartment. When the compartment leaves the bath the filter cake is sucked free of liquor and washed. As the drum rotates further the vacuum is released for the compartment in question and the cake is loosened from the cloth by means of compressed air, and then removed by means of a scraper. The same procedure occurs for each compartment in turn as the cycle is repeated.
Rotary vacuum discs filters consist of a series of vertical discs which rotate slowly in a bath of liquor in a similar cycle to drum filters. Each disc is divided into segments and each segment has an outlet to a central shaft. The discs are fitted with scrapers to continuously remove the cake.

Environmental issues
Filter cake and waste water are issues. Vacuum filtration may cause air pollution.

#### 2.2.3.5 Membrane separation (C.5)

Objective
Membrane separation aims at the selective removal of water (and solutes and/or suspended material) from a solution by using semi-permeable membranes. Therefore, it can also be seen as a fractionation technique. There are two membrane separation techniques used in the food industry: membrane filtration and electrodialysis.

Field of application
Membrane separation is applied for the concentration of liquids (for example cheese whey), demineralisation of whey, whey fractionation, and water purification.

Description of techniques, methods and equipment
a) **Membrane filtration**

Membrane filtration is a pressure driven filtration technique in which a solution is forced through a porous membrane. Some of the dissolved solids are held back because their molecular size is too large to allow them to pass through. This is dependent upon the types of membranes used. Fractionation of the feed stream occurs with some molecules being concentrated on the upstream side of the membrane, which is known as the concentrate or retentate, while the smaller molecules pass through the membrane into the permeate stream.

The various membrane filtration techniques can be characterised by their membrane pore size (the size of the smallest particle that cannot pass through the membrane), for example milk component fractionation is characterised by the size of filter used:

- Micro Filtration: ~0.1 µm to 5 µm the (MF) process can be used to remove bacteria from skimmed milk during the production of ultra clean milks, or for fractionation of the skimmed milk into a casein rich retentate and a milk serum devoid of casein.
- Ultrafiltration: ~10 – 100 nm range (UF) is applied to both skimmed milk and whey in order to concentrate the respective protein components.
- Nanofiltration: ~1 – 10 nm range (NF) membranes have selective permeability for minerals and some small organic/inorganic molecules, and are used predominantly for concentration and pre-demineralisation of whey.
- Reverse Osmosis: ~0.1 – 1nm range (RO) membranes are permeable to water and not minerals and are therefore used for dewatering, concentration of whey or skimmed milk, or for polishing of NF permeates or evaporator condensate and water treatment (softening/ demineralisation).

b) **Electrodialysis**

Electrodialysis (ED) is membrane separation in the presence of an applied electro potential. In electrodialysis, low molecular weight ions migrate in an electrical field across cationic or anionic membranes. These membranes are alternately arranged between the cathode and anode within a stack. The principle application in the dairy industry is for the demineralisation of whey.

Environmental issues
Energy and waste water are the main issues.

#### 2.2.3.6 Crystallisation (C.6)

Objective
Crystallisation is the formation of solid crystals from a solution. Crystals solidify in a definite geometric form. The objective of crystallisation is to separate a solute from a solvent. Any impurities in the liquid are usually not incorporated into the lattice structure of the desired crystal. Accordingly crystallisation is also a purification process.

Field of application
Crystallisation is applied in the sugar industry and in the dairy industry (where lactose is produced from cheese whey or casein whey).
Crystallisation (fractionation) is also used in the edible oil industry to modify the properties of edible oils and fats.

Description of the technique, methods and equipment
Crystals are usually grown by the introduction of nuclei into a super-saturated solution.

a) **Crystallisation of sugar in sugar factories**

**Figure 2.1: Crystallised sugar**

The crystallisation process takes place in vacuum pans in which the juice is boiled under vacuum in order to minimise the temperatures involved. The growth of the sucrose crystal only involves sucrose and water. The non-sugars contained in the sugar juice are not incorporated into the crystal structure. Most of them remain in the liquid phase while some are released to the vapour phase. The sugar crystals are removed from the liquid phase by centrifugation.

b) **Crystallisation of lactose in whey processing**

For the production of lactose from whey, whey is normally evaporated to a supersaturated solution (total solids content 60 to 65 %). In cooling down the solution, crystallisation is started and the crystals begin to grow. The crystals are removed from the liquid phase by centrifugation. Depending on the required grade, further purification (refining) can take place by washing the crystals, or redissolving them and recrystallising them, followed by treatment with active carbon for the removal of any impurities.

c) **Fractionation of edible oils and fats**

Fractionation is based on the principle that the solubility of the higher melting components in the liquid phase change at different temperatures. This difference can be extended by using an

organic solvent which has the effect of decreasing the viscosity and leading to better washing of the crystals.
Methods and equipment: tanks for preheating, stirred and cooled tanks for crystallisation, band or membrane filters for the separation of the crystals from the liquor, and distillation vessels for solvent recovery. The oil is heated to 10 °C above the melting point of the highest tricylclycerol present, to give a fully liquid starting-material (typically 75 °C for palm oil). The molten oil is then cooled and stirred to form crystal nuclei, and the temperature maintained at a lower temperature to induce crystal growth (typically 12 hours at 28 - 30 °C for palm oil). If a solvent is used, it is added to the molten oil prior to cooling. The mixtures containing the crystallised solids and the dissolved liquids are separated by filters. If a solvent is used, it is removed from the fractions by distillation.

Environmental issues
Cooling water, energy and if they are used, spent adsorbers are issues.

### 2.2.3.7 Neutralisation (removal of fatty acids) (C.7)

Objective
The objective of the neutralisation process is to remove fatty acids and phosphatides from vegetable oils, using chemicals such as phosphoric acid or citric acid and lye.

Field of application
Neutralisation is applied in the refining process of vegetable oils, such as soybean oil, sunflower oil, rapeseed oil, and of animal oils and fats such as tallow or fish oil. Neutralisation is also used in processes like HPP manufacture.

Description of techniques, methods and equipment
The process increases the water-solubility of both phosphatides and fatty acids so that both components can be easily separated from the oil. The fatty acids are transformed into soaps by adding lye. These fatty acids can be separated from the water afterwards in a soapstock splitting process, where the water-solubility of the fatty acids is decreased after boiling the soap stock in an acid environment.

Methods and equipment
A neutralisation process basically requires: mixing equipment, centrifuges and heating (steam). A soap stock splitting process also requires heating and mixing equipment in addition to decanting vessels.
After preheating the oil, phosphoric acid or citric acid is mixed with the oil to increase the water-solubility of phosphatides. The acidified oil is further mixed with a caustic solution, which neutralises both the fatty acids (crude oil content of: 0.5 to 6 %) and the phosphoric or citric acid and further increases the water-solubility of the phosphatides. The mixture of soap and phosphatides, is separated from the oil by a centrifuge. Finally the oil is mixed with water. Again the water is removed from the oil by a centrifuge. The alkali-refined oil may be dried and is pumped to a storage tank. The process is mostly operated in a continuous way but it can also be done in a semi-continuous way or in batch, using long-period mixing equipment.
The combined-centrifuge aqueous discharges (soap stock), are further treated in a soap stock-splitting system. This is an acidulation process, used to recover the fatty acids after treatment with concentrated acid (i.e. sulphuric acid or hydrochloric acid) and heating with steam. The separated fatty acids are removed in a decantation vessel. In integrated plants, the soap stock can be added to the meal toasting process.

Environmental issues
Energy, phosphorous in waste water, odour are the major issues.

### 2.2.3.8 Bleaching (C.8)

Objective
The objective of the bleaching of oil is to remove pigments, metals (nickel or iron, from other oil-refinery processes), residual soaps and phospholipids from the oil or fat.

Field of application
Bleaching is applied in the refining process of edible oils and fats.

Description of techniques, methods and equipment
Edible oils and/or fats are mixed with bleaching earth that has an affinity to adsorb impurities, such as vegetable pigments, metals, residual soaps and phospholipids.

The oil is mixed under vacuum conditions with 0.1 to 3 % of bleaching earth, which is a clay mineral, such as bentonite or montmorrillonite, that has been activated by thermal and/or acidic or other treatments. These earths (sometimes mixed up with small amounts of activated carbon) have a very high absorbing capacity. After bleaching for 30 min – 90 minutes, the oil is separated from the bleaching earth, using filters. The spent earth contains high amounts of oil (up to 30 %). A steam stripping process can recover a part of the oil or fat. The bleached oil is further processed in other refinery processes.
The equipment used for bleaching consists of mixing vessels, vacuum generators and filters.

Environmental issues
Energy, odour, disposal and inflammability of bleaching earth are issues.

### 2.2.3.9 Deodorisation by steam stripping (C.9)

Objective
The objective of deodorisation is to remove fatty acids and volatile compounds from crude degummed and/or alkali refined edible oils and fats after bleaching.

Field of application
Deodorising is applied in the refining of edible oils and fats.

Description of techniques, methods and equipment
Deodorisation is the use of steam distillation to strip fatty acids and volatile components, under vacuum conditions, from oils and fats.

The equipment used for deodorisation consists of a steam distillation column, barometric condenser, demisters and scrubbers.
Steam is injected into the heated oil (>200°C) at the bottom of the distillation column, which is under vacuum conditions. The steam strips the fatty acids and other impurities from the oils and fats (gums are not removed by this process). The steam is condensed afterwards, using a barometric condenser of either “once through” or closed loop design (see also U.4, 2.2.9.4). The separation of the volatile components from this steam can be enhanced by one stage of a two-stage scrubbing/condensation system and by demisters. Deodorisation can be operated in batch or continuous deodorising vessels.

Environmental issues
Energy, odour, pollution and amount of cooling water are issues.

### 2.2.3.10 Decolourisation (C.10)

Objective
Decolourisation is carried out to improve the colour, purity, ageing, microbiological stability and shelf-life of certain food products.

Field of application
Decolourisation is used in the sugar, glucose, syrup and fermentation industries

Description of techniques, methods and equipment
Decolourisation can be carried out in two ways:

1) by the addition of an active powder (e.g. powdered activated carbon) to the product in aqueous solution, which is then mixed under controlled conditions. The powder is then removed by filtration (static filters, rotary vacuum filters) while the purified product is processed further. This process is often carried out in multiple stages with the active material being re-used until exhausted, often using a counter-current system
2) by passing the food product in aqueous solution through a column of active material (e.g. granular activated carbon or ion exchange resin beads). Here only minimal filtration is required after the process as the active material is held in place. Active material is withdrawn from the column at regular intervals and replaced by new or reactivated material.

The main purpose of both these operations is to remove colour molecules from the product as well as precursors, which may give rise to colour formation on storage (known as ageing). The majority of the impurities removed are organic in nature. Passage over activated carbon may also be helpful in removing phenolic material (which may cause taints), pesticide residues and some heavy metals.

Environmental issues
Solid waste disposal, energy are major issues.

### 2.2.3.11 Distillation (C.11)

Objective
Distillation is the separation of the components of a liquid mixture by partial vaporisation of the mixture and separate recovery of the vapour and residue. The more volatile components of the original mixture are obtained at higher concentration in the vapour, the less volatile in higher concentration in the liquid/solid residue.

Field of application
Distillation enables the separation and purification of volatile food products from aqueous blends. Distillation can be used to separate flavours or essential oils, but it is mainly used either for the production of potable alcohol or spirits, or for the industrial production of alcohol from agricultural raw materials (e.g. fruit, grain), which can then be used in alcoholic beverages (liquors).

Spirituous beverages are regulated by EC Council Regulation (EEC) No 1576/89. They are prepared from the distillate of alcoholic products of yeast fermentation of preparations of agricultural origin.

Distillation normally follows alcoholic fermentation (29).

Description of techniques, methods and equipment
The process takes place in two basic types of equipment; the pot still and the column still.

Stills may be operated singly or in groups. Heat addition enables separation of alcohol/aqueous compounds from the initial liquid feed in the still. Condensed aqueous alcohol is removed as a liquid spirit from the head of the still, whilst a residual stream is discharged from the base.

### a) Column still

In column distillation, the alcoholic liquid, or beer, enters a distillation tower heated with vapour. Into each contacting device (generally trays) an equilibrium is created between the vapour enriched with volatile components and condensed liquid. From the top of the tower crude alcohol is drawn off and then rectified through another tower where 95 % alcohol is separated from higher alcohols.
At the bottom of the first tower, an aqueous blend or stillage is drawn off. A condensed water or stillage water contaminated slightly by organics is drawn off at the bottom of the second tower once the alcohol has been dehydrated.
95 % alcohol can be turned into anhydrous alcohol by a number of different technologies: azeotropic distillation using a third component, adsorption by molecular sieve or dehydration by a membrane technique.

### b) Pot still

The pot still can be operated in a batch or continuous manner. In the former case, a batch of material is charged to the still pot, boiling is initiated, and the vapours are then continuously removed, condensed and collected until their average composition has reached a desired value.
When operated in a continuous manner, feed is continuously passed to the still pot with vapour and liquid portions being continuously removed.
The use of distillation in the Food and Drink industry is illustrated by the following two examples; the distillations of whisky and cognac:

### c) Scotch Whisky

Distillation units in the production of Scotch Whisky range from simple pot stills to continuous multi-column stills. Energy is introduced in the form of steam to the bottom of the still and selectively volatilises the alcohol and other components from the fermented liquids and from the pre-distilled alcohol water mixtures.
The volatile components are recirculated within the still to achieve the correct separation, selection and concentration of alcoholic/aqueous compounds for the many varied and desirable congener profiles required by the various types and brands of products. Stills may be operated singly or in series.
The volatile components are condensed by heat exchange with water in condensers and removed as a liquid spirit. The residual material known as pot ale, spent lees, stillage and spent wash, is discharged from the bottom of the still.
(In column-stills other fractions are also removed such as fusel oils and high feints. The high feints are fed back into the stills and the fusel oils (largely amyl alcohol) are sold as a co-product.

### d) Cognac

Cognac is obtained by the distillation of white wines harvested in the Controlled Appellation area. The distillation of Cognac is a two-stage process:

- stage one; a first distillate, known as "brouillis" is obtained. This has an alcoholic strength of between 28 to 32 % volume
- stage two; the "brouillis" is returned to the boiler for a second heating, known as "la bonne chauffe". The distillation "heads" and "tails" are separated, leaving only the "heart" of the spirit below 72 % volume of alcoholic strength which will become Cognac.

Distillation is carried out in two 'chauffes' (two separate heatings) in a special Charentais copper pot still comprising a characteristically shaped boiler, heated with a naked flame and topped with a cowl shaped like a turban, an olive or an onion. A Charentais-still often has an energy-saving wine reheater. This optional device, in which the heat is provided by the alcohol vapours passing through it, preheats the wine, which is to be distilled in the next cycle.
The final day for distillation is 31 March of the year following harvesting.

Environmental issues
Energy, noise, waste water and solid waste may be issues.

## 2.2.4 PRODUCT PROCESSING TECHNOLOGY (D.)

### 2.2.4.1 Soaking (D.1)

Objective
The objective of soaking (of legume seeds) is to moisten and soften the seed to reduce cooking time or to aid in seed coat removal.

Field of application
Soaking is predominantly applied in the processing of legume seeds.
It is also applied with grain, where the grain is soaked in the malting process prior to germination. This is often called “steeping”.

Description of techniques, methods and equipment
Soaking is performed by putting the legume seeds in water for a specified time. The time needed varies with the variety and species and with the length and storage conditions. Traditionally, dry beans are soaked (8 - 16h) in cold water. High temperature soaking accelerates hydration.
To steep the grain, the grain is immersed in water at about 16°C. During steeping, the moisture content increases from 12 - 15 % to about 45 %. During steeping, the water in the steep tanks is changed two or three times and the wet grain is then aerated. The steeping process takes about three days.

Environmental issues
Waste water.

### 2.2.4.2 Dissolving (D.2)

Objective
Dissolving is the addition of powder to liquid in order to produce solutions or suspensions for further processing.

Field of application
This process is used in a variety of products to recombine and reformulate them. For example, dissolving is used for recombining or reformulating milks in the dairy products industry.

Description of techniques, methods and equipment
A variety of processes and equipment are used for this purpose. Different mixing systems may be used for the same task, ranging from simple batch dissolving tanks with efficient mixing devices, to continuous mixing processes which involve either drawing solid materials into the liquid phase or mechanical powder injection into the liquids.
Depending on the product, the liquid may be at ambient or elevated temperatures.

The main types of dissolving systems are:

- blending system: a blending pump sucks the powder into the liquid. For total solids up to 25 %.
- jet dissolving system which uses the venturi principle to suck powder into the liquid. For total solids up to 30 %.
- dissolving tank with high shear mixing impeller. For total solids up to 70 %.
- dissolving tank under vacuum with high shear impeller. For total solids up to 30 %.

Environmental issues
Waste water and energy may be major issues.

### 2.2.4.3 Solubilisation (alkalising) (D.3)

Objective
Solubilisation (or alkalising) is the neutralisation of cocoa nibs or cocoa liquor with an alkaline solution, resulting in a darker colour and a milder taste. The milder taste is mainly the result of the neutralisation of the light acidity of fermented beans. Considerable experience and skill is required to obtain end-products with a constant colour and hue.

Field of application
Solubilisation is used primarily in cocoa processing.

Description of techniques, methods and equipment
The process is carried out by adding a solution of an alkali, usually potassium carbonate ($K_2CO_3$), to the cocoa. Two different methods can be applied:

a) **Liquid process**

Processing the liquid cocoa liquor gives the opportunity to modify the flavour. The potash solution is added to the liquor until a pH value of 7 to 8 is achieved. The desired solubility is obtained by increasing the temperature from 45 °C up to 130 °C. Water vapour and undesirable volatile components are released to the atmosphere during the heating phase.

b) **Nibs alkalising**

Processing green or pre-dried nibs has the advantage of combining the drying with the nibs roasting. A disadvantage is the presence of the cocoa butter in the nibs, which may result in slight damage to the fat.
There are batch and continuous processes available. Batch processes consist of a solubilisation tank at atmospheric pressure with a high shear impeller. Continuous processes take place in a reactor followed by a mixing tank, usually under vacuum.
A typical batch alkalising process involves two steps. Firstly, the nibs are neutralised by adding the alkaline solution in a reactive vessel at atmospheric pressure. The reaction takes place within a temperature range of 80°C to 105°C. In the second step, water evaporation and nibs roasting are carried out in a fluidised bed dryer.

Environmental issues
Energy and waste water are issues.

### 2.2.4.4 Fermentation (D.4)

Objectives
Fermentation is the controlled action of selected micro-organisms to alter the texture of foods, to preserve foods by the production of acids or alcohol, or to produce flavours and aromas.

Field of application

Fermentation is an important processing step for a number of food products. Typical applications include beer, wine, various dairy products, vegetables, meat, fish, etc.

Description of techniques, methods and equipment

a) **Alcoholic fermentation**

The breakdown of simple sugars into alcohol is normally referred to as "Alcoholic Fermentation".

Alcoholic fermentation is used in beer and wine making and for the production of spirits (mostly with molasses as a raw material).

Yeast, usually Saccharomyces sp. (cerevisae, bayanus) is used to produce ethanol from carbohydrates and very small amounts of other organic compounds. This conversion can be represented by the following equation.

$C_6H_{12}O_6 \quad = 2C_2H_5OH \qquad + 2CO_2$

(Glucose) = (Ethyl Alcohol) + (Carbon dioxide)

This is an anaerobic process, i.e. it does not require the presence of oxygen.

The temperature of fermentation is usually in the range 8 - 30 °C. Temperature affects the rate of fermentation, the efficiency of conversion and the flavour and aroma of the finished product.

Nitrogen, vitamins and trace elements are usually added as yeast nutrients; also pH may be adjusted. This ensures that the fermentation is efficient and produces the required flavour. The yeast species used affects rate, efficiency, flavour and aroma and is therefore specially selected to give the desired results.

Traditionally, fermentation in making beer and wine has been carried out in open fermentation vessels. These are now being replaced by cylindrical closed fermenters, which make recovery of the $CO_2$ possible.

b) **Lactic acid ferm*e*ntation**

Lactic acid fermentation is used for making yoghurt and other fermented dairy products, fermented meat products (certain types of sausages) and vegetables (i.e. sauerkraut). To start the fermentation, bacteria cultures known as starters are added to the raw material to be fermented.

In lactic acid fermentation lactose or other sugars are converted into lactic acid and small amounts of other components. Lactic acid formation is accompanied by a decrease in pH, which is important for the taste, the aroma and the preservation of the product. There are several species of bacteria, which are able to produce lactic acid. Each species gives its own typical taste and aroma.

Lactic acid fermentation is an anaerobic process. It is sometimes necessary to remove as much of the oxygen as possible to enhance the fermentation process. Lactic acid fermentation is carried out at 20 – 40 °C

The preparation of starter cultures is a sensitive process since the risk of airborne infection must be reduced to an absolute minimum. Starter cultures must therefore be prepared in a separate room supplied with filtered air at a slight positive pressure compared to normal atmospheric pressure. The equipment cleaning system must also be carefully designed to prevent detergent and sterilant residues from coming into contact with the cultures and spoiling them. These very high hygiene constraints, coupled with the requirements of the temperature regulation (heat treatment of the substrate first and then cooling) require specific energy consumption and the use of cooling water.

Environmental issues

Yeast in waste water and carbon dioxide in air are major issues.

### 2.2.4.5 Coagulation (D.5)

Objective
Coagulation is a means of separation. It is often used to separate the curd from the whey in milk processing.

Field of application
Coagulation is used in cheese production and in the recovery of casein from milk.

Description of technique, methods and equipment
Temperature is one of the key factors that influences milk curdling. The required temperature is obtained by using either heat exchangers or by direct injection of steam into the curdling vat.
The temperature must be between 30 and 40°C.
Starters and other ingredients are added to the milk. These ingredients help determine the specific characteristics of the final product. Curdling is carried out in suitable vats or tanks, using one or both of the following methods:

a) using enzymatic coagulants (animal or microbial rennet)
b) using acidifying starters.

When enzymatic coagulants or acidifying starters are used, a casein jelly is formed which encloses the fat. The jelly will have different characteristics depending on which coagulant method is used. This is important for achieving the desired final production.
The curd is produced by the separation of the whey, which is then gathered and sent for further processing as appropriate.
To obtain further separation of the whey (e.g. in order to obtain a hard or semi-hard cheese), another heat treatment is given to the curd under stirring at up to 40 - 53°C.
For other kinds of cheese, such as mozzarella or provolone, besides heating the curd at a higher temperature mechanical processing is also carried out to obtain the characteristic stretching/melting properties (organic acids are used to control the pH and to hold the curd at the right pH for the stretching properties to form).

Environmental issues
High requirements for raw water; energy and waste water treatment are major issues.

### 2.2.4.6 Germination (D.6)

Objective
The objective of germination is to activate and develop the enzyme system in the grain kernel. This activated enzyme system is necessary to activate starch and protein break down in the mashing process.

Field of application
Germination is an important processing step within the malting process of cereals. Malted cereals (mainly barley) are used for beer production and the production of distilled drinks (e.g. whisky). Malt is also used for food flavouring.

Description of processing techniques, methods and equipment
To start germination, the grain is steeped (soaked) in steeping tanks until a moisture content of about 45 % is reached. The steeped grain is then transferred into germination vessels, which have perforated steel plates floors, or onto perforated germination floors. The grain is layered about 70 to 100 cm thickness. The germination step lasts between 96 and 200 hours. Conditioned air (cooled or heated and humidified) is blown through, or over, the grain layer, to control the temperature and moisture content during germination. To prevent the grain kernels from matting (felting) the layer of grain is mixed from time to time, either mechanically or by air. The germination process is stopped by drying.

Environmental issues
Energy and odour may be issues.

### 2.2.4.7 Brining, curing (D.7)

Objective
Brining and curing is a process whereby a product is treated with common salt (NaCl) to which one or more curing salts might be added. The objectives of brining and curing are long-life preservation of the quality and to add to the taste of the product.

Field of application
Brining and curing is applied in the production of certain types of cheese, meat and vegetables (e.g. sauerkraut). Salt levels in the product can range from 1 to 5 %.

Description of techniques, methods and equipment
In the brining and curing of meat products, the meat is treated with common salt (NaCl) and with one or more of the following curing salts: sodium nitrate ($NaNO_3$), sodium nitrite ($NaNO_2$), potassium nitrate ($KNO_3$) or potassium nitrite ($KNO_2$). The process is designed to produce an acceptable salt level in the product of about 1 – 3 %, or a level of curing salt sufficient to produce an acceptable cured meat colour (which is produced by reaction of the meat pigment myoglobin with nitrite). Nitrite may be used per se or derived from nitrate, which is converted to nitrite in the curing system. The presence of salt and nitrite in the product inhibit microbial growth and enhance durability and safety of the product. Thus salt and nitrite are essential to the curing process. Whereas the salt content is determined by consumer acceptability, the curing salt content is constrained by law. At present this is a maximum of 100 mg/kg of nitrite and 250 mg/kg of nitrate, as measured in the finished product.
Other ingredients may be added to cured meats for a number of reasons, including taste. These include polyphosphates, sugars, spices, non-meat proteins and starches.
Also certain types of cheese are brined for reasons of taste and preservation. In the process of making sauerkraut, salt is added (brining) to promote the growth of lactic acid bacteria, again for development of the desired taste and for conservation.

Methods and equipment
The following methods are applied for brining and curing:

a) **Dry-brining/curing**

Dry-brining/curing is applied to meat and cheese. In making cured meat products, salt and other curing ingredients are deposited on the surface of the piece of meat and are absorbed by diffusion over a period of days or even weeks. At the same time liquor diffuses out of the meat, equivalent to about 10 % of the initial meat weight.
In the production of certain types of cheese (e.g. Cheddar) dry salt is added to the curd.

b) **Injection-brining/curing**

Injection-brining/curing is used in meat processing (bacon, ham). A prepared solution (brine) containing the ingredients is injected by needle(s) into the meat, either manually or by machine, to achieve a rapid deposition of curing salts and salt throughout the mass. After injection, the meat may be sealed in a plastic vacuum bag for a number of days, or immersed in a brine that will be identical or similar in composition to the brine being injected.

c) **Immersion brining/curing**

Immersion brining/curing is applied to cheese, meat and vegetables (sauerkraut). During immersion, salt gradually penetrates into the product while water containing soluble product components is extracted from the product. The immersion brine may be discarded after each usage or it may be continually re-strengthened and re-used with a bleed being discharged. The water extraction by brining can range from 5 - 15 % of the product weight. The salt content of the brine ranges from 5 - 20 %.

d) **Tumble/massage brining/curing**

This type of process is especially applied to meat. In this process, the movement of brine into the meat is accelerated by mechanical action. The meat may be injected with the brine before treatment or it may rely on the mechanical action to accelerate absorption of the brine. This process is normally used when the meat is to be subsequently cooked or canned.

Environmental issues
Salt content and high BOD in waste water are issues.

### 2.2.4.8 Smoking (D.8)

Objective
The aim of smoking is the preservation of food by exposure to smoke from smouldering wood. In addition to preservation of the food, special much appreciated aromas are added to the product.

Field of application
Smoking is commonly used in the processing of fish, cheese, meat and meat products.

Description of techniques, methods and equipment
Composition of Smoke

Wood smoke consists of two phases: a disperse liquid phase, e.g. droplets, and a vapour phase. The former contains particles of smoke, which are not regarded as important in the smoking process. The vapour phase is the more important in imparting flavour to the meat. The vapour contains up to 200 chemical components, not all of which have been identified. They include a range of organic acids, aldehydes, ketones, alcohols and poly-cyclic hydrocarbons.

Techniques of generating smoke:

a) **Smoke from burning wood**

Traditional smoking equipment consists of a chamber with a smoke generator. In the simplest operation, the products are hung on racks in the chamber with a fire of wood dust or chips ignited on the floor. This fire is suitably dampened to maximise smoke production and to avoid flame production. The product increases in temperature to about 30 ºC. The smoking period may last for up to 48 hrs.
In more sophisticated systems, the smoke may be generated outside the chamber and fed into the room using fans, which also produce circulation within the chamber and ultimate venting to the atmosphere.
The equipment may also include an air conditioning unit (ventilator, cooling, heating, moisturising).
The smoke generator can be a small oven where hard wood chips or sawdust are slowly added onto a bed of already smouldering wood or onto an electrically heated grid. Air is blown through the small oven and carries the smoke into the smoking chamber where the product is located. The smoke exiting the chamber is vented to atmosphere or partially recirculated.

b) **Friction smoke**

Smoke is generated by friction; a high speed-rotating wheel is pressed against a piece of wood through which heat is generated and smoke is formed. This method claims to enable a more precise control of the volume of smoke produced by altering the pressure between the wheel or disc and the wood.

c) **Steam pyrolyses smoke**

Smoke is generated by passing superheated steam over chips of wood.

d) **Liquid Smoke**

Liquid smoke is produced by condensation of smoke followed by fractional distillation to reduce the content of tarry matter and other contaminants. The resulting solution is diluted with water and sprayed onto the product. In some cases, it is incorporated into a curing brine and injected into the product for flavouring purposes.

Process conditions
The smoking can take place at two temperature levels: ambient (upto 30°C) and at elevated temperatures (between 50 and 90 °C). The heat from the smouldering of the wood is not enough to raise the temperature to 50 – 90 °C, so extra heat is added by means of steam or a heat exchanger.
The duration of the smoking is dependent on the product. Some products require pre-drying or drying or maturing between smoking steps. For this drying/maturing conditioned (temperature, moisture) air (heated by steam-pipes or electrical heaters) is used to control the drying of the product. The time the product is in the chamber may vary from hours to days. The duration the product is smoked per step can be between 15 minutes and 4 hours.

Environmental issues
Strong odour, VOCs in air and energy are major problems. Waste water produced in cleaning may also be an issue.

### 2.2.4.9 Hardening (D.9)

Objective
The objective of hardening is the transformation of edible oils into edible fats.

Field of application
Hardening is applied in the processing of edible oils for the production of margarine and other edible fats.

Description of techniques, methods and equipment
Hardening or hydrogenation of oils is the process of saturating mono- or poly-unsaturated fatty acids by adding hydrogen ($H_2$) gas for the hydrogenation and nickel as a catalyst.
Hydrogen molecules, in the presence of nickel and under special process conditions, saturate the unsaturated bonds of fatty acids of edible oils.

Methods and equipment
Neutral or bleached oil is heated to a temperature of 150 to 205 °C in the presence of the nickel catalyst (max. 10 kg catalyst/tonne product). Then, $H_2$ gas is added to the mixing reactor to perform the hardening, i.e. the transformation from oil to fat. Hydrogenation is an exothermic process.
After the reaction, the fats are separated from the nickel, using filter presses or other filter systems. In a minority of the cases, the nickel catalyst can be re-used several times until it is deactivated. Specialised companies recycle the spent nickel. The residual nickel concentration in the fats is removed by bleaching, which produces bleaching earth contaminated with nickel.
The equipment used for hardening consists of mixing vessels, reaction tanks, autoclaves and filters.

Environmental issues
Explosion and fire risk because of hydrogen, energy, water consumption, nickel content in waste and waste water are major issues.

### 2.2.4.10 Sulphitation (D.10)

Objective
The aim of sulphitation is to prevent either bacterial degradation or unwanted colour formation.

Field of application
Sulphitation is applied for example in sugar production and wine making.

Description of techniques, methods and equipment
Sulphitation is the introduction of sulphur dioxide ($SO_2$) into liquids.
The sulphur dioxide can be produced in a sulphur stove where elemental sulphur is oxidised to sulphur dioxide. The sulphur dioxide is drawn by a fan into an absorption column in which the liquid is flowing. The sulphur dioxide may also be stored as liquid (under approximately 5 bar) in horizontal cylindrical tanks of 25 - 50 $m^3$ capacity, from which it can then be introduced into the desired process stream. An alternative, but more expensive, sulphite source is ammonium bisulphite.

Environmental issues
Sulphur dioxide in air may be an issue.

### 2.2.4.11 Carbonatation (D.11)

Objective
The aim of carbonatation is to remove impurities from a solution.

Field of application
In the Sugar industry.

Description of techniques, methods and equipment
Carbonatation is the introduction of milk of lime (calcium hydroxide) and carbon dioxide gas ($CO_2$) into a liquid to form calcium carbonate to precipitate and remove impurities. The $CO_2$ is obtained either from bulk storage of liquefied gas or from the production of the gas by means of lime kilns (dissociation of calcium carbonate).

Methods and equipment
Any non-sugar components contained in the raw sugar juice after extraction from the beet make the subsequent stages in the sugar process impossible to perform. Therefore, the raw juice must be purified in order to allow further processing. This is achieved by continuously adding milk of lime and carbon dioxide from the lime kiln to precipitate most of the non-sugars. The product after filtration contains calcium carbonate and the non sugars and is used in agriculture as a liming material to improve the structure of arable soil and to regulate soil acidity. (For aspects relating to lime kilns, see reference document on ‘Best Available Techniques in the Cement and Lime Manufacturing Industries’.)

Environmental issues
Noise and air pollution are issues.

### 2.2.4.12 Coating, spraying, enrobing, agglomerisation, encapsulation (D.12)

Objective
The aim of this group of operations is to cover a food product with a layer of material to improve the eating quality, to provide a barrier to the movement of moisture and gases, or as protection against mechanical damage.

Field of application
Coating (by one of the above-mentioned techniques) is applied to confectionery, ice-cream, baked goods, snack foods, fish, poultry, potato products, etc.

Description of techniques, methods and equipment
Confectionery, ice cream and baked goods are often coated (enrobed) with chocolate or chocolate containing compound coatings. The principal ingredients in such coatings are fat and sugar. The fat is tempered and held at a temperature of 31 - 32 °C, this results in a liquid coating mass. This coating is applied to the food products in the form of a single or double curtain through which the food is passed on a stainless steel wire conveyor. A pan beneath the conveyor collects the excess coating, which is then recirculated through a heater to the enrobing curtain.
Products like fish, poultry and potato products can be coated with batters; this is a suspension of flour in water to which sugar, salt, thickening, flavourings and colourings are added to achieve the required characteristics. It is applied to the product by passing the product through a batter between two submerged mesh conveyors.
Coating with breadcrumbs can take place by depositing food products onto a moving bed of breadcrumbs and then passing through a curtain of breadcrumbs.
Other methods for coating are spraying the coating material onto the product, encapsulation of food particles and agglomerisation of products.

Environmental issues
Waste water may be an issue.

## 2.2.5 HEAT PROCESSING (E.)

### 2.2.5.1 Melting (E.1)

Objective
The objective of melting is to obtain a phase change from solid to liquid, in order to prepare the material for further processing (fats, processed cheese) or to recover the melted fraction (fat recovery).

Field of application
The main applications of melting in the food industry are in chocolate moulding, the production of processed cheese, the processing of oils and fats and the recovery of animal fat from meat residues.

Description of techniques, methods and equipment
For melting, processing kettles are used, which are operated either batch-wise or continuously. Heating may be carried out by direct steam injection or indirectly by steam jackets. Processing kettles are available in various sizes and shapes. In continuous processing scraped surface heat exchangers are applied. Some typical examples are described below.

a) **Melting in the production of processed cheese**

Milled cheese and other ingredients are put into a processing kettle and heated to a temperature normally not less than 75 °C to ensure a complete pasteurisation of the processed cheese. Agitation during processing is important for a complete emulsification of the processed cheese.

The temperature and duration of the process depends on the type of processed cheese and the nature of the raw cheese.

b) **Melting for recovery of fat from meat residues**

To recover fat from meat residues two process methods are used: wet melting or dry melting.
In the wet melting process the raw material is heated in the processing kettle by direct steam injection to a temperature of about 90°C. This results in a watery phase and a fat containing phase. The phases are separated by decantation and centrifugation.

In the dry melting process, the raw material is indirectly heated in the processing kettle (a kettle with a steam jacket). All the water which evaporates is removed from the kettle (under vacuum). The liquid phase (molten fat) and dry phase (fat free meat residue) are separated by decantation.

Environmental issues
Energy, odour, high BOD in waste water after cleaning and, in some cases, solid waste are the issues.

### 2.2.5.2 Blanching (E.2)

Objective
Blanching operations are designed to expose the entire product to high temperatures for a short period of time. The primary function of this operation is to inactivate or retard bacterial and enzyme action, which could otherwise cause rapid degeneration of quality.
Two other desirable effects of blanching include the expelling of air and gases in the product, and a reduction in the product volume.

Field of application
Blanching is an important step in the processing of green vegetables and fruits.

Description of techniques, methods and equipment
Depending on the product and/or availability of equipment, blanching may be accomplished by immersion in hot water (80 to 100°C) or exposure to live steam. The operation is normally carried out in horizontal chambers. The residence time in the blancher can vary from approximately 1 minute to 5 minutes depending on the vegetable or fruit being blanched.

Environmental issues
Energy, high BOD and suspended solids in water, solid residues and odour are the issues.

### 2.2.5.3 Cooking, boiling (E.3)

Objective
Cooking and boiling are heat processing techniques applied to foodstuffs to alter the texture, colour and moisture content of the food.

Field of application
Cooking and boiling are applied on an industrial scale for the preparation of ready-to-eat products, the preparation of complete meals or for meal components like various meat products.

Description of techniques, methods and equipment
Cooking is done in ovens. The ovens can be of different types: water, shower, steam and air/steam circulation. Water ovens allow the best homogeneity of heating to be obtained. The immersion in hot water causes weight loss, and result in proteins and greases being released into the water. Shower ovens allow a good uniformity of heating and include the simultaneous action of water sent through the showers and the saturated steam which rises from the collecting basin,

at the bottom of the oven, which is heated, in turn, by coils. In steam ovens, the water shower is eliminated and any heating is due only to the steam produced in the collection basin. Air ovens include, when it is necessary to control surface humidity steam inlet and the recirculation of hot air, obtained by passage through heat exchangers.
Boiling is carried out by immersion in water at boiling temperature.

Environmental issues
Energy, odour and waste water may be issues.

### 2.2.5.4 Baking (E.4)

Objective
The aim of baking is to enhance the eating quality (taste, texture) of food by heating with hot air. A secondary objective of baking is preservation by destruction of the micro-organisms and a reduction of water activity at the surface of the food. However, the shelf life of most baked foods is limited, unless products are refrigerated or packaged.

Field of application
Baking can be applied to fruits and vegetables. Baked vegetables may be used as a filling or as a topping component in many food products such as pies, pizza and snack foods.
It is a common problem with such filled food products that the moisture content of the filling component (commonly fresh vegetables) adversely affects the casing or base component of the food product during storage via moisture migration into the casing or base. The alternative of conventional dehydrated vegetables is not suitable, since those have undesirable taste and texture properties and require rehydration prior to use. Baked vegetables do not have these drawbacks. Suitable vegetables according to this process, include zucchini, peppers, mushrooms, potatoes, cauliflowers, onions, artichokes and aubergines.

### 2.2.5.5 Description of techniques, methods and equipment

In a baking oven the food is exposed to hot air (110 – 240°C) or infrared irradiation. The moisture at the surface is evaporated and removed by the circulating air. When the rate of moisture loss at the surface exceeds the rate of transport of moisture from the interior of the product to the surface, the surface dries out and a crust is formed.

Ovens, using hot air as the heat transfer medium, are classified as direct or indirect heating types. For baking of fruits and vegetables infrared ovens are used. All oven types can be batch or continuous in operation.

a) **Direct-heating ovens**

In this type of oven, air and combustion gases are recirculated (by natural convection or fans) around the product to be baked. The temperature in the oven is controlled by adjustment of air and fuel flow rates to the burner. Fuels normally used are natural gas, propane and butane. The gas is burnt in ribbon burners above, and sometimes below, the conveyor belt and product. The advantages of direct heating ovens are: short baking times, high thermal efficiencies, rapid start-up and good temperature control.
Good management and care is necessary to prevent contamination of the food by undesirable products of combustion.

b) **Indirect-heating ovens**

In this type of oven, the air in the baking chamber is heated via a heat exchanger, by steam or by burning a fuel.

The air in the baking chamber is typically recirculated through the baking chamber and the heat exchanger. Other methods include: passing the combustion gases through radiator tubes in the baking chamber, or burning the fuel between a double wall, whilst exhausting e the combustion gases from the top of the oven.

Electric ovens are heated by induction heating radiator plates or bars.

In batch ovens, the walls and the base are heated. In continuous ovens radiators are located above, alongside and below the conveyor belt.

Batch ovens incur higher labour costs than continuous ovens. Another drawback can be the non-uniformity in baking times, caused by the delay in loading and unloading the oven.

c) **Infrared oven for baking of vegetables**

For baking vegetables the following steps can be carried out:

- flash blanching vegetables in up to 100 % saturated steam
- steam cooking vegetables in 35 to 65 % saturated steam
- baking vegetables by exposure to infrared radiation.

The raw material is washed and sliced (or diced).

The vegetable pieces are then flash blanched for 60 - 80 seconds, in 100 % saturated steam in a jet stream oven at 200 - 300 °C. The steam is delivered to the oven at a rate of approximately 500 to 540 kg/h. The air speed in the oven is 17 - 25 m/s.

The product is next transferred into a second jet stream where it is steam cooked at 270 – 300 °C in 50 % saturated steam for 65 - 85 seconds (same conditions as in the previous step for steam and air speed).

The product is then transferred to an oven for infrared baking for 3.5 – 5 minutes. The air temperature in the oven increases from 240 °C to 350 °C as the product travels through the oven on a conveyor belt. In this process, the vegetables lose approximately 30 to 60 % of their water content, depending on the vegetable.

Environmental issues

Energy, odour and residuals are the issues.

### 2.2.5.6 Roasting (E.5)

Objective

The aim of the process is to dry and to enhance the aroma, and/or to enhance the structure, of raw products.

Field of application

Typical products that are roasted are coffee, cereals, nuts, cacao, chicory, and fruits.

Description of techniques, methods and equipment

The raw product is usually exposed to hot air (temperatures over 100 °C). Sometimes the raw product is pre-dried. First the water is evaporated from the product. The moisture content is decreased from 8 - 20 % to less than 1 %. If the product reaches a sufficient high temperature (over 120 °C) reactions take place in the product. These so-called Maillard reactions are important in the formation of aromas in coffee and cacao. The duration of this roasting process is depending on the product and the specific aromas that are required. Roasting times for coffee range between 1 and 20 minutes, for cacao and other product this can be up to 120 minutes. When the product temperature reaches the required level the Maillard reactions are stopped by either cooling the product with air or by quenching the product with water followed by cooling with air.

Methods and equipment

The roasting can be done either batch-wise or continuously. Typical equipment for batch roasting can be a drum roaster, a column roaster (cacao), a rotating disc roaster, a fluidised bed roaster, a spouting bed roaster, etc. Common to all equipment is that the product is heated and agitated at the same time. The product can be in direct contact with the hot air (convective heat transfer) or in contact with a heated surface (conductive heat transfer). Usually it is a combination of both. The cooling takes place in separate equipment. This can be a cooling sieve where air is pulled through or a spouting bed cooler or any other equipment where the raw product is in contact with fresh air. Quenching with water can take place in the roasting chamber and sometimes in the cooling equipment.
Cyclones are used as an integral part of the process to remove particulate matter/dust (mainly consisting of product residues and skins (chaff)) from the air before it is exhausted to the atmosphere. The recovered material is then reprocessed.

The cooling air is also emitted to the atmosphere.

Environmental issues

VOC and odour in air, energy, and solid residues are major issues.

### 2.2.5.7 Frying (E.6)

Objective

Frying is a cooking operation where the food is cooked in edible oil at temperatures in the region of 20°C. Vegetable oil or a mixture of animal fat and vegetable oil is normally used.

Field of application

Raw material such as fish, potatoes and chicken can be fried producing products such as fish fingers, potato chips and chicken nuggets.

Description of techniques, methods and equipment

Product is fed into the fryer on a slatted belt. The fryer is a horizontal chamber, which contains the oil. The product drops into the oil and the expansion of the batter brings the product to the surface of the oil. The slatted belt feeds the product under the main fryer belt, which takes the product through the fryer and controls the frying time. The take-out belt at the end of the fryer lifts the product out of the oil, allows drainage and transfers the product to the inspection and packing belts. Fryers are equipped with a fume extraction fan to eliminate fume leakage. The frying temperature and time varies according to the product being processed. Temperatures range from 190 to 205°C and residence times in the fryer are normally around 35 seconds but can be as high as 6 minutes.

Environmental issues

Spent oil, energy, VOC and odour in air, and fat in waste water are major issues.

### 2.2.5.8 Tempering (E.7)

Objective

Tempering serves three purposes:

1. to ensure product quality and appearance
2. to enable handling of liquid chocolate for various applications, e.g. demoulding
3. to ensure viscosity control and enable net weight requirements to be met.

Tempering is also the controlled thawing of meats.

Field of application

Tempering is applied in the manufacture of chocolate and chocolate containing products. Chocolate formulations containing cocoa butter, or cocoa butter equivalents, need to be tempered before use. This is because cocoa butter can exist in various crystalline forms, which if left untempered transform into unstable forms that impact severely on production capability and product quality. The tempering process ensures that the crystallisation of the fat occurs into stable forms which then enables products to be manufactured with good gloss, hardness or snap and delays the formation of grey white spots on the surface known as fat bloom. Poorly tempered chocolate results in the formation of the unstable crystalline forms, which give rise to poor appearance and texture.

Chocolate may be under-tempered, well-tempered or over-tempered depending on the particular application.

Description of techniques, methods and equipment

The tempering process involves the melting of all the fat crystals present by heating to at least 40 °C or above, then cooling the mass to typically below 30 °C (known as the seeding temperature). This allows formation of stable crystalline forms, which, on holding, enables further desirable transformation to occur. Finally the mass is warmed slightly to melt out any remaining unstable crystalline forms and to establish further crystallisation of the stable forms. Depending on the particular recipe or formulation, temperatures and holding times will vary accordingly to ensure the optimum product quality.

Methods and equipment

a) **Single stream tempering**

Uses the standard technique of inducing crystallisation of stable forms from liquid followed by changes in temperature. Product is carried by a conveyor screw feed into a tempering tube where it is tempered in three stages.

b) **Twin stream tempering**

This requires an already seeded stream being introduced into a molten untempered chocolate stream.

c) **Multi-stage tempering**

This is based on gentle cooling to produce seed crystals, followed by gentle reheating to allow formation of stable crystalline forms. The cooling and reheating zones are made up of multi-stages maintained at the required temperature ranges via a jacketed recirculating water system.

Various tempering machines are available based on this principle and are widely used in industry for a wide range of applications.

Environmental issues

Energy and – to some extent – cooling water are issues.

### 2.2.5.9 Pasteurisation, sterilisation, UHT (E.8)

Objective

Heat treatment of products is one of the main techniques in the food industry for conservation. Heat treatment stops bacterial and enzyme activity; this prevents loss of quality and keeps food non-perishable.

In heat treatment various time/temperature combinations can be applied, depending on product properties and shelf life requirements.

In pasteurisation, generally a heating temperature below 100 °C is applied. This partly reduces enzyme and bacterial activity, thereby improving shelf-life. Sterilisation commonly means applying a heat treatment of over 100 °C long enough to lead to a stable product shelf-life. UHT has a heat treatment over 100 °C during very short times; it is especially applicable to low viscous liquid products.

Field of application
Pasteurisation and sterilisation are used to treat all types of food products. These may include milk, juices, beer and many others.

Description of techniques, methods and equipment
a) **Pasteurisation**

Pasteurisation temperatures commonly ranges from 62 to 90 °C and pasteurisation times vary from seconds to minutes.
We can distinguish:

- batch wise pasteurisation: 62 – 65 °C, up to 30 minutes
- short time pasteurisation: 72 – 75 °C, 15 - 240 s
- high temperature short time (HTST) pasteurisation: 85 – 90 °C, 1- 2 s.

Batch wise pasteurisation is carried out in (agitated) vessels. Sometimes the product (i.e. beer, fruit juices) is pasteurised after bottling or canning, here the products in their containers are immersed in hot water or fed through a steam tunnel.
For continuous pasteurisation flow-through heat exchangers (tubular, plate and frame) are applied, with heating, holding and cooling sections.

b) **Sterilisation**

Sterilisation temperatures range from 110 to 120°C and sterilisation times from 20 - 40 minutes. Generally for sterilisation, the product is canned or bottled and then heat-treated in a retort in hot water (under overpressure) or steam. Sterilising retorts may be batch or continuous in operation.

c) **UHT treatment**

UHT treatment means a very short heat treatment at temperature of approximately 140°C for only a few seconds. This results in a sterilised product with minimal heat damage to product properties. UHT treatment is only possible in flow-through equipment. The product is thus sterilised before it is transferred to pre-sterilised containers in a sterile atmosphere. This requires aseptic processing.
For UHT treatment, indirect heating in plate and frame or tubular heat exchangers is applied. However, direct steam injection or steam infusion may also be applied.

Environmental issues
Energy, cooling water and waste water after cleaning are issues.

## 2.2.6 CONCENTRATION BY HEAT (F.)

### 2.2.6.1 Evaporation (liquid to liquid) (F.1)

Objective
Evaporation is the partial removal of water from liquid food by boiling. For instance, liquid products can be concentrated from 5 % dry solids to 72 % or even higher depending on the viscosity of concentrates.
Evaporation is used to pre-concentrate food, increase the solid content of food and to change the colour of food.

Field of application

Evaporation is a process, which is used in the production of many food products. For example, it is used to process milk, starch derivatives, coffee, fruit juices, vegetable pastes and concentrates, seasonings, sauces, and in sugar processing.

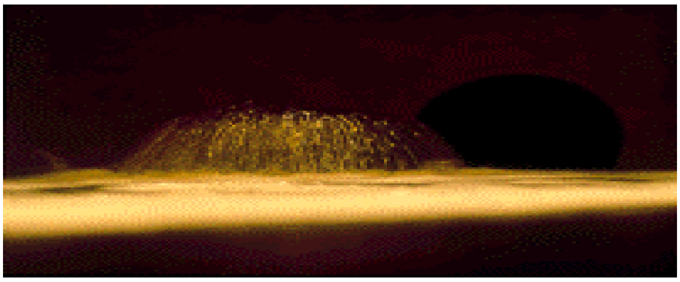


**Figure 2.2: Evaporation in sugar industry**

Description of techniques, methods and equipment

Steam, vapour, or exhaust gases from other (drying) operations, are usually used as the heating medium. The latent heat of condensation is transferred to the liquid food to raise its temperature to boiling point to evaporate the water. The vapour is then removed from the surface of the boiling liquid.

Since food products are heat sensitive it is often necessary to work at low temperatures. This is achieved by boiling the liquid part under vacuum. Evaporation occurs normally in the range 50°C to 100°C, although it may reach as high as 130°C in the sugar industry.

In its simplest form, evaporation is carried out by boiling off water to atmosphere with immersed electric heaters.

However, the most equipment used most commonly, are multistage shell and tube evaporators, or plate evaporators. Shell and tube evaporators may be natural or forced circulation, climbing or falling film types.

Centri-therm evaporators, wiped film evaporators (WFE), thin film evaporators and vacuum pans are specially designed for the evaporation of highly viscous products.

Typical total solids concentrations for various types of evaporators are:

| Evaporator type | TS inlet (%) | TS outlet (%) |
|---|---|---|
| Shell and tubes, multistage | 5 – 25 | 40 – 75 |
| Plates, multistage | 5 – 25 | 40 – 75 |
| Vacuum pans | 60 – 70 | 80 – 85 |
| Centri-therm, single stage | 5 – 25 | 40 – 60 |
| WFE, single stage | 40 – 50 | 70 – 90 |

**Table 2.2: Typical total solids concentrations for various types of evaporators**

For the evaporation of products which require significant energy supplies, for example in sugar beet processing, starch processing and the evaporation of milk and whey, multiple-effect evaporators are used. These use fresh steam or exhaust gases from other operations (energy recovery/re-use) to boil off water vapour from the liquid in the first effect. The evaporated water still has sufficient energy to be the heat source for the next effect, and so on. Vacuum is applied in a multiple-effect series in order for the water to boil off. The liquid being processed is passed from one evaporator body through the others so that it is subject to multiple stages of evaporation. In this way one unit of steam injected in the first evaporator might remove three to six units of water from the liquid.

Additional energy can be saved by recompression of the vapour using a thermal vapour recompressor (TVR) or a mechanical vapour recompressor (MVR).

However this can lead to steam contamination, making it unsuitable for return to the boilers and so therefore increasing the waste water load.
In the final stage the vapour may be condensed by cooling using cooling water.
Some of the vapours can be drawn off the evaporators to be used as heat sources for other process requirements.
During processing product compounds gradually deposit on the heat exchange surfaces and can affect the efficiency of the heat exchange and lead to heat loss in the system. These deposits can be inorganic or organic, depending on the product. The installation must therefore be cleaned at regular intervals to prevent too high a heat loss and subsequent loss of product quality.

Environmental issues
Energy is the major issue, but noise, air and water pollution shall be tackled.

#### 2.2.6.2 Drying (liquid to solid) (F.2)

Objective
Drying is defined as the application of heat under controlled conditions, to remove the water present in liquid foods by evaporation to yield solid products. It differs from evaporation, which yields concentrated liquid products.
The main purpose of drying is to extend the shelf life of foods by a reduction in water activity.

Field of application
Typical applications of drying techniques include milk, coffee, tea, flavours, powdered drinks and sugar.

Description of techniques, methods and equipment
Two different principles can be applied for drying:

a) **Hot air drying**

Hot air is used as the heating medium and is in direct or indirect contact with the liquid product. The heat transferred from the hot air to the product causes water evaporation.

b) **Surface drying by heat conduction through a heat transfer system (contact dryers)**

The heating medium is not in contact with the wet food but separated from it by a heat transfer surface. The heat is transferred by conduction through the surface, and by convection from the hot surface to the food product for evaporating and removing water from the food. This has two main advantages compared to hot air dryers; less air volume is required and therefore thermal efficiency is higher, and the process may be carried out in the absence of oxygen.

c) **Spray dryers**

In spray drying, the material to be dried is suspended in air, i.e. the liquid is converted into a fog-like mist (atomised), providing a large surface area. The atomised liquid is exposed to a flow of hot air in a drying chamber. The moisture evaporates quickly and the solids are recovered as a powder consisting of fine, hollow, spherical particles. Air inlet temperatures up to about 250 °C or even higher (depending on the type of product) are used, but due to evaporation, the temperature drops very rapidly to a temperature of about 95 °C (outlet temperature of the air). The product temperature will be 20 to 30 °C below the air outlet temperature. Heating of the drying air can be accomplished by steam or by direct gas-fired air heaters or indirect heaters fired by gas, liquid or solid fuels. Spray drying is applied on a large scale in the dairy industry and for drying coffee.
Generally, as an integral part of the process, the exhaust air is passed through cyclones to recover particulate materials (dust) which are carried over in the exhaust air. The recovered material is incorporated back in the product.

c) **Roller drying**

The principle of the roller drying process is that a thin film of material is applied to the smooth surface of a continuously rotating, steam heated metal drum. The film of the dried material is continuously scraped off by a stationary knife located opposite the point of application of the liquid material. The dryer may consist of a single drum or a pair of drums with or without "satellite" rollers. The applied steam pressure in the drums can vary from 4 to 8 bar, depending on the product. Roller drying is for example applied for milk, starch and potato flakes.

d) **Vacuum band and vacuum shelf dryers**

Food slurry is spread or sprayed onto a steel belt (or "band"), which passes over two hollow drums, within a vacuum chamber. The food is dried by the first steam-heated drum, and then by steam-heated coils or radiant heaters located over the band. The dried food is cooled by the second water-cooled drum and removed by a doctor blade.
Rapid drying and limited heat damage to the food makes this method suitable for heat-sensitive foods.

Environmental issues
Energy and air pollution are the major issues. Noise, water pollution and disposal of solid outputs are also issues.

### 2.2.6.3 Dehydration (solid to solid) (F.3)

Objective
Dehydration is defined as the application of heat under controlled conditions to remove, by evaporation, the water present in solid foods or by-products from agricultural raw material processing.
The main purpose of dehydration is to extend the shelf life of foods by reducing water activity. Dehydration, however, affects the food texture, colour and causes loss of volatile components, which has a detrimental effect on both the quality and the nutritional value of the food. The design and operation of dehydration equipment aims to minimise these changes by selecting appropriate drying conditions for individual foods.

Field of application
Examples of dried foods are dried potatoes, starch derivatives, sugar, beet, pulp, flour, beans, fruits, nuts, cereals, tealeaves, vegetables and spices.
Dehydration of wet grain is applied in the production of malt (also called kilning).

Description of techniques, methods and equipment
For dehydration two different principles can be applied:

**Hot air drying**

Hot air, used as heating medium, is in direct or indirect contact with the wet food. The hot air is blown over the wet food.

**Surface drying by heat conduction through a heat transfer system (contact dryers)**

The heating medium is not in contact with the wet food but separated from it by a heat transfer surface. The heat is transferred by conduction through the surface and by convection from the hot surface to the food product for evaporating and removing water from the food. This has two main advantages compared to hot air dryers: less air volume is required and therefore thermal efficiency is higher, and the process may be carried out in the absence of oxygen

Methods and equipment

### a) Fluidised bed dryers

Metal trays with mesh or perforated bases contain a bed of particulate foods up to 15cm deep. Hot air is blown through the bed, causing the food to become suspended and vigorously agitated (fluidised). The air thus acts as both the drying and the fluidising medium. Dryers may be batch or continuous in operation. Fluidised-bed dryers are compact and have good control over drying conditions, relatively high thermal efficiencies and high drying rates. The dryer has very high rates of heat and mass transfer and consequently short drying times. Drying can take place with air temperatures below 100 °C, but also up to 170 °C or higher depending on the product/process. Fluid bed drying is often applied as a last drying step after spray drying (dairy industry).

### b) Cabinet dryers (tray dryers)

These consist of an insulated cabinet fitted with shallow mesh or perforated trays, each of which contains a thin layer of food. Hot air is circulated through the cabinet. A system of ducts and baffles is used to direct air over and/or through each tray in order to promote uniform air distribution. Tray dryers are used for small-scale production. They have low capital and maintenance costs but are relatively difficult to control and produce variable quality of product.

### c) Conveyor dryers (belt dryers)

Continuous conveyor dryers are up to 20m long and 3m wide. Food is dried on a mesh belt. The airflow is initially directed upwards through the bed of food and then downward in later stages to prevent dried food from blowing out of the bed.

### d) Pneumatic dryers, flash and/or ring dryers

In these dryers, powders or particulate foods are continuously dried in vertical or horizontal metal ducts. A cyclone separator or a bag filter is used to remove the dried product. The moist food is metered into the ducting and suspended in hot air.

Pneumatic dryers have relatively low capital costs, high drying rates and thermal efficiencies, and close control over drying conditions.

### e) Rotary dryers

A slightly inclined rotating metal cylinder is fitted internally with flights to cause the food to cascade through a stream of hot air as it moves through the dryer. Airflow may be parallel or counter-current. The agitation of the food and the large area of food exposed to the air produce high drying rates and a uniformly dried product. The method is especially suitable for foods that tend to mat or stick together in belt or tray dryers. In the sugar industry it is used on a large scale for sugar and beet pulp drying. In the case of pulp, exhaust gases from the combustion plant are used as a heat source, which also reduces the fuel usage.

### f) Tunnel dryers

Thin layers of food are dried on trays, which are stacked on trucks programmed to move semi-continuously through an insulated tunnel in which hot air is circulated.

### g) Steam bundle dryers

The heating medium (steam) is not in contact with the wet product; a heat transfer surface is used to transfer the heat to the product's surface for drying. The steam passes through the dryer through cylindrical tubes/bundles which are rotating, in order to avoid local overheating and to improve uniform drying. This dryer uses less air volume and subsequently emissions into the atmosphere are limited.

h) **Steam drying**

A special dryer design uses superheated steam produced via a heat exchanger. The dryer consists of a pressure vessel in which the water from the product is driven off, turned to steam and used to dry more product. This system is used in the sugar industry, on a limited scale, for drying beet pulp. One advantage is the low energy consumption for drying.

Environmental issues
Energy and air pollution are the major issues. Noise, water pollution and disposal of solid outputs are also issues.

## 2.2.7 PROCESSING BY REMOVAL OF HEAT (G.)

### 2.2.7.1 Cooling, chilling (G.1)

Objective
The objective of cooling and chilling is to reduce the rate of biochemical and microbiological changes in order to extend the shelf life of fresh and processed foods. Cooling can be defined as a processing technique that is used to reduce the temperature of the food from processing temperature to storage temperature. Chilling is a processing technique in which the temperature of a food is kept at a temperature between -1 °C and 8 °C.

Field of application
Cooling is a process step in many food production processes. Chilling for food preservation is widely applied for a lot of perishable foods.
The supply of chilled foods to consumers requires a sophisticated distribution system, which involves chilled stores, refrigerated transport and chilled retail display cabinets.
Chilled foods can be grouped into three categories according to the storage temperature (Hendley, B. (1985) Market for chilled foods. Food Process 52, 29-33):

- -1°C to +1°C (fresh fish, meats, sausages and ground meats, smoked meats and fish)
- 0°C to +5°C (pasteurised canned meat, milk and milk products, prepared salads, baked goods, pasta, pizzas, unbaked dough and pastry)
- 0°C to +8°C (fully cooked meats and fish pies, cooked or uncooked cured meats, butter, margarine, cheese and soft fruits).

Description of techniques, methods and equipment
Cooling of liquid foods is commonly carried out by passing the product through a heat exchanger (cooler). The cooling medium in the cooler can be ground water, water recirculating over a cooling tower or water (eventually mixed with agents like glycol) which is recirculated via a mechanical refrigeration system (ice-water).
Cooling and chilling of solid foods is carried out by contacting the food with cold air, or directly with a refrigerant like liquid carbon dioxide or liquid nitrogen. Some typical applications are given below:

a) **Cooling of sugar**

Sugar to be stored in silos must be dedusted and cooled to the storage temperature. This is done in a sugar cooler, which is a device in which warm and dried sugar is intensively aerated by cold filtered external air to cool the sugar to the storage temperature, approximately 20 °C. The most common systems in use are coolers (typically drum or fluidised-bed coolers) with chilling systems with counter-current or cross-current phase flow.

b) **Cryogenic cooling**

In cryogenic cooling the food is in direct contact with the refrigerant, which can be solid or liquid carbon dioxide, liquid nitrogen or a liquid freon. The refrigerant evaporates or sublimates removing the heat from the food, thereby causing rapid cooling.
Both liquid nitrogen and carbon dioxide refrigerants are colourless, odourless and inert.

Environmental issues
Electrical energy, cooling water (using flow-through or closed loops), noise, and air pollution in cryogenic cooling are the major issues.

### 2.2.7.2 Freezing (G.2)

Objective
Freezing is a method for preservation. In freezing, the temperature of a food is reduced below the freezing point, and a proportion of the water undergoes a change in state to form ice crystals.

Field of application
Several types of food can be frozen, e.g. fruits, vegetables, fish, meat, baked goods and prepared foods (ice-cream, pizzas, etc.).

Description of techniques, methods and equipment
During the freezing process, first the sensible heat is removed to lower the temperature of the food to the freezing point; this includes heat produced by respiration (as in fresh foods) and then the latent heat of crystallisation is removed and ice crystals are formed.
A whole range of methods and equipment for freezing foods is available. Most common are:

a) **Blast freezers**

Cold air of -30 to –40°C is circulated over the food at a velocity of 1.5 to 6 m/s. In batch blast freezers, the food is stacked on trays in rooms or cabinets. In continuous equipment, trays with food are stacked on trolleys or the food is moved through a freezing tunnel with conveyor belts. Sometimes multiphase tunnels are applied with a number of belts. The product falls from one belt onto the other, which also breaks up clumps of frozen food. The thickness of the food layer on the belts can vary from 25 to 125 mm. In blast freezers, large volumes of air are recycled, this can cause freezer burn and oxidative changes to unpackaged food. Moisture from the food is transferred, via the air, to the refrigeration coils, which makes frequent defrosting necessary.

b) **Belt freezers (spiral freezers)**

The principle of belt freezer operation is the same as a blast freezer. A continuous flexible mesh belt is used and formed into spiral tiers. The food is brought up through a refrigerated chamber on the belt. Cold air or liquid nitrogen is directed down through the belt stack (counter-current flow). This reduces the evaporation of water from the food.

c) **Fluidised-bed freezers**

The food is fluidised with air of -25 to -35°C by passing the air vertically upwards through a perforated tray or conveyor belt and a bed of food 2 - 13 cm thick. The shape and size of the food pieces determine the thickness of the fluidised bed and the air velocity for fluidisation. Food comes in more extensive contact with the air than in blast freezers; all surfaces are frozen simultaneously and uniformly. This results in faster freezing and less dehydration, which also results in less frequent defrosting. Fluidised-bed freezing is restricted to small particulate foods (peas, sweet corn kernels, shrimps, strawberries, etc.)

### d) Cooled surface freezers

Vertical or horizontal hollow plates are cooled with a refrigerant of about -40°C. The food is put on the surface in thin layers. Sometimes the plates are pressed slightly together. This improves the contact between the food and the freezing plates. An advantage of such freezers is that little dehydration of the food takes place, which reduces the frequency of defrosting.
A special form of a plate freezer is the scraped surface freezer. It consists of a freezing cylinder containing rotating knives which remove the frozen material from the freezing surface. This type of equipment is used, for example, for ice-cream production.

### e) Immersion freezers

Packaged food is passed through a bath of refrigerated glycol, brine, glycerol or calcium chloride solution on a submerged mesh conveyor. High freezing rates are obtained with this method. It is used for example for freezing concentrated orange juice in cans and pre-freezing film-wrapped poultry prior to blast freezing.

### f) Cryogenic freezers

In cryogenic freezing the food is in direct contact with the refrigerant, which can be solid or liquid carbon dioxide or liquid nitrogen. The refrigerant evaporates or sublimates removing the heat from the food causing rapid freezing.
Both liquid nitrogen and carbon dioxide refrigerants are colourless, odourless and inert.

Environmental issues
Energy is the major issue; waste water produced in immersion freezing, air pollution in cryogenic freezing are issues.

## 2.2.7.3 Freeze drying, lyophilization (G.3)

Objective
Lyophilization, commonly referred to as freeze-drying, is the process of removing water from a product by sublimation and desorption.
The aim of the process is to preserve sensitive material that cannot be dried by evaporation at elevated temperature because of the degradation of specific components at high temperature which could result in a loss of taste or other quality aspects.

Field of application
The technique is used for drying coffee extract, spices, soup vegetables, flowers, instant meals, fish, meat, etc.

Description of techniques, methods and equipment
This process is performed in lyophilization equipment, which consists of:

- a drying chamber with temperature controlled shelves (this can be a batch chamber, where the trays remain fixed on the heating plates through the drying operation, or a semi-continuous type, in which the trays move through a vacuum lock into a drying tunnel)
- a condenser to trap water removed from the product in the drying chamber
- a cooling system to supply refrigerant to the shelves and the condenser
- a vacuum system to reduce the pressure in the chamber
- a condenser to facilitate the drying process.

If the incoming product is a liquid (e.g. coffee extract) the liquid is frozen in two steps (different freezing temperatures and freezing times) and ground. Then the solid material is fed (manually or mechanically) onto the trays in a drying chamber. The temperature of the drying chamber is well below 0 °C. The exact temperature depends on the product that is being dried. A vacuum is applied in the chamber. The ice evaporates under these conditions. This evaporation causes a further decrease in the temperature of the product, which is compensated for by adding heat (by means of heating plates) to the product through the temperature-controlled trays. The evaporated water is re-frozen on the surface of a condenser, which has a temperature well below the sublimation temperature under the existing conditions in the chamber. From time to time the condenser is de-iced by heating the condenser surface. The water is liquified and drained. The vacuum is maintained by a vacuum pump. The outlet of the vacuum pump is emitted into the air. To prevent solids entering and damaging the vacuum pump a filter is usually applied in front of the pump.

Environmental issues
Energy and waste water are issues.

## 2.2.8 POST PROCESSING OPERATIONS (H.)

### 2.2.8.1 Packing, filling (H.1)

Objective
The objective of the packing process is to ensure that the product will be contained, protected and preserved from the production line to the consumer.
Filling is the process of putting the product in the package in a proper way.

Field of application
The majority of food products are packaged before they enter the distribution chain. In some cases packing is an integral part of the production process, which means that the packaged product is further processed. An example is the canning and bottling of foods and subsequent heat conservation.

Description of techniques, methods and equipment
Most products involve primary and secondary packing processes throughout the manufacture and distribution chain.

Primary packing is the packaging containment directly surrounding the product. This can be metal containers, glass bottles, jars, rigid and semi-rigid plastic tubs and containers, collapsible tubes, paperboard cartons, flexible plastic bags, sachets, etc.

Secondary packing involves a safe and economic route to the consumer using methods such as crates, pallets (wooden and plastic), shrink-wrap, trays, boxes and wrap-around cartons.

a) **Type of packing materials**

Various types of packing materials can be distinguished.

**Textiles and wood**
Textile has poor barrier properties. Textile bags are still used to transport bulk products including grain, flour, sugar and salt. Wooden (shipping) containers have traditionally been used for a range of foods like fruits, vegetables, tea, wines, spirits and beer. These wooden containers are increasingly being replaced by plastic drums and crates.

**Metal**
Hermetically sealed, metal cans have high barrier properties and can withstand high temperature processing and low temperatures. Materials used for metal cans are steel and aluminium. They may be coated with tin or lacquers to prevent interactions with foods. Metal cans are widely used for soft drinks and beer. They are also used for canning sterilised foods (fruits, vegetables, condensed milk, meat products). Metal cans are recyclable.
Aluminium foil is also widely used for packaging of several types of food.

**Glass**

Glass has high barrier properties, is inert, and is suitable for heat and microwave processing. However, two disadvantages are the weight and risk of fracturing. Glass bottles and jars are widely used for milk, beer, wines and spirits, preserves, pastes and purées and also for canning foods. Glass bottles and jars are re-usable and recyclable.

**Rigid and semi-rigid plastic containers**

Bottles, jars, cups, trays and tubs can be made from single or co extruded polymers. The main properties are low weight, tough and unbreakable, easy to seal, reasonably high barrier properties and great chemical resistance. Several techniques are available for the production of these containers, such as thermoforming, blow moulding, injection blow moulding, extrusion blow moulding and stretch blow moulding. Materials used are PVC, PS (polystyrene), PP (polypropylene), HDPE (high-density polyethylene), PET (polyethylene terephthalate), polycarbonate, etc. The containers are often made on-site. Some of the containers are re-usable, e.g. polycarbonate bottles for milk.

Rigid and semi-rigid plastic containers are used for milk, soft drink, dairy products, margarine, dried foods, ice cream, etc.

**Flexible films**

Flexible films are formed from non-fibrous plastic polymers, which are normally less than 0.25 mm thick. Typical materials used for flexible films are, PP, polyethylene (PE), PET, LDPE, HDPE, PVC, etc.

Flexible films in general are relatively cheap, they can be produced with a range of barrier properties, are heat sealable, add little weight, can be laminated to paper, aluminium and other plastics, and are easy to handle.

Flexible films are used for packing a large range of both wet and dry food products.

**Paper and board**

Paper and board can be produced in many grades and many different forms. It is recyclable and biodegradable and can easily be combined with other materials. Laminated paperboard packs are used on a large scale for milk and fruit juices. Paper and board are also extensively used for food packing, often as secondary packing.

### b) Methods and techniques for filling, bottling and canning

The filling of liquids, pastes, powders and particulate foods can usually be distinguished by the packaging medium and the food product, for example, the filling of milk and other drink in glass bottles is normally called bottling, whilst filling in metal cans and subsequent heat processing is normally called as canning.

The requirements for filling are:
- accuracy to ensure the required amount of product is packed
- hygienically filled at the correct temperature to guarantee the highest possible quality and optimum shelf life.

The selection of an appropriate filling technique depends on the nature of the product and the production rate required. The filling can be by volume or weight. Two examples using the different filling types are:

Volumetric filling, applied for liquids, but also for a range of other products like pastes and powders. Most common is the piston filler.

Weight filling, large particulate materials (e.g. confectionery, tablets, etc) are filled into containers using a photoelectric device, similar to a sorter to count individual pieces. Also multi-head weighers are in development which aim to be able to weigh different products simultaneously, prior to filling into the same container.

Containers need to be filled accurately without spillage and without contamination of the seal.

The filling of liquid foods like milk and fruit/vegetable juices can be categorised by the temperature of the food at the time of filling, e.g. hot, ambient or fresh cold filling, or as aseptic filling. The temperature ranges involved in the filling process are best illustrated by the hot filling and fresh cold filling processes. Hot filling are done at temperatures of up 95 °C to be microbiologically safe, whilst many drink products are formulated with ingredients that do not need to be heat treated in order to be microbiologically safe and are therefore fresh cold filled at between 0 to 5 °C.

For aseptic packing presterilised (by hydrogen peroxide) containers are necessary, with the filling taking place in an isolated flow cabin.

### c) **Sealing**

An important step in the packing process is sealing of the container or packs. The maintenance of the food quality depends largely on adequate sealing of the packs. Seals are mostly the weakest part of the packs and also suffer more frequent faults during production, such as food trapped in a seal, incorrect sealing temperatures or in correct can seamer settings.

There is a large range of materials and techniques in use for sealing, these include metal crowns, metal/plastic screw caps, aluminium ends and corks.

A growth area in food packaging is form-fill-sealing. In this process the container is formed and partly sealed, filled and then finally closed by full sealing.

Environmental issues

Waste and waste water produced, energy and noise (bottle filling) are major issues.

## 2.2.8.2 Gas flushing (H.2)

Objective

Gas flushing is a process in which products are stored in an artificially produced atmosphere, normally within a plastic container such as a hermetically sealed tray or pouch. The process is also referred to as MAP or Modified Atmosphere Packing, and is used to enhance colour-retention of, for example, fresh meat or cured meats such as bacon and cooked ham, especially in sliced form.

Field of application

Gas flushing is mainly used for meat and meat products but also for others products, such as bakery products.

Description of techniques, methods and equipment

The gas mixtures used will vary depending on whether the meat to be protected is fresh or cured. The desirable bright red colour of fresh meat can be prolonged by storage in an atmosphere high in oxygen, whereas the purple-red colour of uncooked cured meat and the pink colour of cooked cured meat is better preserved in an atmosphere completely free of oxygen.

In all types of meat or meat products, gas mixtures are used which also contain carbon dioxide ($CO_2$). This inhibits bacterial growth on the meat and marginally extends storage life.

Normal air contains:

Nitrogen 78 %, Oxygen 21 %, and $CO_2$ less than 1 %.

In comparison, typical gas mixes for use with meats and meat products are:

| | **Nitrogen** | **Oxygen** | **$CO_2$** |
|---|---|---|---|
| Fresh meat | 20 % | 60 % | 20 % |
| Cured meats | 80 % | 0 % | 20 % |

**Table 2.3: Typical gas mix composition for gas flushing**

Another use of gas is the use of solid $CO_2$, usually in pellet form, which is added to meat during comminution. This has the effect of rapidly reducing the temperature of the meat mixture and creating a “blanket” of inert gas over the surface of the meat, thereby enhancing the colour retention. Again a temporary increase in the $CO_2$ content of the atmosphere surrounding the equipment will occur, but this dissipates rapidly.
Solid or liquid nitrogen or $CO_2$ is sometimes used to par-freeze meats prior to slicing. This involves passing the pieces of meat to be sliced through a tunnel in which they are sprayed with the liquefied gas to reduce their temperature to about minus 8 °C. In such instances, extractor fans are located near the ends of the tunnel in order to expel surplus gas to atmosphere, and no adverse effects have been reported.

Environmental issues
Gas used in the process may cause air pollution.

## 2.2.9 UTILITY PROCESSES (U.)

### 2.2.9.1 Cleaning and sanitisation (U.1)

Objective
In the food and drink industry, the processing equipment and production facilities are cleaned and sanitised periodically. The frequency can vary considerably according to products and processes. The aim of cleaning and sanitisation is to remove product remnants, other contaminants and microbes from the foregoing process run.

Field of application
Whole of the food industry.

Description of techniques, methods and equipment
Cleaning and sanitisation can be carried out in various ways: manually, Cleaning In Place (CIP), high-pressure jet cleaning and foam cleaning.

Manual cleaning means that the equipment to be cleaned is taken apart and manually cleaned (brushed) in a cleaning solution. Only mild conditions, with regard to temperature and cleaning agents, can be used.

CIP is used especially for closed process equipment and tanks. The cleaning solution is pumped through the equipment and is sometimes distributed by sprayers. The cleaning programme is mostly run automatically. The following steps can be distinguished: pre-rinse with water, circulation with a cleaning solution, intermediate rinse, disinfection, final rinse with water. In automatic CIP-systems the final rinse water is often re-used for pre-rinsing or may be recycled/re-used in the process. In CIP-cleaning high temperatures (up to 90°C) are used, together with strong cleaning agents.

In high pressure jet-cleaning, water is sprayed at the surface to be cleaned at a pressure of about 40 to 65 bar. Cleaning agents are injected in the water, at moderate temperatures up to 60°C. An important part of the cleaning action takes place due to mechanical effects.
In foam cleaning, a foaming cleaning solution is sprayed on the surface to be cleaned. The foam adheres to the surface. It stays about 10 to 20 minutes on the surface and is then rinsed away with water.
High-pressure jet cleaning and foam cleaning is generally applied for open equipment, walls and floors.

Cleaning agents are used in the food and drink industry are alkalis (sodium and potassium hydroxide, metasilicate, sodium carbonate), acids (nitric acid, phosphoric acid, citric acid, gluconic acid), composed cleaning agents containing chelating agents (EDTA, NTA, phosphates, polyphosphates, phosphonates), and surface-active agents. For disinfections

(sanitisation) various sanitisers can be used, such as hypochlorites, iodophors, hydrogen peroxide, peracetic acid and quaternary ammonium compounds (QACs).
In some cases, cleaning is done only using hot water via direct steam injection, however, this depends on the nature of the product and process.

Cleaning agents are delivered in bags (powdered cleaning agents), drums or sometimes bulk tankers. All required safety precautions need to be taken when handling and storing cleaning agents.

Environmental issues
Water, energy and selection of cleaning agents are major issues.

### 2.2.9.2 Energy generation/consumption (U.2)

Objective
Food manufacturing requires electrical and thermal energy at every step of the process. Electricity is needed for lighting, for plant process control, for heating and as driving power for machinery. It is usually generated and supplied by utility companies. When steam and electricity are generated on-site the efficiency factor can be considerably higher.

Field of application
Required by all processes.

Description of techniques, methods and equipment
Thermal energy is needed for heating of processing lines and buildings. The heat generated by the combustion of fossil fuels is transferred to the consumers by means of heat transfer media, which, depending on the requirements, are steam, hot water, air or thermal oil.
Steam boilers, hot water generators, thermal oil heaters and air heaters are commonly used for this purpose. The basic boiler/generator design generally consists of a combustion chamber, wherein the fuel combustion takes place. The heat is transferred by radiation followed by a tubular heat exchanger for heat transfer by convection. The hot flue gas and heat transfer media are separated from each other by a specially designed heat exchange system. Thermal efficiencies of heat generators very much depend on the application and fuel type. Efficiencies, calculated on the basis of lowest calorific value, range from 75 to 90 %.
Some food products are heated up by means of direct radiation with open flames or convection with directly heated process air. In this particular case, natural gas or extra light fuel oil is burned.

In-house combined generation of heat and power (CHP) is a valuable alternative for food manufacturing processes for which heat and power loads are balanced. The following cogeneration concepts are used in food factories: high pressure steam boilers/steam turbine, gas turbines or gas engines or diesel generators with waste heat recovery for steam or hot water generation. The overall fuel utilisation factor of CHP systems exceeds 70 % and is typically about 85 %. Energy efficiency can be up to 90 – 95 % when the exhaust gases from a waste heat recovery system (steam boiler) are used for other (drying) purposes. The fuel conversion efficiency greatly exceeds that of any design of commercial power station, even the latest generation of combined cycle gas turbines, which can achieve a conversion efficiency of 55 %. Sometimes surplus electricity can be sold to other users.
Natural gas and fuel oil are the most convenient fuels. However, a few factories are still burning solid fuels such as coal or process wastes. Utilisation of process wastes can be a convenient and competitive source of energy, and additionally help to eliminate the waste. The fuel selection depends on local requirements, fuel availability and costs.

Environmental issues
Air emission, treatment of boiler feed water, waste water produced, noise and solid outputs are the major issues besides the selection of high energy efficient methods.

### 2.2.9.3 Water treatment (in coming process water) (U.3)

Objective
The water used by food factories may be city water, groundwater or surface water. The type of water used depends on the application. When it is feasible to do so, and it will not affect food safety, water is recycled and re-used, after prior appropriate purification treatment, for specific process applications, e.g. washing, cleaning, make-up for utilities, and, exceptionally, for the process itself. Water treatment is used to provide the requisite quality of water to a variety of different processes, many of which with have their own individual technical requirements.

Field of application
Treated water is used in the food industry for:

- human consumption
- food processing, for which we distinguish the process water intended to come into contact with foodstuffs at any step of the process, and the water used as thermal fluid for heating or cooling
- plant cleaning
- washing of raw materials
- fire fighting and industrial services e.g. boilers, cooling circuits, refrigeration, chillers, air conditioning and heating.

Description of techniques, methods and equipment
The pretreatment required to produce safe water quality depends very much on the water source and its analysis. There is no general rule. A minimum pretreatment concept involves water filtering, disinfecting and storage, but depending on the water requirements may also include de-ironing, desilication, active carbon filtering.
Pretreated potable water is pumped from the storage tank and distributed through the factory piping-network to the users.
Additional treatments like softening, dealkalising, demineralising or chlorinating water will be needed for usage in specific food process or utilities. Ion exchangers or membrane-filtration processes are the most common techniques used for this purpose.

Environmental issues
Waste water from regeneration, water consumption, disposal of solid wastes are major issues.

### 2.2.9.4 Vacuum generation (U.4)

Objective
Vacuums are used primarily to reduce the temperature at which operations take place thereby reducing potential deterioration in the quality of the material being processed.

Field of application
A vacuum is applied to many unit operations in the food industry (drying, evaporation, deodorisation, filtration etc).

### 2.2.9.4.3 Description of techniques, methods and equipment

There are three basic systems for producing a vacuum. These are:
- steam-jet ejectors, which can produce absolute pressures down to 1 or 2 mm Hg
- reciprocating pumps, which can produce absolute pressures down to 10 mm Hg
- rotary vacuum pumps, which can produce absolute pressures as low as 0.01 m Hg.

### a) Steam Jet Ejectors

A steam jet ejector consists of a steam nozzle that discharges a high velocity jet across a suction chamber that is connected to the equipment to be evacuated. The gas is entrained in the steam and carried into a venturi-shaped diffuser that converts the velocity energy of the steam into pressure energy. The steam and vaporised material from the ejector are condensed either directly in a spray of water (barometric condensers) or indirectly with surface type condensers.
With barometric condensers, the cooling water can be used on a straight-through basis or recirculated over cooling towers. With indirect condensers, the condensate can be recovered. The size of the condenser depends on the cooling temperature used, this also controls the amount of steam required. Chilling or freezing systems can be used to enable operation at low temperature, thereby reducing steam usage.

### b) Reciprocating pump

The reciprocating pump is of the positive displacement type. Air is drawn into the pump chamber and then compressed by means of a piston before being discharged. Reciprocating vacuum pumps can be either single or multistage devices. The number of stages is determined by the compression ration. The compression ratio per stage is generally limited to four.

### c) Rotary vacuum pump

Rotary vacuum pumps are again of the positive displacement type, essentially constant volume with variable discharge pressure. The discharge pressure will vary with the resistance on the discharge side of the system. The widely used water-ring vacuum pump has the inlet and outlet ports located on the impeller hub. As the vaned impeller rotates, centrifugal force drive the sealing liquid against the walls of the elliptical housing, causing the air to be successively drawn into the vane cavities and expelled with discharge pressure.

Environmental issues
Energy, noise, air pollution and - to some extent – water pollution are the issues.

## 2.2.9.5 Refrigeration (U.5)

Objective
In a food factory refrigeration equipment is needed for cooling, chilling and freezing.

Field of application
In many food manufacturing processes cooling is an important process step. Often mechanical cooling (using refrigeration equipment) is applied. Furthermore, many food products are stored and distributed either chilled or frozen.

Description of techniques, methods and equipment
The main components of a mechanical refrigeration plant are the evaporator, the compressor, the condenser and the throttling valve. The refrigerant circulates through these four parts of the refrigeration plant, changing state from liquid to gas, and back to liquid again. In the evaporator, heat is absorbed from the surrounding. This causes part of the refrigerant to vaporize. Where ammonia is used as a refrigerant, common temperatures of evaporation are – 20°C to –25°C, which corresponds to a pressure of 100 to 200 kPa.
Refrigerant vapour goes from the evaporator to the compressor where the pressure is raised to about 1000kPa, which corresponds to a temperature of about 25°C. The pressurised vapour then goes into the condenser, where the vapour is condensed. The heat absorbed by the refrigerant in the evaporator is released in the condenser. The condenser is cooled by water or air
The liquid refrigerant then goes to the expansion (throttling) valve, where the pressure and temperature are reduced to restart the refrigeration cycle.

The important components of the refrigerants are: ammonia ($NH_3$) and halogen refrigerants (chlorofluoro-carbons (CFCs) and partially halogenated CFCs (HCFCs)). Ammonia has excellent heat transfer properties and is not miscible with oil, but it is toxic and flammable. Halogen refrigerants are non-toxic, non-flammable and have good heat transfer properties.
The interaction of halogen refrigerants with ozone in the atmosphere has resulted in a ban on CFCs. HCFCs are less environmentally harmful, but have to be phased out before 2015. Some new ozone-friendly HCFCs are being developed.

Condensers of refrigeration equipment can be divided into three types:

a) **Air-cooled condensers**

In the air-cooled condenser, the refrigerant goes through fin elements, around which the cooling air circulates.

b) **Water-cooled condensers**

The most common type of water-cooled condenser is the tube condenser. It operates by circulating cooling water inside the tubes. This condenses the refrigerant on the external tube surface. The water-cooled condenser is cooled according to the water once-through-system or with water which circulates over a cooling tower.

c) **Evaporation condensers**

The evaporation condenser is a combination of an air-cooled condenser and a cooling tower. Water evaporates at the condenser surface.

Environmental issues
Energy, air pollution, noise are major issues. Water consumption and water pollution may be issue as well.

## 2.3 Overview of processing in food and milk sector

### 2.3.1 Meat and poultry processing (SIC 15.11)

The activities of the meat sector can be divided into three areas, slaughtering (this is covered by a separate guidance note ref), meat cutting and further processing.

Cutting is size reduction of large to medium sized parts of food material. For cutting knifes, blades, cleavers or saws are used. Cutting of meat is used post slaughter to dress and split carcases, to remove offal and to remove appendages such as head and fat and, where required, excess fat and bones. Carcases are further reduced into retail cuts of joints by removal of bone, skin and fat. Meat prepared for further processing into ham, bacon, sausage etc., will be treated initially in a similar manner to fresh meat, and will then be subject to further processing operations. These may include deboning, derinding, defatting, slicing, comminuting, emulsifying, etc. Equipment for cutting in meat processing includes power operated cleavers and circular or straight saws for splitting carcases, and band saws for further reduction of the carcases. These are all electrically operated. Special derinding machines are used for separating rind and fat from pork carcases.

For mincing of meat a meat grinder is used. This is a lightly constructed screw press, with a cutting plate or rotating knives at its outlet. The process is a combination of cutting and passing it through a plate with orifices.

#### 2.3.1.1 Brining and curing

Brining and curing is a process whereby a product is treated with common salt (NaCl) to which one or more curing salts might be added. The objectives of brining and curing are the long-life preservation of the quality and to add to the taste of the product. Brining and curing is applied in the production of certain types of cheese, meat and vegetables (e.g. sauerkraut). Salt levels in the product can range from 1 to 5 %.

In the brining and curing of meat products, the meat is treated with common salt (NaCl) and with one or more of the following curing salts: sodium nitrate ($NaNO_3$), sodium nitrite ($NaNO_2$), potassium nitrate ($KNO_3$) or potassium nitrite ($KNO_2$). The process is designed to produce an acceptable salt level in the product of about 1 – 3 %, or a level of curing salt sufficient to produce an acceptable cured meat colour (which is produced by reaction of the meat pigment myoglobin with nitrite). Nitrite may be used per se or derived from nitrate, which is converted to nitrite in the curing system. The presence of salt and nitrite in the product inhibit microbial growth and enhance durability and safety of the product. Thus salt and nitrite are essential to the curing process; the salt content is determined by consumer acceptability; the curing salt content is constrained by law. At present this is a maximum of 100 mg/kg of nitrite and 250 mg/kg of nitrate, as measured in the finished product. Other ingredients may be added to cured meats for a number of reasons. These include polyphosphates, sugars, spices, non-meat proteins and starches. Certain types of cheese are brined for reasons of taste and preservation. In the process of making sauerkraut, salt is added (brining) to promote the growth of lactic acid bacteria, again for taste development and conservation.

The following methods for brining and curing are applied:
- dry-brining/curing
- immersion brining
- tumble / massage brining/ curing.

### 2.3.2 Fish Processing (SIC15.20)

Fish and shellfish are processed and preserved by a large variety of methods and may be consumed in their primary form, raw or cooked. The group may also be further processed to produce fish or shellfish based foods such as moulded products or seafood style prepared dishes. Preservation methods involved in fish and shellfish processing, include freezing, chilling, canning, curing (drying, salting, smoking, fermenting, acid curing) and modified atmosphere packaging (MAP).

#### 2.3.2.1 Frozen processed fish/moulded fish products/fish fingers

Frozen fish blocks (layered fillets, jumbled or minced) are cut into the required dimensions. In the case of moulded products, the fish off-cuts, seasoning and binding materials are fed into a moulding machine and formed into the required shape. The product then passes through a series of enrobing machines, which cover the fish with batter and/or breadcrumbs. The type and number of enrobers is dependent upon the product. The product is then fried in an edible oil; temperatures vary but around 190 °C is typical. The fryers may be heated by gas or by electrical means. The fried product then travels into a freezing unit where it is subjected to a stream of cold air to reduce the product to a pre-determined target temperature (-18 °C being typical).

#### 2.3.2.2 Canned fish/shellfish products

Raw fish are washed, cut into fillets and then steamed in cooking/cooling tunnels. De-scaling is sometimes achieved using caustic baths. After steaming, the fish are filled into cans, which contain either brine, oil or sauce. The cans are sealed by passage through a can seamer. After seaming, the cans pass into a retort for sterilisation. Here the product is heated for a time at a sufficient temperature to inactivate food poisoning micro-organisms. The product is then cooled with chlorinated water. Shellfish are processed in a similar manner but are often transported under a rocking motion through a scalding system to open the shells and dislodge the flesh. Additional washing and trimming steps may also be incorporated to remove sand and mud.

Process diagram for frozen processed fish/moulded fish products/fish fingers

### 2.3.3 Potato processing (SIC 15.31)

Two of the main potato-based products are crisps and chips. Both essentially consist of peeling the raw material, slicing to an appropriate size and blanching, followed by frying to achieve the desired sensory properties. Chips are generally sold frozen and may be part fried or fully fried. Crisps are increasingly sold in modified atmosphere packs.

#### 2.3.3.1 Manufacture of potato chips (french fries)

Potatoes are delivered to the plant and are commonly passed through sorting equipment to remove stones, pebbles and other extraneous matter. The raw material is washed, graded and peeled. A number of peeling methods are available, including steam and lye peeling (caustic solution). Lye peeling produces waste which has a very high pH and organic loading, which adds to water treatment costs. Large tubers are generally sorted for use in chip production. Potatoes are cut into the required size using independently driven multiple knives. Off-cuts, slivers and broken pieces are removed before blanching. The chips are blanched using steam or water (generally at around 60 - 85°C). Multiple blanching stages may be used. Excess moisture must be removed from the chips both to preserve the life of the frying oil and to lower the moisture content of the chips, thereby reducing the required frying time. Conveyor dryers are used in large processing plants. The chips are fried, typically at around 160 - 180°C, the time of frying varies for finished fried and par fried products. Excess fat is removed from the chips before freezing; some manufacturers recover the fat for re-use. Fluidised-bed freezing may be used for freezing the finished product, although belt freezing provides a more energy efficient option.

#### 2.3.3.2 Manufacture of potato crisps (‘potato chips’)

Processing methods for crisp manufacture vary greatly but generally take the form of washing, peeling, trimming, sorting, slicing, rinsing, partial drying, frying, salting, flavouring, cooling and packaging. Potatoes are washed; drum or flotation washers are usually used. Stones, sand, dirt and any extraneous matter are removed. Potatoes are elevated into washers and peeled by abrasion. Peeled potatoes are trimmed to remove eyes, bruises and decaying portions. Slicing is carried out using a series of blades mounted on a circular stationary plate and a rotating drum. Water is supplied to flush starch from the equipment. Sliced potatoes are washed, usually in drum washers, to remove surface starch and sugars. Some manufacturers blanch crisps prior to frying using steam-jacketed water filled tanks. Typical process conditions are 65 - 95°C for one minute or more. After washing, surface moisture is removed by various methods including compressed air and blower fans, vibrating mesh belts and heated air. Crisp frying may be batch or continuous; temperatures are in the range 160 °C to 190 °C and cooking times are typically between 1.5 and 3 minutes. When the crisps leave the fryer they are agitated to remove excess oil and discharged to a belt running underneath a salter. Flavouring may be mixed with the salt or dusted/sprayed onto the crisps in rotating drums. Finally the crisps are cooled and packed

### 2.3.4 Fruit and vegetable processing (SIC 15.32)

The characteristic features of fruit and vegetables are that they are soft edible plant products which, because of their relatively high moisture content, are perishable in their fresh state. Fruit and vegetable processing takes numerous forms including juicing, canning, freezing, pickling/preserving and drying.

#### 2.3.4.1 Fruit processing - Juice

Fruit juices are produced throughout temperate and tropical areas of the world; oranges being the predominant juice in temperate climates and pineapple in tropical climates. The bulk of world fruit juice production is from citrus (mostly orange), pome (apple and pear type fruits) and vine fruits. Some stone fruit juices are manufactured but in much smaller quantities.

In a typical citrus juice process the fruit is sorted, graded and cleaned to remove extraneous matter such as sticks and leaves, adhering dirt and insects. The fruit is then passed through oil extraction equipment where the fruit is subjected to hundreds of small cuts of the skin to rupture the oil sacs and release the citrus oil which is removed by washing. Oil extraction may be carried out after juice extraction. The fruit juice is mechanically extracted and screened to remove excess pulp, pieces of skin and seeds. The screened juice is preserved by a number of methods (canning, aseptic processing, chemical inhibition, freezing, membrane filtration) and may be concentrated before packaging to reduce transport cost. Juice may be clarified before or after preservation.

A typical pome juice process includes similar processes (without an oil extraction step) but generally with the additional step of milling the fruit before the extraction.

#### 2.3.4.2 Fruit processing - Heat treated

In a typical canned fruit process, the fruit is ideally used as soon as possible after delivery, although it often has to be stored for a time under chilled conditions. The fruit is cleaned, sorted and graded before peeling and coring. A variety of methods are used for peeling, including the use of lye or mechanical peeling. Peeled fruit may be blanched or transferred to tanks containing materials such as brine or ascorbic acid solutions to prevent browning. If necessary, the fruit is sliced. Products such as orange segments are subjected to acid and caustic soaks to remove stringy fibres before canning. The fruit is filled into containers (e.g. cans) with syrup or a natural juice. Before sealing, the can may be gently heated to remove entrained gases, a process known as exhausting. The container is then sealed, heat processed and cooled.

#### 2.3.4.3 Fruit processing - Frozen

The freezing of fruits is a major preservation method in its own right but is also widely used to preserve fruits which are to be further processed, e.g. for jam manufacture. Fruits for freezing are generally washed and inspected before being individually quick frozen (IQF), or packed in syrup or pureed before freezing. Typical freezing methods involve either slow freezing, direct contact with a cooled solid (metal), (e.g. band or drum freezers), direct contact with cooled air or other gaseous mixture (e.g. air blast, fluidised bed and spiral freezers), direct immersion in a cooled liquid (e.g. brine freezers), or cryogenic freezers.

#### 2.3.4.4 Fruit processing - Preserves and dried fruit

Preserves such as jams, marmalade and mincemeat are preserved by the use of high concentrations of sugar which suppress the growth of micro-organisms. The basic ingredients of a preserve are fruit, sweetening agents (typically sucrose and/or various sugar syrups), acids and buffers (typically citric or malic acid and buffers such as trisodium citrate), fats (in curds/mincemeat), citrus peel (mincemeat and marmalade), gelling agents (usually pectin) and anti-foaming agents. In a typical process for preserve manufacture, fruit usually arrives pre-prepared either frozen or sulphited and transferred to appropriate storage. The prepared fruit, pectin, sucrose, glucose syrup and other small ingredients are then blended together in a mixing vessel. The mix is boiled either at atmospheric pressure or under vacuum using batch or continuous methods. After boiling, the jam is filled into containers which vary from individual portions to bulk tankers for bakery use.

Dried fruit processing uses raw materials such as grapes, apricots, pears, bananas and plums. A basic process consists of fruit harvesting, drying, sorting, grading, washing and packing. Many fruits are sun dried at source although some producers use mechanical methods (typically tunnels through which hot air is passed). Some fruits are sulphited before drying; this preserves the fruit and softens the fruit tissue resulting in a faster loss of moisture during drying. In some cases, the fruit is sprayed or dipped after harvesting with potassium carbonate solution also containing “dipping oil”. The composition of the dipping oil varies between producers, for example, some producers use olive oil, others may use mixtures of ethyl esters of fatty acids and free oleic acid.

#### 2.3.4.5 Vegetable processing - Juice

Significant quantities of juice are produced from vegetable sources such as carrot, celery, beetroot and cabbage. In general the fresh vegetables are washed and sorted before being coarsely milled and then pressed to extract the juice. Most vegetable juices are low acidity, i.e. have a pH >4.5, and therefore require a full sterilisation process or freezing to be rendered safe. Vegetable juices are sometimes acidified with organic or mineral acids to reduce the pH so that a milder heat treatment (pasteurisation) is possible. Some low acidity juices are blended with high acid juices such as tomato, rhubarb, citrus, pineapple or sauerkraut, so that they are acidic enough to only require pasteurisation. Some vegetables may be blanched prior to acidifying and extraction. Root vegetables are usually peeled before maceration and extraction.

#### 2.3.4.6 Vegetable processing - Heat treated and frozen

Process conditions vary depending upon the vegetable type but preliminary operations for both heat treated and frozen vegetables are similar and usually involve washing, grading and screening to remove extraneous matter such as stone and dirt. After washing, the vegetables are peeled and may be trimmed; a number of peeling methods are available including abrasive, lye (caustic), steam and flame peeling. After peeling the vegetables may be left whole or cut in a number of ways such as sliced or diced. Some vegetables are washed after slicing to remove surface starch. Most vegetables require blanching; steam or water blanching are the most common methods. The product is then rapidly cooled. After cooling the product may be re-inspected and screened before being quick frozen or filled into cans, usually with a hot brine, and heat processed. Vegetables generally undergo a full sterilisation process because the pH is too high to inhibit microbial action.

#### 2.3.4.7 Vegetable processing - Pickling

In a typical pickling process, raw vegetables are delivered and subjected to washing and screening operations to remove extraneous matter such as stones. Depending upon the vegetable, the raw material may be steam cooked and then cooled. The product is then peeled (typically using steam) and re-inspected before being cut to the required dimensions, e.g. sliced/diced/shredded and transported to the filling line. The chopped vegetables are then filled into containers. An acidifying liquor is mixed with spices and transferred to the filling line to be used in the pickling sauce. This liquor typically consists of acetic acid, malt vinegar, spirit vinegar, distilled malt vinegar, liquid sugar and salt depending upon the formulation. The acidifying liquor is deposited into the containers. The container is sealed and typically pasteurised (e.g. hot filling and hot water spray tunnel) before cooling and packaging.

### 2.3.5 Vegetable oil production (SIC 15.41)

Oils and fats occur naturally in a wide range of sources, but only around 22 vegetable oils are processed on a commercial scale around the world. Of these, soya bean, palm, rapeseed (also known as colza oil in some parts of Europe) and sunflower oils are produced in the largest quantities. Animal fats are generally "rendered" from slaughtered carcases using material fit for human consumption; although some are also produced from marine sources.

#### 2.3.5.1 Seed oil extraction

There are a variety of methods of manufacture associated with the large range of oil sources. However a number of key steps are typically undertaken. The raw material is first cleaned to remove extraneous matter. The husks and hulls are then removed, typically by cracking and air classification, to expose the "meats" of the raw material. The meats are conditioned or dried to a required moisture level (typically 9 - 10 %) and rolled into flakes which releases oil and improves subsequent extraction.

Extraction may be brought about by either pressing, solvent extraction, or a combination of the two. Hexane is typically used as a solvent for this purpose. The recovered solvent/oil mixture is called "miscella" and the extracted flakes "spent flake" or "cake". The miscella is subjected to evaporation and steam stripping to separate the oil from the solvent. The meal is processed by steam distillation in a desolventiser to recover most of the solvent. The meal is dried, cooled and may be ground before use in products such as animal feed. Most of the solvent from both the oil and the cake is recovered and re-used.

#### 2.3.5.2 Seed oil refining

Refining removes impurities such as gums, free fatty acids, pigments and undesirable flavour and odour compounds. In general, there are two ways to refine seed oils: physical and the more conventional chemical refining.

Degumming typically involves the addition of water to hydrate any gums present, followed by centrifugal separation. Non-hydratable gums are removed by converting them to a hydratable form using phosphoric or citric acid, followed by the addition of water and centrifugation. Degumming is followed by a process called "neutralisation" in which an aqueous alkali, typically caustic soda or sodium carbonate is sparged into the oil which has been preheated to around 75 - 95°C. The alkali reacts with free fatty acids in the oil to form soaps, which are separated by settling or centrifugation. A drying step may be incorporated after neutralisation to ensure complete removal of the added water. The neutralised oil is bleached to remove colouring matter (such as carotenoids) and other minor constituents, such as oxidative degradation products or traces of transition metals. Bleaching uses activated fuller's earth with treatments typically in the range of 90 - 130°C for 10 - 60 minutes. The earth is sucked into the oil under vacuum and is removed by filtration. The bleached oil is steam distilled at low pressure to remove volatile impurities including undesirable odours and flavours. This process, known as deodorisation, takes place in the temperature range 180 - 270 °C and may last from 15 minutes to five hours depending upon the nature of the oil, the quantity and the type of equipment used. For example, if a batch deodoriser is used it would take between 4.5 –5 hours depending on the oil type and quantity. However, if the same oils were processed in a semi-continuous deodoriser it would take about 15 minutes.

Physical refining is a simpler process in which the crude oil is degummed and bleached, followed by steam stripping which removes free fatty acids, odours and volatiles in one step. The oil is heated to temperatures of up to 270 °C and then refined by flowing it over a series of trays counter-current to the flow of the stripping steam. The advantages of physical refining are higher yield, lower cost and fewer chemicals used.

Most plants carry out hydrogenation to produce fats with superior keeping qualities and higher melting points. Hydrogenation is usually carried out by dispersing hydrogen gas in the oil, in the presence of a finely divided nickel catalyst supported on diatomaceous earth. Hydrogenated fats are filtered to remove the hydrogenation catalyst, subjected to a light earth bleach and deodorised before they can be used for edible purposes.

There are three other processes which may be carried out during oil refining, depending upon the oil source. These are ‘winterisation’, which essentially is the removal of wax which would otherwise cause cloudiness; this is carried out on oils such as sunflower. The process involves cooling the oil followed by filtration, using a filter aid to remove wax. The second process is fractionation; typically this may be carried out on crude or refined oil. This involves completely melting the solid oil, followed by cooling to yield solid and liquid fractions which have different functional properties. The third process is interesterification; this involves the separation of triglycerides into fatty acids and glycerol followed by recombination. The reaction is carried out using citric or phosphoric acid plus a catalyst, typically sodium methoxide. Boron trifluoride is also used, although usually on a laboratory scale rather than a commercial scale. Interesterification modifies the functional properties of the treated oil and may be carried out after neutralisation or deodorisation.

## 2.3.6 Dairy (SIC 15.51/52)

Milk is approximately 87 % water, the remainder being protein, fat, lactose, calcium, phosphorus, iron and vitamins. The milk of goats and sheep is often consumed by humans but it is primarily cows’ milk which is consumed in large quantities in the EU. A number of dairy products such as cream, cheese and butter are produced from milk.

### 2.3.6.1 Milk and cream

Raw chilled milk is received at the dairy and transferred to bulk storage. The milk may be centrifugally separated to produce a skimmed or semi-skimmed milk and cream stream. The milk is heat treated by a variety of methods such as pasteurisation, UHT (ultra high temperature) and sterilisation to inactivate spoilage organisms, pathogens and certain enzymes. Heat processing may be batch or continuous depending upon the quantity of the milk to be processed and the method employed. Typical heating parameters for a continuous pasteurisation process would be 72 °C for 15 seconds. This is known as high temperature short time pasteurisation (HTST). Hot milk is often used to partially heat incoming cold milk in a heating step known as “regeneration”. Following pasteurisation, the milk is rapidly cooled to around 2 °C. Milk which is not in-container heat processed, is filled and sealed in containers under clean or aseptic conditions. Milk may be homogenised after the regeneration stage, before completion of the pasteurisation step. Homogenisation disperses fat globules evenly and prevents separation of the cream component

Powdered milk is made by concentrating clarified, homogenised milk using an evaporator, followed by removal of water, commonly using a spray-dryer. The powder is typically agglomerated to improve reconstitution. Dry whole milk is susceptible to oxidative rancidity and may be packaged in a protective atmosphere to extend shelf life.

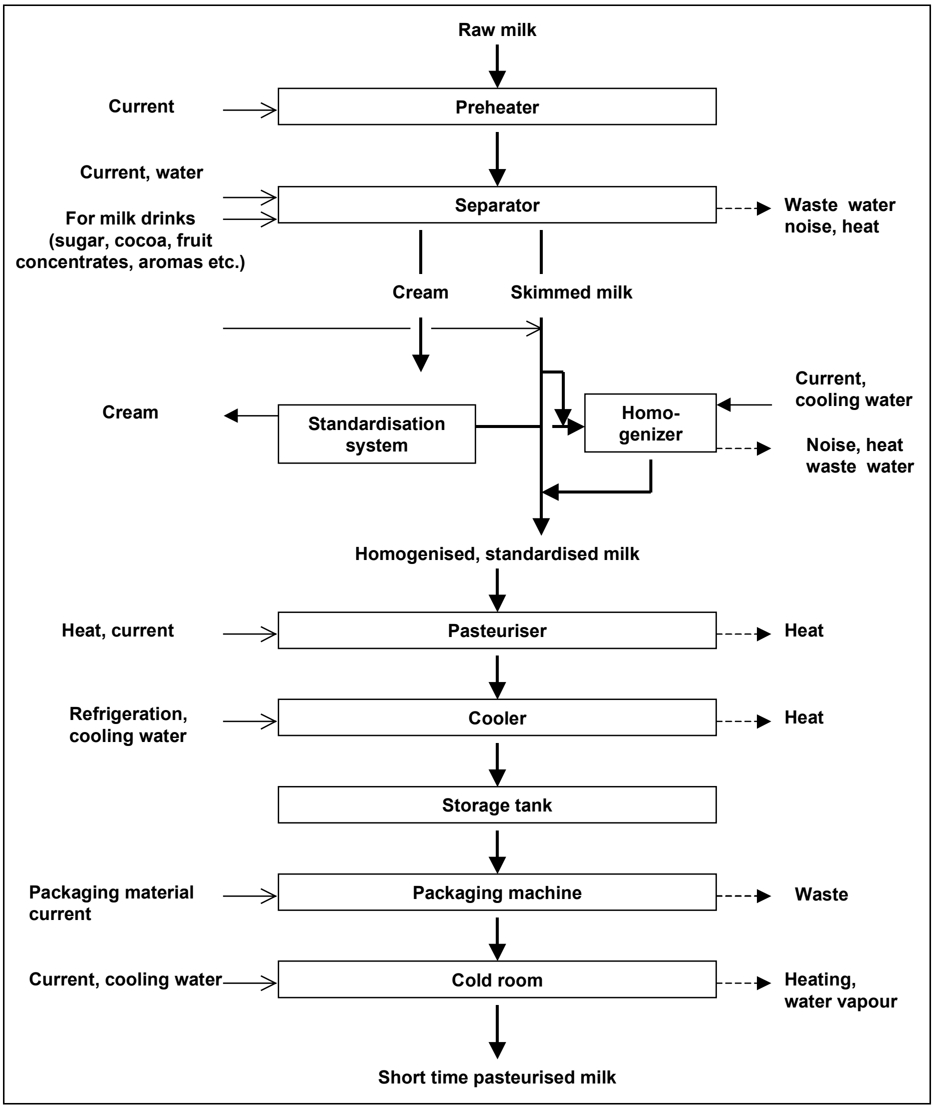


**Figure 2.3: Flow sheet for short time pasteurised milk process**

In addition to the operational chart on milk heating and standardisation, the following points are noted concerning possible environmental impact reduction measures which can be utilised by the dairy industry for energy, water & waste water, waste and emissions:

- optimised process engineering helps to minimise energy expenditure by heating as well as by refrigeration (heat regeneration, raw milk partial stream refrigeration). When dimensioning the heat regeneration the increase of heat regeneration must be weighed against the ensuing increase of pressure drop, operational time, cleanability and blending phase (and thus product losses and effluent load).

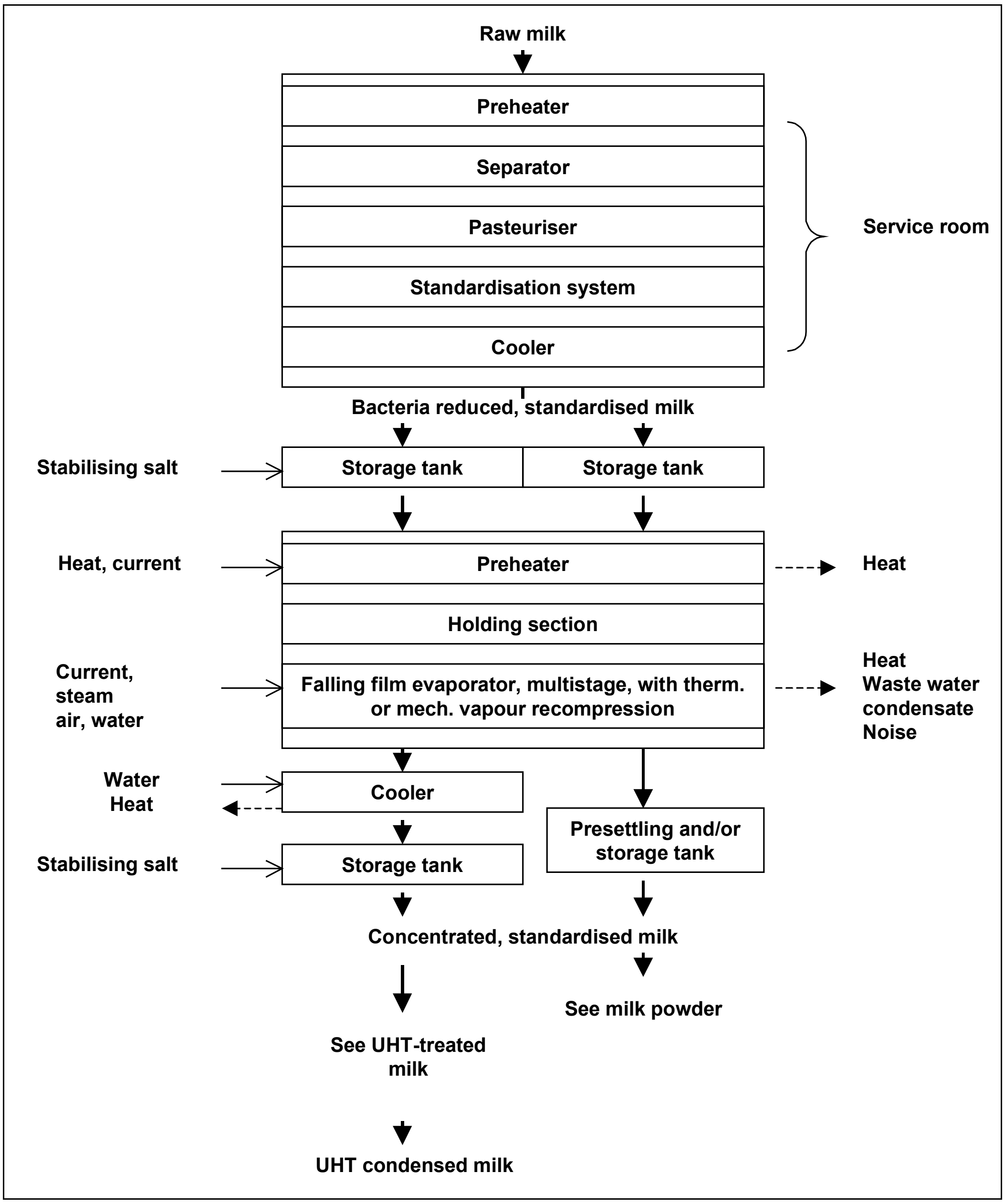


**Figure 2.4: Flow sheet of processes for condensed products (e.g. UHT condensed milk) and intermediate products (e.g. milk concentrates)**
**[9, Hannemann, 1999]**

In pasteurisation, start up and stop procedures of equipment and cleaning generate waste water. Significant energy is needed for heating and cooling steps.

In addition to the operational chart on condensed milk products, the following points are noted concerning possible environmental impact reduction measures which can be utilised by the dairy industry for energy, water & waste water, waste and emissions:

- for lower energy consumption requirements, mechanical vapour recompression is used instead of thermal recompression. However, it is necessary to check on a case by case basis whether an evaporator with thermal recompression is economically advantageous under the specific circumstances
- the mechanical vapour compressor and the thermal vapour compressor are two components which cause noise emissions; they are therefore sound insulated

- further noise emitters are product pumps, these tend to cavitations in certain operating states. This can be avoided by designing the plant with an appropriate supply height and/or by operating the pumps via frequency converters
- generally the evaporator is run with the highest possible concentrations of product; this is because the energy consumption needed for water evaporation in the evaporator is lower than it is in drying plant.

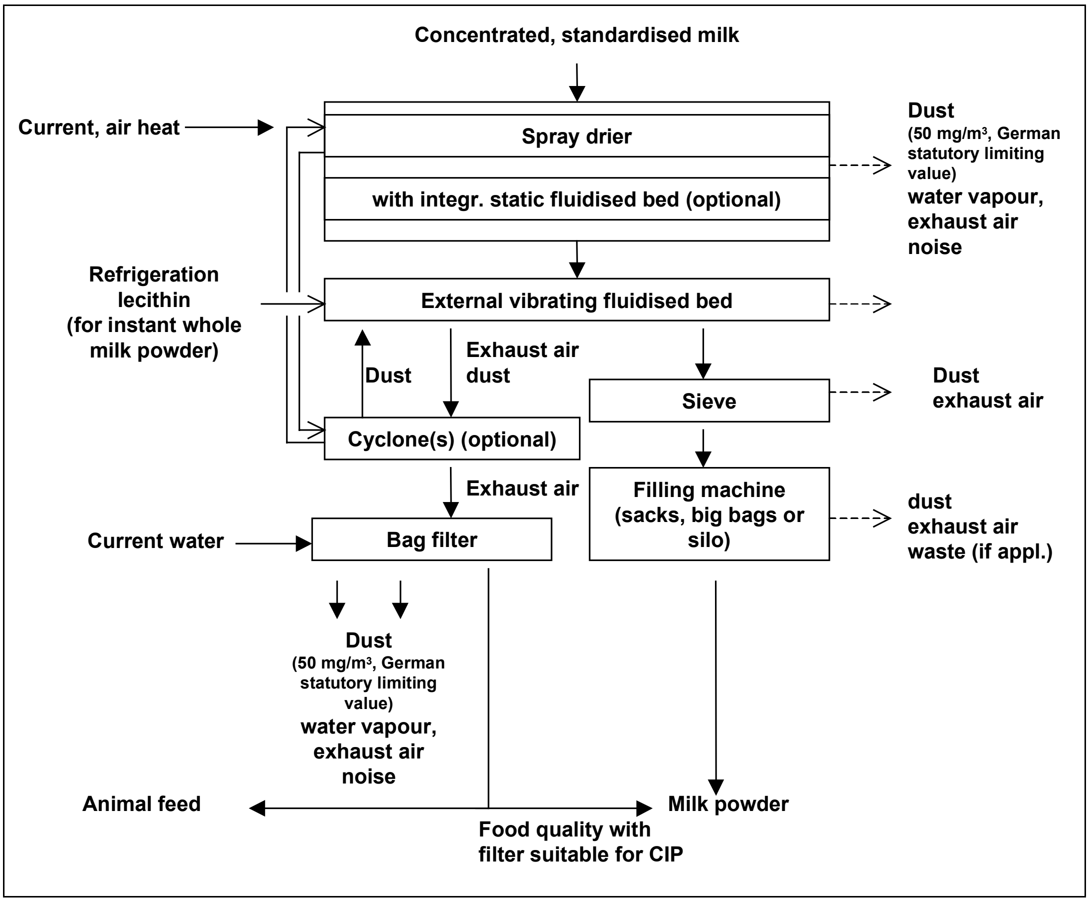


**Figure 2.5: Flow sheet of powdered milk production**

In addition to the operational chart on milk powder, the following points are noted concerning possible environmental impact reduction measures which can be utilised by the dairy industry for energy, water & waste water, waste and emissions:

- spray driers produce noise emissions, to which the operating personnel are exposed
- if filtering installations suitable for CIP are used for outgoing air, it is not necessary to use cyclones allowing huge energy savings and noise reductions to be achieved. The filter powder in food quality can be used for other purposes
- if an integrated fluidised bed is used the energy consumption for drying can be reduced by approx. 20 %
- in spray drying plants for milk, explosive dust/air mixtures can occur. Improved fire and explosion protection can be obtained by using an early warning fire alarm (e. g. CO-detection)
- electrical energy can be saved if throttle valves in ventilators are avoided and if ventilator drives are adapted to frequency converters
- powder residues need to be eliminated in dry state processing, but if there are they may be disposed of as feeding stuffs.

### 2.3.6.2 Manufacture of butter

Butter is produced from cream which is centrifugally separated from pasteurised milk. The cream contains around 35 - 40 % milk fat. The process is basically a mechanical one in which cream, an emulsion of oil in water, is transformed to butter, an emulsion of water in oil. This is achieved by a process of batch or continuous churning. Cream is rapidly chilled and held for a period in a process known as “ageing”. The cream is then subjected to churning and working. Churning agitates the cream to partially break down the oil in water emulsion until fat globules bind together to produce “butter grains”. The liquid phase (butter-milk) is removed and the butter grains are washed in water. Salt is added if required before the “working” stage of the process commences. This involves slow agitation of the grains, subjecting them to a kneading and folding action. The butter is packaged and stored, typically in chilled or frozen storage. A number of continuous techniques are available such as methods in which cream is subjected to high speed churning and continuous working.

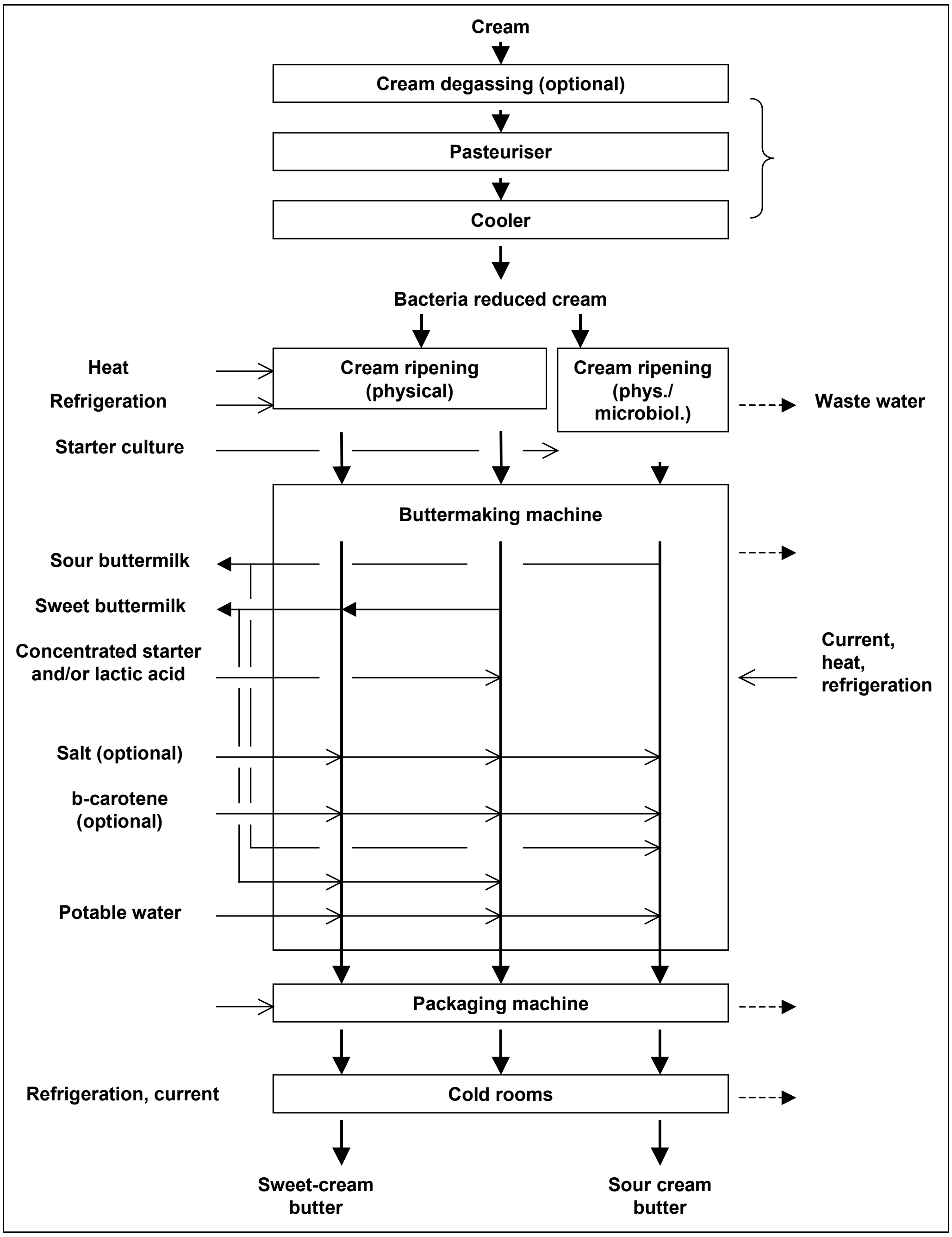


Figure 2.6: Continuous buttermaking
[9, Hannemann, 1999]

In addition to the operational chart on buttermaking, the following points are noted concerning possible environmental impact reduction measures which can be utilised by the dairy industry for energy, water & waste water, waste and emissions:

- butter and cream remnants in the buttermaking machine are removed completely at the end of production, i.e. before the cleaning (which is done manually, with hot water or steam). The remnants do not get into the waste water
- butter in tubings are removed at the end of production before the cleaning. This can be effected by means of a cooled butter block which is pushed out with compressed air
- due to the high viscosity of cream the cream heater can be drained with skimmed milk before the cleaning to reduce fat losses
- any buttermilk which results as a by-product must be utilised as a product and must not get into the waste water.

#### 2.3.6.3 Manufacture of cheese

There are a range of cheese varieties and many subtle differences in processing methods. In general, however, the following process steps apply; production of a coagulum through the action of rennet and/or lactic acid, separation of the resulting curds from the whey, and manipulation of the curds to produce the desired characteristics of the cheese.

Traditional cheese manufacture is a manual process but modern processes are highly mechanised. Starter cultures are added to the milk to produce lactic acid and rennet is then used to coagulate the milk protein. The curds and whey are separated and the curds washed and cut into cubes. Texturisation of the cheese involves compressing and stretching the curds and can be carried out in tower systems. The curd blocks are milled, salt is added, and the curds are pressed. Pressed cheese is wrapped to protect it against moisture loss and mould growth during storage. Cheese is matured to develop flavour and texture in temperature and humidity controlled stores, with regular turning and salting or brine washing of the cheese surface.

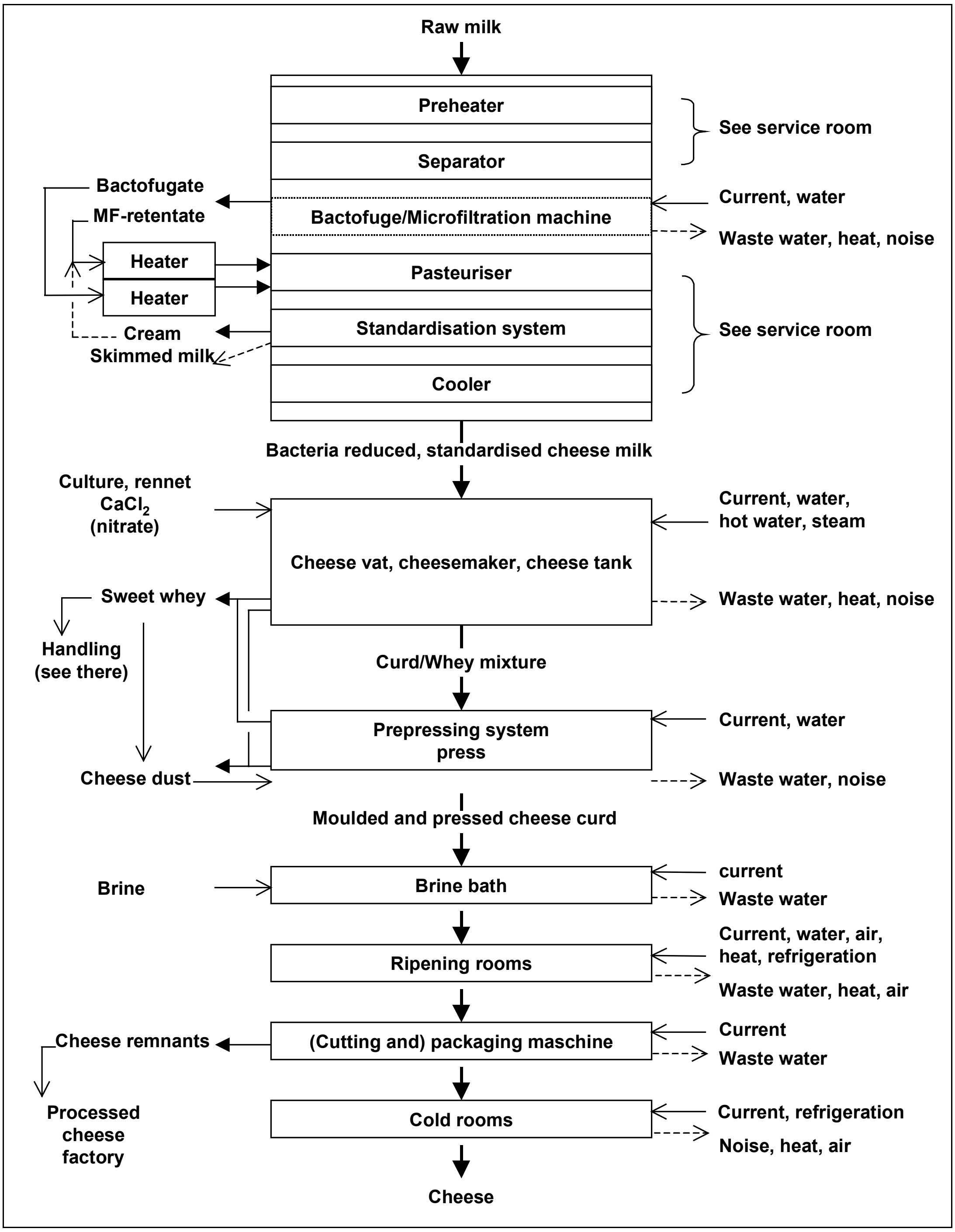


**Figure 2.7: Cheesemaking**

In addition to the operational chart on cheesemaking, the following points are noted concerning possible environmental impact reduction measures which can be utilised by the dairy industry for energy, water & waste water, waste and emissions:

- it is necessary to eliminate the whey completely, especially at critical points in the production, e.g. at portioning, draining sections, pressing, turning stations etc.
- it is not advisable to retain cheese curd with junk baskets in gullies or with sieves in the waste stream (when sieves are used to limit the amount of settleable solids in the waste water) unless regular cleaning of the floor drainages can be ensured, otherwise there might be problems with hygiene
- the plant design and operation ensures that systems are completely drained of whey and curd

- draining warm whey is used for preheating the entering cheese milk
- the use of special heat exchangers are considered in batch processing
- in order to save energy the air-conditioning of ripening rooms are checked with regard for any possibilities of heat regeneration.

#### 2.3.6.4 Manufacture of yoghurt

Yoghurt is a fermented milk product which differs from cheese in that rennet is not added and thickening occurs as a result of acidification by lactic acid bacteria. The main ingredients of yoghurt include milk, milk powders and stabilisers such as modified starches. Most of the yoghurt produced in the UK is manufactured in bulk before the addition of fruit and/or flavourings.

The main steps in the manufacture of yoghurt are as follows: the fat and solids not fat (SNF) content of the milk is first increased by the addition of milk powders, stabilisers may be added at this point. The milk is then homogenised at a temperature of around 55 °C and heat treated at 80 - 90°C for 30 minutes in a batch process, or 90 - 95°C for 5 minutes, in a continuous process. The heat-treated milk is cooled to around 40 - 43 °C and seeded with two starter organisms; Streptococcus salivarius subspecies thermophilus and Lactobacillus delbrueckii subspecies bulgaricus. The fermentation takes around four hours at the end of the process. The milk is cooled to 15 - 20 °C, using either tank cooling coils or, more commonly, tubular or plate heat exchangers. Fruit and flavours are blended into the yoghurt which is then cooled to less than 5 °C and filled into pots ready for storage and distribution.

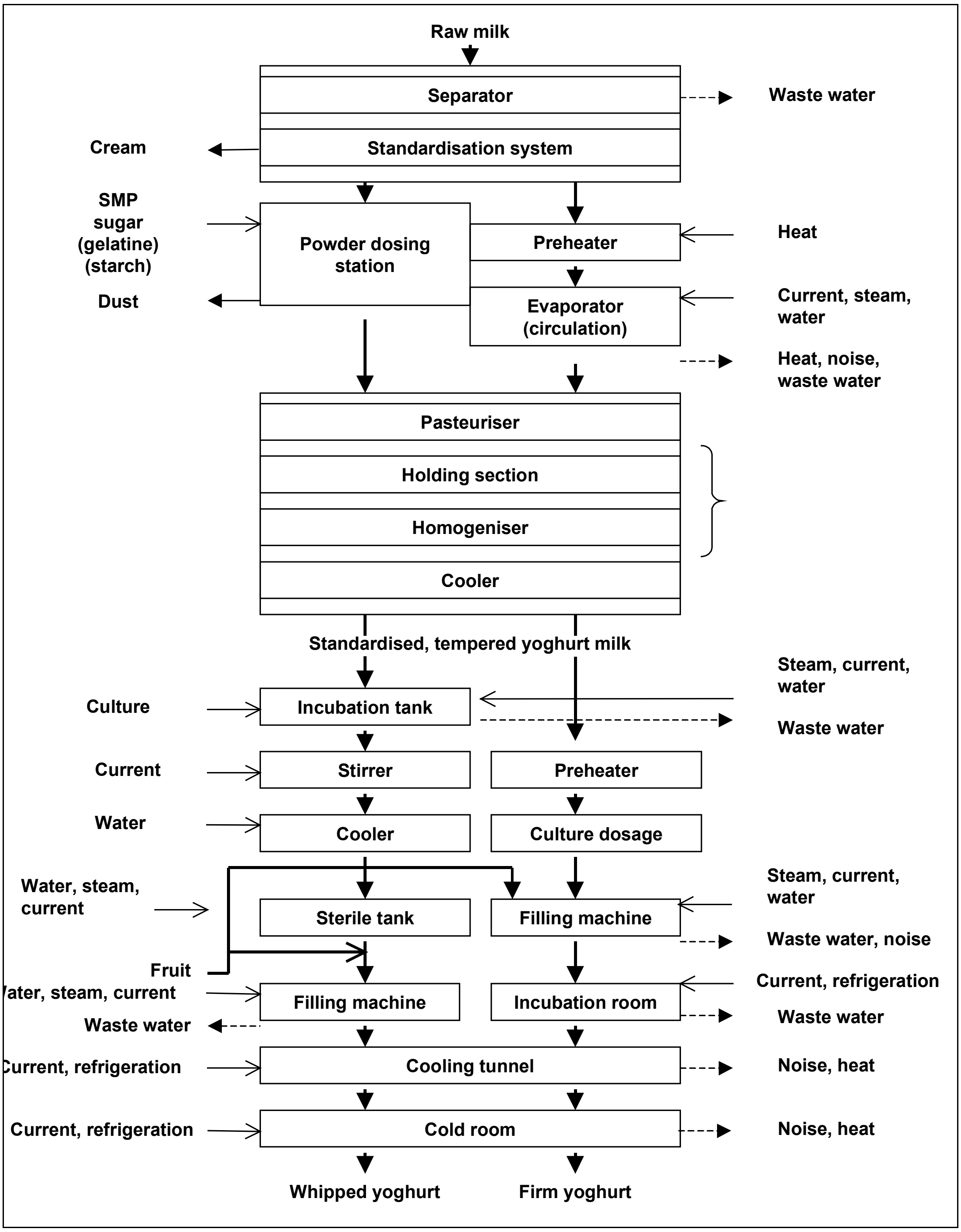


Figure 2.8: Yoghurt production

In addition to the operational chart on yoghurt production, the following points are noted concerning possible environmental impact reduction measures which can be utilised by the dairy industry for energy, water & waste water, waste and emissions:

- normally the fruit containers are sent back to the producer without previous cleaning. If they are cleaned in place, the possibility of an increase of $BOD_5$ values and settleable solids are taken into account
- it is checked if adjuvants and additives can be reasonably used in returnable packings or in silo tankers instead of non-returnable packings
- the plant design and operation must ensure that the systems are completely drained.

- for very viscous products it can be useful to employ pigging systems to prevent product losses before cleaning
- to reduce energy consumption in yoghurt milk heating operations, it is checked if the heat loss from the operation can be used for pre-warming.

#### 2.3.6.5 Manufacture of ice-cream

Ice-cream is a dairy based product which typically contains 6 - 12 % fat, 7.5 to 11.5 % milk solids (not fat) and 13 - 18 % sugars. Stabilisers, emulsifiers, colours and flavours are also added. Sugar is usually added as sucrose, and milk solids not fat are usually from skimmed milk solids. The fat source may be milk, cream, butter or butter oil. Most ice-cream contains vegetable fat. The ingredients are blended, heated to around 70 - 75 °C and homogenised. The mixture is then pasteurised by heating to 80 - 85°C for 2 - 15 seconds before cooling and "ageing" by holding at chilled temperatures for 4 - 24 hours. Colours and flavours are added at the ageing stage. Continuous freezers are used to rapidly freeze the ice-cream down to around –6°C with compressed air being introduced into the ice-cream during the freezing process. The increase in volume due to the addition of air is known as "over-run". The ice-cream is filled into containers and frozen further in tunnel freezers operating at -30 to –40 °C.

### 2.3.7 Grain milling (SIC 15.61)

There are a number of cereals which are of importance as food sources, these include wheat, barley, maize, oats and rice. Wheat grain is milled into flour and is the prime ingredient used in the manufacture of products such as bread and biscuits. Barley is one of the oldest cultivated cereals and is used in industries such as brewing and distilling. Maize is used as a source of starch but also as an ingredient in breakfast cereals and snack foods. Oats are used in products such as porridge, oatcakes and biscuits. Rice, along with wheat and maize is one of the major cereals of the world and is the basic food for much of the world's population. The flour milling industry deals with wheat as its raw material.

The wheat grain is made up of three main components, the enveloping skin (bran), the embryo (germ) and the endosperm, which makes up the majority of the grain and is used as a food source for the developing embryo. The object of the milling process is to separate the endosperm with minimal contamination from the bran and germ. The main operations associated with flour milling are: cleaning, conditioning, breaking, scalping, purification, reduction and dressing.

The incoming grain is transferred to bulk silos prior to further processing. The grain is first cleaned by passing through a series of screening, scouring, brushing and aspiration operations. These processes remove extraneous matter such as other cereals, stones, metal contaminants, chaff, loosened bran layers, seeds and dust. After cleaning, the grain is conditioned to optimise the milling process. This involves dampening the grain by the measured addition of water at a rate between 1 and 5 %; this is immediately bound to the kernels. Conditioning has a number of functions, such as toughening of the bran, thereby improving the separation of the bran from the endosperm, and allowing the endosperm to be reduced more effectively in subsequent stages of the process.

The conditioned grain enters the break system of the mill, which consists of pairs of corrugated rolls which revolve in opposite directions at different speeds. Five sets of break operations are common, with the aperture gradually decreasing and the corrugation becoming finer between subsequent sets. The grain is split by the break-rolls and the endosperm is scraped from the bran. A screening operation known as "scalping" and grading is carried out after each break-roll which separates: 1) coarse particles which contain the remains of the grain and some endosperm which is yet to be recovered; 2) flour; 3) particles of intermediate size which contain chunks of endosperm called semolina or “middlings”, depending on their particle size and purity. The semolina and middlings pass through a purification system, consisting of sieving and air classification, to remove particles of endosperm with bran adhering, for further treatment by finely fluted rolls elsewhere in the process. The semolina and middlings are then transferred onto reduction rolls, which are smooth rolls whose purpose is to crush the endosperm. As in the break section of the mill, there are a series of rolls and screening operations so that flour is screened off whilst coarser endosperm, retained on the sieves, passes to a further set of reduction rolls to be further reduced in size. At the end of the reduction process, most of the endosperm has been converted to flour, the coarse bran has been removed and there is a third stream of endosperm containing fine bran containing material which cannot be practically separated. There could be as many as 12 reduction stages in the process. Flour is normally passed over a final redresser at the end of the milling process or after bulk storage to ensure the safety of the final product with respect to foreign body contamination. The majority of flour is delivered in bulk; some 25 % are bagged for delivery to bakers and other food manufacturers. Grains such as oats and barley, with a tightly adhering husk cannot simply be separated in a traditional wheat mill and are usually subjected to an abrasion process called “pearling” prior to milling.

### 2.3.8 Starch manufacture (SIC 15.62)

**[10, Environment Agency (UK), 2000], [Association, 2001 #84]**

Starch is a high molecular mass carbohydrate produced by plants as a food store. Purified starch is usually a white powder that can be used as a thickening agent in the food industry. Starch used in food processing is usually chemically treated or “modified” to enhance desirable functional properties. Hydrolysis of starch by acid and/or enzymes yields a variety of sugar syrups. Incomplete hydrolysis yields a mixture of glucose, maltose and non-hydrolysed fractions called dextrins. Germ is a by-product of starch manufacture, and can be used to produce oils. Other co-products are fibre, gluten and de-fatted meal which are all used or sold on for other uses, including animal feed.
Corn or potato is the raw material for the majority of modified food starches.

#### 2.3.8.1 Maize starch process

Corn can be used to produce starch, sugar syrups and oil. The raw material is cleaned using aspiration and screening to remove dust, chaff, broken grain, cobs and other extraneous material. The corn is soaked in water with sulphur dioxide, for around 36 hours, in a process known as steeping. This removes solubles in the corn, softens the kernel to improve separation of the various components and reduces microbial activity. After steeping, the corn is passed through several grinding and separation operations until only starch and gluten remain. The grain is first ground coarsely and the germs removed from the coarse grist. After removing the germ, the grist is finely ground and fibre is removed by screening. Starch and gluten are separated, typically using centrifugal methods. The starch is washed, dewatered and dried. The gluten, and fibre are collected separately as co-products.

The maize starch extraction (wet milling) process is summarised in the figure below. The process is operated as an enclosed system in which process water is re-used in a closed circuit. The addition of fresh water is limited to one point of the production process.

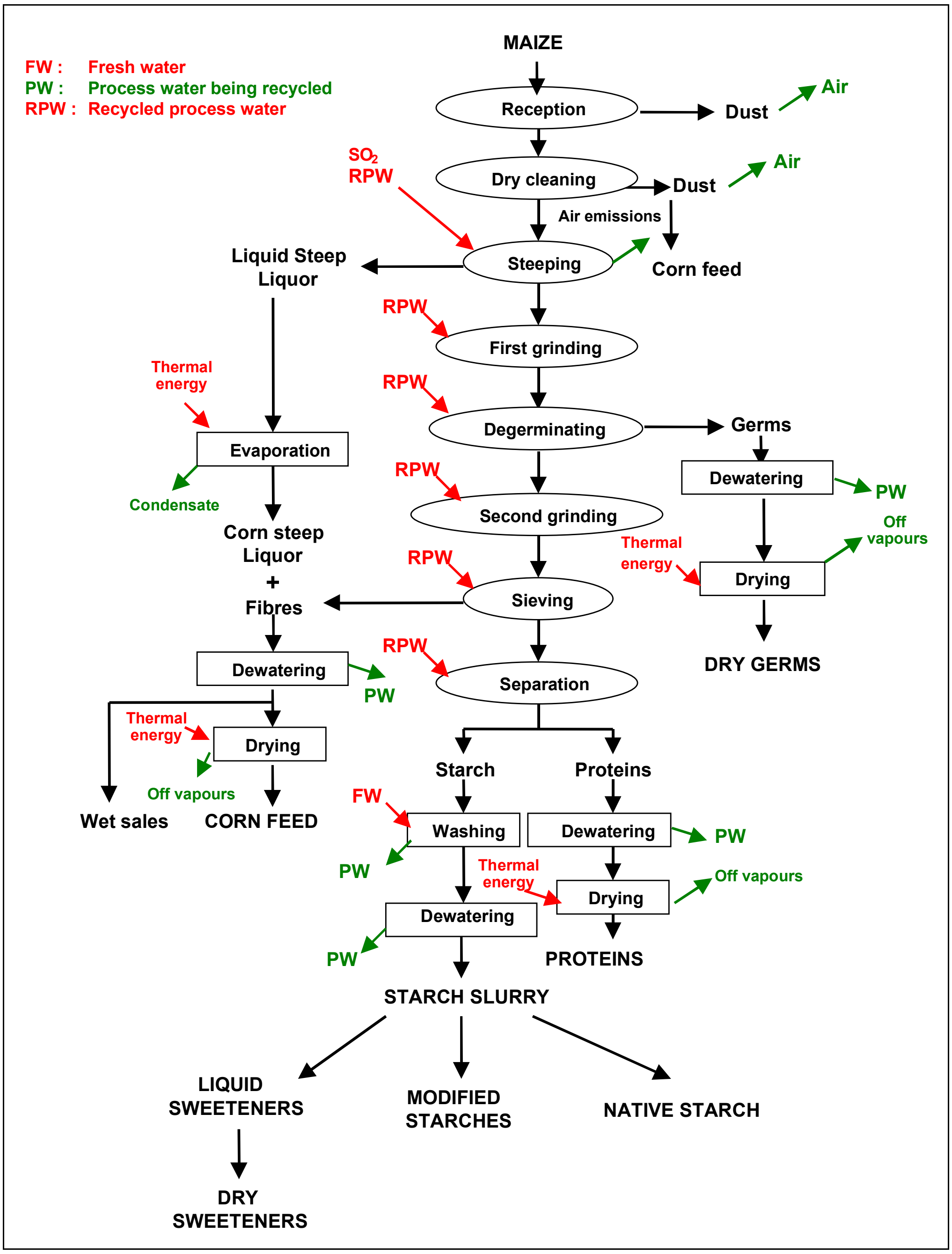


**Figure 2.9: Maize starch process**
**[84, European Starch Association, 2001]**

### 2.3.8.2 Wheat starch process

The commercial separation of pure starch from wheat is achieved by a two phases process. During the first phase the wheat kernel is ground or converted into wheat flour by a dry milling process. The second phase separates the ground wheat or the wheat flour in its components (starch, gluten, solubles, eventually fibre) by a wet separation process.

The process is operated as an enclosed system in which process water is recycled in a closed circuit. The addition of fresh water is linked to a few points in the process.

The wheat starch extraction process is summarised in Figure 2.10.

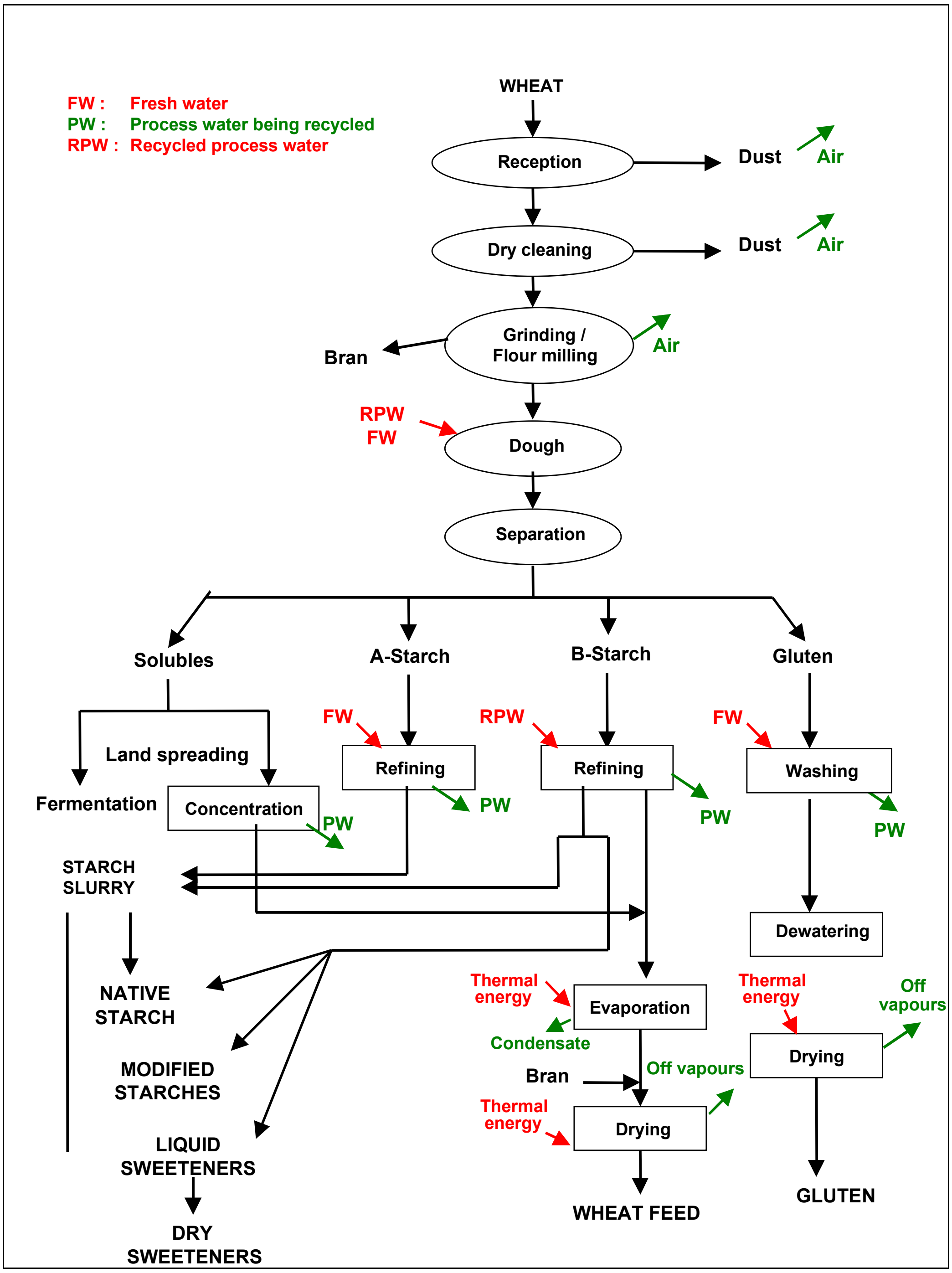


Figure 2.10: Wheat starch process
[84, European Starch Association, 2001]

### 2.3.8.3 Potato starch process

The potato starch process is a completely wet process. It consists of the disintegration of the tuber into pulp and of its separation into starch, fibre and fruit juice.

The potato starch extraction process is summarised in the Figure 2.11 below.

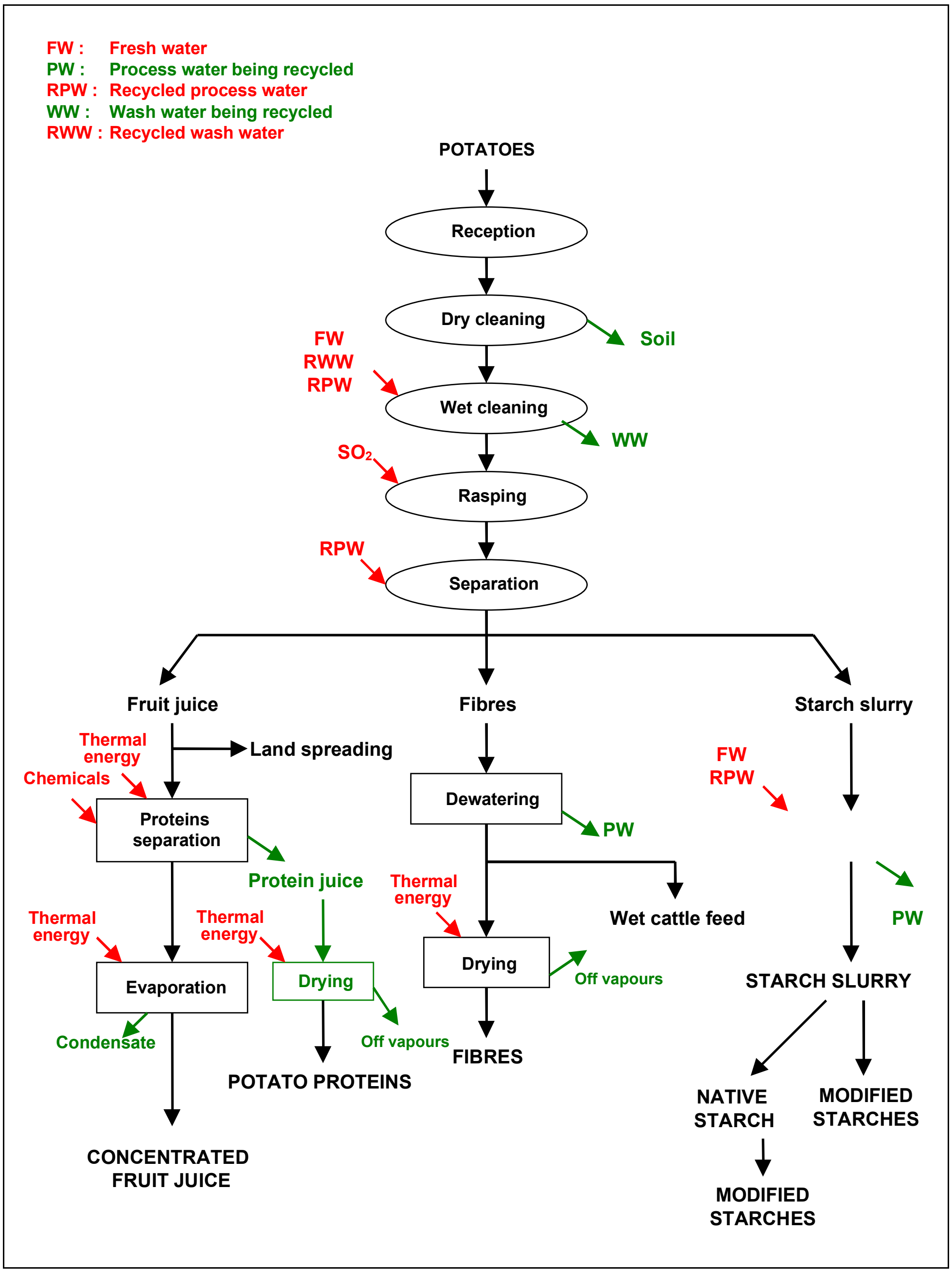


**Figure 2.11: Potato starch process**
**[84, European Starch Association, 2001]**

### 2.3.8.4 Oil manufacture

The separated germ is washed and dried. Hexane is commonly used to extract oil from the germ. The hexane can be recovered for further use.

### 2.3.8.5 Sugar syrup manufacture

The starch slurry is also the starting raw material for the manufacture of sugar syrups; which are produced by the action of acids, enzymes or a combination of both. In a typical process, dilute hydrochloric acid and a starch slurry (the final product of starch manufacture before drying) are mixed. The temperature is then raised to around 140 °C. Conversion of the starch only takes a few minutes. The mass is neutralised, insoluble matter removed by filtration and the liquor is concentrated. The liquor is usually filtered and treated with active charcoal or ion exchange resins to remove colour, ash and other minor impurities.

## 2.3.9 Animal feeds (SIC 15.71/72)

The compound feed industry consists of two distinct sectors: animal feeds and pet foods. Animal feeds are predominantly dry, while pet foods often have a significant moisture content. In both sectors, the manufacturing process involves the blending of a range of ingredients such as cereals, protein sources, vitamins, minerals and lipids to produce nutritionally balanced foods.

By far the most important moist pet food ranges are those for dogs and cats. These foods are classified according to moisture, packaging and processing systems, and include moist foods and semi-moist foods. Although moist foods currently comprise a major portion of the UK market, semi-moist foods are becoming increasingly popular. Moist foods have a moisture content of 60 to 85 % and are usually preserved by heating. The heat treatment may be applied before or after packaging. Moist foods can be subdivided into canned foods, premium moist foods, brawns and frozen meats.

### 2.3.9.1 Animal feeds and dry pet foods

The main animal feed types are compound feeds; these consist of a variety of blended ingredients, the composition of which depends upon the type and age of the animal but typically include cereals, fibre, protein and supplements such as vitamins, minerals and veterinary ingredients. Some of the ingredients are by-products of the food processing industry.

The raw materials are received at the feed mill and may be pneumatically conveyed or mechanically transferred to bulk storage silos. Some small ingredients which may be mixed in during the process, such as supplements, may be sent pre-bagged in appropriate quantities. Ingredients are weighed (automatically in modern plants) and transferred to holding bins prior to grinding, typically using hammer mills. After grinding the ingredients are thoroughly mixed and any supplements added. The blend may then be drawn off as “meal (mash) feed” or pressed to produce rolled feed. More commonly, the blend goes on to be manufactured into feed pellets. Steam is injected into the feed in a process known as “conditioning” before it is extruded through dies, the resulting pellet size varies depending on the intended use. During this stage of manufacture the pellets are dried and then cooled, typically in coolers in which the pellets enter from the top and cool air is blown in from the bottom. This product is also dried as a result of the cool air. To account for moisture loss during extrusion, drying and cooling, water may be added at the blending stage with some feeds. The pellets are then either stored in bulk or packaged. Some feeds may be coated in fat prior to packing.

### 2.3.9.2 Moist pet foods

The raw materials used in moist pet foods are typically by-products of foods manufactured for human consumption. These by-products must be fit for human consumption although they would not typically be used for this purpose. Ingredients used include meat processing by-products, whole grain, ground cereals, flavourings and vitamin and mineral supplements. Pet foods are designed to be nutritionally balanced to meet the needs of a particular type of animal.

### 2.3.9.3 Semi-moist pet foods

The raw materials used in semi-moist pet foods are typically by-products of foods manufactured for human consumption. Ingredients commonly used include dry cereal sources, vitamin and mineral supplements and some meat slurries. The ingredients are blended, conditioned and extruded into small shaped pieces. The pieces are dried and fat or meat extracts may be sprayed onto the surface. This type of feed is often multi-component. After drying, various fractions manufactured in a similar way, are blended to produce the finished feed. The feed is then packaged.

### 2.3.10 Bread (SIC 15.81)

One of the main bakery products is bread. This is made by combining flour, water, salt and yeast. Commercial production of bread may also involve the addition of preservatives and additives to improve flavour, texture and prevent microbiological growth. There are two main methods for making bread, the Chorleywood Bread Process (CBP) and the sponge-dough method. In the UK, the majority of commercial bakers employ the Chorleywood (CBP) process. The sponge-dough process involves mixing some of the ingredients and leaving the mixture to ferment for about 3 hours before adding the remaining ingredients and baking. In the Chorleywood process, dough mixing and development take place in a single operation. An oxidising improver, fat or emulsifier, and extra water and yeast are mixed in at this stage. The whole mixing and development process lasts between two and five minutes. The dough ingredients are mixed together with an intensive energy input and transferred to a hopper which is sometimes sprayed with oil. The dough is divided into loaf size pieces. A preliminary rounding is given to the dough at this stage. The dough is then allowed to rest ("first proof") before being given a final moulding and (normally) placed into tins. The tins may be sprayed with oil before filling. The dough is allowed to ferment a second time ("second proof") and may be "cut" before baking. Baking normally takes place at around 220 to 270 °C for 21 to 30 minutes. The most common energy source is the combustion of natural gas although electricity may also be used. Combustion gases and volatiles from the oven are released via a stack. After cooling, the bread may be sliced before being wrapped ready for distribution.

### 2.3.11 Biscuits, cakes, cocoa, chocolate and boiled sweets (SIC 15.82/84)

#### 2.3.11.1 Biscuit manufacture

The principal ingredients used in the manufacture of biscuits are wheat flour, fat and sugar. Water plays an important role in the biscuit making process but is largely removed during baking. There are two basic dough types: hard doughs, and short doughs. Whatever the dough type, the basic process steps involved in manufacture are dough mixing, formation of the dough pieces, baking, cooling and packaging. The methods used at each stage vary considerably depending on the product type. Raw materials are usually received in bulk and automatically metered into dough mixers but small ingredients such as salt and sodium bicarbonate may be weighed and added by hand. The ingredients are blended and, in the case of hard doughs, mixed to promote a gluten network in the dough. In the case of short doughs mixing is such that gluten development is deliberately limited. Formation of dough pieces varies depending on the biscuit type. Crackers and semi-sweet biscuits are cut from continuous sheets of rolled hard dough; crackers require considerable processing as they are built up in a series of thin layers. Most short doughs are formed by rotary moulding, but soft doughs for cookies are usually wire cut. The biscuits are baked, usually in tunnel ovens. The times and temperatures used vary depending on the product. Ovens may be direct or indirect fired, gas or electric. The baked biscuits are cooled and packed or transferred for secondary processing (e.g. layering of cream fillings). Crackers may be oil sprayed immediately after baking. Cooling is typically achieved by conveying the biscuits around the plant for a set time period.

### 2.3.11.2 Cake manufacture

The main ingredients used in cake manufacture are wheat flour, fat, eggs, sugar, milk powder, water flavourings and raising agents. Cakes are generally made using either the sugar batter or flour batter method. In the sugar batter method, the fat and sugar are creamed together and the egg is added in stages. Several alternate additions of flour and liquid are carried out throughout mixing. In the flour batter method, the fat and flour are blended together. The eggs and sugar are whisked together and then blended into the fat and flour in stages. The required quantities of liquids are then added in small amounts as mixing progresses.

In continuous mixing systems such as the Oakes and Mondo cake mixers, the ingredients are given a preliminary mix and then fed in a continuous even stream, into the head of the mixer. “All in” high speed cake mixing is being increasingly used. In this method, all ingredients except fruit are added and a fixed amount of work is used. The fruit is then added in short bursts.

Batters are typically deposited into oil sprayed trays (or continuous sheets for products such as Swiss rolls). After baking, the cakes are removed from the tins and cooled. The empty tins are washed, rinsed, dried and cooled.

### 2.3.11.3 Cocoa manufacture

Drinking cocoa typically consists of cocoa powder, vanillin, cinnamon, salt, cassia and other powdered spices. Raw beans are received at the factory and subjected to a series of cleaning operations to remove extraneous matter such as fibre, stones, grit, metal, bean clusters and immature beans. The latter two materials may be used for cocoa butter manufacture. The beans are roasted; conditions vary depending on the equipment and the desired product, but are typically in the range of 100 - 140 °C for 4 - 6 minutes. Whole beans or the separated “nibs” may be roasted. Winnowing is the separation of the bean outer shell from the edible “nibs” and typically consists of cracking the roasted bean between rollers, followed by air classification to remove the shell fragments. The nibs are ground to produce a cocoa liquor whose particle size is further reduced by grinding mills, which are water-cooled. The particle size is important for chocolate beverage manufacture but less important for chocolate since this requires some further refining. The liquor or nibs from roasted or unroasted beans is likely to be subjected to a process known as “alkalisation” which increases the dispensability of cocoa powder in milk or water when used in beverages. It is also used to modify the colour of the cocoa. Only permitted acids, bases and emulsifiers may be used for this process. Cocoa powder is produced by hydraulic pressing of cocoa liquor to express cocoa butter and reduce the fat content of the press cake to the desired level. The expressed cocoa butter is used in chocolate manufacture. The press cake is pulverised to produce a cocoa powder. The final product is then packaged.

### 2.3.11.4 Chocolate manufacture

The basic ingredients for chocolate manufacture include cocoa liquor, sugar, other sweeteners, cocoa butter, butter fat, milk powder, milk crumb and emulsifiers. The basic operations involved in chocolate production are preparation and mixing of ingredients, refining and conching. Conching involves agitating the refined material to induce desirable physical changes in the final product and to improve flavour. Chocolate production has traditionally been undertaken in a device called a melangeur, which accommodates all of the steps involved; melangeurs are, however, being increasingly replaced by large specialist machines.

The refining stage in chocolate manufacture is intended to reduce the size of the particles of cocoa solids in the mix, thus ensuring that the mixture has a smooth consistency. This is achieved by passing the mixture through vertically mounted rollers which have to be water cooled to prevent distortion arising from frictional heating.

A number of systems are available for conching which is a specialised activity, inducing complex changes in the chocolate. Processing milk chocolate in a traditional batch conch takes in excess of a day, whilst modern, continuous systems achieve the same end in around 4 hours. Finished chocolate is typically stored in bulk and must be tempered (a cooling and warming cycle) before final use.

Chocolate products may be produced by casting the chocolate into moulds, followed by cooling and demoulding. Such methods may be used to produce solid chocolate blocks or shells, which may be hollow or filled with a confectionery such as fondant. Alternatively liquid chocolate may be used to coat confectionery using units known as "enrobers".

### 2.3.11.5 Boiled sweets

Boiled sweets are highly concentrated solutions of sugar, glucose syrup (and sometimes invert sugar) with added flavourings. The sugar, glucose syrup and invert sugar are metered into continuous dissolvers. This mixture feeds cookers, of which there are a number of designs such as thin film, coil cookers or batch vacuum cookers. Water is rapidly evaporated from the syrup, which is then discharged and partially cooled due to evaporative cooling. The boiled sweet mass is transferred to water-cooled tables and acid, flavour and colours are added to the partially cooled mass in a batch or continuous process. The mix is then transferred to forming machinery. The formed sweets are cooled and wrapped in moisture proof packs as rapidly as possible

## 2.3.12 Sugar refining (SIC 15.83)

Sugar (sucrose) is produced from two principal sources, sugar beet and sugar cane. Sugar beet tends to be grown in Europe and sugar cane in hotter climates such as the West Indies. Sucrose is also available in a form called "liquid sugar"; this has been refined but with the crystallisation step omitted. Sugar crystals may also be ground to make powdered or confectioner's sugars; anti-caking agents such as cornstarch are added to keep these sugars free flowing.

### 2.3.12.1 Beet sugar manufacture

The crop is delivered to the factory and the beets are washed and sorted to remove extraneous matter such as stones and dirt. The beets are sliced into thin strips known as "cossettes". Sugar is extracted from the cossettes in a "diffuser" which uses water introduced counter-currently at around 70 °C.

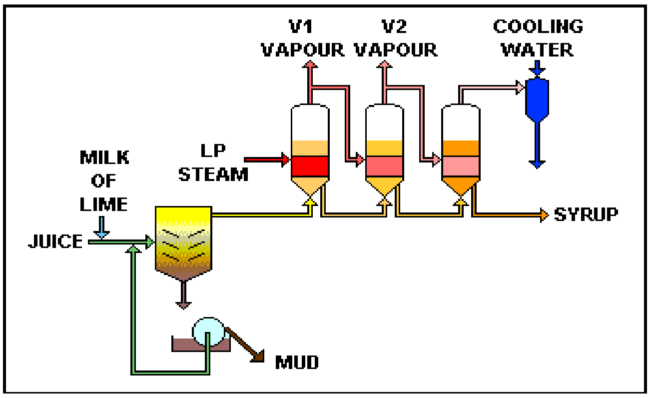


**Figure 2.12: Clarification of raw sugar**

The extracted sugar solution is heated with milk of lime and carbon dioxide. This produces a precipitate which carries down with it impurities such as gums, waxes and resins.

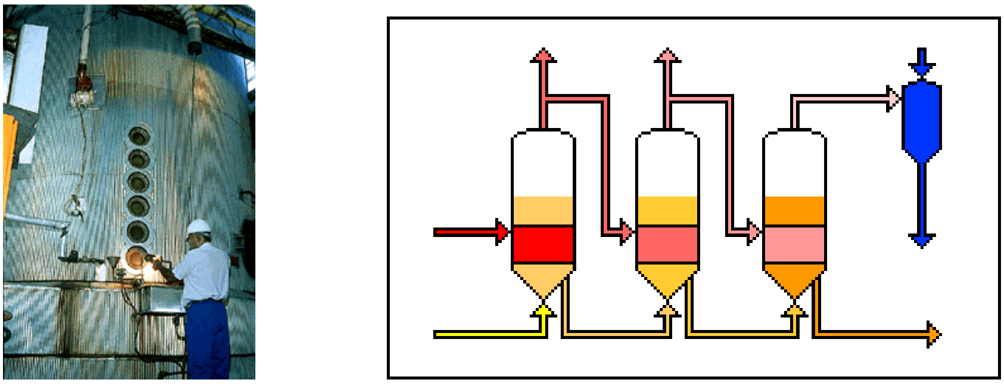


**Figure 2.13: Evaporation in sugar production**

After clarification, the solution is evaporated in multiple effect evaporators to produce a syrup of around 50 - 65 % solids known as “thick juice”. The juice is filtered, transferred to vacuum pans and seeded with very fine sugar crystals to initiate crystallisation of the sugar in the juice. The sugar is centrifugally separated from the juice, washed and then dried to yield the final product. The syrup is re-cycled into the vacuum pans for further crystallisation of sugar. The spent syrup is termed molasses.

The beet pulp generated from the extraction process is dewatered; molasses may be added before the mixture is dried and pelletised for animal feed.

### 2.3.12.2 Cane sugar manufacture

Raw cane sugar is usually separated, purified and crystallised in the country of origin. The cane sugar, which is in a crudely refined state, undergoes final processing when transferred to the country of use.

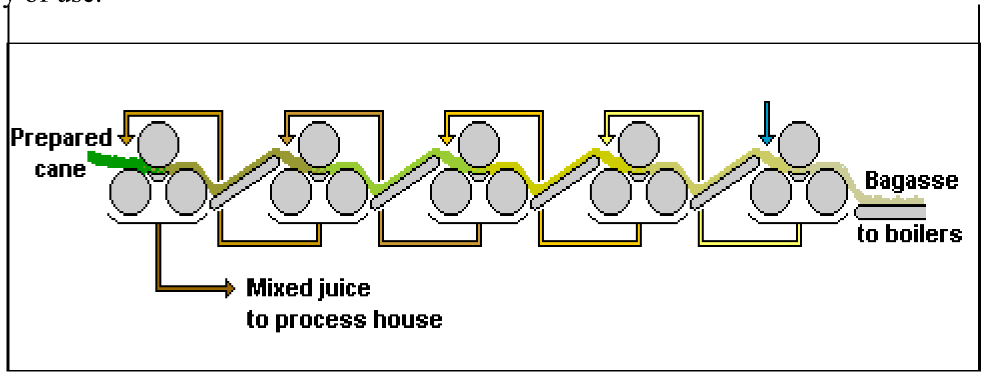


**Figure 2.14: Production of raw cane sugar**

The raw sugar is typically a minimum of 96 % sucrose. The impure crystals, with adhering molasses, are “affined” in a saturated sugar solution to soften the surface molasses film which can then be removed by centrifugation. The affined sugar is dissolved in reclaimed liquors (“light waters” from the refining process). Carbonation (treatment with milk of lime and carbon dioxide) follows. This removes suspended impurities such as waxes, gums and starches. The sugar syrup is filtered and decolourised using ion exchange resins and activated carbon to produce “fine” liquor, which may be sold as a finished product or passed on for crystallisation in vacuum pans. The fine liquor is concentrated by evaporation. When the liquor is slightly supersaturated, the pan is “seeded” with fine icing sugar. The mixture is centrifugally separated to extract crystalline sugar, which is dried, conditioned for packaging or bulk loaded. Each pan boiling yields around 50 % of the available sugar. The liquor separated during centrifugation ("jets") is re-boiled for further extraction. Three boilings yield white sugar. A fourth boiling yields "off white" industrial sugar. Jet four together with liquor from affination goes to a recovery house for 3 further boilings to produce brown sugars which go back to the start of the process and are treated as raw sugar. When it is no longer economically feasible to extract further sugar, the spent liquor is known as "molasses". Various intermediary products from jets one to four and the corresponding syrups from recovery and boiling are sold as the starting materials for syrups such as golden syrup and treacle. Molasses are used for animal feed, fermentation and a number of non-food uses.

### 2.3.13 Coffee processing (SIC 15.86)

Commercial coffees are grown in tropical and subtropical climates at altitudes up to around 1800m. Coffees from different producing regions possess characteristic flavours. Commercial roasters mix varieties either before or after roasting to produce a desired end-product. The main processing steps in the manufacture of roasted coffee are blending, roasting, grinding and packaging. Instant coffee is produced from a water extract of roasted ground coffee. Roasting coffee beans and the production of instant coffee are energy intensive processes.

#### 2.3.13.1 Roasting coffee

Green coffee is received at the factory and sorted to remove extraneous matter. Coffees from different varieties or sources are blended before or after roasting. Roasting is usually carried out by hot combustion gases in rotating cylinders. The final bean temperature is around 200 - 220 °C. A water or air quench terminates the roast. Most of any added water is evaporated from the heat of the beans. Fluidised bed systems may greatly reduce roasting times from around 8 - 15 minutes to 1 - 3 minutes. Finished coffee is transferred to storage bins. Any residual foreign bodies are removed before grinding, usually by air classification methods. Most coffees are ground in steel cutting rollers which are scored, once longitudinally and once across the circumference. Cracking rolls break the beans before they are fed into a further series of rollers. For fine grinds, the coffee may pass into further sets of rollers, being scored on each subsequent pair of rollers and becoming progressively finer as the coffee travels through the system. Roasted and ground coffee in Europe is typically vacuum packed in flexible pouches of plastic-laminated foil.

#### 2.3.13.2 Instant coffee

Instant coffee is subjected to similar processing, namely blending, roasting and grinding although processing details such as particle size after grinding may differ. The roasted, ground coffee is charged into columns called percolators, through which water is pumped to produce a concentrated coffee extract. Some manufacturers vacuum-concentrate the extract. The extract is dried, typically by spray-drying or freeze-drying. The powder may be agglomerated to improve solubility. The final product is then packed into containers.

#### 2.3.13.3 Decaffeinated coffee

Green beans are moisturised by steam or water to a moisture content of around 20 %. Solvents are then used to extract the caffeine from the wet beans. The solvent extraction may be by direct contact with the beans or by contact with a secondary water system that has previously removed the caffeine from the beans. Steaming or stripping is used to remove solvent from the beans. The beans are then re-dried to their original moisture content prior to roasting. The use of carbon dioxide under supercritical conditions is also used for decaffeination. Solvent extraction of the caffeine from the extract used to make instant coffee rather than from the bean itself, may also be used.

### 2.3.14 Yeast products (SIC 15.89/90)

Yeasts are single cell fungi used in a wide range of fermentation processes such as baking, beer brewing and the manufacture of wines and spirits. Yeast is usually supplied to food manufacturers either in a crumbled/compressed form or as active dry yeast. Although methods vary, the essential steps in conventional processing are as described below.

Propagation takes approximately 6 - 8 days on a commercial scale using 20000 to 50000 gallon (i.e 90800 to 227000 litres) propagators. Yeast production initially involves a series of small propagations; the yeast produced at each stage being used to "seed" the subsequent propagation. Ingredients typically added to the fermenter are cane and beet molasses (blended and clarified before addition), ammonia, phosphoric acid, vitamins, minerals and de-foaming agents. Aeration of the fermenter is essential to achieve optimum growth. Air is introduced by bubbling through a series of parallel pipes fitted at the bottom of the vessel. In agitated vessels, air is usually introduced through a doughnut shaped sparger, located just underneath the stirred blades. In general, 100g of dry yeast matter requires 102.5g of oxygen to be supplied during fermentation. Temperature and acidity must be regulated to optimise yields; typically, fermentation is carried out at 30 °C and a pH of 4.5 - 6.5. Water may be used in external heat exchangers or internal coils to maintain the fermentation temperature, which otherwise tends to rise due to the yeast growth.

After propagation, the fermenter contents are cooled and the yeast crop is removed by centrifugal separators. The yeast "cream" is washed to improve colour and cooled. Crumbled yeast is produced by pressing in a plate and frame filter or a vacuum filter. Alternatively the crumbled yeast may be mixed with emulsifiers and extruded to produce yeast blocks. Dried yeast is produced in a similar manner but is extruded through a perforated plate to produce strands of around 3 mm diameter and 0.3 to 1 cm long. The strips are usually dried in rotary or tunnel dryers before grinding and packaging. Dried yeast is usually packed in hermetically sealed containers or film with a headspace of nitrogen to extend its "active" shelf life.

### 2.3.15 Brewing (SIC 15.96)

Beer is traditionally considered to include products such as ale, porter and stout and can be thought of as an alcoholic beverage derived from malted barley, with or without other unmalted cereal grains, and flavoured with hops. Sugar may also be added. There are three basic steps in the process; firstly it is necessary to make a fermentable substrate for yeast, known as "wort", from the malt and grains. This is achieved by the process of "mashing". Second is the fermentation of the wort using yeast which converts the sugars present, into alcohol and carbon dioxide. Thirdly maturation and conditioning are carried out to produce the finished product.

Grains are normally received in bulk at breweries and transferred to silos. The malted barley is milled before use, the aim being to crush the endosperm with minimal damage to the husk. After milling, the ground materials ("grist") are "mashed" to produce a fermentable substrate for yeast fermentation. A number of mashing methods are available. In a simple infusion mash, the grist is mixed with hot water to produce a thick slurry. The mix is then held for a period sufficient for the enzymes present in the malted barley to breakdown starch and proteins in the cereals. The vessel used for mashing is known as a "mash tun". The wort is drained from the mash tun and water is sprayed over the spent grist to extract as much wort as possible. The wort is boiled with hops. Sugar or sugar syrup may be added at this stage. A coarse coagulum of proteinaceous precipitated material is separated from the wort. This is known as "hot trub". The wort is screened to remove the hops and then transferred to a fermentation vessel.

The clear hopped wort is cooled and aerated to encourage yeast propagation prior to fermentation. Different beers use different strains of yeast during fermentation. Some yeasts tend to rise to the top of the fermentation vessel and are termed "top yeasts". These strains are typically used for ales. Strains which tend to settle to the bottom of the vessel toward the end of fermentation are termed “bottom yeasts” and are typically used in lagers. The yeast is seeded into the wort to initiate fermentation. The temperature of fermentation is controlled but varies depending upon the yeast used. At the end of fermentation the yeast is separated from the product. The beer is clarified and may be subjected to a number of preservation processes such as flash pasteurisation and aseptic filling, membrane filtration and aseptic filling or in-container pasteurisation. Lagers require conditioning by chilled storage for several weeks before clarification.

### 2.3.16 Malting (SIC 15.97)

Malt is a product derived from artificially germinated grain (barley, oats or wheat) which is dried in kilns. Malts are fermented to make beers and lagers or may be fermented and then distilled to make spirits such as whisky. Malts may also be used in a range of foods such as non alcoholic malted drinks, breakfast cereals, infant foods and animal feeds.

Malting develops a number of enzymes including amylolytic and proteolytic enzymes. Amylolytic enzymes break down starch to fermentable carbohydrates. Proteolytic enzymes act as flavour pre-cursors and as nutrients for yeast in subsequent fermentations. Malting involves controlled wetting (by steeping) and germination of the seeds. The process must be carefully controlled to induce the desired physical and chemical changes required, whilst at the same time minimising weight loss due to germination and respiration. The malted grain is dried to halt growth, stop enzymic activity and produce a stable product with the desired colour and flavour. Drying is followed by the removal of malt sprouts.

Two types of malt are generally produced on a commercial scale: brewers and distillers malts. Both types use barley as the starting raw material. Brewers’ malt is made from plumper, heavier barley kernels with friable starch mass. The barley is cleaned and then steeped in water at around 12 - 16 °C for around 55 - 60 hours. Steeping may occur in multiple stages. The barley is germinated at moisture contents of around 43 - 46 %. The resulting malt is dried at approximately 71 - 82 °C, to a final moisture content of around 4 %. Distillers’ malt (“high diastatic malts”) is made from small kernelled barley high in protein and enzymic potential. The barley is steeped at higher moistures (45 - 49 %) and dried at lower temperatures (49 - 60 °C) to a higher final moisture content (5 - 7 %). Brewers’ malt tends to be darker than distillers malts and has increased malt flavour and aroma.

Germination of the steeped grain can be brought about with a range of equipment but essentially the process consists of subjecting the grain to a stream of humidified air at around 10 - 16°C. The grain temperature is around 18°C due to the heat developed from respiration. Periodically the grain is slowly agitated to ensure an even temperature distribution and to prevent matting of rootlets. Germination has traditionally been carried out on concrete floors in cool moist rooms with the grain turned manually but this method is being replaced by more modern mechanised techniques.

Most kilns are of one or two floor designs. Kilning requires around 18 - 20 hours in one-floor kilns and 44 hours in two-floor kilns. Kilning is done in several stages to ensure that moisture is removed effectively without unduly reducing enzyme activity. In general, air flow rate reduces and air temperature increases as the kilning progresses.

After kilning, malt sprouts are removed in a cleaning stage to yield the final malted grain. This grain may be milled to produce malt flour. Malt extract may be produced by hot water extraction and concentration of the germinated grain.

## 2.3.17 Manufacture and bottling of soft drinks (SIC 15.98)

Soft drinks can be categorised into two main areas, carbonated and still. Soft drinks can incorporate spring waters, fruit and juice based drinks (such as cordials, squashes and barley waters), flavoured drinks (such as ginger beer, tonic waters, lemonades) and drinks made from infusions (such as tea and coffee).

Ingredients typically found in most soft drinks include water, sweetener, acid and flavourings. Optional ingredients include fruit, carbon dioxide, preservatives and colour. Water is the main ingredient of all soft drinks and, as such, the quality of the water in terms of its microbiological loading and other parameters which affect the final sensory qualities of the drink are of paramount importance. Most soft drinks are sweetened with natural sweeteners such as sugar and sugar syrups, and/or intense sweeteners such as saccharin and aspartame. Flavourings used in manufacture are often derived from highly concentrated liquid mixtures of plant extracts such as fruit, flowers, seeds, leaves, bark and root. Alternatively, they may be synthetic.

All sparkling soft drinks require the addition of carbon dioxide; this may be sourced as a by-product from the petroleum, beer and whiskey industries, or produced on site. The preservation of soft drinks can be achieved by a number of techniques including heating, chemical preservation and filtration. These methods, in combination with low pH, prevent microbiological spoilage.

The basic processes for the manufacture of soft drinks involve the assembly of ingredients in the syrup room, followed by the addition of water that has been subjected to various water treatments. The mixture may be heat processed or chemically preserved at this stage. The product is carbonated if required. Alternatively, after the syrup and water are combined, the product may be filled into packaging and in-pack heat processed. Syrups or their ingredients may require filtration or homogenisation and may be pasteurised. Most packaging is cleaned prior to filling either by rinsing with water, possibly containing rinsing aids, or by air blasting.

# 3 CURRENT EMISSION AND CONSUMPTION LEVELS

Chapter 3 provides data and information concerning current emission and consumption levels reflecting the situation in existing installations at the time of writing.

This information is important for benchmarking, to use the data in the selection of techniques considered as BAT and to assess overall performance of a special plant or a whole sector.

In this respect data on waste minimisation, water and energy consumption, and emissions to air and water are generally relevant. In food industry, odour is also an important factor.

Waste minimisation is generally considered as a cost-effective goal of all manufacturers but benchmarks are not readily available. As an example, a typical waste generation in dairy industry is shown in Figure 3.1.

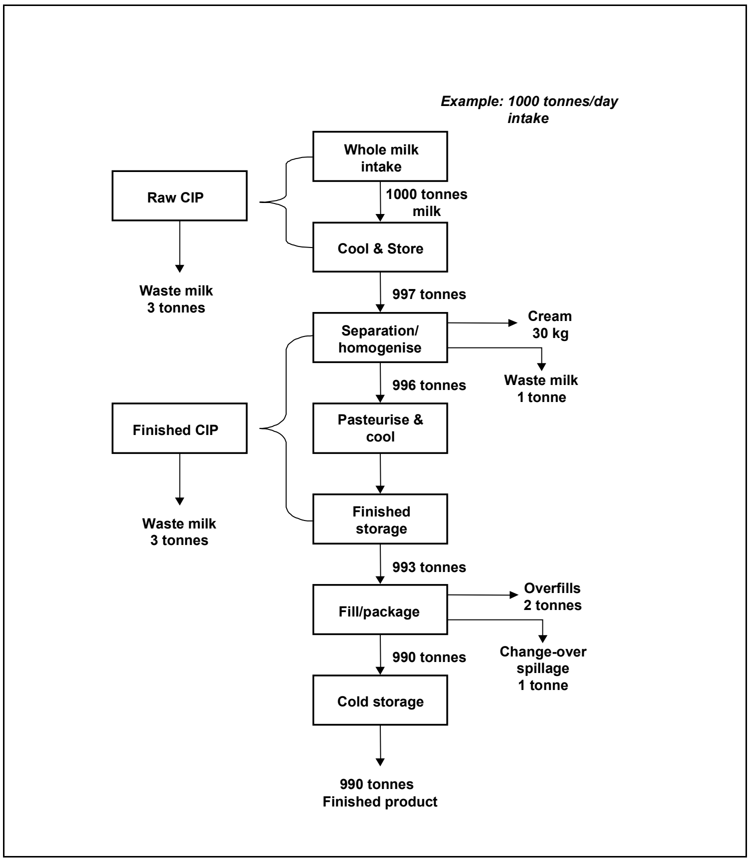


Figure 3.1: Typical waste production in dairy industry

## 3.1 General description

### 3.1.1 Water consumption

The food and drink industry has a significant water consumption. The food industry is one of the biggest consumers among sectors and normally the biggest industrial consumer of water of drinking water quality. In **Germany** in 1995, total industrial water consumption was about 10 billion $m^3$/yr (more than the half of which was used for cooling), with the total water consumption of the food industry being 468 million $m^3$/yr. For the type of water resource used see Figure 3.2.

Water is needed as a raw material (higher proportions in manufacturing of drinks, beer, etc.), as process water (e.g. for washing of raw materials, intermediates and products, cooking, dissolving, cleaning, etc.), as cooling water, as transportation water, as auxiliary water (production of vapour, vacuum, etc.), as sanitary water, etc. The quality of water depends on the needs of the special use.

The proportion of drinking-water quality water is generally high, i.e. in the industrial sector as a whole, about 2/3 of the total fresh water used is of this quality. In some sub-sectors, like dairy, soft drink and mineral water manufacturing, and beer manufacturing, the proportion of use of this water quality can even reach 98 %.

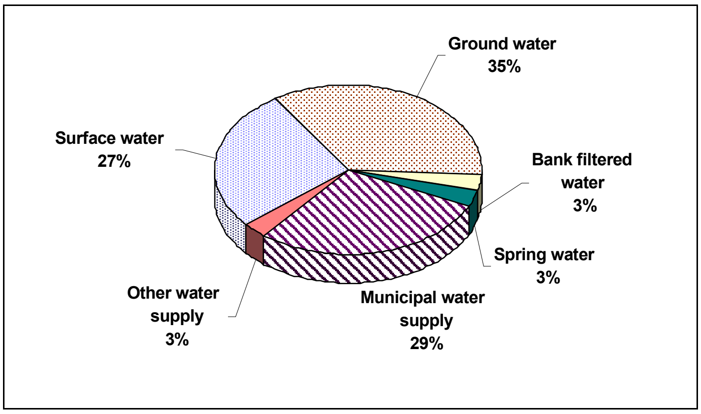


**Figure 3.2: Food industrial water use of different sources in Germany (1995)**
**[27, Austermann-Haun, 2000]**

In comparison, the municipal drinking water supply (in Germany) was 5.6 billion $m^3$/yr. However, this industry was a major consumer of total industrial water, i.e. 285 million $m^3$/yr out of the 952 million $m^3$/yr total industrial drinking water consumption. (1995) [27, **Austermann-Haun**, 2000]

Water use has significantly dropped in the last few decades by the multiple use of water and by reducing raw water use.

### 3.1.2 Waste water emission

Although food and drink industry is an extremely diverse sector, certain sources of waste water are common to many installations. These include:

- washing of the raw material
- water used for transporting (fluming) raw material or waste
- cleaning of plant, process lines, equipment and process areas
- washing of product containers
- blowdown from steam boilers
- once-through cooling water or bleed from closed loop cooling water systems
- backwash from regeneration of water treatment plant
- freezer defrost water
- stormwater run-off

This section provides an overview of the quantity and composition of waste water arising from these sources. Any category-specific issues will be addressed in Section 3.2, as will any additional sources of waste water not encountered in the food and drink sector as a whole.

### 3.1.3 Quantity of waste water

The industry has traditionally been a large user of water as an ingredient, cleaning agent, means of conveyance and feed to utility systems. Large food processing installations will use several hundred cubic metres of water a day. Most of the water not used as an ingredient ultimately appears in the waste water stream. In the fruit and vegetable sub-sector, for example, in the order of 10 $m^3$ of waste water is generated for every tonne of raw material processed.

Substantial reductions in the volume of waste water generated in this Sector can be achieved through waste minimisation techniques (see Chapter 4). It is, however, imperative that water conservation measures do not lead to unsatisfactory levels of cleanliness, hygiene or product quality.

Waste water flowrates may be very variable on a diurnal, weekly or seasonal basis. The waste water profile is largely dependent on production patterns and when cleaning, which is often the largest water use, takes place. In some categories (e.g. sugar beet, olive oil production) processing takes place on a campaign basis and there will be little or no waste water for part of the year.

### 3.1.4 Composition of waste water

Food industrial waste water is notable for its extreme variability in composition. Some general information is given below and the more detailed information is given in Section 3.2 for the different sub-sectors.

Typically food process waste water is high both in chemical oxygen demand (COD) and in biochemical oxygen demand (BOD). It is normally 10 - 100 times stronger than domestic waste water.

BOD is directly associated with levels of products. The BOD content of the main food constituents is:

| | **kg BOD/ kg food constituent** |
|---|---|
| Carbohydrate | 0.65 |
| Fats | 0.89 |
| Protein | 1.03 |

**Table 3.1: BOD equivalent of food constituents**

Suspended solids concentration vary from negligible to as high as 120000 mg/l. Waste water from some sub-sectors (e.g. dairy, meat) has high concentrations of fats and oils.

Food processing waste waters vary from the highly alkaline (pH 11) to the highly acidic (pH 3.5). Factors affecting waste water pH include:

- the natural pH of the raw material
- pH adjustment of fluming water to prevent raw material deterioration
- use of caustic or acid solutions in processing operations
- use of caustic or acid solution in cleaning operations
- acidic waste streams (e.g. acid whey)
- acid-forming reactions in the waste water (e.g. high yeast content waste water, lactic and formic acids from degrading milk content)
- nature of raw water source (hard/soft).

Waste water contains few compounds that individually have an adverse effect on treatment plants or receiving waters. Possible exceptions include:

- salinity where large amounts of salt are used (e.g. pickling, cheese making)
- pesticide residues not readily degraded during treatment
- residues and by-products from the use of chemical disinfection techniques
- some cleaning products.

The presence of pathogenic organisms in the waste water may be a consideration, particularly where meat or fish are being processed.

Waste water generally contains low level of plant nutrients. Where food processing waste water is deficient in nitrogen and/or phosphorus needed to support biological activity during treatment. The ideal BOD: nitrogen: phosphorus ratio is about 100: 5:1.
Excessive levels of phosphorus can also occur, particularly where large quantities of phosphoric acid are used for the process (e.g. vegetable oil de-gumming) or in cleaning. If such waste water becomes anaerobic during treatment there is a risk that phosphate containing constituents could release phosphorus to the final effluent. The use of nitric acid in a process will produce a similar effect, increasing the levels of ammonia in the waste water.

## 3.2 Water consumption and waste water production in sectors

### 3.2.1 Meat processing

#### 3.2.1.1 Scope

This sub-sector includes:

- preservation of meat and poultry meat (e.g. freezing, curing, drying, smoking, canning)
- production of meat and poultry meat products (e.g. sausages, pates, sectioned and formed meats, restructured meats, meat-based ready meals).

Slaughtering and animal by-product processing are the subject of a separate BREF and will not be discussed here, except where they affect other processes or in the context of common or transferable techniques.

#### 3.2.1.2 Sources & nature of waste water

Typical waste water sources in meat processing are presented in Figure 3.3.

##### 3.2.1.2.1 Production of meat & poultry meat

Slaughtering animals is not included. However, there are several installations where both slaughtering and further processing of meat is done, and where waste waters are produced and need to be treated.

Stringent hygiene measures lead to relatively large quantities of waste water for cleaning.

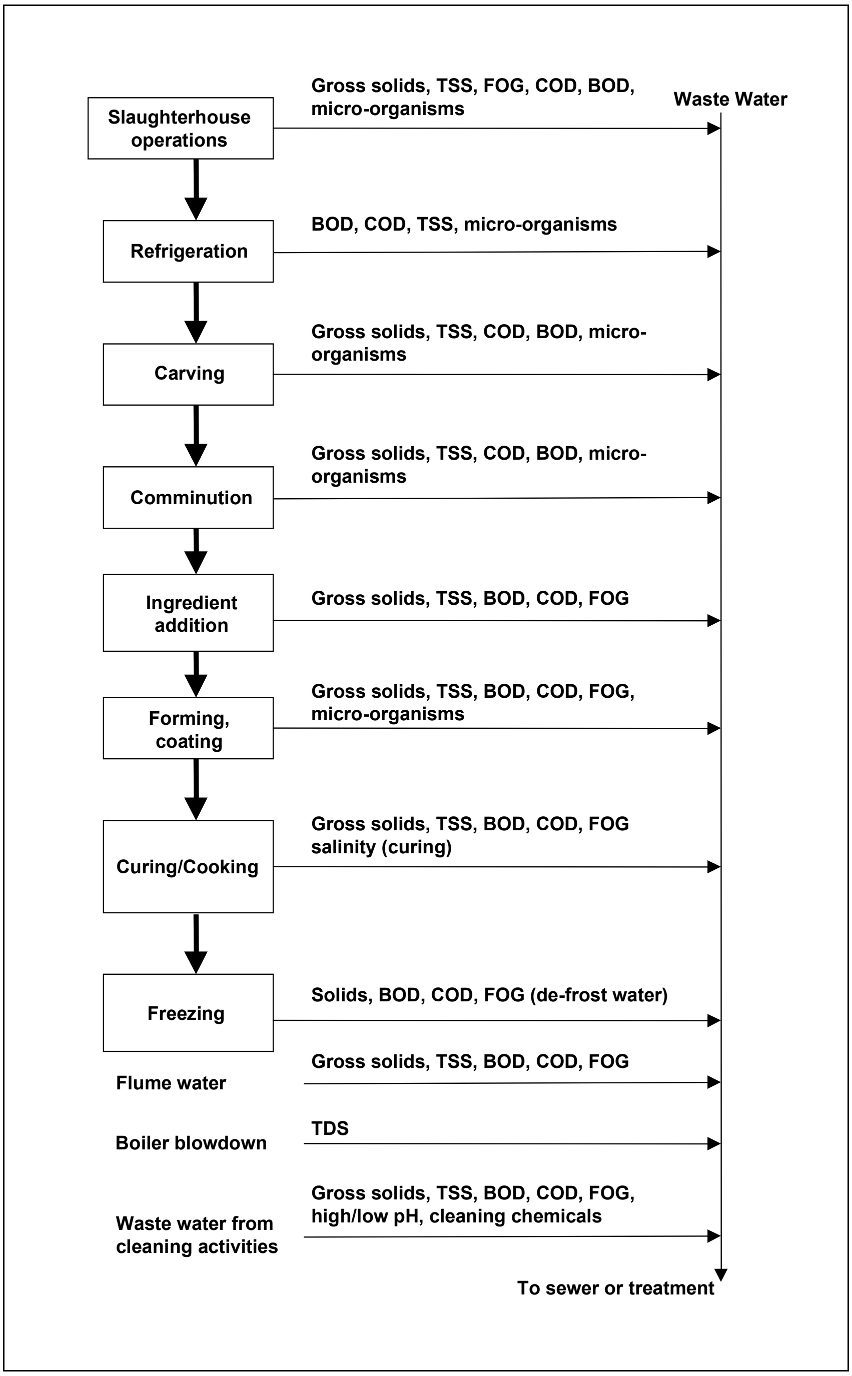


**Figure 3.3: Waste water produced in meat processing (including slaughterhouses) [13, Environment Agency (UK), 2000]**

### 3.2.1.2.2 Preservation of meat & poultry meat

a) **Freezing**

The only waste water generated from freezing is overflow from the cooling system and freezer defrost water.

b) **Curing**

The injection under pressure of a brine containing curing ingredients is a widely used technique for extending the life of meat. The ingredients used are sodium chloride, often with sodium or potassium nitrite and other materials to impart special characteristics e.g. sugar, polyphosphates and spices. Alternatively the meat may be immersed in a vat of brine. Operators may minimise over production of brine and also production of out of specification brine. Not only would this constitute discharge of raw material, excess/waste brine would also have a detrimental effect on the effluent treatment plant if discharged in large quantities. Chloride (brine) is a conservative substance and is therefore not reduced through effluent treatment, apart from dilution.

Traditional dry curing is practised by a number of small highly specialised companies. The process liberates small quantities of cooking waste water only.

#### c) **Smoking**

Smoking is most often carried out on cured meat, however, it can be used on fresh meat products that are cooked before serving. Traditional smoking techniques rely on smouldering wood or sawdust and do not generate waste water. The mass production alternative is to use liquid smoke, prepared by the destructive distillation of wood and applied by spraying, dipping or atomisation. Contaminated waste water will be produced when containers or equipment that have been in contact with liquid smoke are washed.

#### d) **Drying**

Dried meats are produced by curing, followed by drying at low humidity. Unless odour abatement considerations make it necessary to condense water vapour from the dryer off-gases no waste water will be generated.

#### e) **Canning**

Canned meats must be heat-processed to achieve pasteurisation or shelf stability. The use of hot water or direct steam heating for cooking produces waste water contaminated with fat, protein and fragments of meat.

Can washing, generally both before and after filling, and can cooling use considerable quantities of water.

### 3.2.1.2.3 Production of meat & poultry meat products

This category covers a wide range of products and processing techniques, which it is not practicable to consider individually. At a generic level, the unit operations may include combinations of the following:

- comminution (e.g. chopping, mincing, flaking)
- emulsification (e.g. for sausage-making)
- blending with other ingredients
- forming
- breading or battering
- cooking
- filling (cans, foil trays etc)
- chilling
- freezing.

All lines, equipment and process areas that are not in designated dry areas require wet cleaning, which generates waste water contaminated with product, raw materials and cleaning chemicals. As in primary meat processing, scraps may be washed down the drain, increasing the COD, fat and suspended solids content of the waste water. Cooking methods that involve direct contact between water or steam and product produce waste water, as do cooling, chilling, freezing and filling operations.

Ingredients added to the meat are likely to enter the waste water stream as a result of equipment washouts and spillage. Those used in large quantities (e.g. batter, breadcrumbs, cooking oil) can make a significant contribution to the waste water BOD, TSS and FOG levels.

Fresh meats, especially poorer quality beef, are often treated with enzymes of plant or fungal origin to improve tenderness. The meat is either dipped in or sprayed with enzymes in solution. Operators ensure that the discharge of the enzyme solutions is kept to a minimum. Enzymes are complex organic structures and as such will carry a BOD contribution and may potentially affect the biology of a treatment facility.

#### 3.2.1.2.4 Consumption of resources and pollution in salami and sausage production

Only very limited information is available about the use of resources and pollution from the manufacturing of Salami and Vienna sausages. One reason is that a meat processing plant or an abattoir may have many other activities than those mentioned here and that the companies do not have sufficient separation of the figures for consumption or pollution for each product line.

| Product | Unit* | Salami | Salami | Various | Var. sausages |
|---|---|---|---|---|---|
| **Country** | | DK | DK | SE | NO |
| Water | $m^3$/tonne | 7.5 | 5.3 | 7.7 | (10) |
| Electricity | kWh/t | unknown | 1000 | 750 | 1300 |
| Heat | kWh/t | 1240 | 900 | 1000 | 450 |
| Recuperation | kWh/t | unknown | 230 | 250 | unknown |
| Total energy | kWh/t | unknown | 2130 | 2000 | 1750 |
| BOD | kg/t | | 4.7 | 15 | (8 - 10) |
| N | g/t | | 300 | | |
| P | g/t | | 140 | | |
| ** t refers to tonnes finished products* | | | | | |

**Table 3.2: Specific consumption of water and energy, and pollution in waste water in salami and sausage production**
**[41, Nordic Council, 2001]**

The main environmental factors relating to sausage manufacture concern the **smoking and cooling** processes.
Wood smoke contains many compounds, which are of concern from a health point of view. They are e.g. polycyclic aromatic hydrocarbons (PAH), phenols, nitrite and N-nitroso compounds plus CO. Effective ventilation and exhaust is therefore necessary for kilns and rooms.

Smoke is emitted to the surroundings through chimneys and exhaust outlets. The smoke can produce smell problems in the surroundings.

The odour strength in the emission from a smoking kiln depends on the smoking process and the ventilation and drying conditions. The typical odour strength in untreated air will be 5000 - 20000 odour units per $m^3$.

A wet scrubber for cleaning the emission from a smoking kiln will typically have an efficiency of 50 – 70 %, measured in odour units per $m^3$.

With respect to other emissions, a carbon content of 1000 ppm has been measured in the exhaust from a modern warm smoking and cooking unit. After incineration at 815 °C and cooling to 26 °C, 5 ppm carbon was measured. The maximum permissible emission level after incineration will often be 50 ppm total carbon.

In a Norwegian investigation, the following levels are given for pollution from smoking processes:

0.3 kg CO per tonne of product
0.15 kg inorganic particles per tonne
0.2 kg TOC per tonne

When examining a cooking/smoking cabinet, the following emissions were found after incineration of the smoke gases:

7 mg TOC per $m^3$ or
0.2 mg TOC per tonne of sausages

The gas did not contain CO.

Soot and tar compounds are deposited in the kilns and on smoking sticks and frames. This must be removed and this is often done with powerful alkaline detergents. Waste water from the smoking department can therefore contain a large number of chemical compounds.

## 3.2.2 Fish processing

### 3.2.2.1 Scope

This sub-sector covers:

- In terms of raw materials:
  - herring
  - mackerel
  - whitefish
  - sea food industry
  - fresh water fish.

- In terms of processing:
  - production of fillets
  - frozen fish
  - smoked fish
  - salted fish
  - marinaded/canned fish.

### 3.2.2.2 Sources and nature of waste water

The process related waste water is produced in different processing steps (e.g. thawing, washing and deicing, head cutting, filleting, skinning, trimming) and in cleaning of equipment and floor. The waste water contains blood, flesh, guts, soluble protein and waste material and is high in BOD, COD, TSS and FOG.

Waste water production rates and characteristics depend highly on the production lines. Data for Germany are presented in Table 3.3 [27, **Austermann-Haun**, 2000]

| Production | Waste water production | Suspended solids | BOD$_5$ | Fats* |
|---|---|---|---|---|
| | m$^3$/t | mg/l | mg/l | mg/l |
| Herring | 17 - 40 | 220 - 1520 | 2.3 - 4.0 | 190 - 450 |
| Fresh fish | About 8 | 170 - 3650 | 1.0 - 6.25 | 46 - 2500 |
| Smoking of fish | About 8 | 14 - 845 | 1.0 - 1.7 | 24 - 180 |
| Salting of Salmon | About 35 | - | - | - |
| Deep frozen fish | | | | |
| Thawing | 2 - 15 | 0 - 70 | 0.03 - 1.8 | 4 - 46 |
| In blocks | - | - | - | - |
| Marinated fish | About 2 | About 1200 | 0.5 - 2.3 | 760 - 970 |
| * It is expressed as petrolether extract | | | | |

**Table 3.3: Typical waste water production and characteristics in fish processing [27, Austermann-Haun, 2000]**

Water consumption and specific COD load for traditional fish processing were reported in the relevant Nordic BAT document. [28, **Nordic Council of Ministers**, 1997] Results are summarised in Table 3.4.

| Production | Water consumption m$^3$/t raw fish | COD Kg/t raw fish |
|---|---|---|
| Herring filleting | 3.3 - 10 | Up to 95 |
| Mackerel | | |
| Cleaned and head cut | 20 | 270 |
| Thawing included | 26 - 32 | |
| White fish processing | | |
| Fresh fish | 4.8 | 5 - 36 |
| Thawing included | 9.8 | |
| Shrimp processing | 23 - 32 | 100 - 130 |

**Table 3.4: Specific water consumption and organic load in Nordic countries [28, Nordic Council of Ministers, 1997]**

## 3.2.3 Fruit & vegetable processing

### 3.2.3.1 Scope

This sub-sector covers:
- fresh-pack fruit and vegetables
- fruit and vegetable preservation (e.g. canning, freezing, drying, pickling)
- fruit and vegetable juices
- other fruit and vegetable products (e.g. sauces, ready meals, jams, preserves).

### 3.2.3.2 Sources and nature of waste water

#### 3.2.3.2.1 General

Waste water characteristics in this sub-sector are affected by various factors, including the raw material being processed, seasonal and source variations in the raw material, the unit operations, production patterns and operator practice. Typically the waste water is high in suspended solids, organic sugars and starches. Residual pesticides that are difficult to degrade during waste water treatment may be a concern, especially with produce imported from countries with less stringent controls on pesticide use.

Typical levels of BOD and TSS in the waste water arising from the processing of various fruits and vegetables are shown in Table 3.5.

A typical process schematic showing the main waste water which arises is shown in Figure 3.4.

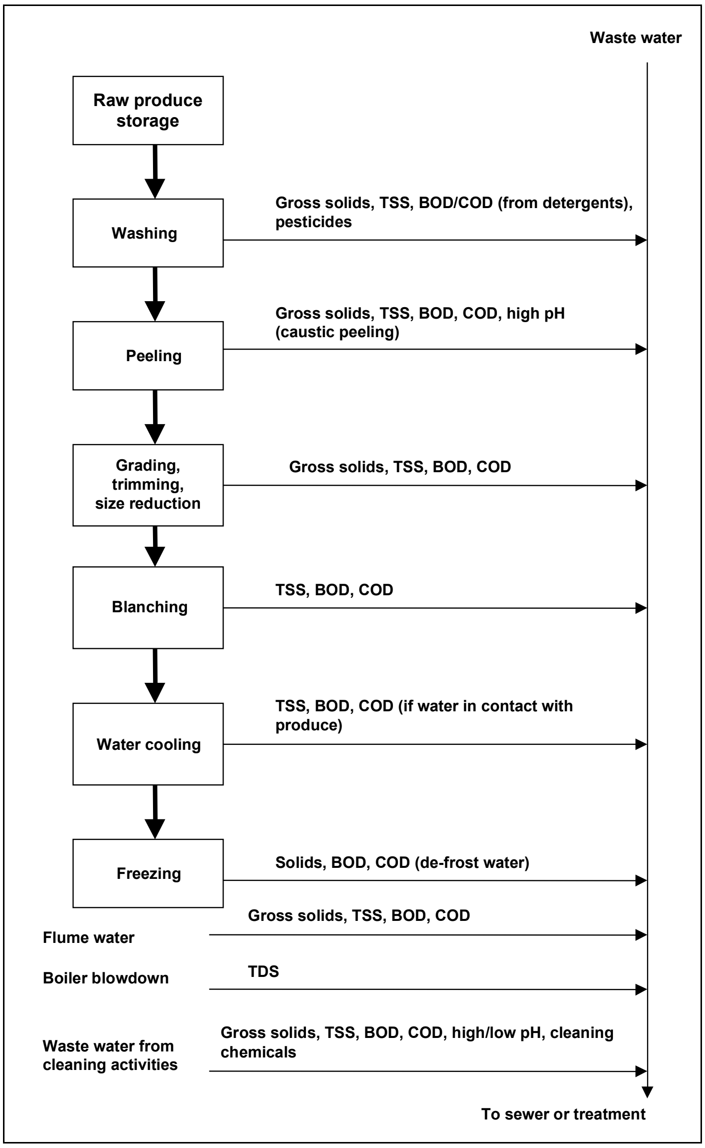


**Figure 3.4: Waste water produced in fruit and vegetable processing**
**[13, Environment Agency (UK), 2000]**

### a) Washing

The incoming produce is washed in chlorinated water to remove residual soil, stones and other debris and to reduce the microbial population. Large volumes are required, especially for root vegetables which carry a lot of earth and leafy vegetables which have a large surface area. Mechanical or air flotation techniques are employed to aid soil removal and reduce the quantity of water used. Some degree of recirculation or re-use of water from other operations is common. Waste water from pre-washing contains mainly field debris and soil particles with small fragments of the fruit or vegetable. If detergents are used to increase cleaning efficiency they will contribute to the COD of the waste water.

### b) Grading, trimming and size reduction

Most processes will involve some type of grading, trimming and size reduction. Sometimes density graders containing brines of different strength are used. Operators ensure that discharges of spent brine are controlled, as significant quantities would adversely affect any biological treatment plant. Washing of the produce after these operations will create waste water containing soluble starch, sugars and acids. The use of water fluming to convey both the product and waste material permits additional leaching of these substances. Waste water from citric fruit processing also contains pectic substances that can interfere with the settling of suspended solids.

| BOD < 500 mg/l | | BOD 500 - 1000 mg/l | | BOD 1000 - 2000 mg/l | |
|---|---|---|---|---|---|
| **Product** | **TSS mg/l** | **Product** | **TSS mg/l** | **Product** | **TSS mg/l** |
| citrus | 130 | apple juice | 104 | frozen potatoes | 1716 |
| asparagus | 43 - 114 | Strawberry | 96 - 210 | dried potatoes | 981 |
| broccoli | 100 - 455 | baby foods | 101 - 533 | apricots | 33 - 387 |
| Brussels sprouts | 29 - 1680 | Peeled tomatoes | 280 - 1280 | mushrooms | 33 - 467 |
| cauliflower | 18 - 113 | Tomato products | 512 - 1180 | peaches | 164 - 1020 |
| Dehydrated vegetables | 168 - 778 | | | plums | 60 - 187 |
| leafy greens | 19 - 419 | | | | |

| BOD 2000 - 3000 mg/l | | BOD 3000 - 5000 mg/l | | BOD >5000 mg/l | |
|---|---|---|---|---|---|
| **Product** | **TSS mg/l** | **Product** | **TSS mg/l** | **Product** | **TSS mg/l** |
| carrots | 262 - 1540 | dried fruit | 8 - 568 | beetroot | 367 - 4330 |
| grape juice | 216 - 228 | jams, jellies & preserves | 404 - 711 | sweetcorn | 131 - 2440 |
| peas | 79 - 673 | Pears | 84 - 702 | white whole potatoes | 1660 - 24300 |
| potato crisps | 1450 - 3910 | | | | |

**Table 3.5: BOD and TSS concentration in waste water from fruit & vegetable processing**
**[87, Carawan Roy E. et al, 1979]**

### c) Cleaning

All lines, equipment and process areas that are not in designated dry areas require wet cleaning, which generates waste water contaminated with raw material, product and cleaning chemicals. There is generally less requirement for aggressive chemicals in this sub-sector than in others, unless oil or fat is used in processing.

#### 3.2.3.2.2 Fresh-pack

Fresh pack vegetables, salads and fruits require minimal processing. Water consumption is mainly for produce washing, transport flumes and line cleaning. Processing installations are often close to growing areas, creating opportunities for the use of waste water in irrigation.

Some fresh-pack vegetables require peeling (see Section 3.2.3.2.3).

#### 3.2.3.2.3 Preservation of fruit & vegetables

Fruit and vegetables that are to be preserved undergo further processing. The most common types are discussed below.

a) **Peeling**

Many vegetables and some fruits require peeling, which can be a major source of BOD and TSS and represent a substantial proportion of the total waste water volume. Peeling can be achieved by mechanical cutting or abrasion; or by the application of steam, hot water or heated air. Caustic soda is often used to soften the cortex so that the peel can be more easily removed by mechanical scrubbers or high pressure water sprays. Peeling is followed by washing to remove peels and any residual caustic.

Conventional steam or hot water peeling uses large quantities of water and produces waste water with high levels of product residue. At potato processing installations, the peelings can contribute up to 80 % of the total BOD. In fruit processing, peeling waste water can account for as much as 10 % of the total waste water flow and 60 % of the BOD. Dry caustic peeling methods can greatly reduce the volume and strength of the waste water from this operation and allow for the collection of peel as a pumpable slurry.

The use of caustic in peeling may lead to pH fluctuations in the waste water. Some produce (e.g. tomatoes) requires strong caustic solutions and the addition of wetting agents. Dry caustic peeling tends to have a lower caustic consumption that wet methods.

b) **Blanching**

Most vegetables destined for canning, freezing or drying must first be blanched, typically using hot water or steam. If the produce is to be frozen, blanching is followed by water cooling (in a cold water flume or with sprays) or air cooling.

Both liquid and steam blanching produce waste water high in BOD; in some cases over half of the total BOD load. The volume of waste water is less with steam blanching than with liquid blanching. The quantity of waste water from steam blanching can be reduced by steam recycling, effective steam seals and equipment designs that minimise steam consumption.

Waste water can be completely eliminated by microwave blanching, which has been used in Europe and Japan.

c) **Ultra-High Pressure Processing**

Ultra-high pressure (UHP) processing is an alternative to heat treatment in the preservation of food. It is increasingly being used in Japan to destroy micro-organisms whilst retaining vitamins, colour and flavour. Not all foods can be treated by this method without damage.

#### 3.2.3.2.4 Juices

Juices are obtained by pressing and solids/liquid separation. The juice is concentrated by evaporation, giving rise to condensate as a waste water stream. High-temperature-short-time (HTST) pasteurisation of fruit and vegetable juices produces waste water at start-up and product changeover cleaning.

#### 3.2.3.2.5 Other products

Jams, jellies and preserves are based on the production of pectin-acid-sugar gels from extracted juices, purees or the whole fruit respectively. The use of sugar and additional cooking tends to increase the waste water BOD compared with most other fruit processing. The presence of natural or added pectin in the waste water may have an adverse effect on solids settling.

### 3.2.4 Potato processing industry

**[65, Germany, 2002]**

Although the organic constituents of the waste water from the potato processing industry are readily biodegradable, problems may arise during waste water treatment. These are largely due to the following factors:

- pollution loads that fluctuate substantially in the course of the day, week, year
- mostly high concentrations of impurities
- imbalanced composition of waste water (preponderance of carbohydrates and sometimes imbalanced mineral nutrient supply)
- presence of foam-producing substances (protein)
- risk of bulking sludge formation
- temperature of production waste water sometimes exceeds 35 to 40°C, which may make it necessary to use evaporation coolers
- the rapid onset of the anaerobic fermentation process may give rise to undesirable odours. Moreover, the acids present during the fermentation processes may result in the pH being reduced to between 4 and 4.5. This acidification takes place within about 2 hours.

In anaerobic/aerobic treatment systems it is necessary to investigate whether, in view of the $N_{tot}$ load, it is possible to treat the entire production waste water or only a substream, in order to ensure that the aerobic stage still has enough carbon for nitrogen elimination.
If the above considerations are taken into account, it is certainly possible to use biological processes to clean the highly concentrated waste water from potato processing facilities.

### 3.2.5 Dairies

#### 3.2.5.1 Scope

This sub-sector includes:

- reception and front-end processing
- manufacture of liquid milk and cream
- manufacture of butter and cheese
- manufacture of cultured milk products (e.g. yoghurt)
- manufacture of ice cream
- manufacture of dried milk and whey products
- manufacture of casein (milk protein)

[Environment agency, UK, 2000 # 13]

#### 3.2.5.2 Sources and nature of waste water

Dairy waste water contains high concentrations of BOD, TSS and FOG. The BOD arises mainly from the fat, lactose and protein contained in milk and milk products. There are smaller contributions from non-dairy ingredients used in some of the products and from cleaning chemicals and lubricants. Suspended solids are associated with coagulated milk, particles of cheese curd and non-dairy ingredients.

Other significant pollutants present in the waste water are phosphorus, nitrogen and chloride. Individual waste water streams of a wide pH range are produced. The temperature of waste water streams may also be a consideration. [Environment agency, UK, 2000 # 13]

Waste water characteristics vary considerably depending on milk load, cleaning practices and the age of the plant. Indicative composition data for dairy processing waste water, dating back to the mid-1970s, are presented in Table 3.6.

Waste water containing milk or milk products has a high BOD. The typical BOD of various milk products is shown in Table 3.7.

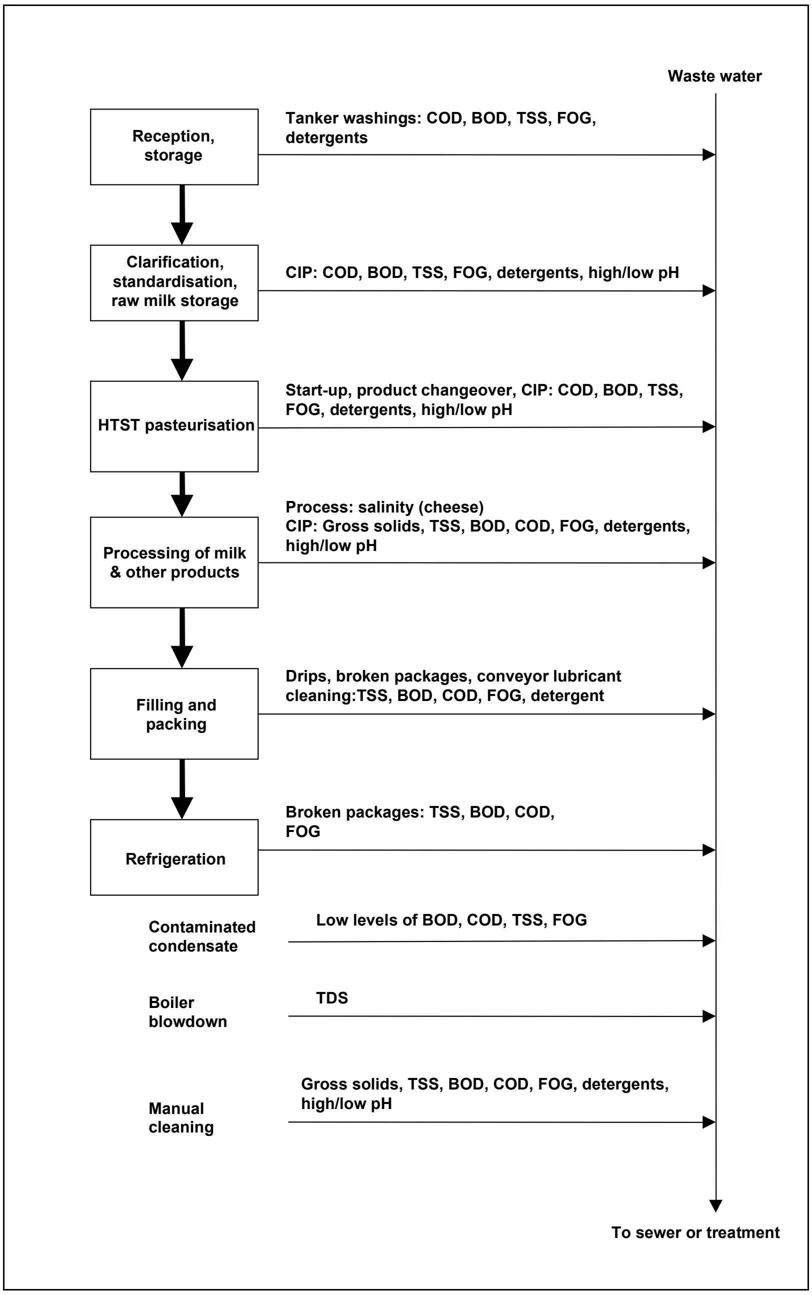


**Figure 3.5: Waste water produced in dairy industry**
**[13, Environment Agency (UK), 2000]**

Figure 3.5 indicates the main types of waste water generated in dairy processing. The largest proportion is wash-water from operations that include equipment washing; line purging at product changeover; start-up, shutdown and changeover of HTST pasteurisation units and product washing. In normal operation, about 0.5 - 1.5 % of product is wasted. It can be found in wash-water; for example the start-up, shutdown or changeover of an HTST unit can result in about 50 gallons of product being diluted with water and sent to drain, which represents in the order of 70 kg of BOD per day.

| Component | Range | Average |
|---|---|---|
| Suspended solids | 24 - 5700 mg/l | - |
| Total solids | 135 - 8500 mg/l | 2397 mg/l |
| $BOD_5$ | 450 - 4790 mg/l | 1885 mg/l |
| Protein | 210 - 560 mg/l | 350 mg/l |
| Fat | 35 - 500 mg/l | 209 mg/l |
| Carbohydrate | 252 - 931 mg/l | 522 mg/l |
| Nitrogen | 15 - 180 mg/l | 76 mg/l |
| Phosphorus | 11 - 160 mg/l | 50 mg/l |
| Sodium | 60 - 807 mg/l | - |
| Chloride | 48 – 469 (up to 2000*) mg/l | 276 mg/l |
| Calcium | 57 - 112 mg/l | - |
| Magnesium | 22 - 49 mg/l | - |
| Potassium | 11 - 160 mg/l | 67 |
| pH | 5.3 - 9.4 (4 – 12*) | 7.1 |
| Temperature | 12 - 40 °C | 24 °C |
| * *CIAA comments [83, CIAA, 2001]* | | |

**Table 3.6: Indicative composition of dairy processing waste water**
**[13, Environment Agency (UK), 2000]**

| Product | $BOD_5$ (mg per kg of product) |
|---|---|
| Whole milk | 104000 |
| Skimmed milk | 67000 |
| Double cream | 399000 |
| Yoghurt | 91000 |
| Ice cream | 292000 |
| Whey | 34000 |

**Table 3.7: Typical BOD of various milk products**
**[13, Environment Agency (UK), 2000]**

About 90 % of the milk used in cheese-making ends up as whey. Sweet whey is often recovered and used as a food grade additive. Salt whey, produced after salt has been added to the curd to remove additional liquid, is not suitable for this application unless the salt is removed by reverse osmosis. The RO permeate is highly saline. Unless whey is processed quickly it becomes acidic due to lactic acid formation. Large quantities of acid whey is kept separate from other waste water as it will produce unacceptably low pH levels for on-site treatment or discharge to sewer.

Waste water with high concentrations of dissolved solids is produced by the regeneration of ion exchange resins and from membrane backwashing.

Although CIP operations contribute to save water, energy and chemicals, they still generate large volumes of waste water, which may have a high or low pH due to the use of acid and alkaline cleaning solutions. The use of phosphoric and nitric acids will increase the phosphate and nitrate content of the waste water. Badly designed CIP systems and inadequate product removal prior to the start of the CIP cycle permit large quantities of product to enter the wash water. Some UK dairy sites have seen a reduction of 40 – 65 % in their waste water COD as a result of improvements in this area. [Envirowise (UK); Entec UK ltd., 1999 #43]

Large evaporators are used in the production of milk concentrate (the first stage in the production of milk powder) and dried whey. The evaporated water is condensed, giving rise to large quantities of condensate. Normally this will be clean, but vacuum leaks on the condensers can lead to contamination with product.

## 3.2.6 Sugar manufacture

The main reference used for this subsector is "Guidance Note for Establishing BAT in the European Sugar Industry; Comite European des Fabricants de Sucre".

### 3.2.6.1 Scope

This sub-sector includes:

- sugar beet processing and manufacture of beet sugar products
- cane sugar refining and manufacture of cane sugar products.

There are nine factories which process the UK sugar beet crop on a campaign basis. Five of these factories store thick sugar juice for processing between the beet campaigns. The UK has the largest sugar beet factory in Europe which is regarded as a showpiece for the British beet processing industry. [13, **Environment Agency (UK)**, 2000]

The largest cane sugar refinery in the world is also situated in the UK.

### 3.2.6.2 Sources & nature of waste water

#### 3.2.6.2.1 Sugar beet processing

Sugar beet is made up of over 75 % water. The extraction process, by definition, aims to release a high proportion of that water. Approximately half of this water is lost due to evaporation or inclusion in various product streams. The remainder is a source of high strength waste water. "Process waste water" is deemed to be the excess condensate from the concentration and crystallisation stages. This surplus condensate is high in ammonia and relatively low in COD content.

Another major source of waste water comes from the fluming water and washing of the incoming beets. They are floated through the cleaning stage where stones, weeds and other gross contaminants are removed. The beets then enter the factory and are washed before being sliced into cossettes in order to maximise surface area for the extraction process.

The combined waste water has a high BOD and is produced in large volumes.

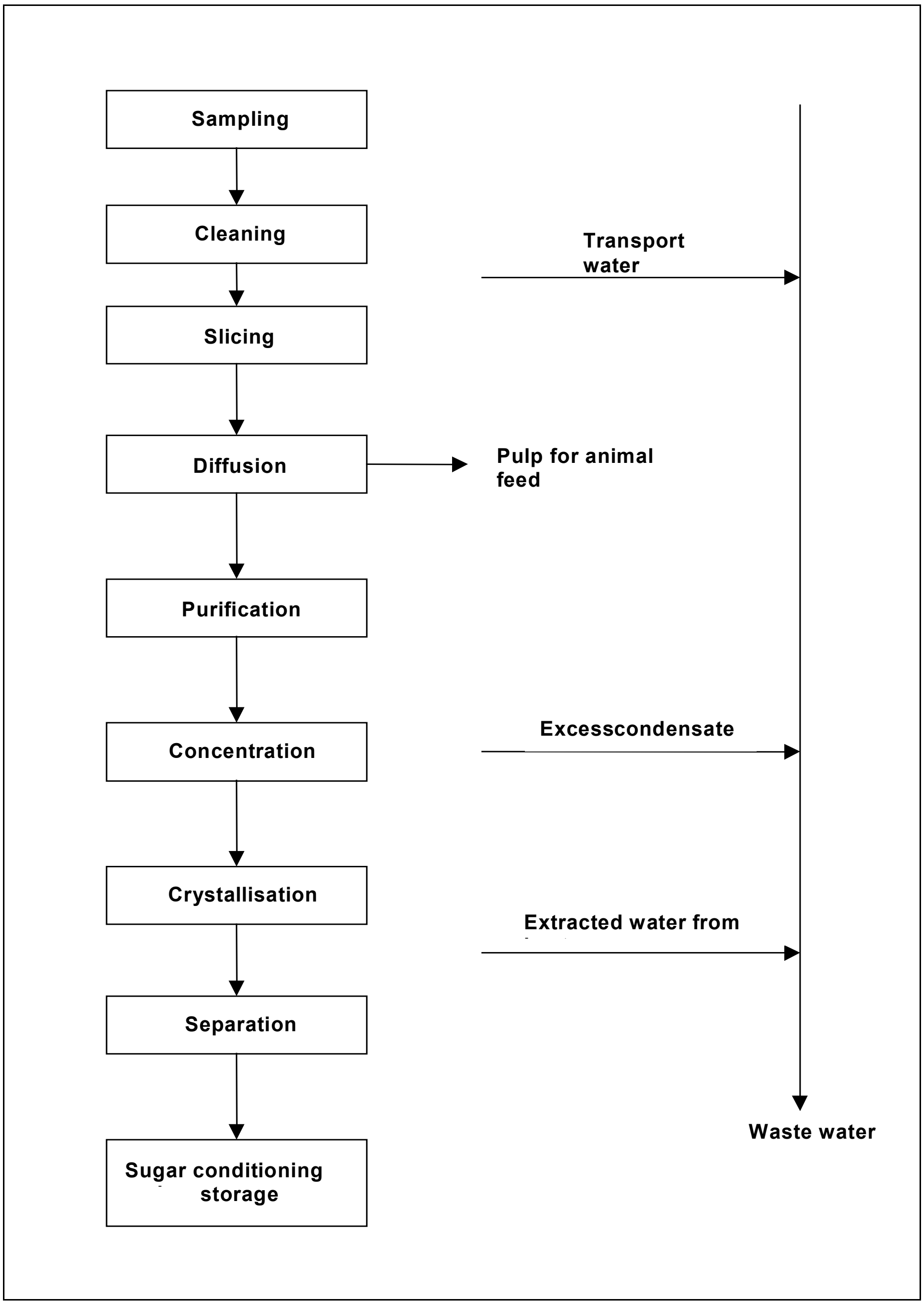


**Figure 3.6: Waste water produced in sugar beet processing**
**[13, Environment Agency (UK), 2000]**

Figure 3.6 shows a typical process flow diagram for a sugar beet processing plant.

### 3.2.6.2.2 Cane sugar refining

The starting point is raw sugar therefore less water is required than in sugar beet processing.

The regeneration every 40 - 50 hours of the ion exchange resin cells used in the decolourisation process generates a difficult waste water. Caustic brine is used as the regenerant. [13, **Environment Agency (UK)**, 2000]

There may be excess condensate and sweet water although these can be eliminated – see Section 4.14.6.3.

Waste water will be generated from the steam cleaning of the bulk road tankers used to transport liquid sugar products.

## 3.2.7 Vegetable oil production

### 3.2.7.1 Vegetable oil refining

| Source | Volume $m^3/t^1$ | $BOD_5$ mg/l | COD mg/l | $FOG^3$ mg/l | $SS^4$ mg/l |
|---|---|---|---|---|---|
| Neutral oil washing | 0.1 | 1000 | 15000 | 5000 | n.d.[5] |
| Neutralisation reaction<br>pH = 10 - 12 | 2.1[2] | 4300 | 7200 | 670 | 2900 |
| Barometric condensers<br>pH = 6.5 - 7.5 | 2 | 140 - 200 | 500 - 600 | 20 - 200 | 40 - 100 |
| Steam boiler | 10 % of steam | 20 | 40 | - | 100 |
| Water softening | 5 % of steam | 20 | 40 | - | 100 |
| Floor and equipment cleaning | 0.1 | 1500 | 2000 | n.d. | 300 |
| *[1] Tonnes of crude oil*<br>*[2] Tonnes of free fatty acids* | *[3] FOG = fats, oil and grease*<br>*[4] SS = suspended solids* | *[5] n.d. = no data* | | | |

**Table 3.8: Waste water characteristics in vegetable oil refining**
**[Panagopoulos J.; Malliaros C., 2001 #74]**

## 3.2.8 Soft drinks and beverages

### 3.2.8.1 Scope

This sub-sector includes:

- production of ethyl alcohol by fermentation
- manufacture of wine from grapes and from concentrated grape must
- manufacture of grape juice
- manufacture of fruit wines and other fermented fruit beverages
- manufacture of cider and perry
- manufacture of distilled alcoholic beverages
- production of mineral waters
- manufacture of soft drinks
- manufacture of malt.

The manufacture of beer is the subject of a separate project and will not be discussed here, except in the context of common or transferable techniques. Tea and coffee and their substitutes belong to another sub-sector.

### 3.2.8.2 Sources & nature of waste water

#### 3.2.8.2.1 General

Processes for the manufacture of different beverages have common sources of waste water, including:

- plant and equipment cleaning
- washing of containers (bottles, cans, casks)
- pasteurisation of containers
- floor washing
- once-through cooling water or bleed from closed loop cooling systems
- boiler blowdown
- backwash from water treatment systems
- “chase” water purged from pipework between uses.

The preparation and cleaning of equipment is the largest source of waste water in this sector.

The cleaning of fermenter vessels in particular is a major source of COD/BOD and suspended solids load. In breweries, they are the source of almost half the COD load and about 70 % of the suspended solids load in the waste water. Proprietary products used in the cleaning process (e.g. clay, disinfectants, detergents, sanitising agents) contribute to the waste water loadings. Dilute solutions of peracetic acid, a widely used sanitising agent, have a COD of approximately 1000 mg/l. When one soft drinks manufacturer changed the lubricant they used on their conveyors, they reduced soap usage by 75 % and substantially reduced COD discharges associated with the soap.

In addition to these point sources, overflowing vessels and tanks often make a significant contribution to the waste water strength.

### 3.2.8.2.2 Soft drinks, fruit juice, mineral waters

Waste water treatment in biological treatment systems has proved successful in both the fruit juice industry and the soft drinks industry. Only where bottling is confined exclusively to mineral water may biological treatment cause problems owing to a lack of substrate.
Buffering and smoothing (mixing and equalisation basins) before the biological treatment is always advisable. [65, Germany, 2002] Depending on the product range and packaging system (returnable or non-returnable), the constant or intermittent addition of nutrient salts may be necessary. On the other hand cleaning and disinfecting measures may lead to temporary peaks in P concentrations, which may cause problems for direct dischargers in spite of equalisation measures. In the case of returnable bottle systems and the associated bottle cleaning operations, the nitrogen contained in the label adhesive may make it necessary to design the treatment system for targeted nitrogen elimination.

| Type of waste water | $BOD_5$ (mg/l) | SS (mg/l) | pH |
|---|---|---|---|
| **Soft drinks**<br>Sweet lemon | 42000 | 56860 | 2.95 |
| Coca Cola | 60000 - 80000 | 114900 | 2.4 |
| Pepsi Cola | 79500 | 122000 | 2.5 |
| **Juices**<br>Tomato | 25000 | 66860 | 4.1 |
| Pineapple | 65000 | 138950 | 3.15 |
| Orange | 200000 | - | 2.5 |
| Lemon | 170000 | - | 2.4 |

**Table 3.9: Characteristics of waste water from different soft drink and juice productions [Panagopoulos J.; Malliaros C., 2001 #74]**

### 3.2.8.2.3 Production of ethyl alcohol by fermentation

The major sources of waste water are the cooling water system, which serves the condensers and fermentation tanks, and the residues (vinasses) from the distillation towers.

a) **Manufacture of Cider and Perry**

There are two main processes which liberate waste water in cider and perry manufacturing installations;

- the production of final product from juice
- the milling of fruit.

The production of the final product occurs all year round, whereas the milling of fruit is dictated by the harvesting of the fruit.

Waste water from the production of the final product is generally generated from wash water, waste product (kept to a minimum), and spillages from storage areas etc.

During the milling season the waste water volumes and strengths increase significantly. The main sources of waste water during this period are:

- transport water (conveying the fruit through the process)
- surplus evaporator water (from juice concentrating)
- general waste (wash water etc).

The transport water is recycled as often as possible, however, this waste water is high in strength. Towards the middle of the milling season, flows and loads increase due to the quantity of fruit entering an installation. Towards the end of the milling season the volume of waste water decreases; however, the BOD and solids content of the waste water increases due to the deteriorating quality of the fruit being received.

#### 3.2.8.2.4 Production of malt

The main sources of waste water are the discharge from the steeping tanks and the cooling system for the germination stage.

## 3.3 General description. Energy consumption

In Germany, the food industry consumed about 54.5 thousand MWh/yr in 1998 representing 6.7 % of the total German energy consumption and being the fifth biggest energy consumer among the sectors. The energy was produced using 49 % gas, 23 % electricity, 21 % oil, and 7 % coal. The energy consumption doubled in 30 years from 1950 through to 1980. There was a slight decrease in the `80s and `90s. However, the specific energy consumption was almost constant from 1960 to 1978. It decreased after the world energy crisis. [2, **Meyer**, 2000]

The fifteen sub-sectors that were the biggest energy consumers were as follows:

| No | NACE Code | Sub-sector in food industry | Energy consumption (MWh/yr) |
|---|---|---|---|
| 1 | 15.83 | Manufacture of sugar | 212109 |
| 2 | 15.41 | Manufacture of crude oils and fats | 177898 |
| 3 | 15.62 | Manufacture of starches and starch products | 158918 |
| 4 | 15.42 | Manufacture of refined oils and fats | 70862 |
| 5 | 15.86 | Processing of tea and coffee | 35370 |
| 6 | 15.97 | Manufacture of malt | 29889 |
| 7 | 15.31 | Processing and preserving of potatoes | 27372 |
| 8 | 15.88 | Manufacture of homogenized food preparations and dietetic food | 24939 |
| 9 | 15.51 | Operation of dairies and cheese making (without ice cream) | 22323 |
| 10 | 15.52 | Manufacture of ice cream | 19477 |
| 11 | 15.43 | Manufacture of margarine and similar edible fats | 17395 |
| 12 | 15.92 | Production of ethyl alcohol from fermented materials | 15295 |
| 13 | 15.96 | Manufacture of beer | 13012 |
| 14 | 15.89 | Manufacture of other food products n.e.c. (without drinks) | 12898 |
| 15 | 15.84 | Manufacture of cocoa; chocolate and sugar confectionery (without bakery products) | 11904 |

**Table 3.10: The 15 biggest energy consumer sub-sectors in the German food industry in 1998 [2, Meyer, 2000]**

The fifteen sub-sectors having biggest specific energy consumption in 1998 were as follows:

| No | NACE Code | Sub-sector in food industry | Specific energy consumption (MWh/million DM) |
|---|---|---|---|
| 1 | 15.92 | Production of ethyl alcohol from fermented materials | 1830.38 |
| 2 | 15.62 | Manufacture of starches and starch products | 1615.89 |
| 3 | 15.83 | Manufacture of sugar | 1349.76 |
| 4 | 15.97 | Manufacture of malt | 1256.04 |
| 5 | 15.31 | Processing and preserving of potatoes | 779.35 |
| 6 | 15.41 | Manufacture of crude oils and fats | 424.66 |
| 7 | 15.42 | Manufacture of refined oils and fats | 419.77 |
| 8 | 15.96 | Manufacture of beer | 277.23 |
| 9 | 15.85 | Manufacture of macaroni, noodles, couscous and similar farinaceous products | 264.06 |
| 10 | 15.89 | Manufacture of other food products n.e.c. (without drinks) | 230.84 |
| 11 | 15.61 | Manufacture of grain mill products | 224.81 |
| 12 | 15.81 | Manufacture of bread; manufacture of fresh pastry goods and cakes | 215.48 |
| 13 | 15.13 | Production of meat and poultrymeat products | 214.15 |
| 14 | 15.82 | Manufacture of rusks and biscuits; manufacture of preserved pastry goods and cakes | 206.02 |
| 15 | 15.88 | Manufacture of homogenized food preparations and dietetic food | 199.80 |

**Table 3.11: Sub-sectors in German food industry having the biggest energy consumption per turn over in 1998**
[2, **Meyer**, 2000]

It is interesting to see how the energy consumption related to the number of employees varied in German food sector:

| No | NACE Code | Sub-sector in food industry | Specific energy consumption (MWh/yr/capita) |
|---|---|---|---|
| 1 | 15.41 | Manufacture of crude oils and fats | 1991 |
| 2 | 15.97 | Manufacture of malt | 1334 |
| 3 | 15.83 | Manufacture of sugar | 1233 |
| 4 | 15.62 | Manufacture of starches and starch products | 1122 |
| 5 | 15.42 | Manufacture of refined oils and fats | 655 |
| 6 | 15.92 | Production of ethyl alcohol from fermented materials | 531 |
| 7 | 15.86 | Processing of tea and coffee | 238 |
| 8 | 15.31 | Processing and preserving of potatoes | 227 |
| 9 | 15.51 | Operation of dairies and cheese making (without ice cream) | 168 |
| 10 | 15.61 | Manufacture of grain mill products | 141 |
| 11 | 15.96 | Manufacture of beer | 123 |
| 12 | 15.32 | Manufacture of fruit and vegetable juice | 112 |
| 13 | 15.71 | Manufacture of prepared feeds for farm animals | 110 |
| 14 | 15.88 | Manufacture of homogenized food preparations and dietetic food | 99 |
| 15 | 15.85 | Manufacture of macaroni, noodles, couscous and similar farinaceous products | 98 |

**Table 3.12: Sub-sectors in German food industry having the biggest energy consumption per employee in 1998**
**[2, Meyer, 2000]**

## 3.4 General description. Emission to air

### 3.4.1 Waste gas

Waste gas streams can roughly be divided into ducted and non-ducted (diffuse, fugitive) emissions. Only ducted emissions can be treated. As far as fugitive emissions are concerned, the objective of waste gas management is their prevention and/or minimisation (e.g. by capturing them in a ducted system).

The emissions for waste gas and exhaust air in chemical industry are:

- Ducted emissions, such as:
    - process emissions, released through a vent pipe by the process equipment and inherent to the running of the plant
    - flue gases from energy-providing units, such as process furnaces, steam boilers, combined heat and power units, gas turbines, gas engines
    - waste gases from emission control equipment, such as filters, incinerators or adsorbers, probably containing unabated VOCs
    - tail gases, from reaction vessels and condensers
    - waste gases, from catalyst regeneration
    - waste gases, from solvent regeneration
    - effluent of vents from storage and handling (transfers, loading and unloading) of products, raw materials and intermediates
    - waste gases from purge vents or preheating equipment, which are used only on start-up or shut-down operations
    - discharges of safety relief devices (e.g. safety vents, safety valves)
    - exhaust of general ventilation system
    - exhaust of vents from captured diffuse and/or fugitive sources, e.g. diffuse sources installed within an enclosure or building.

- Diffuse emissions, arising from point, linear, surface or volume sources:
    - process emissions by the process equipment and inherent to the running of the plant, released from a large surface or through openings, etc.
    - non-ducted emissions (working losses and breathing losses) from storage equipment and during handling operations (e.g. filling of drums, trucks or containers)
    - emissions from flares
    - secondary emissions, resulting from the handling or disposal of waste (e.g. volatile material from sewers, waste water handling facilities or cooling water).

- Fugitive emissions, such as:
    - equipment leaks from pump and compressor seals, valves, flanges, connectors and other piping items, or other equipment items, such as drain or vent plugs or seals
    - non-routine emissions, resulting from operations other than the routine processing of the facility, including emissions during start-up or shutdown, and during maintenance
    - accidental emissions, caused by incidents and spills of volatile products during which vapours are released to the atmosphere.

The main air pollutants from chemical processes and energy supply are:

- sulphur oxides ($SO_x$) and other sulphur compounds ($H_2S$, $CS_2$, COS)
- nitrogen oxides ($NO_x$, $N_2O$) and other nitrogen compounds ($NH_3$, HCN)
- halogens and their compounds ($Cl_2$, $Br_2$, HF, HCl, HBr)
- carbon monoxide
- volatile organic compounds (VOC) and organosilicon compounds, potentially encompassing compounds with carcinogenic potential
- particulate matter (dust and soot, potentially containing or adhering to heavy metals, incomplete combustion compounds and dioxins, with probable carcinogenic properties).

### 3.4.2 Odour

Odour is not considered to impose serious health and/or environmental risks and is mostly a local problem. This might be the reason why legislation and enforcement were not of primary interest. However, legislative controls governing odour emissions from industrial operations are becoming progressively more stringent. It is largely driven by an increased public awareness of environmental issues and the fact that people living in the vicinity of industrial premises have less of a tolerance to nuisance emissions than in previous years. This factor is evident in the number of complaints received by factories in recent years and the number of abatement systems that have been installed in order to minimise the impact of the odorous emissions.

Legislation applied to odorous emissions is generally related to the impact of the odorous emission with only the magnitude of the odorous discharge being subject to legislative control in a relatively few cases. The potential for a factory site to attract complaints and be subject to legislative controls is strongly related to the surrounding locality of the factory. Thus, for two identical factories producing the same products and using the same raw materials and process operations, one factory may be subject to considerable complaints whilst for the other factory the odour emission may not a problem. There are many cases where factories, previously situated in rural areas on the outskirts of a town or city, are now faced with odour problems as the new housing estates have been constructed as the town has grown. This factor, coupled with the increased public perception of environmental issues and the need to maintain a “quality of life”, has resulted in an increase in the number of complaints.
It is reflected in the fact that, in the vast majority of countries, odour emissions are legislated under laws of **nuisance**. In this respect the severity of an emission can be judged by the number of complaints from nearby domestic dwellings.

There are some countries where quantified legislation is in place. This quantified legislation can relate to either the magnitude of the odorous emission or alternatively a maximum concentration of a component or group of components which are known to cause odorous emissions. The internationally accepted units of odour are Odour Units per cubic metre.

Instrumental odour measurements exist but the quantification of odour is still based on olfactometry on a great extent. The full definition and measurement technique for odour are discussed further in Section 4.12.5.

In the Netherlands, for example, there is a national guideline stating that the impact of an odour emission should be such that an odour level of 1 OU/m$^3$ is not exceeded at any residence or recreational area for more than 2 % of the time. The odour level of 1 OU/m$^3$ in this case is based on a maximum one hour average value. There are other countries where the legislation differs in terms of the magnitude of the odour units and also the averaging period over which the analysis is conducted. For example in Denmark the guideline legislation states that an odour level of 5 OU/m$^3$ should not be exceeded based on an averaging period of 1 minute. In practice, these two examples of quantified odour legislation are not too different in that the increased odour concentration of 5 OU/m$^3$ is offset by the shorter averaging period. In Germany, the legislation for odorous processes is largely geared to ensuring that the outlet concentration of organics is limited in relation to the process being conducted and the efficiency of the chosen abatement plant. The legislation, under TA Luft [German Federal Ministry for Environment; Nature Conservation and Reactor Safety, 1986 #82], provides a general statement relating to odour emissions and describes the need to consider containment, the surroundings and the ability of the abatement plant to achieve 99 % odour reduction for odour emissions greater than 100000 OU/m$^3$. For specific process operations T A Luft provides maximum outlet concentrations of organics that should not be exceeded, for example, coffee roasting is subject to a maximum limit of 50 mg carbon/m$^3$. Thus the operator is duty bound to install an abatement plant that is capable of meeting this limit.

### 3.4.2.1 Odour measurement

From a scientific viewpoint a quantitative measure of odour is far more meaningful than a qualitative description such as strong, sweet, pungent etc. An odorous emission can be quantified in a number of ways. Physical measurements such as airflow, temperature and humidity are important parameters in the overall assessment of the problem. Measurement of specific components known to be present in the exhaust also provides additional valuable information, for example, measurement of inorganic species, $H_2S$ and ammonia, or defined organic components by mass spectrometry. The overall organic emission can also be fairly easily measured using flame ionisation detectors for example. Whilst the above-mentioned measurements provide valuable information in characterising the exhaust emissions there is no relationship between the concentration of given components and the overall intensity of the odour. Whilst individual components will have odour threshold values available in the literature, there is no accurate mechanism for combining the individual odour thresholds to produce an overall threshold where there is a number of components present in a mixture.

#### Olfactometry

The most widely accepted quantified measurement of odour is by olfactometry employing a panel of human observers to assess a sample of the odour at defined levels of volumetric dilution. The evaluation involves taking a sample of a given exhaust gas and subjecting the panel of observers to varying dilutions of the sample. The procedure enables the calculation of an odour threshold defined as "the number of times the exhaust sample requires dilution to a point where 50 % of a panel of observers can detect a smell and 50 % cannot detect a smell". The resultant odour level is given the units of Odour Units per m$^3$ (OU/m$^3$) and is defined as a 50 % perception threshold level. The perception level implies that there is a smell present although the smell is not recognisable but is merely different from the odour free dilution air. This definition is the most widely used and accepted definition for odour measurement. There is also a recognition odour threshold, which is seldom used, relating to the level at which the panellists can recognise the diluted odour as being representative of the source from which the sample was taken.

The measurement of odour by a panel of observers, could be considered rather subjective and is potentially open to considerable variability as a result of the human interface incorporated within the measurement. In order to minimise the subjective nature of the evaluation and reduce the variability of the analysis there are a number of national standards which detail the procedures and methodologies which need to be adhered to during the test. This is an important requirement in order to attain standardisation between different types of olfactometers and different laboratories conducting the analysis.

National Standards relating to the methodology for odour quantification exist predominantly in Europe and USA. There are essentially two types of olfactometers in use world-wide:

- firstly the yes/no system where the panellist is presented with one diluted smell and requested to respond with yes/no depending whether or not they can detect a smell.
- secondly a forced choice system where the panellist is presented with two or more smells and requested to define which stimulus is conveying the tainted air.

The standards in Germany are incorporated in VDI guideline documents and relate to the yes/no type of olfactometer. The Dutch standard is based on a given Olfactometer, the Olfactomat, which is a forced choice system based on two smell ports. In the USA the Olfactometry standard is also based on the forced choice system using three smell ports. A CEN standard "Air Quality- determination of odour concentrations by dynamic olfactometry" will be adopted shortly which standardises the methodologies for odour quantification by dynamic olfactometry. The key requirements of the testing methodology contained in the CEN standard are given in the **Annex 2.** [Willey A.R.; Williams D. A., 2001 #34].

#### 3.4.2.2 Odour emissions

There is little information available for odour levels. As an example, the following table was presented in the Report "Management of Odorous Emissions in the Food Industry".

| **Source** | **Airflow** | **Odour Level** | **Odour Emission** | **Operation Hours** |
|---|---|---|---|---|
| | ($m^3$/hr) | (OU/$m^3$) | (OU/s) | (h / yr) |
| Raw material handling | 50 | 1610 | 22 | 480 |
| Raw material heating | 48 | 1250 | 16 | 960 |
| Process heating | 1.1 | 11290 | 3.4 | 2100 |
| Vacuum generation | 400 | 17180 | 1909 | 5760 |
| Fat trap | 1.6 | 90 | 0.04 | 6240 |
| Vent to atmosphere from process plant | 1920 | 350 | 190 | 48 |
| Packing hall | 12700 | 80 | 275 | 5760 |
| Waste facility | 3500 | 2690 | 2611 | 387 |

**Table 3.13: Odour levels in a food manufacturing site**
**[Willey A.R.; Williams D. A., 2001 #34]**

## 3.5 Unit operations

It is quite difficult to give quantitative data on environmental aspects of the individual processing techniques. This is due to a lack of reliable data or due to natural variations (seasonal etc.) in many of the raw materials. This often leads to changes in the processing techniques applied. It must be made clear that the ranges in the quantitative data will necessarily be very large due to the very wide variation in individual process applications. Often better quantitative information on the environmental aspects of the whole production line is available than on individual processing techniques. This is due to the fact that companies have never had to report the environmental impact of their internal process before, only those of the entire production line and the overall emissions to the environment. As a consequence, it has not needed to carry out environmental studies of individual techniques, hence the lack of quantitative data.

In this document (Chapter 3) examples will also be given of environmental aspects (qualitative, quantitative) of typical production lines. In the description of environmental aspects of the various processing techniques 'solid output' covers both by-products from the process which could be valorised as well as waste which cannot be valorised. For example, some by-products from the food industry may be used as animal feed, complying fully with applicable legislation.

### 3.5.1 Materials handling, unpacking, storage (A.1)

Water

The main release into water is caused by leakages. During the transport by water of solid raw materials, such as vegetables, roots and tubers, suspended solids (both organic and/or inorganic) and soluble compounds (both organic and/or inorganic) are released to water. Cleaning of the various pipes and storage tanks also contributes to water usage and waste water load.

Air emissions

Emissions to air may occur from vessel vents whilst filling, and/or conveying (by air). These emissions may consist of particulates, gases and odours and are usually minor in quantity and local in effect.

Solid output

Some solid residues can result from vessels or other material handling equipment and can be used for either reworking, for sale as animal feed (by-product) or may be waste. These outputs will be specific to the process. Vegetable raw materials, such as sugar beets and potatoes, lead to solid output in the form of soil.

Energy

Materials handling is almost exclusively electrically driven. No significant heat is involved. The environmental issues are minor and relate to electrical consumption.

**Example**: In manufacturing frozen vegetables, transportation and storage operations require energy:

1.) the transportation of frozen vegetables requires 2 - 14 $kWh_e$ /tonne frozen vegetables. For most production lines, the electrical rating of the belts is between 5 - 30 $kW_e$.
2.) the storage of vegetable need 20 - 65 $kWh_e$/ $m^3$ storage/ year electricity and about 95 $MJ/m^2$ storage/year is needed in the form of hot water.

Data from the literature shows that the average energy balance is made up as follows: [32, Bael, 2001]

- 11 % for the evaporator fans
- 5 % for the condenser fans
- 7 % for peripheral equipment
- 77 % for compressors:
    - 21 % by heat input via doors/hatches
    - 48 % due to loss via the shell of the building
    - 8 % through product.

Noise

Short periods of noise may occur from certain types of vehicle-mounted blowers used to discharge solids and liquids from road vehicles into silos and other vessels.

### 3.5.2 Sorting, screening, grading, dehulling, trimming (A.2)

Water
Wet screening may result in a waste water stream containing primarily solid matter.

Air emissions
During dry cleaning of food/agricultural raw materials dust may be produced. These emissions are minor in quantity and local in effect.

Solid output
Material that is sorted out, or removed, is recovered as far as possible and often used as feed for cattle or pigs (by-product). If the material cannot be used it is processed as solid waste.

Energy
Although sorting generally needs little energy, there are large variations in electrical energy consumption.

**Example**: Sorting in vegetable processing has electrical energy consumption of 0 - 20 kWh$_e$/tonne frozen vegetable.

| **Product** | **Electricity consumption (kWh$_e$ / tonne frozen vegetables)** |
|---|---|
| Carrots | 8 |
| Salsifies | 20 |
| Spinach | 0 |
| Peas | 4 |
| Beans | 5 |
| Sprouts | 4 |
| Cauliflowers | 1 |

**Table 3.14: Electricity consumption during the sorting of vegetables**
**[32, Bael, 2001]**

### 3.5.3 Peeling (A.3)

Water
In most peeling operations a water spray is used to remove the peeled skin. Waste water is generated containing solid matter.

Air emissions
When flame peeling is applied some dust and odour emissions can take place.

Solid output
The peels are often recovered and used as animal feed (by-product) when possible, otherwise they are processed as solid waste.

Energy
Flash steam peeling, caustic peeling and flame peeling require heat; in the other peeling operations electrical energy is used.

**Example**: In vegetable processing, salsifies and carrots are peeled before being mechanically processed. Caustic peeling and steam peeling are two methods used.

| Energy carrier | Order of magnitude indicators |
|---|---|
| Hot water (MJ/tonne frozen vegetables) | 0 |
| Steam (tonne /tonne frozen vegetables) | 0.16 |
| Steam pressure (bar) | 7 |
| Electricity (kWh/tonne frozen vegetables) | 2 |

**Table 3.15: Energy carrier and order of magnitude indicators for caustic peeling of vegetables**

| Energy carrier | Order of magnitude indicators |
|---|---|
| Hot water (MJ/tonne frozen vegetables) | 0 |
| Steam (tonne /tonne frozen vegetables) | 0.9 |
| Steam pressure (bar) | 7 - 15 |
| Electricity (kWh/tonne frozen vegetables) | 3.5 |

**Table 3.16: Energy carrier and order of magnitude indicators for steam peeling of vegetables**

Caustic peeling needs less energy (both in terms of electricity consumption and steam consumption) than steam peeling, but creates more work for the waste water treatment plant. [32, Bael, 2001]

### 3.5.4 Washing (A.4)

Water

For washing water is required and waste water, with dissolved organic matter (BOD) and suspended solids, is produced. The water consumption can be reduced by operating counter-currently or by recycling the water after cleaning (sedimentation, settlement, filtration, etc.).

Solid output

The dirt removed during washing is usually solid material (soil, vegetable matter, etc.),. for example, the washing of sugar beets and potatoes results in soil, which is reapplied to arable land or landfills.

Energy

**Example**: Washing, as used in the production of frozen vegetables, needs 0 - 5 $kWh_e$ /tonne frozen vegetables electrical energy.

| **Product** | **Electricity consumption ($kWh_e$ / tonne frozen vegetables)** |
|---|---|
| Carrots | 2.5 |
| Salsifies | 3 |
| Spinach | 5 |
| Peas | 3 |
| Beans | 0.5 |
| Sprouts | 0 |
| Cauliflowers | 0 |

**Table 3.17: Electricity consumption for washing of vegetables**

Electricity consumption for washing operations is heavily dependent on the vegetable concerned. Certain vegetables (for example, sprouts and cauliflowers) do not require any cleaning at the deep-freeze companies, while others do. Washing Spinach is energy-intensive.

During washing operations, hot water can be used to increase the speed and efficiency. Most companies do not heat the water. Sometimes (hot) residual water from the blanching system is used for washing. [32, Bael, 2001]

### 3.5.5 Cutting, slicing, chopping, mincing, pulping (B.1)

Water

Waste water results mainly from the cleaning of equipment. It usually contains product remnants, such as small particles of meat, fruit and vegetables. In meat processing the waste water may also contain soluble protein, suspended fat and other solids, such as curing salts etc.

Solid output

The by-products generated depend on the raw material and process, for example, in meat cutting, typical by-products are: bones, fat, skin, viscera and parts of the carcase such as heads and feet, or fruit and vegetable peelings.
These are usually used for other manufacturing processes, which might even be outside the food industry, such as soap manufacture.

Energy

Electrical energy is used for various equipment.

**Example**: Some vegetables are cut before deep freezing. The electrical energy consumption is up to 9 kWh/tonne frozen vegetables.

| **Product** | **Electricity consumption (kWh$_e$ / tonne frozen vegetables)** |
|---|---|
| Carrots (diced) | 2.5 |
| Carrots (sliced) | 1 |
| Salsifies | 6 |
| Spinach | - |
| Peas | 0 |
| Beans | 9 |
| Sprouts | 0 |
| Cauliflowers | 0 |

**Table 3.18: Electricity consumption of mechanical processing of vegetables before freezing**

Carrots, salsifies and beans require a reasonable amount of electrical energy for mechanical processing. Other vegetables examined do not require any electricity at all.
[32, Bael, 2001]

Noise

Some high-speed, power-operated equipment is used which can generate high noise levels, e.g. circular saws used to cut through bones and bowl cutters. However, this is usually not an off-site issue.

### 3.5.6 Mixing, blending, conching, homogenisation (B.2)

Water

The use of water in this group of operations is normally restricted to cleaning of the equipment. The amount used depends on the type of equipment. The resulting waste water contains soluble and suspended organic solids.

Air emissions

In operations where solid and volatile materials are treated, emissions to air can occur.

Odour may be produced by operations which involve volatile organic compounds.
Particulates (dust) are emitted in operations involving solids such as solid/solid mixing.

Solid output
In those operations where solid materials are processed solid organic output may be generated when equipment is emptied for the next batch or for cleaning. Normally some losses occur during such operations. This solid waste can consist of raw materials or waste products. By careful operation and good housekeeping the amount of solid output can often be reduced and be re-used or sold as feed (by-product).

Energy
The operations of this group require mainly electrical energy input.

Noise
Homogenisation may be a source of noise.

### 3.5.7 Grinding, milling (B.3)

Air emissions
Particulates (dust) are emitted in operations involving solids.

Solid output
Solid organic output is generated when equipment is emptied for the next batch or for cleaning. Some losses occur in such situations. This solid output can consist of raw materials or waste products and can be reprocessed or sold as feed (by-product).

Energy
Grinding (milling) requires a substantial energy input.

Noise
No issues identified.

### 3.5.8 Forming, moulding, extruding (B.4)

Water
Waste water is generated during the cleaning of equipment and contains primarily soluble organic material (BOD) and solid matter.

Air emissions
Extrusion at high temperature may result in some air emissions of volatile organic compounds and odour.

Solid output
Some solid waste may be generated due to the loss of product at the beginning and end of the production process.

Energy
Extruders are typically major users of electrical energy.

### 3.5.9 Extraction (C.1)

Water
Water usage is an issue when water is used as a solvent in the extraction process. Also, periodically extraction equipment is cleaned in order to ensure efficient and optimum operating

conditions. The frequency of cleaning depends on the product and extractor design. This generates a certain amount of waste water containing soluble/insoluble organic material (BOD) and solid matter.

Air emissions
Extraction with organic volatile solvents may cause emissions of VOCs. Extraction plants may also cause odour, due to emission of $H_2S$ and organic compounds.
When extraction with water takes place, water vapour containing non-condensable volatile organic matters may be released to the atmosphere.

Solid output
The solid output can be re-used (by-product). An example is the extracted spent grounds of coffee after coffee extraction. After the removal of the adhering water the spent grounds can be used as fuel in steam boilers, or as raw material for further processing.
If the solid output is not re-used then it has to be disposed of as a solid waste.

Energy
Electrical energy and steam are required, the levels depending on the type of application..

Noise
Possible sources of noise are: cooling towers, fans, steam safety valves.

### 3.5.10 Deionisation (C.2)

Water
The regeneration of ion exchange columns produces water containing the chemicals used for the regeneration (usually acids or alkalis, and brine), ions removed from the product and impurities extracted from the used column. Regeneration starts with rinsing the ion exchange columns with water. This produces waste water containing product residues, which depending upon dilution, may be reprocessed in the process.

Solid output
The only solid output from a deionisation process is the ion exchange resins at the end of their life. This can be anything from 6 months to 10 years depending on the operation and product. This material is normally sent to landfill.

### 3.5.11 Centrifugation/sedimentation (C.3)

Water
Water is used periodically to clean the separation equipment. Frequency and volumes vary depending on the product and the equipment. Sometimes the water can be reprocessed. Waste water is produced from washing the equipment as well as in the form of the separated waste products from the operational process (in which case it will contain dissolved organic matter (BOD) and suspended solids).

Solid output
Separator sludges can sometimes be re-used in the process or sometimes have to be disposed of as by-product or waste.

Energy
When gravity separators are used, electrical energy is required for pumping operations.

Noise
The operation of centrifuges may be accompanied by relatively high levels of noise in close proximity to the machines and suitable control measures need to be put in place.

### 3.5.12 Filtration (C.4)

Water
Depending on the purpose of the filtration operation the process may result in a liquid waste stream containing dissolved organic matter and suspended solids.

Air emissions
The air discharge from the vacuum pump during vacuum filtration may contain particulates (dust).

Solid output
A filter cake residue may be produced which will require a suitable method of recovery or disposal, e.g. bleaching earth in edible oil refining or kieselguhr in a brewery.

Energy
Pumping requires electrical energy.

### 3.5.13 Membrane separation (C.5)

Water
Water is used periodically to clean the separation equipment. Frequency and volumes vary depending on the product and equipment. Waste water is produced from washing as well as in the form of the separated waste products from the process and contains dissolved organic matter and suspended solids.

Energy
Membrane separation is a pressure driven process, electrical energy is required. In electrodialysis, electrical energy is required for the transport of ions.

### 3.5.14 Crystallisation (C.6)

Water
Water is used for cooling and is normally recirculated. Depending on the cooling requirements water is recirculated via chilling units or cooling towers. Waste water appears after crystal removal.

Solid output
In the refinery process (if required), active carbon is used. Spent active carbon is either regenerated or disposed of as waste.

Energy
Electricity for pumps and drives. Energy for cooling system.

### 3.5.15 Neutralisation (removal of fatty acids) (C.7)

Water
The neutralisation process requires cooling water. The waste water that results from a combined neutralisation and soap stock splitting is at about 100 °C, has a high acidity and contains salts of sodium phosphate and sodium-sulphate or chloride in high concentrations. The use of citric acid increases the BOD-load of the effluent.
Disposal of process effluent with high concentrations of sulphates (2000 mg/l) into public sewer systems may cause corrosion of the concrete. Occupational health problems may arise in treatment systems due to the formation of $H_2S$.

Air emissions
The soap stock acidulation system may be a source of odour.

Solid output
Fatty acids are considered a by-product. The treatment of a neutralisation waste water can produce high amounts of sludge, due to the presence of phosphates and/or sulphates. The effluent of this waste water treatment may have high salt concentrations.

Energy
Steam is the main source of energy for neutralisation and soap stock splitting.

### 3.5.16 Bleaching (C.8)

Air emissions
Cleaning of the filters can cause emissions of organic compounds that cause odour. The storage of spent bleaching earth can also cause odour.

Solid output
Spent bleaching earth has a risk of self-ignition. The spent earth of an oil refinery can be added to the meal of a crush (by-product). The spent earth used for bleaching hardened oils can also be added to the meal, when it does not contain nickel and/or activated carbon. Otherwise, it can be used as an energy source (e.g. in the production of concrete), since it has a high caloric content.

Energy
Steam is needed for the oil recovery from the spent bleaching earth. The oil and bleaching earth are heated by steam during the bleaching process.

### 3.5.17 Deodorisation by steam stripping (C.9)

Water
Water is used for cooling of the condensers. The water from the barometric condensers may be polluted. In a once-through-barometric condenser, the heat load to the surface water is equivalent to the steam consumption in the vacuum-system.

Air emissions
Vacuum pumps release some organic compounds that may cause odour.

Solid output
Fatty acids and distillates are produced by this process. These products are in most cases considered as by-products.

Energy
For this processing technique energy is needed in the form of steam and electricity. The energy consumption ranges from 55 - 200 kJ/kg, and steam consumption from 0.15 to 0.40 tonne/tonne product.

Noise
Issues may arise associated with the cooling tower fans.

### 3.5.18 Decolourisation (C.10)

Water
During start-up and shut-down low volumes of aqueous product, containing low quantities of solid material, may be discharged. Normally this discharge is reprocessed/re-used in the

process. However, it is not always economical to concentrate this material, in which case it is discharged as waste water. This waste water may contain dissolved organic material (BOD), suspended and dissolved solids.

Solid output
The decolourisation process produces a filter cake consisting of the active material, any filter aid that was required and some residual product. This solid output may be sent to landfill or for land spreading/composting depending on its nature. Depending on the type of process/product, this solid output can also be used as animal feed (by-product).

Energy

Any heating of the product used to meet the optimum conditions for the operation can usually be recovered by normal heat recovery systems.
The regeneration of activated carbon involves kilning at elevated temperatures in the absence of oxygen. This is mainly done off-site by specialised companies (mainly the supplier).

### 3.5.19 Distillation (C.11)

Water
A residual liquid (stillage, pot ale, spent lees and spent wash) is discharged from the stills. This can have very high BOD. Where recovery systems exist, a proportion of the stillage may be re-used. The balance is normally processed to animal feed compounds, leaving a residual condensate for disposal.

Air emissions
There may be minor emissions of uncondensable volatilities, mainly carbon dioxide and ethanol, from column stills. There are no issues for pot stills.

Solid output
Concentrated stillage or dried stillage provides a co-product used for incorporation in animal feed, as a feedstock in sugar and grain-based production, or as a fertiliser.

Energy
The distillation tower is heated by steam. Several techniques are proposed to minimise the energy consumption of the distillery. For pot stills, 12 to 3 kWh per litre of pure alcohol (excluding animal feed conversion) is required.

Noise
Some of the production equipment may have high noise levels, e.g. in the concentration of stillage and in the dehydration of alcohol by molecular sieve adsorption.

### 3.5.20 Soaking (D.1)

Water
For soaking, water is required and some waste water with dissolved organic matter (BOD) and suspended solids is produced.

Solid output
Some dirt, which is lost during soaking can be produced.

### 3.5.21 Dissolving (D.2)

Water
Waste water is generated during cleaning. This waste water may contain product residues (e.g. powder, oil from rinsing) resulting in dissolved organic matter (BOD) and suspended solids in the waste water.

Air emissions
Dust emissions may occur during bag tipping. These emissions are typically minor and generally remain inside buildings.

Energy
In the dissolving process steam and electricity are used.

### 3.5.22 Solubilisation (alkalising) (D.3)

Water
Waste water is generated from the cleaning of equipment and typically contains soluble organic matter (BOD), suspended solids and fat.

Air emissions
Air emissions may consist of water vapour containing low concentrations of volatile organic matters and particles.

Energy
Typical energy requirements per tonne of cocoa:

| | **Electrical power (kJ/kg)** | **Steam (kg/tonne)** |
|---|---|---|
| | | |
| Liquid process | 35 – 70 | 300 – 500 |
| Nips alkalising | 35 – 550 | 700 – 1000 |

**Table 3.19: Typical energy requirement per tonne of cocoa**

### 3.5.23 Fermentation (D.4)

Water
Water is used for cooling the fermentation vessels. Mostly, cooling water from cooling towers or a once-through system is used. Waste water is generated from cleaning of the equipment and vessels and contains raw material and fermented produce residues.
Yeast, as an organic product, has a high COD and suspended solids content and is a major contributor, along with the carrying liquid phase, to the COD load of the waste water from the fermentation process. However, this fraction is mostly recovered and used as animal feed.

Air emissions
Emissions to the air are alcohol and $CO_2$. Carbon dioxide is a natural product of alcoholic fermentation. Within controlled fermentation processes it is generally allowed to vent to the atmosphere. Recovery and re-use may also take place.

Solid output
Spent yeasts are a by-product with secondary uses as food products or animal feed.

Energy
Electrical energy is needed for circulating cooling water.

### 3.5.24 Coagulation (D.5)

Water

Water of high quality is needed for curd washing. Waste water is generated during the cleaning of the equipment and contains dissolved organic matter (BOD) and suspended solids.

Energy

Energy is needed for heat treatment (steam) and for cooling (electricity).

### 3.5.25 Germination (D.6)

Water

Some water is required for humidification of the air.

Air emissions

The air from the germination process will be loaded with water vapour and minor amounts of volatile organic compounds.

Energy

Energy is needed for conditioning and circulation of the air.

### 3.5.26 Brining, curing (D.7)

Water

Brine that is discarded after use, or excess brine from immersion baths, is discharged as waste water.

The quantity will depend on the method of brining or curing used. This waste water will contain salt, curing salts and other ingredients, and also soluble product components like protein which has been exuded from the product (cheese, meat) during brining.

Washing down of premises and equipment also yields waste water, containing residual curing ingredients and product residues resulting in dissolved organic matter (BOD), dissolved solids and solid material being present in the waste water.

### 3.5.27 Smoking (D.8)

Water

Waste water is generated during periodical cleaning of the smoking equipment.

Air emissions

Strong odours are produced during the smoking and drying operations. The emission during the smoking stage is much higher than that during the drying step. The vented smoke also contains VOCs. The smoke has to be treated to remove odours prior to emission to the atmosphere.

Solid output

Ashes from wood.

Energy

Energy is needed for smoke generation and for heating and drying.

### 3.5.28 Hardening (D.9)

Water

Water is used for cooling purposes since the end-product cannot be warmer than 100 °C. Steam (demineralised water), is necessary to heat the autoclaves and/or reactors. Water is also used to clean the installation.

Air emissions

There is an explosion/fire risk associated with $H_2$ emissions

Solid output

Specialised companies recycle spent nickel. The cleaning water from these operations can contain traces of nickel that can accumulate in, and thus contaminate, the sludge of a waste water treatment plant.

Energy

Energy is supplied as steam and electricity.

Noise

Noise issues may arise from the cooling towers, compressors or vacuum systems.

### 3.5.29 Sulphitation (D.10)

Air emissions

A substance of environmental concern is sulphur dioxide. However, the $SO_2$ is readily absorbed by the liquid and actual residual emissions are extremely low.

### 3.5.30 Carbonatation (D.11)

Air emissions

Excess $CO_2$ is vented to atmosphere.

If a limekiln is used then there will be CO emitted due to the inevitable incomplete combustion within the kiln. $SO_2$ and $NO_x$ combustion products will be vented to air accompanied by small amounts of particulates. Lime hydrators used in conjunction with kilns will also emit small quantities of particulates.

There is usually an over-pressure vent on the kiln. The normal kiln exhaust gases are washed before being introduced in the process. Exhaust gases and vapours from the carbonatation vessels contain $NH_3$ and CO and other odorous compounds.

Solid output

Any complexes formed during the carbonatation are separated out from the sugar juice and used as a fertilizer (by-product). Residual alkaline earth metals are sent to landfill.

Noise

If a limekiln is used then the charging of limestone and coke may produce noise off-site.

### 3.5.31 Coating, spraying, enrobing, agglomerisation, encapsulation (D.12)

Water

Waste water is produced from the cleaning of the equipment and will contain product residues, consisting of dissolved organic material (BOD) and solid material.

### 3.5.32 Melting (E.1)

Water
Waste water is generated during cleaning. This waste water may contain fat along with dissolved organic material (BOD) and solid matter.

Air emissions
Odour emissions may occur in the dry melting process of meat residues.

Solid output
In some melting processes, a solid phase remains. This is considered a by-product.

Energy
In the melting process, the use of steam is the main energy component.

### 3.5.33 Blanching (E.2)

Water
The leaching of sugars, starches and other soluble organic compounds from the raw fruit or vegetables into the blanching water results in a waste water containing dissolved organic matter (BOD), and dissolved and suspended solids. As blanching water is normally re-used/recycled, the volume of water from blanching is normally relatively small. However this tends to concentrate the pollutants (BOD) in the waste water.

Air emissions
Steam/water vapour may be discharged to atmosphere. Depending on the raw material being blanched, the exhaust air may contain low levels of volatile organic compounds, which may generate a low level of odour.

Solid output
Some solid material may accumulate in the bottom of the blanchers. This is removed periodically.

Energy
Heat is used for heating the blanching water.

**Example**: Drum and belt blanchers are used in deep frozen vegetable manufacturing. Energy consumption depends on not only the type of blanching device but also the type of subsequent freezing step. Typical energy consumption are given for some combinations used in Belgium:

**Example 1 Drum blancher with counter-current freezer**

| Energy carrier | Order of magnitude indicators |
|---|---|
| Hot water (MJ/tonne frozen vegetables) | 0 |
| Steam (tonne /tonne frozen vegetables)<br>Steam pressure (bar) | 0.16<br>7 |
| Electricity (kWh$_e$/tonne frozen vegetables) | 0.5 - 1.3 |

**Table 3.20: Energy carrier and order of magnitude indicators for drum blancher in deep freezing of vegetables**

| Energy carrier | Order of magnitude indicators |
|---|---|
| Hot water (MJ/tonne frozen vegetables) | 0 |
| Steam (tonne /tonne frozen vegetables)<br>Steam pressure (bar) | 0<br>0 |
| Electricity ($kWh_e$/tonne frozen vegetables) | 0.5 - 1.3 |

**Table 3.21: Energy carrier and order of magnitude indicators for counter-current freezer in vegetable processing**

The electricity consumption for the production of ice water is included in the electricity consumption shown for deep-freezing.

**Example 2 Belt blancher / water freezer combination**

| Energy carrier | Order of magnitude indicators |
|---|---|
| Hot water (MJ/tonne frozen vegetables) | 0 |
| Steam (tonne /tonne frozen vegetables)<br>Steam pressure (bar) | 0.09<br>7 |
| Electricity ($kWh_e$/tonne frozen vegetables) | 2 - 9 |

**Table 3.22: Energy carrier and order of magnitude indicators for belt blancher / water freezer combination in vegetable processing**

**Example 3 Belt blancher / blast freezer combination**

| Energy carrier | Order of magnitude indicators |
|---|---|
| Hot water (MJ/tonne frozen vegetables) | 0 |
| Steam (tonne /tonne frozen vegetables)<br>Steam pressure (bar) | 0.16<br>7 |
| Electricity ($kWh_e$/tonne frozen vegetables) | 7 - 30 |

**Table 3.23: Energy carrier and order of magnitude indicators of the belt blancher / blast freezer combination in vegetable processing**

In terms of energy consumption, the belt blancher / water freezer combination scores the best. The heat released by the cooling of the product in the refrigeration zone is used to preheat the vegetables. In this way, less steam is necessary for blanching.
With regard to electricity consumption, the drum blancher with counter-current freezer scores best. The water consumption for such an installation is rather high.
Due to the use of heavy-duty fans (60 $kW_e$) in the belt blancher / blast freezer, the electricity consumption is high for this type. [32, Bael, 2001]

## 3.5.34 Cooking, boiling (E.3)

Water
Waste water is generated during cleaning. This waste water may contain product residues resulting in waste water containing dissolved organic matter (BOD) and solid materials.

Air emissions
Odour emissions may occur during boiling and cooking.

Solid output
Solid output like fat and grease may result from the cleaning of cooking equipment.

Energy
Heat (from steam) is used.

### 3.5.35 Baking (E.4)

Air emissions
During baking odour is emitted to the atmosphere together with water vapour.

Solid output
Some residuals may result from dry cleaning.

Energy
For baking fuel is used in the form of natural gas or oil. For infrared ovens special types of burners are applied. The energy usage for baking normally ranges from 450 – 600 KJ/kg of product.

### 3.5.36 Roasting (E.5)

Water
Small amounts of water are used for quenching roasted coffee. This water is partly evaporated and emitted into the atmosphere and partly absorbed by the product (coffee).

Air emissions
The outlet of both the roaster and the cooler contain odour components and other VOCs. The concentration of volatile organic compounds (VOCs) causing this odour is higher for the roaster outlet than for the cooler outlet. The VOC levels are higher when the product is roasted to a higher degree (e.g. the product temperature at the end of the roasting process is higher). The difference in emissions between a low roasted and a very high (= very dark) roasted product can be a factor 10.
For batch roasters the highest concentrations are emitted just before the end of the roasting process. In continuous roasters the emissions are continuous as well. The absolute level of VOCs depends on the product temperature at the end of the roasting, the amount of air used for roasting, the product itself and the roasting time.

Solid output
Organic solid output, e.g. the skins of coffee, is collected in the cyclones. For coffee the solid output can be between 0.1 to 1.5 % of the amount of green coffee.

Energy
The energy consumption depends on the type of roaster that is being used and also depending on the layout of the roast off-gas system.

### 3.5.37 Frying (E.6)

Water
Waste water arises from the cleaning of equipment and will contain fat, both in the form of free fat and emulsified fat, and product residues. The waste water will therefore contain TFM (total fatty matter), suspended solids and dissolved organic matter (BOD).

Air emissions
The air above a fryer is extracted to prevent any escape into the working environment. This exhaust air may contain volatile organic compounds, such as the breakdown products of the edible oil. Odour may also be an issue associated with the exhaust.

Solid output
Oil, which has reached the end of its useful life, needs to be disposed of.

Energy
The frying oven is usually heated with steam or hot oil.

### 3.5.38 Tempering (E.7)

Water
Water is used for the recirculating chilled water system.

Energy
Electricity for pumps and drives. Energy for the cooling system.

### 3.5.39 Pasteurisation, sterilisation, UHT (E.8)

Water
Water is required for cooling the product after heat treatment. Cooling after UHT treatment can be performed in two steps: firstly, flash cooling to atmospheric pressure in flash vessels, followed by cooling with water.
There are product losses, of both organic and inorganic deposits, on the heat transfer surface which are discharged in the waster water during the cleaning of the equipment. This results in a waste water containing dissolved organic matter (BOD) and solid material.

Energy
Energy, usually in the form of steam or hot water, is required for the heat treatment. After the heat treatment, cooling is typically necessary. Cooling can be accomplished by once-through cooling or with a recirculating chilled water system; the latter implicates energy consumption by a mechanical refrigeration system.

### 3.5.40 Evaporation (liquid to liquid) (F.1)

Water
The removal of deposits during cleaning and product losses from start-up and shutdowns contributes to the organic and inorganic load in the waste water. During evaporation, condensates from the product are also produced. Depending on their quality (organic, inorganic and suspended solids), these condensates can be re-used in the process or need to be treated in a waste water treatment plant. The final vapours are condensed in an open or closed condenser using cooling water.
The waste water will contain dissolved organic matter (BOD) and dissolved inorganic and suspended solids.

Air emissions
There may be cases of incondensable gases being vented to air to ensure efficient heat transfer. The environmental effects depend on the gases being vented.

Energy
Steam requirements for single stage evaporators are 1.2 to 1.4 tonne/tonne.
Typical energy requirements (per tonne of water evaporation) for multistage evaporators are:

| | Electrical Power (kJ/kg) (tonne/tonne) | Steam (tonne/tonne) |
|---|---|---|
| TVR evaporator | 7 | 0.1 – 0.3 |
| MVR evaporator | 35 | None |

**Table 3.24: Typical energy requirements for multistage evaporators**

Sometimes exhaust gases can be used recovering energy from other (drying) processes.

Noise

Noise is often produced from the evaporation processes. It is principally generated by the thermo compressor, the mechanical compressor, the steam ejectors and the high velocity of the fluids in the piping. This is usually managed by appropriate acoustic insulation.

## 3.5.41 Drying (liquid to solid) (F.2)

Water

The use of water is normally restricted to the cleaning of the equipment. The amount used strongly depends on the type of equipment.
During cleaning, waste water is generated containing soluble organic material and suspended solids.
When air scrubbers are used, a waste water stream containing organic material (fine dust) is generated.

Air emissions

In hot air drying, a gas/vapour is generated and exhausted into the atmosphere. This gas/vapour may contain dust and volatile organic compounds originating from the product. This may cause odour nuisance and might require treatment prior to discharge. If drying is done using direct (gas, fuel) fired burners, the exhaust gases might contain $CO_2$/CO/$SO_2$/$NO_x$. This depends on the heat source and burner type. However, food safety requirements must take precedence, especially when drying very sensitive products.

Solid output

Solid output may be generated when equipment is emptied for a next batch or for cleaning. This solid output can consist of raw materials, product residues and dust, which has been recovered from the exhaust air. These solid products/dust can be recycled in the process or sold as feed.

Energy

For the evaporation of water, theoretically 2.2 MJ/kg is required. Due to energy losses in the process in practice the energy consumption for water evaporation (drying) ranges from 2.5 to 3.5 MJ/kg.

Noise

Noise issues may occur from the air inlet and outlet of the dryers.

## 3.5.42 Dehydration (solid to solid) (F.3)

Water

Water is used in the cleaning of the equipment. The waste water contains dissolved organic material (BOD) and solid matter.

Air emissions
In the hot-air drying process, air with water vapour, containing volatile organic matters, is released to the atmosphere. If drying is done using direct-fired burners, the exhaust gases might also contain $CO_2$/$CO$/$SO_2$/$NO_x$, depending on the heat source and burner type.

Solid output
Solid organic material may be generated when equipment is emptied for a next batch or for cleaning. These outputs can consist of raw material, product residues and dust. These solid products/dust can be recycled in the process or sold as animal feed.

Energy
For the evaporation of water, theoretically 2.2 MJ/kg is required. However, in practice, this very much depends on the type of dryer used and can range from 2.0 – 3.5 MJ/kg. Steam dryers can have a considerable lower energy consumption, if they consist of more effects. Sometimes exhaust gases from a combustion (CHP) plant are used to dry products, thereby reducing the energy requirement. The energy consumption for dehydration can be further reduced by increasing the dry substance content of the wet product. This can be achieved by pre-evaporation or by using special dewatering equipment.

### 3.5.43 Cooling, chilling (G.1)

Water
Water may be used as the cooling medium in a once-through system. When cooling water is recirculated, closed loop cooling towers can be used for heat removal.

Air emissions
In cryogenic cooling, emissions of gaseous $N_2$ or $CO_2$ takes place. Leaking refrigeration equipment can lead to emissions of refrigerant.

Energy
Electrical energy is needed for pumps for circulating the cooling water or fans for air cooling. Mechanical refrigeration systems generally require 0.3 - 1.0 kW power per cooling effect. However, overall, their energy consumption is significantly less than the total energy required for manufacturing and using liquid $N_2$ or $CO_2$.

Noise
Noise issues may occur from the operation of the fans and cooling towers.

### 3.5.44 Freezing (G.2)

Water
A waste stream of used brines may result from immersion freezing.

Air emissions
In cryogenic freezing, emissions of gaseous $N_2$ or $CO_2$ takes place.

Energy
Electrical energy is needed for the fans for air circulation. The freezing system also requires electrical energy.

**Example**: Deep freezing is the most energy consuming step in manufacturing of deep frozen vegetables. 80 - 280 $kWh_e$/tonne of frozen vegetable is used in the Flemish vegetable sector. About 0.01 MJ/$m^2$ floor surface of tunnel/ h of operation energy is consumed as well in the form of hot water.

The energy consumption of a freezing tunnel depends on various factors:

1) type of vegetables that are frozen. Voluminous vegetables (such as cauliflower florets) are more difficult to freeze than small vegetables (like peas and diced carrots)
2) temperature of the vegetables at the entrance to the freezing tunnel. The higher this temperature, the more heat has to be removed from the vegetables before they are frozen
3) mass flow rate of the vegetables. The higher the flow rate, the higher the quantity of energy that needs to be removed, and the greater the demand for cold in the tunnel
4) sojourn time also determines the demand for cold in the freezing tunnel. The longer the sojourn time, the more chance the vegetables have to freeze. The thickness of the layer on the vegetable bed is directly proportional to the sojourn time
5) energy consumption is also determined by the air flow rates in the freezing tunnel. The higher the air flow rates, the better the heat exchange between the evaporators and the air on the one hand, and the air and the vegetables on the other hand. Higher air flow rates do lead to higher energy consumption by the fans and higher cooling loads for the freezing tunnel (the full output of the motors needs to be cooled)
6) efficiency or the COP plays a role in the energy consumption of freezing tunnels. As explained earlier, the efficiency is mainly determined by the condensation and evaporator temperature.

| | |
|---|---|
| 1 | Type of vegetables |
| 2 | Temperature of the vegetables at the entrance to the freezing tunnel |
| 3 | Mass flow rate of the vegetables |
| 4 | Layer thickness – sojourn time |
| 5 | Air speed – fan output |
| 6 | COP (coefficient of performance) of freezing machinery |

**Table 3.25: Parameters that determine the energy consumption of freezing tunnels in vegetable processing**

All the above-mentioned parameters have an influence on energy consumption. Energy consumption per unit of weight of frozen product depends very heavily on the parameters set for evaporator temperature, fan rating and product flow rate, and the condensation pressures and the type of product being processed. That is the reason for the broad range in which the specific energy consumption situated.
[32, Bael, 2001]

Noise
Noise issues may occur from the operation of the fans.

### 3.5.45 Freeze drying, lyophilization (G.3)

Water
The condensed water is drained. This water may contain dried product. The concentration depends on the original water content of the material and on the type of material that is being dried. The waste water will contain dissolved organic material (BOD) and solid matter.

Energy
For freeze drying - mainly electrical energy is used.

### 3.5.46 Packing, filling (H.1)

Water
Releases occur due to product spills. Cleaning of equipment also produces waste water. The waste water will contain dissolved organic material (BOD) and solid matter.

Air emissions
No issues identified.

Solid output
Solid waste includes packing cast-offs, from machine faults/inefficiencies during filling, and capping process waste, especially from the machine start-ups/shut-downs.
Processes such as glass bottle blowing are completed off-site by suppliers but waste can result from breakages in-situ.
Bottle blowing of PET may be carried out on-site using either PET pellets or supplied pre-forms. This produces waste from off-cuts.
Aluminium/steel can cylinders and aluminium can ends are supplied pre-pressed by the supplier: production occurs off-site. Laminated cartons and pouches are pressed on-site. This results in waste from off-cuts. There will also be minor amounts of solid waste from inks and from the cleaning of printing equipment.

Energy
Energy consumed by filling/capping/packing equipment and other associated activities.

Noise
No issues identified.

### 3.5.47 Gas flushing (H.2)

Air emissions
Gas mixtures used in the above processes are all supplied to the packing plant either in premixed form or as individual gases that are mixed in situ.

### 3.5.48 Cleaning and sanitisation (U.1)

Water
Water of appropriate quality (see Section 4.4.2) is required for cleaning and sanitisation. In many factories, this is the main usage of water. The amount depends on the type and size of equipment to be cleaned. The cleaning and sanitisation produces waste water, which typically contains:

- soluble organic material (BOD/COD) and suspended solids from products remnants and removed deposited soil
- residues of cleaning agents. In principle the cleaning and sanitising agents that are used are discharged via the waste water, either in their original state or as reaction products with the soil which was removed during cleaning. Often acids and alkalis are used in cleaning and are discharged in the waste water.

Air emissions
No issues identified.

Solid output
Produce residues may be recovered during cleaning. Depending on the circumstances this may be sold as a by-product or disposed of as a solid waste.

Energy
Cleaning is commonly carried out at elevated temperatures, which require the use of heat.

### 3.5.49 Energy generation/consumption (U.2)

Water
Boiler treatment chemicals, silica and other soluble minerals are concentrated within boilers. They are removed by blowing down the boiler at a rate of 1 % to more than 10 % of the steam production rate. The blow down water is discharged and treated either in the municipal or in the on-site effluent treatment facilities. Blow down must take place to maintain the efficient, and ultimately safe, operation of the boiler.

Air emissions
The main products resulting from the combustion process are carbon dioxide ($CO_2$) and water vapour ($H_2O$).
$CO_2$ emissions from coal firing are almost twice those from natural gas.
Depending on fuel type, combustion process and combustion plant design, contaminants will be generated and emitted. These are sulphur dioxides ($SO_2$), carbon monoxide (CO), Nitrogen oxides ($NO_x$) and particulates.
Emissions of sulphur dioxide are a result of the fuel sulphur content. Gas has only trace amounts of sulphur. Gas oil has up to 0.1 % by weight of sulphur. Coal has between 0.5 % and 2.5 % by weight of sulphur. Fuel oil may have up to 3.5 % by weight of sulphur.
Emissions of nitrogen oxides ($NO_x$) depend not only on the fuel but also on the inherent design of the combustor unit and the flame temperature. Gas, generally, does not contain any meaningful amounts of nitrogen compounds but will produce $NO_x$ from the oxidation of the nitrogen in the combustion air. Therefore, $NO_x$ from gas combustion is the lowest of any fossil fuel. $NO_x$ emissions may be reduced by steam injection into the burning chamber of the gas turbine or by using low $NO_x$ burners.
When the product is heated by direct contact with combustion gases then volatile organic compounds (VOC) and odours will be released with the process air.
Sensible heat release at the chimney depends on fuel type and plant design.
Consumption of purchased electricity does not cause emissions at food installations as emissions take place at the local power station. They are therefore controlled under the IPPC Directive at that stage.

Solid output
Ashes from solid fuel fired boilers, scale and inert soot deposits, removed during the periodic boiler maintenance and cleaning, are produced. They can be used for land filling or hauled to authorised dumping sites.

Noise
Normal boiler operations do not give rise to noise outside the installation. During process interruptions, and during periods of testing and commissioning, there may be short periods when the boiler safety relief valve operates. This effect is likely to be local to the installation but could be a source of nuisance during that period. Large relief valves can be provided with silencers.

### 3.5.50 Water treatment (in coming process water) (U.3)

Water
Effluents from regeneration and retentates from other processes are discharged to water.
Minimisation of water consumption by process optimisation and water recycling may be applied where feasible.

Solid output
Mineral sludges and spent resins from water treatment processes will need disposal to landfill.

Energy
No issues identified.

### 3.5.51 Vacuum generation (U.4)

Water
**Vacuum Pumps**

Water is used in vacuum pumps for cooling and for sealing. To reduce water consumption the water is normally recirculated and closed loop systems utilised.

**Steam Jet Ejectors**

In spray condensers, water is used to condense the steam along with any volatiles carried over. For large installations, the volume of water used to condense the steam can be significant (i.e. sugar or edible oil refining). The volatile material carried over is condensed in the water thereby increasing the level of dissolved organic material (BOD). To reduce water consumption, water can be recirculated over cooling towers. In this case a bleed from the system is required for the condensed steam. This can lead to a concentration of the organic material (BOD) condensed in the water.
With indirect condensers (heat exchanges) the volume of condensate is equivalent to the condensed steam and will contain any organic volatiles carried over. With chilling or freezing systems, the volume of condensate is reduced further.

Air emissions
**Vacuum Pumps**

Depending on the material being processed, air evacuated by vacuum pumps may contain volatile material, which if not properly controlled may result in odour problems.

**Steam Jet Ejectors**

Non-condensable material may be discharged into the air. Depending on the material being processed this discharge may result in odour problems.
If condenser water is recirculated over cooling towers, the drift/mist from the towers may result in odour problems.

Energy
The energy usage will depend on the type, absolute pressure to be achieved and the size of the system. For large operations it can be reasonably high.

Noise
Issues may occur due to the operation of the fans associated with cooling towers.

### 3.5.52 Refrigeration (U.5)

Water
Water usage can be an issue when water is used as the cooling medium for the condenser in a once-through system. When the cooling water is recirculated over a cooling tower water usage is limited. Accidental release of liquid ammonia needs to be prevented.

Air emissions
Refrigeration equipment (mainly containing $NH_3$ or (H)CFCs) does not cause relevant emissions of refrigerants since the systems are closed. Accidental release of ammonia into the atmosphere needs to be prevented.

Energy
Refrigeration equipment needs electricity input.

Noise
Noise produced by the compressors of refrigeration equipment needs attention

## 3.6 Summary of emission sources to air, water and solid residues of unit operations

In this section, sources of emissions to air, water and solid residues are identified for each processing technique. It should be borne in mind that the identified list of sources is not all encompassing, nor will every plant falling within an individual sector have every one of the emissions, which are associated with the sector as a whole.

Emissions are considered under the following headings: fugitive and unscheduled emissions, and specific process emissions. Some of the latter are considered to have little potential environmental significance and these are designated as minor (m). (However, obviously there could be specific plants where this designation of minor may not be correct. Such emissions must then be examined on a one-off basis).

### 3.6.1 Process emissions

The environmental impacts (process emissions) for each processing technique identified in Section 2.1 “Overview of processing techniques and unit operations” are summarised in Table 3.26. The symbols alongside each operation describe the characteristic of the emission. The interpretation of the symbols is given in Table 3.27, Table 3.28 and Table 3.29.

| | | **Environmental aspects** | | |
|---|---|---|---|---|
| | **Unit operation** | **Air** | **Water** | **Solid** |
| | **A. Raw material preparation** | | | |
| A1 | Mats handling, unpacking, storage | | | W1 |
| | Tank vents | S1, S3 | N | N |
| | Silos | S2 | N | N |
| | Material handling/transport | S1, S2, S3 | E1, E2, E3, E4, E5 | W1 |
| A.2 | Sorting, screening, grading, dehulling, trimming, destemming | S1, S2 | E1, E2 | W1,W3 |
| A.3 | Peeling | N | E1,E2 | W1 |
| A.4 | Washing | N | E1, E2 | W1 |
| | **B. Size reduction, mixing, forming** | | | |
| B.1 | Cutting, slicing, chopping, mincing, pulping, pressing | N | E1, E2, E4 | W1, W2 |
| B.2 | Mixing, blending, conching, homogenisation | S1, S2, S3 | E1, E2, E4, E5 | W1 |
| B.3 | Grinding, milling, crushing | S2, S3 | E1, E2, E4 | W1, W3 |
| B.4 | Forming, moulding, extruding | N | E1,E2,E5 | W1 |
| | **C. Separation Techniques** | | | |
| C.1 | Extraction | S1, S3 | E1, E2 | W1, W4 |
| C.2 | Deionisation | N | E1,E3,E5 | W1 |
| C.3 | Fining | N | E1, E2 | W1, W3 |
| C.4 | Centrifugation/Sedimentation | N | E1, E2 | W1, W3 |
| C.5 | Filtration | M | E1,E2,E4 | W1, W3 |
| C.6 | Membrane separation | N | E1,E2 | N |
| C.7 | Crystallisation | N | E1 | N |
| C.8 | Neutralisation (removal of fatty acids) | N | E1, E2, E4 | N |
| C.9 | Bleaching | N | N | W1,W3 |
| C.10 | Deodorisation by stream stripping | S1, S3 | E1, E2, E4 | W2 |
| C.11 | Decolourisation | N | E1,E2 | W1 |
| C.12 | Distillation | S1,S3,S4 | E1,E2 | W1 |
| | **D. Product Processing Technology** | | | |
| D.1 | Soaking | N | E1, E2 | W1 |
| D.2 | Dissolving | N | E1, E2, E6 | N |
| D.3 | Solubilisation (alkalising) | S1,S2,S3 | E1,E2 | N |
| D.4 | Fermentation | S1,S4 | E1,E2 | W1 |
| D.5 | Coagulation | N | E1, E2 | N |
| D.6 | Germination | S3 | N | N |
| D.7 | Brining, curing | N | E1, E2, E6 | W1 |
| D.8 | Smoking | S1, S3 | E1 | N |
| D.9 | Hardening | S1 | E1, E2, E4 | W5 |
| D.10 | Sulphitation | S6 | N | N |
| D.11 | Carbonatation | S1,S4,S5,S6,S7 | N | W3 |
| D.12 | Carbonation | S4 | N | N |
| D.13 | Coating, spraying, enrobing, agglomerisation, encapsulation | S1 | E1, E2, E4 | W1, W2 |
| D.14 | Ageing | S1, S3 | E1,E2 | W1, W6 |
| | **E. Heat Processing** | | | |
| E.1 | Melting | S1 | E1, E2, E4 | W1, W2 |
| E.2 | Blanching | S1 | E1, E2, E6 | W1 |
| E.3 | Cooking, boiling | S1, S3 | E1, E2, E4, E5, E6 | W1 |
| E.4 | Baking | S1, S2, S3, S4 | E1, E2, E4 | W1 |

| | | Environmental aspects | | |
|---|---|---|---|---|
| | **Unit operation** | **Air** | **Water** | **Solid** |
| E.5 | Roasting | S1,S2 | N | W1 |
| E.6 | Frying | S1, S3 | E1, E2, E3, E4 | W1, W2 |
| E.7 | Tempering | N | E1,E2 | N |
| E.8 | Pasteurisation, sterilisation, UHT | N | E1, E2 | W1 |
| | | | | |
| | **F. Concentration by Heat** | | | |
| F.1 | Evaporation (liquid to liquid) | S1,S2 | E1,E2,E5 | N |
| F.2 | Drying (liquid to solid) | S1,S2 | E1,E2 | W1 |
| F.3 | Dehydration (solid to solid) | S1,S2 | E1,E2 | W1 |
| | **G. Processing by Removal of Heat** | | | |
| G.1 | Cooling, chilling, cold stabilisation | W1 | M | N |
| G.2 | Freezing | S4, S7 | N | N |
| | Cryoextraction | N | E1 | W1, W3 |
| | Concentration by cold | N | E1 | N |
| G.3 | Freeze drying, lyophilization | N | E2 | N |
| | | | | |
| | Post Processing Operations | | | |
| H.1 | Packing, filling, storage under gas | S2 | E1, E2 | W1, W6 |
| H.2 | Gas flushing | S4 | N | N |
| | **U. Utility Processes** | | | |
| U.1 | Cleaning/sanitisation | N | E1, E2, E3, E4, E5 | N |
| U.2 | Energy generation/consumption | S2, S4, S5,S6 | N | N |
| | Boiler blowdown | N | E5 | N |
| U.3 | Water treatment (incoming process water) | | | |
| | Demineralisation plant | N | E1, E2, E3, E5 | W1, W3 |
| U.4 | Vacuum generation | S1 | E1 | N |
| U.5 | Refrigeration | S7 | E5 | N |
| U.6 | Compressed air generation | | | |

**Table 3.26: Environmental impacts of processing techniques**
**[1, CIAA, 2002]**

| Code | Type of Emission |
|---|---|
| S1 | Odour |
| S2 | Particulates |
| S3 | Organics* |
| S4 | $CO_2$ |
| S5 | $NO_2$ |
| S6 | $SO_2$ |
| S7 | $NH_3$ |
| M | Minor |
| N | None |
| * Organics covers emissions containing organic material at the actual processing conditions and regardless of the vapour pressure of the individual components present in the emission | |

**Table 3.27: Codes used for emissions to air**
**[1, CIAA, 2002]**

| Code | Type of Emission |
|---|---|
| E1 | Soluble organic material (BOD/COD) |
| E2 | Total suspended solids |
| E3 | Acid /alkali |
| E4 | Oils / fats / greases |
| E5 | Nitrate, Nitrite, ammonia, phosphate |
| E6 | Dissolved solids |
| M | Minor |
| N | None |

**Table 3.28: Code used for emissions to water**
**[1, CIAA, 2002]**

| Code | Type of Emission |
|---|---|
| W1 | Organic (waste product / processing materials) |
| W2 | Oils / fats / greases |
| W3 | Inorganic (e.g. soil, calcium carbonate, bleaching earth etc) |
| W4 | Solvent |
| W5 | Metals e.g. Nickel catalyst |
| W6 | Packaging from process operations (paper, cardboard, drums etc) |
| M | Minor |
| N | None |

**Table 3.29: Codes used for solid outputs**
**[1, CIAA, 2002]**

### 3.6.2 Fugitive and unscheduled emissions

Air

- odour losses during storage, filling and emptying of bulk tanks and silos
- stripping of odorous compounds from waste water treatment plants (WWTP) resulting in releases to air and/or odour problems
- storage tank vents
- fumigation
- vapour losses during storage, filling and emptying of bulk solvent tanks and drums (including hose decoupling)
- bursting discs and relief valve discharges
- leakages from flanges, pumps, seals, valve glands, etc.
- building losses (windows, doors etc.)
- settling ponds
- cooling towers and cooling ponds.

Water

- contaminated storm waters
- storage tank leaks
- pipe work leaks
- spillages
- bund drains
- leakages from flanges, pumps, seals, valve glands etc.

## 3.7 Summary of key environmental issues in the sectors

**[10, Environment Agency (UK), 2000]**

In this section, an overview of the key environmental issues are presented according to the UK document on process descriptions. [10, **Environment Agency (UK)**, 2000] A simplified process scheme is always given which does not necessarily reflects the real production process but is useful for a short overview of the unit operations involved. The key environmental issues are listed, no ranking or weighting is given. For a special process some issues may not be relevant at all.

### 3.7.1 Meat and poultry processing

The simplified process diagram for meat and poultry industry includes all stages of the industry but only stages 6 and 7 are relevant for this BREF. Preceding stages are covered by the Slaughterhouses and Carcases BREF.

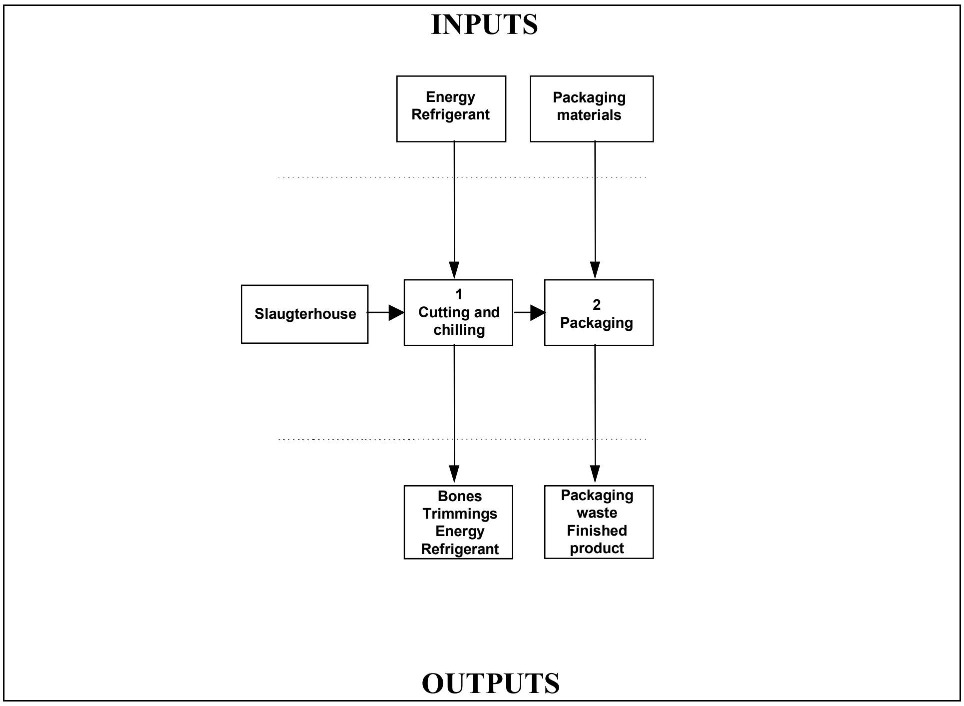


**Figure 3.7: Simplified process diagram for meat and poultry processing**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emissions/by-products |
|---|---|---|
| Air | 1,3,4,5,6<br>6 | Odour<br>Potential for refrigerant leak |
| Water | CLEANING<br>1,2,4,5<br>3 | BOD/COD/SS<br>Wash/soak water<br>Blood |
| Land | 7<br>4<br>5<br>6 | Packaging waste<br>Hair, skin, feathers<br>Numerous by-products, SRM<br>Bones, trimmings |
| BOD = biological oxygen demand<br>COD = chemical oxygen demand<br>SS = suspended solids | | |

**Table 3.30: Summary of key emissions in the processing of meat and poultry**
**[10, Environment Agency (UK), 2000]**

### 3.7.2 Fish processing

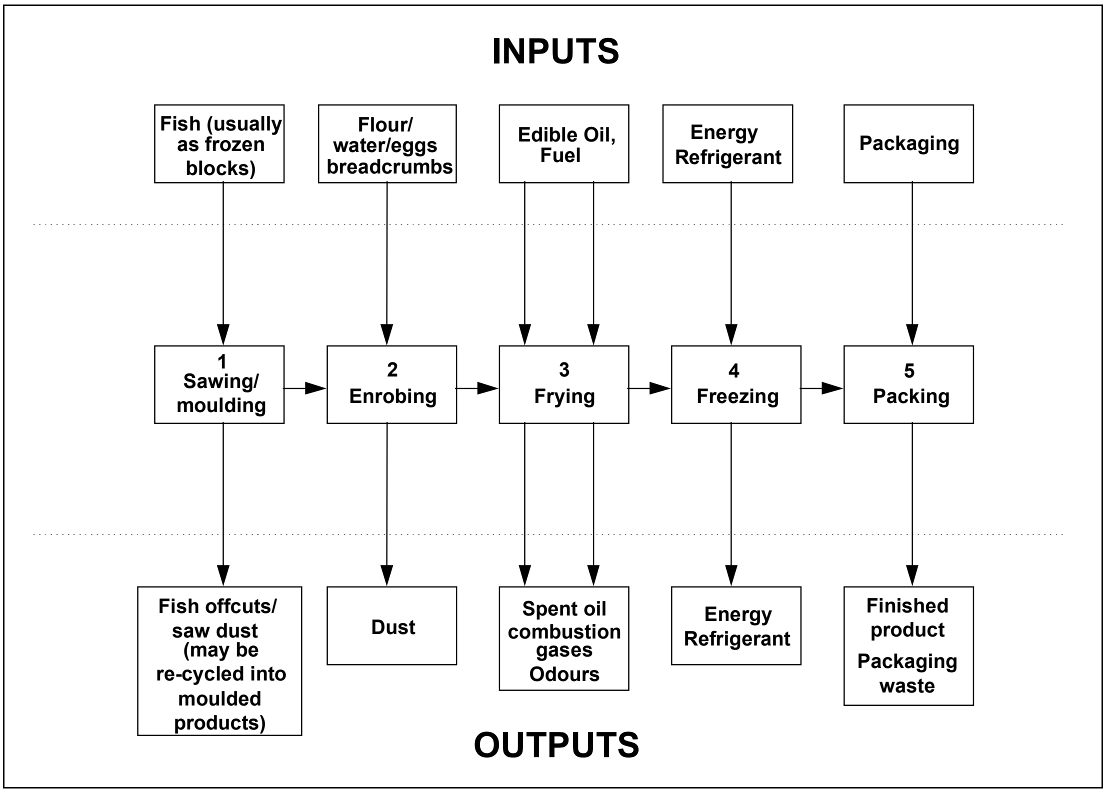


**Figure 3.8: Simplified process diagram for fish processing**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 2<br>3<br>3<br>4 | Dust<br>Odours, Combustion gases<br>Heat energy, potential for<br>refrigerant leak |
| Water | Cleaning | BOD/COD/SS |
| Land | 1<br>3<br>5 | Food waste<br>Spent oil,<br>Packaging waste |

**Table 3.31: Summary of key emissions in frozen processed fish/moulded fish products/fish fingers**
**[10, Environment Agency (UK), 2000]**

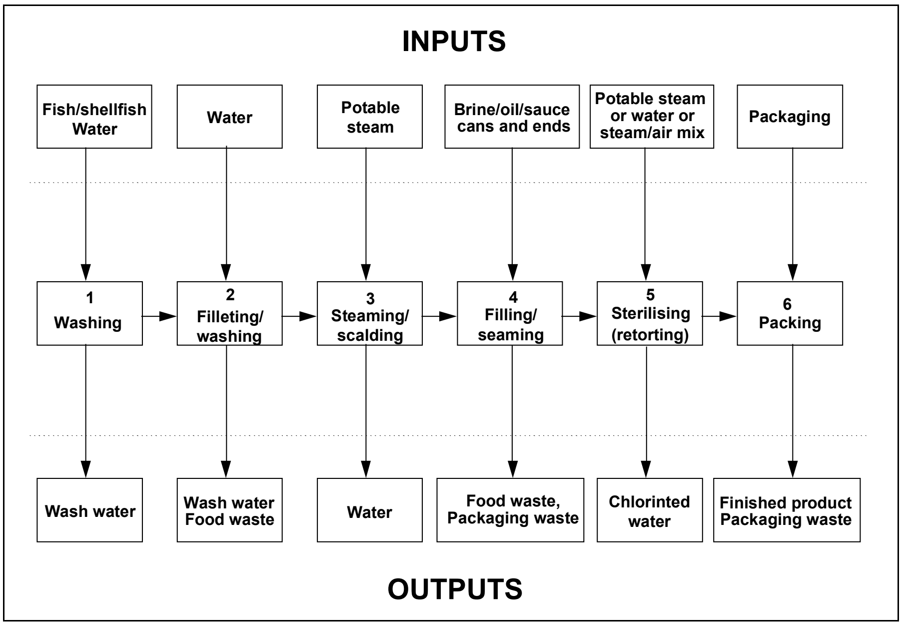


**Figure 3.9: Simplified process diagram for canned fish/ shellfish**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | | |
| Water | 1<br>2<br><br>3<br>4<br>5<br>Cleaning | BOD/COD/SS<br>BOD/COD/SS<br>Inorganic pollutants<br>BOD/COD/SS<br>BOD/COD/SS<br>Inorganic pollutants<br>BOD/COD/SS |
| Land | 2 | Offal/scales/shells |

**Table 3.32: Summary of key emissions for canned fish/shellfish products**
**[10, Environment Agency (UK), 2000]**

### 3.7.3 Potato processing

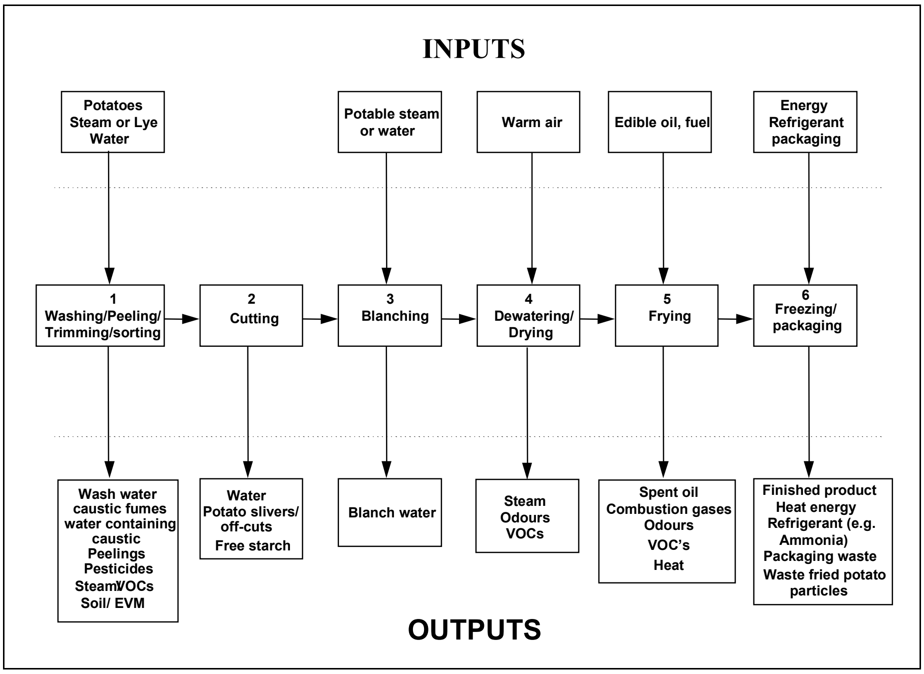


**Figure 3.10: Simplified process diagram for the manufacture of frozen chips**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1 | VOCs/odour |
| | 4 | Heat energy/VOCs/odour |
| | 5 | VOCs/odour/heat energy/ Combustion gases |
| | 6 | Heat energy/ Potential for refrigerant leak (e.g. ammonia) |
| Water | 1 | BOD/COD/SS/pesticides |
| | 2 | BOD/COD/SS/Free starch |
| | 3 | BOD/COD/SS |
| | 5 | Fat/oil |
| Land | 1 | Soil/ EVM |
| | 2 | Sliver/off-cuts (co-product) |
| | 5 | Spent oil (reprocessed) |

**Table 3.33: Summary of key emissions in the manufacture of chips**
**[10, Environment Agency (UK), 2000]**

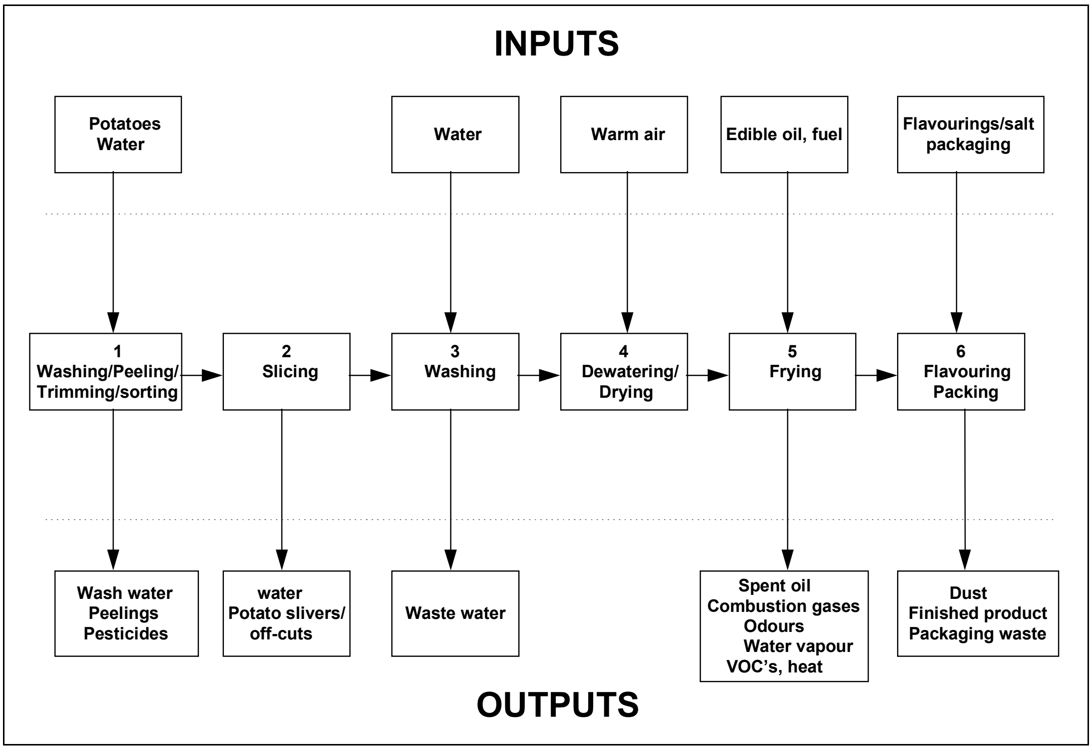


**Figure 3.11: Simplified process diagram for the manufacture of potato crisps**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 5 | VOCs/odour/<br>Combustion gases/heat |
| | 5 | Water vapour |
| | 6 | Dust |
| Water | 1 | BOD/COD/SS |
| | 2 | BOD/COD/SS |
| | 3 | BOD/COD/SS |
| | CLEANING | BOD/COD/SS |
| | 1 | Pesticides |
| Land | 1 | Peelings |
| | 2 | Sliver/off-cuts |
| | 5 | Spent oil |

**Table 3.34: Summary of key emissions in the manufacture of crisps**
**[10, Environment Agency (UK), 2000]**

### 3.7.4 Fruit and vegetable processing

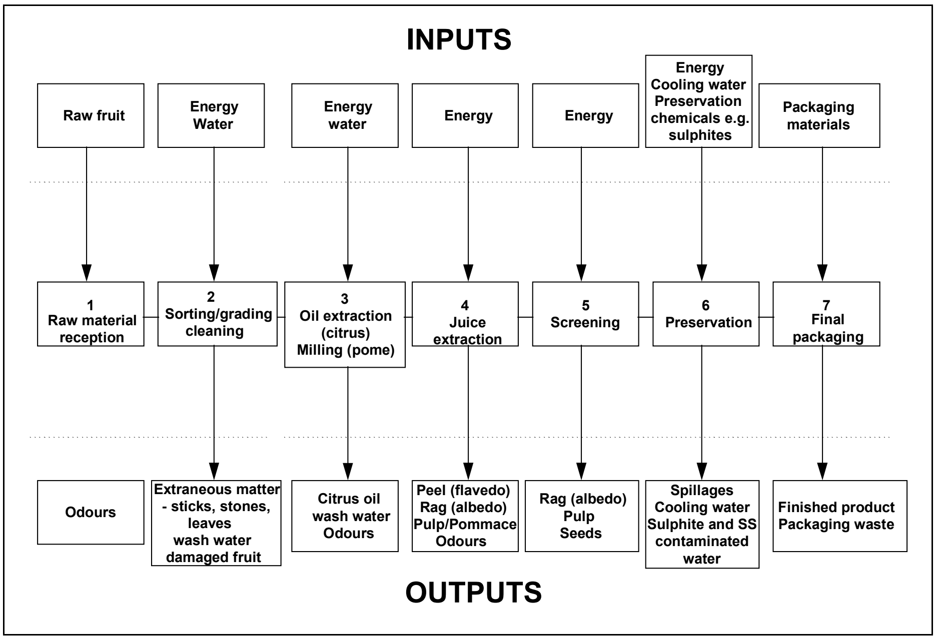


**Figure 3.12: Simplified process diagram for fruit and vegetable juice**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | | |
| Water | 2,3 | Wash water |
| | 6 | Spillages, cooling water |
| | Cleaning | BOD/COD/SS |
| Land | 2 | Extraneous matter, damaged fruit |
| | | Citrus oil |
| | 3 | Peel, rag, pulp, pommace |
| | 4 | Rag, pulp, seeds |
| | 5 | Packaging waste |
| | 7 | |

**Table 3.35: Summary of key emissions in the manufacture of fruit and vegetable juices**
**[10, Environment Agency (UK), 2000]**

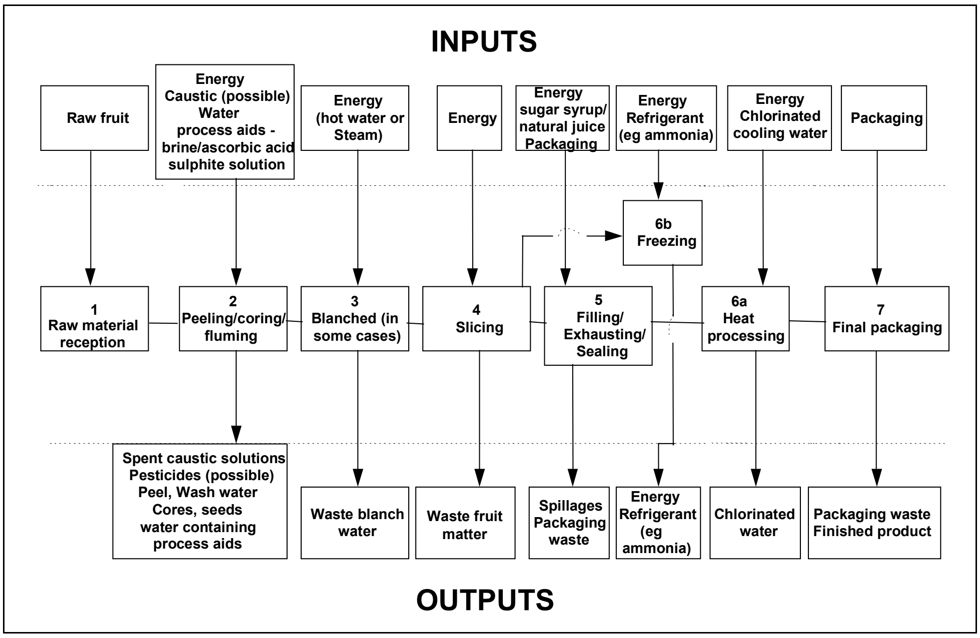


**Figure 3.13: Simplified process diagram for canned and frozen fruits**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 6b | Potential for refrigerant leak |
| | | Water vapour |
| | 6a | |
| Water | 2 | Spent caustic, pesticides, wash water, water containing process aids |
| | | Waste blanch water |
| | 3 | Packaging waste |
| | 5 | Chlorinated water |
| | 6 | |
| Land | 2 | Peel, cores, seeds |
| | 4 | Waste fruit matter |
| | 5,7 | Packaging waste |

**Table 3.36: Summary of key emissions in the manufacture of canned and frozen fruits [10, Environment Agency (UK), 2000]**

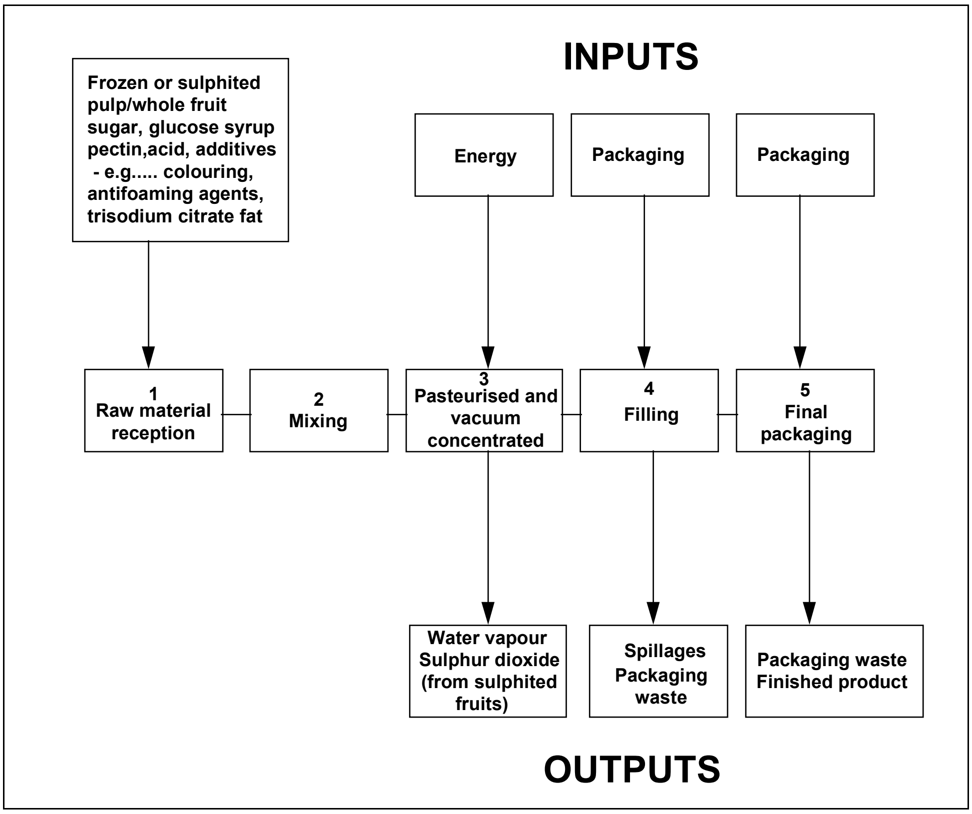


**Figure 3.14: Simplified process diagram for the manufacture of preserves [10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 3 | Water vapour, energy, sulphur dioxide possible |
| Water | 4 | Spillages (e.g. depositing errors) |
| Land | 4,5 | Packaging waste |

**Table 3.37: Summary of key emissions in the manufacture of preserves [10, Environment Agency (UK), 2000]**

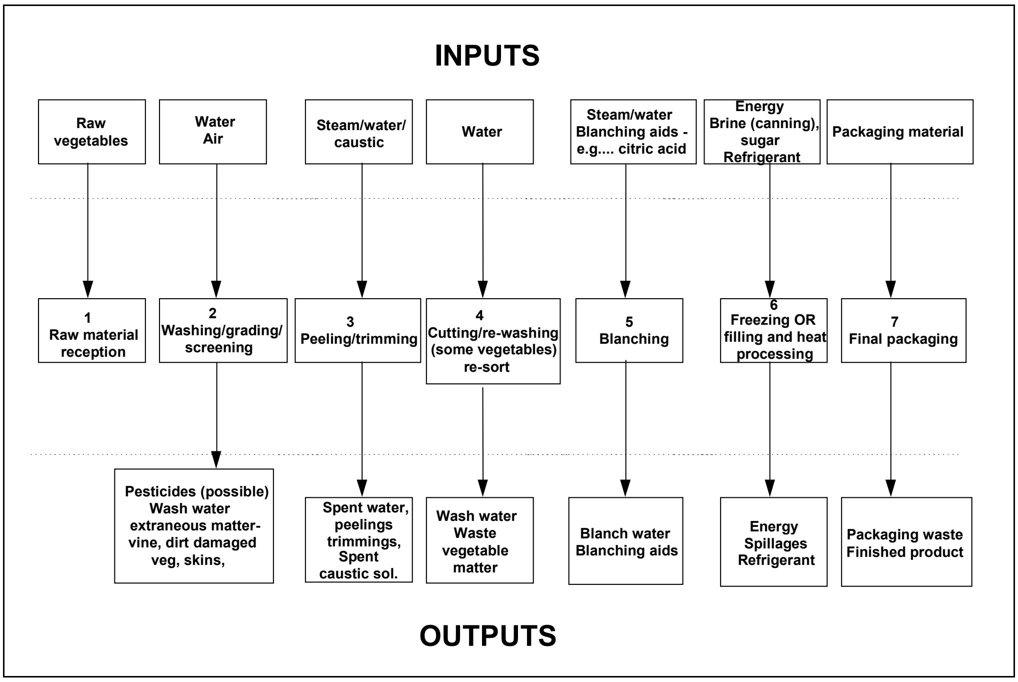


**Figure 3.15: Simplified process diagram for canned and frozen vegetables**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 6 | Energy, possible refrigerant leaks. |
| Water | 2 | Pesticides, wash water |
| | 3 | Spent water, spent caustic solutions |
| | | Waste water |
| | 4 | Blanch water, blanching aids |
| | 5 | Spillages |
| | 6 | |
| Land | 2 | Extraneous matter |
| | 3 | Peelings, trimmings |
| | 4 | Vegetable waste matter |
| | 7 | Packaging waste |

**Table 3.38: Summary of key emissions in the processing of frozen and canned vegetables**
**[10, Environment Agency (UK), 2000]**

<u>Energy consumption in the Flemish frozen vegetable sector</u>

The process which uses the most electricity is the deep-freezing process (80 to 280 kWh$_e$/tonne of vegetables frozen), here cooling to a very low temperature level (-30 °C to –40 °C) is necessary. The other process steps require less electrical energy (maximum 28 kWh$_e$ per tonne of frozen product). Carrots (±8 kWh$_e$/tonne frozen product) and salsifies (± 20 kWh$_e$/tonne frozen product) require a lot of electrical energy for sorting. Washing spinach (± 4 kWh$_e$/tonne frozen product) is electricity-intensive. The mechanical processing of beans (± 6 kWh$_e$/tonne frozen product) and salsifies (± 9 kWh/tonne frozen product) consumes a lot of electricity compared with other vegetables. The electricity consumption of the belt blancher/blast freezer combination (7 - 28 kWh$_e$/tonne frozen product) is significantly higher than that of the belt blancher/water freezer combination (2 - 8 kWh$_e$/tonne frozen product) or the drum blancher with counter-current freezer (1 – 2.6 kWh$_e$/tonne frozen product). Spinach requires most electricity for intermediate processing (packing or making of portions).

Steam is used for peeling and blanching. Steam-peeling uses approximately five times more steam than lye peeling. Belt blanching with water freezing consumes approximately half the energy of belt blanching with blast freezing or drum blanching with counter-current freezer.

For storage, electricity consumption is between 20 and 65 $kWh_e$ / $m^3$ of storage space/year.
The frozen vegetable sector is already a large consumer of electricity and natural gas. Almost every process step requires electricity. For steam production, natural gas boilers can be used. Total energy saving can be an attractive option, in view of the large demand for electricity and heat in deep-freezing firms.

The major energy savings are in the cooling plant and the freezing tunnel: savings are possible by correct adjustment of the working parameters (evaporator temperature, belt speed and blower power in the freezing tunnel), depending on the product being processed and the throughput. In addition, it is important to keep the condensation pressures as low as possible by providing sufficient condenser units. The consumption of electrical systems in the freezing tunnel is kept as low as possible by opting for frequency converters on the blowers and by installing low-energy lighting. Furthermore, it is important to reduce the transmission and ventilation losses in the freezing tunnel by using adequate thermal insulation and screening of the freezing tunnel from its surroundings. The vegetables are best transported as cold and dry as possible in the tunnel, in order to reduce the freezing load. With short production shops, the blowers can be reduced in power, and the automatic defrosting can be switched off.

For pre-processing and blanching, energy can be exchanged. Hot residual water from the blanching system can be used by the booster pumps or as washing water. With a belt blancher / water freezer combination, the heated cooling water can be used to heat the fresh vegetables before blanching.

In storage, energy savings are possible by restricting the transmission losses and the ventilation losses through applying adequate thermal insulation, and limiting air movements when doors and hatches are opened. If the number and duration of the opening of doors is limited, refrigerating at night could be an option. The defrosting cycle of the evaporators is best optimised. If the time between two defrosting cycles is too long, then the efficiency of the evaporator falls and the pressure drop via the evaporator rises. If the time is too short, then considerable heat is generated unnecessarily in the storage area. [32, Bael, 2001]

### 3.7.5 Vegetable oil production

| | **Process source** (See Figure 3.16 and Figure 3.14) | **Type of emission/by-product** |
|---|---|---|
| Air | 1,2,3<br>3<br>4<br>7<br>13 | Dust<br>Odours<br>Odours, solvent<br>Odours, solvent, acid<br>Hydrogen, odours |
| Water | CLEANING<br><br>9,10<br>12 | BOD, inorganics, oils, fats, grease<br>Spent acids/alkalis<br>“acid oil” containing free fatty acids (FFAs), odours, volatiles, and possibly pesticides (bound with the FFAs) |
| Land | 11 | Spent bleaching aids (Fullers earth) containing gums, metals, pigments |

**Table 3.39: Summary of key emissions in the manufacture of vegetable fats**
**[10, Environment Agency (UK), 2000]**

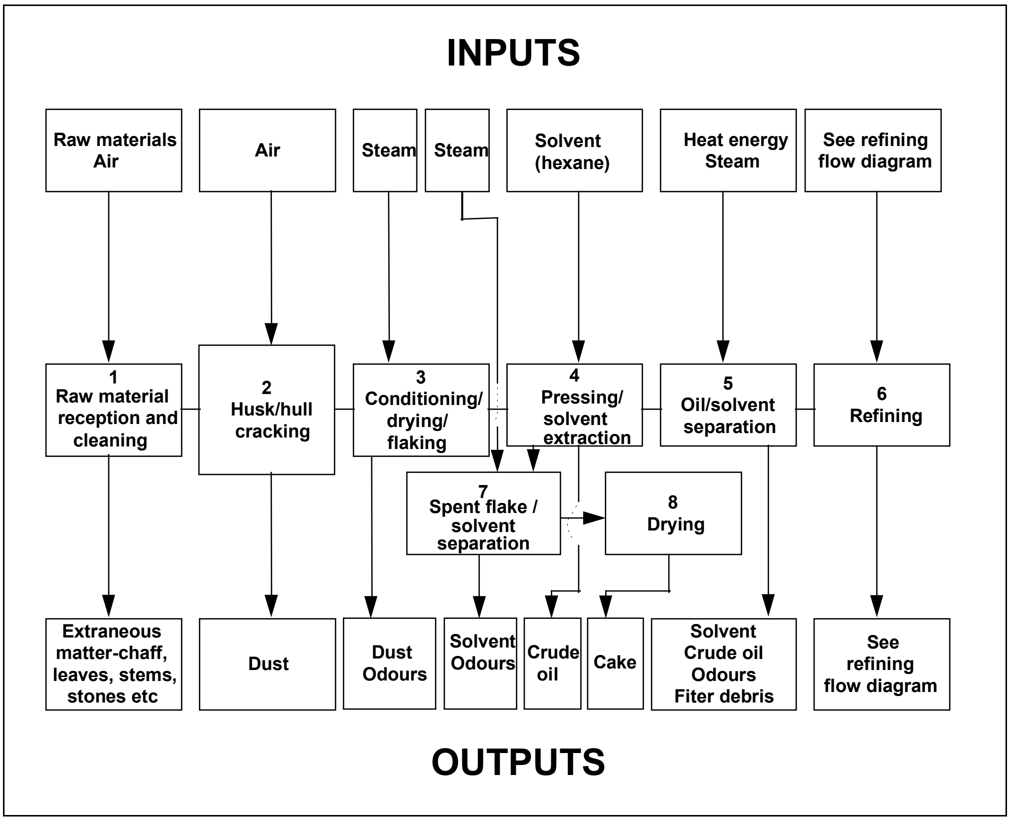


Figure 3.16: Simplified process diagram for seed oil extraction
[10, Environment Agency (UK), 2000]

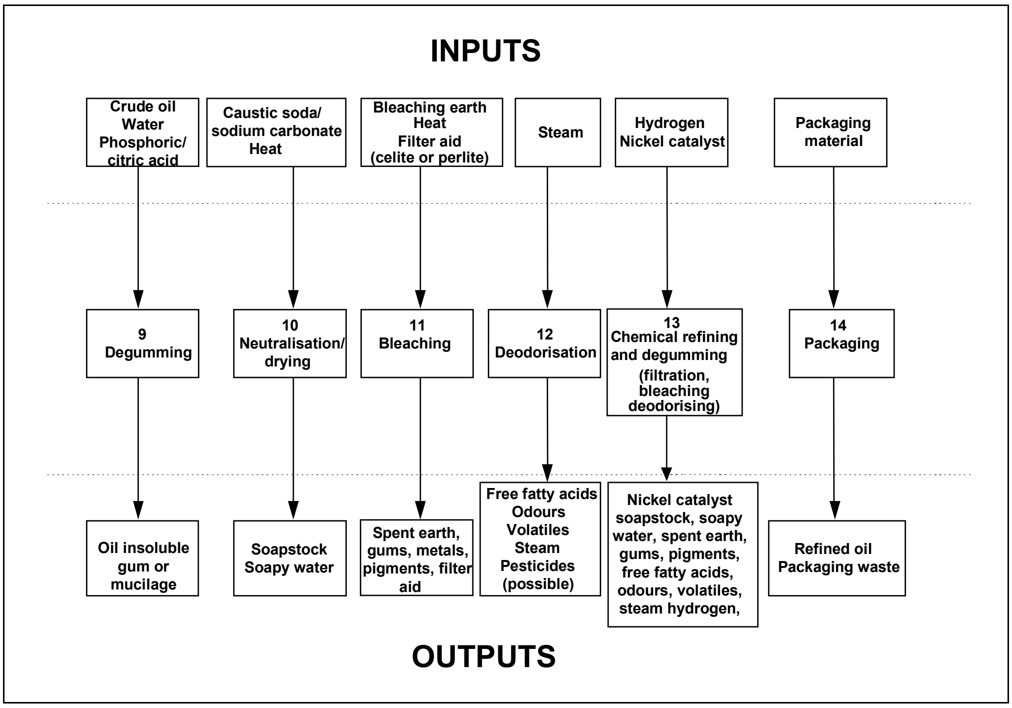


Figure 3.17: Simplified process diagram for seed oil refining
[10, Environment Agency (UK), 2000]

### 3.7.6 Dairy

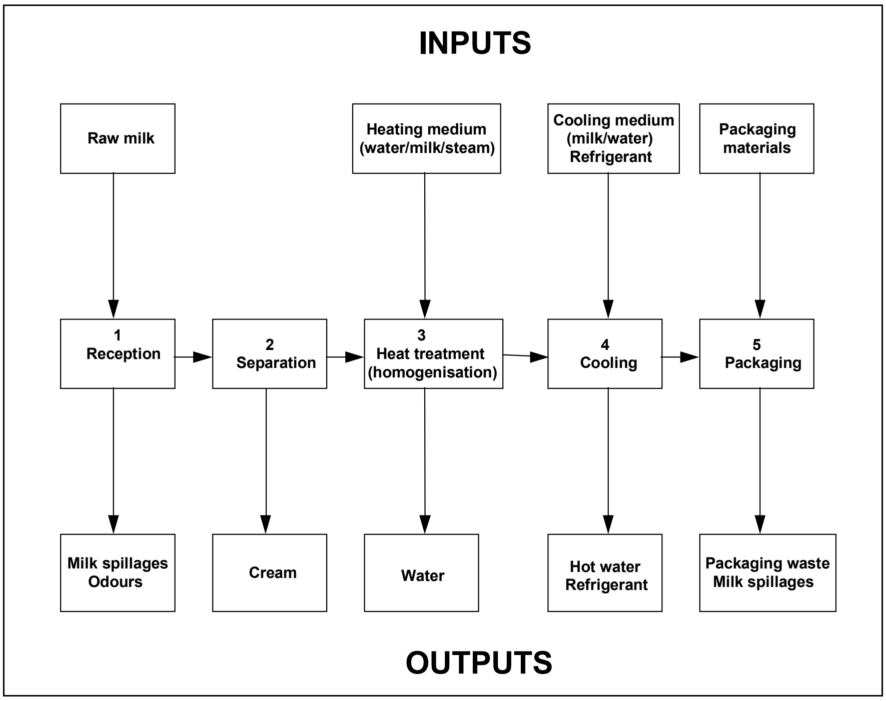


**Figure 3.18: Simplified process diagram for milk and cream**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1 | Odours |
| Water | 1,5<br>4<br>CLEANING | Spillages<br>Hot water<br>BOD/COD/SS |
| Land | 1,2,3<br>5 | Organic waste<br>Packaging waste |

**Table 3.40: Summary of key emissions in the manufacture of milk and cream**
**[10, Environment Agency (UK), 2000]**

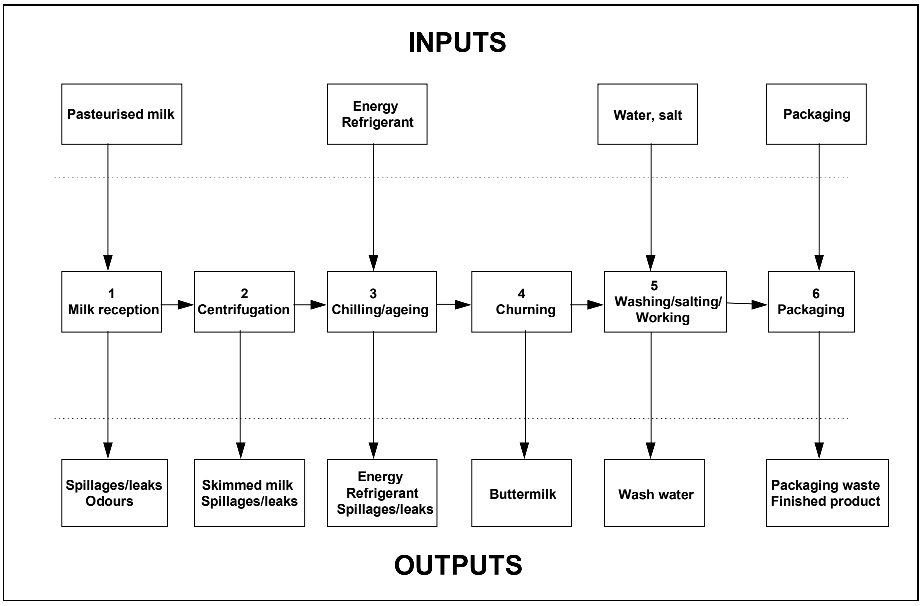


**Figure 3.19: Simplified process diagram for butter manufacture**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1<br>3 | Odours<br>Potential for refrigerant leak |
| Water | 1,2,3<br>4<br>5<br>CLEANING | Spillages, leaks<br>Butter milk<br>Wash water<br>BOD/COD/SS |
| Land | 6 | Packaging waste |

**Table 3.41: Summary of key emissions in the manufacture of butter**
**[10, Environment Agency (UK), 2000]**

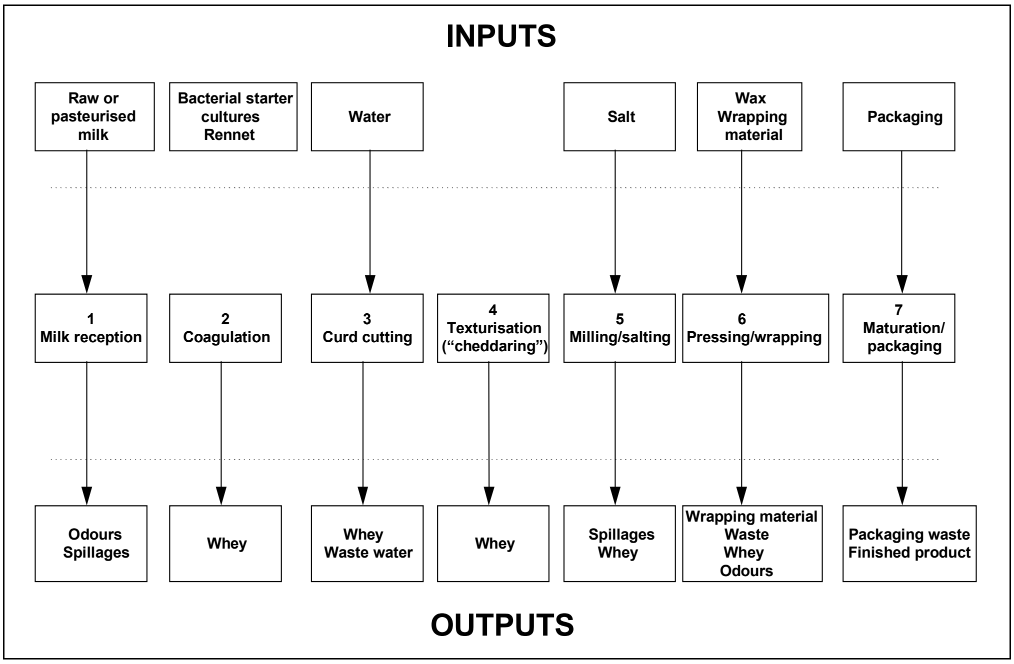


**Figure 3.20: Simplified process diagram for the manufacture of cheese**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1 | Odours |
| Water | 2,3,4,5,6<br>3<br>CLEANING | Whey<br>Waste water<br>BOD/COD/SS |
| Land | 6 | Packaging waste |

**Table 3.42: Summary of key emissions in the manufacture of cheese**
**[10, Environment Agency (UK), 2000]**

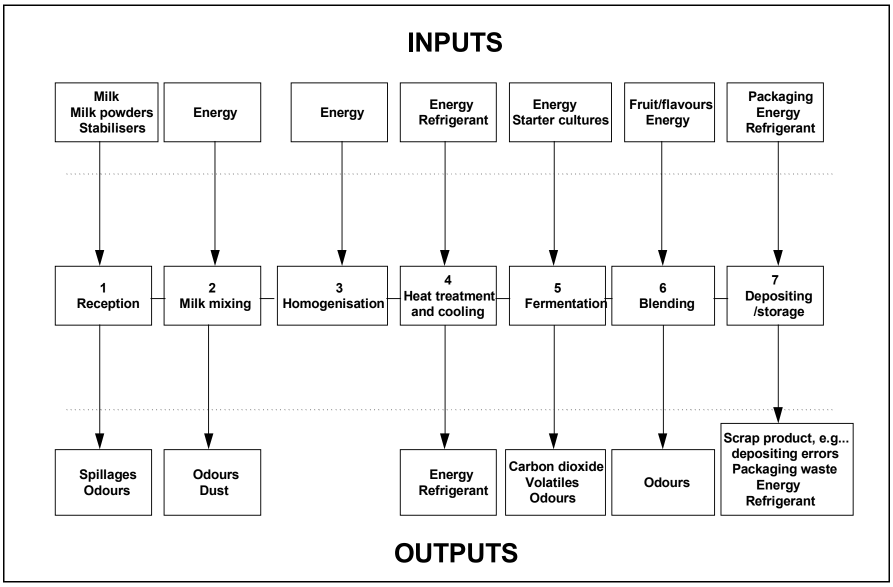


Figure 3.21: Simplified process diagram for the manufacture of yoghurt
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1 | Odours |
| | 2 | Odours, dust |
| | 4,7 | Potential for refrigerant leak |
| | 5 | $CO_2$, volatiles, odours |
| | 6 | Odours |
| Water | 1 | Spillages |
| | Cleaning | BOD/COD/SS |
| | 7 | Scrap product |
| Land | 2 | Dust |
| | 7 | Packaging waste |

Table 3.43: Summary of key emissions in the manufacture of yoghurt
[10, Environment Agency (UK), 2000]

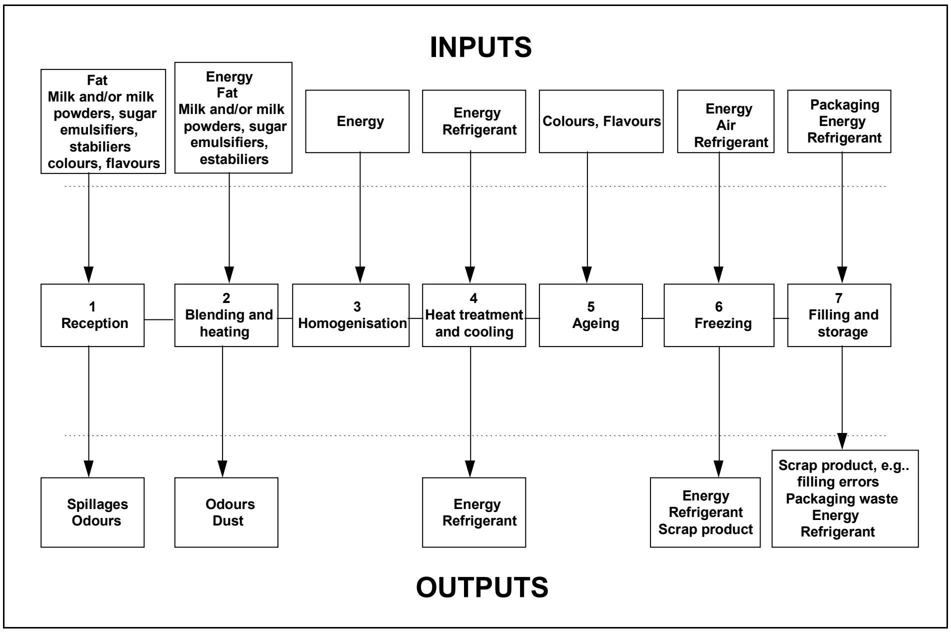


Figure 3.22: Simplified process diagram for the manufacture of ice cream
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1<br>2<br>4,6,7 | Odours<br>Odours, dust<br>Potential for refrigerant leak |
| Water | Cleaning<br>1<br>6,7 | BOD/COD/SS<br>Spillages<br>Scrap product |
| Land | 2<br>7 | Dust<br>Packaging waste |

**Table 3.44: Summary of key emissions in the manufacture of ice-cream**
**[10, Environment Agency (UK), 2000]**

### 3.7.7 Grain milling

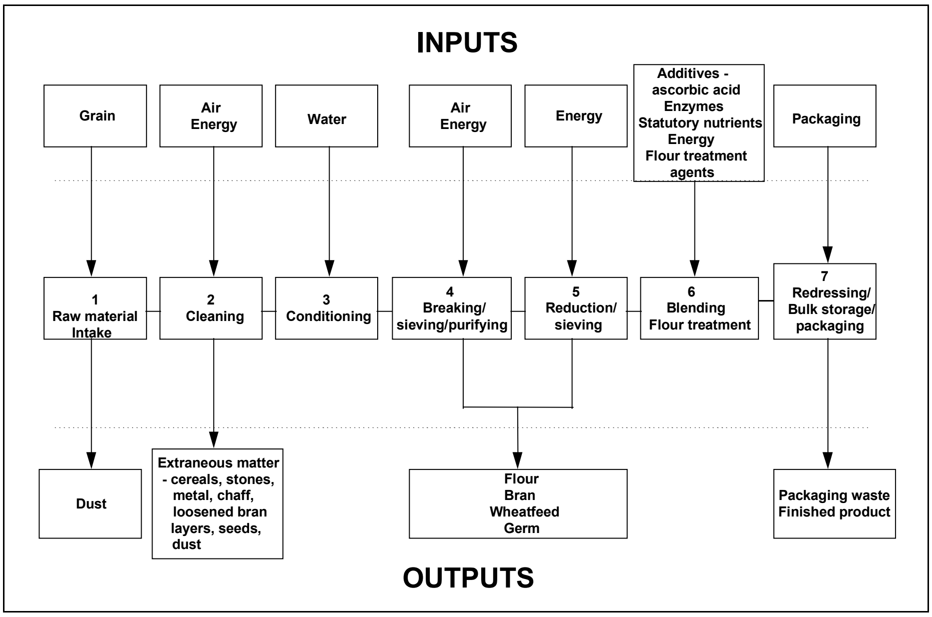


**Figure 3.23: Simplified process diagram for flour milling**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2,4,5 | Dust |
| Land | 1,2,4,5<br>2<br>4<br>5<br>7 | Dust<br>Cereals, stones, metal, chaff, loosened bran layers, seeds<br>Bran, wheatfeed, germ - all by product<br>Wheatfeed - by product<br>Packaging waste |

**Table 3.45: Summary of key emissions in flour milling**
**[10, Environment Agency (UK), 2000]**

### 3.7.8 Starch manufacture

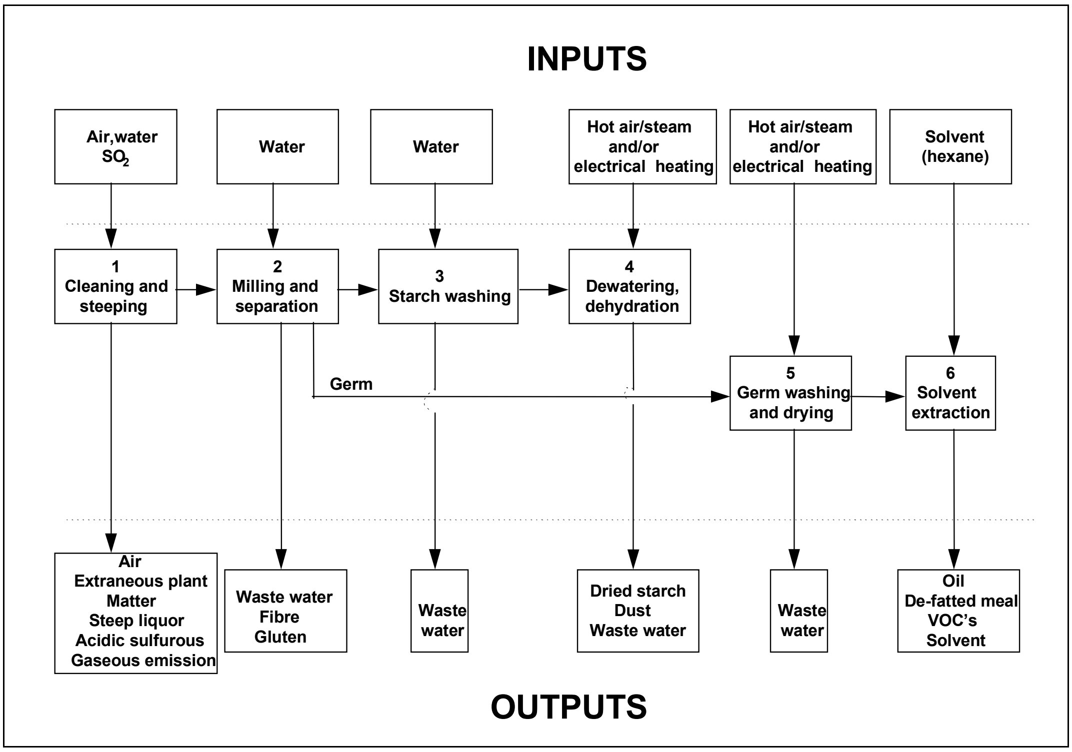


**Figure 3.24: Simplified process diagram for corn starch and corn oil manufacture**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 4<br>6<br>1 | Dust<br>VOCs<br>Acidic sulphurous gaseous emission |
| Water | 2,3,5<br>Cleaning<br>1 | Waste water<br>BOD/COD/SS<br>Steep liquor |
| Land | 1<br>2<br>6 | Plant matter<br>Fibre, gluten (co-product)<br>De-fatted meal (co-product) |

**Table 3.46: Summary of key emissions from the manufacture of cornstarch and corn oil**
**[10, Environment Agency (UK), 2000]**

### 3.7.9 Animal feeds

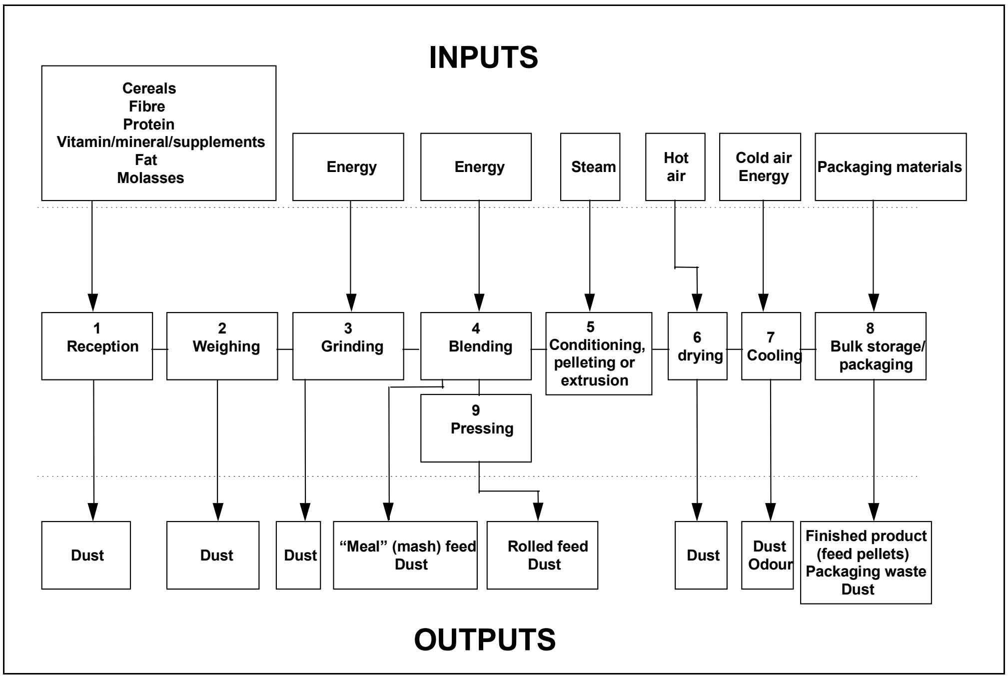


Figure 3.25: Simplified process diagram for animal feed and dry petfood
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2,3,4,6,7,8,9<br>8 | Dust<br>Odour |
| Land | 7 | Packaging waste |

Table 3.47: Summary of key emissions from animal feeds and dry pet food manufacture
[10, Environment Agency (UK), 2000]

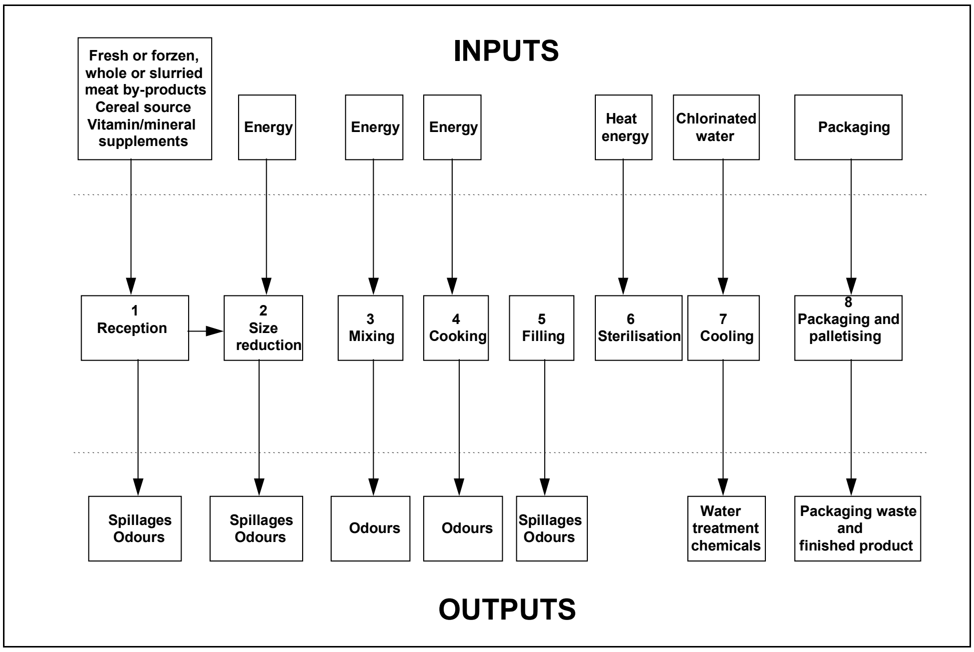


Figure 3.26: Simplified process diagram for the manufacture of moist pet food
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2,3,4,5 | Odours |
| Water | 1,2,5<br>7 | Spillages<br>Water treatment chemicals |
| Land | 3,8 | Packaging waste |

**Table 3.48: Summary of key emissions in the manufacture of moist pet foods [10, Environment Agency (UK), 2000]**

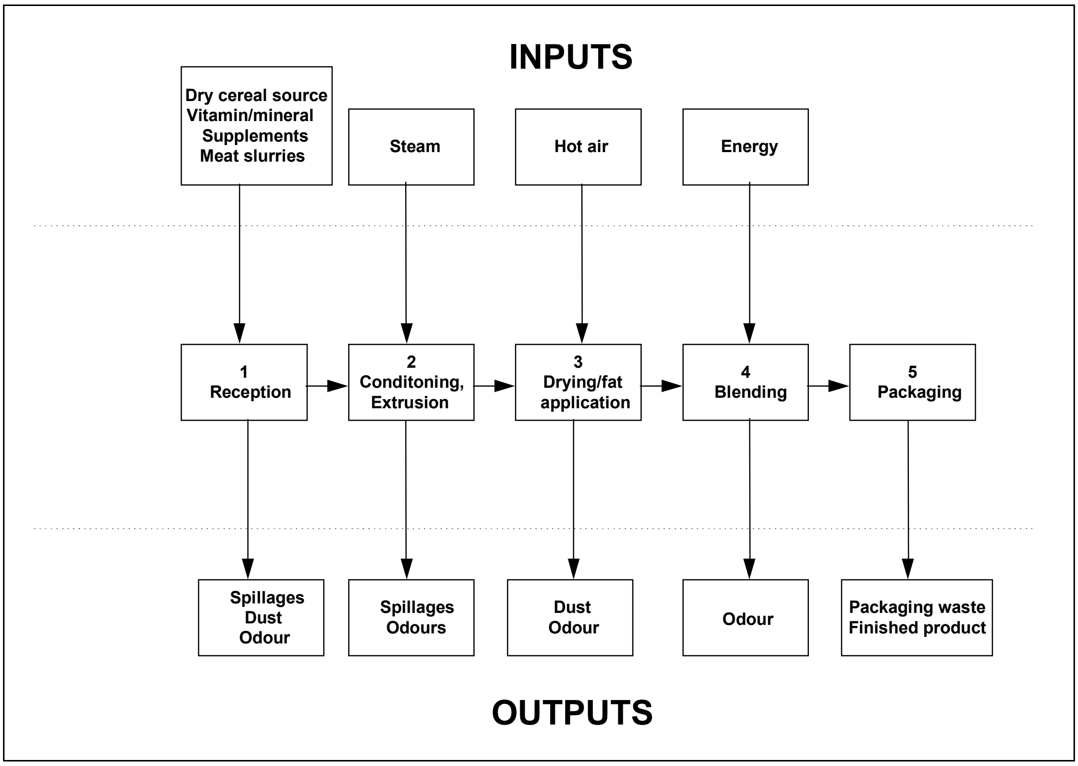


**Figure 3.27: Simplified process diagram for semi-moist pet foods [10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2,3,4 | Dust |
| Water | 1,2,3 | Spillages |
| Land | 2,5 | Packaging waste |

**Table 3.49: Summary of key emissions in the manufacture of semi-moist pet foods [10, Environment Agency (UK), 2000]**

### 3.7.10 Bread

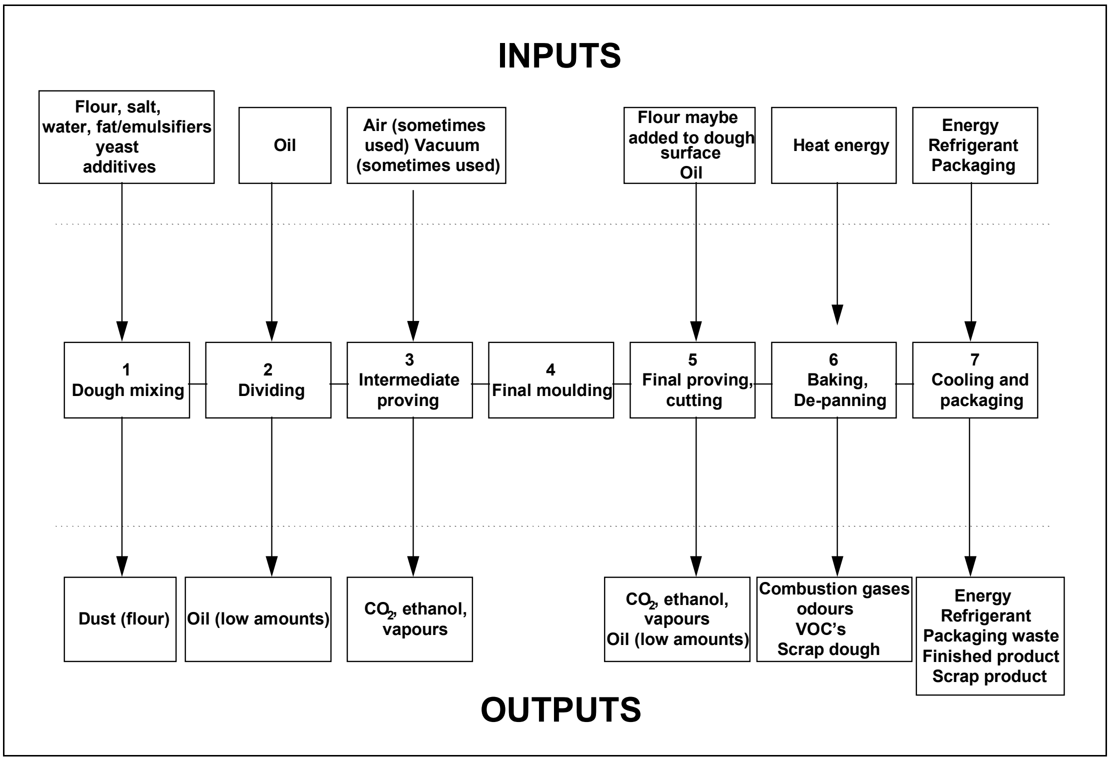


**Figure 3.28: Simplified process diagram for bread manufacture**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1 | Dust |
| | 2,5 | Oil droplets |
| | 3,5 | $CO_2$, ethanol, volatiles |
| | | VOCs, odours |
| | 6 | Combustion gases |
| | 7 | Potential for refrigerant leak |
| Water | CLEANING | BOD/COD/SS |
| Land | 7 | Packaging waste |
| | 1 | Dust |
| | 6,7 | Scrap product |

**Table 3.50: Summary of key emissions in the manufacture of bread**
**[10, Environment Agency (UK), 2000]**

### 3.7.11 Biscuits, cakes, chocolate, cocoa and boiled sweets

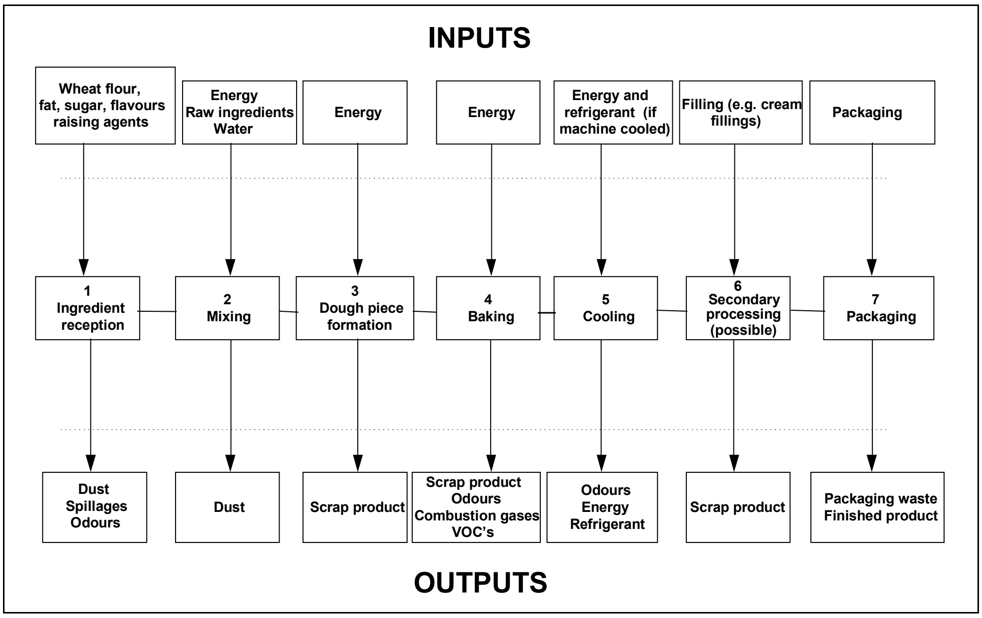


Figure 3.29: Simplified process diagram for the manufacture of biscuits
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2<br>1<br>1,4,5<br>4<br>5 | Dust,<br>Spillages<br>Odours<br>Combustion gases, VOCs<br>Potential for refrigerant leak (if mechanically cooled) |
| Water | Cleaning | BOD/COD/SS |
| Land | 3,4,6<br>1,2<br>7 | Scrap product<br>Dust<br>Packaging waste |

Table 3.51: Summary of key emissions in the manufacture of biscuits
[10, Environment Agency (UK), 2000]

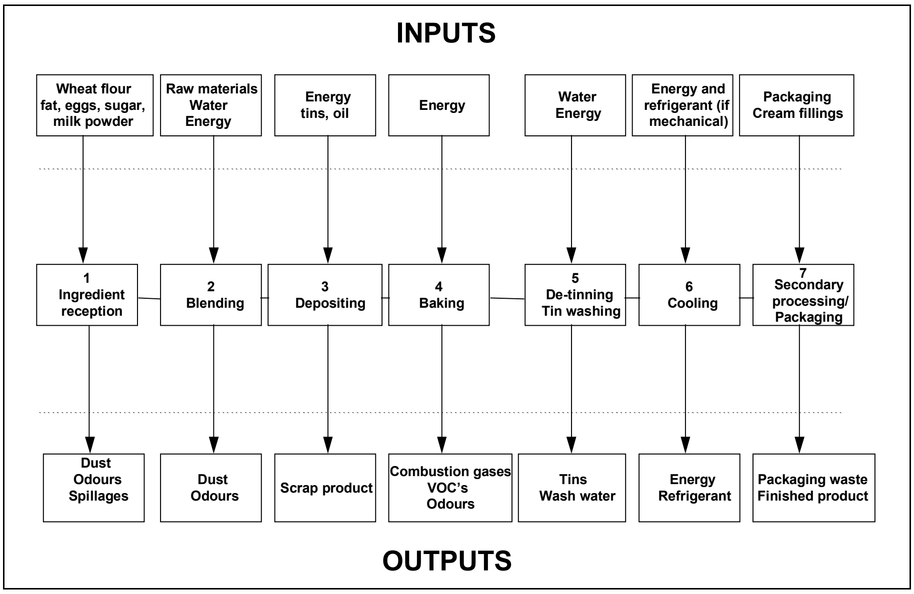


Figure 3.30: Simplified process diagram for cake manufacture
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2<br>1,2,4<br>4<br>6 | Dust<br>Odours<br>Combustion gases, VOCs<br>Potential for refrigerant leak |

Table 3.52: Summary of key emissions in the manufacture of cakes
[10, Environment Agency (UK), 2000]

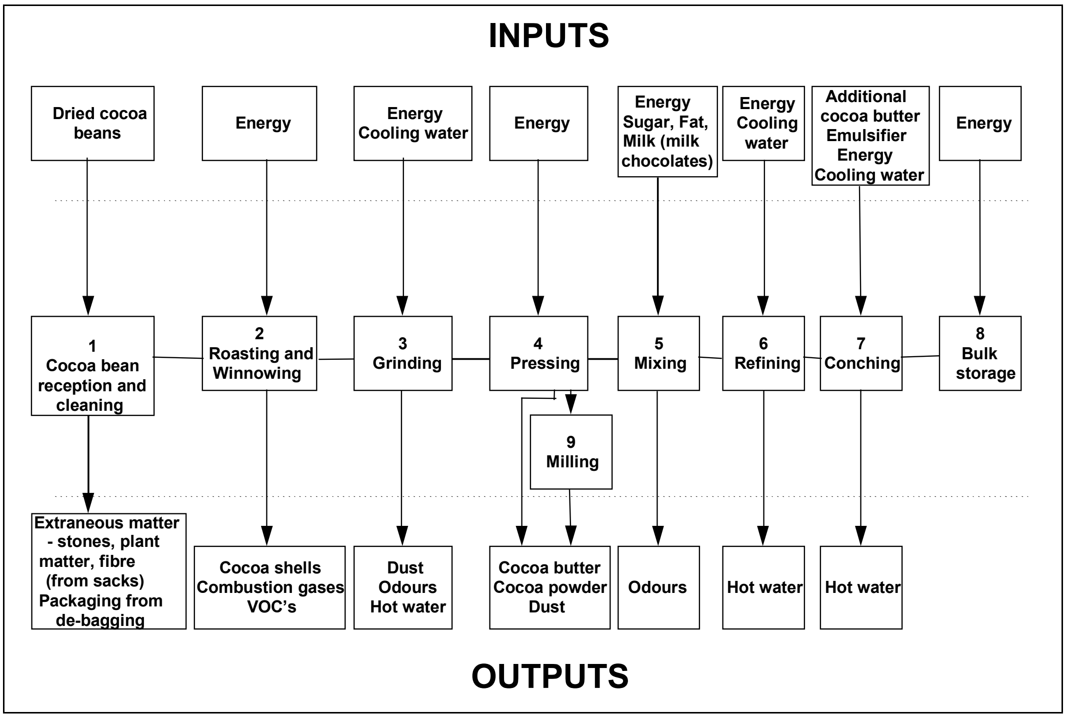


Figure 3.31: Simplified process diagram for cocoa and chocolate manufacture
[10, Environment Agency (UK), 2000]

| | Process source | Type of waste/emission |
|---|---|---|
| Air | 2<br>3<br>9<br>5 | Combustion gases, VOCs<br>Dust, odours<br>Dust<br>Odours |
| Water | 3,6,7 | Hot water |
| Land | 1<br>2<br>9 | Extraneous matter, Packaging waste<br>Cocoa bean shells<br>Dust |

Table 3.53: Summary of key emissions in cocoa and chocolate manufacture
[10, Environment Agency (UK), 2000]

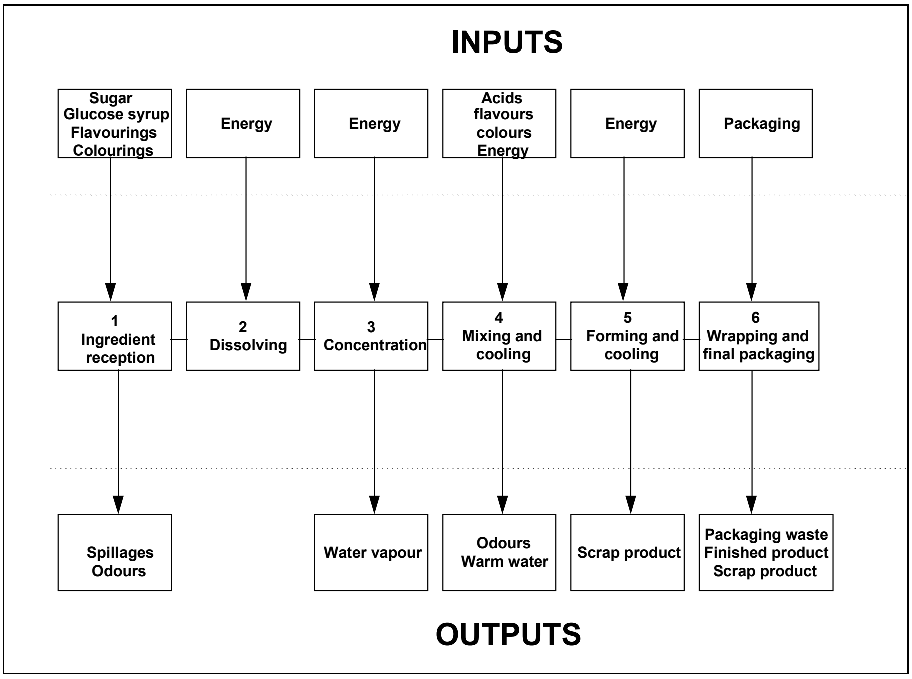


**Figure 3.32: Simplified process diagram for the manufacture of boiled sweets**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of waste/emission |
|---|---|---|
| Air | 1,4 | Odours |
| Water | 1<br>3<br>4<br>CLEANING | Spillages<br>Condensate<br>Warm water<br>BOD/COD/SS |
| Land | 6<br>5,6 | Packaging waste<br>Scrap product |

**Table 3.54: Summary of key emissions in the manufacture of boiled sweets**
**[10, Environment Agency (UK), 2000]**

### 3.7.12 Sugar refining

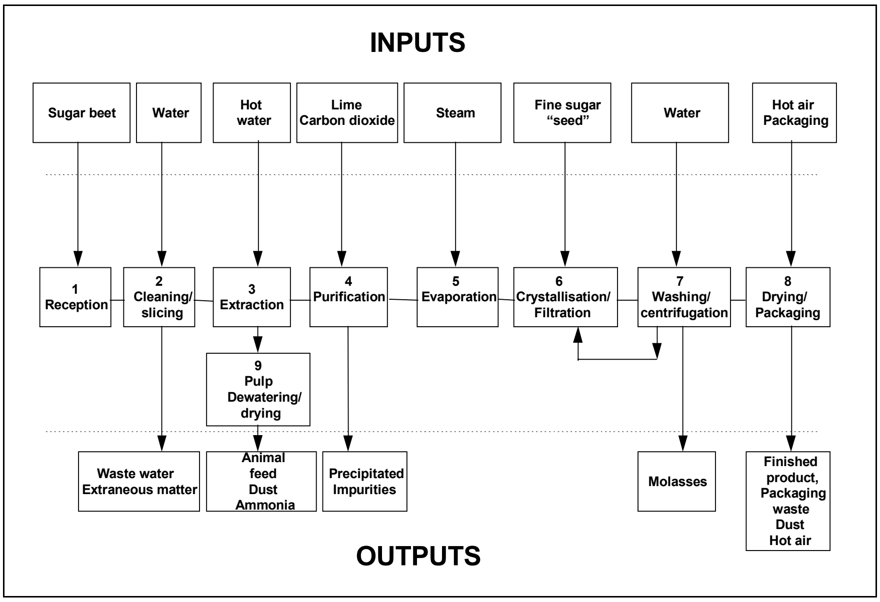


**Figure 3.33: Simplified process diagram for beet sugar refining**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 8,9 | Dust |
| Water | 2,9,7 | Waste water |
| | Cleaning | BOD/COD/SS |
| | 9 | Ammonia |
| Land | 2 | Extraneous matter |
| | 4 | Precipitated impurities (Calcium carbonate, gums, resins, waxes) |
| | | Molasses |
| | 7 | Packaging waste |
| | 8 | Dried pulp |
| | 9 | |

Table 3.55: Summary of key emissions in the manufacture of beet sugar
[10, Environment Agency (UK), 2000]

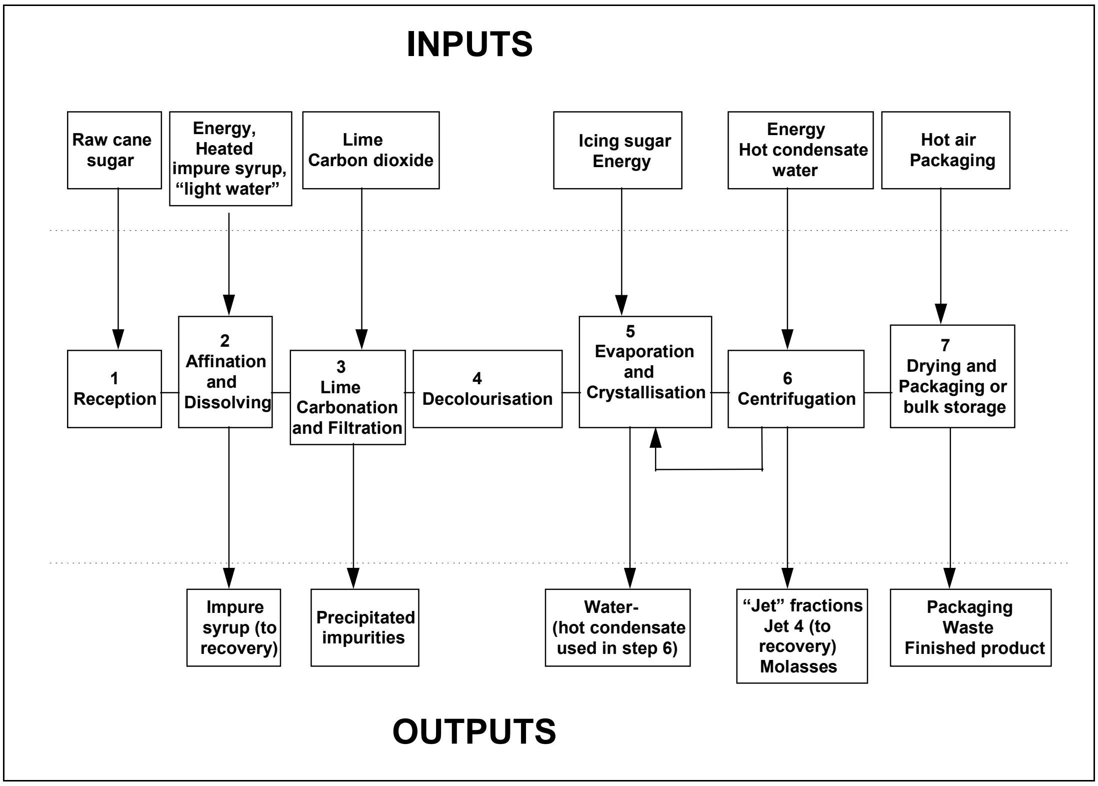


Figure 3.34: Simplified process diagram for the manufacture of cane sugar
[10, Environment Agency (UK), 2000]

| | Process source | Type of emission/by-product |
|---|---|---|
| Water | Cleaning | BOD/COD |
| Land | 3 | Precipitated impurities |
| | 7 | Packaging waste |
| | 6 | Molasses |

Table 3.56: Summary of key emissions in the manufacture of cane sugar
[10, Environment Agency (UK), 2000]

### 3.7.13 Coffee processing

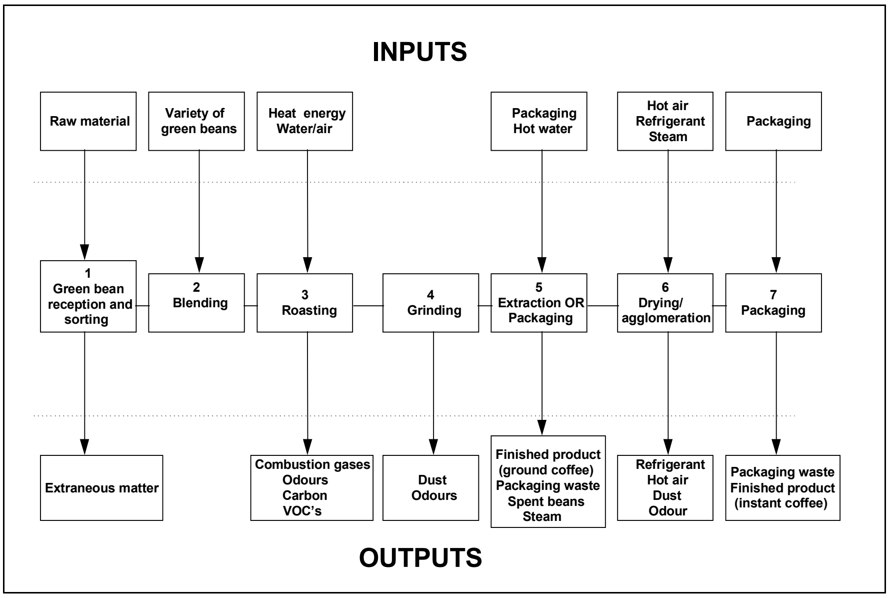


**Figure 3.35: Simplified process diagram for coffee manufacture**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 3<br>4,6 | Combustion gases, odours<br>Dust, odours, VOCs |
| Water | Cleaning<br>5 | BOD/COD/SS<br>Waste water |
| Land | 1<br>5,7<br>7 | Extraneous matter<br>Packaging waste,<br>Spent beans |

**Table 3.57: Summary of key emissions in the manufacture of coffee**
**[10, Environment Agency (UK), 2000]**

### 3.7.14 Yeast products

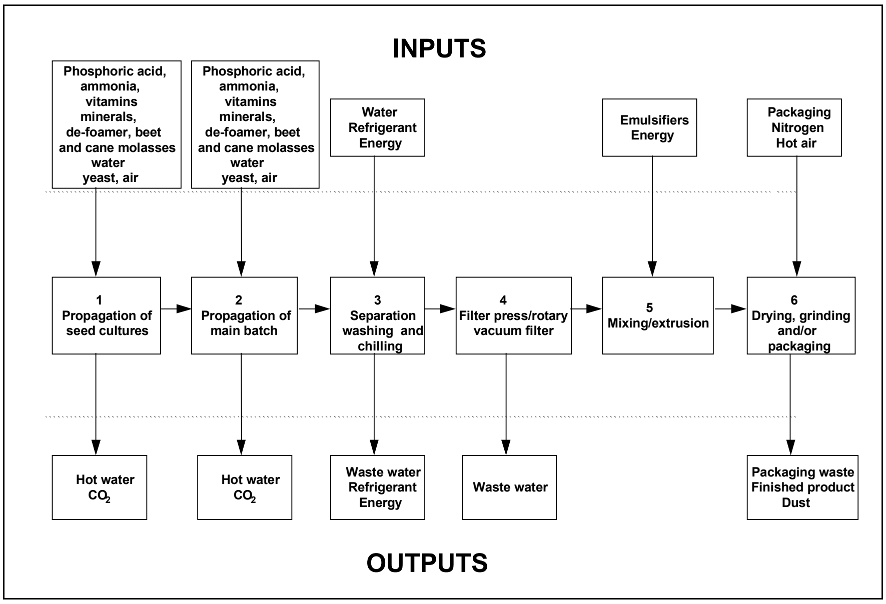


**Figure 3.36: Simplified process diagram for the manufacture of yeast**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1,2 | $CO_2$ |
| | 3 | Potential for refrigerant leak, heat energy |
| | 6 | Dust |
| Water | Cleaning | BOD/COD/SS |
| | 1,2 | Hot water from cooling heat exchangers |
| | 3,4 | BOD/COD/SS |
| Land | 6 | Packaging waste |

**Table 3.58: Summary of key emissions in the manufacture of yeast**
**[10, Environment Agency (UK), 2000]**

### 3.7.15 Brewing

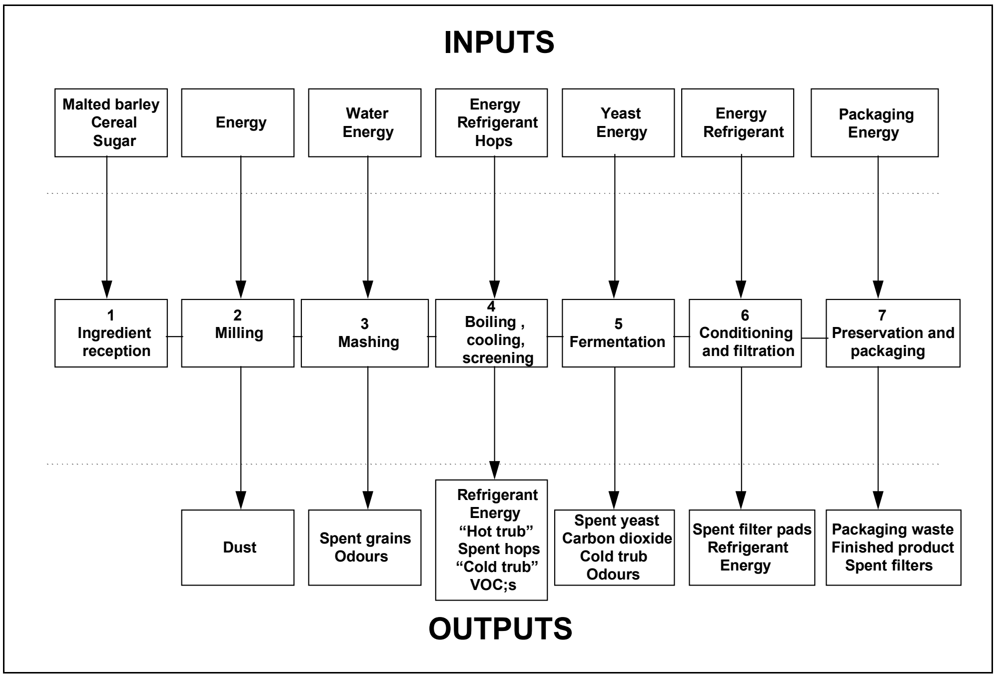


**Figure 3.37: Simplified process diagram for brewing**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 2 | Dust |
| | 3 | Odours |
| | 4,6 | Potential for refrigerant leak |
| | 4 | VOCs |
| | 5 | Carbon dioxide, Odours |
| Water | CLEANING | BOD/COD/SS |
| Land | 2 | Dust |
| | 3 | Spent grains |
| | 4 | Hot trub, cold trub, Spent hops, Spent yeast, cold trub |
| | 5 | Spent filter pads |
| | 6,7 | Packaging waste |
| | 7 | |

**Table 3.59: Summary of key emissions in brewing**
**[10, Environment Agency (UK), 2000]**

## 3.7.16 Malting

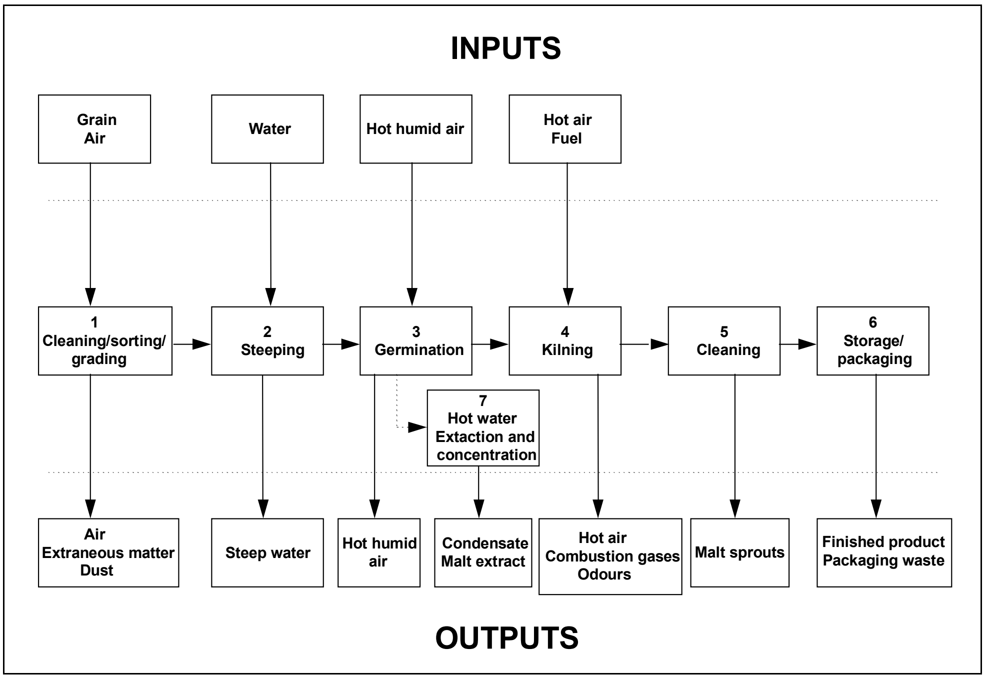


**Figure 3.38: Simplified process diagram for malting**
**[10, Environment Agency (UK), 2000]**

| | Process source | Type of emissions/by-products |
|---|---|---|
| Air | 1<br>4 | Dust<br>Combustion gases, Odours |
| Water | 2<br>7<br>Cleaning | Steep water - BOD/COD<br>Condensate<br>BOD/COD/SS |
| Land | 1<br>5<br>6 | Extraneous matter<br>Malt sprouts<br>Packaging waste |

**Table 3.60: Summary of key emissions in malting**
**[10, Environment Agency (UK), 2000]**

### 3.7.17 Manufacture and bottling of soft drinks

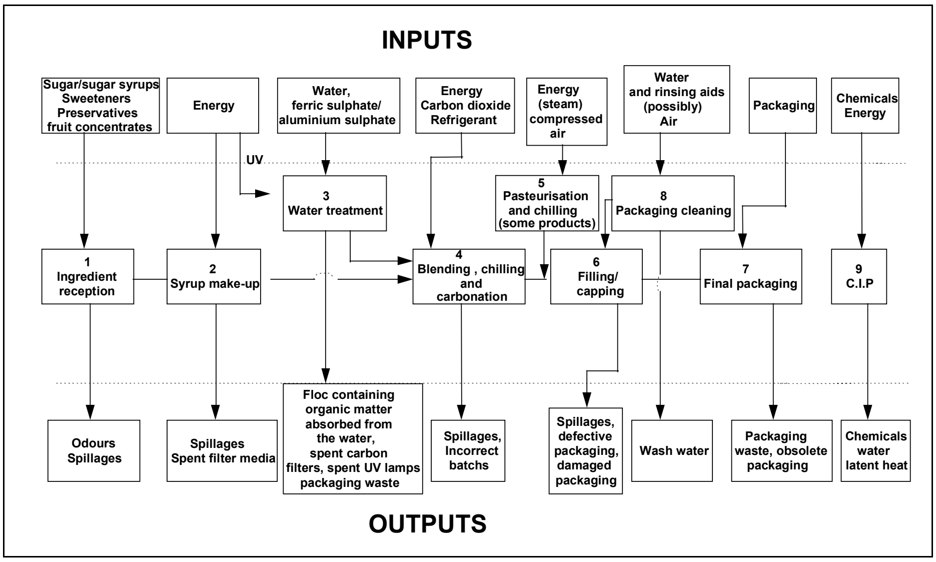
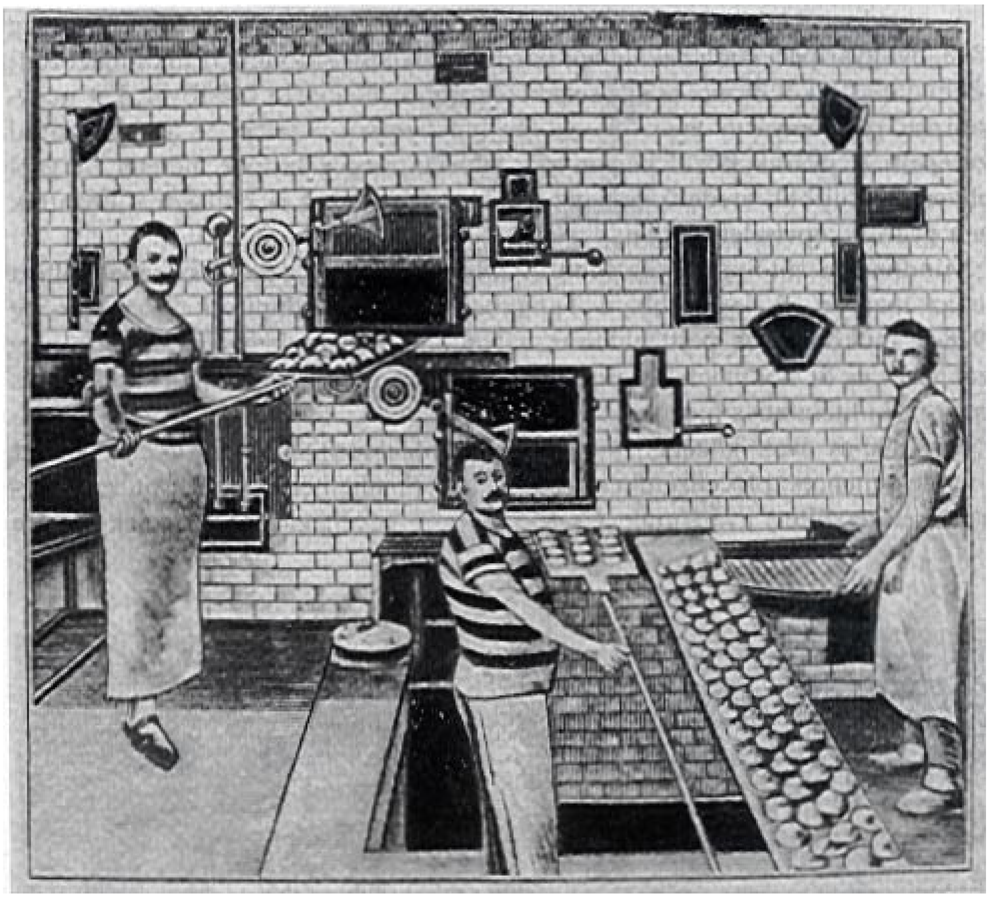


**Figure 3.39: Simplified process diagram for the manufacture and bottling of soft drinks [10, Environment Agency (UK), 2000]**

| | Process source | Type of emission/by-product |
|---|---|---|
| Air | 1<br>4,5 | Odours<br>Potential for refrigerant leaks |
| Water | 1,2,4,6<br>CLEANING (9)<br>8<br>3<br>4<br>QC Sampling | Spillages<br>BOD/COD/SS<br>Wash water containing rinsing aids<br>Floc.<br>Incorrect batchs<br>QC product samples |
| Land | 3,6,7<br>2,3<br>3 | Packaging waste<br>Spent filter media<br>Spent UV lamps |

**Table 3.61: Summary of key emissions in the manufacture of soft drinks [10, Environment Agency (UK), 2000]**

# 4 TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT



**Appropriate training of staff is needed**

The food and drink industry is so diverse that it is impossible to detail all the techniques that can be considered in the determination of BAT for every activity and in every circumstance. However, it is evident that there are various good techniques that are used in one sector that may also be applicable in other sectors. Thus in this chapter techniques are not presented sector by sector but by different issues (for further details see Section 4.1).

The descriptions of general measures are supplemented by **special techniques** that are also described and characterised. All descriptions are detailed using the following standard parts/aspects:

<u>Description</u>

<u>Achieved environmental benefits</u>

<u>Cross-media effects</u>

<u>Operational data</u>

<u>Applicability</u>

<u>Economics</u>

<u>Driving force for implementation</u>

Example plants

Reference literature

Additionally, where possible, **case studies** will be given for special measures (e.g. energy savings) or for special sectors.

## 4.1 Available techniques for minimising environmental impact

The approach to be used in selecting BAT to minimise the environmental impact of factory operations is based on the following actions:

1. process design/redesign changes to prevent emissions and eliminate waste
2. substitution of materials by environmentally less harmful ones
3. end-of-pipe treatment techniques such as waste water treatment, waste treatment, off-gas treatment, odour control, noise control, etc.

End-of-pipe treatment techniques are presented in Sections 4.11-4.17.
Process-integrated measures include, e.g.:

- selection of materials used
- waste minimisation by means of process control and operational procedures
- proper water management
- techniques for re-use/recovery
- energy efficiency.

These aspects are presented in Sections 4.2 - 4.9.
***Management of accidental releases*** is an important issue to minimise the risks. Some important aspects are presented in Section 4.10.

## 4.2 Raw material use

A large proportion of manufacturing costs within the Food and Drink sector are associated with raw and auxiliary materials (auxiliary materials are those materials used in processing raw materials that do not end-up in the final product, for example cleaning materials). The true cost of waste (including all production losses and disposal costs) can be 5 - 20 times that of the cost of waste disposal. Improving the efficiency and the use of raw materials can produce significant environmental, financial and other benefits.[1, **CIAA**, 2002][Enviros (UK), 2000 #11]

### 4.2.1 Raw material selection

A proportion of virtually all of the raw and auxiliary materials used will end up as waste or in a plant’s effluent discharge. The majority of raw materials used in the Food and Drink sector have a high organic matter content and their effect on the local terrestrial and aquatic environment can be considerable, for example, the release of milk into a watercourse is roughly 400 times more polluting than raw domestic sewage. In practice, the raw materials that food products use are specified in recipes and there are often no or few alternatives. A comprehensive list of all the raw materials and alternatives used by the industry was not readily available and therefore could not be detailed in this document.

#### 4.2.1.1 Auxiliary materials used in cleaning

Although chemicals are often used as raw materials in food processes, the more harmful chemicals are used in auxiliary processes, such as in cleaning (for example caustic materials, acids, bleaches and biocides). Chemical usage is important to prevent biological contamination of food and drink, however most of these materials are discharged as trade effluent. Any Cleaning-in-Place (CIP) system is designed to recirculate these chemicals for the extent of their useful life to minimise their wastage. These materials cannot be continually re-used and need to be discharged/purged and replenished periodically, for example, when the particulate content of a detergent reaches a specific level it will need to be disposed of as effluent. It is also desirable to reduce the need for excessive pH balancing of effluent discharges with chemicals; installations are ideally pH balanced, by using a combination of acid and caustic detergents in CIP systems [17, **Envirowise (UK)**, 1998], [1, **CIAA**, 2002], [Enviros (UK), 2000 #11].

<u>Reduction in use of chemicals in the dairy industry</u>
**Automated CIP** reduces the consumption of chemicals compared to manual cleaning. The consumption can be further reduced if the CIP includes:

- recirculation of cleaning chemicals
- automatic dosage of chemicals and monitoring of concentrations by means of conductivity transmitters
- use of optimised cleaning sequences
- self-neutralisation in the neutralisation tank.

[Nordic Dairy BAT, #42]

#### 4.2.1.2 Raw materials used in packaging

Extensive packaging is used throughout the food and drink sector as products must be packaged appropriately for the distributor and consumer to avoid biological contamination, to be attractive to the consumer and to protect the product (this includes both bulk and individual packaging). Packaging raw materials may be selected which cause the least environmental impact. However, the selection largely depends on factors outside the scope of this document. An example is given to illustrate the issue:

---

**Example**

Selection of packaging materials in the UK

Although current legislation is limited, respective legislation in the UK [Enviros (UK), 2000 #11], for instance, specifies that packaging and hazardous packaging substances should be minimal and that packaging must be recoverable and reusable. Limits are also set for the heavy metal content of the packaging with regard to cadmium, mercury, lead and hexavalent chromium. This legislation 'is not considered to include choices between materials types (e.g. glass versus plastics) or packaging systems (e.g. single trip versus reusable)', although consideration of the overall environmental impact of the packaging system is encouraged. Therefore, packaging raw materials need to be selected which cause the least environmental impact. The table below provides basic guidance to packaging raw material selection.

| Raw Material | Use | Selection Techniques |
|---|---|---|
| Paper | Primary[1] (e.g. sugar bags) and secondary[2] packaging (e.g. labels). | Where possible, select recycled paper. |
| Cardboard cartons | Primary (e.g. Tetra packs) and secondary packaging (e.g. cereal boxes). | Select cartons made from recycled paper/board. |
| Cardboard boxes | Secondary (e.g. crisp boxes) and tertiary[3] packaging (e.g. butter boxes) | Select cardboard boxes made from recycled paper/board. |
| Wood | Primary (e.g. grocery produce), secondary (e.g. display boxes) and tertiary packaging (e.g., pallets) etc. | Select non-virgin wood. |
| Plastic | Primary (e.g. cooked meat slices) and secondary (e.g.. multipack biscuits). | Select recyclable thermo plastic over thermosetting plastic. |
| Metal | Primary (e.g. processed vegetable tins), secondary (e.g. biscuit tins) | Select packaging, which uses one metal type, to improve recycling potential. |
| Paint and Solvents | All printing | Select water-based paints and solvents in preference to organic alternatives. |
| Glue | General packaging | Select water based glues in preference to organic solvent-based glues. |
| Glass | Primary (e.g. milk bottles) | Select recycled glass packaging in preference to virgin glass. |
| [1] Primary packaging – in contact with food product<br>[2] Secondary packaging – not in contact with food product and sold to consumer.<br>[3] Tertiary packaging – For distribution purposes. | | |

**Table 4.1: Basic guidance for selection of packaging materials in the UK. An example**

See also Section 4.3.7.4, waste minimisation in packaging.

# 4.3 Waste minimisation

## 4.3.1 Introduction

The objective of a waste minimisation programme is to reduce the environmental impact of manufacturing operations as much as is practicably possible, taking into account the economics and the environmental benefit, and consistent with meeting all regulatory requirements. In principle, the quantity of material and energy wastage are minimised to:

- conform with the law
- reduce the associated financial costs to the producer through loss of product and raw material and costs associated with disposal both on- and off-site
- conserve natural resources.

Waste may appear as gaseous, liquid or solid emissions. Minimisation of waste not only has a beneficial effect for the environment but can also lead to considerable cost savings.

Hygiene and food safety are paramount for the production of food and drinks. Waste minimisation can not jeopardise these prerequisites, e.g. when there is any doubt about meeting quality standards the product is reprocessed or rejected as waste. Furthermore, thorough cleaning is necessary to meet a desired level of cleanliness and hygiene, this then leads to waste water. Undoubtedly savings in cleaning, resulting in less waste going to the drain (water, chemicals), can often be achieved, but this can never be allowed to endanger hygiene.

The objective of this section is to provide guidance on how to manage waste minimisation, thereby also allowing achievement of a reduction in the loss of raw materials, products and auxiliary materials and crucially in costs. Case studies will be used to demonstrate successful waste minimisation measures.

## 4.3.2 Sources of waste

### 4.3.2.1 By –products, co-products, waste

For the food and drink industry, it is useful to distinguish the following streams in the production process: main product, co-products, by-products and waste (see Figure 4.1) Normally the main product has the highest economic value.

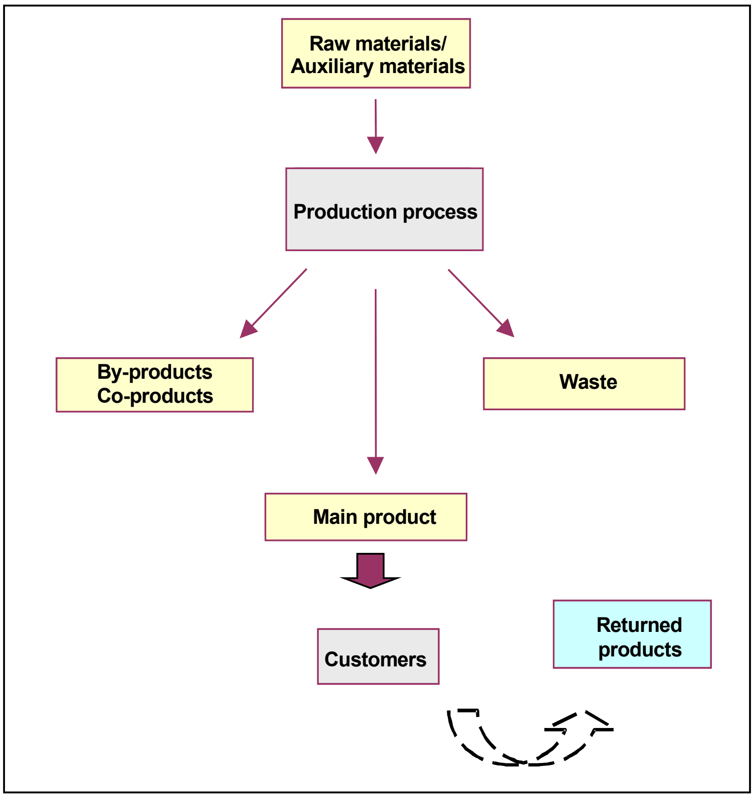


**Figure 4.1: By-products, co-products and waste in food industry**
**[CIAA 2002, #1]**

A co-product in Figure 4.1 is a material, intentionally and unavoidably, created in the same process and at the same time as a main product. Both a main product and a co-product may each meet a set specification or design, and individually each is capable of being used directly for a particular purpose. Some examples from the food industry are: wheat gluten, corn gluten feed, corn gluten meal, corn germs, wheat feed, corn steep liquor, pulp, concentrated fruit water, potato fibres and potato proteins.

A by-product in Figure 4.1 is a residual material, which arises during the manufacture of a product. It may be used directly itself as an effective substitute for a product or used as an ingredient in another manufacturing process to create a different product. For example: sludge and filtercakes from filtration.

Sometimes products are returned from retail and wholesale as they do not meet the required specifications or due to the fact that they are out of date.

**Waste minimisation can be defined as**:
"the application of a systematic approach to reducing the generation of waste at source, by understanding and changing processes and activities to prevent and reduce waste."[Enviros (UK), 2000 #11]

In the context of waste minimisation and the IPPC guidance, avoidable waste relates to the inefficient use of raw materials and other substances at an installation and will typically be represented by gaseous, liquid and solid emissions. Much of the waste will have a negative impact on the environment.

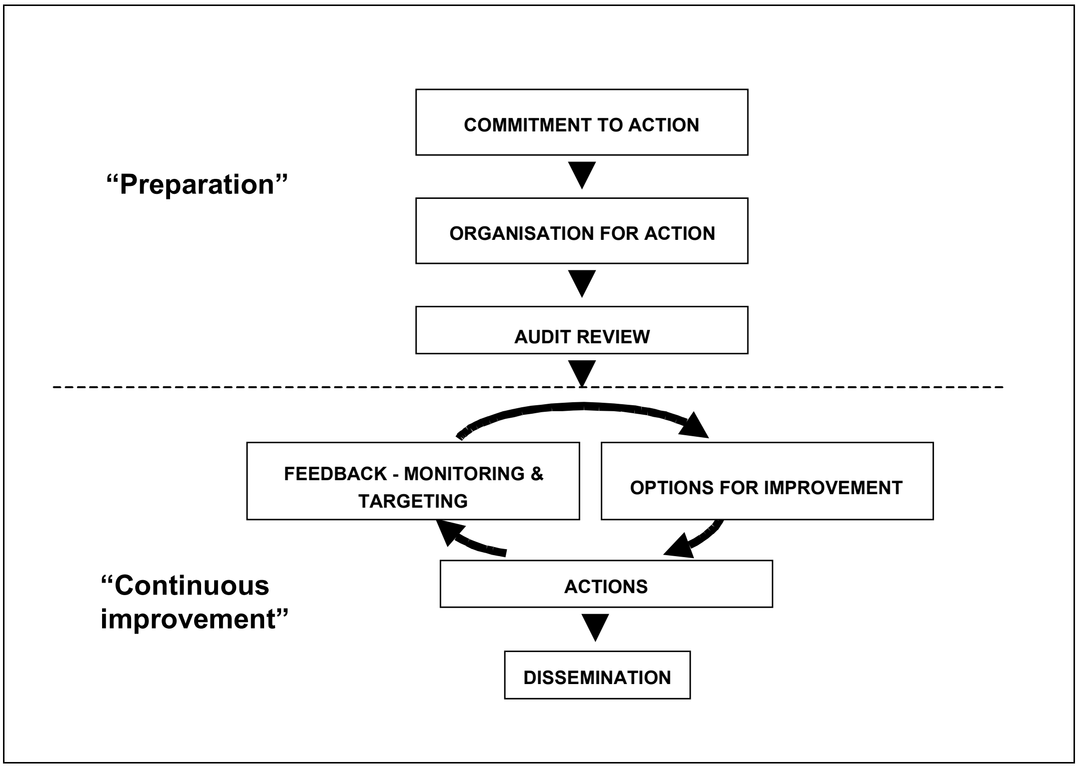


**Figure 4.2: Waste minimisation methodology**

### 4.3.2.2 General sources of loss of materials

Loss of materials may originate from the following main sources:

(a) Over-fill (Give away of products)

Even with the most accurate filling equipment operating to average filling weight legislation, the packaged product will unavoidably contain marginally more than the nominal package contents. Because of its economic significance, overfill is normally very closely monitored by check-weighing on a continuous or sampling basis. Such loss of material is normally of no environmental significance. It is, however, very important when conducting a mass balance to accurately quantify the amount of overfill, so that this can be allowed for in the mass balance equation.

(b) Spillage

Spillage of product, e.g. onto the floor, results in product which is unfit for human consumption and must be defined as loss and waste, if not properly recovered. Routinely occurring spillage indicates poor equipment design or poor maintenance, an example may be a poorly designed and operated packaging line. This often causes a considerable loss of product and packaging material. When manual handling is practised and spillage seems routine then the working procedures need to be checked.

(c) Leakage/overflow

Leakage of liquid product from pipe joints and overflow from tanks may be an important source of loss of material and waste, if not properly recovered. These problems can be caused by obsolete gaskets or faulty high-level alarm switches.

(d) Product defects/returned product

Products not meeting the required specification, whether identified prior to despatch or returned by customers, can be a major source of loss of materials and waste, if not properly recovered. This group also includes over-produced fresh product, e.g. in cases where order fluctuations result in too much product being produced which cannot then all be sold in time due to shelf-life considerations.

(e) Inherent loss

Some process equipment, even with the most appropriate technique, can cause a loss of materials and waste which is unavoidable by design. An obvious example is the self-desludging separator, where solids from the bowl, and inevitably some product, are flushed to waste during desludging.

A similar situation exists where product is purged through the equipment with water at the end of production or at product changeover, e.g. in CIP systems. Inevitably the interface between the product and the water will not be sharp and a quantity of a mixture of the two will be produced.

(f) Retained material

Retained material occurs when liquid products or ingredients cannot freely drain to the next stage in the process. This can, for example, be caused by dips in supposedly continuously falling pipelines, which traps product and prevents it from draining either way. Another example is where the product rises in pipelines, trapped product will not drain, thus leading to a loss of material. If the product cannot drain, then it must be purged with gas, water or a pigging system.

Also with very viscous products (e.g. yoghurt), adhesion to pipeline and tank walls is a significant source of retained material. Unless mechanically removed, prolonged pre-rinsing is likely to be required.

(g) Heat deposited waste

Whenever liquid products are heated, there is a likelihood of deposition of product on the heat exchange surface. Deposits on the plates or tubes in heat exchangers, and on batch kettles will not rinse off and when removed with detergents are lost in the waste stream.

In many sectors, the above-mentioned sources of loss are contained and recycled or back/recovered in the process, they cannot therefore be considered as waste.

Waste minimisation programme

Waste minimisation can be defined as the application of a systematic approach to reducing the downgrading of raw materials and products and the generation of waste at source, by understanding and changing processes and activities.

### 4.3.3 Waste minimisation methodology

Waste minimisation requires a **systematic approach**. For running a successful waste minimisation programme, a step-by-step approach is advised. It may consist of the following steps [CIAA 2002, #1]:

Step 1 Obtaining management commitment, organisation and planning
Step 2 Analysis of production processes
Step 3 Assessment of objectives and targets
Step 4 Identifying waste minimisation options
Step 5 Evaluation and feasibility study
Step 6 Implementation.

In this section the various steps in a waste minimisation programme are described in more detail.

#### 4.3.3.1 Obtaining management commitment, organisation and planning

(a) Obtaining management commitment

All successful waste minimisation programmes begin with senior management commitment. This ensures that all individuals within the organisation work together in a positive manner to gain maximum benefit from the initiative. One of the best ways of gaining senior management commitment is to convince them of the financial benefits that can be achieved.

It is advisable to start by identifying one or two areas where substantial amounts of materials or products are lost and where waste is produced and then illustrating the associated costs for the company. This cost survey includes the cost of wasted raw materials, rework, lost production time, waste treatment costs, wasted labour, loss of materials to atmosphere and to the drain, as well as the excessive use of energy and water.

Sometimes up to 20 % of the raw material (or product equivalent) goes to waste or to the drain (see for example case study 1). Often people do not realise this. Highlighting this can trigger senior management (i.e. shock them) into giving full support to the waste minimisation programme.

(b) Establishing a project team

It is usually beneficial to appoint a team leader or company champion to co-ordinate and facilitate waste minimisation programmes. Involving project teams and champions helps to increase staff awareness at all levels and motivates individuals to take action and participate.
The team leader and the project team are responsible for progressing the assessments and for developing and evaluating proposals and measures.

(c) Planning

The project team draws up a detailed project plan with a time schedule for activities to be carried out within the waste minimisation programme. Responsibilities are allocated for each task.

#### 4.3.3.2 Analysis of production processes

An important condition for successful waste minimisation is to have a good overview of the areas and process steps that are relevant to the loss of materials and the generation of waste. Such an overview makes it easier to trace waste minimisation options.

This requires a detailed inventory of the production processes in the factory. In developing the inventory, three data levels can be distinguished:

(a) Level 1: Collection of quantitative data at the site level

In this level, data on quantities and costs are collected for the total plant (site). Most data will already be available within the company recording systems, e.g. stock records, accounts, purchase receipts, waste disposal receipts and production data. Where information is not available, estimates or direct measurements will be required.
The quantities of all raw materials, energy and wastes are usually provided for an annual period. Note that the units need to be consistent, for example for different solid materials, energy consumption or water/effluent. This is essential to allow quantities and activities to be compared in a meaningful way today and in future years.

Information is collected in a systematic manner to ensure that as complete an initial assessment is made as possible. It is advisable to begin a paper or electronic database of all the information collected.

(b) Level 2: Inventory per process step

The objective of this step to get an overview of all the production processes and related environmental aspects. Production processes are best represented by a flow chart showing inputs, outputs and environmental problem areas. Figure 4.3 provides one example of an input/output worksheet, although it may be represented in different formats.

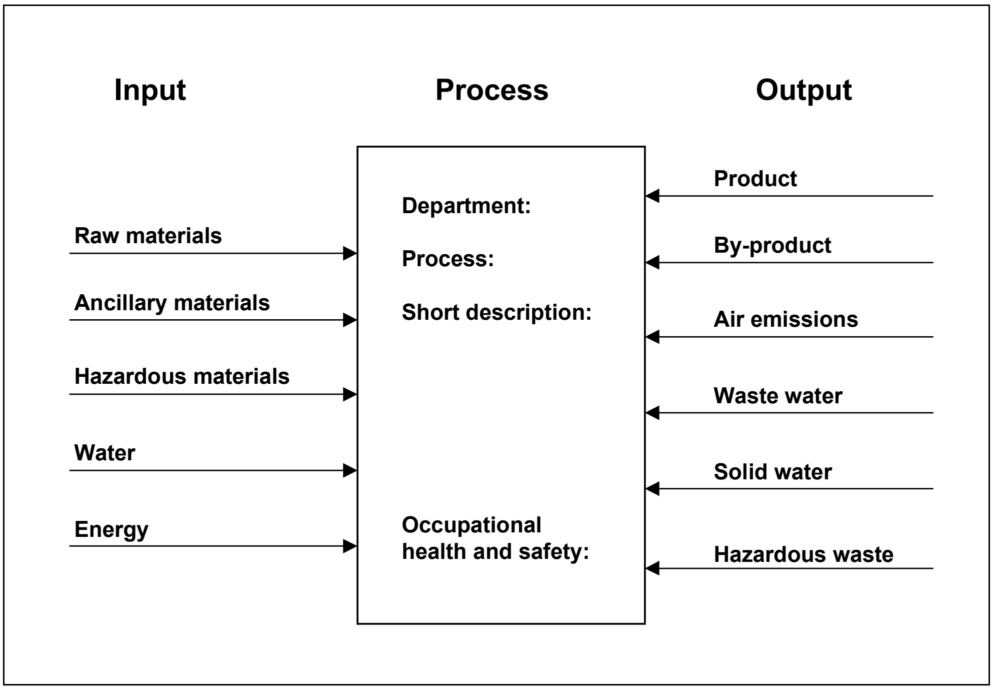


**Figure 4.3: Work sheet for input/output and environmental issues**

Material balance

The purpose of making a material balance is to account for the consumption of raw materials and services that are consumed by the process, and the losses, wastes and emissions that result from the process. A material balance makes it possible to identify and quantify previously unknown losses, wastes and emissions, and provides an indication of their sources and causes. Material balances are easier, more meaningful, and more accurate when they are undertaken for individual process steps. An overall plant-wide material balance can then be constructed from these.

The material balance can also be used to identify the costs associated with inputs, outputs and identified losses. Environmental performance indicators for the process can be developed from the material balance data.

(d) Level 3: Inventory of selected parts

Depending on the inventory at level 2, certain parts of the process (plant) may need further analysis for waste minimisation options. This requires a more detailed inventory of these parts. In an ideal world, all processes will be assessed. However, time and resource constraints may make it necessary to select only the most important aspects or process areas.

#### 4.3.3.2.1 Process maps, mass balances and action plans

**[Enviros (UK), 2000 #11]**

The production of process maps and mass balances can improve the operators' understanding of their raw and other material use, energy use, waste production and general efficiency. The quantification of all process inputs and outputs, through a mass balance, is used to identify where process losses and inefficiencies occur, and where more information (monitoring) is required. Using this information, an Action Plan is produced which details the improvement programme. Further information on waste minimisation methodology can be found in various guides, such as UK Environment Agency's (2001): Waste Minimisation -An Environmental Good Practice Guide For Industry [64, Environment Agency (UK), 2001], and in publications of the Environmental Technology Best Practice Programme series such as Waste minimisation pays: Five business reasons for reducing waste - GG 125 [Envirowise (UK);EEF;Lloyds Bank, 1998 #62], or Cutting costs by reducing waste: Running a workshop to stimulate action - GG 106 [Envirowise (UK); W. Battle Ass., 1998 #63].

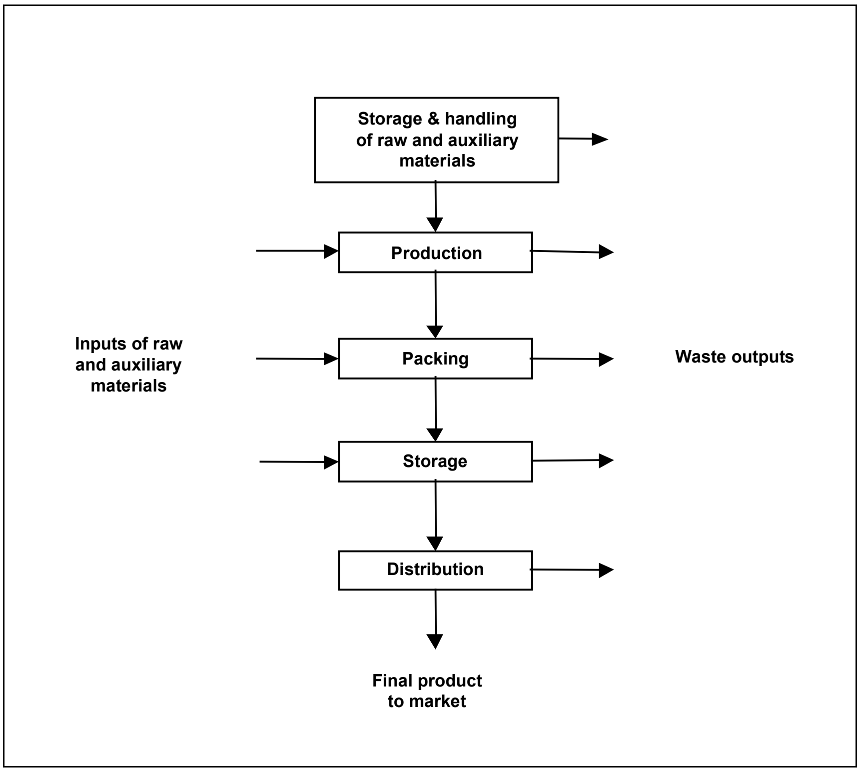


**Figure 4.4: Flow sheet of waste production**
**[Enviros (UK), 2000 #11]**

### 4.3.3.2.2 Generic process map

The generic process map separates each of the main process stages commonly found in the food, drink and milk sector.

Ideally, inputs (materials and utilities consumed) and outputs (productivity and wastes) are recorded on a regular basis (daily, weekly, monthly) and analysed in a spreadsheet, or more powerfully in a monitoring and targeting programme. This will provide the installation with a considerably improved understanding of process efficiency, will help to identify areas of inefficiency and will provide it with the ability to report and monitor performance and cost savings. Once the basic process has been drawn and inputs and outputs quantified, it will then be necessary to understand each individual sub-process. This is best achieved through a mass balance, as shown below for the dairy industry.

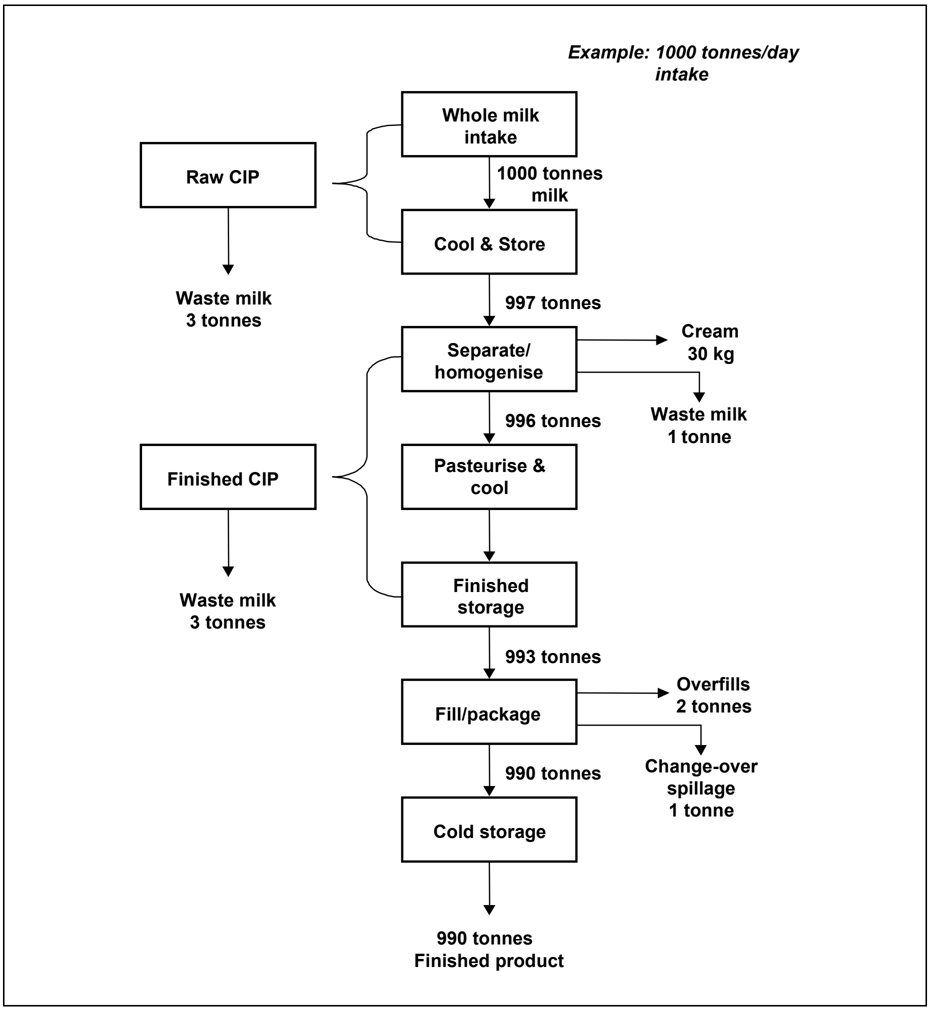


**Figure 4.5: Simplified mass balance for liquid milk production**
**[Enviros (UK), 2000 #11]**

*The process flow of a liquid milk site (above) has been expanded with specific mass balances, which give an overview of where the main waste milk opportunities are.*

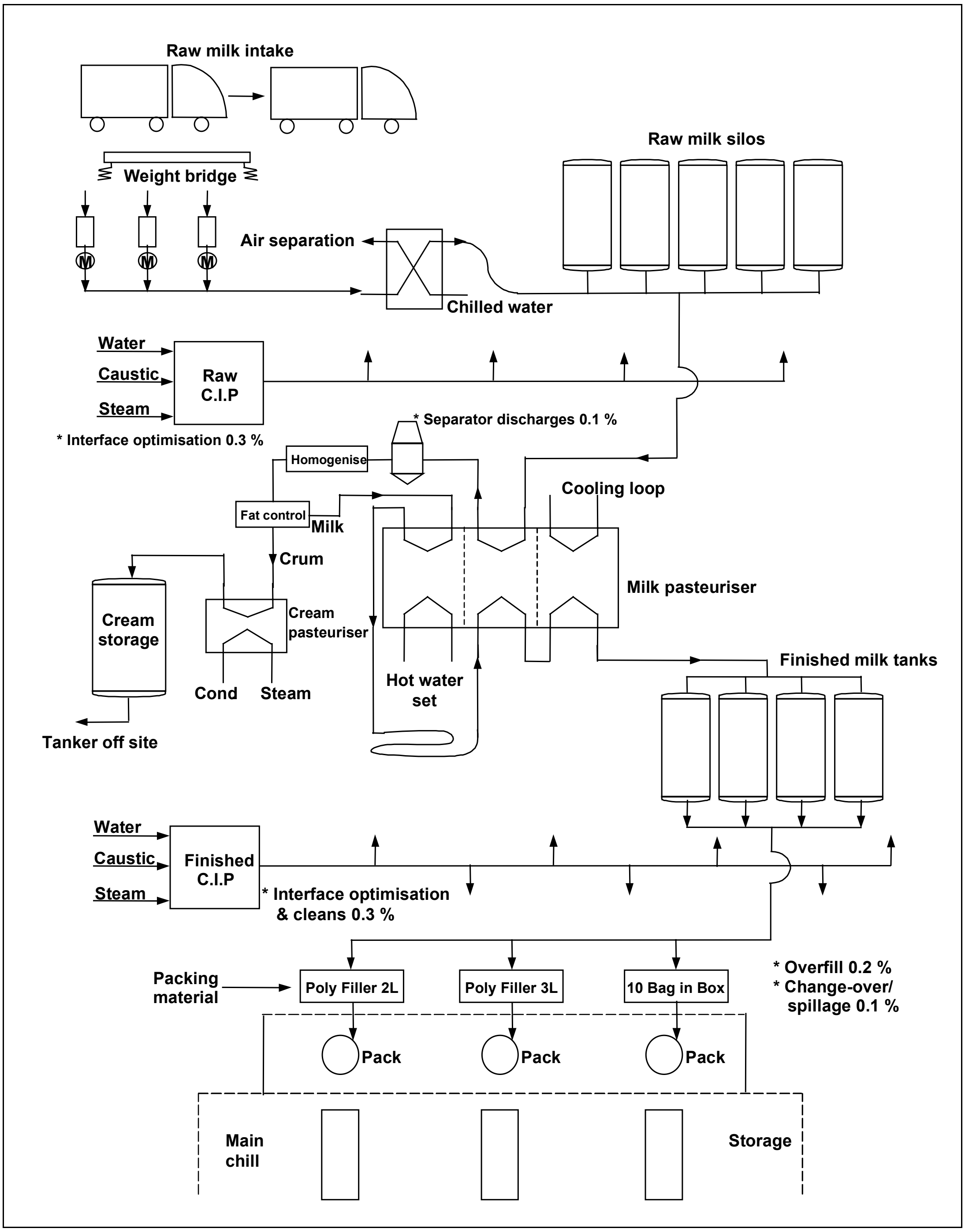


**Figure 4.6: Detailed process flow of liquid milk production**
**[Enviros (UK), 2000 #11]**

*The above process flow diagram shows that the overall process loss of raw milk of 0.7 % to 1.0 % is indicative of industry best practice. The key areas of waste milk generation identified in the diagram are:*

| | |
|---|---|
| ** Raw CIP and associated plant* | *0.3 %* |
| ** Processing – mainly separator discharge* | *0.1 %* |
| ** Finished CIP and associated plant* | *0.3 %* |
| ** Overfilling during packaging* | *0.2 %* |
| ** Changeover / Spillage during packaging* | *0.1 %* |
| *Total Raw Milk Loss* | *1.0 %* |

*This analysis excludes any reclaimed process milk, which is typically 1.5 % and fully accounted for in the waste reporting systems.*

Applying effective techniques in each of the key wastage areas will give significant environmental benefits. Some of the main areas for attention are summarised below.

#### 4.3.3.3 Assessment of objectives and targets

The objectives of the waste minimisation programme are to reduce the consumption of materials and to minimise the generation of waste. It is advisable to set reduction targets for the loss of materials and the amount of waste generated. These targets need to be measurable and scheduled into the programme plan so that they can be used to monitor if the programme is proceeding as planned.

#### 4.3.3.4 Identifying waste minimisation options

Identifying waste minimisation options depends on the knowledge and creativity of the project team members and plant staff, much of which of course comes from their own experience. Several options can often be found by carefully analysing the cause of any problem.

Another way of identifying waste minimisation options is to hold a brainstorming session. Here people from different parts of the organisation can meet to discuss solutions to specific problems in an open and non-threatening environment.

Additional ideas may also be generated by hiring a consultant with specific expertise in waste minimisation and letting him make a walk-through inspection.

#### 4.3.3.5 Evaluation and feasibility study

The objective of the evaluation and feasibility study phase is to evaluate the proposed waste minimisation options and to select those suitable for implementation. The options may all be evaluated according to their technical, economic and environmental merits. However, the depth of the study depends on the type of the option.

The quickest and easiest method for evaluating different options is to discuss the possible options one by one in the project team. This process gives a good indication of which projects are feasible and what further information is needed. More thorough evaluations can then be performed on the best options.

(a) Technical evaluation

The potential impacts on products, production processes and hygiene and safety from the proposed options need to be evaluated before complex and costly projects can be decided upon. In addition, laboratory testing or pilot tests may be required if options significantly change existing processes.

(b) Economic evaluation

The objective of this step is to evaluate the cost effectiveness of the proposed options. When performing the economic evaluation, the costs of the change are weighed against the savings that may result. Economic viability is often the key parameter that determines whether or not an option will be implemented.

(c) Environmental evaluation

The objective of the environmental evaluation is to determine the positive and negative environmental impacts of the option. In many cases the environmental advantages are obvious.

In some cases it may be necessary to evaluate whether, for example, an increase in electricity consumption would outweigh the environmental advantages of waste reduction.

#### 4.3.3.6 Implementation

Finally an implementation and action plan is prepared and then put in place in order to implement the waste minimisation options. A step-by-step approach is recommended. Make sure that the action plan includes realistic and achievable waste and reduction targets and which top management have agreed. Involve all staff when implementing the action plan and provide regular feedback to them. Regular feedback to all staff will help to keep momentum going for the waste minimisation programme and encourage staff to look for future waste minimisation ideas and initiatives. Review progress against targets at least once a year.

### 4.3.4 Generally applicable measures for waste minimisation

Some existing measures for waste minimisation are described in this section. These range from relatively simple containment measures to sophisticated process optimisation techniques.

The technical feasibility of the measures listed below has been demonstrated by various sources. Used singly, or in combination, the measures represent effective techniques when implemented in the appropriate circumstances. The circumstances depend on the plant scale, materials used, nature of the products made, number of different products produced, etc.
(No priority ranking is intended, and the appropriate selection in a particular case will depend on the specifics of the process concerned and any on-site constraints).

Some examples are given for illustrative purposes. These are not exhaustive, many other similar examples could be given.

#### 4.3.4.1 Good housekeeping

There are many potential opportunities through no, or low, cost measures to reduce the loss of materials by using good housekeeping measures. Issues that need to be considered as part of any programme to improve housekeeping include:

- maintaining good inventory control to avoid waste of raw materials
- ensuring that employees are aware of the environmental aspects of the company’s operations and their personal responsibilities
- keeping the work area tidy and uncluttered to avoid accidents
- training staff in good cleaning practices
- assessing waste collection systems to see if they can be improved? e.g. by elimination of the source of a waste or by using trays to collect waste as it falls/drips from machinery
- scheduling regular maintenance programmes to avoid breakdowns
- identifing and marking all valves and equipment settings to reduce the risk that they will be set incorrectly by inexperienced staff
- segregating solid output for re-use and recycling.

#### 4.3.4.2 Operating practices

Some examples of improvements in operating practices which can minimise waste are:

- appropriate reception and handling of raw materials
- separation of cooling water, storm water and process effluents of different origins in order to permit appropriate treatment options

- dry equipment cleaning and dry vacuum systems
- selection and use of fumigants (e.g. phosgene, methyl bromide) to minimise environmental impact, e.g. controlled post-fumigation release, to ensure local downwind ground level concentrations in the vicinity are acceptable
- selection and use of cleaning/sanitising agents to provide effective hygiene control but with due consideration of environmental implications.

#### 4.3.4.3 Process optimisation

Examples of waste minimisation by process optimisation are:

- water minimisation, i.e. by re-use, recycling, or the reduced use of materials, or by preventing losses
- high efficiency dust collection on dryers and bagging system.

### 4.3.5 Benchmarking

Benchmarking is a technique used to assess performance against internal or industry standards [Enviros (UK), 2000 #11]. Monitoring and targeting is a proven way of focussing on (and reducing) the areas of greatest waste. It is important to measure and evaluate the results of any improvements implemented. Benchmarking within the Food and Drink Sector is currently underused and needs to be increased. Typically, benchmarks are expressed as ratios, but can be expressed as percentages of efficiency.

Within the food, drink and milk sector, the most common benchmarks compare utilities consumption against production. Such information provides a good indication of efficiency and therefore, of wastage occurring within the process. Much of this information can be relatively easily obtained.
Energy efficiency is also important. However, it is not presented here as it is covered in a separate section.

Typical waste benchmarks used in the food and drink industry are as follows:

| Performance monitor | Measurement |
|---|---|
| Air emissions | Mass of emission per unit of production |
| Liquid waste | Volume of water, mass of contaminants or oxygen demand per unit of production |
| Solid waste | Mass of waste per unit of production/raw material |
| Energy resources | Energy use per unit of production |
| Utilities and services | Use of water, compressed air, steam per unit of production |
| Other | Consumption of specific materials, e.g. packaging per unit of production, number of labels per kg of printing ink etc. |

**Table 4.2: Benchmarking in food and drink industry**
**[Enviros (UK), 2000 #11]**

#### 4.3.5.1 Example benchmarks

Little waste benchmarking information was available, as shown in Table 4.3. However, this information could prove highly valuable to industry, as it could indicate which areas they need to focus on to improve efficiency and reduce wastage and to make the greatest cost savings. Additional information can be found in Chapter 3.

| F&D Sub-Sectors | Percentage of Raw Material Loss. | Ratios<br>(water: final product) |
|---|---|---|
| Liquid Milk | 0.7 - 1 % wastage | 0.6:1 |
| Baking | 1 - 1.5 % wastage | |
| Soft Drinks | 1 % wastage | 1:1 |
| Brewing | 4 – 6 % wastage<br>(post fermentation) | 4:1 |

**Table 4.3: Benchmarks for some sub-sectors**
**[Enviros (UK), 2000 #11]**

### 4.3.6 Spillages

Accidents and the associated waste may occur from time-to-time. It is therefore important to minimise the chances of accidents and to control any spillages that occur. Operators need to be trained, and receive adequate supervision, to carry out procedures to reduce the opportunity for accidents and to manage any spillage. The procedure ensures that tanks, valves, gauges, bunding, coupling, pipe-work, etc. are appropriate and maintained; that tankers are managed on-site; and that an inventory of tank levels, pressure levels and contents are regularly recorded to prevent overfilling and contamination of product.

### 4.3.7 Packaging

Packaging includes a number of raw materials, for example corrugated cartons, plastic bags, shrink-wrap, stretch-wrap, layer pads, pallets and slip sheets, drums and other containers and filler materials (polystyrene, foam paper), etc.

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**Example**

The food and drink industry is responsible for using over 50 % of the total packaging output of the UK (4 - 5 million tonnes per year). This packaging has a value of approximately GBP 4 billion for raw materials alone. On average, packaging represents 13 % of the sector's production costs. Packaging is important for the sector, especially for hygiene. Packaging for products sold for direct consumers are important because of the high competence and the market. [Envirowise (UK); Aspinwall & Co., 1999 #47]

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Costs associated with packaging are included as part of the overall packaging costs. These include the cost of:

- delivery to site
- storage on-site
- processing
- packing and filling
- delivery off-site
- waste disposal
- staff time
- packaging obligation
- any other costs.

To reduce packaging it is necessary to consider the material and design requirements of the packaging and to examine ways of eliminating or reducing packaging. Only the necessary packaging is used, it may be possible, for example, to eliminate the use of an unnecessary layer.

It is important to tackle waste packaging using the waste minimisation hierarchy by:
[Envirowise (UK); Aspinwall & Co., 1999 #47]

- firstly, avoiding packaging whenever it is possible
- secondly, reducing packaging
- thirdly, re-using packaging
- fourthly, recycling packaging.

### 4.3.7.1 Packing line efficiency

Poorly designed and operated packing lines cause many companies to lose as much as 4 % of their product and packaging [Envirowise (UK); Enviros, 2000 #48]. To improve efficiency and productivity and to reduce wastage, individual machines are correctly specified so that they work together as part of an efficient overall design.

The bottleneck machine (slowest machine) is the most important to keep constantly running at maximum capacity. The plotting of machine speeds on the packaging line ideally produces a V-shape (V-graph). Ideally it is never starved of feedstock and therefore sufficient buffer capacity (conveyors and accumulators) is built into the design.

Packing line efficiency is monitored on a weekly basis through the use of the V-graph and KPIs (key performance indicators, e.g. waste to production ratio). The optimum and the actual design values are plotted to identify if the machinery is operating at optimum efficiency. Effective values are also plotted to show the reliability of individual machines. KPIs could include the number of rejects during a shift or day, downtime and possibly other external factors.

CASE STUDY – Soft drinks and beverages (brewery)

- To combat poor packing line efficiency at a large brewery, teams were set up to monitor performance and identify problem areas. An understanding of the packing lines enabled actions to be taken to reduce stoppages and to increase efficiency. This action resulted in reduced operating costs and wastage, producing cost savings in excess of GBP 137000 per year.
  [Enviros (UK), 2000 #11]

CASE STUDY – Preserves and peanut butter

- A packing line study identified that static electricity associated with the sleeve film effected the availability of the automated tamper-proofing sleeve machine. By increasing the film thickness by 20 µm, the machine speed could be maintained at 250 jars per minute and stoppages reduced by 40 %. Savings in film waste alone equated to GBP 25000 per year.
  [Enviros (UK), 2000 #11]

CASE STUDY – Dairies

- A study identified that packing line sensors on the cap shoot were too close to the base filler and were causing them to become covered by milk froth and unable to detect cap blockages. This caused up to 20000 bottles per week being rejected. By repositioning the sensors the company was able to save GBP 35000 per year in disposal cost from spoilt poly-bottles and save a further GBP 5000 per year in milk waste and reprocessing costs and increase production.
  [Enviros (UK), 2000 #11]

CASE STUDY – Confectionery

- A UK sweet manufacturer monitored its packing lines performance to discover that an inappropriate machine speed was causing inaccurate weighing of product and failure of heat sealing equipment. A simple adjustment of the machine’s speed enabled savings to be made in product, packaging, reworking and waste disposal to the tune of over GBP 120000 per year. Other benefits were increased production and a 500 tonnes per year reduction in waste to landfill.
  [Enviros (UK), 2000 #11]

#### 4.3.7.2 Data collection

Before any opportunities can be identified and improvements made, packaging flows and associated waste streams are monitored, analysed and understood. The data acquired consists of packaging specifications, packaging recipes, purchase and sales information and waste disposal information.

#### 4.3.7.3 Packaging design

Companies usually use the optimum packaging size, which takes account of product size, shape, weight, distribution requirements and packaging material selected. Ideally the packaging will achieve fitness of purpose, minimise the amount of packaging material used, maximise the amount of product per pallet and optimise warehouse storage. Often by designing the packaging effectively waste can be avoided or at least reduced.

| CASE STUDY – Confectionery |
|---|
| • Investment in a new wrapping machine enabled Nestle Rowntree to eliminate the inner collation wraps on its bumper packs of biscuits. This action reduced polypropylene use by 100 tonnes per year, with a payback of under two years.<br>[Enviros (UK), 2000 #11] |

| CASE STUDY – Animal feed (pet foods) |
|---|
| • To reduce packaging, Pedigree Masterfoods lowered the sides of the cardboard transit trays, without loss of strength. This action reduced wastage and resulted in 49 % less corrugated card and ink being used, which produced annual savings of GBP 100000.<br>[Enviros (UK), 2000 #11] |

#### 4.3.7.4 Material selection

A wide variety of packaging materials are used within the food and drink sector. Packaging materials are selected that cause the least environmental impact, taking into account the whole life cycle of the packaging. (See also Section 4.2.1.2 raw material selection in packaging.)
To keep waste to a minimum the weight and volume of each material, together with its recycled content are considered, especially as the potential for re-use, recycling and disposal of the packaging. Often one material can replace the need for another, for example recyclable shrink-wrap can sometimes replace the need for cardboard trays and shrink-wrap (see Douwe Egberts case study below).

| CASE STUDY – Coffee |
|---|
| • Douwe Egberts improved the use of their shrink-wrap (recyclable) and removed the need for using cardboard transit trays for coffee packets. The benefit was the elimination of card, glue and printing on cardboard transit trays, which resulted in reduced waste and operating costs.<br>[Enviros (UK), 2000 #11] |

#### 4.3.7.5 Re-use of packaging

Some packaging is designed for re-use, for example, pallets, drums, plastic boxes, metal crates, plastic trays, etc. For the packaging to be re-used, it is necessary for companies to have closed-loop systems. Here back-haulage allows the packaging to be readily returned for re-use. This is usually more effective where transportation distances are relatively short. The use of a tracking system, for example, employing bar codes, could aid the management of transit packaging.

| CASE STUDY – Ready made meals |
|---|
| • The Boots Company re-used their transit trays for the delivery and display of sandwiches, which resulted in annual savings in plastic of 163 tonnes per year, cost savings of GBP 500000 per year and a reduced packaging obligation.<br>[Enviros (UK), 2000 #11] |

#### 4.3.7.6 Segregation and recycling

Some packaging waste is inevitable. The segregation of this waste can produce opportunities for recycling of waste and reducing volumes to landfill and may even act as a further income stream. This process can be as simple as putting paper, wood, plastics, food, etc into separate skips or can involve a more complex process, such as a macerator, which can separate packaging from product.

| CASE STUDY - Cakes/desserts |
|---|
| • Devon Desserts (BG Foods Ltd) developed a machine in-house to separate waste end-of-line product from its packaging. This enabled plastic carton packaging to be compacted and recycled, and for the solid product waste to be mixed with liquid food waste and sold as pig feed. The result was reduced waste and lower waste disposal and effluent charges.<br>[Enviros (UK), 2000 #11] |

### 4.3.8 Process control

Production costs can be reduced by up to 5 % by focusing on waste minimisation techniques. The benefits of improved process control include an increase in saleable product, improved quality and reduced waste.

Improved process control inputs, conditions, handling, storage and effluent generation will minimise waste by reducing off-specification product, spoilage, loss to drain, overfilling of vessels, water use and other losses.

To improve process control it is important to identify at which stage in the process waste is generated, what is the cause of the waste and what improvements can be made to reduce the waste. For example, fitting a level switch, float valve, or flow meter will eliminate waste from overflows.

It is vital that the process monitoring and control equipment is designed, installed and operated so that it does not interfere with hygiene conditions in the production process, and does not lead to product loss and waste itself.

#### 4.3.8.1 Control systems

To ensure that the process is controlled and waste is minimised, it is important to consider how the process can be optimised. This may be through the use of measurement sensors, controllers/transmitters and control devices, a number of the options are listed below:

#### 4.3.8.2 Temperature measurement

Raw material waste and effluent generation can be reduced by controlling the temperature, for example, in storage vessels, processing vessels, transfer lines, etc. The benefits will be reduced deterioration of materials, reduced out-of-specification products and less contamination (for example, solid or biological).

Where possible temperature sensors are used for dual purpose, e.g. for monitoring both product and cleaning temperatures.

**Examples**

Applications:

*Dairies* – Milk temperature can be maintained during pasteurisation by controlling the flow of steam or hot water.

*Pasta* – Integrating measurements and controlling flow and temperature can be used during water addition to pasta dough kneaders.

*Confectionery* – Temperature sensors can be used to minimise the temperature drop during product transfer, thereby minimising product deterioration.

*Meat Processing* – The temperature of thawing baths for frozen meat can be maintained by controlling water flow.

Thermometers:

Resistance thermometers - used to control temperatures over a relatively narrow range, for example, during the pasteurisation of milk. [18, **Envirowise (UK)**, 1999]

| CASE STUDY - Drinks and beverages |
|---|
| • A company fermenting molasses to produce alcohol installed an improved temperature control in a fermentation vessel, which was regularly exceeding the required temperature by 5 °C. The result was increased production yields and a 15 % reduction in waste.<br>[18, **Envirowise (UK)**, 1999] |

Temperature can be measured with either an intrusive or a non-intrusive device. There are three basic options: thermowells (non-intrusive), dip systems (intrusive) or surface mounted measurements (non-intrusive). Thermowells provide the greatest advantage as they are hygienic and more sensitive to temperature changes than surface mounted measurements. [18, **Envirowise (UK)**, 1999]

Thermocouples - used where accurate measurements of temperature are required over wide temperature ranges.

| CASE STUDY – Meat processing |
|---|
| • Thermocouples to provide temperature control allowed a meat processing company to reduce water, energy and effluent and produced a cost saving of GBP 13000 per year.<br>[18, **Envirowise (UK)**, 1999] |

Filled-system thermometers – have limited usage because of a risk of product contamination. Also, they are uneconomic in situations where remote readings are required [18, **Envirowise (UK)**, 1999].

Optical thermometers (pyrometers) - portable and suitable for taking multiple measurements around a site. They measure surface temperatures. They are generally used for high temps but they cannot be used to provide a signal for process control [18, **Envirowise (UK)**, 1999].

### 4.3.8.3 Pressure measurement

Pressure sensors are typically used for the indirect control of other parameters, for example flow or level. Pressure sensors in transfer lines control pump speed, pressure and flow velocity and are used to minimise waste from material damaged by shear friction forces.

Differential pressure systems are used to monitor levels in storage or processing vessels. This minimises material loss from overflow or production downtime due to lack of stock. They can also be used to monitor pressure drop across filters, to control cleaning cycles and to optimise operation.

**Examples**

*Fruit Juice* – The differential pressure across filters is monitored and a cleaning cycle is initiated as required.

*Dairy* – Used in monitoring and controlling the flow velocities in pipelines (via pump control) to avoid friction damage to product.

*Brewery* – Used in monitoring and controlling the sparge water pressure for mash filters.

### 4.3.8.4 Level measurement

Level detecting sensors indicate whether or not a media is present at a specific point in a vessel.

These sensors prevent storage overflow of materials and associated wastage from storage or reaction tanks; minimise waste from transfer losses in inaccurate batch recipes in vessels; and minimise out-of-date stock or production losses due to insufficient material.

**Float Valves are relatively cheap and effective, but can be easily damaged.**

| CASE STUDY – Vegetable processing |
|---|
| • Float Valves were used in a large vegetable-processing company to control the transportation of vegetables. Savings were over GBP 15000 per year in reduced water costs, effluent charges and operator time.<br>[Enviros (UK), 2000 #11] |

Mechanical indicators and float switches give direct level readings

Capacitance level switches indicate whether or not the metallic probe of the measurement system is immersed in liquid in a vessel. They can also detect the interface between two different liquids. This property is commonly used in CIP systems to accurately detect the water/product interface to minimise product loss to drain.

| CASE STUDY – Soft drink and beverages (beer) |
|---|
| • The vessel that separated the beer from dead yeast cells accounted for 80 % of beer losses. Clear beer was run off using a fixed standpipe and the bottom phase discharged to drain. The clarity of beer varied with beer type and therefore the use of a fixed pipe resulted in varying losses of beer to drain. The solution was to drain off the yeast, until a capacitance level switch at low level in the vessel detected the interface. The beer was then run-off to storage and the residue discharged to drain. The reduction in beer losses and effluent charges alone totalled GBP 800000 per year.<br>[Enviros (UK), 2000 #11] |

Vibrating level switches require little maintenance. Typical applications include viscous sauces or mixtures, e.g. wet yeast in brewing.

Hydrostatic devices are popularly used in the food and drink sector. They work by converting the static pressure of a liquid head acting on a diaphragm into an electrical signal. They are not suitable for applications where solids can build up on the diaphragm and for materials held constantly above 100 °C, as their accuracy is reduced.

Ultrasonic sensors use a non-contact reflection technique to measure volume. This makes them suitable for hygienic applications. However, surface foaming can affect accuracy.

Microwave Devices are similar to ultrasonic devices, but can be used in more extreme process conditions, as process temperatures, pressure and vacuum do not affect them. However, surface foaming can affect the accuracy.

#### 4.3.8.4.1 Installation of level sensors

Switch points – a vibrating fork system is installed as low in the vessel as possible to ensure that a low switch point is achieved. With high-level float switches, the float is placed so that process fluids do not overflow continuously.

Hydrostatic sensors – an isolating valve is essential for hydrostatic level sensors installed directly in a vessel. This enables the unit to be removed for cleaning and maintenance, without effecting the process.

Reflection-based sensors - the sensor mounting arrangement can affect the quality of the reflected echo and various factors must be taken into account when installing them.

### 4.3.8.5 Flow measurement

Flow measurement and control techniques can reduce material waste and effluent generation in food and drink processing.

Flow measurement and control used in transfer lines will allow accurate addition of materials to processing vessels, thereby minimising excessive use of materials and formation of out-of-specification products. In steam supplies, it will help maintain correct operating temperature, thereby minimising waste from under-heated or overheated materials and products. In cleaning systems, it will control and optimise water use, thereby minimising effluent generation.

---

**Examples**

- Application:

*Soft Drinks and Beverages* – Flow measurement and feedback control are used for raw material addition.

*Bulk solids* – Used in determining the flow of potato crisps to a flavour drum to ensure correct ratio of flavouring.

*Milk powder* – Flow measurement is used for accurate batching of ingredients into the process as specified in recipes.

*CIP* – Flow measurement is used to ensure a fixed volume of water issue for each cleaning stage.

- Techniques:

Cleaning-In-Place (CIP)

Raw and Finished CIP are associated with substantial losses of raw milk. These unavoidable losses can be partly due to the processing plant configuration and/or the control system inflexibility.

The control of clean and purge interfaces is worthy of serious attention. This area alone contributes to significant losses. By utilising flow or conductivity control, water/milk interfaces are accurately detected to minimise the amount of raw milk lost to drain.

CASE STUDY – Optimisation of CIP in dairy

- A dairy site processing 3000 $m^3$ of raw milk a week saved 0.2 % on waste milk by optimising water/milk interface through flow meters and conductivity probes. The final site effluent COD reduced from 3100 mg/l to 2500 mg/l. Raw milk and effluent saving were GBP 88640 per year.
  [Enviros (UK), 2000 #11]

CASE STUDY – Vegetable processing

- Manual flow control valves installed on the water supply to the conveying system enabled operators to set the optimum flow, which resulted in a saving of GBP 18000 per year.
  [Enviros (UK), 2000 #11]

Variable Area Flow Indicator (rotameter) – provides a low cost local indication of flow rate measured by the movement of a float within a tube in the system. It is only suitable for low flows and does not provide an associated control.

Positive Displacement meters – highly accurate and can provide both a local indication and a control signal.

CASE STUDY – Ready made meals

- A positive displacement meter installed for the measurement of cleaning water showed actual consumption was not related to production levels. This led to improved cleaning procedures and a reduction in water use and effluent costs, thereby saving the company GBP 3000 per year.
  [Enviros (UK), 2000 #11]

Turbine meters – are reliable instruments when used with low viscosity liquids, such as milk, beer and water. These meters have the advantage of being able to be cleaned in situ and are relatively low cost, offering accuracy +/- 2 %.

Electromagnetic meters - these meters are ideal for use in hygienic applications as there is no physical contact between the meter and the material. They can be used to monitor a range of flows, from milk to rice pudding. The meters can be cleaned in place, are able to withstand high temperatures (up to 180 °C) and can provide a control signal. They are high cost and usually used on product lines for high accuracy monitoring.

CASE STUDY – Confectionery

- To reduce the variation in chocolate coating of a confectioner's products, an electromagnetic flow meter and a control valve were installed. This resulted in a 10 tonne per year reduction in chocolate usage and a saving of GBP 15000 per year.
  [Enviros (UK), 2000 #11]

Ultrasonic transit time meters – To obtain accurate readings, the pipe must be full and the media relatively clean and free of air bubbles. The signal produced can be used to indicate flow rates and for control purposes.

Vortex shedding meters – are suitable for measuring steam and low viscosity liquids. They can monitor flow over a wide range and provide a linear output signal. Also, they are easy to install and their maintenance requirements are low.

Differential pressure meters – are suitable for measurement and control of relatively constant flow rates and are commonly used where high pressure and temperatures are required, for example to monitor boiler feed water. Although robust, the accuracy of the meter decreases with wear or deposition at the orifice.

Installation requirements for flow measurement – To reduce contamination, flow meters are easy to clean and robust. In processes where fluids may solidify at low temperature, heat tracing may be required to ensure that it does not solidify in or around the equipment. To ensure that the meters read accurately, they must be positioned correctly, this will be dependent upon the type of meter, for example rotameters are mounted in vertical pipelines.

#### 4.3.8.6 Analytical measurement

To minimise wastage and to check the quality of materials, the pH, conductivity and turbidity of a range of fluids are commonly checked in-line. For example, pH sensors can be used to control additions of acid or alkali to reaction vessels, therefore minimising the waste resulting from overdosing of raw materials and the production of out-of-specification product. Conductivity sensors can be used to monitor levels of dissolved salts prior to water re-use to minimise freshwater use and effluent volumes. Turbidity sensors can be used to monitor the quality of process water and CIP systems and will therefore both minimise effluent from out-of-specification products/process water and optimise re-use of cleaning water.

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**Examples**

- Applications:

*Dairy* – The pH of milk deliveries are checked to minimise losses caused by mixing unsuitable milk with other raw materials

*Jam Production* – The gelling point is identified through pH measurement.

*General (Bottling)* – Caustic used in bottle-washing treatments is monitored with conductivity.

*General (Product Recovery)* – Turbidity monitoring of process waste streams is carried out to determine viability for recovery.

*General (CIP)* – Conductivity monitoring is carried out for plant valve control and is based on differences between products, i.e. the difference between beer and water.

- Methods:

pH probes – The measurement of pH is very important in many applications in process control, for example, in controlling product quality (e.g. milk and infant food quality), waste quality (e.g. effluent for treatment) and for process monitoring purposes (e.g. cheese ripening and fermentation processes).

A large number of probes are available. These can be either fitted in a process line or manually dipped into tanks or storage vessels (must be hygienically carried out).

Conductivity – electrode cells – These measure the concentration of ions in a fluid and therefore help determine water purity or the concentration of liquids. They are often used for monitoring process water for re-use (thus minimising effluent generation) and monitoring boiler water quality levels.

| CASE STUDY – Dairy |
|---|
| • Taw Valley Creamery installed conductivity meters on all CIP sets to optimise detergent use. The result was a 15 % reduction in detergent and shorter cleaning times.<br>[Enviros (UK), 2000 #11] |

Conductivity – inductive sensors – These are suitable for hygienic applications as they use non-contact sensors. The units have a greater range than electrode cells and are commonly used in CIP, bottle-washing systems and for product monitoring in the soft drink and beverage sub-sector.

Turbidity – scattered light devices – This method is recommended for use for low to average turbidity readings. To reduce incidents of contamination, sampling devices are used when it is difficult to install a turbidity meter into a process line.

| CASE STUDY – General food manufacturing |
|---|
| • During a food manufacturing process, product was lost to drain during the separation stages and resulted in a breach of the company's effluent discharge consent. The installation of a hygienic turbidity meter and a flow meter resulted in reduced product losses to drain, increased product yield, lower effluent treatment costs and savings of over GBP 100000 per year.<br>[Enviros (UK), 2000 #11] |

Turbidity (suspended solids) – this method is suitable for measuring medium to high levels of turbidity.

| CASE STUDY – Dairies |
|---|
| • Taw Valley Creamery saved GBP 16000 per year by installing a turbidity switch, which enabled whey, which was previously lost when equipment was taken off-line for CIP, to be recovered.<br>[Enviros (UK), 2000 #11] |

#### 4.3.8.7 Process controllers/transmitters

Limit detectors or continuous transmitters are commonly used in the food and drink sector to receive data from measurement devices and/or to compare measured data to a set point and/or to transmit a signal to a control device, such as an actuated valve.

Limit Detectors – Typically used to change the position of an on-off valve and to switch a pump or agitator on or off.

Continuous transmitters – These can be complex systems. They are usually designed by equipment suppliers to control whole process units, for example a CIP system.

#### 4.3.8.8 Control devices

In both manual and automatic control systems, a device must be used to control flow, the most common device used is the valve.

Manual control devices – Globe and angle valves, needle control valves, butterfly valves and weir diaphragm valves are all used for the manual control of liquid flow rates. The basis for valve selection is accuracy requirements, the viscosity of the liquid and the solid content. Needle control valves, for example, are the most accurate, allow sensitive flow adjustments but are best suited to low viscosity liquids with minimal solid content.

| CASE STUDY – General food manufacturing |
|---|
| • The installation of constant flow valves, to control flow rate to water ring vacuum pumps in a food manufacturing company, reduced excessive water and effluent costs by GBP 70000 per year.<br>[Enviros (UK), 2000 #11] |

Fixed control devices – Restricting orifice plates fitted into a pipeline provide a constant flow, but they must be maintained to prevent erosion and increased flow rates or to prevent solid deposits which can reduce the orifice and flow. Flow regulators are adjustable devices that provide a constant flow.

| CASE STUDY – Meat processing (chicken) |
|---|
| • Excessive water use led to flow regulators being installed to fix process water flow rates for specific processes. The result was a saving of over GBP 10000 per year.<br>[18, **Envirowise (UK)**, 1999] |

Solenoid actuated valves - These are low cost control techniques used throughout the food and drink sector, particularly for the control of process water.

| CASE STUDY – Fish processing |
|---|
| • A solenoid system on the water supply to a pre-wash system enabled the supply to be closed off when the conveyor was not in use and produced a saving of GBP 2500 per year.<br>[18, **Envirowise (UK)**, 1999] |

Automatic control valves – provide automated, accurate and variable control of the flow rate.

Other devices – Pumps can be controlled by monitoring devices, for example, to control material transfer. Some monitoring devices are available which will indicate abnormal process conditions and will sound visual and audible alarms. Rapid response to these alarms can prevent product loss and prevent wastage from occurring.

### 4.3.9 Storage and handling

Raw materials and chemicals are usually stored and handled before use in the plant. Final products are also stored and transported at plant premises.

All food and drink products are stored and distributed in appropriate conditions to ensure that they remain fit for consumption in line with their ‘best before’ or ‘sell by’ date. Unsuitable storage and distribution conditions can result in product spoilage and wastage.

Losses can occur, these are occasionally associated with poor storage and materials handling. Product losses or spillages are common in warehouses and are usually caused either by poorly trained or motivated staff (for example, fork lift truck drivers) or by poorly designed warehouse (for example, racking may be poorly designed for use with a fork lift truck). These losses may be real losses or just perceived losses, i.e. due to inaccurate meters, spillages, inaccurate billing or changes in product volume due to temperature changes.

Raw materials arriving on site need to be measured and fully accounted for. To achieve this:

- meters are fitted and regularly calibrated
- conversion factors are used to take account of changes in volume due to temperature
- billing data are checked
- a mass balance is carried out
- yields are calculated and benchmarks set. The specific yield shows the quantity of product produced per unit of raw material consumed. The relative yield is the percentage of raw material converted to product.

### 4.3.9.1 Containment of emissions

Some examples of methods used to contain emissions are given below [Enviros (UK), 2000 #11]:

- dedicated area for bulk tanks, enclosure and storage of materials within a suitable building
- closed storage and transfer systems for dusty materials etc.
- bunding of tanks
- over ground pipelines and transfer lines
- overfilling protection on bulk storage tanks
- prevention of rain ingress, wind entrainment etc. for stored materials
- heat recovery to be used where practicable
- local extract systems as appropriate, e.g. drier unloading; separators etc.
- condensers on all appropriate process equipment, e.g. evaporators etc.

#### 4.3.9.1.1 Particulate emissions in the transhipment, storage or processing of solids

Handling of dust-producing goods is a characteristic feature of many systems in the food industry.
Systems in which solid substances are loaded or unloaded, conveyed, transported, processed, treated or stored may need to meet appropriate emission reduction requirements if such substances may give rise to particulate emissions as a result of their density, particle size distribution, particle shape, surface condition, abrasion resistance, shear and fracture resistance, composition or low moisture content.

When defining such requirements, special attention needs to be paid to the following points (having regard to the principle of proportionality) [65, Germany, 2002]:

- the nature and properties of the solids and their constituents (e.g. hazardous or toxic properties, possible impacts on soil and water, dust formation, moisture content)
- the handling equipment or method of transhipment
- the mass flow rate and duration of the emissions
- the meteorological conditions
- the location of the transhipment facility (e.g. distance from residential buildings).

When defining the measures, their possible impact on water and soil must also be taken into account.

#### 4.3.9.1.2 Control of dust during loading and unloading

When defining the requirements for loading and unloading, the following measures can be considered:

Measures relating to the transhipment method:

- minimising the falling distance when dumping (e.g. by means of guide plates or fins for chutes)
- automatic drop height adjustment where pouring height varies
- adjustment of equipment to the individual bulk material (e.g. avoiding overloading with consequent spillage in transit in the case of grabs)
- gentle movement of grabs after filling
- returning empty grabs to closed condition
- minimising tidying and cleaning work
- automating transhipment operations.

Measures relating to the transhipment equipment:

- regular maintenance of equipment (e.g. checking that grab edges meet properly to avoid trickling losses)
- using totally or largely enclosed grabs to avoid or reduce wind losses from the surface of the material
- minimising adhesion (especially on grabs or, for example, use of smoothable loading bellows in vertical loaders/telescopic tubes)
- pouring tube with loading head and extraction
- conical top with extraction system for vertical loaders
- reducing exit speed from down pipes by means of baffles or by using cascaded chutes
- largely avoiding the use of thrower belts outside closed rooms
- using loading shovels as far as possible only for moist or non-dusty materials.

Measures relating to the transhipment site:

- complete or almost complete enclosure (e.g. doors or strip curtains for entrances and exits) of equipment for loading and unloading vehicles (e.g. filling units, pouring gutters, trench bunkers and other discharge points)
- extraction from hoppers, transfer points, chutes, loading pipes (adequate dimensioning of suction capacity)
- improving the effect of extraction facilities (e.g. by means of guide plates)
- using hoppers (e.g. with lamellar shutters, floor traps, swing flaps, lids etc.)
- use of water mist outside exit apertures and feed hoppers
- wind protection for outdoor loading and unloading operations
- increasing grab residence time at the discharge point after discharging
- restrictions on transhipment when wind speeds are high
- planning the position of the transhipment point within the factory site.

Measures relating to solid materials:

- increasing material moisture content, possibly with the addition of agents to reduce surface tension, in cases where moisturising does not conflict with the needs of subsequent further processing, storage or the product quality of the substances transhipped
- using dust binding agents
- pelletising
- standardising particle size (separating finest fraction)
- preventing bulky impurities
- minimising transhipment operations. [65, Germany, 2002]

#### 4.3.9.1.3 Control of dust while conveying or transport

Enclosed receptacles (bulk carriers, containers, tarpaulins) are used for vehicular transport. Closed or largely closed equipment are otherwise used for materials handling and transport within the factory site (e.g. enclosed conveyor belts, bucket elevators, worm, screw or pneumatic conveyors). In the case of pneumatic conveyors, the dust-laden feed air needs to be recirculated or fed to a dedusting system. Open continuous conveyor/materials handling equipment (e.g. conveyor belts) can be encapsulated or enclosed as far as possible.

When filling enclosed transport containers with solid materials, the displaced air must be collected and fed through a dedusting system. [65, Germany, 2002]

Open transfer points may be humidified, provided this does not conflict with the needs of subsequent further processing, storage or the product quality of the transhipped materials. Alternatively the transfer points are encapsulated and dusty air is fed through a dedusting system.

Openings (e.g. doors, windows) in rooms where solids are openly transported or handled are kept closed as far as possible. Doors are only opened for essential vehicle movements.

If using roads gives rise to particulate emissions, such roads in the vicinity of the facility are to be sealed with a surface of asphalt concrete, concrete or equivalent material, kept in a proper state and cleaned as necessary. Steps must be taken to ensure that deposition of dirt on roads by vehicles after leaving the facility is prevented or eliminated. Tyre washing units, sweeping machines, road grids or other suitable equipment can be used for this purpose.

#### 4.3.9.1.4 Control of dust during storage

Enclosed storage

When defining storage requirements, preference is always given to enclosed types (e.g. silo, bunker, warehouse, hall, container). Where storage is not completely enclosed, dust formation, especially in the case of walk-in storage facilities, may be minimised by appropriate design of the geometry of the storage containers or facilities and the equipment used for depositing or withdrawing the stored material. Waste gases from filling or extraction units and displaced air from containers must be collected and passed through dedusting systems. All filling systems are equipped with safety devices to prevent overfilling. For example, folding bellows with combined extraction and conical closure can be used for emptying or for the dust-tight closure of silos and containers; similarly cellular wheel sluices can be used in conjunction with a belt discharge or pneumatic handling. [65, Germany, 2002]

Outdoor storage

When defining requirements for the creation or removal of tips or the operation of levelling equipment in the open, the following measures may be considered:

- covering the surface (e.g. with mats)
- growing grass on the surface
- spraying with dust-inhibiting agents when creating the tip
- stabilising the surface
- ensuring adequate material moisture content of the tips and the transfer and discharge points, possibly with the addition of agents to reduce surface tension, in cases where moisturising does not conflict with the needs of subsequent further processing, storage or the product quality of the substances stored
- discharge or removal behind embankments
- adjustable-height conveyor belts
- planting windbreaks
- aligning the long axis of the tip with the main wind direction
- limiting the height of tips
- largely refraining from deposition or removal operations under weather conditions that are particularly favourable to emissions (e.g. long dry periods, frost periods, high winds).

By roofing over, or enclosing or a combination of the two, it is possible to convert such storage facilities, including their ancillary installations, into a partially or completely enclosed storage facility. [65, Germany, 2002]

### 4.3.9.2 Separator discharges

Separator discharges (frequency and volumes) are usually specified by the manufactures of the plant. Where this information is known, it is worth checking performance against specification. Once under control it may be possible to reduce the volume or frequency of the discharge action thus minimising wastage. This is an opportunity that needs to be carefully implemented with input from the quality department. [Enviros (UK), 2000 #11]

### 4.3.9.3 Overfilling

The overfill performance on a new filler may be between 0.03 % and 0.1 % overfill. On older machines this can be between 0.15 % and 0.25 %. This can be reduced and optimised by a knowledgeable filler operator. Techniques such as SPC (Statistical Process Control) may be used to monitor overfill and identify when the machinery requires adjustment.[Enviros (UK), 2000 #11]

## 4.3.10 Techniques for waste minimisation in frying

Emissions to air:

- oil recovery to remove entrained oil from exhaust gases
- process control of the crisp frying process to ensure that the frying process ends when the final moisture content is in the critical range of 1 – 2 %
- exhaust gas recirculation to the burner (see Figure 4.7).

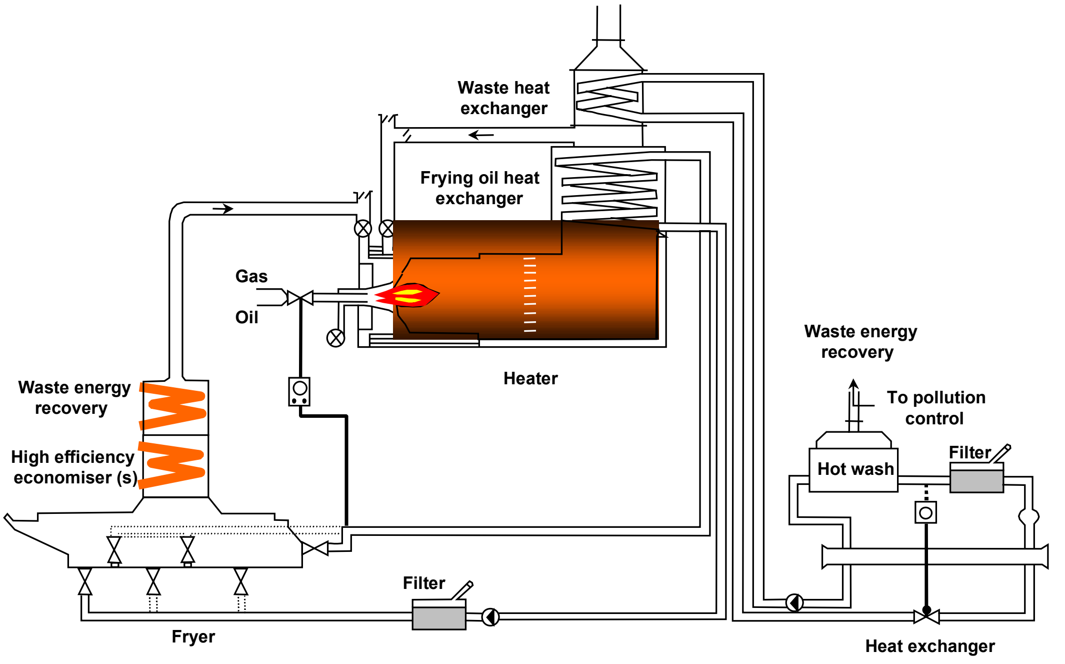


**Figure 4.7: Heat and oil recovery: heat exchangers mounted in the fryer exhaust hood [85, Environment Agency (UK), 2000]**

### 4.3.11 Techniques used in meat processing for waste minimisation

Manufacture of meat mixture (batter)
[41, Nordic Council, 2001]

- Flake ice is often used to cool the meat mixture. By using a suitable mixture of chilled and frozen raw materials it is possible to avoid the use (and thus the production) of flake ice.
- Many raw materials are received or transported/stored in open vats or trolleys. A quantity of meat juice collects in the bottom of such containers. Rather than emptying this juice into the sewer and therefore, increasing the pollution of the waste water, it is used in the manufacturing of processed meat products.
- When meat batter, particularly meat mix for salami production, is left standing in mixers, choppers and fillers, it sticks to the surfaces and make the subsequent cleaning difficult. To minimise the cleaning efforts and the need for water and detergents, such equipment need to be cleaned immediately after the end of production.
- Spices are often used in pre-weighed lots. They are stored in plastic bags, which are discarded after emptying. To minimise the use of plastic packaging materials, spices are dosed automatically from a suitable container.
- Meat batter residues in the sausage department (from choppers, fillers and floors) need, to the maximum practical extent, be manually removed prior to cleaning and sent to the rendering plant.
- The water supply to sausage fillers and similar equipment need to be minimised. The water supply is stopped automatically, when the equipment is not used at breaks or production stops.

Smoking
[41, Nordic Council, 2001]

The quantity of organic compounds in the smoke depends to a large extent on the method of smoke generation. The method influences the emissions from the installation and thus the need for air cleaning. However, it must be pointed out that the product (cold or hot smoked) and the wish for a special smoke aroma, in the product make it impossible to choose freely between different types of smoke. It will not therefore be possible to report an optimal technique. The environmental aspects of different methods of smoke generation will be dealt with briefly in the following paragraphs.

Burning of sawdust produces smoke with a large content of organic compounds. An open or semi-open system is used and a supply of air is necessary, i.e. a surplus of air is used which will require cleaning before it is released to atmosphere. In older types of cold smoking kilns, the sawdust is often burned directly on the floor.

When wood chips are used in the smoke generator, the air supply and thus the temperature is normally higher. More tar compounds are formed and the need for cleaning is therefore greater. Smoke cleaning is also normally required in this case.

In a Norwegian investigation, the control programme for the smoking process was altered to take account of the need for smoke. The smoke generator was thus closed down before the smoking process was completed. This reduced the consumption of wood chips from 8.9 to 3.6 kg per tonne of sausages without changing the product quality.

Pyrolysis of wood chips/shavings can be carried out with superheated water vapour, which transfers the smoke and aroma compounds to the products (steam smoke). This reduces the number of compounds in the smoke; the air surplus can also be reduced to a minimum. As the surplus steam can be condensed, the exhaust is therefore low. Cleaning is eased due to a lower level of deposits in the smoking chamber.

- Friction between wood and a rapidly rotating rough roller creates pyrolysis. As a result friction smoke is produced. The smoke is mild and contains hardly any carcinogenic compounds. The process can be carried out in a closed system with recirculation, so that use of afterburner or other smoke cleaning system is unnecessary (the energy saving is often 50 % of the energy consumption). As a result of the mild smoke, the deposits in the smoking chamber are less than 10 % of the deposits created with wood chip smoke. Cleaning is therefore much easier, and the use of powerful detergents is avoided. There are fewer organic compounds in the waste water, and water is saved due to longer intervals between cleaning.
  [41, Nordic Council, 2001]

Liquid smoke is also described. This is condensed smoke or a smoke aroma which is added to the products. The advantage is that the smoke aroma can be achieved without smoking and therefore the components in the smoke, which are suspected to be damaging to health, are to a large extent avoided. As there is no emission of smoke the need for cleaning will be considerably reduced.

CASE STUDY – Use of liquid smoke to avoid odour problems

- When Vienna sausages are smoked/cooked, emissions of 2 - 3 million odour units per batch have been measured in Denmark from a kiln using a scrubber, and in the order of 100000 odour units from a kiln where liquid smoke was used (unpublished results, DMRI). It can, therefore be suggested that odour could be eliminated by using liquid smoke.
  However, it must be emphasised that liquid smoke results in a smoke aroma which is different from the aroma achieved with conventional smoking; this might not necessarily be acceptable to the customers, on the grounds of taste or smell. It will thus not always be possible to choose liquid smoke for processed meat products.
  [41, Nordic Council, 2001]

Large quantities of tar often collect in kilns or troughs. This material is collected and handled as chemical waste. Tar is not to be removed via the sewer system.

A lot of tar is deposited on smoking sticks. They are best cleaned in a special smoking stick washer (container with drum). The drum is in constant movement to ensure that the sticks rub hard on each other. The water supply is controlled; it is better not to use running water.

Cooking and smoking frames are often cleaned manually with a pressure cleaner. A washing cabinet which collects and recirculates water containing detergents is used. The drain may automatically be changed over to the sewer at the final rinse. As an alternative, a washing tunnel could be used with water from the second stage re-used for the initial rinse.

Energy consumption for the incineration of the exhaust from smoking kilns can be reduced by catalytic incineration and heat recuperation.

Cooling of sausages

CASE STUDY – Nozzles save water in cooling sausages

- Vienna sausages must be cooled after cooking/smoking. This is normally done by showering the sausages in the cooking/smoking cabinet or in a specially designated area. A large quantity of water is often used for this purpose. Quantities in the range of 3.5 $m^3$ per tonne are not rare. Instead of irrigation pipes, it is possible to use water saving nozzles and a timer control. All the water needs to hit the sausages to avoid unnecessary waste.
  [41, Nordic Council, 2001]

Cooling can be carried out as evaporative cooling in cabinets specially designed for the purpose. The sausages can then be sprayed with finely atomised water, the water supply stopped and air then pulled through the cabinet. This causes the water on the surface of the sausages to evaporate. As the surface dries out, a new cycle of water spray and drying is started. The method results in substantial water savings.

Cooling water
Sausages are often vacuum packed. A vacuum packaging machine uses cooling water, often in the order of 0.2 $m^3$ per tonne of sausages. Setting the water quantity and locking the position to ensure that the operative does not alter it may save water. Another possible alternative is to collect and re-use the cooling water.

### 4.3.12 Pigging cuts costs, recovers product and reduces effluent

**[CIAA 2002, #1]**

Summary
This case study illustrates the significant savings (over EUR 380000/yr) achieved by a company by using line pigging to recover valuable product and to reduce water and effluent costs at a preserves factory.

Project Background
Nelsons of Aintree normally makes jam for bulk sale in 2.5 tonne batchs. The cooked jam is held in two high-temperature kettles, before being pumped to holding tanks next to the loading bay (where the batch can be kept warm) and then into a bulk tanker, or cooled for transfer into intermediate bulk containers.

Old Practice and Waste
In addition to cleaning for hygiene reasons, the Company had to clean the pipes and vessels between batchs when colours change. For the bulk production process, the cleaning sequence was:

- water rinse of the whole system
- cleaning-in-place (CIP) vessel wash (sometimes with caustic)
- final water rinse of the whole system.

The whole system rinse involved sucking wash waters, under vacuum, through the pipes between the pulping and evaporator vessels and the kettles, and then using the jam pump to pump the wash water through the pipe run to the tanker bay. As the jam pump was not designed to pump water, each flushing took some time. A large amount of water (5.4 $m^3$ /wash) was also used, typically twice a day.
Saleable product left in the pipe was pushed out by the flush waters to drain. The site effluent thus had high suspended solids (SS) and chemical oxygen demand (COD) levels, making it expensive and potentially damaging as a discharge to sewer.

Description
The Pigging System

Following an assessment of available systems by the Engineering Manager and an on-site demonstration by one supplier, a new pigging system was purchased for the bulk line and commissioned in March 1999. Installation and operator training were carried out on-site with assistance from the supplier.
The new simple, inherently safe system included launchers, catchers, compressed air equipment and a new in-line valve to allow the pig to pass through the system.
One-piece rubber pigs, made from food grade rubber, are propelled from the launcher using compressed air and stopped at the other end of the pipe by a bar that allows jam to pass, but not the pig. The pig is returned to the launcher by using a valve to switch the direction of the

compressed air. A window at either end of the pipe allows the pig to be seen by the operator. The pig is used between each batch, with additional system rinses being carried out when colour cross-contamination occurs. Occasional caustic CIP washes are used for hygiene reasons. Regular checks made in Nelsons' own laboratory show that the new system did not compromise hygiene standards nor affect product quality.

Achieved environmental benefits and economics
Jam used to be wasted between batchs on the bulk line. Following installation of the pigging system there was an increased batch yield of jam. This resulted in some 173 tonnes of saleable product being recovered annually. The amount of mains water used to flush the bulk pipeline fell from 2020 $m^3$ /yr to 310 $m^3$ /yr

Effluent volumes from the bulk line decreased by the same amount. The reduction in average COD levels for the site effluent, from around a peak of 25000 mg/litre to around 5000 mg/litre, meant that unit costs fell by over 76 %, from EUR 12/$m^3$ to EUR 2.83/$m^3$. Although pigging is the most significant reason for the reduction in COD levels, Nelsons believe that there is also a significant contribution from the vacuum cleaning of sumps, gulleys and food traps. The pigging system required virtually no maintenance during the first year and no new pigs were needed. However, due to wear and tear of the pigs, Nelsons expect to replace a maximum of two a year. Energy consumption fell by around 680 kWh/yr because the compressed air mechanism required less energy than the old pumping arrangements.

| **Item** | **Savings** | **Annual savings (EUR)** | | **Annual costs (EUR)** |
|---|---|---|---|---|
| Reduced effluent COD and volume | 76 % | 167000 | | |
| Recovered product | 173 tonnes/year | 217000 | | |
| Reduced water use | 2020 $m^3$/yr | 2000 | | |
| Reduced energy consumption | | 48 | | |
| Gulley cleaning, etc | | | | 6200 |
| Replacement pigs (two/year) | | | | 180 |
| Total | | 386500 | | 6380 |
| Net cost savings | | | 380120 | |
| Total capital cost | | | 30800 | |
| Payback period | | | 4.2 weeks | |

**Table 4.4: Environmental benefits and cost reduction using pigging systems**
**[57, Envirowise (UK), 2000]**

Nelsons recently installed three further pigging systems on other non-bulk manufacturing lines. Substantial cost savings are expected, together with a further reduction in COD, hopefully below the site target.

Cross-media effects

Operational data
Line cleaning takes slightly less time with the pigging system than with the old system.

Applicability

Driving forces for implementation
To recover valuable product and to reduce water and effluent costs.

Example plant
Nelsons of Aintree, Liverpool, UK

Reference literature
[57, Envirowise (UK), 2000]

### 4.3.13 Improved operation procedure in yoghurt production – a case study

**[CIAA 2002, #1]**

Description
In a Dutch dairy, to reduce product loss and water consumption, the dairy modified its process by allowing each batch to drain out and then mixing the remaining product with the next batch.

Achieved environmental benefits and cost savings
Only 50 litres of "mixed" product had to be sold as cattle feed, compared to 110 litres ending up as waste water in the former situation.

By not rinsing between batchs the following results were achieved:

- product recovery 12500 litres/year, cost savings EUR 5000
- reduction of waste water treatment costs EUR 2300
- reduction in water charges EUR 900.

Cross-media effects

Operational data

Applicability

Economics
The dairy saved EUR 8200 per year with no capital investment or loss of product quality.

Driving forces for implementation
Rinsing after each batch of yoghurt was resulting in significant product loss and an over-consumption of water.

Example plants

### 4.3.14 Confectionery

**[CIAA 2002, #1]**

Description
A simple adjustment of a machine speed enabled savings to be made in the loss of product with less packaging, reworking and waste disposal.

Achieved environmental benefits

Cross-media effects

Operational data

Applicability

Driving forces for implementation
A UK sweet manufacturer monitored its packing lines performance and discovered that an inappropriate machine speed was causing inaccurate weighing of the product and failure of the heat sealing equipment.

Economics
Savings to the tune of over EUR 190000 per year were made. Other benefits were an increase in production and a 500 tonnes per year reduction in waste to landfill.

Example plants

Reference literature
[Enviros (UK), 2000 #11]

#### 4.3.14.1 Soft drink and beverages (beer)

**[CIAA 2002, #1]**

Description
The vessel that separated the beer from dead yeast cells accounted for 80 % of beer losses. Clear beer was run off using a fixed standpipe and the bottom phase discharged to drain. The clarity of beer varied with beer type and therefore the use of a fixed pipe resulted in varying losses of beer to drain. The solution was to install a capacitance level switch that could detect the interface between two different liquids.
The new procedure involved draining off the yeast, until the capacitance level switch situated at low level in the vessel detected the interface. The beer was then run-off to storage and the residue discharged to drain.

Achieved environmental benefits

Cross-media effects

Operational data

Applicability

Economics
The reduction in beer losses and waste water discharges totalled EUR 1290000 per year.

Driving forces for implementation
Reduction in product loss

Example plants

Reference literature
[Enviros (UK), 2000 #11]

### 4.3.15 Effluent reduction at a dairy in England

**[CIAA 2002, #1]**

Description
The dairy processes 1.2 million litres of milk per week, producing around 200 tonnes of yoghurt and 15 tonnes of cottage cheese per week. The balance of the milk is used for pasteurised and UHT milk and cream production. Effluent is discharged to a municipal treatment plant with consent (acceptance) standards of 1130 kg COD per day, and volume consent of 450 $m^3$ per day, both of which were exceeded frequently.

The own waste water treatment plant, which had previous only settled effluent prior to discharge to sea, was upgraded to full treatment and, as a result, the dairy faced new effluent treatment costs of EUR 500000/yr.

A major effluent control exercise was instigated, with all employees briefed on the implications of the new charges. All the staff were involved in completing the following actions:

1. for cottage cheese, the whey was already collected for animal feed, but the number of tanks installed was increased to allow for the collection of curd wash water and yoghurt residues, also each tank was fitted with high level alarms
2. yoghurt pipelines were modified by incorporating 135° bends to improve drainage
3. drainage times on emptying yoghurt vats were increased by 5 minutes
4. burst rinsing was introduced for yoghurt vats, with all rinsings collected for animal feed
5. a requirement to collect all the drainings of yoghurt and fruit throughout the dairy, for use as animal feed, was more rigidly enforced.

Achieved environmental benefits and reduced costs
As a result of these initiatives, average COD discharges were reduced to 450 kg/d, volumes were brought into consent limits at around 420 $m^3$/d and effluent treatment charges of around EUR 125000/yr were achieved.

Cross-media effects

Operational data

Applicability

Economics
Savings in effluent treatment charge with very little investment costs. Additional effluent treatment charges of around EUR 125000 per year were actually needed instead of the forecasted EUR 500000 per year expected without modifications in the technology.

Driving forces for implementation

Example plants

### 4.3.16 Focus on waste makes the difference – a case study

**[CIAA 2002, #1]**

Description
In 2000, Pedigree Masterfoods started a focused project at one UK site to significantly reduce the amount of solid waste generated and subsequently the associated environmental impact. The first priority was waste prevention by using the raw materials more efficiently, but in parallel with waste separation to recycle more materials of the mixed waste stream.
The opportunity Pedigree had was that it was just about to embark on a number of significant asset changes. The significant cost reduction potential was a good fillip to invest money and start the project.

The project was set a challenging target of reducing the amount of mixed solid waste fraction by 50 %.

Previously Pedigree had attempted to tackle waste by latching waste issues onto the shift team responsibilities or as part of the quality team objectives. A big part of the actual step change achieved was due to forming a new team focussed purely on the reduction of waste, this ensured that the focus on waste was maintained regardless of other issues in the company. It also sent out a clear message that it was something that the business took seriously.
The team got involved in the design of a new pet food line that needed to replace older factory assets. This ensured that right from the design stage the engineers were looking at ways of waste reduction.
Daily communication was displayed prominently in the factory on a ‘waste-o-meter’, showing how workers were doing against the daily target, what the causes of the waste were and what actions were in place to prevent further waste. A weekly report was also sent to senior management so that they could show leadership on waste when talking to their teams.

A simple system was set up whereby any incident that created over 2 tonnes of waste was logged by the operators, an investigation carried out and actions put in place to prevent re-occurrence.

Achieved environmental benefits

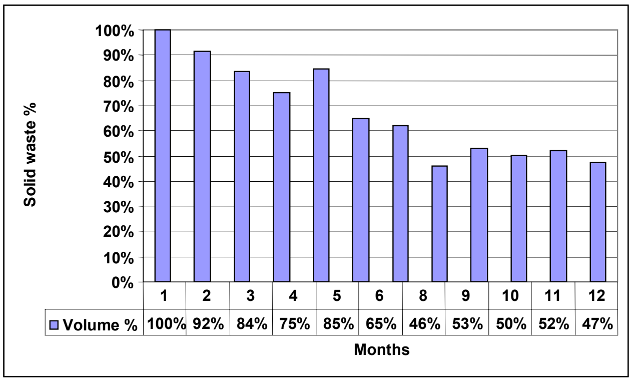


**Figure 4.8: Waste reduction in animal feed production**
**[1, CIAA, 2002]**

As can be seen from the graph, the 50 % reduction in waste was achieved in month 8 and has been maintained since. The environmental impact was significantly reduced and they achieved very significant cost reductions by reducing the loss and waste of raw materials.
Having to deal with less waste also improved the hygiene and safety of the waste disposal area. Some simple actions and focus therefore delivered significant cost savings in an 8-month period. Since then waste levels have stayed flat so the challenge for the company now is how to re-apply the focus so a similar reduction can be made in the following year.

Cross-media effects

Operational data

Applicability

Economics

Driving forces for implementation

Example plants

### 4.3.16.1 Vegetable oil degumming enzyme – a case study (Cereol, Germany)

**[35, OECD, 2001]**

Description
As mentioned before, physical refining offers lower costs, higher yields and less chemical use for refining crude vegetable oils. A prerequisite for physical refining is a low phosphatide content in the oil entering the final deacidification/deodorisation stage. The content of phosphatides is reduced in the degumming step. Degumming can be made by enzymatic hydrolysis of phosphatides. The enzyme pospholypase $A_2$ catalyses the splitting of the fatty acid ester under mild conditions. The liquid enzyme is dispersed into the oil at 60 °C and pH 5 (citric acid and caustic soda work as a sodium citrate buffer). To increase the low reaction rate of the enzymatic reaction, a battery of continuous stirred reactors is applied. The resulting lysolecithin molecule is water soluble and can be separated by centrifugation.

Achieved environmental benefits

The EnzyMax® process uses considerably reduced amounts of caustic soda, phosphoric and sulphuric acids, as well as water. The conventional method produces a waste water stream of about 3200 kg/h, which also contains sulphate and phosphate, compared to about 400 kg/h waste water for the EnzyMax® process. In addition, the amount of sludge is reduced by a factor of about 8.

| **Resource** | | **Consumption (units/t of crude oil)** | |
|---|---|---|---|
| | | Conventional method | EnzyMax® degumming |
| Caustic soda (100 %) | kg | 5.3 | 0.43 |
| Phosphoric acid (75 %) | kg | 2.0 | - |
| Sulphuric acid (96 %) | kg | 5.3 | - |
| Soft water | kg | 127.8 | 10.76 |
| Steam | kg | 95.5 | 28 |
| Cooling water | $m^3$ | 1.5 | - |
| Electric power | kWh | 7.7 | 7 |
| Citric acid | kg | - | 1.0 |
| Enzyme solution | kg | - | 0.014 |
| Total | | | |

**Table 4.5: Consumption figures for conventional and enzymatic degumming of vegetable oil [35, OECD, 2001]**

Cross-media effects

Introduction of the enzymatic substance reduced not only the use, and consequently the emission of chemicals but also resulted in water and energy savings.

Operational data

Operational problems were observed after the start of production. Emission limit values were achieved within a quarter of a year, whilst costs were reduced significantly by having a novel phospholipase of improved features.

Applicability

Economics

| **Resource** | | **Specific cost** | **Total cost** | |
|---|---|---|---|---|
| | | | Conventional | EnzyMax® |
| | | (USD/unit) | (USD/t oil) | (USD/t oil) |
| Caustic soda (100 %) | kg | 0.6 | 3.18 | 0.26 |
| Phosphoric acid (75 %) | kg | 0.672 | 1.34 | - |
| Sulphuric acid (96 %) | kg | 0.075 | 0.39 | - |
| Soft water | kg | 0.013 | 1.66 | 0.14 |
| Steam | kg | 0.09/0.013* | 1.24 | 0.36 |
| Cooling water | $m^3$ | 0.09 | 0.69 | - |
| Electric power | kWh | 0.09 | 0.69 | 0.63 |
| Citric acid | kg | 1.87 | - | 1.87 |
| Enzyme solution | kg | 143.75 | - | 2.01 |
| Total | | | 9.19 | 5.27 |
| * Difference due to different steam pressure | | | | |

**Table 4.6: Costs of conventional and enzymatic degumming of vegetable oil [35, OECD, 2001]**

Driving forces for implementation

The aim was to cut costs.

Example plants
EnzyMax® was developed by Lurgi Öl Gas Chemie. The enzyme is supplied by Novozymes. The technique is used by Cereol, in Mannheim, Germany.

#### 4.3.16.2 Minimising P emissions into waste water by using citric acid instead of phosphoric acid for separating phospholipids

**[65, Germany, 2002]**

Description
In view of the market situation it is not always possible or economically justifiable to purchase raw materials with the desired low content of organically bound phosphorus. However, unrefined vegetable oils and fats may contain up to 300 ppm phospholipids (lecithin). These are not all hydratable, i.e. they cannot all be swollen with water and thereby made separable. The market demands a P content of <5 ppm in the refined oil.
Targeted lecithin separation may be undertaken by means of acid treatment, which also makes the remaining phospholipids hydratable. These can be very effectively separated by means of special centrifuges.

Usually phosphoric acid is used to convert the phosphatides. This can result in considerable waste water loads of phosphorus. It is therefore necessary, in view of the special conditions at the location, to use citric acid instead of phosphoric acid.

The following diagram shows the process flow.

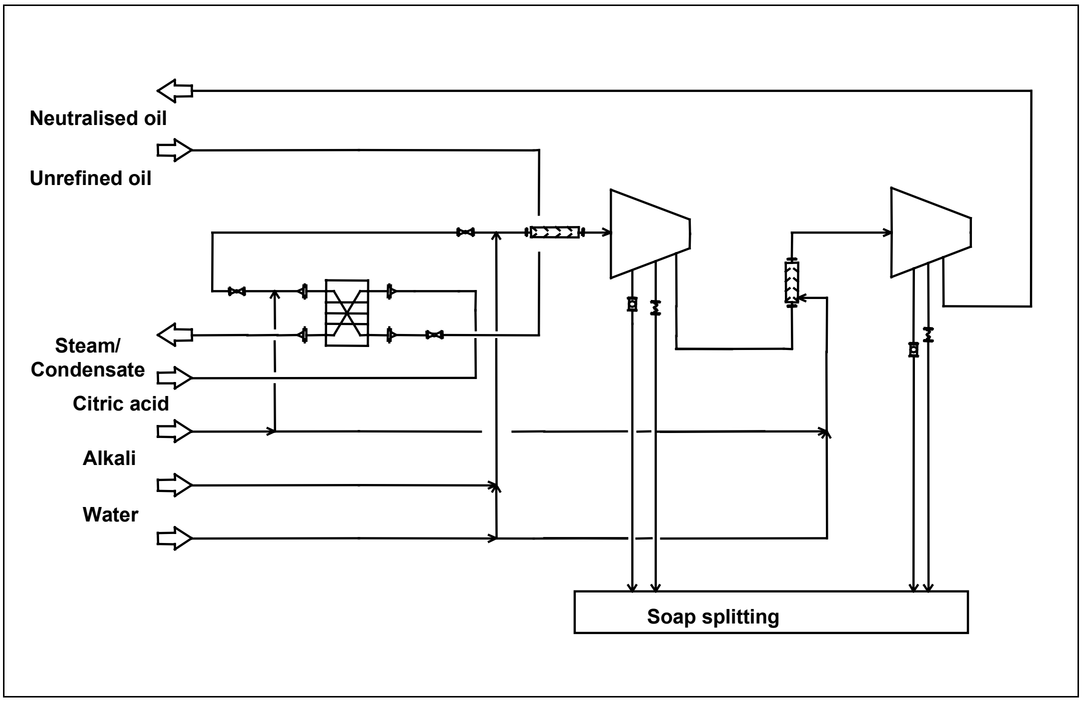


**Figure 4.9: Vegetable oil refining with citric acid**
**[65, Germany, 2002]**

Achieved environmental benefits
No changes in waste water produced.
More than 50 % reduction in phosphorus load in waste water (depending on product portfolio).

Applicability

| | |
|---|---|
| Area of application: | universal |
| Restrictions: | none |
| Operating reliability: | very good |
| Availability: | very good |

Cross-media effects
Increased COD emission due to citric acid. Using 1 kg citric acid results in a COD output of 0.75 kg into the waste water.

Economics
- reduction in costs due to lower waste water levy
- increase in costs due to citric acid, which costs 2 to 3 times more.

Driving force for implementation
More stringent official requirements with regard to waste water quality.

Reference literature
BOCKISCH, M: Nahrungsfette und –öle, Verlag Eugen Ulmer, 1993, ISBN 3-8001-5817-5

## 4.4 Waste management

A large part of the food and drink industry cannot operate without a substantial amount of good quality water. Without sufficient good quality water it is impossible to produce high quality food products. Since water is such an important material for the food and drink industry, a lot of attention is, or should be, paid to the supply of the water and its quality. Taking into account that water supply is not an unlimited source, it is also necessary to reduce water consumption as far as possible. This is an important aspect of the conservation of natural resources. However, in the food and drink industry food safety is paramount and takes precedence over all conservation issues.

Any programme set up to look at the use of water or reduction in water consumption requires a systematic approach, i.e. water management.
The objective of this section is to provide guidance on how to control water usage in a plant and how to minimise water consumption to a realistic level. Furthermore, the framework for setting up a water management system is given. Case studies will be used to demonstrate successful water saving measures.

### 4.4.1 Various water uses in the food and drink industry

In the food and drink industry the following types of water can be distinguished: process water, cooling water and boiler feed water.

#### 4.4.1.1 Process water

Process water can be defined as water which can come into contact with the food product either directly or indirectly, or water used for technical purposes, which can in some way or another affect the quality of the food products.
In the food and drink industry process water is, for example, used for:

- direct preparation of products or other direct contact with products
- cleaning and disinfection
- regeneration of water treatment equipment
- various technical purposes.

(a) Water in direct contact or for direct preparation of food products

Examples of this water are:

- water used for starting up continuous process lines like pasteurisers, evaporators, etc.
- water used for flushing-out the product from the process equipment at the end of a production run
- water used for washing raw materials and products
- water used for dissolving ingredients
- water used in the production of drinks.

In principle, in all these cases, water must be of drinking water quality.

(b) Water for cleaning and disinfection

Most cleaning operations consist of various steps, for which in principle, water of varying quality can be used. The main steps are pre-rinsing with water, cleaning with cleaning agents, post-rinsing with water and disinfection. Water is also needed for cleaning of the outside of equipment and walls and floors
Water, which can come into contact with the food product (post-rinsing), needs to be of drinking water quality. In the case of cleaning the outside of equipment and walls and floors, contact with the food product is rather unlikely, so strictly speaking drinking water quality is not required. However, often drinking water quality is used, to avoid any hazard.

(c) Water for the regeneration of equipment and for product treatment

Often large quantities of water are required for regeneration of equipment for the removal of iron (manganese), water and for product softening and/or demineralisation. This water needs to be of good (bacteriological) quality, to prevent bacteriological contamination of the filter material and a need for the water to be treated afterwards. Furthermore, it will preferably have a low iron content and low hardness, to prevent rapid fouling and scaling.

(d) Water for various technical purposes

Examples for this type of water are:

- cooling water for pump seals
- seal water for vacuum pumps
- water in closed circuits for hot water systems and heat exchange systems
- water for air conditioning humidity control in stores.

If there is a risk that in the event of equipment failure, contact with the food product is possible, the water needs to meet drinking water quality.

#### 4.4.1.2 Cooling water

Cooling water is the water used for the removal of heat from process streams and products. An extensive review of BAT on cooling is laid down in the Reference Document on the application of Best Available Techniques to Industrial Cooling Systems (Seville, 2000) [European Commission; European IPPC Bureau, 2000 #67].

In the food and drink industry the following cooling systems are commonly applied:

- once-through cooling systems, with no recirculation of cooling water
- closed circulation cooling systems (chilled water, brine)
- open circulation cooling systems (cooling towers)
- cooling by direct contact with cooling water.

In a once-through cooling system, water at a relatively low temperature (ground water, surface water) is run through the process equipment to be cooled, and then discharged. Cooling via once-through systems generally means a very high water consumption. Considerably less water is needed by using other cooling systems, such as closed circulation cooling, cooling towers or air-cooling.

Direct contact cooling in the food and drink industry is found in cooling autoclaves and towers for the sterilisation of products in glass bottles or cans. In these cases, direct contact between packages and water occurs. A risk in such cooling is that the water is entrained into the package through tiny holes in the seals or seams. In this situation the water needs to be of drinking water quality. Very often such water is circulated, in which case it is disinfected to guarantee bacteriological quality.

#### 4.4.1.3 Boiler feed water

In the food and drink industry steam is generated using boilers with working pressures up to about 30 bars. For power generation with steam turbines, higher steam pressures are needed.
An important property of boiler feed water is that is does not cause scaling in the boiler or corrosion of the steam system. This means that boiler feed water has a very low hardness and is de-aerated. For boiler feed water, preferably returned condensate is used supplemented by suitably treated make-up water.
Sometimes steam is used for the sterilisation of tanks and pipelines. Another application is UHT treatment with direct steam injection. Sometimes steam injection is used for heating the product or for adjusting the water content of the raw material. In all these cases more or less extensive (direct) contact between steam (condensate) and the food product is possible. This means that for these purposes culinary (potable) steam (meeting the standards necessary for human consumption) needs to be used. This means that the boiler feed water also needs to meet these requirements.

### 4.4.2 Water quality requirements in the food and drink industry

As indicated in the previous section, each application of water requires its own specific quality. In the food and drink industry, the quality requirements depend strongly on whether or not contact between water and the food product is possible. Both chemical and microbiological quality aspects are of importance. Furthermore, for certain technical applications specific technical quality aspects need to be considered.

#### 4.4.2.1 Quality requirements for process water

From its definition, process water is, in principle, at least of drinking water quality. For the production of soft drinks and beer, often special quality characteristics are required that sometimes exceed those of drinking water quality.

The quality standards for drinking water are laid down in the “European Council Directive 98/83/EC on the quality of water intended for human consumption”[European Council; European Parliament, 1998 #66]. The directive covers water used in industrial food manufacture.

Quality standards for organoleptic, physico-chemical, microbiological parameters, parameters concerning undesired components and toxic substances are included in the directive. The most critical for the food industry are often the microbiological parameters. Therefore, it is advisable to conduct a regular check of the critical microbiological parameters of the process water at the most critical places (point of use). This is normally incorporated in the HACCP (Hazard Analysis Critical Control Point) system.

The quality of water delivered by a mains water supplier is the responsibility of the concerned supplier. When a plant is using own ground water (or other water) as a source for process water, the plant itself will be responsible for meeting the quality standards. Sometimes the authorities require notification of the results of regular analyses of the water quality.

Article 2.1 of the EC-directive states that
"water intended for human consumption" shall mean: …
(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form".

This reflects the fact that not all process waters need to meet all the standards for drinking water. For example, the quality of water for transportation and washing of sugar beets, raw potatoes, fruits and vegetables does not necessarily need to meet the values for drinking water, since it has no effect on the quality of the finished food product. If the water comes into contact with potatoes, fruits and vegetable in critical steps like blanching and subsequent process stages, it must fulfil the requirements as stated for drinking water. Prior to blanching, recycling and re-use of the water (with an intermediate purification of the water if necessary) is common practice.

#### 4.4.2.2 Quality requirements for cooling water

In general, in the operation of cooling systems the following main problems can be encountered:

- corrosion (due to oxygen, high or low pH, salt, unsuitable construction materials)
- biological growth (slime forming bacteria, algae, etc.)
- scaling (due to precipitation of Ca- and Mg salts)
- fouling (caused by sludge, rust, organic deposits).

To prevent such problems, conditioning of the cooling water with chemicals is often necessary.

It is recognised that in open cooling systems (cooling towers) not only does evaporation of the water occur but also a small part of the water is sprayed. Furthermore, in a cooling tower the conditions for growth of Legionella bacteria are favourable. This means that the spray of cooling towers, if contaminated, may be a possible source of Legionnaire's disease. Precautions against this are periodical cleaning and chlorination.

(For details see: Cooling BREF [European Commission; European IPPC Bureau, 2000 #67].)

#### 4.4.2.3 Quality requirements for boiler feed water and boiler water

The quality requirements for boiler water depend on the boiler pressure and temperature. The higher the pressure and temperature, the higher the quality requirements are. The quality of the boiler water is controlled by the quality of the boiler feed water. The amount of blowdown of boiler water also controls the quality.

Table 4.7 and Table 4.8 show some requirements according to the relevant Guideline of the European Confederation of Organisations for Testing, Inspection, Certification and Prevention (CEOC) [68, CEOC, 1984].

| Parameters | Units | Requirement | |
|---|---|---|---|
| Working pressure | bar | > 0.5 – 20 | > 20 – 30 |
| Appearance | Clear, no suspended solids nor stable foam | | |
| pH (at 25 °C) | | >9 | >9 |
| Total hardness ($Ca_2$+ + $Mg_2$+) | mmol/l | <0.02 | <0.01 |
| Iron (Fe) | mg/l | <0.3 | <0.1 |
| Copper (Cu) | mg/l | <0.1 | <0.1 |
| Oxygen ($O_2$) | mg/l | <0.1 | <0.02 |
| Oil | mg/l | <1 | <1 |

**Table 4.7: Requirements for boiler feed water**
**[68, CEOC, 1984]**

| Parameters | Units | Requirement | | |
|---|---|---|---|---|
| | | Conductivity feed water | | |
| | | > 30 µS/cm | | < 30 µS/cm |
| Working pressure | bar | > 0.5 – 20 | < 20 - 30 | > 1 – 30 |
| Appearance | | Clear, no suspended solids nor stable foam | | |
| Conductivity (25 °C) | µS/cm | 8000-((p[1]-20)*2300) | | < 1500 |
| pH (at 25 °C) | | 10.5 – 12 | 10.5 – 11.9 | 10 – 11 |
| P-alkalinity | meq/l | 1 –15 | 1 – 10 | 0.1 – 1 |
| Silica ($SiO_2$) | mg/l | Pressure dependent | | |
| Phosphate ($PO_4$) | mg/l | <30 | <30 | 5 – 15 |

[1] pressure (bar)

**Table 4.8: Requirements for boiler water**
**[68, CEOC, 1984]**

The requirements for boiler feed water make extensive water treatment (removal of iron, softening, chemical conditioning) necessary.

### 4.4.3 Sources of water supply

In principle, the following sources of water are used in the food and drink industry:

1. Mains or tap water

Mains supply or tap water is distributed by a water mains. The supplier is usually responsible for the quality of the water delivered and checks the quality of the water regularly.

2. Own groundwater wells

This is groundwater extracted from own boreholes or wells. The composition of groundwater is reasonably constant and microbiological counts are mostly low, especially in deep bore holes. In most cases little treatment is necessary before the groundwater can be used for process water or cooling water. In most countries a licence is needed for extraction of groundwater.

3. Surface water

Generally, the quality of surface water is such that it cannot be used for process water unless treated. When available, it is often used for cooling water. A licence may be required for such a use.

4. Rainwater

Depending on the region, rainwater may be a source of water. It requires a storage basin. After appropriate treatment rainwater may be used for process water, or used in open cooling systems (make-up water).

5. Water originating from the raw material

Some raw materials that are processed in the food and drink industry contain a considerable percentage of water, which is usually removed during processing by evaporation or reverse osmosis. Some examples are milk, potatoes and sugar beets. Such water can sometimes be used without further treatment (condensate of the first stages of evaporators for boiler feed water), otherwise appropriate treatment is necessary.

### 4.4.4 System for water management

For maintaining a required level of water consumption and for assessing improvements, a water management system can be very helpful.
Such a water management system can easily be incorporated in an integral environmental management system. A waste management system usually involves:

1) Setting up a monitoring system

This includes:
- establishing the relevant account centres for water consumption
- implementing a system for data collection.

2) Establishing standards (targets)

3) Setting up a system for data processing and reporting

4) Imbedding in the organisation

### 4.4.5 Methodology for reducing water consumption

In order to achieve water savings a step-by-step approach is advised. It typically consists of the following steps [1, **CIAA**, 2002]:

| | |
|---|---|
| Step 1 | Obtaining management commitment |
| Step 2 | Analysis of Water consumption |
| Step 3 | Assessment of water quality requirements for each application |
| Step 4 | Assessment of minimum water consumption for each process step |
| Step 5 | Assessment of measures for reducing water consumption |
| Step 6 | Evaluation and feasibility study |
| Step 7 | Implementation |

#### 4.4.5.1 Obtaining management commitment

All successful water management programmes begin with senior management commitment. This ensures that all individuals within the organisation work together in a positive manner to gain maximum benefit from the initiative. One of the best ways of getting senior management commitment is to convince them of the financial benefits that can be achieved.

### 4.4.5.2 Water consumption analysis

An important condition for successful water management is having a good overview of the areas and process steps that are relevant to water consumption. Such an overview makes it easier to trace water saving options. Howver, this requires a detailed inventory of water flows in the factory. In developing this inventory, three levels of analysis can be distinguished:

Level 1: Analysis of the total water input and water output

At this level the water input and water output of the total plant (site) is specified. The use and production of the water is taken into account, including recycled (re-used) water and water incorporated in the product (e.g. drinks, canned fruits and vegetables) or evaporated.
A distinction is usually made between the total and the fresh water use.

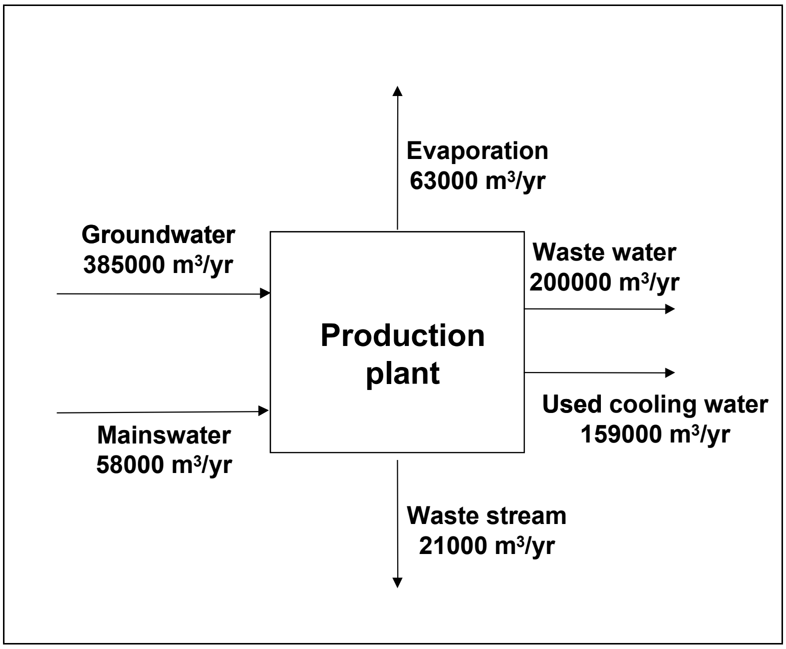


**Figure 4.10: Overview of water input and output of a plant (Example)**
**[1, CIAA, 2002]**

The data can often easily be obtained from existing flow measurement, bills for water and waste water discharges and data provided for a permit. It may also be important to give an overview of the costs that are related to water input and output.

On the basis of the information gathered in this stage, **benchmarks** can be derived. Some examples of benchmarks are:

- specific water consumption
  ($m^3$ water/ tonne of raw material or finished product)
- specific waste water discharge
  ($m^3$ water/ tonne of raw material or finished product)
- ratio of water costs between water input and water output
- water costs per product-unit.

Using such benchmarks and (if possible) comparing them with external benchmarks may give an initial indication of whether or not savings are possible.

Level 2: Inventory of water input and (waste) water output per process step or activity

> Depending on the type of plant, a distinction can be made between departments, types of processes and the main levels in a process. Apart from the production processes, water treatment, waste water treatment and cleaning activities may also be incorporated in the inventory.
>
> How to get the data
> Sometimes the water flows for the main processes and departments are already measured. If not, it may be advisable to install metering equipment on the main streams (even on a temporary basis). An alternative is to try to estimate water consumption of the various parts on the basis of production volume. However, the latter method gives less reliable results.
>
> On the basis of the information gathered in this stage it is possible to select the areas to target for further investigations into water savings.

Level 3: Inventory of water input and (waste) water output for selected parts

> On the basis of the inventory at level 2, certain parts of the process (plant) may need further analysis for saving options. This requires a more detailed inventory of these parts. The selected parts are split up in logical building blocks, i.e. relevant process parts, unit-operations, equipment and installations. The water input and output are determined for each building block. Furthermore, it may be important to characterise the function of the water in that particular part, e.g. as transport water, washing water, product water, cooling water, etc.

Frequently, all the data that is needed in this detailed level may not be available. Missing data can be completed by performing additional measurements or by calculation from other data or even by estimation. It depends on how relevant the concerned water flow is in the overall scheme. The level of detail is kept to what is strictly necessary in order to avoid excessive time consumption and costs for the inventory. Furthermore, the parts of the plant under investigation need to be physically definable and have logical recognisable names.
It is advisable to make separate flow charts for each level and process part and to present the data in a uniform way. Flow chart software programs are a useful tool for achieving this.

### 4.4.5.3 Assessment of water quality requirements

A survey can be made of the quality requirements of the water used in each step of the production process. The most important criteria generally are (depending on the type of process): the presence of organic material (from raw materials and product), the presence of auxiliary substances in the water, the microbiological count, pH, chloride content, hardness, iron and manganese content. It is advisable to group the processing steps requiring the same water quality together and to limit the defined water qualities to a maximum of five to ten. Of course, the defined quality requirements are such, that the water quality does not affect the quality of the finished product.
Also the qualities of the released flows of each processing step are established.
The above-mentioned information is necessary to be able to judge whether it is possible to re-use water, either with or without intermediate treatment.

### 4.4.5.4 Assessment of minimum water consumption

An estimate on the minimum water consumption can sometimes be obtained from external benchmarking. A prerequisite is obviously that data is available for comparable activities.

Another approach is to determine the minimum water consumption level based on the specifications (of the suppliers) of the various parts of the process lines. Totalling the individual process water requirements throughout the plant leads to a theoretical design water consumption, although in practice this may not be realistic.
Furthermore, performing a water pinch analysis may give useful information on the minimum water consumption for the represented production process.

### 4.4.5.5 Identifying measures for reducing water consumption

Various methods can be applied to identify measures to reduce water consumption:

(a) brainstorming
(b) external consultancy
(c) water pinch analysis.

For more complex situations WaterPinch may be a powerful tool for identifying water re-use, recycling and regeneration opportunities within a process. WaterPinch uses advanced algorithms to identify and optimise the best water re-use, regeneration and effluent treatment options. The basic concepts are analogous to those for heat recovery. Water flow and the content of water contaminants are taken into consideration, leading to so-called sources and sinks. The method maximises the re-use of water, taking into account the quality requirements for each application and results in minimum freshwater make-up and waste water discharge. For performing water pinch studies, the extensive help of external consultants is normally necessary. This makes this method costly.

(d) Types of measures for reducing water consumption

In the food and drink industry there are many measures for reducing the amount of water used. They can divided into:

- elimination of the use of water
- good housekeeping
- process optimisation
- recycling of water
- re-use of water.

Some examples of possible water savings:

| **Water saving measure** | **Typical reduction in process use (%)** |
|---|---|
| Closed loop water recycle | > 90 |
| Cleaning-in-place (CIP) (new) | 60 |
| Re-use of wash water | 50 |
| Counter-current rinsing | 40 |
| Good housekeeping | 30 |
| Optimisation of CIP | 30 |
| Spray/jet upgrades | 20 |
| Brushes/squeegees | 20 |
| Automatic shut-off | 15 |

**Table 4.9: Typical achievable reductions in water use**
**[Envirowise (UK); Dames & Moore Ltd, 1998 #23]**

#### 4.4.5.6 Evaluation and feasibility study

The objective of the evaluation and feasibility study phase is to evaluate the proposed water savings options and to select those most suitable for implementation. The options are all evaluated according to their technical, economic and environmental merits. However, the depth of the study depends on the type of the option.
The quickest and easiest method for evaluating the different options is to form a project team, consisting of staff and management personnel, and to discuss the possible options one by one. This process gives a good indication of which projects are feasible and what further information is needed for more thorough evaluations.

(a) Technical evaluation

The potential impacts on products, production processes and hygiene and safety from the proposed options need to be evaluated before complex and costly projects can be decided upon. In addition, laboratory testing or pilot tests may be required when options significantly change existing processes.

(b) Economic evaluation

The objective of this step is to evaluate the cost effectiveness of the proposed water savings options. When performing the economic evaluation, the costs of the change are weighed against the savings that may result. Economic viability is often the key parameter that determines whether or not an option will be implemented.

(c) Environmental evaluation

The objective of the environmental evaluation is to determine the positive and negative environmental impacts of the option. In many cases the environmental advantages are obvious, namely reduced water usage. In some cases it may be necessary to evaluate whether, for example, an increase in electricity consumption would outweigh the environmental advantage of reduced water consumption. An example is replacing once-through cooling by a closed circuit cooling system with refrigeration equipment. This reduces water consumption but will also considerably increase the electricity consumption.

#### 4.4.5.7 Implementation

To ensure the implementation of the selected options, an action plan is developed, detailing the activities to be carried out, the resource requirements, persons responsible for undertaking those activities and the planning.
It might be important to evaluate the effectiveness of the implemented measures and to monitor the effects on the long term.

### 4.4.6 Elimination of the use of water

Whenever it is feasible, elimination of water use is an option for consideration.

**Examples:**

- in the processing of fruits and vegetables peeling is often an important water using process step. If possible, apply dry peeling, e.g. mechanical peeling (knives) or with a carborundum peeler
- utilise closed circuit cooling systems instead of once-through cooling, this eliminates most of the water waste in cooling
- utilise dry mechanical transport instead of transport by water.

### 4.4.7 Good housekeeping

Good housekeeping involves low cost methods, which essentially means improvement of work practices and proper maintenance.

**Examples:**
- installing meters on high-use equipment to monitor consumption
- installing restrictors or timers and automatic flow control valves to interrupt water supply during production stoppages
- installing trigger nozzles on hoses to reduce flow rates
- utilising spray guns instead of open-ended hoses for cleaning
- pre-soaking floors and open equipment to loosen dirt before the final cleaning
- reporting and fixing leaks promptly
- installing level controls on water storage tanks and balance tanks
- installing timers on back-wash systems for water treatment equipment (filters for removal of iron and water softeners)
- introducing a routine programme for visual auditing of the handling of water and waste water in the plant. It is recommended that this be periodically conducted by an eternal expert
- optimising water consumption by monitoring the water pressure and the condition of the water spray nozzles.

### 4.4.8 Process optimisation

Process optimisation means optimising existing processes to reduce water usage. Process optimisation options are typically low to medium cost.

Examples are:
- utilising high pressure water for cleaning floors and open equipment
- utilising alternative water sources, e.g. by using rainwater or river water for feeding evaporative condensers
- optimisation of cleaning-in-place (CIP) processes.

## 4.5 Recycling and re-use in water management

Opportunities for the recycling or re-use of water are identified and thoroughly evaluated, taking into consideration hygiene issues and practical constraints. An optimal scheme is likely to include a combination of:

- sequential re-use (water stream used for two or more processes or operations before disposal)
- recycling within a unit process or group of processes without treatment
- recycling with treatment.

### 4.5.1 Design

New processes, plant and equipment are designed with water efficiency and waste water minimisation in mind. Important considerations include [13, **Environment Agency (UK)**, 2000]:

- minimising water use at source
- maximising water recycling and re-use
- minimising the risk of water or product overflow from vessels
- minimising product spillage from conveyors
- avoiding overfilling of product containers
- facilitating effective and efficient cleaning
- incorporating appropriate metering and monitoring systems
- ensuring that the operator can optimise water and chemical use
- making water pipework, valves and instrumentation readily accessible for maintenance.

Existing processes, plant and equipment are modified where practicable to improve water efficiency and deliver waste water minimisation.

**Recycling of water**

Recycling of water means using the water again for the same application and without intermediate purification.

Examples are:

- recovering steam condensate for boiler feed water. This also leads to recovery of a considerable amount of heat and savings in the use of chemicals for treatment of boiler feed water
- recirculating wash water through a holding tank.

**Re-use of water**

Re-use of water involves using the water for the same or another application, often after an intermediate cleaning step.

Examples are:

- re-use of final rinse water from cleaning-in-place (CIP) for the initial rinse of the next cleaning
- re-use of washing water (from tins and jars) in the peeling process
- re-use of the condensate created during the concentration of fruit and vegetables juices for mixing or diluting the end-product
- re-use of hot coolant water from the autoclaves (preserves sector) as rinsing water after peeling or as cleaning water.

Counter-flow re-use, in which the water flows counter-current to the product so that the final product only comes into contact with fresh water, is often the most appropriate.

Figure 4.11 shows a diagram of 4-stage water re-use scheme at a pea cannery.

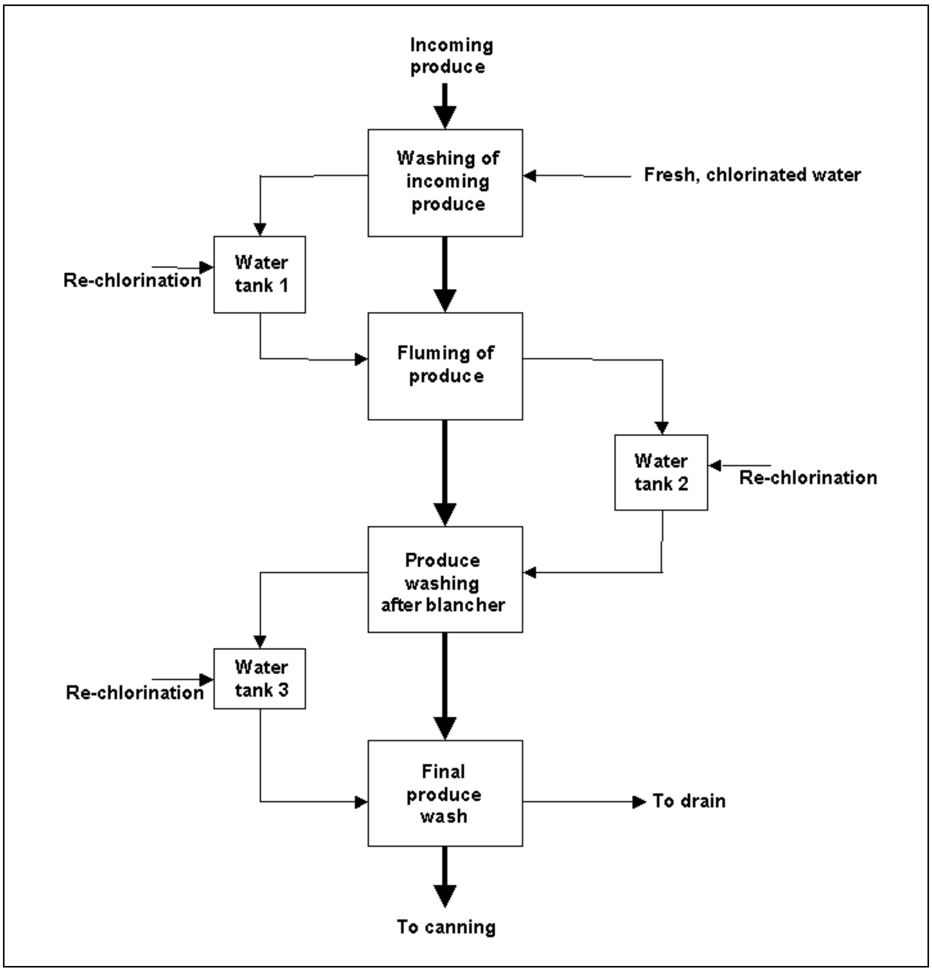


**Figure 4.11: Re-use of water in canning industry**
**[13, Environment Agency (UK), 2000]**

Once-through use of cooling water is preferably avoided in favour of closed loop systems. Where this is not possible, the cooling water, which is generally uncontaminated, can be re-used.

Condensate can be returned as boiler feedwater when it is of suitable quality. Contaminated condensate is used for lower grade cleaning activities, e.g. yard washing.

<u>Examples in different sectors:</u>

**Sugar production from sugar beets**

- in the processing of sugar beets, the major mass of water on the site is used for transporting the sugar beets into the factory. This transport water must be re-used as much as possible. On many sites transport water is re-used in extensive circuits (usually only after intermediate purification via settling ponds) before final treatment and discharge
- in most cases it is feasible, assuming there is enough storage capacity, to retain enough water from the previous year’s campaign to start the new campaign. This prevents the need to abstract water from a river or underground sources.

**Processing of fruits and vegetables**

- in potato, fruit and vegetable processing, in the process stages from washing the raw materials to blanching, extensive re-use of water is possible by applying the principle of counter flow re-use (cascading). Fresh water is used for the final product wash or in the blanching step and then carried back to earlier washing and peeling steps. Chlorination of the water or another method of disinfection may be necessary to maintain acceptable bacterial counts in the water throughout the process
- the effluent after biological waste water treatment can, after proper treatment (coagulation/flocculation and filtration eventually chlorination), be used for the first wash of vegetable raw materials such as potatoes and fruits and vegetables.

## 4.5.2 Water saving in meat industry

### 4.5.2.1 Waste/waste water recycling

**[Environment agency, UK, 2000 # 13, 7.1.3]**

Chiller effluent has substantial COD and TSS levels, especially that from separate giblet chillers in which concentrations may be as high as 4000 mg/l COD and 3000 mg/l TSS. Where practicable, it is treated and recirculated. Experience in the USA has shown that high levels of recirculation are achievable for poultry pre-chiller effluent if it is treated to reduce micro-organism concentrations by at least 60 %. Treatment also reduces the COD and TSS in the bleed to drain. Treatments found to be successful involve screening, filtration (sand or diatomaceous earth) and ozonation. Chlorination, UV light and hydrogen peroxide disinfection are more economical alternatives to ozonation.

### 4.5.2.2 Waste water minimisation

**[Environment agency, UK, 2000 # 13, 7.1.4]**

The following waste water minimisation measures may be applied in addition to the general guidelines:

- optimise blood collection
- prevent meat scraps, ingredients and product from entering the drains where practicable
- use mechanical conveyors in place of water fluming.

## 4.5.3 Waste water saving in fruit and vegetable processing

The following measures, specific to this sub-sector, may be adopted where appropriate:

- carry out crop washing, grading and trimming in the field to reduce soil and food residues generated on site
- use mechanical conveyors rather than water flumes, where practicable
- minimise the water volume where flumes are used (may involve optimising the water pH)
- use dry caustic peeling techniques
- convert from water to steam blanching
- use air cooling after blanching
- recover starch from high starch waste water streams.

## 4.5.4 Water saving in breweries

In a brewery, water is mainly used in the technology for mashing, heat transfer and cleaning. A well-run brewery can produce 1 $m^3$ beer using 5 - 6 $m^3$ water.
Some possibilities for water savings in beer production are listed in Table 4.10.

CASE STUDY – Family brewery makes big water savings

- J W Lees & Co produces mainly casked ales and lager in old, traditional premises. Recognising that water consumption, beer losses and trade effluents charges were above the industry average the Company installed meters to measure water consumption and effluent discharge in the main process areas. It then implemented a range of associated good housekeeping and low investment measures to improve the efficiency of water and energy use and to minimise effluent generation.

  (Type of measures: introducing better procedures for using hot water from wort cooling, installing float-operated top-up valves in wash water tanks, replacing faulty valves, optimising cleaning procedures, installing high-efficiency nozzles in cask washing).

  As a result of these and other initiatives J W Lees reached an:
  Annual water consumption reduction of 73000 m$^3$ (40 %);
  Annual cost savings of nearly EUR 160000;
  Payback period of less than three months for nearly EUR 130000 of savings.
  [1, **CIAA**, 2002]

Although the major consumption may be attributed to cleaning [59, Danbrew Ltd., 1996], a case study for water conservation in pasteurisation is given:

CASE STUDY – Closed loop for pasteurisation unit

- Replacing open loop system (cooling by fresh water) with closed loop system can save 80 % of water consumption. The water is recirculated via cooling tower or possibly via a cooler connected to the central refrigeration plant, i.e. it is re-chilled and returned to the pasteuriser. To prevent algae or bacterial growth, chemicals are added to the recirculated water.

  In an Asian brewery having 500000 hl/yr capacity, the open loop system for their pasteuriser was changed to a closed loop system. The reduction in water consumption was estimated to be 50000 m$^3$/yr. The investment cost of the installation of the cooling tower and other necessary equipment was USD 45000 (before 1996) with a pay-back period of approximately 1 year. [59, Danbrew Ltd., 1996]

| Measure | Method | Description/ purpose | Equipment / technique | Major benefits | Other benefits | Potential cost[1] | Potential payback[2] |
|---|---|---|---|---|---|---|---|
| Liquor metering | Metering and training | Avoid excess wort production | Meter | Water and effluent savings | Consistent wort quality | High | Med |
| Wort disposal | Storage and disposal | Reduce effluent COD | Tank | Effluent savings |  | Low | Short |
| Keeping brewers' grains dry | Training | Minimise leaching during storage and transport | Brush | Effluent savings | Ease of grain | Low handling | Med |
| Cleaning mash tun and copper | High pressure hose | Reduce water use for manual cleaning | Pressure washer | Water and effluent savings | Improved cleanliness | Med | Med |
| Wort boiling | Reduce boiling time | Reduce steam consumption | Training | Water & energy saving |  | Low | Long |
| Copper condensate recovery | Heat exchanger | Recover waste heat and reduce odours | Heat exchanger | Source of hot liquor | Energy savings, reduced steam discharge | High | Long |
| Trub disposal | Storage and disposal | Reduce effluent COD | Tank | Effluent savings |  | Low | Short |
| Heat exchanger automation | Actuated valves on temperature control | Optimise cooling and hot liquor production | Valves and controllers | Water and effluent savings | Consistent wort cooling | Med | Long |
| Heat exchanger optimisation | Minimise cold liquor storage time | Prevent production of extra hot liquor | Training | Water and effluent savings | Cooler wort into fermenter | Low/Med | Med |
| Hot liquor storage | Increase capacity | Prevent overflow from hot liquor tank | New tank | Water and effluent savings |  | High | Long |
| Fermenter cooling | Cooling jacket or panels | Improved cleaning efficiency | New vessel or cooling panels | Water and effluent savings | Easier cleaning | High | Long |
| Fermenter cooling | Closed-circuit cooling | Reduce water consumption | Chiller and recirculation pump | Water and effluent savings | Improved cooling | Med | Short |
| Fermenter cleaning | Training, use of scrapers, etc | Reduce water and effluent volumes | Training/cleaning equipment | Water and effluent savings |  | Med | Short |
| Yeast disposal | Storage and disposal | Reduce effluent COD | Tank | Effluent savings |  | Low | Short |
| Beer filtration | Cross-flow filtration | Reduce water use and effluent strength | Proprietary equipment | Water and effluent savings | Less haze | High | Med/Long |

*Potential costs and paybacks are for guidance only. Actual costs and paybacks will depend on the particular site.*

[1] Potential cost: Low = Minor alterations to practices or existing plant (GBP 0 - a few GBP 100s); Med = Some alterations to existing plant or minor new plant (GBP 100 - GBP 1 000); High = Extensive alterations or new plant (several GBP 1 000s).

[2] Potential payback: Short = Months; Med = Less than a year; Long = Over a year.

**Table 4.10: Water and effluent saving opportunities in the brew-house**
**[Envirowise (UK); Dames & Moore Ltd, 1998 #23]**

### 4.5.5 Water saving in the fishing industry

The use of dry transport systems that avoid or minimise water use is an option that has been applied in different countries [Panagopoulos J.; Malliaros C., 2001 #74; Nordic Council of Ministers, 1997 #28]
Additional water can be saved if skin is removed from drums by vacuum instead of water. [Panagopoulos J.; Malliaros C., 2001 #74]

#### 4.5.5.1 Thawing

Traditional thawing of frozen fish takes place under running water.

- water consumption can be reduced in thawing vessels by using recirculation and air stirring. A typical reduction is from 5 $m^3$ to 2 $m^3$ per tonne raw fish
- thawing by sprinkling is another alternative
- thawing by 100 % water saturated hot air is used as well. In this case, the energy consumption is higher.

These methods are commonly used.

| CASE STUDY – Whitefish thawing |
|---|
| • Thawing is made in containers filled with warm water (30 - 35 °C). Air is bubbled in at the bottom. Compared to thawing in running water, up to 60 % reduction in water was achieved, resulting in a specific water consumption of 1.8 - 2.2 $m^3$/t raw fish.<br>- water consumption decreased from 5 $m^3$/t to 2 $m^3$/t raw fish<br>- the cost of the equipment with a capacity of 18 t raw fish/day (3600 t/yr) is estimated to make about DKK 300000<br>- saving in water consumption is DKK 10800.<br>[28, **Nordic Council of Ministers**, 1997] |

#### 4.5.5.2 Reduction of water consumption in the filleting of fish

The frame is cut from the fillets by two sets of rotating knives. The knives are watered in order to cool the knives and to clean off fish meat and scale.

| 60 - 75 % reduction in water consumption may be obtained by: |
|---|
| • removal of the nozzles so that water is added where necessary<br>• mounting the nozzles on wash-deck pipes where they have not been mounted already<br>• replacement of those nozzles that take the fish from the tail cut to a mechanical device<br>• replacement of the nozzles for washing the driving wheels on the filleting part dredges<br>• replacement of existing nozzles by nozzles with a smaller water consumption<br>• pulsation of the water nozzles, i.e. alternating the opening and closing of the wash water by an automatic valve<br>• replacement of waste drain by drain-belts and closing the nozzles in the waste drain. Thus the waste will be separated from the process water directly near the filleting machine, resulting in shorter contact time<br>• replacement and closing of nozzles on the skinner drum.<br>[28, **Nordic Council of Ministers**, 1997] |

The waste water will also contain less pollution due to the reduction in the contact time.

CASE STUDY – Reduction of water use in filleting white fish

- water consumption can be reduced up to 90 % by installing nozzles and sprinkling the water in one or two seconds out of every three. Specific water consumption can be reduced to about 0.13 or 0.2 $m^3$/t raw material depending on the type of fish
- the maximum costs of fitting the nozzles is DKK 5000.

[28, **Nordic Council of Ministers**, 1997]

#### 4.5.5.3 Cutting water and effluent costs in fish processing – a case study

Description

Marr Foods Ltd. produces 12000 tonnes/yr of frozen and chilled fish products at its two sites at Hull. Their major products are: hot smoked mackerel and herring, cold smoked haddock, white fish fillets, battered and breaded frozen fish.

The company implemented a waste minimisation project which initially focussed on water and effluent issues, but soon expanded to cover raw materials, packaging and energy. A waste minimisation team analysed water use and effluent generation for different processes and prepared water balances for the Company's two sites. Cost effective measures to improve performance were then implemented. These included:

- a new defroster, eliminating water losses from leakages
- improved cleaning procedures (reducing number of hose pipes and encouraging employees to use plastic shovels and rubber blades to sweep up fish waste)
- dry filleting
- leak repairs
- training and raising employees awareness.

Achieved environmental benefits

Overall water use was reduced by 58 % per tonne of product. Energy efficiency and hygiene standards were improved.

Cross-media effects

Operational data

Applicability

Economics

The benefits of the water and effluent minimisation project include:

| | |
|---|---|
| - Cost savings | over EUR 150000 per year; |
| - Payback period | 36 weeks for the new defroster. |

Driving force for implementation

In November 1996, Marr Foods Ltd learnt that its trade effluent charges would increase significantly in January 2001.

Example plants

Marr Foods Ltd., Kingston upon Hull, UK

Reference literature

[58, Envirowise (UK), 1999]

### 4.5.6 Water re-use in the fruit and vegetable industry

A valuable study on BAT for the Flemish fruit and vegetable industry [31, An Derden, 2001] describes an evaluation system and the evaluation of 134 candidate BAT. Although the evaluation has not supported by data, the techniques considered are presented in this document in the relevant Sections.
The techniques applying re-use of water are summarised in Table 4.11.
The process integrated other techniques are presented in Section 4.9.2.

| | Technique | Comments |
|---|---|---|
| 1 | Only pump up the quantities of water that are actually required in the production process | |
| 2 | Check water consumption by installation of a flow-rate meter at the main consumers and various water sources | |
| 3 | Recycling transport water | |
| 4 | Re-use of washing water (from tins and jars) during the peeling process | If quality make it feasible |
| 5 | Re-use of peeling water to prewash the raw products | |
| 6 | Re-use of the condensate generated during the concentration of fruit and vegetable juices for mixing or thinning of the end-product | |
| 7 | Re-user of water from sterilisation processes to prewash raw products | |
| 8 | Re-use of hot coolant from the autoclaves (preserves sector) for heating up cold water in the blanching process, as rinsing water after peeling, or as cleaning water | For the preserves sector |
| 9 | Re-use of blanching water as first cleaning water when cleaning the freezing tunnel | |
| 10 | Re-use of cooling water (no direct contact with product) | |
| 11 | Use of rainwater or pond water for feeding the evaporating condensers | |
| 12 | Use of cleaned effluent (e.g. sand filter) from the effluent treatment plant to supply the evaporating condensers | Technical problems as a result of high conductivity of the re-used water |
| 13 | "Chlorinate" effluent and re-use for cleaning floors and process plant | |
| 14 | Tertiary cleaning of effluent using "coagulation/flocculation + filtration + active carbon filtration + microfiltration" and re-use for first washing of raw material | Increased energy consumption / waste production |
| 15 | Tertiary cleaning of effluent using "coagulation/flocculation + filtration + active carbon filtration + microfiltration" and re-use for washing of containers for sterilisation or as coolant (refrigeration circuit) or transport water (pump circuit) | Increased energy consumption / waste production |
| 16 | Tertiary cleaning of effluent using "coagulation/flocculation + filtration + active carbon filtration + microfiltration + reverse osmosis" and re-use for blanching water or coolant (cooling of product after blanching) | Increased energy consumption / waste production |

**Table 4.11: Techniques for re-use of water in fruit and vegetable industry**
**[31, An Derden, 2001]**

## 4.5.7 Reduction of water consumption in the dairy industry

### 4.5.7.1 Waste water minimisation

In addition to the general advice on waste water minimisation, the following minimisation techniques specific to this sub-sector may be adopted where applicable [13, **Environment Agency (UK)**, 2000]:

- collecting leaks and spills in drip pans for use as animal feed
- treating spills of curd, yoghurt or ice cream mix as solid waste rather than washing them down the drain
- using condenser pumps that do not require seal water
- handling curd in such a way that minimises the loss of fines along with the whey
- removing the salt from salt whey so that it can be processed along with sweet whey
- minimising the occurrence of acid whey and avoiding spillage
- utilisation of whey for
  - protein recovery
  - in animal food production
  - in the production of mitzithra cheese
  - as a natural ingredient in food supplement, baby food, etc.[Panagopoulos J.; Malliaros C., 2001 #74]
- using turbidity meters and carrying out more visual inspections to reduce the amount of product left in the equipment at the start of the CIP cycle
- maximising the recovery of diluted, but otherwise uncontaminated, product from CIP initial rinses, HTST start-up, shutdown and changeover and from the rinsing of other equipment and pipework
- substituting acid detergents with new products that reduce water consumption for CIP and decrease the nutrient loading in the waste water
- adopting dry cleaning methods, in order to collect solid residues of cheese production. [Panagopoulos J.; Malliaros C., 2001 #74]
- fitting drains with screens and/or traps to prevent solid material from entering the effluent system. [Panagopoulos J.; Malliaros C., 2001 #74]

### 4.5.7.2 Waste water re-use

**[Environment agency, UK, 2000 # 13] (7.3.3)**

Table 4.12, which is taken from a recent ETBPP publication [52, Envirowise (UK), 2000], summarises the water re-use opportunities in dairies.

In some cases cross-contamination risks will need to be considered when re-using the water, e.g. between starter batchs in cheese-making.

Avoiding the unnecessary contamination of condensate maximises the potential for re-use. The cleanest condensate may be suitable for use as boiler feedwater.

| | CIP Used Cleaning Solution | CIP Final Rinse | Condensate | Permeate from Reverse Osmosis Plant |
|---|---|---|---|---|
| Vehicle Washing | 1 | 1 | 1 | 1 |
| Crate Washing | 2 | 1 | 1 | 1 |
| Manual Cleaning of Equipment | 3 | 3 | 2 | 1 |
| CIP Pre-Rinse | 1 | 1 | 1 | 1 |
| CIP Main Wash Supply | 2 | 3 | 2/3 | 1 |
| CIP Final Rinse | 3 | 3 | 3 | 1 |
| Water Purge of Product Lines | 3 | 3 | 3 | 1 |
| *Key:* *1.Direct re-use*<br>*2.Re-use after screening of solids*<br>*3.Re-use after suitable membrane separation* | | | | |

**Table 4.12: Water re-use opportunities at dairies**

The use of membrane techniques in whey processing enables valuable by-products, whey protein concentrate and lactose concentrate to be produced. When a reverse osmosis stage is included, demineralised water is produced which is suitable for use as boiler feedwater or membrane CIP. [52, Envirowise (UK), 2000]

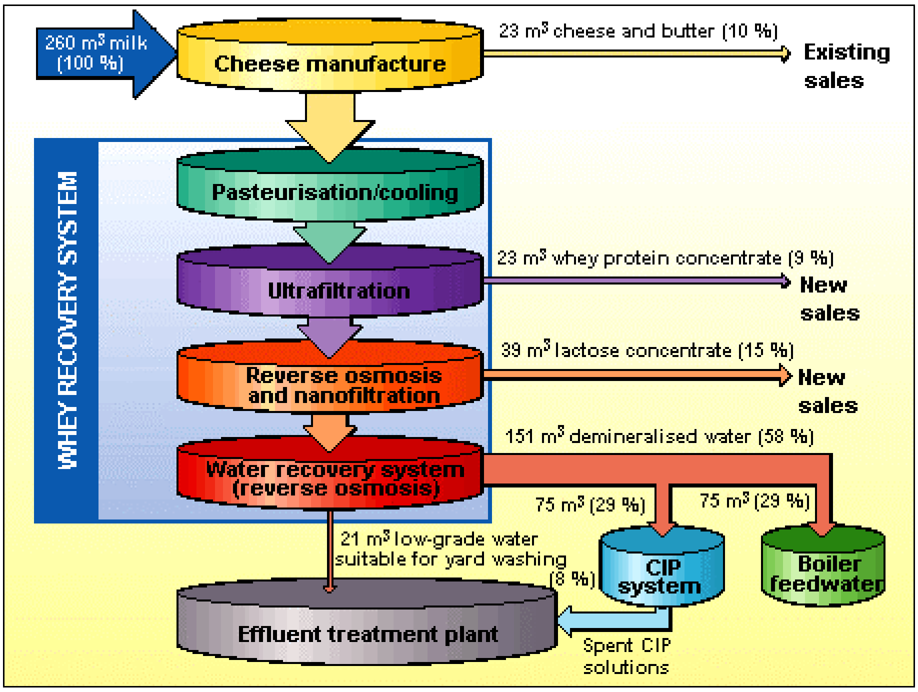


**Figure 4.12: Flow diagram of the membrane processing system**
**[52, Envirowise (UK), 2000]**

### 4.5.7.3 Recycling in CIP

**[42, Korsstrom, 2001]**

Cleaning is the most water consuming process in the dairy industry, therefore large savings are possible in this area. CIP is thought to be superior to manual cleaning. When using secondary water or re-use warm cooling water, the hygienic aspects need to be considered. Some possible options for saving water are:

- re-use of final rinsing water for prerinsing
- optimisation of CIP sequences, i.e. cleaning and rinsing times
- automatic and continuous cleaning of cheese moulds, racks and frames
- re-use of secondary water, such as reverse osmosis water and product condensate, for cleaning of less sensitive areas, or for preparation of cleaning solutions
- re-use of warm cooling water for cleaning
- use of low-pressure foam cleaning in manual cleaning.

#### 4.5.7.3.1 Re-use of warm cooling water for cleaning

**[42, Korsstrom, 2001]**

Description

Warm cooling water above 50 °C can be re-used for the cleaning of milk tankers or for manual cleaning and CIP of equipment.

Achieved environmental benefits

The water savings depend on the amount of re-usable warm cooling water. A reduction of about 2 % has been reported.

Cross-media effects

Re-use of warm cooling water also results in an energy reduction.

When using this water for cleaning surfaces which may be in contact with products, the hygiene of the warm cooling water is of great importance. Normally, it is stored for some time in an insulated buffer tank awaiting further use. The risk can be reduced by treating the water with UV light.

Operational data

Applicability

It can also be applied in existing plants but the space requirements for the warm water storage tanks may be a constraint.

Economics

Driving forces for implementation

Reducing costs for water.

Example plants

Arla Foods, Kallhall dairy, Stockholm, Sweden
Valio Ltd., Turku dairy, Finland

#### 4.5.7.3.2 Re-use of water from final rinse

Description

The aim of the final rinse is to remove the last traces of cleaning solutions from the cleaned equipment. Clean water is used and the rinsing water, which returns to the central CIP unit, is still clean enough to be re-used for prerinsing or intermediate rinsing instead of being discharged to the drain. Its recovery requires a connection from the CIP return pipe to the pre-rinsing tank. The returning final rinsing water is diverted to the pre-rinsing tank with the aid of a conductivity transmitter.

The final rinsing water can also be used for the preparation of cleaning solution.

Achieved environmental benefits

1. Reduction in water use and waste water production.

Cross-media effects

Operational data

Applicability

It is currently common practice.

It can be used in existing CIP units but the operation system needs modification.

Economics

Driving forces for implementation

Example plants

### 4.5.8 Minimisation of water pollution in fishing industry

**[28, Nordic Council of Ministers, 1997]**

#### 4.5.8.1 Sorting of herrings and mackerel

**[28, Nordic Council of Ministers, 1997]**

A 50 - 65 % reduction in water consumption can be achieved by regulating the nozzle sizes so that they only supply the necessary amount of water.

#### 4.5.8.2 Vacuum suction for removal of viscera

**[28, Nordic Council of Ministers, 1997]**

Vacuum suction for removal of viscera is considered to be too noisy and energy consuming in herring filleting but it can be used in mackerel processing.

The sucking equipment consists of a vacuum installation ending in a specially designed sucking nozzle placed immediately after the head cut.

#### 4.5.8.3 Dry process for removal and transport of viscera

**[28, Nordic Council of Ministers, 1997]**

Description

The dry transport of the viscera is carried out by a chute with a 20 % slope mounted under the gutting wheel. Here viscera, fatty belly strips and the water from the wheel are caught. The method used on a filleting machine is in figure Figure 4.13.

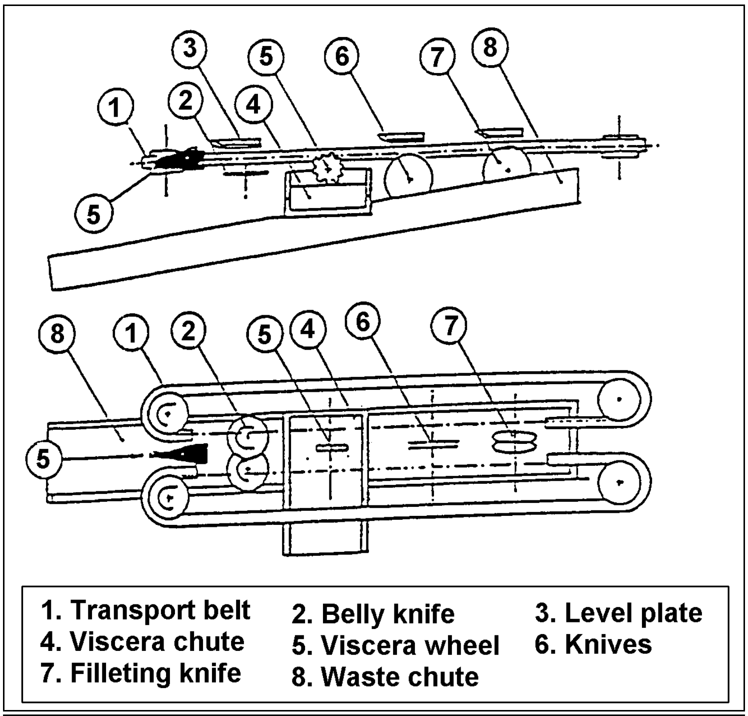


**Figure 4.13: Equipment for dry removal of viscera**
**[28, Nordic Council of Ministers, 1997]**

Achieved environmental benefits

The volume of waste water is practically the same, as water is still needed for cooling the machines` knives and wheels, for cleaning the belly cavity, and for cleaning the filter belt. However, pollution in the waste water can be reduced by 30 - 50 %. (See Table 4.13.)

| **Parameter** | **Wet (kg/t raw herring)** | **Dry (kg/t raw herring)** | **Reduction (%)** |
|---|---|---|---|
| Total nitrogen | 1.4 | 0.99 | 30 |
| Total phosphorus | 0.17 | 0.12 | 29 |
| COD | 26.3 | 15.0 | 43 |
| Dry material | 17.8 | 10.9 | 39 |
| Oil | 7.3 | 3.5 | 52 |

**Table 4.13: Discharge data before and after introduction of dry removal and transport of viscera**
**[28, Nordic Council of Ministers, 1997]**

Cross-media effects

A larger amount of sellable by-product is produced, this can be sold for fish-meal production. The water content of the by-product is smaller.

Operational data

Applicability

Economics

- savings in waste water treatment
- a higher price can be obtained for the by-product with a smaller water content by selling it for fish-meal production.

Driving forces for implementation
Viscera are very oily and relatively easily soluble after gutting. Reduction of the contact time with water results in a pollution reduction in the waste water.

Example plants

#### 4.5.8.4 Dry reception and transport of waste from the skinner drum

**[28, Nordic Council of Ministers, 1997]**

Description
The technique to reduce water consumption and organic load consists of a suction device which sucks the drum clean of skin and fat. Water is only used to moisten the drum in order to maintain the sucking effect.

Achieved environmental benefits
Both COD and water consumption are reduced by 95 - 98 %.

Cross-media effects

Operational data

Applicability

Economics

Driving forces for implementation

Example plants

### 4.5.9 Further case studies for water management

CASE STUDY - Dry peeling scores over wet peeling

- Water use and resulting waste water were compared for wet and dry caustic peeling at a plant processing 72 tonnes/day of table beet. For the same quantity of produce processed, dry peeling reduced water use by 75 % and solid waste by 90 % compared to wet peeling. In addition, the effluent generated during dry peeling contained 88 % less suspended solids, 94 % less COD and 93 % less BOD than that from wet peeling. [1, **CIAA**, 2002]

CASE STUDY – Segregation waste water streams saves water and money

- In 1993, a snack food company began a major operations review to improve performance. A Water Action Group consisting of managers, shift operators and the site adviser used a bucket-and-stopwatch approach to study the ideal flow rates for each piece of equipment. When the results of this water audit were reviewed, the company realised that substantial savings could be made if waste water streams were segregated prior to on-site treatment. The waste water streams were treated to remove solids and oils, which were then processed into animal feed cake.

  Three main waste streams were identified, i.e.:
  - potato wash water
  - cold starch water
  - hot starch water containing oils.

    The potato wash water is now re-used after grit is removed and the cold starch water is recycled after the good quality starch has been recovered. Water recycling and re-use reduces water consumption by 19 %. This is equivalent to 165000 m$^3$/year or EUR 145000 in water supply costs. [Envirowise (UK); Ashact, 2001 #45]

CASE STUDY - Installation of a cooling tower for a tunnel pasteuriser

A brewery, which used an open loop cooling system for the tunnel pasteuriser, installed a cooling tower in order to make the changeover to a closed loop system.

- reduction in water consumption: 50000 $m^3$/year
- pay-back period: approx. 1 year
- brewery capacity: 500000 hl/year
- investment EUR 50000

[59, Danbrew Ltd., 1996]

CASE STUDY - Beet washing in the sugar industry

- Beet washing is an operation designed to remove earth and vegetable matter still present in the raw material. It can be carried out in different ways, the principle being to circulate the beet and the wash water in opposite directions so as to transfer the soil.
  The flume water is separated from the beet as it enters the washing unit. It is then taken to a decanter whose overflow is directly re-used for transport water and wash water. The dense part in the decanter is drawn off and taken to the settling ponds properly speaking. The wash water can be recycled for transport after passing through a decanter or taken to the settling ponds after being separated from the vegetable part and the stony residues separated from the beet during cleaning. Following a decanting stage, the water from these ponds can undergo biological purification (aerobic and/or anaerobic) before being taken to settling and collection ponds. The water stored in these ponds can then be re-used for washing or transport. Surplus water that cannot be used for the next campaign is discharged into an outlet leading to a watercourse. In regions where this is appropriate, the mixture of soil and water is taken away from the factory site and spread on the fields.
  The closed circuit made up of the wash water and the flume water is also fed by some of the condensed water coming indirectly from the beet itself. As the beet consists of about 75 % water, this is not an insignificant input. [1, **CIAA**, 2002]

### 4.5.10 Water recovery in a vegetable processing company – case study

**[35, OECD, 2001]**

Description

A vegetable processing plant increased its production capacity of 17000 t/yr to 55000 t/yr in ten years. Because of the water shortage in groundwater resources, and due to a lack of alternative water sources (no surface water resource available, drinking water supply too expensive) the following water saving techniques were applied:

- re-use of treated effluent for processing operations where drinking water quality is not needed. The aerobic treatment of waste water was supplemented by a polishing step (sand filtration). As a result, the specific water consumption was reduced to 3 - 3.5 $m^3$/t of product
- reduction of salt content in the waste water by steam stripping
- increase in capacity of aerobic waste water treatment and the use of anaerobic pretreatment.

The final aim was to replace at least 50 % of the raw water demand, thereby decreasing the specific water consumption below 2 $m^3$/ t product.

The waste water treatment consists of an anaerobic pretreatment (reactor volume 5000 $m^3$, load 30 t COD/d, specific load 6 kg COD/$m^3$/d) followed by an aerobic activated sludge plant. After clarification, the effluent is treated in a two step sand filtration process with a maximum capacity of 100 $m^3$/h. The water is then fed to the ultrafiltration unit (40 $m^3$/h capacity) after pH correction and/or addition of flocculants. The ultrafiltration device is operated at low pressure (0.5 - 1 bar) and has hollow fibre membranes. The water is finally treated by a two–step reverse osmosis technique. The retentate of the first step is fed to the second step. The reverse osmosis equipment has a capacity of 20 $m^3$/h; the operating pressure is 8 – 10 bar, and efficiency is

70 %. Although the water is free of salts and bacteria, water is sterilised by UV radiation. Backwash water from the sand filters and ultrafiltration unit is recycled to biological treatment. The typical water quality parameters of the waste water in the different treatment steps and that of fresh ground water are included in the following table:

| Parameter | Unit | Waste water | After biological treatment | After polishing filtration | After sterilisation | Ground water | Process water* |
|---|---|---|---|---|---|---|---|
| COD | mg $O_2$/l | 12000 | 114 | | 0 | 0 | |
| PH | | 8.5 | 8.3 | 8.2 | 5.5 | 8.3 | 7 |
| Turbidity | NTU | | 16 | 4.3 | 0 | | 0 |
| Total phosphorus | mg/l | | 34 | 34 | <0.5 | <0.5 | <0.5 |
| Conductivity | mS/cm | 4.3 | 4.3 | 4.2 | 0.15 | 2.6 | 1.4 |
| Ammonia-N ($NH_4^+$) | mg/l | | <2 | <2 | <2 | 0.17 | |
| Iron | mg/l | | | | 0.03 | 0.23 | 0.1 |
| TH | mmol/l | | 1.0 | 1.0 | <0.3 | <0.3 | <0.3 |
| Bicarbonate | G/l | | 2.9 | 2.9 | <0.3 | <0.1 | <0.2 |
| Total bacteria (CFU) | i/ml | | | | 0 | 0 | 0 |
| *E. coli* | i/ml | | | | 0 | 0 | 0 |
| *1:1 *mixture of ground water and sterilised water* | | | | | | | |

**Table 4.14: Water quality parameters of treated waste water, raw water and process water**

Achieved environmental benefits

Reduction of use of water resources by 50%. Re-use of waste water, reduction in water pollution load.

Cross-media effects

High energy demand for waste water treatment.

Operational data

Applicability

Economics

The drinking water cost varied between 0.99 – 1.54 euros/ $m^3$ and it was expected to increase because of the great demand. The cost of the process water was 1.03 euros / $m^3$.

Driving forces for implementation

The company was using ground water as it was bacteriologically safe. However, there were some difficulties:

- it had to be drawn from a depth of 300 meters
- the local groundwater levels were dropping, leading to shortages
- the groundwater had growing salt concentrations and some parameters were not meeting quality standards. Some parameters compared to WHO guidelines:

| Parameter | Unit | Groundwater | WHO guideline |
|---|---|---|---|
| pH | | 8.3 | 6.5 - 8.5 |
| Sulphate | mg/l | 126 | 400 |
| Bicarbonate | mg/l | 552 | |
| Chloride | mg/l | 550 | 250 |
| Conductivity | mS/cm | 2.6 | 0.25 |

**Table 4.15: Quality of groundwater source for a vegetable processing plant compared to WHO guideline**

Example plants
Vegetable processing plant of Pasfrost Company in Passendale, Belgium

## 4.6 Cleaning

Processing equipment and production facilities are cleaned and sanitised periodically, with the frequency varying according to the products and processes. The aim of cleaning and sanitation is to remove product remnants from the foregoing process run, other contaminants and microbes.
Cleaning and sanitation can be carried out in various ways [Environment Agency (UK), 2000 #37]:

- manually
- cleaning in place (CIP)
- high-pressure jet cleaning
- foam cleaning.

Manual cleaning means that the equipment to be cleaned is taken apart and manually cleaned (brushed) in a cleaning solution. Only mild conditions, with regard to temperature and cleaning agents, can be used.

**Cleaning in place** (**CIP**) is discussed in Section 4.6.3.

In **high pressure jet-cleaning**, water is sprayed at the surface to be cleaned at a pressure of about 40 to 65 bar. Cleaning agents are injected in the water, moderate temperatures up to 60 °C are used. An important part of the cleaning action is due to mechanical effects. Pressure washing reduces water and chemical consumption compared with mains hoses. It is important, however, that a pressure that is both safe and efficient is used. There is some concern in the food industry about the hygiene implications of over-splash and aerosols associated with the use of high pressure hoses.
A pressurised water ring main is generally preferable to mobile pressure washing machines, which require longer downtime, emit diesel fumes and tend to use more water.
In **foam cleaning**, a foaming cleaning solution is sprayed on the surface to be cleaned. The foam adheres to the surface. It is left on the surface for about 10 to 20 minutes and is then rinsed away with water.
High-pressure jet cleaning and foam cleaning are generally applied for open equipment, walls and floors.

It is common practice for the staff involved in clean-up operations to remove floor-drain grates and flush raw materials and product directly down the drain, believing that a subsequent screen or catch pot will trap all solids. However, when these materials enter the waste water stream they are subjected to turbulence, pumping and mechanical screening. This results in the breakdown and release of soluble BOD, along with colloidal and possibly suspended grease solids. Subsequent removal of this soluble, colloidal and suspended organic matter can be far more complicated and expensive than the use of simple screens.

**Cleaning agents** used in the food and drink industry are alkalis (sodium and potassium hydroxide, metasilicate, sodium carbonate), acids (nitric acid, phosphoric acid, citric acid, gluconic acid), composed cleaning agents containing chelating agents (EDTA, NTA, phosphates, polyphosphates, phosphonates) and surface-active agents.

### 4.6.1 Sanitation chemicals and techniques

**Oxidising biocides** oxidise the bacterial cell walls and prevent replication. They rely on the use of strong oxidising agents such as chlorine/bromine, ozone, and hydrogen peroxide. The use of **chlorine compounds** (chlorine gas, chlorine dioxide, sodium hypochlorite) relies upon the formation of hypochlorous acid (the active biocide) in aqueous solution. Bromine based biocides are also becoming more prevalent in industrial applications due to the hypobromous acid species dissociating at a higher pH than the equivalent chlorine based compounds.

The main disadvantage of chlorine based chemistry is the ability of chlorine to react with a wide number of other compounds and so actually reduce the 'effective' chlorine dose rate. This situation is further complicated by the formation of 'chloramines' and other organo-halogen compounds, many of which are dangerous to living organisms, and the discharge which must be tightly controlled within the receiving water.

The use of **ozone** is also increasing for disinfecting purposes.

**Non-oxidising biocides** operate by chemically altering the cell structure in order to prevent bacterial cell replication. These are becoming more common, examples are quaternary ammonium salts and formaldehyde/glutaraldehyde.

**UV light** is perhaps the most significant advancement in disinfection technique over the past 10 years. UV light at 254 nm is readily absorbed by the cellular genetic material within bacteria and viruses, which prevents the cell from replicating. The main advantages of UV disinfection over other techniques includes, no storage or use of dangerous chemicals, the absence of harmful by-products (no organo-halogens) and the fact it is a simple technique with relatively low capital and operating costs.
The dose rate is measured in milliwatts per square centimetre multiplied by the contact time in seconds. The actual dose is dependant on the transmittance (i.e. compounds which can absorb and reduce UV light effectiveness) of the waste water stream. UV light is also an immediate reaction so therefore does not impart any residual effect. Treated waters are therefore liable to re-infection.
The main disadvantage of UV disinfection, is that a direct line of sight must be maintained between the lamp and the bacteria/virus. Any appreciable levels of suspended solids (hence decreasing transmisivity) will actually shield the bacteria and prevent their disinfection.

| | |
|---|---|
| **Air:** | Not applicable. |
| **Water:** | Wash waters will contain remnants of cleaning agents, product rinsed from the system and removed form the equipment that is cleaned. |
| **Land:** | Not applicable. |
| **Waste:** | Not applicable. |
| **Energy:** | Cleaning is commonly carried out at elevated temperatures utilising steam. Pre-clean systems, for example vacuum transfer, blowers and pigging systems require power and compressed air. |
| **Accidents:** | Spillage of cleaning chemicals. Leakage from effluent system. Overloading of effluent treatment system. |
| **Noise:** | Not applicable. |

**Table 4.16: Environmental impacts of cleaning**

### 4.6.2 Dry clean-up

The single most important factor in reducing waste water strength in this sector is the adoption of dry clean-up techniques. Wherever possible raw materials and product are kept out of the waste water system. This may be achieved by [13, **Environment Agency (UK)**, 2000]:

- removing as much residual material as possible from vessels and equipment before they are washed
- sweeping, shovelling or vacuuming spilt material rather than hosing it down the drain
- making sure suitable dry clean-up equipment is always readily available
- providing convenient, secure receptacles for the collected waste.

Wherever practicable, process lines and operations that cause excessive spillage of material onto the floor are modified to eliminate or reduce any spillage problems.

The single most important factor in reducing waste water strength in this sector is the adoption of dry clean-up techniques. Wherever possible raw materials and product are kept out of the waste water system. Dry clean-up technology include measures such as:

- Equipment design:
  - wherever practicable, process lines and operations that cause excessive spillage of material onto the floor is modified to eliminate or reduce the problem [17, **Envirowise (UK)**, 1998]
  - removing as much residual material as possible from vessels and equipment before they are washed
  - ensuring that drains are equipped with catchpots
  - that the catchpots are in place during cleaning (for example by installing lockable catchpots)
  - optimisation of water pressure at jets, nozzles and orifices
  - automatic water supply shut off on trigger operated spray guns or hoses.

- Good housekeeping:
  - installing trays to collect waste as it falls to the floor
  - sweeping, shovelling or vacuuming spilt material rather than hosing it down the drain
  - making sure suitable dry clean-up equipment is always readily available
  - providing convenient, secure receptacles for the collected waste.

- Optimisation of cleaning schedules:
  - matching cleaning cycle durations to the vessel size
  - product scheduling to minimise the number of product changes and subsequent cleaning between products.

- Management of manual cleaning:
  - procedures to ensure that hoses are only used after dry clean-up.

- Cleaning chemicals usage:
  - the operator ensures that staff are trained in the handling, making up of working solutions and their application, i.e. not setting the concentration of the chemical agent too high and avoiding the overuse of chemicals, particularly where manual dosing is used.

- Sanitisation:
  - The operator justifies the use of organo-halogen based oxidising biocides over the alternatives, such as ozone and UV light.

- Recycling of water and recovery of cleaning chemicals

### 4.6.3 Cleaning-in-place

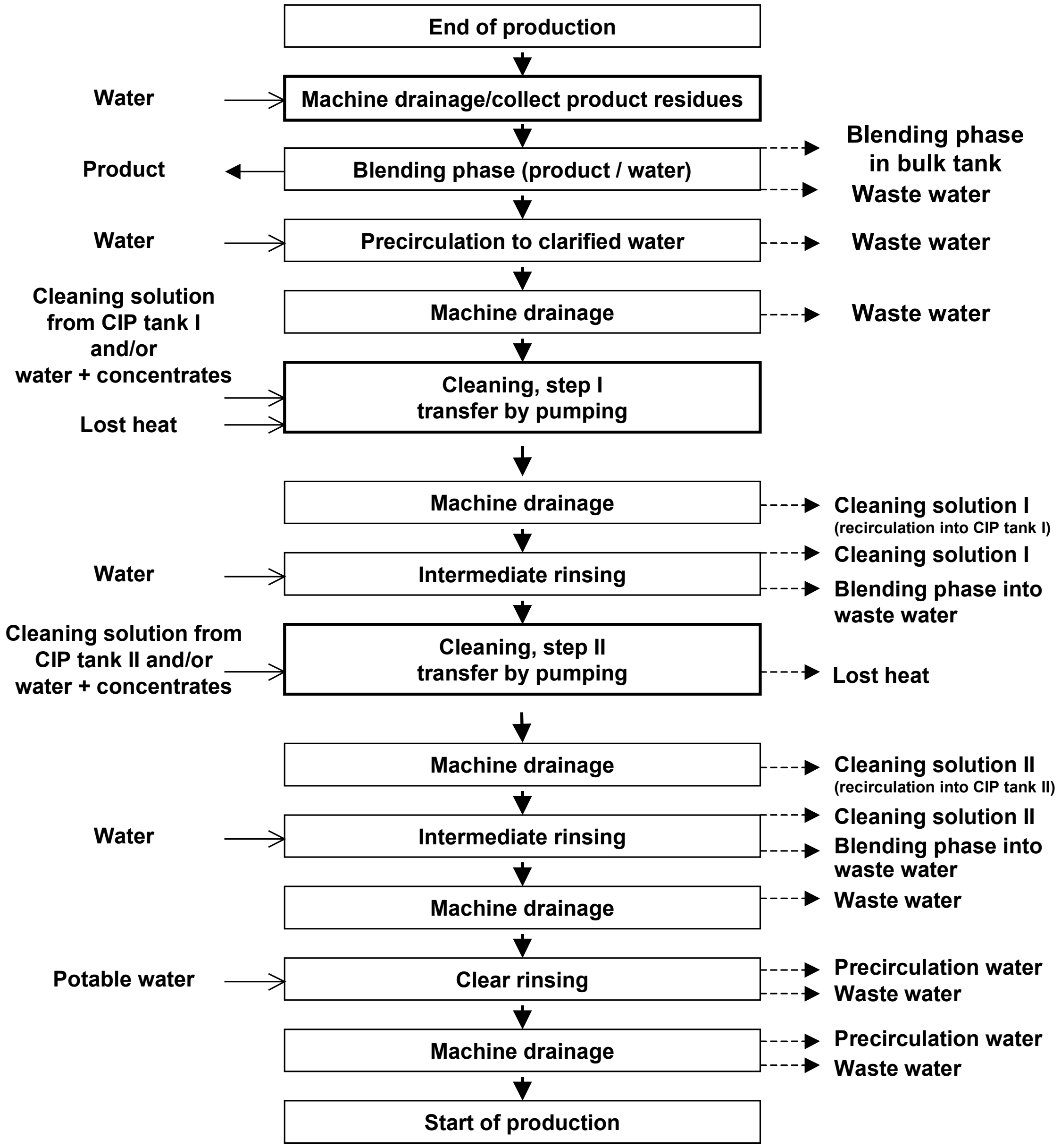


**Figure 4.14: Flow sheet of cleaning-in-place**
**[39, Germany, 2001]**

The detergents are recirculated (except for commingling losses) so that losses to the environment are relatively small. An additional effect is a partial recuperation of the thermal energy.

Cleaning-in-place (CIP) systems can be much more efficient than manual cleaning but need to be designed and used with due consideration to waste water minimisation. Desirable features include:

- dry product removal before the start of the wash cycle by gravity draining, pigging or air blowdown
- pre-rinse to enable remaining product to be recovered for re-use or disposal
- use of turbidity detector to maximise product recovery
- optimal CIP programme for the size of plant/vessel and type of soiling
- automatic dosing of chemicals at correct concentrations
- internal recycling of water and chemicals
- recycle control on conductivity rather than time
- continuous cleaning of recirculated solutions
- water-efficient spray devices.

#### 4.6.3.1 CIP in dairy industry

CIP is widely used as it offers many advantages. However, some further aspects have to be mentioned [65, Germany, 2002]:

- for large dairy plants with highly branched tubing it is first necessary to check if a centralised CIP system is appropriate. Often the distances are too long which causes considerable heat losses, losses by the commingling of detergents and water as well as superfluous pumping capacities. One solution can be to use several small CIP systems or decentralised cleaning stations, which are supplied with the necessary cleaning media by the centralised CIP system via a closed circular pipeline
- in the case of single-phase cleaning, the independent acid cleaning is normally omitted and only an alkaline cleaning with special additives added to the alkaline detergent is carried out. The omission of the acid cleaning reduces the water and energy consumption
- as the technical requirements of single-use cleaning systems are relatively simple they are often employed in small or rarely used plants. They can be used in bigger plants for some process equipment when the cleaning solution is so polluted that re-use of the agents is excluded as it could risk impeding the cleaning effect in other installations. These are usually UHT plants, membrane filtration plants, and the preliminary cleaning of evaporators and spray driers
- different systems for lye treatment are available on the market. However, none of them have proven their economic functionality yet.

### 4.6.4 Mains hoses

Mains hoses are always fitted with trigger action guns, which need to be properly maintained. Hoses are not used where dry clean-up is possible. [13, **Environment Agency (UK)**, 2000]

### 4.6.5 Pressure washing

Pressure washing reduces water and chemical consumption compared with mains hoses. It is important, however, that a pressure that is both safe and efficient is used. There is some concern in the food industry about the hygiene implications of over-splash and aerosols associated with the use of high pressure hoses.

A pressurised water ring main is generally preferable to mobile pressure washing machines, which require longer downtime, emit diesel fumes and tend to use more water. [13, **Environment Agency (UK)**, 2000]

### 4.6.6 Maintenance

In general, the maintenance of utility systems receives much lower priority than maintenance that has a direct impact on production or safety. This can be a major contributing factor in excessive water use and unnecessary waste water generation. The maintenance regime ensures the prompt repair of water leaks and faults which can lead to overflow or spillage to drain. Operation of the cooling tower is usually optimised to avoid excessive blowdown. [13, **Environment Agency (UK)**, 2000]

## 4.7 Techniques for re-use/recovery

Some examples of techniques that may be applied to enable re-use or recycling of materials or utilities and other forms of recovery are given below [1, **CIAA**, 2002]:
(No priority ranking is intended, and the appropriate selection in a particular case will depend on the specifics of the process concerned and on site constraints).

- re-use of by-products and co-products, e.g. in animal feed or as fertilisers
- recovery of evaporator condensate for re-use (e.g. in boiler, washing etc.)
- re-use of collected dusts
- solvent recovery plant
- recovery of residues from extraction/refining, alkali saponification and deodorisation distillation condensate
- energy recovery
- landspreading (waste water, surplus biomass from biological treatment plants and other solid residues).

## 4.8 Energy efficiency

In many sectors of the food and drink industry energy use is an important cost factor. Depending on the nature of the production activities, energy costs may vary from less than 1 to more than 10 % of the production costs. Reducing energy use is an important issue, both from the point of view of the environmental impact (greenhouse effect) and also due to cost savings.

The energy use of a plant is determined to a large extent y the applied process equipment and techniques utilities and buildings. However, human behaviour also plays an important role, i.e. how people operate energy consuming equipment in an efficient manner. Therefore, in order to improve the energy efficiency of a plant both the technical and human behavioural aspects need to be addressed.

Energy saving measures may be limited by the availability of human resources.

Note equipment such as that seen in the figure below are not used any more:

**Figure 4.15: Energy saving butter churn**

### 4.8.1 General approach

To measure the energy consumption in an industrial plant the concept of energy efficiency is usually used, often defined as the amount of energy used per unit of product. Improving energy-efficiency therefore means reducing the amount of energy per unit of product. This will result in energy savings on a plant level, if the product output remains at a constant level.
In improving the energy efficiency two aspects can be distinguished:

- reduction of the energy consumption by efficient energy management
- reduction of the energy consumption by process optimisation and by process innovation.

An illustration of the relationship between the effects of efficient energy management and implementing energy saving measures such as process optimisation and process innovation is given in Figure 4.16.

Energy management is a management approach to controlling and minimising energy use and energy costs, and depends to a large extent upon placing accountability for usage on those individuals who are responsible for using it. An essential part of energy management is “monitoring and targeting”.
Energy management is a tool for encouraging good housekeeping. This often results in a substantial improvement in the energy efficiency. In several case studies, energy savings of 5 - 15 % are reported.

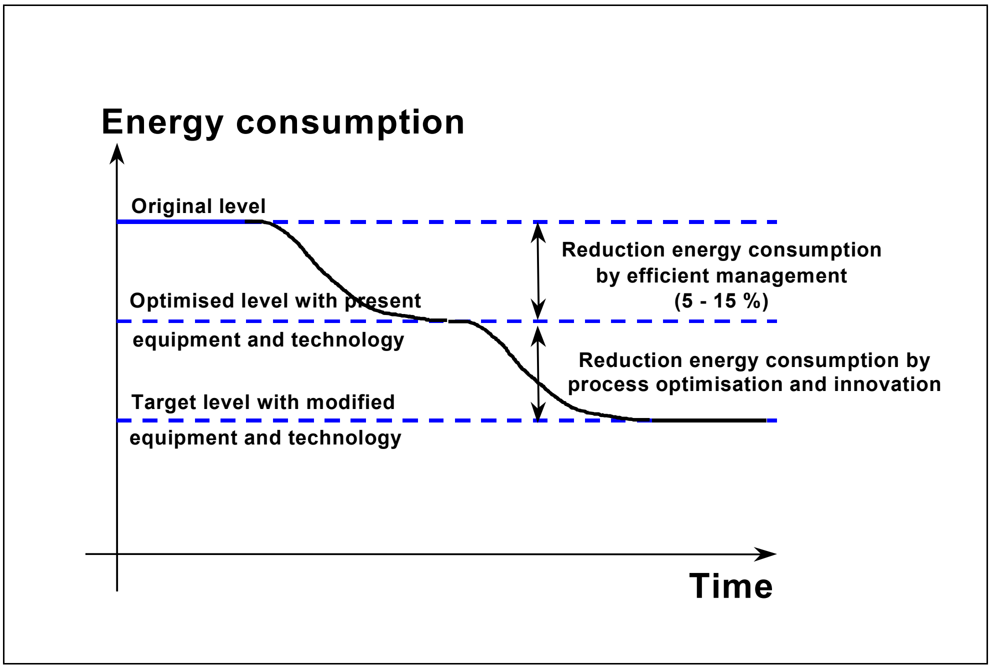


**Figure 4.16: Reduction in energy consumption**

A further step in improving energy efficiency can be made by process optimisation and process innovation. Sometimes this requires only minor investments. Often, for innovations that have an important impact both on the process and energy use, larger investments are necessary.
Investment in process optimisation and process innovation without an efficient system of energy management (monitoring and targeting) cannot give a good insight into whether the expected energy savings are indeed realised. Furthermore, it is possible that the effect of the energy savings gained by process adaptations can be offset by not maintaining good housekeeping.

## 4.8.2 Methodology for improving the energy efficiency

In order to achieve sustainable energy savings a systematic approach is advised which involves the following steps:

Step 1 Energy consumption analysis of the plant
Step 2 Identification of energy efficiency measures
Step 3 Evaluation and feasibility study
Step 4 Setting up of an energy management system.

Naturally, these steps are very similar to the ones previously discussed in relation to the reduction in water consumption in Section 4.4.5.

### 4.8.2.1 Energy consumption analysis

Information about energy consumption is fundamental to identifying where the most effective energy savings and cost-effective improvements can be made. Furthermore, it is a basis for demonstrating that the installation is operated in an efficient manner and that energy saving measures are taken in the most appropriate areas.

(a) Energy input

The information is broken down by energy source. Besides purchased electricity, it also includes fuels converted to energy at the site, heat imported directly from external sources and renewable energy sources. Recent values for delivered energy sources over a recent 12-month period may be used. Conversion to primary energy is advised. Where energy from a combined heat and power plant (CHP) is used, the calculated energy used is based on energy input to the CHP plant, not on the units of energy produced by the CHP plant. A possible breakdown can be seen in Table 4.17.

| Energy source | Energy consumption | | |
|---|---|---|---|
| | **Delivered** | **Primary (MJ or MWh)** | **% of total** |
| Electricity | MWh | | |
| Gas | m$^3$ | | |
| Oil | tonnes | | |
| Imported steam | tonnes | | |
| Energy from waste/renewable sources | MJ | | |
| Other, specify<br>………………<br>……………… | …<br>… | | |
| Exported steam | tonnes | | |
| Exported electricity | MWh | | |

**Table 4.17: Example of breakdown of the energy consumption**

(b) Energy consumption throughout the process

Next an analysis is made of the energy consuming equipment per department or production line. It is advisable to supplement the energy consumption information with energy balances or flow diagrams to illustrate how energy is used throughout the process. A Sankey diagram is especially useful for representing situations where energy conversion is highly integrated within the production activities. (See an example in Section 4.8.3.10.2.

(c) Specific energy consumption

Specific energy consumption (SEC) means the amount of energy that is consumed per unit of raw material processed or product output.

### 4.8.2.2 Identification of energy efficiency measures

It is advised, that in the process of identification of energy efficiency measures, the production processes, utilities and buildings be considered separately. For identifying energy efficiency measures, methods similar to the ones mentioned in connection with water management (see Section 4.4.5.5) can be applied.

(a) brainstorming
(b) external consultancy
(c) pinch analysis.

A pinch analysis provides a systematic approach to analysing energy networks and improving the energy efficiency of industrial processes. A pinch analysis uses a graphical representation of the energy flows in the process and utility streams to determine the minimum amount of energy an energy system needs to use to satisfy the processing requirements. The technique uses temperature-enthalpy diagrams to characterise the hot and cold streams available for heat transfer. The sum of the hot streams and cold streams in a process can be drawn on a similar diagram from which the "pinch" temperature can be determined. This information can be used to identify where in the process heat recovery is possible and to what degee. Furthermore, the minimum hot utility requirement and minimum cold utility requirement can be determined. To realise this minimum energy requirement a heat exchanger network is installed. The pinch analysis yields the optimum design.

Pinch analysis is successfully applied in the chemical process industry and refineries. It may also be a useful tool for the bigger and more complex food industries. For relatively simple operations, it does not result in any more or better options than those that can be raised by the other methods. Also the method is difficult to apply for batch processes and it is does not take into account electricity consumption.

### 4.8.2.3 Evaluation and feasibility study

Many measures applicable for reducing the environmental impact of energy use have no effect on other polluting emissions associated with the installation. Such measures could be considered as "stand alone" techniques and evaluated according to their individual economical and environmental benefits. The evaluation of such "stand alone" measures are based on balancing the energy efficiency effect of such a measure against the costs of implementation of the measure.

With regard to the costs of a measure the following elements can be distinguished: capital costs, average change in annual operating and maintenance costs. On this basis, the annualised costs for each measure can be calculated. Sometimes the annual average carbon dioxide saving and the cost (savings) per tonne of saved $CO_2$ are estimated

Some energy efficiency measures can lead to adverse implications for other environmental releases, such as increased emissions to air or generation of waste. In these cases, the wider environmental impacts need to be taken into account to determine what is the best available technique. On the other hand, there are many techniques used for the control of other environmental releases that consume significant amounts of energy. In the case of trade-off between energy consumption and other environmental objectives, an assessment, taking into account the costs and environmental benefits needs to be undertaken to justify the selection of appropriate measures.

Energy efficiency techniques are listed and prioritised in their order of implementation. In principle implementation is required for all measures that are cost-effective (i.e. the costs are not excessive in relation to the environmental protection the measure provides). These measures are considered to be effective. Ranking also often takes place for the cost effectiveness of the measures in reducing environmental pollution.

### 4.8.2.4 Setting up an energy management system

Energy management is based on the same principles as environmental management and it is therefore considered practical to incorporate energy management within the overall environmental management system.

An energy management system is based on the following main pillars:

(a) Energy management policy

It is advisable to write and publish an energy policy which provides targets and performance indicators for energy efficiency. Energy policy is an integrated part of the overall policy.

(b) Monitoring and targeting

Essential steps in monitoring and targeting are as follows:

- recording the energy consumption with regular intervals
- relating the energy consumption to (production) activities and/or other relevant parameters
- introducing targets for energy consumption
- comparing the real energy consumption with the targets
- reporting on it
- taking actions if the real energy consumption deviates substantially from the target consumption.

Setting realistic targets is not always easy.
One approach is to set a figure lower than the average level (e.g. 10 %).
Another approach is to determine the minimum energy consumption level based on the specifications of the various parts of the process lines.

| CASE STUDY - Energy monitoring and target setting at a dairy |
|---|
| • Associated Dairies-MD Foods installed a computer-based monitoring and targeting (M&T) system at its Accrington dairy, to help reduce costs and improve profitability. A number of meters were installed in the dairy to measure electricity, oil and water usage. The meter readings were entered into the M&T system, which presents data to enable the company to pinpoint areas of waste and to take corrective action. The principle of M&T has been well proven in this case, with improvements in energy efficiency constantly being made. Substantial energy and utility savings were achieved. These savings, which were achieved with low capital costs, were partly due to the high motivation of staff at all levels. Potential users: any organisation with significant energy or utility costs.<br>(Caddet, Project No. UK-1994-522<br>URL: http://www.caddet-ee.org/infostore/details.php?id=1711) |

(c) People management

Good energy management requires the awareness of, and involvement in, energy efficiency by all staff.

### 4.8.3 Energy efficiency techniques

There is a lot of information on energy efficiency techniques available in various public sources. However, the available techniques are strongly dependent of the particular site and type of process. Mentioned below are some generally applicable energy efficiency techniques. The techniques range from rather simple methods such as good housekeeping, process optimisation to more complex ones, such as heat recovery and applying combined heat and power (CHP) generation.

#### 4.8.3.1 Good housekeeping and process optimisation

A large part of the energy consumption of a plant is related to the utilities. Important utilities are compressed air, steam, refrigeration, air conditioning and electricity supply.
In the UK Environmental Agency horizontal guidance note [69, Environment Agency (UK), 2001], good housekeeping measures are given for these utilities. They are presented as energy efficiency checklists. For example:

(a) Checklist for steam systems
- ✓ maximise condensate return
- ✓ avoid losses of flash steam from condensate return
- ✓ isolate unused piping
- ✓ improve steam trapping
- ✓ repair steam leaks.

(a) Checklist for compressed air
- ✓ good housekeeping: consider turning off during non-productive hours, review the pressure level and reduce it if possible, etc.
- ✓ treatment of compressed air: regularly inspect and maintain the treatment, check the dryer temperature, etc.
- ✓ check the use of compressed air and the need for it
- ✓ establish compressed air leakage.

(b) Checklist for air conditioning and refrigeration
- ✓ for refrigeration plants: keep the condensers clean, make sure that the air entering the condensers is as cold as possible, check for leaks of refrigerant, check oil level, etc.
- ✓ for cooled rooms: keep the doors closed as much as possible, check that evaporators defrost properly, do not keep the store colder than necessary, etc.

(c) Checklist for motors and drives
- ✓ is the equipment still needed
- ✓ switching the motor off
- ✓ reducing the load on the motor
- ✓ minimising motor losses
- ✓ slowing down the load
- ✓ use variable speed drives to reduce the load on fans and pumps.

### 4.8.3.2 The use of Pinch technology in a food processing factory

**[1, CIAA, 2002]**

Description

The objective was to achieve energy savings through process integration, based on heat recovery between hot and cold streams. Refining edible oil is an energy intensive process. The host company wanted to ensure that a new refinery was more energy efficient than its predecessor, which used steam for process heating and river water for cooling. Pinch technology (an analysis method that identifies the best use of heat transfer from hot streams, which require cooling, to cold streams, which require heating) offered significant potential. However, the company's engineers were not experienced in this technology, so consultants were appointed to work with an in-house engineer on a study. This revealed that the Pinch point was 55 °C and enabled the formulation of a heat recovery strategy. It also revealed that existing batch processes would lead to a disparity between the timing of heat availability and demand, making it impractical for direct heat exchange between many of the hot and cold process streams. A heat transfer/storage medium was required before any process integration projects could be carried out. A heat recovery network was developed using water for heat transfer and storage. This has proven highly successful and has not adversely affected production capacity nor flexibility. In addition, the use of the utility system has enabled disparate batch processes to be successfully integrated. After two years, an updated Pinch study showed that the Pinch point had moved and operational changes are now under consideration.

The utility water system is based on three water temperatures: 30 °C, 55 °C and 95 °C and uses four thermal tanks.

Achieved environmental benefits
Energy use reduced by 35 %.

$CO_2$ emissions reduced by 16700 tonnes/yr. Reduced quantities of waste heat discharged into river.

Cross-media effects

Operational data

Applicability

Economics

| | |
|---|---|
| Costs Consultancy fees for Pinch Study | EUR 32000 |
| In-house staff costs for Pinch Study | EUR 16000 |
| Implementation of Pinch Study recommendations | EUR 3066000 |
| Link to neighbouring factory for export of heat | EUR 203000 |
| **Total costs** | **EUR 3317000** |
| Savings Reduction in energy costs | EUR 1145000 |
| Sale of surplus heat | EUR 90000 |
| Annual utility water system operating costs (EUR 84000) | |
| **Net savings** | **EUR 1152000** |

Driving forces for implementation
Reduction of energy costs.

Example plants
Purfleet, United Kingdom

Reference literature
Caddet project No. UK-1999-524 The Use of Pinch Technology in a Food Processing Factory; URL: http://www.caddet-ee.org/infostore/details.php?id=2656

### 4.8.3.3 Frequency converters on motors

**[42, Korsstrom, 2001]**

Description
Controlling the speed of the pump by frequency converters ensures that the speed of the impeller is exactly adapted to the required output of the pump, as are the power consumption and treatment of the liquid.

Achieved environmental benefits
The reduction of the power consumption depends on the capacity and number of pumps and motors. Generally, a 10 % reduction in the output of a pump corresponds to a 28 % reduction in the power consumption of the pump.

Cross-media effects
Not relevant

Operational data

Applicability
Frequency converters can be used with standard three-phase motors. They are available for both manual and automatic speed controls. They can be applied in existing and new plants for pumps, ventilation equipment and conveying systems.

Economics
The price of a 5.5 kW frequency converter is about EUR 600.

| CASE STUDY – Frequency converters in a dairy |
|---|
| • 203 motors in a Taulov dairy plant were equipped with frequency converters. The total power of the motors was 1216 kW. The estimated cost of the investment is EUR 311000. The estimated annual saving is EUR 90000 (1325 MWh). |

| CASE STUDY - Speed-controlled centrifugal pump in a whey factory |
|---|
| • Borculo Whey products processes whey into several raw materials for the pharmaceutical and food industries. One of these products is lactose, the production of which involves a refining process, in which "wet" lactose (9 % pure) is dissolved in hot water in a circular process. Wet lactose is transported through a shaking tray to a mixing vessel, where it is mixed with hot water. The mixture is pumped into a buffer vessel, where it is stirred, and from which it is returned to the mixing vessel. Thus, the lactose content of the mixture gradually increases. After approximately 1 hour, the mixture is discharged from the mixing unit for further processing. The liquid level in the mixing vessel used to be controlled by regulating the water/lactose flow from the buffer tanks. This was achieved by a choke valve on the delivery side of the centrifugal pump used for the transport. This choke system had several disadvantages: it was inefficient (unnecessary dissipation of electric energy) and it caused unnecessary wear of the pump. It was therefore decided to replace the flow regulation system with a speed control system on the motor driving the pump.<br>This has resulted in energy savings amounting to 12600 kWh/year, with a value of NLG 1638, and a reduction in maintenance costs of NLG 10257/year, giving a payback period of 0.3 years.<br>(Caddet project NL-1994-508,<br>URL: http://www.caddet-ee.org/infostore/details.php?id=1763) |

Driving force for implementation
The reduced consumption of electrical power in combination with a gentler treatment of the product acts as the driving force.

Example plants
Taulov dairy plant of Arla Foods, Denmark

Reference literature
[42, Korsstrom, 2001]

### 4.8.3.4 Heat recovery in evaporation and drying

(a) Heat recovery

Significant savings can be made through the recovery of waste heat in many processes. Opportunities for heat recovery from gaseous and liquid streams need to be explored for use in applications, such as direct process heat exchange, preheating of combustion and drying air, etc.

(b) Evaporation

Evaporation and drying are often the main energy using processes within the food industry. Multiple-effect evaporators are used in the sugar industry, in starch processing and in the evaporation of milk and whey. These use fresh steam or exhaust gases from other operations (energy recovery/re-use) to boil off water vapour from the liquid in the first effect. The evaporated water still has sufficient energy to be the heat source for the next effect, and so on. Vacuum is applied in a multiple-effect chain in order for the water to boil off. The liquid being processed is passed from one evaporator body through the others so that it is subject to multiple stages of evaporation. In this way one unit of steam injected in the first evaporator might remove three to six units of water from the liquid.

By recompression of the vapour using a thermo re-compressor (TVR) or mechanical re-compressor (MVR) additional energy can be saved.
In the final stage, cooling using cooling water may condense the vapour.
Some of the vapours can be drawn off the evaporators to be used as heat sources for other process requirements.

> Steam requirements for single stage evaporators are 1.2 to 1.4 tonne/tonne of evaporated water.

> Typical energy requirements (per tonne of water evaporation) for multistage TVR evaporators are: 0.1 - 0.3 tonne of steam and 2 kWh electricity.

> The energy consumption of a MVR evaporator is in the range of 10 kWh/ tonne of water evaporation, with negligible steam consumption.

| CASE STUDY - Application of multi-effect evaporation in the sugar industry |
|---|
| • The sugar juice resulting from purification has a dry matter content, which is still in the region of 15 %. It is necessary to raise this dry matter content to isolate the sugar. The evaporation process allows the dry matter content to be increased from 15 % to more than 68 %. It is based on the principle of heat exchange between the juice and the steam produced in a boiler.<br>A so-called multi-effect device produces the heat exchange that takes place between the sugar juice and the low-pressure steam. This recycles the steam obtained from the juice after the first exchange.<br>In practice, the low-pressure steam from the generator is condensed after undergoing a heat exchange and returns to supply the boiler. Following the same exchange, part of the water of the sugar juice evaporates and the steam produced in this way heats the second effect, in which a new part of the water evaporates. The effects follow on from each other in this way, the operation can be repeated up to six times in all.<br>A decreasing level of pressure and temperature from one effect to the other allows the operation to be repeated several times with approximately the same amount of energy. [61, CEFS, 2001] |

CASE STUDY - Application of multi-effect evaporation in dairy industry

- The evaporation of milk and milk products mainly serves to produce milk powder, concentrated milk (evaporated milk, yoghurt milk), whey powder and concentrate. Milk is evaporated under vacuum and therefore at temperatures < 100 °C. The operational range normally comprises temperatures between 75 and 40 °C. (Higher temperatures involve the danger of a deposit of denatured whey proteins and milkstone. The lowest temperatures are determined in particular by cooling water temperatures and quantities.)
  Energy consumption can be minimised through the use of falling film evaporators with several evaporation stages. Further energy savings can be made using thermal re-compression and mechanical re-compression as can be seen in the following table:

| **Installation** | | **Use of primary energy (kJ energy/kg evaporated water)** |
|---|---|---|
| | | |
| Evaporator with TVR | | |
| Duple effect TVR | | approximately 1160 |
| Triple effect TVR | | approximately 885 |
| 5 effect TVR | | approximately 470 |
| 6 effect TVR | | approximately 450 |
| Evaporator with MVR | | |
| Duple effect MVR | | approximately 222 |
| Triple effect MVR | | approximately 168 |

**Table 4.18: Comparison of efficiencies of multi-effect evaporators in dairy industry [39, Germany, 2001]**

(c) Drying

A wide variety of dryers are on the market. Theoretically, for the evaporation of water 2.2 MJ/kg is required. However, in practice, this very much depends on the type of dryer used and can range from 2.0 – 3.5 MJ/kg. Steam dryers can have considerable lower energy consumption if they consist of more effects. Sometimes exhaust gases from a combustion (CHP) plant are used to dry the products, thereby reducing the energy requirement. The energy consumption for drying can be further reduced by increasing the dry substance content of the wet product. This can be achieved by pre-evaporation or by using special dewatering equipment such as presses or centrifuges.

#### 4.8.3.5 Conversion to mechanical vapour recompression (MVR)

Description
A Japanese dairy upgraded its milk powder process and installed a four-effect MVR evaporator to replace its existing four-effect TVR evaporator.

Achieved environmental benefits
Reduction in thermal energy consumption.

Cross-media effects

Operational data
When the MVR system was adopted, it was necessary to prevent milk being scorched and contaminating the surfaces of the heat transfer pipes in the evaporator, in order to maintain the design evaporation capacity. As a result, an automated control system was installed to control operating parameters, such as flow rate, temperature and pressure.

Applicability

Economics
The cost of the new MVR evaporator was EUR 1.5 million, compared with EUR 1.3 million for a new TVR evaporator.

At an evaporation rate of 30 tonnes/hour, the annual operating costs of the MVR evaporator was EUR 175000, compared with previous annual operating costs of EUR 680000 for the TVR evaporator, a saving of nearly 75 %. The savings were mainly a result of the greatly reduced steam consumption.

Driving forces for implementation
Saving energy costs

Example plants

Reference literature
Cleaner production Assessment in Dairy Processing. Paris (2000) [UNEP; Danish EPA; COWI, 2000 #70]

### 4.8.3.6 Heat pumps for heat recovery from various sources

Description
The working principle of a heat pump is based on heat transfer from a lower temperature to a higher temperature by aid of electrical power.

Achieved environmental benefits
Energy is recovered. One example is the recovery of heat from warm cooling water. The cooling water is cooled and the heat can be used for heating hot water.

| CASE STUDY - Low temperature drying using heat pump |
|---|
| • A system developed in Brisbane, Australia, reduces energy costs through a hybrid food drying system. There were (in 1997) more than 16 food companies in Australia using over 30 heat pump dryers for low temperature drying of food materials. The heat pump dryer consists of a conventional drying chamber with an air circulation system and the usual components of an air-conditioning refrigeration system. The drying air is dehumidified by the evaporator (cooling section of the refrigeration cycle) and reheated by the condenser of the heat pump. The energy efficiency expressed by specific moisture extraction rate (kg water removed per kWh energy used) is between 1 - 4, with an average of 2.5 kg/kWh. Fluidised bed dryers are not suitable for sticky materials or if the shape is irregular. The two dryers can be used in series. Dehumidified air from the heat pump is directed first to the fluidised bed with the semi dried product. The airflow then passes through the cabinet dryer. Using this combination, energy efficiency could be improved by up to 80 %.[CADDET; UK National team, 1997 #73] |

Cross-media effects
Heat pumps require electricity.

Operational data

Applicability
It needs a good heat source in combination with a simultaneous need for heat near the source.

Economics
The economic feasibility depends on the price of fuel in relation to that of electrical power.

Driving force for implementation
Reduced costs for energy and water.

Example plants

Reference literature
[42, Korsstrom, 2001]

### 4.8.3.7 Heat recovery of pasteurisation – Ice cream production

Description
Heat can be recovered from the ice cream pasteurisation process. The ice-cream mix enters the pasteuriser at a temperature of 60 °C and is heated to 85 °C, followed by cooling to 4 °C prior to ageing. The cooling phase consists of several steps. In the first step, the ice cream is cooled to 70 °C by regenerative heat exchange and in the second step cooling water is used for further cooling to approximately 20 °C. The final temperature of 4 °C is achieved by cooling with ice water.
The heat released from the ice-cream mix in the second cooling step can be used for preheating water for various purposes, mainly for cleaning operations. This requires a number of storage tanks for the hot water.

Achieved environmental benefits

| CASE STUDY – Heat recovery in an ice cream plant |
|---|
| • In an ice cream plant, the heat from the second cooling step is used for preheating of approximately 25 % of the total amount of water used in the plant. The heat recovery yields hot water of approximately 70 °C. The average inlet temperature of the cooling water is 10 °C, the corresponding quantity of heat recovered is 7600 GJ/yr, which represents approximately 14 % of the energy consumption of the plant. The hot water is used for CIP and the quantity of water saved is approximately 1000 litres/tonne ice cream mix produced. [42, Korsstrom, 2001] |

Cross-media effects
The hygienic quality of the water has to be checked as leaks in the plates of the heat exchanger may result in contamination of the water with the product.

Operational data

Applicability
It can be applied both in new and existing plants. Space is needed for water storage tanks.

Economics

Driving force for implementation
Reduced costs for energy and water.

Example plants
GB Glace, Flen, Sweden

Reference literature
[42, Korsstrom, 2001]

### 4.8.3.8 Heat recovery from cooling systems

**[42, Korsstrom, 2001]**

Description
Heat can be recovered from cooling equipment and compressors. The system comprises several heat exchangers and storage tanks for warm water. Depending on the cooling equipment, 50 - 60 °C temperatures can be achieved.

Achieved environmental benefits
Heating energy savings can be achieved by using the recovered heat for heating tap water or ventilation air, defrosting deep frozen goods, preheating the cleaning liquids or the product.

| CASE STUDY – Heat recovery from compressors |
|---|
| • Installing heat recovery system in the cooling unit of a dairy plant including both screw and piston compressors with a cooling capacity of 3200 kW resulted in energy savings of about 1200 MWh/yr. The investment cost was about EUR 160000, payback 6.3 years. |

Cross-media effects

Operational data

Applicability
It is almost always installed in new plants. Lack of space can be an obstacle for existing plants.

Economics
It is mainly economically feasible in production plants with deep freeze storage, as normal cold storage does not produce sufficient quantities of heat during winter time.

Driving force for implementation
Reduced consumption of energy.

Example plants

Reference literature
[42, Korsstrom, 2001]

#### 4.8.3.9 Heat recovery from vapour from the wort kettle in a brewery

**[59, Danbrew Ltd., 1996]**

Description
Wort boiling is the largest single heat consuming process in a brewery. When the wort is boiled, 6 – 12 % normally evaporates. The vapour is usually emitted to the atmosphere, wasting energy and producing unpleasant odours. Recovering heat from wort kettles saves energy and avoids odour problems.

The simplest way to recover heat from the vapour is to use it to produce hot water for various processes and for cleaning. This system is found in some breweries. If hot water is also recovered during the wort cooling process (which is very common) there will still be an excess of hot water, which needs to go to the drain.

There are two options to consider:
1. Using the vapour to boil the wort. The vapour, heated by means of a compressor (steam injector or mechanical compressor), can be used to boil the wort in a special heat exchanger. The heat of the vapour condensate (which will have a temperature of about 100 °C) can be recovered by using it to produce hot water. This will of course be done only if more hot water is needed than is produced during wort cooling.
2. Using the heat in the vapour to produce 95 °C water for preheating the wort before boiling. The wort can be heated from 75 °C to approximately 90 °C by means of recovered heat. This option requires installation of an energy store. The heat in the vapour condensate can, if required, produce hot water for use in production and cleaning operations. The recovered heat can also be used for room heating, etc.

In either case, the vapour condensate, after heat recovery, can be used for flushing brew kettles.

Achieved environmental benefits

Cross-media effects

Operational data

Applicability

Economics
The above-mentioned systems are expensive and are only considered after other significant energy reductions (to a level of 150 - 200 MJ/hl) have first been made. In a new brewery, however, the use of these systems can be strongly considered at the outset.

Driving forces for implementation

Example plants

#### 4.8.3.10 Energy saving by combined heat and power generation (CHP)

In the last few years, there have been major developments in the market for CHP, both in technology and also in financing packages. Such developments include using energy supply companies to completely finance the investments and using CHP for cooling.
A powerful option for saving energy is the implementation of combined heat and power generation. In some sectors of the food industry (e.g. sugar industry) CHP is already commonly applied.

Environmental benefits
The efficiency of a CHP can be up to 90 %. This high energy efficiency optimises the use of fossil fuels and reduces the production of $CO_2$. Furthermore, gas-fired CHP schemes can eliminate $SO_2$ emissions, while $NO_x$ can be controlled to meet environmental legislation.

Operation
Modern CHP equipment is likely to require less effort to operate and maintain than many older boiler systems as CHP systems are equipped with automatic control and monitoring systems.

Applicability
The applicability of CHP depends highly on the specific cicumstances. Therefore, a decision on whether to implement CHP requires a thorough investigation of the technical, economical and financing aspects.

(a) Technical aspects

Although CHP is a well-established and technically mature technique, it is vital that the right design decisions are made. The main factors to consider are the consumption pattern of electricity and heat (steam) in the plant and the ratio between electricity and heat consumption. Additional important factors are whether the plant is running continuously and whether large variations in processes occur. A simple rule of thumb is that the site needs to have simultaneous demand for heat and electricity for at least 4000 hours a year.

(b) Economic aspects

In the UK, CHP can now reduce the total site energy bills by 20 % [69, Environment Agency (UK), 2001].
The economics of CHP are dependent on using one fuel, normally gas, to generate electricity and heat. If electricity prices fall or gas prices rise, the financial return from CHP will decrease. This is a real threat in a fully liberalised energy market.

An option, which is sometimes applied, is to design the CHP-installation on heat consumption with delivery of excess electricity to the public grid. Whether this is an attractive option very much depends on the price obtained for the excess electricity that is sold.

(c) Financing aspects

A tendency is that companies installing CHP do not finance the CHP plant themselves. Sometimes Joint Ventures with energy suppliers are formed, sometimes third parties completely finance the CHP plant. A contract for delivery of electricity and heat by the CHP plant normally runs for 10 to 15 years.

#### 4.8.3.10.1 Application of combined heat and power (CHP) in the sugar industry

**[61, CEFS, 2001]**

Sugar manufacturing requires electrical and thermal energies at every step of the process. Electricity is needed for lightning, for plant process control, and as the driving power for machinery. Steam and hot water are needed for heating process vessels and buildings.
Most of the energy required by the sugar process is obtained by burning gas, heavy fuel oil or coal in a boiler house, which converts it, by means of a combined heat and power plant, into steam and electricity. In-house combined generation of heat and power is a valuable alternative for food manufacturing processes for which heat and power loads are balanced.
The overall fuel utilisation factor of combined heat and power systems exceeds 70 % and is typically above 80 %. This fuel conversion efficiency greatly exceeds that of any design of commercial power station whose steam is not used further, even the latest generation of combined cycle gas turbines, which are around 55 %. Excess electricity produced may be sold to other users.

#### 4.8.3.10.2 Combined heat and power (CHP) in dairy industry

**[39, Germany, 2001]**

With the growing size of dairy plants, electrical energy needs are also growing, making own electricity production a feasible alternative. CHP is a good option for dairy plants which have evaporation/drying steps where, together with the electricity, thermal heat is also needed in larger amounts.

The comparison of energy efficiencies for a conventional dairy plant and a CHP dairy plant is presented in the form of Sankey diagrams:

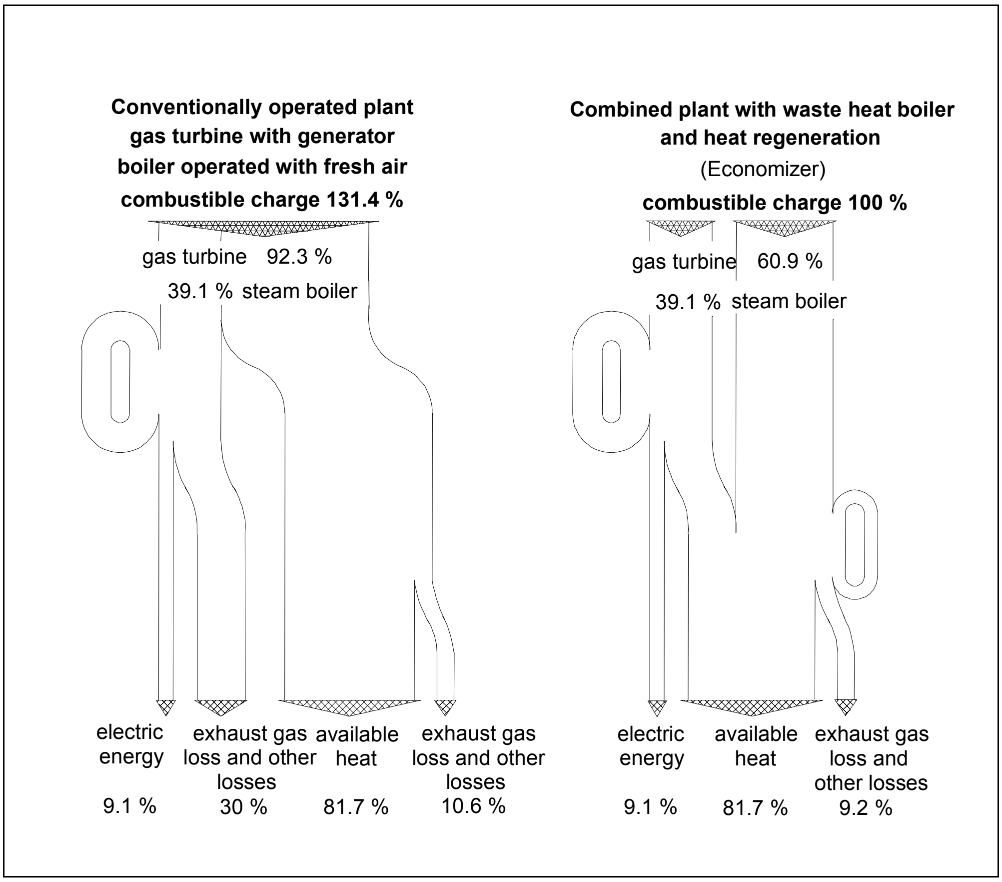


**Figure 4.17: Comparison of energy efficiencies of a conventional and a CHP dairy plant [39, Germany, 2001]**

In addition to the CHP operational chart, the following remarks can be made for the dairy industry:

During whey and milk drying, hot air is needed for the quick drying of the atomised liquid drops in the drying plants. This hot air is mainly produced with steam-heated ribbed-pipe heat exchangers. The air temperature necessary for the process ensures the required steam pressure (normal air temperature range: 220 – 240 °C).
Due to the required temperature difference in the heat exchangers, a steam pressure of 32 - 34 bar is necessary. Losses in the pipe system must also be taken into consideration, so that steam generation must occur at 40 bar minimum.
The generation of this live steam requires steam generators with an appropriate design. An admission pressure of 40 bar also relates to an improved power generation in the back pressure steam turbine.
Several process steps which precede the milk drying proceed at lower temperatures. All other types of dairy production also take place at a lower temperature level. For these multiple production processes in a dairy plant, steam with a relatively low steam pressure (e.g. 6 bar) is sufficient (milk heating 75 °C, yoghurt heating 90 °C, etc.).
This low pressure steam can be provided by steam pressure reduction with throttle valves or by using back pressure steam turbines.
Steam pressure reduction with throttle valves "destroys" energy, whereas the steam pressure difference in the back pressure steam turbine generates mechanical energy for the propulsion of an electric generator and thus electric energy. Therefore it is a combined heat and power plant on the basis of a back pressure steam turbine.
In dairy plants without milk or whey drying the temperature level is considerably lower for all production processes, and steam is generated at pressures of about 16 bar. In these cases no CHP plants with back pressure steam turbines are employed because the steam pressure head is

too small which results in poor efficiency. For these applications block-type thermal power stations with gas or diesel engine or CHP plants with gas turbines and downstream waste heat boiler would be more appropriate.

For these kinds of plants, emissions are determined as a function of their rating in the applicable law, for instance the German Technical order on air emissions.

Other common procedures of air heating are thermal oil plants, directly fired air heaters and the steam heating of the air heaters without back pressure steam turbines.

### 4.8.3.11 To ensure proper insulation of pipes and equipment

**[42, Korsstrom, 2001]**

Description

Hot and cold products are stored and pumped in a dairy plant. Insulation is normally used but it can be improved by using better coatings and by using pre-insulated pipes. These have the advantage that the pipe supports are mounted outside of the insulation coating, whereas they are traditionally mounted directly on the utility pipes thus increasing the heat loss.

Achieved environmental benefits

Over 80 % of the heat loss can be eliminated by using proper coating on warm/cold pipes and tanks/vessels. Additional heat can be saved by using pre-insulated utility pipes.

Cross-media effects

Not relevant.

Operational data

Applicability

It can be applied in both new and existing plants. Pre-insulated pipes are normally installed in new plants.

Economics

CASE STUDY

- In a new dairy in Taulov (Denmark), all the pipes with a temperature difference of at least 10 °C above ambient temperature were equipped with 30 mm insulation. Tanks were coated with 50 mm insulation. Pre-insulated pipes were used with a coating of metal sheet covered with mineral wool. More than 9 km of piping and 53 tanks were insulated. The calculated savings in energy were:

  6361 MWh/yr heating energy
  2397 MWh/yr cold energy (equivalent of 479 MWh/yr electricity)

  Investment cost was about EUR 1408000 with a payback period of 7.6 years. [42, Korsstrom, 2001]

Driving force for implementation

Reduction in energy costs.

Example plants

Arla Foods dairy plant in Taulov, Denmark

Reference literature

[42, Korsstrom, 2001]

#### 4.8.3.12 Utilisation of heat from whey for preheating of cheese milk

**[42, Korsstrom, 2001]**

Description
The incoming milk is preheated with warm whey, which is simultaneously strained off from another vat. Heat exchangers and tanks for the circulating water are needed.

Achieved environmental benefits
Savings in heating energy of incoming milk and cooling energy for processed whey.

| CASE STUDY – Heat recovery using the heat of whey for preheating of milk |
|---|
| • In the Taulov dairy plant, the cheese milk is heated from 12 °C to 32 °C with heat from a closed system with circulating water of 34.5 °C. The temperature of the water decreases to 13 °C and the water is subsequently reheated in the cooling section of the whey pasteuriser, where the whey is cooled from 36 °C to 14.5 °C. In addition to the plate heat exchangers, two buffer tanks of 150 $m^3$ were installed for the circulating water. The saving potential was calculated assuming 250 million kg/yr whey. 1200 MWh/yr electrical energy, 6065 MWh/yr heat energy and 4200 $m^3$/yr water. Cost estimation is made for the whole whey processing including the reverse osmosis (RO) unit. The total costs for RO filtration, heat treatment and heat recovery amounted about EUR 1.6 million with a payback of 3.8 years. |

Cross-media effects
Not relevant.

Operational data

Applicability
Application in existing plants can be a constraint because of the lack of enough space.

Economics

Driving force for implementation
Reduced energy costs.

Example plants
Arla Foods dairy plant in Taulov, Denmark

Reference literature
[42, Korsstrom, 2001]

#### 4.8.3.13 Pre-cooling of ice water, either with ammonia, which is commonly applied in new installations, or, if possible, by using a nearby river or lake

**[42, Korsstrom, 2001]**

Description
The amount of energy consumed for the production of ice water can be reduced by the installation of a plate heat exchanger for pre-cooling of the returning ice water with ammonia prior to final cooling in an accumulating ice water tank with a coil evaporator. This is based on the fact that the evaporation temperature of ammonia is higher in a plate cooler than in evaporator coils (- 1.5 °C versus –11.5 °C).

Achieved environmental benefits
Electrical energy consumption is reduced to some extent depending on the temperature of the river water. However, energy is still needed for pumping the water to the tower.

Cross-media effects
Using ammonia involves safety risks.
Small effect: cooling river water returns unpolluted and with a slightly increased temperature.

Operational data

Applicability
The capacity of an existing ice water system can be increased without the need to increase compressor capacity by installation of a plate cooler for pre-cooling of the returning ice water.

Cooling with river water can only be applied if the dairy is located near a river with cold water.

Economics
The price depends on the existing ice water system and capacity.

Driving force for implementation
Reduced consumption of electrical energy and/or increased cooling capacity without investment in a new ice water tank.

Example plants
Pre-cooling with ammonia is used in new plants
Pre-cooling with river water: Milko Grådö dairy, Sweden

Reference literature
[42, Korsstrom, 2001]

#### 4.8.3.14 Automatic defrosting of cooling evaporators in deep freeze storage

**[42, Korsstrom, 2001]**

Description
The layer of frost formed on the surface of evaporators reduces the heat exchange efficiency. Compressors` warm gas can be used for defrosting.

Achieved environmental benefits
Energy savings. The actual figure depends on the capacity/number of evaporators and the operating time with frosted evaporators.

| CASE STUDY – Automatic defrosting saves energy |
|---|
| • In an ice cream plant, 5 evaporators running for 3000 hours per year with an ice layer of 0.87 mm were equipped with automatic defrosting system. Approximately 100000 kWh/yr energy could be saved. The estimated investment cost was EUR 15000, with a payback of 2.2 years. |

Cross-media effects
Not relevant.

Operational data

Applicability
It is widely used in new plants. It can easily be applied to existing operations.

Economics
Short payback periods.

Driving force for implementation
Reduction in energy consumption and costs.

Example plants

Reference literature
[42, Korsstrom, 2001]

#### 4.8.3.15 Use of mechanical vapour recompression (MVR) in multiple-effect evaporators

**[42, Korsstrom, 2001]**

Description
A mechanical vapour recompression (MVR) system draws all the vapour out of the evaporator and compresses it by aid of mechanical energy before returning it to the evaporator. No thermal energy is supplied, except for the steam required for the start-up. The only electricity required is for the operation of the evaporator.

Achieved environmental benefits
MVR has a higher heat recovery efficiency than the thermal vapour evaporation (TVR) system. Also a lower evaporation temperature is needed, which means less burn-out product. The latter allows longer production cycles and a reduction in cleaning frequency.

- MVR can evaporate 100 - 125 kg water using 1 kW energy.

Cross-media effects
MRV generates noise. The system therefore has to be properly isolated.

Operational data

Applicability
Most new evaporators are equipped with a MVR system.

Economics
Investment costs are rather high but they are compensated for by high savings in energy costs.

- The operating costs of a three-effect evaporator with MVR are approximately half the cost of a conventional seven-effect evaporator with TVR.

Driving force for implementation
Reduction in energy cost

Example plants
Lalio Lapinlahti dairy plant, Finland

Reference literature
[42, Korsstrom, 2001]

#### 4.8.3.16 Monitoring system saved energy – a case study

**[1, CIAA, 2002]**

Description
The "De Bijenkorf" starch factory, a member of the Amylum group, processes maize into starch, starch derivatives, and glucose, both for food and non-food industries. By systematic monitoring and analysis of this process, the company aims to reduce the energy consumption of the plant.
Previously, the energy consumption was determined from incidental measurements or from data provided by the energy supplier. The energy use of the separate production stages and their

respective products was calculated from these data, a process yielding no more than a global overview of the actual energy consumption, insufficient to improve the energy efficiency of the plant. Therefore, a monitoring system that measures and registers the specific energy consumption of several process stages was installed at the site. The production process was divided into separate operational units. Each of the units comprises the manufacture of a particular product or group of products. The energy flows in each module are measured in real-time. The measurements allow the determination of both the energy flows at that time and the integral consumption over a prolonged period of time.
The new system has made it possible to compare the plant's actual and theoretical energy consumption, allowing optimisation of the process in case of unfavourable differences. Moreover, the system compares the measured energy consumption with that of comparable process units at sister companies and is capable of changing process units according to the most favourable design.

The new monitoring system continuously measures the modules' water, steam, natural gas, and electricity flows. The collected data is transferred to a central processor and then converted into tables and graphs, which are distributed among the interested parties.
The system in its present form only registers and reports the actual energy consumption of the factory. Calculation of the specific energy consumption, related to the production of the plant, is still performed manually. The analysis of the data is based on the comparison with historic data of the energy consumption under similar conditions.

Achieved environmental benefits
The annual savings are equivalent to 3 millions m$^3$ of natural gas (95.0 TJ), a reduction of approx. 10 %.

Cross-media effects

Operational data

Applicability

Economics
The overall investment costs amounted to EUR 700000. At a gas price of EUR 0.095/m$^3$, the annual savings are EUR 284000. This equates to a bay back period of about 2.5 years.

Driving forces for implementation
Reduction of energy costs

Example plants
Location: Koog aan de Zaan, the Netherlands

### 4.8.4 Energy efficiency in deep freezing of vegetables

**[32, Bael, 2001]**

In the paragraphs below, a list is made of energy-saving measures per process step. A number of these measures are developed in detail.

a) Pretreatment, washing and mechanical treatment
- frequency converter on distributor conveyor
- heat exchange between production steps.

b) Blanching system
- use of belt blancher / water freezer combination instead of drum blancher.

c) Freezer unit

- adjustment of revolutions on vacuum compressor(s)
- high-output motors for driving compressors
- regular inspection of oil separator
- overcapacity of condensers.

The efficiency or the COP (Coefficient of Performance) of the freezer unit is mainly determined by the evaporator pressure and the condensation pressure. The higher the condensation pressure, the lower the COP of the system. For freezer units in the deep-frozen vegetable sector, the following rule can be used:

| Condensation temperature lowered by 1 °C → COP rises by 2 % |
|---|

Lowering the condensation temperature by 5 °C causes the electricity consumption to fall by 10 %. That is why a low condensation temperature is so important. This reduction can be achieved by fitting an adequate capacity of condenser batteries so that even in summer (which is high season for the vegetable sector) sufficiently low condensation temperatures can be achieved.

- rotation speed regulation on fans (evaporating) condensers
- automatic air bleed of condensers
- regular inspection of the heat exchangers in the condensers
- heat recovery.

d) Freezing tunnel

- restriction of transmission losses
- restriction of ventilation losses
- inspection of door seals
- use high-efficiency lighting
- high-efficiency motors for driving the fans.

The motors for driving the fans are set up in the freezing tunnel. The electrical energy supplied to the motors must therefore be dissipated by the freezer unit. By opting for high-efficiency motors for driving the fans, not only is there a direct saving in electricity (lower consumption by the fans) but also an indirect saving, through a lower cooling load for the refrigeration unit. The following rule can be applied:

| Reduction in fan output by 1 $kW_e$ results in a total reduction of 1.4 to1.6 $kW_e$ |
|---|

- fan rotation speed adjustment
- belt rotation speed adjustment
- adaptation of evaporator temperature and air flow rates.

Vito previously carried out a study on the energy consumption of a freezing tunnel for vegetables. This showed that the greatest saving can be achieved by adjusting the evaporator temperature, the sojourn time of the vegetables in the freezing tunnel, and the air flow rates to the vegetable flow rate and the type of vegetables. This study shows that it is not always necessary to set the evaporator temperature at the lowest level (-40 °C) for good freezing quality. Furthermore, it is very important to monitor the temperature of the product after it has gone through the freezing tunnel. Low temperatures (< - 18 °C to - 20 °C) are not necessary (the vegetables will ultimately be stored in a confined space at - 18 °C) and lead to high energy consumption. High temperatures (> - 16 °C) lead to lower freezing quality. In the worst case, the whole mass can freeze together during storage in crates.

Simultaneous optimisation of various freezing tunnels can be carried out as follows:

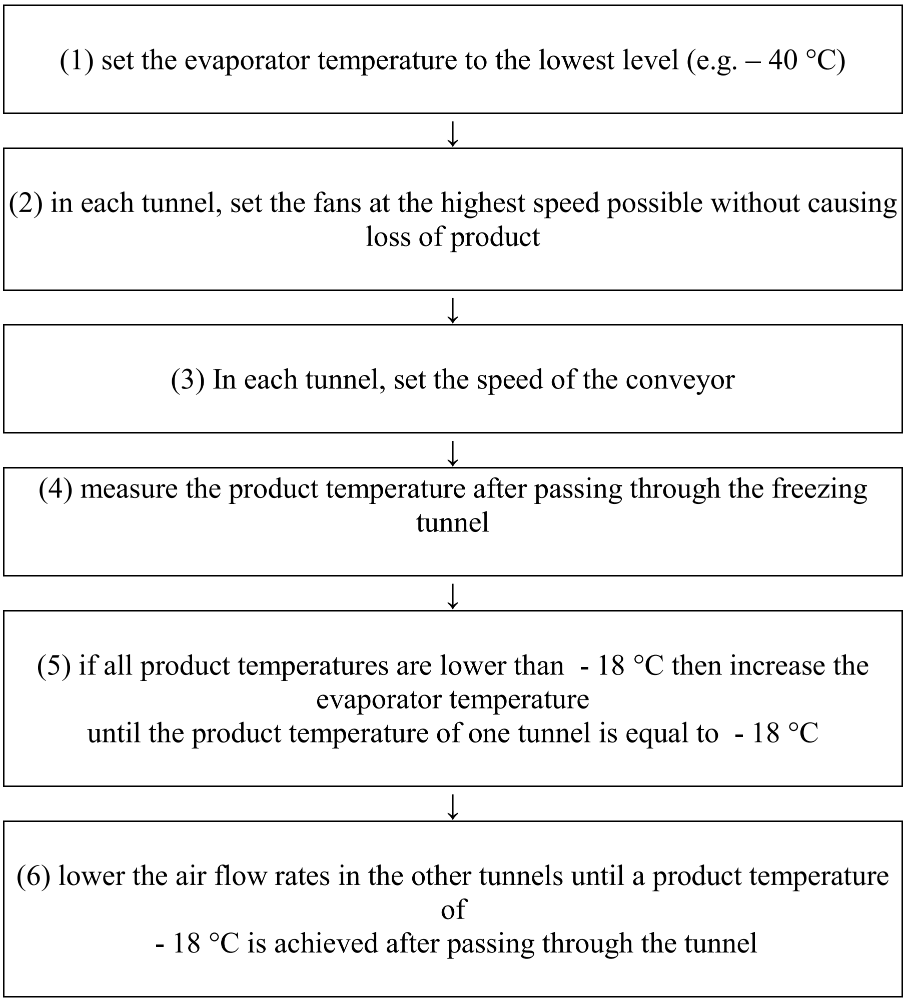


**Figure 4.18: Schema for optimisation of freezing tunnels in production of deep frozen vegetables**

1) The evaporator temperature of the freezing unit is set to the lowest position (e.g. - 40 °C)
2) The fans are set to the maximum air flow rate without product loss. If, when the air regulating valves are fully opened or the rotation speed adjustment is at maximum frequency, product is blasted out of the bed, then the valves are closed more, or the frequency lowered.
3) In the adjustment of the speed of the conveyor belt (inversely proportional to the sojourn time on the belt) care is taken to ensure that the layer thickness is not too low. This always leads to the formation of preferential air channels in the vegetable bed, which means that the rest of the bed receives little airflow. The layer thickness is not set too high either, since this leads to block freezing of the lower layers. As the pressure drop over the vegetable bed rises, the air speeds fall with lower heat removal.
4) The product temperature in each freezing tunnel is measured. In order to take the measurement, an insulated container is filled with product. The reading is taken as soon as the temperature stabilises. Immediately after freezing, the outer temperature has a lower temperature than the centre.
5) If the product temperature is lower than – 18 °C for each of the tunnels, then the evaporator temperature is set higher. This is repeated until the product temperature of one of the freezing tunnels is equal to –18 °C. If, in one of the tunnels, the product temperature at the lowest position of the evaporator is higher than –18°C, then the vegetable flow rate of the tunnel concerned is lowered.
6) In the other freezing tunnels, the airflow rate is lowered if the product temperature of –18 °C is achieved.

This optimisation is carried out again after:

- a tunnel is shut down
- a different product is processed
- another flow rate is set.

When raising the evaporator temperature, the following rule can be applied:

| |
|---|
| Evaporator temperature raised by 1 °C → COP rises by 4 % |
| Evaporator temperature raised by 1 °C → refrigeration capacity rises by 6 % |

- Lowering the vegetable temperature

The temperature of the vegetables as they enter the freezing tunnel is an important factor that also determines the energy consumption of the system. The lower this vegetable temperature, the lower the cooling load, and the lower the energy consumption. The vegetable temperature can be lowered by bringing them into contact with sufficiently cold water for a sufficient time. The cooling water from the counter-current drum freezer of the belt blancher is well cooled (4 °C). If an ice water trough is present, then the feed water is cooled to a temperature of 4 °C. Additionally, the circulating water in the ice water trough can be continually cooled by:

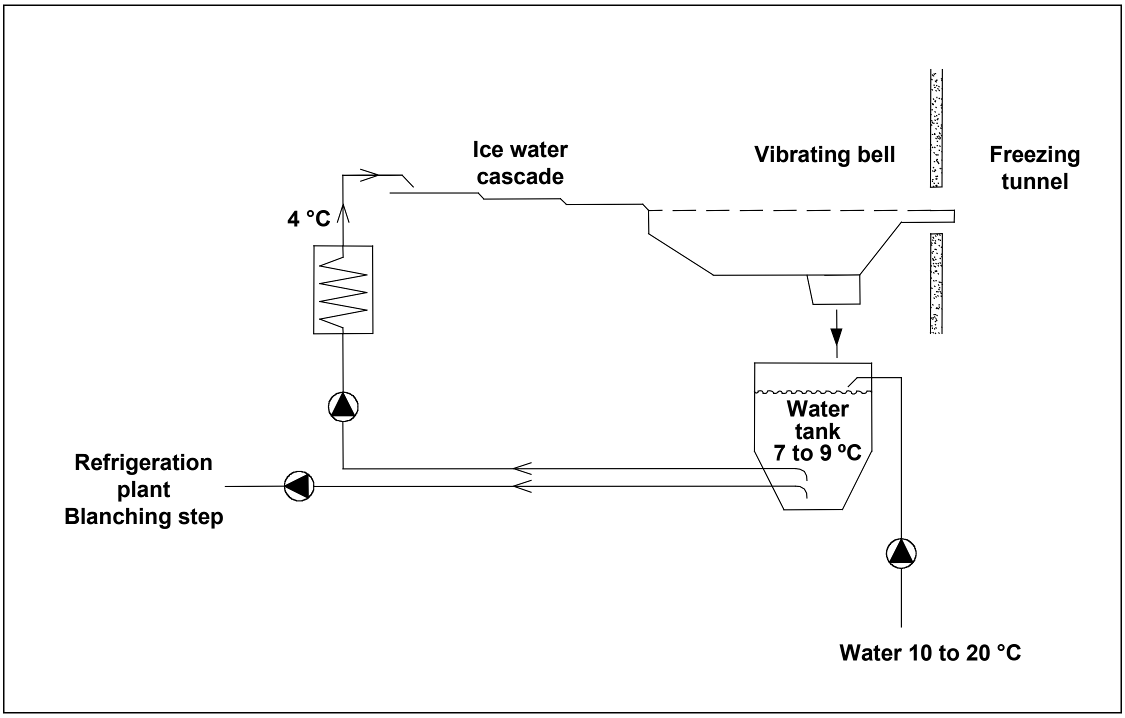


**Figure 4.19: Additional installation of a water cooler in the ice water circuit [32, Bael, 2001]**

- fitting an additional water cooler in the ice-water circuit (see Figure 4.19)
- placing an evaporator plate under the ice-water trough.

This evaporator plate is connected into the freezer system like the heat exchanger for ice-water production (see Figure 4.20).

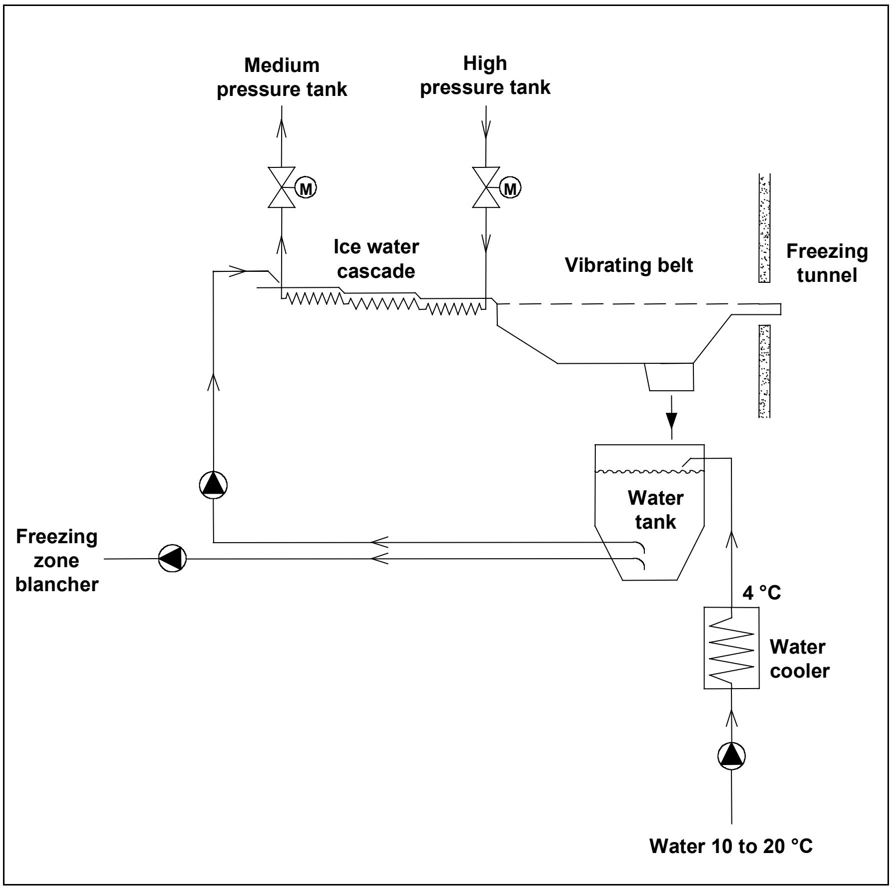


**Figure 4.20: Installation of an evaporator plate under the ice water trough [32, Bael, 2001]**

The following rule can be applied:

Reduction of the product temperature by 10 °C results in
- a reduction of the compressor load for cooling at - 30 °C to - 40 °C by 5 to 7 kWh$_e$/tonne
- an increase in the compressor load for cooling at 0 °C by 1.5 to 2 kWh$_e$/tonne
- total: reduction of the electrical load by 3 to 5.5 kWh$_e$/tonne.

When a freezing tunnel is operating at a product flow rate of 10 tonnes per hours, then the electrical load will fall by 30 to 55 kW if the vegetable temperature is reduced from 30 °C to 20 °C before entering the freezing tunnel.

Furthermore, the heat transfer when cooling is carried out with water is an order of magnitude higher than when the cooling is carried out with air.

When processing vegetables, there are regularly problems with the vegetable feed, problems in a processing step or problems when switching from one product to another. During these periods, it is nevertheless important to keep the empty freezing tunnel at a sufficiently low internal temperature.

In order for this to occur the fans need to keep running, but the airflow rates can be reduced. Motors with regulated rotation speeds, for example, can be switched to the lowest possible frequency. In addition, a number of fans can be switched off (e.g. module 1 off, module 2 and 3 on, module 4 off, etc.). This reduces the energy consumption of the fans and of the refrigeration unit. As already mentioned: any reduction in the fan power by 1 kW$_e$ results in a total saving of 1.4 to 1.6 kW$_e$.

In addition, the automatic defrosting of the evaporators can be switched off. In an empty freezing tunnel, there is little or no transport of moisture or water in the freezing tunnel (only via the vegetable entrance and exit). This avoids re-cooling the evaporator after defrosting. This represents a great deal of cooling. An evaporator weighs approximately 2 tonnes, and is made of steel. In order to cool this mass again from 15 °C to - 35 °C, it takes about 48 MJ of refrigeration. Switching off the automatic defrosting thus yields a saving in the compressor consumption:

Saving of 5 to 9 $kWh_e$ per evaporator that is not defrosted

- regular defrosting of the entire system
- recuperation of coolant during complete defrosting
- inspection and cleaning of the tunnel components.

e) Storage
- optimisation of defrosting cycle
- optimisation of method of defrosting
- optimisation of evaporator fans
- improve door seals
- limited door size
- cooled area in front of system
- improved insulation
- use of residual heat for floor heating
- delayed use of coolant feed pump
- only refrigerate at night.

f) Other potential savings
- choice of boilers
- application of total energy
- restriction of sluicing

  Sluicing is used to restrict the accumulation of salts, chlorides, alkalis and silicic acid, and it is therefore necessary to keep these parameters within the prescribed limits. Sluicing is also used to remove the sludge deposits (calcium phosphates, for example) and corrosion products (ferric oxides) out of the boiler and to keep the water clear and colourless. Saturated water at high pressure and temperature is always discharged, either for a set time or continuously. It is therefore preferable to restrict sluicing as far as possible. The TDS value of the boiler water is best kept as close as possible to the maximum authorised value. This can be done via an automated system consisting of a conductance probe in the boiler water, a sluicing regulator or a sluicing regulating valve. The conductance is continually measured. If the measured conductance exceeds the maximum value, then the sluicing regulating valve is opened (more). Table 4.19 shows the potential fuel savings by reducing sluicing as a function of steam pressure. At a steam pressure of 10 bar, a fuel saving of 2.1 % can be achieved if the sluicing volume is reduced by 10 %.

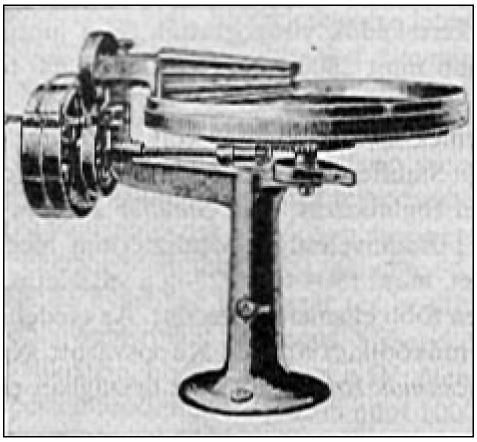
| **Boiler pressure (bar eff)** | **Fuel saving (%) per reduction in sluicing (%)** |
|---|---|
| 7 | 0.19 |
| 10 | 0.21 |
| 17 | 0.25 |

**Table 4.19: Potential savings by reducing sluicing in deep freezing of vegetables**

- heat recovery from sluicing
- heat recovery from flue gases
- isolation of pipes.

# 4.9 Process design/redesign changes to prevent emissions and eliminate waste

Overall, the total energy savings are usually the result of small savings in a number of areas. Reductions of up to 25 % are possible through improved housekeeping and fine-tuning processes. The use of more energy efficient equipment and heat recovery may also result in additional savings.



**Use simple design**

## 4.9.1 Process modification in dairy industry

### 4.9.1.1 Partial homogenisation of market milk

**[42, Korsstrom, 2001]**

Description
The cream is homogenised together with a small proportion of skimmed milk (the optimum fat content of the mixture is 12 %). The rest of the skimmed milk flows directly from the separator to the pasteurisation section of the pasteuriser. The homogenised cream is remixed into the skimmed milk stream before it enters the final heating section.

Achieved environmental benefits
The size of homogeniser can be significantly reduced. The reduced capacity results in energy savings.

| CASE STUDY – Partial homogenisation of milk |
|---|
| • Introduction of partial homogenisation in a pasteurisation line having a nominal capacity of 25000 l milk/h, homogenisation capacity was reduced to 8500 l/h. Total electrical power was reduced by about 65 % by installing a smaller homogeniser (55 kW). The price of the smaller homogeniser is about 55 % of the price of an equipment having the capacity to treat the nominal capacity of the line. |

Cross-media effects
Not relevant.

Operational data

Applicability
It is widely used in modern dairies.

Economics

Smaller homogenisers are cheaper in terms of investment costs and operational (mainly energy) costs.

Driving force for implementation

Lower investment and energy costs.

Example plants

Reference literature

[42, Korsstrom, 2001]

#### 4.9.1.2 Using ultrafiltration for protein standardisation of cheese milk, which also saves water

**[42, Korsstrom, 2001]**

Description

Protein molecules can be concentrated in the retentate using ultrafiltration. Ultrafiltration can thus be used for protein standardisation.

Achieved environmental benefits

The cheese yield of the processed milk unit can be increased. Energy and water requirements are lower, and less whey and waste water are produced in comparison with traditional standardisation.

CASE STUDY – Ultrafiltration in a cheese plant

- The ultrafiltration unit in the Taulov Dairy (Denmark) consists of 10 spiral wound modules equipped with polymer membranes, four pumps and the necessary flow transmitters and regulating valves. The filtration capacity is 65000 l/h. The protein content of the milk is standardised to 3.7 - 3.8 % by controlling the ratio between feed and permeate. (The permeate is further treated by reverse osmosis [RO]. The so-called RO-water then is used for cleaning purposes.)

  Compared to the traditional standardisation method, cheese yield is higher to such an extent that about a 12 % reduction in milk volume was gained. Calculating with 25000 t/yr yellow cheese production, further savings were estimated as:

| | | | |
|---|---|---|---|
| Electricity | 473 MWh/yr | ↔ | 19 kWh/t cheese |
| Thermal energy | 1235 MWh/yr | ↔ | 49 kWh/t cheese |
| Water | 7500 $m^3$/yr | ↔ | 300 l/t cheese |

The investment cost is estimated to EUR 430000, the payback period to be 5.9 years.

Cross-media effects

Ultrafiltration requires additional electrical power, thermal energy and water compared to traditional standardisation. In large scale production, the increase in cheese yield compensates for the increased consumption of energy and water. However, the membranes need to be cleaned. As chemicals are used for this, the filtration circle has to be well rinsed with large amounts of water.

Operational data

Applicability

Ultrafiltration units can also be installed in existing plants because of the low space requirement.

Economics

The investment cost is high. Payback periods are acceptable only if the capacity is large enough.

Driving force for implementation
Cheese of homogenous quality can be produced using this technique. It also offers a larger flexibility for making different types of cheese.

Example plants
Taulov dairy, Arla Foods, Denmark

Reference literature
[42, Korsstrom, 2001]

### 4.9.1.3 Minimising product recirculation in pasteurisers by optimising the tank capacity before and after pasteurisation

**[42, Korsstrom, 2001]**

Description
Interruptions in the line can be avoided by adapting the size and number of packaging tanks downstream and upstream of the pasteurisation unit and by optimising the product changeover.

Achieved environmental benefits
Energy savings are possible, mainly because of the lower ice water consumption. Additionally, the total electrical power required for pumps, homogeniser, separator and processing times is also reduced. Reductions in cleaning frequencies are beneficial in terms of energy, water and chemicals.

Cross-media effects
An increase in the number (size) of tanks results in more volume to be cleaned thereby, increasing water, energy and chemical consumption.

Operational data

Applicability
Lack of floor space might be a constraint in existing plants.

Economics
Investment costs depend on different factors. Energy savings may provide short payback.

| CASE STUDY – Install tanks in pasteurisation line |
|---|
| • Supplying a pasteurisation line with packaging tanks, together with automation of the product changeovers resulted, in a 30 % reduction of the processing time in a dairy plant. The annual energy savings amounted to 250 MWh electrical energy consumption and 230 MWh in thermal energy. The estimated payback period is 4.5 years. |

Driving force for implementation
If the capacity of the packaging tanks is too small compared to the output of the pasteuriser line, the milk has to be recirculated in the pasteuriser several times during the day. This consumes energy, may harm product quality and the interruptions in the line may increase the frequency of cleaning.
This solution offers improved flexibility, better quality and lower operation costs.

Example plants

Reference literature
[42, Korsstrom, 2001]

#### 4.9.1.4 Regenerative heat exchange in the pasteurisation process

**[42, Korsstrom, 2001], [75, Italian dairy contribution, 2002]**

Description

Pasteurisers are normally equipped with some regenerative counter-current flow heating sections, where incoming milk is preheated with the hot milk leaving the pasteurisation section.

| CASE STUDY – Heat recovery using indirect and direct heat exchange |
|---|
| • 1) Heat exchange between after-thermal treatment product and inlet product<br>By applying indirect heat exchange, with an initial temperature of 4 °C, regeneration heating temperature of 65 °C, pasteurisation temperature of 78 °C, regeneration cooling temperature of 20 °C, pasteurized milk temperature of 4 °C, the specific energy consumption of 148000 kcal/t can be reduced by 80 % to 29000 kcal/t.<br>• 2) Heat exchange between inlet cold product and steam coming from the extraction during vacuum expansion after UHT treatment.<br>After UHT sterilisation, applying direct vapour injection and subsequent expansion, vapours have to be condensed. Cold milk can be used in the heat exchanger. With an initial milk temperature of 4 °C, regeneration heating temperature of 70 °C, UHT treatment temperature of 140 °C, and UHT milk filling temperature of 25 °C the original energy consumption (251000 kcal/t) can be reduced by 26 % to 185000 kcal/t. [75, Italian dairy contribution, 2002] |

Achieved environmental benefits

Energy savings can typically be between 90 - 96 %.

Cross-media effects

Not relevant.

Operational data

Applicability

It is usually applied. In older dairies heating and cooling energy can be further reduced by replacing the old plate exchangers by more effective ones.

Economics

| CASE STUDY |
|---|
| • In the new dairy plant in Taulov, nine plate exchangers were installed with higher regenerative efficiency. Calculations were made for increasing the efficiency from 85 % to 91 % or from 91 % to 95 %. Savings in heating energy were estimated to 2712 MWh/yr and in electricity to 542 MWh/yr with an investment cost of EUR 370000 and a payback of 3.6 years. |

Driving force for implementation

Reduction in energy costs.

Example plants

Arla Foods dairy plant in Taulov, Denmark

Reference literature

[42, Korsstrom, 2001]

### 4.9.2 Techniques used in the fruit and vegetable processing industry

**[31, An Derden, 2001]**

As mentioned earlier (Section 4.5.6), the Flemish document “Best Available Techniques (BAT) for the fruit and vegetable processing industry” [31, An Derden, 2001] gives a proposal for the evaluation of techniques when selecting BAT. It is based on three compartments:

- environmental benefit
- technical feasibility, and
- economic feasibility.

A large number of techniques were evaluated and 81 of them were selected as BAT for the whole fruit and vegetable industry. 19 were considered as not being BAT. Some (34) techniques were considered to be BAT for some special sectors only or under special conditions. The results are summarised in Table 4.20.

| Process | **Number of techniques** | | | |
|---|---|---|---|---|
| | Considered to be BAT | | | Total |
| | yes | yes/no with restriction | no | |
| Supply, unloading, storage and sampling of raw materials and auxiliary materials | 12 | 4 | 1 | 17 |
| Pretreatment | 9 | 6 | 2 | 17 |
| Blanching | 1 | 5 | 1 | 7 |
| Intermediate treatments | 0 | 5 | 1 | 6 |
| Preserving | 6 | 0 | 0 | 6 |
| Packing | 6 | 0 | 1 | 7 |
| Cleaning/decontamination of production facility | 4 | 0 | 0 | 4 |
| Transport of vegetable material between the various processes | 2 | 0 | 1 | 3 |
| Cooling and conditioning of rooms | 7 | 0 | 0 | 7 |
| Drainage and effluent treatment | 24 | 9 | 11 | 44 |
| Water re-use | 10 | 5 | 1 | 16 |
| Total | 81 | 34 | 19 | 134 |

**Table 4.20: Result of BAT evaluation for Flemish fruit and vegetable industry**
**[31, An Derden, 2001]**

Although the evaluation is generally not supported by detailed data or information, the techniques are presented in this document. Those process-integrated techniques and cleaning techniques that were examined, together with some comments are listed in Sections 4.9.2.1 - 4.9.2.9. Drainage/effluent treatment and water re-use techniques are presented in the relevant Sections (Sections 4.14.3.4 and 4.5.3, respectively).

#### 4.9.2.1 Supply, unloading, storage and sampling of raw materials and auxiliary materials

| | Technique | Comments |
|---|---|---|
| 1. | Make agreements with grower/suppler about time of harvesting, harvest production, use of pesticides, harvest processing, etc. | |
| 2. | Start from a clean raw material with limited quantity of direct and pesticides, herbicides, fungicides | |
| 3. | Sand recovery system, to separate out soil that is released during processing of potatoes, inter alia, where the recovered sand can be re-used | |
| 4. | Separator for removal of fine organic material when potatoes etc. are brought into the factory | |
| 5. | Less sampling and re-use of sampled material | Sampling frequencies are usually fixed |
| 6. | Minimise stock (raw materials) to avoid ageing/rotting | |
| 7. | Process vegetables received immediately, to avoid losses of raw materials (avoid storage) | If production planning can be monitored and depending on the storage period of the fresh goods |
| 8. | Storage of raw materials in a clear courtyard, in the shade | If necessary (e.g. modification of production planning) |
| 9. | Storage of raw materials in containers | If necessary (e.g. modification of production planning) |
| 10. | Purchase of auxiliary materials in bulk | If available |
| 11. | Separate collection of packaging material | |
| 12. | Remove remaining fruit and vegetable residue as soon as possible after processing the stored vegetables | |
| 13. | Switch off engine and refrigerator unit of truck during loading/unloading | |
| 14. | Fit sound hoods so that during refrigeration of the loading area, there is less noise nuisance from the truck | |
| 15. | Restrict ventilation by fitting the passage between the load space of the truck and the storage area with an effective seal | |
| 16. | Keep doors and windows closed as much as possible | |
| 17. | Fit fast-closing and effectively insulating doors between areas with different temperatures | |

**Table 4.21: Techniques considered for storage, unloading, etc. in the fruit and vegetable processing industry.**
**[31, An Derden, 2001]**

### 4.9.2.2 Pretreatment

| | Technique | Comment |
|---|---|---|
| 18 | Restrict sorting and spillage losses by quality assurance at grower's/supplier's premises (supply raw materials in top condition) | |
| 19 | Restrict sorting and spillage losses by fitting collecting trays and/or splash protectors | |
| 20 | Regular removal of untreated or sorted fruit and vegetable residues and peel and cutting residues to farms as livestock feed | |
| 21 | Selection of raw materials by size, to restrict the quantity of peeling waste | If technically feasible |
| 22 | Separation of (solid) organic material from the effluent of the peeling process using sieves, filters, centrifuges, etc. to restrict leaching | |
| 23 | Daily emptying of sorted fruit and vegetables, peel and cutting residues and organic waste | |
| 24 | Storage (shortest possible duration) of sorted fruit and vegetables, peel and cutting waste and organic waste in closed containers | |
| 25 | Dry potatoes and mechanically remove dirt | |
| 26 | Peel using hot water with lye[1] | Only for peeling of salsifies and apples[2] |
| 27 | Peel using steam | Except for peeling salsifies and apples |
| 28 | Peel using carborundum[3] | If quality is feasible[4] |
| 29 | Peel mechanically[5] | If quality is feasible[6] |
| 30 | Dry peel[7] | Technical feasibility has not proven |
| 31 | Remove peel (after steam peeling) using a brush conveyor instead of water | If the bacteriological quality of the product poses no problem[8] |
| 32 | Use sharp cutting heads during the cutting process | |
| 33 | Keep cutting water cool (< 10°C) | High costs compared to little environmental benefits |
| 34 | Heat recovery during the concentration of fruit and vegetable juices | |

1. Current situation
2. In practice, the lye peeler (if investment was made in the past and currently there is no alternative peeling system) can be used throughout the season for peeling other products.
   Apples that are stewed after peeling, coring and cutting. Damage to the flesh (e.g. through steam peeling) needs tot be avoided, which is why it is proposed still to allow the lye peeling process.
3. Compared to steam peeling
4. Processing of potatoes
5. With regard to steam peeling
6. Processing of potatoes
7. With regard to steam peeling
   The hygienic quality is sometimes a problem with dry peeling. Since no peeling water is added, the cooling function of that water is not fulfilled, and there can be localised high temperatures.
8. 'Dry brushing' will inevitably and always be accompanied by serious bacterial contamination of the brushes and the damaged fruit or vegetable tissue.

**Table 4.22: Techniques considered for pretreatment in the fruit and vegetable processing industry [31, An Derden, 2001]**

#### 4.9.2.3 Blanching

| | Technique | Comment |
|---|---|---|
| 35 | Classic drum blancher with counter-current freezer | Only if the following techniques are not adequate |
| 36 | Belt blancher/water freezer combination (IBC)[1] | If the bacteriological quality of the product poses no problem |
| 37 | Belt blancher/blast freezer combination (IBC)[2] | Only for the preserves sector if the bacteriological quality of the product poses no problem |
| 38 | Blanching using steam blancher | Only for viscous products |
| 39 | Blanching using microwaves[3] | Problems in technical feasibility and profitability |
| 40 | Making use of the coldest water possible for cooling products | Only for the frozen vegetable sector |
| 41 | Separation of organic (solid) material from the effluent by means of sieves, filters, centrifuges, etc. | |
| 1. in comparison with the classic drum blancher with counter-current freezer<br>2. in comparison with the classic drum blancher with counter-current freezer<br>3. in comparison with classic drum blancher with counter-current freezer | | |

**Table 4.23: Techniques considered for blanching in the fruit and vegetable processing industry [31, An Derden, 2001]**

Blanching using microwave ovens was found to be difficult to apply in terms of the technical feasibility and profitability. It is important to note that another industry had similar results: a pilot project initiated in a Danish fish processing plant which involved the use of a new microwave boiling technique ran into difficulties early on. After only one year of operation, the microwave boiling plant was replaced with a steam boiling plant. [40, Saeby, 2001]

#### 4.9.2.4 Intermediate treatments

| | Technique | Comment |
|---|---|---|
| 42 | Making use of an enclosed freezing tunnel by means of indirect air cooling, where there is no contact between external air and product, and no use is made of a mechanical refrigeration machine (potato processing sector) | For the potato processing sector |
| 43 | Extract vapour from the baking oven and remove the organic odour components by condensing the baking vapour with energy recovery | If there are unpleasant odours |
| 44 | Extract vapour from the baking oven and remove the organic odour components by re-burning the baking vapour. | If there are unpleasant odours |
| 45 | Extract vapour from the baking oven and remove the organic odour components by scrubbing the flue gases | If there are unpleasant odours |
| 46 | Extract vapour from the baking oven and remove the organic odour components by ozonisation | If there are unpleasant odours |
| 47 | Extract vapour from the baking oven and remove the organic odour components by cleaning the baking vapour using biofilters | Has limited effect on the cleaning of vapour containing fat particles. The filter surface is easily blocked by the larger mass flows, bacterial growth may also be inhibited or prevented, thus the cleaning is not efficient. |

**Table 4.24: Techniques considered for intermediate treatment in the fruit and vegetable processing industry
[31, An Derden, 2001]**

### 4.9.2.5 Preserving

| | Technique | Comments |
|---|---|---|
| 48 | Shovel up product losses (from the freeze tunnel) and transport away as livestock feed | |
| 49 | Bleed air from liquids, so that liquids do not foam during filling | |
| 50 | Prevent pouring losses by pouring under vacuum | |
| 51 | Provide collection trays for spillages | |
| 52 | Optimally and automatically defrost and clean freezing tunnels | |
| 53 | Re-use heat from sterilisation processes for preheating | |

**Table 4.25: Techniques considered for preservation in the fruit and vegetable processing industry [31, An Derden, 2001]**

### 4.9.2.6 Packing

| | Technique | Comments |
|---|---|---|
| 54 | Restrict spillages by placing collecting trays (accurate positioning), flaps, screens … | |
| 55 | Accurate positioning of crates under the conveyor belt | |
| 56 | Clear up spilt vegetables manually as far as possibly (avoid rinsing away through plant drains) | |
| 57 | Optimisation of use and dimensions of packages | |
| 58 | Use larger units of transport packaging | |
| 59 | Recycling of transport packaging | |
| 60 | Replace wooden crates (with plastic bag) by plastic crates | Problems with technical feasibility, not clear environmental benefits |

**Table 4.26: Techniques considered for packing in the fruit and vegetable processing industry [31, An Derden, 2001]**

### 4.9.2.7 Cleaning / decontamination of production facility

| | Technique | Comments |
|---|---|---|
| 61 | Design equipment and rooms (with smooth walls and rounded corners) that are easy to clean | |
| 62 | Remove coarse dirt by dry, mechanical cleaning | |
| 63 | Re-use water as much as possible, quality of cleaning water in relation to the required bacteriological quality | |
| 64 | Collect packaging material from cleaning and disinfection products separately depending on saleability | |

**Table 4.27: Techniques considered for cleaning in the fruit and vegetable processing industry [31, An Derden, 2001]**

### 4.9.2.8 Transport of vegetable material between the various processes

| | Technique | Comments |
|---|---|---|
| 65 | Efficient set-up of the production line | |
| 66 | Fit flaps and screens on the conveyor belt | |
| 67 | Dry, mechanical transport | |

**Table 4.28: Techniques considered for transport within the plant in the fruit and vegetable processing industry**
**[31, An Derden, 2001]**

#### 4.9.2.9 Cooling and conditioning of rooms

| | Technique | Comments |
|---|---|---|
| 68 | Commission refrigeration equipment with a test certificate | |
| 69 | Set up condenser so that there is minimum noise reflection | |
| 70 | Use of low-noise compressors and condensers | |
| 71 | Make use of evaporating condensers instead of conventional air or water-cooled condensation systems | |
| 72 | Keep refrigeration unit doors closed as much as possible | |
| 73 | Install fast-closing and effectively insulating doors between rooms with different temperatures | |
| 74 | Use ammonia as a coolant | |

**Table 4.29: Techniques considered for cooling and conditioning of rooms in the fruit and vegetable processing industry**
**[31, An Derden, 2001]**

### 4.9.3 Waste prevention in olive oil processing by introducing the two phase extraction technique

**[Junta de Andalucía; Agencia de Medio Ambiente, 1994 #86]**

Description
Olive oil production has traditionally been one of the major sources of industrial pollution in the regions where they are made, e.g. in Andalucía, Spain. In traditional olive processing (*three phase production*), the extraction of the olive seeds has resulted in three streams:

- an oily stream. This is the virgin oil. Its proportion is about 200 kg/t of olives if obtained using continuous separation by centrifuges, or 150 kg/t using olive presses
- an aqueous waste (waste water) of high pollution strength. Its volume depends on the technique applied but, as a rule of thumb, it is well accepted that 1 $m^3$ of waste water is produced per tonne of olives processed. The specific pollution is estimated to be about 65 kg $BOD_5$/t olive processed. (In Spanish it is called “alpechin”)
- a solid waste. This still has some oil content. Its water content and composition depend on the extraction technique applied. This waste is called “olive pomace”. (In Spanish, it is called “orujo”).

In the beginning of the 90s, the resultant liquid waste during the 100 days campaign represented about the same amount of water as Andalucía’s total population for the whole year. At that time, only the classical (presses) and the three-phase continuous separation by decanter centrifuges were used. This waste is not biologically stable, is difficult to treat, and due to the volume of waste it is a real threat to the environment.

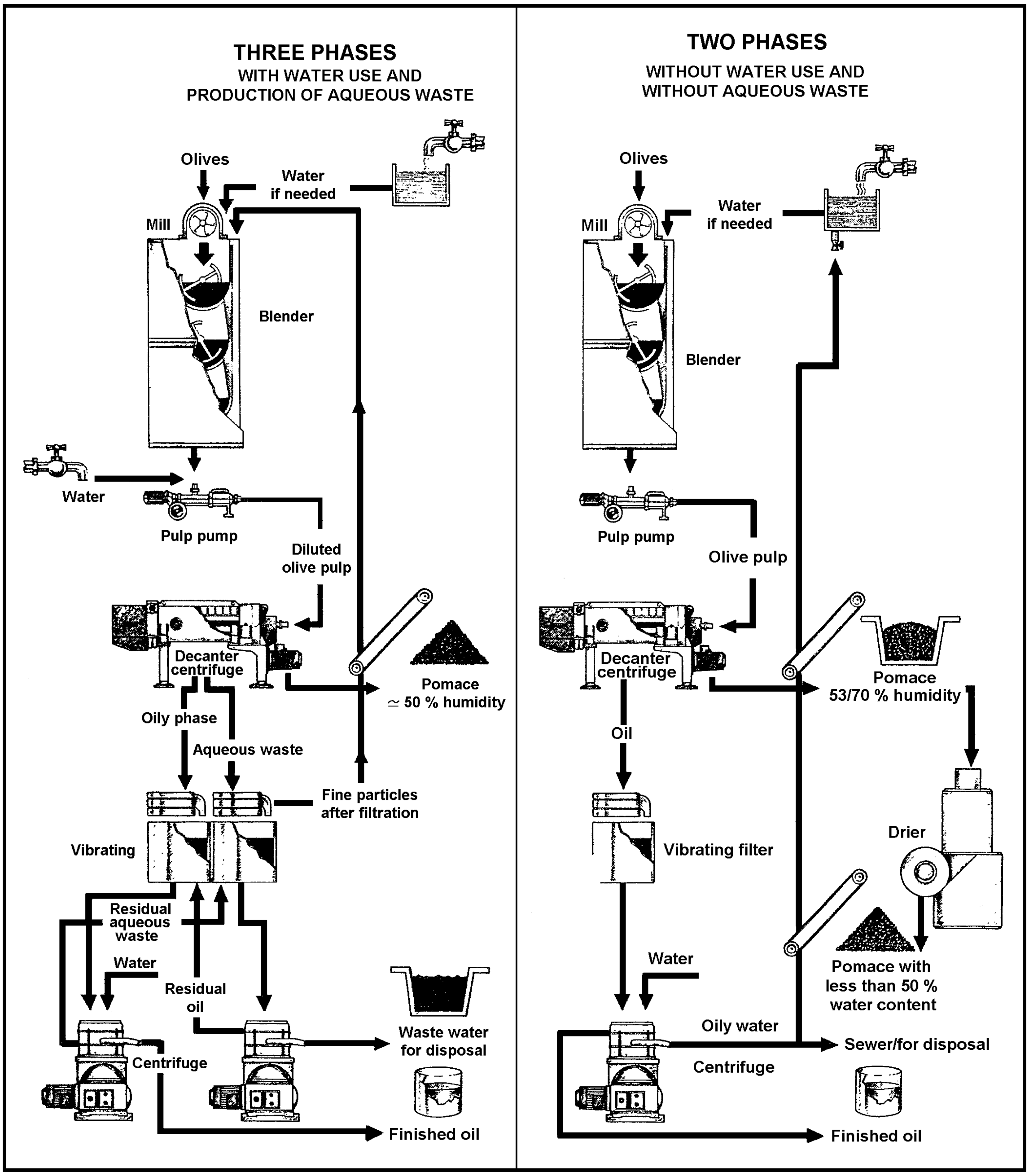


**Figure 4.21: Alternative techniques for olive oil extraction**
**[Junta de Andalucía; Agencia de Medio Ambiente, 1994 #86]**

In the new technique, the centrifuges are modified in such a way that the crushed (mixed) olives are separated into *two phases*: the oil phase and a solid phase. This technique does not require the addition of water to the olive mixture.

Achieved environmental benefits

The amount and the pollution load of the waste water produced in olive processing decreased. In the traditional process, processing 1 tonne of olives resulted in the production of about 1 $m^3$ of waste water with an average $BOD_5$ level of 60000 mg/l. The amount of waste water produced using the two phase technique is about 0.3 $m^3$/tonne olive, with an average $BOD_5$ of 20000 mg/l, i.e. the pollution load is about 1/10. As no water is used in the extraction, there are also savings in water consumption.

Cross-media effects

Water and energy are saved in the extraction process. No water is used and, in consequence, there is no need to heat it. The energy savings are about 20 %.
However, solid waste is produced in larger amounts and with 7 - 21 % more water. After further hexane extraction, the "orujo" is normally dried (after further treatment by, for instance, extraction with hexane), the energy requirement is therefore higher.

Operational data

The extraction can be safely operated. Soluble sugars extracted from the olive are now in the solid waste. During the drying of this waste, caramellisation may occur.

Applicability

The modification of existing techniques is easy and cost effective.

**Example**

In the campaign of 1991/92, the first systems having only *two phases* were installed.
In some years, the whole industry introduced the new system. See Figure 4.22.

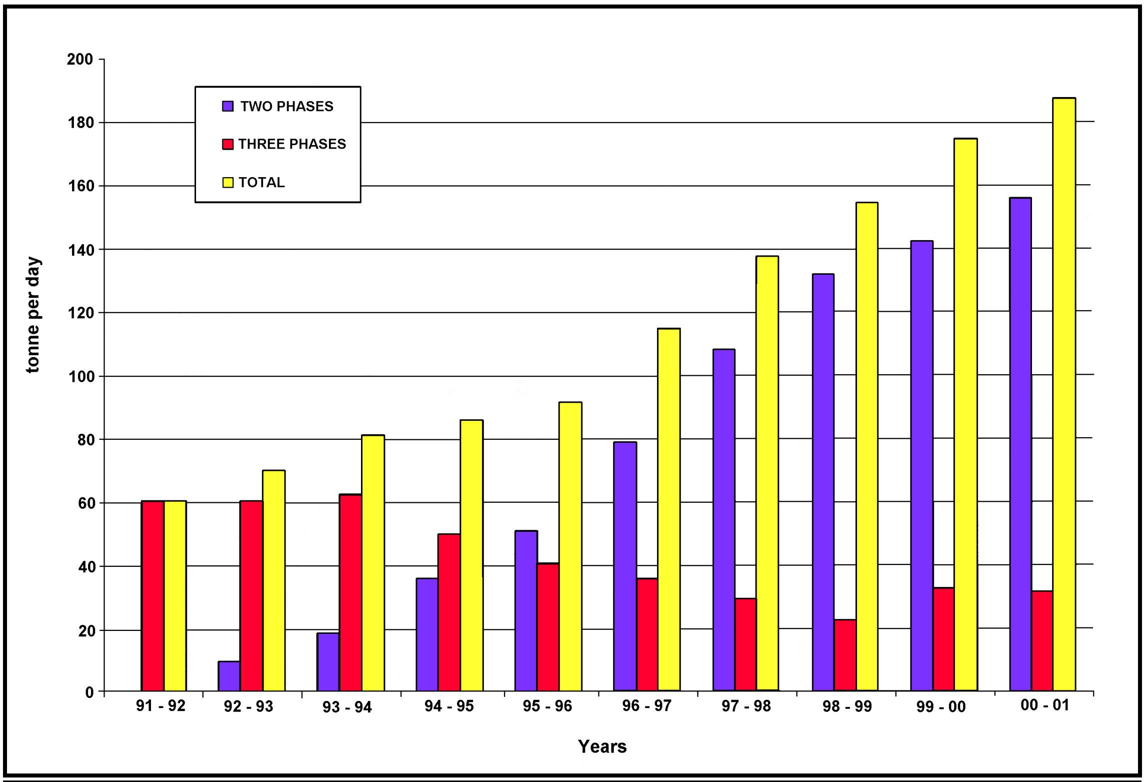


**Figure 4.22: Changes in techniques applied in Andalucean olive oil sector in the 90`s [Junta de Andalucía; Agencia de Medio Ambiente, 1994 #86]**

Economics

Savings in water and energy costs. The decanter centrifuges for the two phase separation are about the same price as the centrifuges for three phase separation.

**Example**

Operational costs of the extraction plant are reduced by EUR 12 - 24/t olive oil produced. In addition, the extraction yield is greater. (1 $m^3$ liquid waste had about 4 - 10 kg of oil.) In Andalucia, 30 % of the olives were processed using the new technique within the first two years. It was estimated that during the 1992/93 campaign

PTA 1150 millions (about EUR 6.9 millions), in the 1993/94 campaign PTA 7200 millions (about EUR 43.3 millions) were invested [Junta de Andalucia; Agencia de Medio Ambiente, 1994 #86].

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The advantages and disadvantages of the two phase system compared to the traditional systems are summarised below:

| Advantages | Disadvantages |
|---|---|
| No liquid waste is produced | There is still some waste water production with high contamination (BOD approximately 20000 mg/l), thus waste water treatment is needed |
| Water is saved | The water content of the solid waste is significantly higher |
| Energy is saved | Higher cost for storage and transport of the solid waste |
| Production costs reduced | Higher costs of drying the solid waste |
| More olive oil are recuperated | Higher sugar content in the solid waste may cause problems in drying due to caramelisation |
| Costs of retrofitting of the existing system are low and easy | |

**Table 4.30: Advantages and disadvantages of two phase separation on the three phase system in the olive oil production**

## 4.10 Management of accidental releases

One of the most significant potential environmental impacts associated with a Food and Drink Industry manufacturing site is that due to an abnormal event which results in an accidental release of material into the environment. For example, the accidental release of the contents of a tank containing raw material, product or an auxiliary material (e.g. milk, crude oil, ammonia) can have a significant detrimental impact on a local watercourse or water supply.

For good environmental management it is essential that all potential sources of accidental releases to the environment are identified and control measures put in place to ensure that the risk associated with these releases are either eliminated altogether or reduced to an acceptable level. The identification of these releases is an essential element of the development of an environmental effects register as part of an **Environmental Management System**.

After the introduction of control measures the probability of an accidental release is extremely low. However to deal with this very unlikely event, emergency procedures / plans need to be developed and put in place to ensure that, if an event occurs, the normal situation can be restored with minimal effect on the environment.

The objective of this section is to provide guidance on the identification of potential routine operations that take place on a site and which may result in an accidental release and which may have a detrimental impact on the environment. Advice on how to eliminate or reduce these risks is illustrated through case studies. Case studies will also be used to demonstrate how emergency plans are developed.

There are a number of stages in the management of accidental releases. In summary, these stages are:

- identification of potential incidents / accidental releases (abnormal operation) that would have an adverse impact on the environment
- conduct a risk assessment on the identified potential accidental releases to determine their risk to the environment
- development of control measures to prevent, eliminate or reduce risk associated with identified potential incidents
- development of emergency plan.

### 4.10.1 Guidance for identifying potential sources of incidents / accidental releases

There are two general categories of incident. These are:

- loss of containment from bulk storage, e.g. leakage, spillage, vessel failure
- loss of containment from unplanned process control failures.

To identify potential sources of these types of incidents information needs to be gathered and assessed. This information can then be used in the risk assessment described in Section 4.10.2.

The information that needs to be gathered is outlined below.

(a) Identification of raw materials on site

The potential for accidental releases is significantly influenced by the raw materials, intermediate products, products and waste that are stored on the site.

A raw material inventory is produced which includes:
- an assessment of their potential environmental (and safety) hazards (A good source of safety and environmental information is material safety data sheets (normally obtained from the suppliers) and product data sheets. (normally developed internally within the company)
- information on quantities stored on site and location.

(b) Identification of emissions from unit processes / emission inventory

It is important that all streams / emissions or potential streams / emissions which could give rise to an abnormal occurrence / accidental release are identified

The most systematic way to do this is to work through each process and identify all the potential emissions into each medium. This will typically include:
- raw material delivery
- bulk raw material storage
- minor raw material storage, egg drums, sacks, IBC's
- production
- packaging
- palletising
- warehousing.

As well as considering the processes, the ancillary equipment / processes on the site will also need to be considered. This will typically consist of:
- utilities, i.e. boiler house, compressed air, water treatment, ammonia systems
- internal transport on the site (fork lift trucks).

Solid waste will in general always be considered to be a parameter which is abated /controlled, as it is removed by a licensed contractor to a licensed disposal facility, i.e. incinerator, treatment plant, landfill etc.

Possible scenarios that may result in an accidental sudden increase in the noise levels at the site boundary are also considered.

(c) Site plan

The site plan is used to show the site drainage system and control / abatement mechanisms already in place. It is also used to indicate the location of bulk storage and drum storage facilities for materials stored in bulk and for materials that are particularly hazardous. Major air emission points may also be indicated, as can sensitive boundaries and receptors. It is important that the plan is kept up to date.

(d) Site location in relation to environmental receptors

To understand the potential environmental impact an accidental release may have it is important to have knowledge of the local environment situation. Although there will be areas of similarity between sites, there will also be differences, e.g. a factory located in a rural area is likely to have different environmental issues to one located in a residential area or to one located in an industrial area. Accidental releases of air emissions, odour and sudden increases in noise levels are all likely to be key issues for factories located close to residential areas, whereas the impact on the local water courses and wildlife may be more of a concern in rural areas. Public amenities will need to be considered, particularly where surface water or treated effluent is discharged into a local river or where there is potential for groundwater contamination.

In addition it is useful to have a basic knowledge of the geology and hydrogeology of the area on which the site is built. If the site is located on clay soils then any spillage will take a long time to permeate through to any groundwater beneath it. If however a site is on sandy or permeable soil then spillages will permeate more quickly through the soil to the groundwater.

A site survey can identify all the environmental receptors for the site and identify any which are particularly sensitive, e.g.

- receiving watercourse collecting treated water and/or surface water
- housing estate on the site boundary
- local tourist attraction adjacent to the site etc
- local schools / hospitals
- sensitive aquifers
- sites of specific scientific interest
- area of outstanding natural beauty.

(e) Site history

The objective in documenting the site history is to demonstrate that a site is free from environmental problems which might arise from past activities. The information gathered can also provide a baseline with which to assess the impact of any accidental releases that may occur in the future

The main issue is normally one of contaminated land or contaminated groundwater. This can arise from sources such as underground storage tanks, poor bunding and spill protection, on-site landfilling, leaky drains etc. By documenting the past land use, areas where contamination might have occurred can be identified and, if necessary, investigations involving soil/groundwater sampling and analysis can be undertaken. Investigations of this type are only likely to be carried out if it is believed that there is a reasonable risk that the land or groundwater is contaminated.

(f) Other information

Other factors which need to be taken into account to assist in the identification of potential sources of environmental incidents are:

- previous incidents including near misses
- engineering and management controls that are in place and the potential failure of these controls
- human behaviour; the interaction between operators and manufacturing operations and the potential of an environmental incident due to human behaviour.

(g) Structured techniques

Structured techniques can be used to identify potential incidents. These techniques examine in detail flow diagrams of the manufacturing operation under study. HAZOPS (Hazard and Operability Studies), FMEA (Failure Mode and Effects Analysis) and SWIFT (Structured What-IF Technique) are examples of such methods. However these techniques can be time consuming and resource intensive and are only used if the site is considered to be a high risk site.

### 4.10.2 Risk assessment

A risk assessment is an important part of the procedure, as it is the application of this technique which will determine whether a site identifies a potential incident /abnormal occurrence as significant or not.

The depth and type of risk assessment will depend on the characteristics of the installation and its location. Factors to be taken into account are:

- the scale and nature of the activities taking place on the site under investigation
- the risks to areas of population and the environmental (receptors).

The risk assessment is carried out on those situations identified in Section 4.10.1 that may result in an adverse environmental impact during abnormal / emergency situations.

In an attempt to quantify the risk, two 0 - 4 scales are used. One scale to measure the likely or potential impact (degree of impact), and the other to measure the frequency / probability of the accident occurring. The proposed scales are set out in the Table below. The overall risk is then obtained by multiplying the degree of impact by the frequency of occurrence.

(a) Degree of impact

It is important when considering the impact that any control measures in place are ignored when assessing the potential impacts. The significance of the environmental impact can be assessed by considering the following factors:

| Impact | Score |
|---|---|
| ✓ Very low environmental damage, **and**<br>✓ Very low public concern, **and**<br>✓ Very low financial effect | 0 |
| ✓ Damage confined to site, or<br>✓ Limited local concern, but no wider interest and/or<br>✓ Financial impact defined by site/company | 1 |
| ✓ Minor or short term damage to the local environment, or<br>✓ Major local issue, but only of limited wider public interest (likely to give rise to a formal complaint from residents association or similar body) and/or<br>✓ Financial impact defined by site/company | 2 |
| ✓ Moderate damage or medium term damage to the local environment and/or<br>✓ Financial impact defined by site/company | 3 |
| ✓ Major damage or long-term damage to the local environment, or<br>✓ or minor or short term damage on National / Regional / International Scale, and/or<br>✓ Major local issue and also of a wider general public concern (e.g. likely to lead to intervention of statutory body or give adverse media coverage regarding nuisance or health affects) (company reputation at stake), and/or<br>✓ Threatens the profitability / viability of the site | 4 |

**Table 4.31: Assessment of potential impact of an accident**

N.B. Public sensitivity does not necessarily correlate with environmental harm or legal compliance. It is more likely to be assessed based on the number of complaints from the public and the regulatory authorities, and the interest shown by these parties over the activities associated with the site.
The factors given above are only put forward as examples. They can be modified to suit the local environment / situation.

The significance of the impact is obtained by assessing the criteria given above and attributing a score of 0 to 4 for potential incidents.

**Examples**:

- a spillage on-site that was completely contained would not cause any environmental harm so would be scored zero
- if the spillage contaminated part of the land on-site this would score one. However if the spillage penetrated into groundwater, and damage on a regional scale could occur from polluted water supplies, the score would be between 2 and 4 depending on the pollutant, the quantities involved and the sensitivity of the groundwater (i.e. is it being used as an aquifer)
- if the spillage entered the surface water drainage system, then there could be minor, moderate or major damage to the local environment. Depending on the scale and toxicity of this release it would score two, three or four.

(b) Frequency /probability

The frequency / probability of the events identified in Section 4.10.1 occurring needs to be determined. This is assessed using the table below:

| Frequency | Score |
|---|---|
| Event has never occurred | 0 |
| Negligible, once every 100 years<br>e.g. explosion | 1 |
| Low every ten years<br>e.g. fire | 2 |
| Medium once a year<br>e.g. operation of emergency vent | 3 |
| High once a month<br>e.g. unplanned shutdown | 4 |

**Table 4.32: Scoring of the probability of frequency of accidents**

(c) Overall risk assessment

The overall level of risk is obtained by multiplying the impact score by the frequency score.

When carrying out the risk assessment, it is important that the following rules are adhered to:

- when assessing the severity of a possible impact then any control measures in place are ignored, and it is assumed that environmental damage / harm has occurred
- when considering the likelihood / frequency of an occurrence then the effectiveness of the control measures in place is taken account of.

A simple example of the above would be the potential spillage of a tank of crude edible oil into a river. When considering the impact (Environmental Harm/Damage) then this would be ranked as a 4. If the tank is unbunded, the possible frequency of occurrence may be once a year, giving a frequency/probability score of 3. Thus the overall level of *risk is scored as 12*.

However if the tank is bunded, with the bund volume being 110 % of the tank, the bund is in very good condition, no valves are fitted, the sump pump is locked, and the key kept with the supervisor, and the bund walls are so positioned that the trajectory of any pin hole would be caught within the bund. Then on this basis the frequency of an incident occurring which would result in environmental harm /damage would be ranked at zero. Hence, the overall significance ranking would be *zero*.

From the scores for each potential incident it can be seen that the accidental releases arising are either:

- adequately controlled to ensure that the frequency of occurrence is low and hence the score is low
- or the potential impact is minor, giving a low ranking on this scale.

Abnormal events that may result in accidental releases are always scored low on the frequency scale, but they may have the potential for high impact scores. Depending on the potential severity of the impact, the significance ranking will determine whether additional control measures are required to make the frequency score lower (i.e. zero).

Application of the assessment allows a systematic analysis of the abnormal events to be made, and provide a basis for a ranking of the relevant events.

### 4.10.3 Identification of potential accidental releases which need control

Once the risk assessments have been completed, it is then necessary to identify incidents that may have a significant environmental impact and which are currently not adequately controlled. This is carried out by comparing the risk assessment scores. It is a site / company decision to determine which of the potential incidents are considered as significant. This may change with time as part of a continuous environmental improvement programme.

### 4.10.4 Control measures

An evaluation has to be undertaken on the identified sources of potential accidental release to determine whether new control measures are required or existing control measures need to be improved.

Typical control measures that can be considered are:

- management procedures
- operational procedures
- preventative techniques
- containment
- process design / process control

(a) Management procedures

Management system procedures can be put in place to assess new activities taking place on the site and to ensure that environmental issues, including the possibility of accidental releases, have been taken into account.

***Examples:***

- procedures to assess environmental risk associated with new raw materials
- to ensure adequate control measures are in place
- compatibility with other materials and feedstocks with which they may accidentally come into contact
- procedures to assess new processes to ensure adequate control measures are incorporated at the design stage to prevent or minimise accidental releases.

(b) Operational procedures

Operational procedures need to be developed covering critical process plant items to ensure that the risk of an accidental release is minimised.

***Examples:***

Operator instructions for the process plant include:

- routine checks on potential sources of accidental releases and any control measures that may be in place
- regular checks on pollution abatement equipment bag filters, cyclones, waste treatment facilities
- regular inspections of underground storage tanks, containment bunding.

(c) Preventative techniques

***Examples:***

- suitable barriers to prevent damage to equipment from the movement of vehicles.

(d) Containment

*Examples:*

- bunding for bulk storage of materials
- spillage equipment to minimise impact of an accidental release
- isolation of drains
- consideration is given to containment or abatement of accidental releases from safety relief valves or bursting discs.

(e) Process design / process control

The process plant needs to be designed and controlled so that the accidental release of material is either eliminated or minimised to acceptable levels.

*Examples:*

- techniques to monitor the efficiency of abatement equipment, e.g. pressure drop across bag filters
- techniques to prevent the overfilling of storage tanks e.g. level measurement, high level alarms, high level cut-offs.

### 4.10.5 Emergency plan

Normally emergency plans are drawn up for the whole site and cover safety and significant environmental risks. Emergency procedures covering the significant environmental risks identified above can then be incorporated into the overall emergency plan.

A typical emergency plan covering environmental incidents includes the following components:

- roles and responsibilities of individuals are clearly defined including:
  - procedures for operators who remain to operate critical plant operations
  - escape procedures and routes
  - procedures to account for all employees.
- rescue and medical duties
- procedure for reporting emergencies and informing relevant environmental and emergency authorities
- action to be undertaken to minimise impact of environmental incident
- names of employees.

For example, it is recommended that emergency procedures are in place to cover incidents which might involve the following accidental release scenarios:

*Examples:*

- ammonia
- liquid raw materials or product stored in bulk, e.g. crude edible oil, milk
- dust from drying operations, e.g. spray drying
- use of potentially hazardous auxiliary materials, e.g. biocides, diesel oil.

The prime aim of an emergency plan is to restore situations as quickly as possible with minimal effect on the local environment. Emergency situations vary greatly in scale and complexity and it is important that emergency plans are flexible enough to deal with the minor as well as major events and are simple enough to be quickly implemented.

The effects of potentially catastrophic incidents can be substantially reduced by systematically preparing and thoroughly testing plans with informed and trained people. There is not enough time in an emergency to decide who is in charge, to survey outside agencies to identify sources of help, or to train people for emergency response. Provisions for these must be made prior to any emergency.

Some other reasons for preparing emergency plans are:

a) Reducing thinking time once an incident has occurred can significantly reduce the consequences of the incident (both in terms of injuries to people, damage to property, environmental effects, loss of business etc).

b) To ensure that the situation is orderly, rather than chaotic.

c) To reduce bad publicity, since serious incidents can have an impact on the organisation's image and subsequently on sales and public relations.

d) To fulfil statutory duties, since emergency plans are required, in many countries.

e) To enable provisions to be in place for informing external agencies, the general public, the media and Company Senior Management.

The emergency plan can also ensure that appropriate control techniques to limit consequences of the incident are put in place, such as oil spillage equipment, isolation of drains, alerting of relevant authorities, evacuation procedures.

## 4.11 End-of-pipe treatment techniques –Techniques for treating air emissions

### 4.11.1 Summary of techniques available

Some examples of techniques that may be applied to treat air emissions are given below.

(No priority ranking is intended, and the appropriate selection in a particular case will depend on the specifics of the process concerned and on site constraints).

- condensation (T1)
- fabric filters (T2)
- cyclones (T3)
- biofilters (T4)
- incineration with heat recovery (T5)
- wet Scrubbers (T6)
- stacks - chimneys (T7)
- catalytic oxidation (T8)
- carbon adsorption (T9)
- cooling (T10)

| Emission Type | Technique |
|---|---|
| Odours | T1,T4,T5,T6,T7,T8,T9 |
| Particulates | T1, T2,T3,T6,T7 |
| Organics | T2,T5,T4,T6,T7,T8,T9,T10 |

**Table 4.33: Summary of techniques for treating air emissions**

### 4.11.2 Waste gas treatment in the food industry

The following are processes of special environmental relevance with regard to waste gas emissions by the food industry:

- transport, transhipment, packaging and storage of dust-producing goods
- drying processes
- extraction
- mills
- cleaning and conditioning of raw materials.

In particular, these processes involve emissions of particulates, gaseous pollutants and odours.

A reduction in pollutant emissions from stationary sources can be achieved by

- using low-emission substances and products (substance-related primary measures)
- using low-emission systems and production processes (process-related primary measures) and
- installing waste gas treatment systems (secondary measures).

Primary measures

Substance-related and process-related primary measures can be taken to prevent, or at least reduce, the creation of pollutant emissions. However, sufficiently effective primary measures do not exist for all sectors.

Waste gases must be collected at source, wherever this is possible at reasonable cost.

The following points in particular must be taken into account when defining the requirements:

- choice of integrated process techniques with maximum possible product yield and minimum emissions into the environment as a whole
- process optimisation, e.g. through extensive utilisation of input materials and recovery of co-products
- use of substitutes for carcinogenic, mutagenic or terratogenic input materials
- reduction of waste gas quantity, e.g. by using air recirculation, having regard to hygiene requirements
- reducing energy consumption and reducing emissions of greenhouse gases, e.g. through energy-optimised planning, construction and operation of systems, in-plant energy utilisation, use of heat insulation measures
- prevention or minimisation of emissions of substances that deplete the ozone layer, e.g. by using substitutes for such substances, enclosing systems in buildings, encapsulating parts of systems, creating a partial vacuum in the encapsulated space and preventing leaks in systems, by collecting the substances during waste treatment, by using optimised waste gas purification technique and by proper management of the recovered substances and the waste
- optimisation of start-up and shutdown procedures and other special operating situations.

If there is a possibility of hazardous substances being emitted, the input materials (raw materials and operating resources) are, as far as possible, selected so that only minor emissions can occur. Process cycles that could result in elevated emissions of hazardous substances are as far as possible to be avoided by means of technical or operational measures. Where such process cycles are essential for operating purposes, e.g. when processing production residues to recover metals, measures must be taken to avoid elevated emissions, e.g. by means of a targeted elimination of substances or by the installation of especially efficient waste gas treatment systems.

Operating procedures that involve switching off or bypassing the waste gas treatment systems must be designed and operated so as to ensure low emissions and must be subject to special monitoring by the recording of relevant process parameters. In the event of a failure of the emission reduction systems, plans must be in place for measures to immediately reduce such emissions as far as possible, bearing in mind the principle of proportionality.

### 4.11.2.1 Overview of waste gas treatment processes

Waste gas treatment processes are universally usable and can be retrofitted to existing production systems at reasonable cost. Waste gas treatment processes have been constantly optimised to achieve better separation results, greater operating reliability and lower cost. A progressive waste gas treatment system does not result in any shift of the air quality problem into the fields of waste management or waste water management. The waste gas purification measures are designed to reduce not only the mass concentrations, but also the mass flows or mass ratios of the air pollutants originating from a system. They are in normal use during the operation of the plant.

Waste gases may contain pollutants in the solid, liquid and/or gaseous state.

To reduce emissions by cleaning waste gases, the pollutants are either converted into environmentally sound compounds or removed from the waste gas stream by means of physical/chemical separation methods. Separation may be preceded by a chemical or phase-change conversion process. The table provides an overview of widely used waste gas treatment processes, subdivided in terms of the state of aggregation of the pollutants.

| **Waste gas treatment processes by state of aggregation of the pollutants** | |
|---|---|
| Solid, liquid pollutants | Gaseous pollutants |
| • Dynamic separation | • Absorption |
| • Wet separation | • Adsorption |
| • Filtration | • Chemisorption |
| • Electrostatic precipitation | • Condensation |
| • Aerosol/droplet separation | • Chemical conversion (oxidation/reduction)<br>- Thermal<br>- Catalytic |
| | • Biological separation<br>- Biofilters<br>- Bioscrubbers |
| | • Membrane technique |

**Table 4.34: Waste gas treatment techniques – an overview**
**[65, Germany, 2002]**

Special mention must be made of the VDI Guidelines, which describe processes and equipment and quote a wide variety of practical examples. The Guidelines are summarised in the manual »Reinhaltung der Luft« (“Air Quality Control” – TA-Luft) and serve among other things as a guide and an aid to decision making. (See **Annex 1**)

### 4.11.2.2 Separation of solid and liquid substances

Dispersed particles can be separated from contained waste gas streams by means of particulate separators. Separation requires the application of external forces. These are primarily gravitational and inertial forces and electrostatic forces. Gravity and inertia separators are also known as dynamic separators. They are mainly used for separation of large particles only (> 10 µm).
Separation based on electrostatic or diffusion processes is used for fine particulates.

### Removal of dust

The overview of waste gas treatment processes distinguishes the following dust removal methods based on the forces applied:

- dynamic separators
- wet separators
- electrostatic precipitation
- filtration.

Specific types of equipment can be grouped under these headings:

| Classes | Equipment types |
|---|---|
| Dynamic separators | Gravity separators, deflection or inertia separators, centrifugal separators: cyclones, multiclones and rotary flow dedusters |
| Wet separators | Washing towers, spray scrubbers, packed towers, injection scrubbers |
|  | Jet scrubbers, vortex scrubbers, rotation scrubbers, disintegrators, venturi scrubbers, special types |
| Electrostatic precipitation | Dry electrostatic filters, wet electrostatic filters |
| Filtration | Bag filters, storage filters, bed filters, special types |

**Table 4.35: Techniques for removal of particles from air**
**[65, Germany, 2002]**

### Dynamic separators

The basis for the separation and removal of particles in dynamic separators is the field forces, such as gravity, inertia or centrifugal forces, which are proportional to the mass of the particles.

Simple implementations of the principles of gravity separation are transverse-flow or counter-flow separators (also known as settling chambers). The characteristic of transverse-flow separators is the horizontal gas flow, whereas in counter-flow separators the gas flow is vertical. Reducing the flow rate causes larger particles to sink.

Deflection or inertia separators permit effective dust removal. Because of their inertia, larger particles are unable to follow the (repeatedly) deflected gas stream and are separated. With the appropriate design, it is possible to achieve separation rates of 50 % for particles in excess of 100 µm.

These separators are used for preliminary separation or as sifters in product recovery. They are of little importance for environmental protection.

Better separation results can be achieved with centrifugal separators (cyclones).

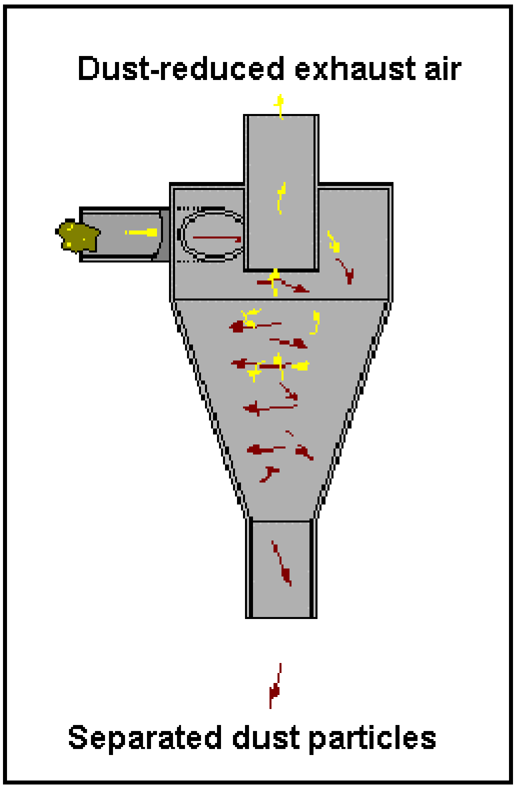


**Figure 4.23: Cyclone**
**[65, Germany, 2002]**

Applications for centrifugal separators

Centrifugal separators are characterised by
- simple, robust design
- small space requirements
- high operating reliability and
- low costs.

Since, as described above, there are limits to their overall and fraction separation rates, they are suitable for use in cases where:

- there are high levels of dust in the untreated gas
- there is no great requirement for the removal of fine particles
- there is a need for preliminary separation and/or protection and relief of downstream systems
- pressures are high (high-pressure dedusting) and
- temperatures are high (high-temperature dedusting).

Wet separators

In dynamic separators, the effective mass forces, i.e. gravity, inertia and centrifugal forces) fall off sharply with increasing particle size. One way of increasing the separation rate of dynamic separators and other dust separators is to increase the surface area of the particles by binding them to liquid droplets or irrigated surfaces.Although generally speaking, this merely shifts the pollutants from the air into the water. There may therefore be special reasons for choosing wet separators, e.g. sticky or highly flammable dust or a clear risk of dust explosion.

Wet separation can be described in terms of the following basic principles:

Dust particles present in the untreated gas are brought into contact with, and become attached to, the considerably larger droplets of the collecting liquid and can then be removed together with the droplets.

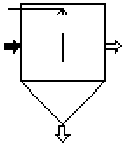
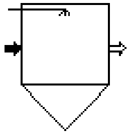
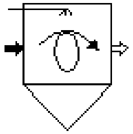
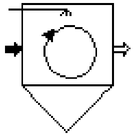
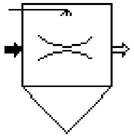
The relatively large dust-laden droplets (diameter 50 to 200 µm) are usually removed from the gas stream by means of cyclones or lamellar separators. Cyclones are preferred for heavy solids loads and small gas streams. Better separation rates and lower pressure losses are achieved by using lamellar separators in high-performance separation units. These consist of vertically arranged metal or plastic plates. These can separate particles larger than 10 µm.
Scrubber water must be disposed of in accordance with waste water legislation. Waste water problems can be avoided by treating the laden collecting liquid and returning it to the process, or possibly concentrating it by evaporation. The cost of waste water treatment may be considerable, in some cases even higher than for dedusting. It is can be advantageous if there is an in-plant opportunity to re-use the laden collecting liquid.

The different types of wet separators can conveniently be distinguished by classifying them in terms of their design features. In this way six basic types can be distinguished:

- washing towers, spray scrubbers, packed towers
- injection scrubbers (high-pressure / dual substance injection scrubbers)
- jet scrubbers
- Vortex scrubbers
- rotary scrubbers, disintegrators
- Venturi scrubbers.

The last two are frequently described as high-performance scrubbers.
Scrubbers are suitable for use in the following situations:

- for flammable or sticky dust
- where there is a risk of explosion
- for simultaneous separation of solid, liquid and gaseous pollutants
- for small dust particles (< 0.1 µm); and
- for simultaneous preliminary separation.

| Description | Scrubber tower Spray scrubber Packed tower | Injection scrubber (high-pressure or dual-substance injection scrubber | Jet scrubber | Vortex scrubber | Rotary scrubber, disintegrator | Venturi scrubber |
|---|---|---|---|---|---|---|
| Symbols according to DIN 30600/28004 |  |  |  |  |  |  |
| Gas speed in contact zone in relation to free cross section (m/s)* | 1 - 5 | 20 - 60 | 5 - 15 | 8 - 20 | 25 - 70 | 40 - 150 |
| Pressure difference over entire separator (hPA)* | 1 - 25 | 5 - 25 | Pressure recovery of approx. 1 - 10 | 15 - 30 | 2 - 10(1) | 30 - 200 |
| Energy requirements ($kWh/1000m^3$) | 0.2 - 3 | 0.4 - 2 | 1.2 - 3 | 1 - 2 | 4 - 15 (1) | 5 - 15 |
| Collecting liquid/gas ratio ($l/m^3$)* | 1 - 5 | 0.5 - 5 | 5 - 50 | No data possible due to process principle | 1 - 3 per stage | 0.5 - 5 |
| Separation limit (µm)* | 0.7 - 1.4 | 0.1 - 1 | 0.8 – 0.9 | 0.6 - 0.9 | 0.1 - 0.6 | 0.05 - 0.5 |
| Separation rate (%)* (2) | 50 - 85 | 90 - 95 | 90 - 95 | 90 - 95 | 92 - 96 | 96 - 98 |

* Approximate values, upward and downward variations possible

1) In disintegrators the energy consumption is often considerably higher depending on the efficiency and the volume of gas handled. A pressure recovery of up to 25 hPa is possible.

2) The separation rate shown in the table merely gives a rough idea of the possible working range. Although the separation rate is easy to measure, it only permits limited conclusions about the efficiency of a separator. For example, it is directly dependent on the particle size distribution of the input material. If the particle size distribution changes, so does the separation rate, even if the other parameters remain constant. A knowledge of the separation rate does however become important in the specific application. The fraction separation rate is a much more suitable parameter for assessing the efficiency of a separator.

**Table 4.36: Dust removal from air – overview of wet separators**

Filtration

In filter separators the untreated gas is fed through a porous medium in which the dispersed solid particles are held back as a result of various mechanisms. Filter separators can achieve the highest separation rates (> 99 %), and even very fine particles are separated very efficiently.

Pure gas concentrations of around 1 to 5 mg/m$^3$ are possible. In view of the dry separation process it is, in principle, possible to utilise or return separated particulate matter. The stricter legal requirements for reducing emission values mean they are being increasingly used, even in the field of flue gas purification.

As a general rule, the average distance between fibres is considerably larger than the particles to be collected. This means that the screen effect alone does not explain the good separation rates of filter separators. The following mechanisms are also responsible for the separation of particulates:

- mass forces
- obstructive effects
- electrostatic forces.

Filter separators can be classified on the basis of filter medium, performance range and filter cleaning facilities (see Figure 4.24).

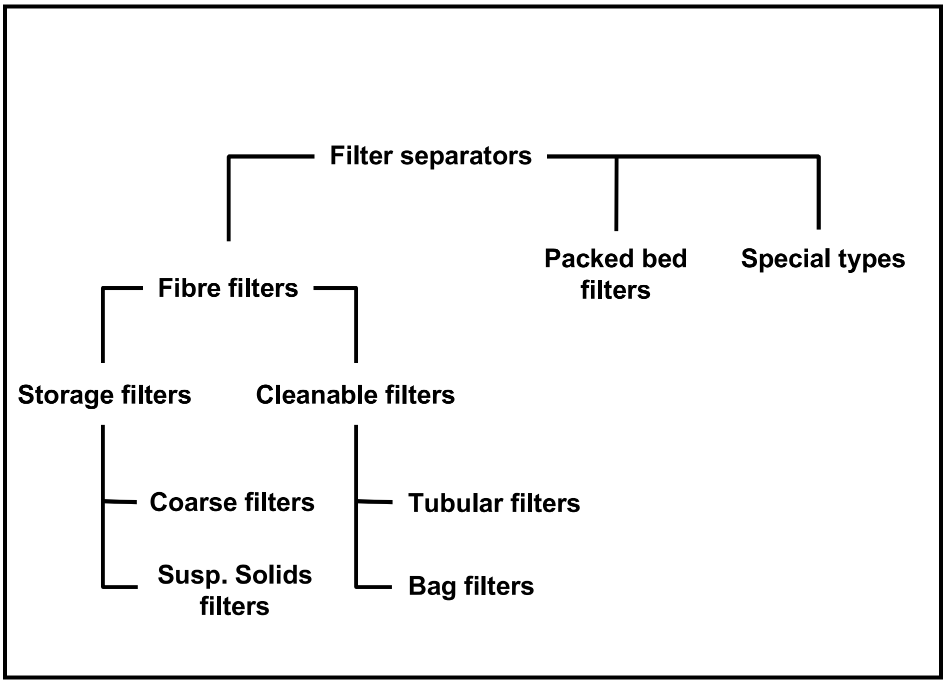


**Figure 4.24: Types and classification of air filters**
**[65, Germany, 2002]**

Cleanable filters

Cleanable filters are among the most important types of filter separators used in industrial particulate removal. Whereas the filter medium (filter material) in past designs was usually of woven fabric, today's designs primarily make use of non-woven and needle-felt materials. Cleanable filter types differ in the geometrical arrangement of the filter medium (tubular or bag-like), the management of the gas flow, and the filter cleaning system. The main parameters are the air to cloth ratio and the pressure loss.

The filter medium performs the actual separation and is the essential component of a filter separator.

Woven fabrics have threads which cross at right angles. Non-wovens and needle felts, by contrast, are flat three-dimensional structures that may be stabilised by the adhesion of the fibres themselves or by alternating insertion and removal of fibres. Non-wovens and needle felts may contain an internal supporting woven fabric (e.g. polyester or glass-fibre fabric) to reinforce them. Needle felts made of synthetic fibres are becoming increasingly established.

Non-wovens and needle felts possess three-dimensional filtering characteristics. Dust particles are caught in the filter structure, forming an ancillary filter layer that ensures good separation of even the finest particles. One characteristic of this "deep filtration" is a large effective specific surface area. Regular intensive cleaning removes the accumulated dust layer and prevents excessive pressure losses. Problems may be caused by sticky, fatty, agglomerating, adhesive, abrasive and hygroscopic dust particles.

**Figure 4.25: Picture of an industrial baghouse**
**[65, Germany, 2002]**

Cleanable filter types differ in the geometrical arrangement of the filter medium (tubular or bag-shaped), the management of the gas flow, and the filter cleaning system.

In tubular filters the filter medium consists of tubes up to 5 m long with a diameter of between 12 and 20 cm. The gas flows from inside to outside or vice versa, depending on the cleaning method (see illustration).

Bag filters are made up of filter material up to about 30 mm thick and measure up to 0.5 m high and 1.5 m long. The filter elements are fitted with their open end towards the clean gas duct. The untreated gas stream always flows from outside to inside, usually in the upper region of the filter bag.

Storage filters

Storage filters consist of fibre mats with a large void volume for sufficient storage capacity and with the minimum possible flow resistance.

The decisive factor for the high separation rate of suspended solids filters (1 to 5 µm), for example, is a small fibre diameter. Performance can also be improved by making the fibre material denser towards the clean gas side of the filter. Fibre mats are made of glass and plastic fibres, and sometimes non-woven paper material. Coarse filters also use mats made of metal turnings coated with a dust binding compound. Synthetic materials can be reconditioned, e.g. by washing or blowing out, but usually they are disposed of after use.

The main application of suspended solids filters used to be in clean room techniques, e.g. in nuclear techniques or hospital operations. Today they are increasingly being used in industrial waste gas cleaning, especially in fields requiring very high standards regarding dust content in the clean gas, e.g. where toxic or hazardous dust is concerned.

The materials available achieve dust concentrations of 0.001 mg/m$^3$ in the clean gas from concentrations of 1 g/m$^3$ in the dirty gas. As a general rule, it is necessary to use conventional filters first.

The use of new pleated filter materials has made it possible to produce cleanable compact filters of the storage filter type. Compared with conventional filter separators these achieve better separation rates despite higher air to filter ratios and smaller sizes. In some fields they are direct competition for cleanable filters. Clean gas dust concentrations of less than 1 mg/m$^3$ are guaranteed. If a preliminary separator is integrated, compact filters can be used for dirty gas concentrations of up to 15 g/m$^3$.

Packed bed filters

Packed bed filters can be used to achieve simultaneous separation of particulate matter and gases. Packed bed filters satisfy an essential requirement for high-temperature or hot-gas dedusting, namely utilisation of the thermal energy of the cleaned gas streams at a high temperature level. Clean gas figures of around 10 mg/m$^3$ for dust have been achieved in trials. The dust content of the dirty gas averaged 18 g/m$^3$ and the mean particle size 0.5 µm.

The filter medium is a granular layer of gravel, sand, limestone or coke in the particle size range 0.3 to around 5 mm. The dust particles become attached to the granulate layer. A dust layer which supports the separation process is formed at the surface of the bed. Penetration of separated dust can be prevented by using fine particles (< 0.5 mm) and low flow speeds (< 0.1 m/s). However, note there is a risk of bridge formation, which may result in reduced separation rates.

The height of the packed bed may be up to several metres. Cleaning is by counterflow rinsing, mechanical shaking in conjunction with flushing air, or by movable nozzles. The filter unit in question is shut off from the gas stream while cleaning is taking place. The multi-compartment design ensures continuous cleaning. The separation rate is not as good as that of fibre layer filters. Packed bed filters are therefore preferred for separating problematical dust particles or at higher waste gas temperatures. Packed bed filters are frequently used in conjunction with preliminary separators (e.g. cyclones).

Areas of application:

- hard abrasive dust
- temperatures up to 1000°C
- chemically aggressive gases
- risk of sparks in connection with combustible dust
- for mist collectors (packing)
- for simultaneous separation of gaseous pollutants (e.g. $SO_2$, HCl and HF) by means of suitable packing.

Today fabric filters are used in almost all sectors of industry. Filter separators are increasingly being used today for cleaning hot waste gases.

| Parameter | Pulse Jet Filter | Membrane Fibreglass Filter | Fibre Glass Filter |
|---|---|---|---|
| Air to cloth ratio | 80- 90 km/h | 70 -90 km/h | 30 -35 km/h |
| Temperature limits | 200 °C | 280 °C | 280 °C |
| Bag type | Polyester/ Nomex® | Gore-Tex® Membrane/fibre glass | Fibre glass |
| Bag size | 0.126 X 6.0m | 0.292 X 10m | 0.292 X 10m |
| Cloth area per bag | 2.0 m² | 9.0 m² | 9.0 m² |
| Cage | Yes | No | No |
| Pressure drop | 2.0 kPa | 2.0 kPa | 2.5 kPa |
| Bag life | Up to 30 months | 6 - 10 years | 6 - 10 years |

**Table 4.37: Comparison between different bag filter systems (Elkem 1998)**

Combined use with other separators

Filter separators are usually operated as final separators. When retrofitting/upgrading, existing separators (e.g. cyclones, wet separators or electrostatic precipitators) continue to be used as preliminary separators where this makes economic sense. Preliminary separators have to be used in particular in cases where the waste gas contains components with properties damaging to filters (e.g. abrasive dust or aggressive gases etc.). This is the only way to ensure adequate filter life and operating reliability.

Dynamic separators can be used for coarse separation. Flue gases usually undergo preliminary cooling combined with preliminary separation (quench cooler, scrubber). Extremely high standards for clean gas dust concentrations can be achieved by using two-stage layouts of high-performance separators (e.g. two fabric filters or in combination with suspended solids or ESP filters).

Electrostatic precipitation

Electrostatic separators (frequently known as ESPs) are used to separate solid or liquid particles from waste gases. The particles distributed in the gas are electrostatically charged so that they stick to collection plates.

Electrostatic precipitators permit

- high separation rates (up to 99.9 %)
- effective separation of even small particles (< 0.1 µm) and
- treatment of large waste gas volumes (> 106 $m^3$/h).

They have comparatively low pressure losses (100 to 400 Pa), low energy requirements (0.05 to 2 kWh/1000 $m^3$) and a long service life. ESPs are preferred in large systems for cleaning large quantities of waste gas at high temperatures. The separation process can be divided into the following individual stages:

- charging of the particles in the ion field
- transport of the charged particles to the collecting platec
- collection and film formation on the collecting plate
- removal of the dust film from the collecting plate.

The main components of an ESP are the filter housing, discharge and collecting electrodes, power supply, gas guides or baffles, and a rapping system for cleaning the collecting plates.

A distinction is made between dry and wet ESPs. These may have a horizontal or vertical gas flow. Dry ESPs are mostly built with collecting electrodes in plate form (plate ESPs). In wet ESPs, the collecting electrodes frequently take the form of tubes (tube ESPs), here the gas flow is usually vertical.

It is generally true to say that ESPs can handle large waste gas flow volumes and achieve high separation rates.

Wet ESPs can achieve even better separation rates. In particular, they can separate fine dusts, aerosols and to some extent heavy metals and gaseous substances. They are used in preference for cleaning liquid-saturated gases, for acid and tar mists or if there is a risk of explosion.

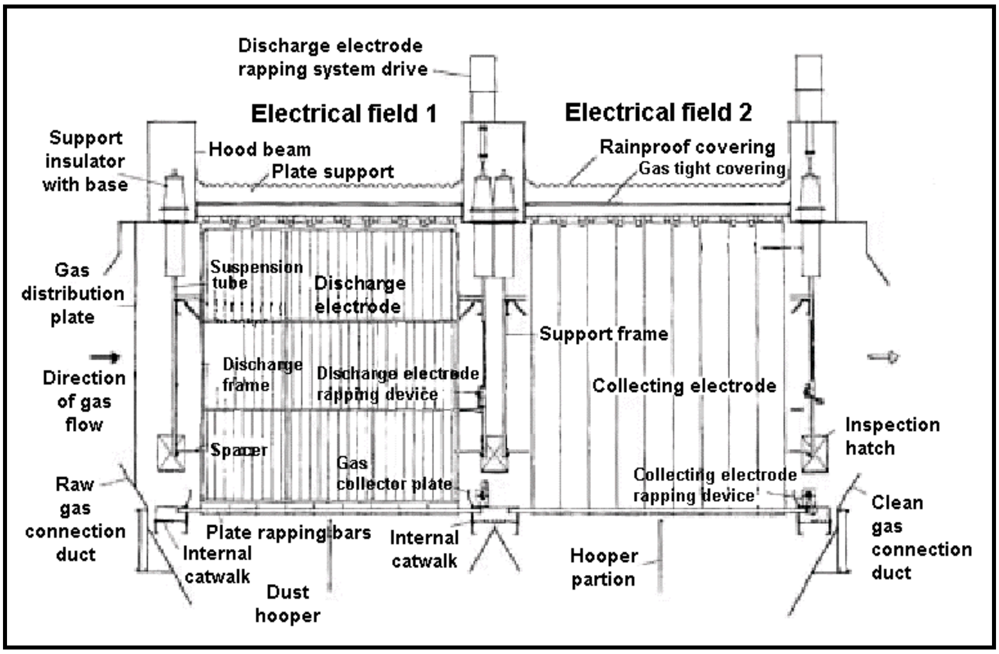


**Figure 4.26: Typical arrangement of an electrostatic precipitator (only two zones shown) (Lurgi 1999)**
**[65, Germany, 2002]**

| Technique | Particle size µm | % collection efficiency at 1 µm | Maximum operation temperature °C | Range of achievable emission levels mg/Nm³ | Comments |
|---|---|---|---|---|---|
| Hot EP | < 0.1 | > 99 % depending on design | 450 | < 5 - 15<br>(pre-abatement > 50) | 4 or 5 zones.<br>Usual application is pre-abatement |
| Wet EP | 0.01 | < 99 | 80 | < 1 - 5<br>Optically clear | EP with 2 zones in series.<br>Mainly mist precipitation. |
| Cyclone | 10 | 40 | 1100 | 100 - 300 | Coarse particles. Used to assist other methods |
| Fabric filter | 0.01 | > 99.5 | 220 | < 1 - 5 | Good performance with suitable dust type |
| Ceramic filter | 0.01 | 99.5 | 900 | 0.1 - 1 | Very good performance with suitable dust type |
| Wet scrubber | 1 - 3 | > 80 - 99 | Inlet 1000<br>Outlet 80 | < 4 - 50 | Good performance with suitable dust types<br>Acid gas reduction |

**Table 4.38: Example of current emissions from some dust abatement applications (dust mg/Nm$^3$)**

### 4.11.2.3 Separation of gaseous substances

Thermal and catalytic processes

Certain pollutants can be converted into environmentally sound substances by means of oxidation (incineration) or reduction. The reaction partners are either already present in the waste gas or added to it.

The speed of the reaction increases exponentially with temperature. In thermal processes the pollutant conversion takes place at high temperatures (> 600 °C). At lower temperatures, catalysts are used to speed up the conversion reaction.

Thermal and catalytic combustion

Oxidisable pollutants include all organic compounds, as well as inorganic substances such as carbon monoxide and ammonia. Given complete combustion, carbon and hydrogen react with oxygen to form carbon dioxide and water. Incomplete combustion may result in new pollutants such as carbon monoxide and in totally or partially unoxidised organic compounds.

If the waste gas contains elements such as sulphur, nitrogen, halogens and phosphorus, combustion gives rise to inorganic pollutants such as oxides of sulphur, oxides of nitrogen and hydrogen halides, which subsequently have to be removed by means of other waste gas purification processes if the concentrations are too high. This restricts the field of applications for combustion of pollutants.

Direct-flame incineration

Thermal combustion, also known as direct-flame afterburner incineration, usually operates at temperatures of between 700 and 900 °C. The reaction temperature depends on the nature of the pollutant; it may be lower, but for less readily oxidisable substances such as organohalogen compounds it may be in excess of 1000 °C.

A direct-flame incineration system essentially consists of the burner, combustion chamber and heat exchanger. Various burner types such as laminar-flow burners, nozzle burners and vortex burners are used to heat the waste gas to the reaction temperature, usually with the aid of supplementary fuel. In special cases, the burner may be replaced by an electric heating system. Possible supplementary fuels include light heating oil, natural gas or LPG. The combustion chamber in which the oxidation reaction takes place must be designed for high thermal stresses. Some combustion chambers are made of heat-resistant metal and chambers with a metal jacket and refractory lining.

For ecological and economic reasons, direct-flame incineration is always combined with heat recovery. The clean gas, after combustion, is used in a heat exchanger to heat the dirty gas and also, if desired, the combustion air. Improved combustion systems are offered by the "combuster" and "thermoreactor".

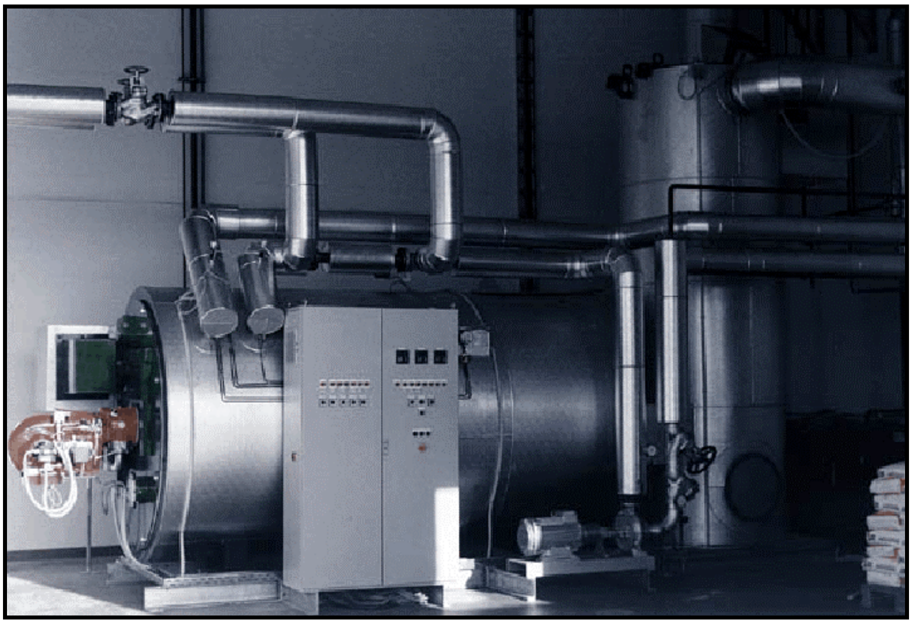


**Figure 4.27: Unit for direct-flame incineration with afterburner**
**[65, Germany, 2002]**

Catalytic combustion

Catalytic combustion, also known as catalytic afterburning, usually takes place at temperatures between 250 to 500 °C. The main components of a catalytic combustion system are auxiliary firing equipment and a heat exchanger and reactor with catalyst. Catalysts (also known as contacts) increase the speed of the reaction so that high conversion rates can be achieved even at relatively low temperatures. However, catalysts do not have any influence on the thermodynamic equilibrium. As with adsorption, the reaction partners for the heterogeneous gas reaction must first be transported to the inner surfaces of the generally porous catalysts.

As there is a general lack of adequate substance data, such as reaction speed constant and diffusion coefficient, reactors are usually designed on the basis of empirical data. An important parameter here is the space velocity (ratio of waste gas flow volume to catalyst volume), if this is known, the catalyst requirements can be calculated.

A variety of catalysts are on the market, differing in shape, structure and composition. There are packings (pellets, cylinders, rings, extruded shapes etc.), networks and structures with channels (e.g. honeycombs and plates). A distinction is made between unsupported catalysts, which consist entirely of the active component, and supported catalysts, in which the active component is applied to a supporting lattice.

Active components commonly used include metals of the platinum group and oxides of the metals Ti, V, Cr, Mo, Fe, Co, Ni, Cu and Wo. The support materials are usually metals, in the form of plates, woven fabrics or nets, and metal oxides ($Al_2O_3$, $SiO_2$, MgO etc.) and minerals (e.g. pumice, zeolite) as moulded shapes.

#### 4.11.2.4 Biofilters / bioscrubbers

(See also Control of Odour Emissions, Section 4.12.12.2)

Biological methods of waste gas treatment can be used to eliminate biodegradable gaseous air pollutants (especially organic pollutants and odours).

In biofilters, the substances are degraded by micro-organisms located on a fixed filter medium. The filter media used include tree bark, compost, peat, heather and mixtures thereof. The materials are arranged in the form of a packed bed and are permeated by the waste gases.

The pollutants are absorbed onto the filter material and degraded by the micro-organisms. To ensure optimum separation performance, it is necessary to comply with defined operating conditions (moisture, pH, temperature, oxygen, nutrients).

Special areas of application are:

- purification of room and process air in gelatine production, beer yeast drying, fat rendering, oil mills
- cleaning of roasting gases in cocoa production
- cleaning of cooling air in animal feed production (roasting line).

Bioscrubbers remove air pollutants (organic pollutants and odours) that can be washed out with water or a mixture of water and activated sludge.

The waste gas constituents washed out in this way are microbiologically degraded. Bioscrubbers are absorbers in which an intensive exchange of substances takes place between the polluted gas and the absorbent (selective-action collecting liquid). The absorber is followed by a mist collector to separate the gaseous and liquid phases. In the subsequent absorbent regeneration step, the waste gas constituents absorbed in the liquid phase are removed from the absorbent. This is performed by micro-organisms which use the separated air pollutants as a substrate.

The micro-organisms are either finely divided in the collecting liquid or applied as a layer to the absorber structures (trickling filter). The reaction speed of the biodegradation process is relatively low, and optising operating conditions can have a crucial influence.

In the case of waste gases with high particulate levels, the gas must first pass through a dust remover.

Possible applications are in the purification of waste gas from processes with waste gases rich in odours and organic components, e.g.

- treatment of waste gas from tobacco dryers (organic pollutants, odour)
- treatment of waste gas from livestock units (odour, ammonia)
- treatment of waste gas from sewage plants (odour, carbon disulphide).

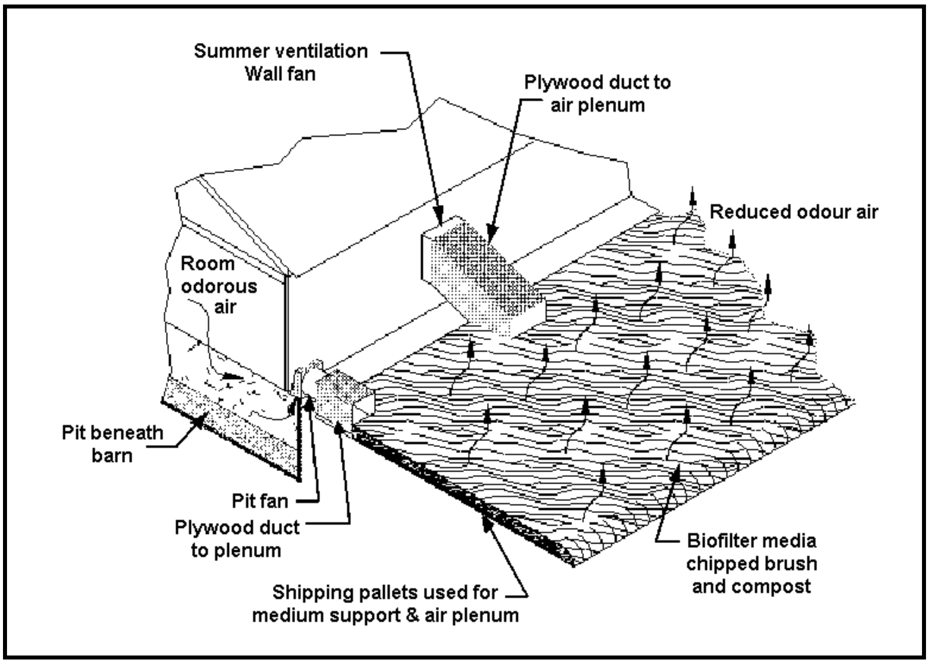


**Figure 4.28: Biofilter for odour abatement**
**[65, Germany, 2002]**

### 4.11.2.5 Waste gas treatment by chemisorption

In waste gas treatment by chemisorption, the air pollutants in the waste gas are bound to an adsorbent as a result of a chemical reaction and separated from the waste gas stream.
In these reactions a distinction must be made between adsorption (attachment of the waste gas constituents to solid surfaces) and absorption (binding of gaseous substances by a liquid).

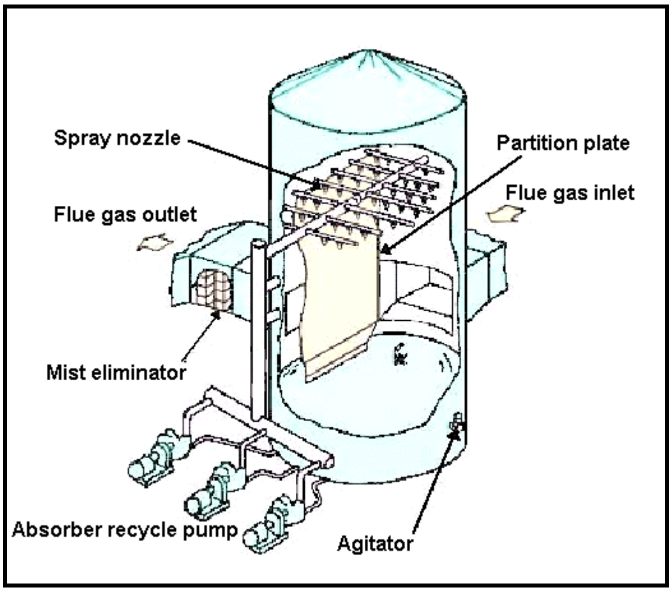


**Figure 4.29: Diagrammatic representation of an absorber**
**[65, Germany, 2002]**

The sorbent can be added directly to the input materials (primary process), e.g. fuel, or added to the waste gas in a stage following the process (secondary process). Sorbents used include

calcium, sodium, magnesium or aluminium compounds. For the separation of organic pollutants and heavy metals in particular, mixtures of activated charcoal and lime are used.
In addition to a large number of inorganic gaseous pollutants, this method can also be used to separate heavy metals and compounds containing hydrocarbons. However, chemisorption process are of minor importance for the food industry.

### 4.11.2.6 Separation of vapours (waste gases rich in water vapour)

Drying plants, in particular, give off vapours laden with water vapour which may contain not only particulate pollutants, but also odours and gaseous pollutants.
Since cyclones do not achieve adequate removal of particulates, an effective technique is to employ (sometimes heatable) fabric filters or wet scrubbers downstream of such dedusting units. Scrubbers are basically suitable for cleaning moist waste gases and can help to abate odour problems.

Odours are emitted from drum drying systems in particular as the relatively high surface temperature of the cylindrical drums causes odorous substances to be emitted with the water vapour. By condensing the vapours it is possible to bind a large proportion of the adhering odorous substances in the condensate and discharge them. [65, Germany, 2002]

**Vapour compression**
By compressing exhaust vapours it is possible to make major cuts in energy requirements for concentration processes in the food industry (e.g. wort boiling in breweries).
The vapour in question here is the water vapour that is given off when a solution is concentrated by condensation. The heat of evaporation that has to be input for a concentration process can be recovered by condensing the vapour that is driven off.
In order for the heat of condensation stored in the vapour to be used to provide additional heat for the concentration process, condensation of the vapour must take place at a temperature higher than the boiling point. To raise the condensation temperature, the vapour is compressed by a few tenths of a bar (0.1 - 0.5 bar). A heat exchanger is then used to return the heat of condensation from the compressed vapour to the concentration unit.
Apart from the energy needed to drive the compressor, no further energy input is required. The ratio of recovered energy to energy input (performance figure) may be as high as 40.
In addition to saving energy and reducing energy costs, another important reason for condensing vapours is to reduce odour emissions.

- **Mechanical compression of vapours**

Mechanical vapour compression uses a mechanical compressor to compress the vapour. Common types used are rotary compressors, screw compressors, radial-flow turbo compressors and blowers.

- **Thermal compression of vapours**

Thermal vapour compression makes use of steam injection compressors to compress the vapour. The steam-injection compressors may have fixed or variable injection nozzles. The thermal energy needed for compression is made available as live steam (booster steam) from a boiler unit.
The live steam flows through the injection nozzle and is throttled to the pressure level of the receiving steam (vapour). Here enthalpy is converted into kinetic energy. Vapour is entrained as a result of the difference in speed (principle of water jet injection pump). Vapour and live steam are mixed in the mixing chamber to form mixed steam. Enlarging the flow aperture in the diffuser determines the pressure at which the mixed steam leaves the steam-injection compressor.
By comparison with mechanical vapour compressors, steam-injection compressors offer advantages in the form of lower purchase, maintenance and operating costs and greater reliability in operation.

## 4.11.3 Thermal afterburning system for a smokehouse

**[65, Germany, 2002]**

The system described here is installed in a smokehouse with an annual production of around 3000 t of smoked products. The direct-flame afterburning system used is regarded as a robust waste gas treatment system requiring little maintenance.

The afterburning system is powered by a modulating combination burner and is installed in the by-pass for the facility's flue stacks, so that the waste gas from the "smokeless" process phases, which are not relevant from the point of view of immission control, can be diverted past the waste gas cleaning system.

During the smoking phase the exhaust gas fan force-feeds the waste gas (dirty gas) through an exhaust gas by-pass flap to the afterburner's integrated dirty gas preheater. Here the dirty gas is heated to 300 - 350 °C before it enters the reaction chamber. After treatment the clean gas is used to preheat the dirty gas in the integrated heat exchanger and cooled to 400 - 450 °C and then discharged to the outside air via the flue stack.

The afterburner system is heated to the optimum operating temperature before the start of the smoking phase. The smoke generators are not enabled until this operating temperature is reached. The smoke-laden waste gas from the smoke chamber is fed to the afterburner unit. In the integrated heat exchanger this dirty gas absorbs the radiated heat from the treated clean gas and passes into the afterburner reaction chamber. Here it is mixed with the hot gases from the gas burner.

| Dimensions of afterburner TNV 2000 | Rated connections |
|---|---|
| Total length including burner: 4250 mm | Fuel: Oil |
| Total length excluding burner: 3750 mm | Electrical connection:220 V / 50 Hz approx. 1 kW |
| Diameter: 1150 mm | |
| Dirty gas connection: 200 x 200 mm<br>Or 200 mm diam. | Exhaust gas fan: 380 V / 50 Hz approx. 4 kW |
| Clean gas connection: 300 mm | |
| Weight: approx. 1250 kg | |

**Table 4.39: Technical measurements of direct-flame afterburner system in a smokehouse**

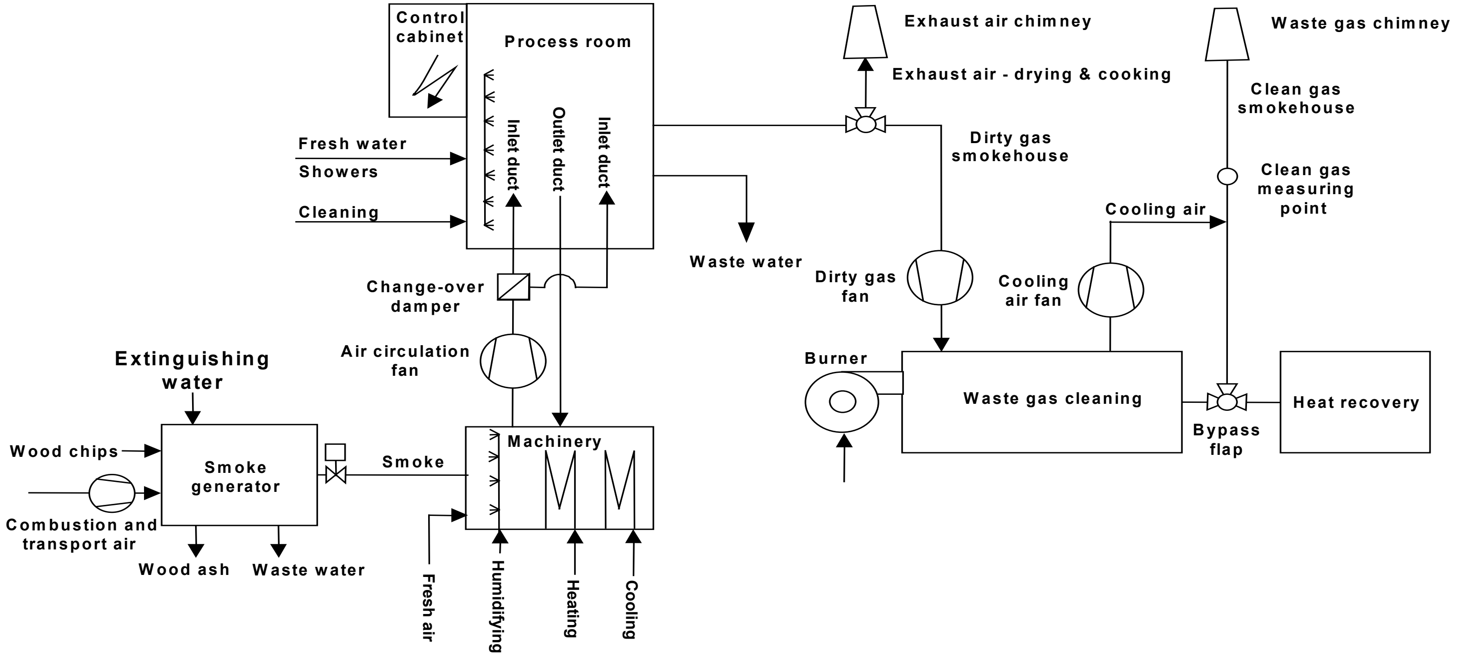


Figure 4.30: Flow diagram of origin and process management of the flue gas from the waste gas cleaning system of a smokehouse [65, Germany, 2002]

Performance data for this technique

All smoke units, regardless of their size, are equipped with a smoke generator. The smoking intensity is determined by the smoking time: approx. 60 - 120 minute/batch. The flow rate for one smoke generator is 200 Nm$^3$/h, resulting in a total flow rate for 11 smoke chambers of 2200 Nm$^3$/h. Applying a realistic parallel operating factor of 75 %, the actual flow rate is 1650 Nm$^3$/h.

| Parameter | Value | Comments |
|---|---|---|
| Waste gas flow rate | 2300 m$^3$/h (1*) | Normal state (i.e. 0 °C and 1013 mbar, dry) |
| Burner capacity | 600 kW (2*) | The capacity is continuously modulated. |
| Substance concentration in waste gas | < 50 mg/m$^3$ total C<br>max. 0.115 kg/h | 2300 Nm$^3$/h x 50 mg/m$^3$ = 0.115 kg/h |

**Table 4.40: Technical data for the direct-flame afterburner system of a smokehouse**

As a general rule, the guide value of 50 mg total carbon (total C) laid down in VDI Guideline 2595 for smoking installations is complied with, and odour emissions are completely suppressed at temperatures as low as 620 to 660 °C. Direct-flame afterburning can be run at temperatures of up to 700 °C, although the ideal operating temperature is usually around 640 to 680 °C.

The following diagram shows the balance of substances as an input/output diagram for the waste gas treatment system.

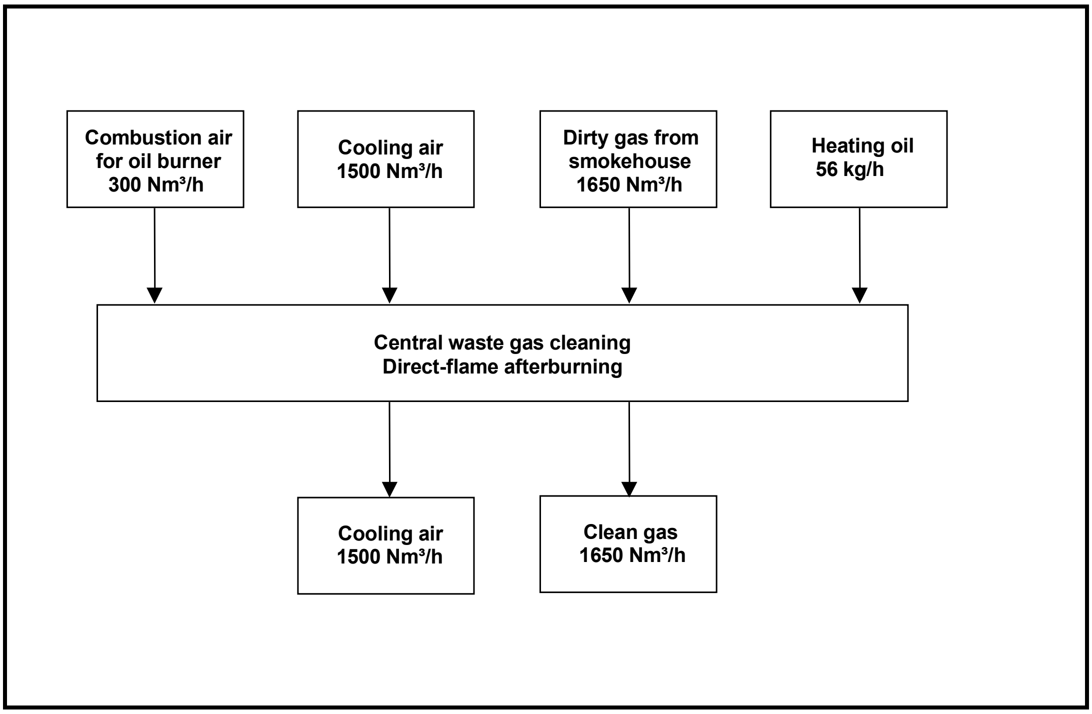


**Figure 4.31: Material balance of waste gas treatment system with direct-flame afterburning [65, Germany, 2002]**

Principal environmental benefit with regard to emissions and consumption

- waste gas cleaning, reduction in odour nuisance.

Cross-media effects

- consumption of fuel for operating the facility.

Economic aspects

As well as the purchase costs it is necessary to bear in mind the cost of regular maintenance. Oil price fluctuations need to be considered in the calculation of substances consumed.

Reasons for using the technique
The technique is used to satisfy official requirements.

## 4.12 Control of odour emissions

The control of odour emissions has not been of major interest to operators due to several factors discussed before in Chapter 2, but it is of particular importance for the food and drink industry. This is the reason why a rather detailed description of the assessment and control of odorous emissions is given in this Section.

Similarly, this Section not only gives a review of the application and performance of commercially available odour abatement techniques (Sections 4.12.8 - 4.12.15) but also covers the development of a strategy to control odorous emissions from manufacturing sites within the food industry (Sections 4.12.1 - 4.12.7.).

Each abatement technique is presented in a separate section with the following subsections:

| | | | |
|---|---|---|---|
| i) | Principle of operation | - | details how the technique works together with any associated theory |
| ii) | Selection of equipment | - | outlines the various configurations of equipment available and their relevant applications |
| iii) | Design considerations | - | details the salient design basis of the equipment and identifies what issues need to be considered |
| iv) | Advantages and disadvantages | - | identifies the general applicability of the technique and lists advantages and disadvantages |

The most appropriate odour abatement technique for a given application is dependent upon a large number of factors. Of particular concern are the physical characteristics of the exhaust(s) to be treated, the flow rate, the components present in the exhaust and the odour intensity, the degree of contamination present, such as particulate and condensable material, and the degree of treatment required to alleviate the problem. All of these factors need to be taken into consideration when deriving the optimum abatement technique.

### 4.12.1 Odour control strategy

Legislative controls governing odour emissions from industrial operations are becoming progressively more stringent. This is largely driven by an increased public awareness of environmental issues and the fact that people living in the vicinity of industrial premises have less tolerance to nuisance emissions than in the past.

There are a large number of potential options for the treatment of odorous exhaust emissions. These can be roughly grouped into absorption, which is inclusive of water and chemical scrubbing, adsorption onto activated carbon or other porous substrate, incineration including thermal and catalytic oxidation, and biological oxidation. The variation in treatment efficiency and capital and operating costs between the various options is potentially very high. Furthermore, legislation governing odorous emissions is impact related as opposed to source controlled. For example, the control of $SO_x$ emissions is by measurement prior to discharge, whereas the control of odour is based on the impact on the surrounding environment. Thus there are additional odour control techniques outside the scope of the aforementioned techniques, which will minimise the environmental impact of an odorous emission. These techniques fall into a physical dispersion category involving an improvement of the dispersion potential of the emission, e.g. extending the height of the discharge stack or increasing discharge velocity.

The selection and design of an odour control plant represents the final stage in the solution to an odour problem. There are a number of stages of work preceding the selection stage that need to be carried out in order to derive the optimum endpoint. In this respect, this section details an overall strategy for the assessment of an odour problem and documents the various stages of work that can be conducted prior to the selection stage. Of particular relevance here is the identification of which odorous emissions require treatment and the degree of treatment required. The majority of abatement techniques are designed on the basis of the volumetric airflow to be treated. Thus there can be considerable cost savings to be made by minimising the volume of odorous air to be treated. In this respect, this section also details techniques for minimisation, optimum containment of airstreams and design criteria for the optimum transport of the odorous airstreams to the point of treatment.

Further areas covered in this section also include an understanding of methods used to quantify the odour associated with an airstream, the application of air dispersion modelling to define the degree of treatment required and a review of legislative controls applied to odorous emissions.

Legislation Controls Applied to Odorous Emissions

Legislative controls regarding odour emissions vary considerably from country to country. In many countries the emission of odours from industrial operations is controlled under laws relating to **nuisance,** whilst in other countries there are specific **quantified odour limits**.

The internationally accepted units of odour are Odour Units per cubic metre. This odour threshold is a measure of the intensity of the odorous emission.

Overall strategy for odour control

The installation of an abatement plant represents the final stage in a programme of work to solve an odour problem. There are a number of preceding stages of work that can be conducted in order to ensure that an optimum solution to the problem is achieved. These stages of work may be consciously considered during the overall project, although they are unlikely to be evaluated in a systematic manner.

This section outlines a systematic approach to the stages involved in an overall study, from the initial definition of the problem through to the selection of an optimum solution. The approach is particularly useful for a large operating site where there are a large number of discrete odour sources and the major contributors to the overall odorous discharge are not fully understood. The systematic approach is divided into a number of stages of evaluation. The extent to which each stage needs to be covered will depend upon the particular factory situation and certain stages may or may not warrant inclusion in the overall work programme. The actual work programme conducted may differ considerably depending upon factors such as the size of the factory, the pressure exerted by the controlling authority, etc.

The total list of stages involved in the systematic study are summarised below. The procedure is illustrated in a flow sheet format in Figure 4.32.

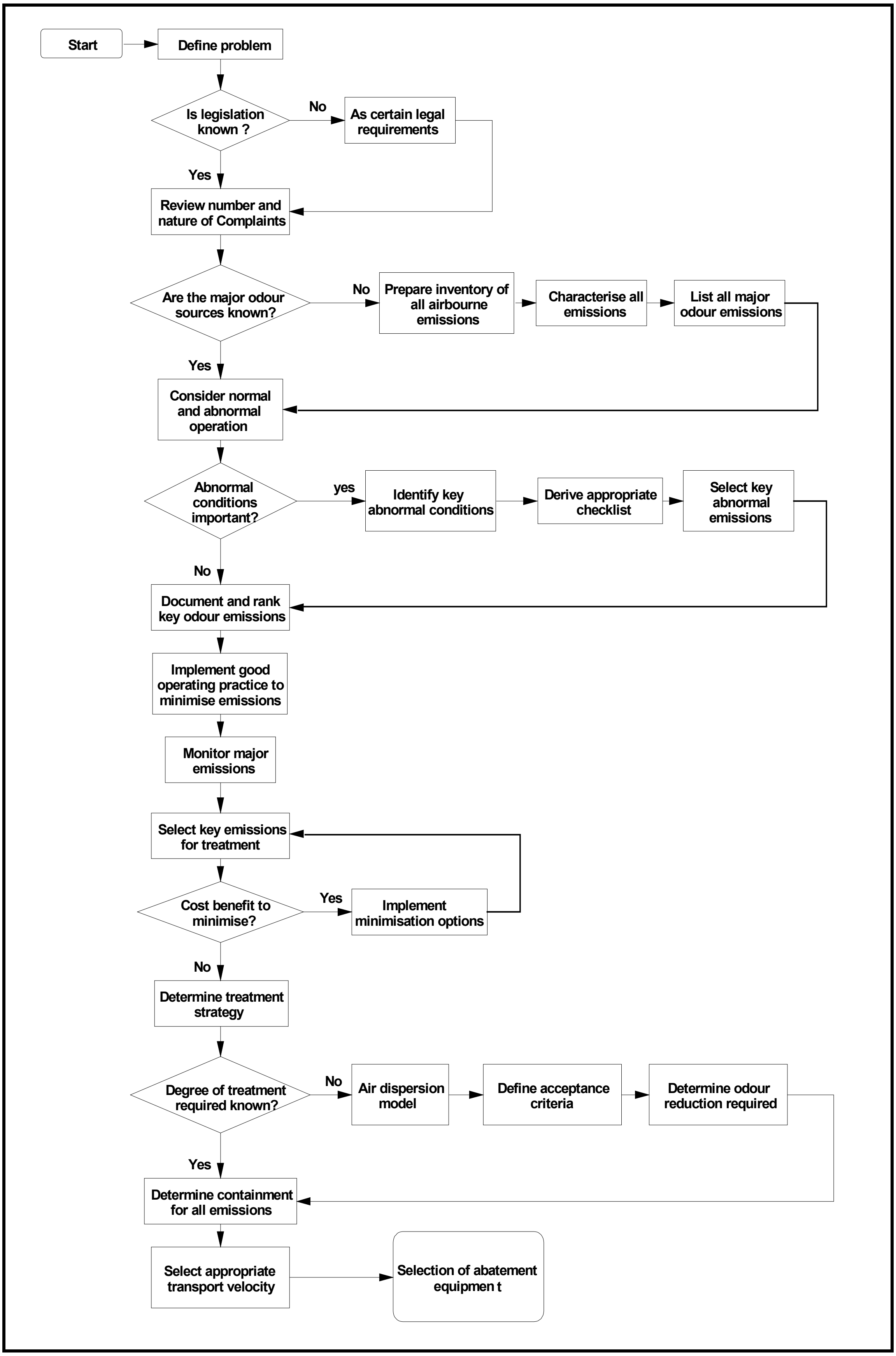


**Figure 4.32: Flow chart for selection of odour abatement technique [Willey A.R.; Williams D. A., 2001 #34]**

| Stage | Action |
|---|---|
| 1 | **Definition of problem** |
| | Fully define the legislative position, complaint frequency and local factors. This stage is really only applicable when the study is being conducted by personnel external to the site, e.g. consultant. |
| 2 | **Documentation of all site odorous emissions** |
| | The preparation of a register of all odorous emissions from the site and identification of major odorous discharges. |
| 3 | **Assessment of minimisation options** |
| | Assessment of potential reductions in the magnitude of the odorous emissions by minimisation. |
| 4 | **Measurement of major emissions** |
| | Olfactometric quantification of the major emissions from the site. |
| 5 | **Assessment of impact via air dispersion modelling** |
| | Evaluation of the dispersion of the quantified odorous emissions into the area surrounding the factory and determination of ground level odour concentrations. |
| 6 | **Selection of abatement technique** |
| | Selection of abatement technique and re-assessment of external impact using the air dispersion model. |

**Table 4.41: Stages of odour control strategy**

The stages involved in the systematic study are covered in more detail in the following sections. Prior to sequentially covering the odour control strategy, odour measurement is first detailed. This section makes a number of references to the measurement of odour by olfactometry and a review of odour measurement is designed to introduce the reader to the principles of applying a quantitative measure to the intensity of an odorous discharge.

### 4.12.2 Definition of problem

The problem definition stage is essentially an information gathering step so that all aspects of the pertaining legislation and local conditions are fully understood. For people working at the particular factory the general aspects of the odour problem will be well known. Thus this stage of the procedure is particularly poignant for a consultant or person not versed with the local situation. The following details regarding the factory site are identified during this stage of the project:

Complaints
The number and frequency of complaints are reviewed. In particular the location of the complainants in relation to the factory together with any comments made by the complainants or the local authority representatives. The factory initiates a complaints logging system and all complaints made directly to the factory are answered with either a return telephone call or personal visit. The exact processing conditions at the time of the complaint are examined and documented.

External correspondence
Any correspondence with the local authority or the local community is reviewed. The level of activity of the local community together with the approach and actions taken by the local authority representatives will enable the severity of the problem to be established and the likely time-scale available to install an abatement plant.

Local Situation
The prevailing climatic conditions for the locality of the factory are established. In particular the prevailing wind direction and wind speed and the frequency of inversions. This information can be used to ascertain whether the complaints are largely generated as a result of certain weather conditions or are generated by specific operations carried out at the factory.

### 4.12.3 Documentation of all odour emissions

In many cases the source of the odour problem is often well known amongst the factory staff and the surrounding community. This will likely be related to a continuous forced discharge from the factory that conveys a distinctive odour to the surroundings. Treating the major emission will in many cases alleviate the odour problem and reduce the number of complaints to zero or a satisfactory level. In other cases the removal of the major odour source will often result in other odour sources from the site becoming more prominent. These odour sources will likely have characteristic odours different from that of the major odour source. This situation can subsequently result in further complaints and require further capital expenditure in addition to that already assigned to treat the major odour source. Thus, it is important to fully evaluate the range of odorous emissions emanating from the factory site and to identify the discrete emissions with the greatest potential to cause odour complaints.

#### 4.12.3.1 Inventory of site emissions

As a first stage it is important to conduct an inventory of all odour emissions from the site. This inventory, as an initial step, identifies all airborne emissions from the site, which will encompass all odorous emissions. The odorous emissions can then, at a later stage, be segregated from non-odorous emissions.

An inventory of all site odour emissions is similar in format to the generation of an Environmental Aspects Register as part of an Environmental Management System. The most systematic way to document the airborne emissions is to work through each process and identify all potential emissions. This study may cover the following site operations:

i) raw material delivery
ii) bulk raw material storage
iii) minor raw material storage, e.g. drums, sacks etc.
iv) production
v) packaging
vi) palletising / warehousing.

The study can be conducted with varying degrees of sophistication. Essentially the inventory employs Process Flowsheets or Process and Instrumentation Diagrams and adopt a tour around the site to systematically identify all odour sources. This approach is best conducted using a team or even a number of teams depending upon the process complexity and the size of the site. The team identifies all the periodic emissions in addition to the more obvious continuous sources. The objective of this exercise is to document all the emissions, so that from these the major odorous emissions can be identified. As such, it is important to characterise each emission point to allow subsequent comparison and ranking with other site emission points. A possible datasheet that can be used for this exercise is detailed in Table 4.42. The right hand side column shows a list of examples to the questions in the left hand column.

| | |
|---|---|
| Odour Source: ____________________ | Examples: ____________________ |
| **Type of discharge:** | Forced / natural / ventilation |
| **Process operation conducted:** | Heating / cooling / maintenance / cleaning |
| **Continuity of emission:** | Continuous / discontinuous / periodic |
| **Operational time:** | Duration per hour / per day / production cycle |
| **Discharge arrangement:** | Stack / manhole / in building / atmospheric |
| **Discharge configuration:** | Stack diameter / elevation of discharge |
| **Description of odour:** | Sweet / sour / pungent / fruity |
| **Strength of odour:** | Very faint / faint / distinct / strong / very strong |
| **Estimated airflow:** | Measurement / fan curves / estimate |
| **Location in factory site:** | Co-ordinates of discharge |
| **Operation:** | Normal / abnormal / emergency |
| **Overall ranking:** | -10 to +10 or 0 to 10 |

**Table 4.42: Data sheet for collecting information on odorous emissions**

### 4.12.3.2 Inventory for abnormal operation

The analysis thus far will largely identify the site emissions during normal operation. Depending upon the severity of the odour problem and the key site operations that result in odour complaints it may be necessary to extend this analysis to cover abnormal and even emergency situations. Indeed, a site may not be deemed to have an odour problem under normal operating conditions and an external odour is only perceived during abnormal operations. In order to systematically cover abnormal emissions then a checklist approach is recommended in conjunction with a PID. The range of keywords to incorporate into the checklist will likely differ considerably from operation to operation. A typical checklist for abnormal operations is shown in Table 4.43.

| Parameter | Examples |
|---|---|
| Loss of containment | Overfilling / leaks / failure control |
| Disposal / emptying | Waste materials and process materials |
| Potential for material to enter process | Steam coil breakage |
| Runaway reaction | Failure to input a material, to control temperature, etc. |
| Corrosion / erosion | Inspection frequency |
| Loss of services | Fail safe instrumentation |
| Effluent washings | Washing frequency and procedures |
| Control / manning | Level of control and supervision |
| Ventilation / extraction | Design basis correct |
| Maintenance / inspection | Frequency, what is required? |
| Start-up / shutdown | Implications for downstream operations |
| Throughput changes | 100 %, 110 % of production + low production |
| Formulation changes | Odorous ingredients |

**Table 4.43: Checklist for abnormal operation**

## 4.12.4 Assessment of minimisation options

The odour emission inventory will identify the major odour sources from the site and roughly identify the specific sources that are part of a treatment plan or strategy. At this stage, it is a useful exercise to identify any sources whose impact could be reduced or even eliminated. Indeed the potential for individual emissions to be minimised could be added to the characterisation exercise as detailed in Table 4.41.

It is most likely that there will be scope for minimising the environmental impact of a significant number of odorous emissions from a site. The exact nature of the minimisation opportunities will differ considerably, depending upon the particular process operation. The following sections highlight the generic areas where minimisation measures can be investigated. The effective containment of an odorous emission is essentially a minimisation measure and there is considerable commonality between minimisation and containment. As such the containment of odorous emissions are considered along with minimisation measures.

a) Housekeeping

It is often the case that significant improvements can be made by improvements to general housekeeping issues within the site and general good practice operation. Focus here is targeted at minimising spillage and leakage and ensuring that spillage are dealt with as and when they occur.

b) Raw materials

In many processes, the quality and age of raw materials plays an important part in odour generation. In other processes there may be a possibility of substituting a less odorous material or one containing less of an odorous or odour producing impurity. In either case there will likely be a cost penalty which can be judged against a possible reduction in odour emission.

c) Plant and equipment

- Pumping and conveying

Careful design and effective planned maintenance can significantly reduce the frequency of odour emissions. The major sources of leaks comprise tanks, pumps, compressor seals and valves and process drains. There are remedies which can be considered to minimise leaks such as tanks with floating roofs, pumps with double mechanical seals for example.

The conveying of solids requires total enclosure of the conveyor and special ventilation arrangements such as hoods, when enclosure is not feasible. Total length and the number of transfer points are kept to a minimum. Conveyors are self-emptying, without dead spaces and provided with drainage to facilitate cleaning.

- Instrumentation and control

The generation of odorous discharges are strongly influenced by the applied temperature and pressure of operation. This is also the case for deviations in such factors as component quantities and reaction times from their design or optimal values. Thus accurate measurement and often elaborate control mechanisms are sometimes warranted in order to minimise the generation of odorous emissions. The control systems in place also require regular and effective maintenance to ensure proper and continued operation.

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**Example**:

> Heating liquid raw materials to desired temperatures prior to processing. The installation of a temperature measurement linked to an automated steam valve can considerably reduce the generation of odour during the heating process. Furthermore, raw materials that require heating prior to use are only heated just before they are required.

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- Ancillary plant

Equipment such as boilers, cooling towers and refrigeration plant need to be adequately sized for maximum expected demand and adequately controlled to always supply the required demand. Leakage of odorous materials into a cooling water system or operation of a cooling tower system to cool contaminated process water directly can cause inordinate problems in terms of odour generation.

d) Plant buildings

There are a number of factors to be considered in the initial design of a building in order to control the generation of odours. The storage and handling of odorous raw materials is a particular concern and the storage area may enable a first in - first out arrangement to be operated. In this respect hopper storage is to be preferred to storage rooms. Areas used for loading and unloading need to be well designed to facilitate frequent and effective cleaning.

For extremely odorous materials then the building is designed such that there is no escape of odour laden air during abnormal conditions such as equipment malfunctioning, leakage or repairs. This requires the minimum number of entry points, suitably protected by double doors with an air lock between.

e) Processes

By and large the choice of processes and of process conditions is governed by the technique and economics of the particular industry. The correct operation of process plant is regularly reviewed and any deviations or modifications assessed in terms of their odour impact.
Simple modifications to a process can result in considerable reductions in odour emissions.

**Example**:

Discharging odorous liquids below the liquid level in a vessel or back venting of raw material deliveries into the delivering road tanker are fairly easy and cost effective to initiate and will control odour emissions.

Process modifications designed to alleviate odorous emissions will often have a knock-on effect of improving product yield and profitability.

**Example**:

Within edible oil refining operations, changing the type of filter to separate bleaching earth from refined oil has been shown to reduce the amount of oil lost on the bleaching earth and at the same time enclose the filtration process, thereby minimising odour losses.

f) Ventilation

In many operations adequate ventilation of the workplace and specific process operations is required to ensure suitable working conditions. The ventilated air needs to be extracted from the building and into an abatement plant or alternatively to atmosphere. It is important to distinguish between general factory ventilation and local ventilation. The general factory ventilation is by far the larger flowrate and would be expensive to treat. In this case, individual odour emissions are better exhausted by a separate ventilation system. The former can subsequently be discharged directly to atmosphere, whilst the separate odour sources can be combined and treated in an abatement plant.

**Example**:

The overall ventilation flowrate from a packing hall is usually very high and it would be expensive to treat this high flow / low odour emission. Thus a separate ventilation system to extract specific odour emission points is fully warranted

The specific design of ventilation systems for minimising the volumetric flowrate of extracted air, whilst at the same time ensuring adequate ventilation, is discussed further in Section 4.12.6.

g) Plant and site management

In many processes where there is a potential for odour generation, and it represents a management concern, there will be operating procedures in place designed to minimise the escape of odours. These procedures could cover, for example, cleaning schedules, spillage procedures and treatment and disposal of wastes.

Management procedures and operating practices need to be regularly reviewed to ensure that procedures are adhered to and that the procedures fulfil the requirements of minimising odour generation. In general, an untidy plant is often an indication that there are no procedures in place or that they are not being carried out effectively. Similarly, any modifications to the plant or to the operational procedures in place are assessed in terms of the potential generation of odorous emissions.

### 4.12.5 Measurement of major emissions

- Ranking of emissions

The emissions can be ranked in terms of the severity of their impact on the surrounding enviornment of the factory. A possible system to devise a ranking order could start with grouping the emissions into categories such as *major*, *medium* and *minor*. The ranking within each category will be strongly influenced by the strength of the perceived odour from the source together with the associated airflow and nature of operation, i.e. continuous or non-continuous emission. Obviously this process will require a degree of professional judgement in addition to the factors detailed above. The number of key odorous emissions will obviously depend upon the size and complexity of the site.

- Odour measurement

The next stage of the systematic study is to measure quantitatively the magnitude of the odour emission from the major sources identified.
The quantification of the major odorous emissions allows the emissions to be ordered in terms of their actual emission relating to the measured odour threshold (OU/m$^3$) multiplied by the associated volumetric airflow (m$^3$/sec). This emission ranking is illustrated in Table 4.44.

At this stage, a tentative treatment strategy will start to unfold. The key odour emissions will be known together with the related flowrates which, in conjunction with the physical location of the emissions within the factory site, allows a reasonable picture of a treatment scenario to be developed. The quantification of odour emissions is also very useful in developing a strategy to determine which odour emissions need to be treated and which emissions do not warrant treatment.

| Source | Airflow | Odour level | Odour emission | Operation hours | Emission ranking |
|---|---|---|---|---|---|
| | (m$^3$/hr) | (OU/m$^3$) | (OU/s) | (h/yr) | |
| Raw material handling | 50 | 1610 | 22 | 480 | 5 |
| Raw material heating | 48 | 1250 | 16 | 960 | 6 |
| Process heating | 1.1 | 11290 | 3.4 | 2100 | 7 |
| Vacuum generation | 400 | 17180 | 1909 | 5760 | 2 |
| Fat trap | 1.6 | 90 | 0.04 | 6240 | 8 |
| Vent to atmosphere from process plant | 1920 | 350 | 190 | 48 | 4 |
| Packing hall | 12700 | 80 | 275 | 5760 | 3 |
| Waste facility | 3500 | 2690 | 2611 | 387 | 1 |

**Table 4.44: A typical odour measurement programme ex a food manufacturing site [Willey A.R.; Williams D. A., 2001 #34]**

A quantitative measurement of odour may ultimately be required by a contractor supplying an abatement plant or in order to demonstrate compliance with any legislative purposes. Indeed, quantified odour levels may form part of the process guarantee offered by the contractor. This factor is discussed further in Section 4.12.7.

### 4.12.6 Assessment of impact via air dispersion modelling

The air dispersion modelling stage of the project will enable the impact of the major measured emissions to be fully quantified. The impact, in this respect, is the resultant ground level odour concentration of the total emissions from the site at varying distances from the site boundary in relation to actual pertaining climatic conditions. This evaluation subsequently enables the degree of odour removal required from the individual sources or combinations of the individual sources to be fully determined.

- Dispersion models

There are a number of computer based air dispersion models available of varying complexity. The choice of which model to use is largely based on the acceptability by the authorities together with any National guidelines. The most widely applied dispersion model in UK is the Industrial Source Complex Short Term Model (ISCST) model as developed and validated by the U.S. Environmental Protection Agency. This model, part of a suite of models named Breeze, is a standard Gaussian plume model based on the Pasquill-Gifford dispersion parameters and climatic classes.
Other models used extensively include the Atmospheric Dispersion Modelling System (ADMS) developed by Cambridge Environmental Research Consultants in the UK and the Long Term Frequency Distribution Model (LTDM) used predominantly in the Netherlands.

As the ISCST model is the most widely applied model it will be used as an illustration in the remainder of this section. The model can be used in two distinct modes; namely a Screening mode and a Detailed mode. The Screening mode allows the computation of ground level concentrations from a number of sources using a matrix of worst case meteorological conditions. All ground level concentrations are calculated downwind of the discharges, i.e. it is assumed that the wind occurs in one direction. The Detailed mode allows the input of actual hourly meteorological climatic data and calculates the ground level concentrations in the actual directions of the predominant winds. The actual climatic data for the given location of the factory can be obtained from many weather stations and airports, although it requires pre-processing in the correct computer format for the model software. It is normal practice to use at least 3 years of successive historic climatic data to cover the majority of climatic conditions occurring over time at a given location.

- Dispersion model - Inputs and outputs

The ISCST model requires a number of **inputs** which are listed below:

- meteorological data for the area
- surrounding land terrain
- site plan with dimensions of factory buildings
- characterisation of emissions - temperature, stack diameter, velocity etc.
- odour emission rate.

The dimensions of buildings on the factory site are required in order to determine the effects of downwash caused by poor dispersion.

The model allows the user to input a grid of points known as receptors at locations within the surroundings of the factory. Typically the grid extends for distances of up to 1 to 5 km radially from the factory with intervals ranging between 10 and 100 metres. The model subsequently

calculates *ground level concentrations at each grid point* for each meteorological condition encountered. The output data is usually in the form of odour concentrations based on a 1 hour averaging period.
Whilst this averaging period is acceptable when studying the environmental fate of chemical components it is clearly not suitable for odours which can be detected over very much shorter time periods. It is now widely accepted that the ground level odour concentrations calculated from a 1 hour averaging period are multiplied by a factor of 10 to account for the short time period over which odours can be detected by the human nose.

The modelling exercise also addresses the variation in ground level impacts of continuous and intermittent sources. As a worst case scenario, the model could be used to assess ground level concentrations for all sources assuming that the intermittent sources could be operating simultaneously. Conversely, continuous and non-continuous sources can be modelled separately and the effect of each type of emission examined separately. Some workers have used the frequency of occurrence of ground level odour concentrations with allowances for the non-continuous sources made in terms of the proportion of operational time.

- Acceptance criteria

There are two acceptance criteria that can be incorporated into the model in order to judge the impact of the odour emissions, firstly the *magnitude of the calculated ground level concentration* and secondly the *frequency* at which the ground level concentration occurs.

The air dispersion model computes the ground level odour concentration in OU/m$^3$ at the receptor positions on the chosen grid. In order to assess whether the calculated ground level odour concentration would be detected by the populace or deemed a “nuisance limit” it is necessary to identify a criteria for acceptance. In practice, the odour threshold that constitutes a *nuisance value* can be as low as 2 OU/m$^3$, although a figure of 5 OU/m$^3$ represents a reasonable compromise for offensive smells and 10 OU/m$^3$ for less offensive odours.

The frequency of occurrence is essentially the number of hours per year when any given receptor location on the grid experiences an odour concentration greater than the adopted criteria. Thus if a calculated ground level concentration exceeds the criteria, of say 5 OU/m$^3$, for only a limited number of hours per year then it is unlikely to present a major problem, i.e. the particular ground level concentration only occurs under exceptional climatic conditions. A criteria can be set to allow ground level concentrations in excess of the criteria for a certain proportion of the time. Thus, e.g. in the Netherlands according to the Dutch guideline legislation, a 1 OU/m$^3$ concentration based on a 1 hourly average should not be exceeded for more than 2 % of the time. Converting the 1 hour averaging period to the much reduced time period in which odours can be detected would infer a concentration of 10 OU/m$^3$ not to be exceeded for more than 2 % of the time. This criteria of 10 OU/m$^3$ is in line with the practical threshold for less offensive odours detailed previously.

- Sensitivity analysis

The model can be also used to assess the reduction in ground level impact by effecting changes to selected exhausts or combining exhausts. For example, the minimisation measures identified previously can be evaluated in terms of the reduced impact. Furthermore, a sensitivity analysis can be conducted to examine the effects of combining key emissions or alternatively extensions to discharge stacks or increases in discharge velocity. If there is an on-site boiler then the effect of routing one or more exhausts either through the boiler or alternatively via the boiler stack can be assessed.

The sensitivity analysis can be utilised to derive what is an acceptable odour emission from the factory site in order to achieve a situation where complaints are unlikely. The criteria for acceptable ground level concentrations and percentile compliance developed previously form the basis for the evaluation. Effectively this type of analysis identifies the degree of odour removal required to achieve the desired goal. It can therefore be used to assess the reduced impact of selected emissions or combinations of emissions expected after treatment.

### 4.12.7 Selection of abatement technique

The final stage of the project involves the selection of the most appropriate and cost effective abatement technique or techniques in order to achieve the quantified reduction in ground level odour concentrations as determined by the air dispersion model. This section discusses a number of factors that need to be taken into consideration as part of the overall selection process. A selection flowsheet has been compiled that allows the reader to select the most appropriate abatement technique.

a) Develop a strategy

The initial stage of the selection of abatement techniques is to develop a strategy in order to treat the key emissions. This overall strategy needs to be inclusive of future factory developments and incorporate flexibility in order to treat additional identified odour sources at a later date if required. Due to logistical reasons this may not necessarily imply that one treatment plant will suffice, the most economic solution may be a number of plants, not necessarily of the same type.

b) Containment of odorous emissions

The identified odour emissions requiring treatment will need to be ducted and possibly combined to the point of treatment. The majority of odour abatement techniques are designed based on the volumetric airflow to be treated. Therefore, there can be considerable cost savings made in the capital cost of the abatement plant by minimising the volumetric flowrate requiring treatment. This can be achieved by effective containment of the separate emissions whilst still maintaining an adequate volumetric flowrate of air to ensure no ingress of odorous exhausts into the working environment.

The design basis of equipment used in odorous areas is to prevent the escape of all odorous products as far as possible and if some gaseous emission is inevitable to confine it in the minimum practical volume. The following are areas of particular concern:

i) access points to process plant
ii) open conveyors
iii) storage vessels
iv) transfer processes
v) filling processes
vi) discharge processes.

Where there is a fanned discharge supplying a certain volumetric flowrate for a given process operation then there is little or no scope in minimising the flowrate without affecting the process operation. However, for the general operations listed above there are best practice guidelines that will enable the optimum ventilation flowrate to be utilised(19). The following figures illustrate best practice guidelines.

c) Transport of the odorous exhausts to the treatment plant

Transport of the odorous emissions to the treatment plant is carefully considered in order to minimise any operational problems. In particular, the potential for particulate deposition and the potential for condensation of water and other airborne contaminants can result in severe fouling, requiring frequent cleaning and increasing any hygienic problems. The ventilation ductwork incorporates cleaning points and drain valves to enable cleaning in the event of accumulation of material in the ducting.

- Transport Velocity

If the presence of particulate in the exhaust is considered a problem then a transport velocity of not less than 10 m/s is chosen. Conversely, where particulate or condensables are not seen as a problem then the lowest transport velocity possible is chosen in order to minimise fanning costs. A transport velocity of 5 m/s is seen as a minimum.
If the presence of particulate is likely to cause operational problems, in spite of operation at high transport velocities, then a plenum chamber system is considered. The plenum chamber is essentially an enlarged duct where the particulate laden airstreams enter and the overall velocity is reduced to between 2.5 and 5.0 m/s. The chamber is purposely designed to enhance particulate deposition and is fitted with a hoppered side and a number of clean-out doors along its length. The outlet ducting from the plenum chamber is reduced in diameter in order to re-attain the system transport velocity.

- Ventilation ducting design

The extract ducting is designed with a common transport velocity throughout, such that the air velocity in all ducts and exhausts branches is the same. The entry of branches to the main duct is angled with a maximum angle of 45º, although an angle of 30º is preferred. At the entry point of the branch into the main duct, the main duct diameter gradually increases at an angle 15º. It is likely that in most cases the design of the ventilation ductwork will be conducted by a specialised third party contractor and there is little input required from the prospective purchaser. The above points are examined as part of the tender evaluation and the reader is referred to the literature for further information in respect of ventilation design.

- System design for discontinuous flows

One final area worthy of mention in this section is the case of discontinuous exhausts. This is the fairly common case where there are a number of exhausts being discharged to a central treatment plant of which some are continuous and others are discontinuous. This particular case brings out a number of issues, such as the potential for certain exhausts to contaminate other process emissions during failure mode and the operation of the fan under varying load conditions.

The control system required for this type of arrangement can become fairly complex and the overall design requires some thought. The fan can be specified as a single speed system, such that it always pulls the design flowrate. This system requires an additional inflow to the ventilation system to rectify the deficiency in the design flowrate once a process goes off-line. This additional inflow could be extracted from the operator workplace or that used to provide additional ventilation to the process building. Alternatively, a fan operating with a frequency inverter can be specified. The fan speed would then be controlled by a static pressure measurement at the inlet to the fan and downstream of the last branched entry. This system would result in a variable flowrate to the treatment plant in line with the particular processes that are operational. The choice of fixed speed or inverter system is largely dependent upon the type of abatement plant installed and whether there are any treatment efficiency drawbacks with a changing flowrate.

The potential for contamination of process equipment by other exhausts within the ventilation system is particularly evident under failure mode of that part of the ventilation system. A typical design for discontinuous emission points would encompass a number of manual and automatic valves in order to control the airflow from the separate emission points. In the case where the treatment plant is off-line or in failure mode, then an automatic valve would open to enable the discharge to exhaust to atmosphere. A further automatic valve is required to seal the exhaust ducting when the particular process goes off-line. This effectively means two automatic valves per emission point together with a manual valve required for system balancing. The overall configuration can become rather complex and requires careful design to iron out any potential operational problems.

d) Identify cost effective solutions

The selection starts by considering the use of existing installations on the factory site. If there is a site boiler in operation with a high discharge stack, then re-routing the odorous emissions to the boiler may often be the most effective solution. The emissions can either be routed through the boiler as part of the boiler combustion air or alternatively routed through the boiler exhaust stack to effect dispersion in the atmosphere. The air dispersion model is used to ascertain whether direct discharge will reduce the ground level concentrations to the desired level.

The choice of abatement equipment is conducted by considering the various treatment options in a pecking order based on expected capital and operating costs. In this respect **scrubbing and biofiltration is initially considered, followed by adsorption and thermal routes**. The choice of abatement plant is made more difficult by the nature of the problem. In the vast majority of cases the exhaust gas to be treated, especially from Food related processes, will contain a complex cocktail of airborne components as opposed to one or two readily definable components. The design basis of the abatement plant is therefore, more often than not, designed on correlated parameters based on experience within other similar installations. The uncertainty caused by the presence of a considerable number of airborne components may necessitate the need for pilot plant trials.

e) Characterisation of exhaust gas

In order to assess the most appropriate abatement technique a reasonable characterisation of the exhaust gas(es) to be treated is required. As part of his design a third party contractor will want to know the values of key parameters associated with the exhaust gas to be treated.

The followings are the key parameters for the selection procedure:

| | |
|---|---|
| - airflow | $m^3$/hr |
| - temperature | °C |
| - relative humidity | % |
| - typical range of components present | |

Additional parameters that may be informative and likely requested by a third party contractor include:

| | |
|---|---|
| - particulate level | mg/$m^3$ |
| - organic level | mg/$m^3$ |
| - odour level | mg/$m^3$ |

f) Process guarantees

The purchase of an abatement plant from a third party contractor will normally encompass a number of guarantees. More often than not there will be guarantee statements relating to mechanical and electrical reliability for a period of one year. As part of the selection and procurement procedure, the supplier will also require information as to what the *expected odour removal efficiency* his process is expected to achieve is. The form of the process guarantee is an important part of the contract. Guarantee statements relating to odour removal performance can take a number of forms. In the absence of any olfactometric data then the guarantee could simply state no perceivable odour outside the process boundary or outside the factory site.

#### 4.12.7.1 Factors affecting choice of technique

The reader is referred to Section 4.12.8, the Control and treatment of odorous emissions where the principles, design and advantages/disadvantages of the most widely used abatement techniques have been documented. Section 4.12.8 has been written in order to allow the reader to judge whether or not a particular abatement technique is suitable for a given application.

The literature offers a selection of the most suitable technique by assessing the flowrate and concentration of material present in the emission and a nomogram type approach subsequently points to the most appropriate technique. Clearly, there are many other factors which need to be considered in the selection process.

The **flowrate** to be treated is a major parameter in the selection process and very often the abatement techniques will be listed against the optimum flowrate range for application. In this respect incineration techniques are often judged to be suitable for low flowrates whilst scrubbing and biofiltration are selected for high flowrates. Adsorption is often judged suitable for both high and low flowrates.
Clearly there are other factors which need to be taken into account such as gas temperature/humidity, particulate concentration, the components present and the actual degree of treatment required.

#### 4.12.7.2 Flowsheet for selection procedure

A comprehensive flowsheet that attempts to address the majority of the key selection parameters is illustrated in Figure 4.33. It should be noted that the flowsheet does not represent a foolproof mechanism for deriving the optimum technique and on this basis it is treated as “guidance”.

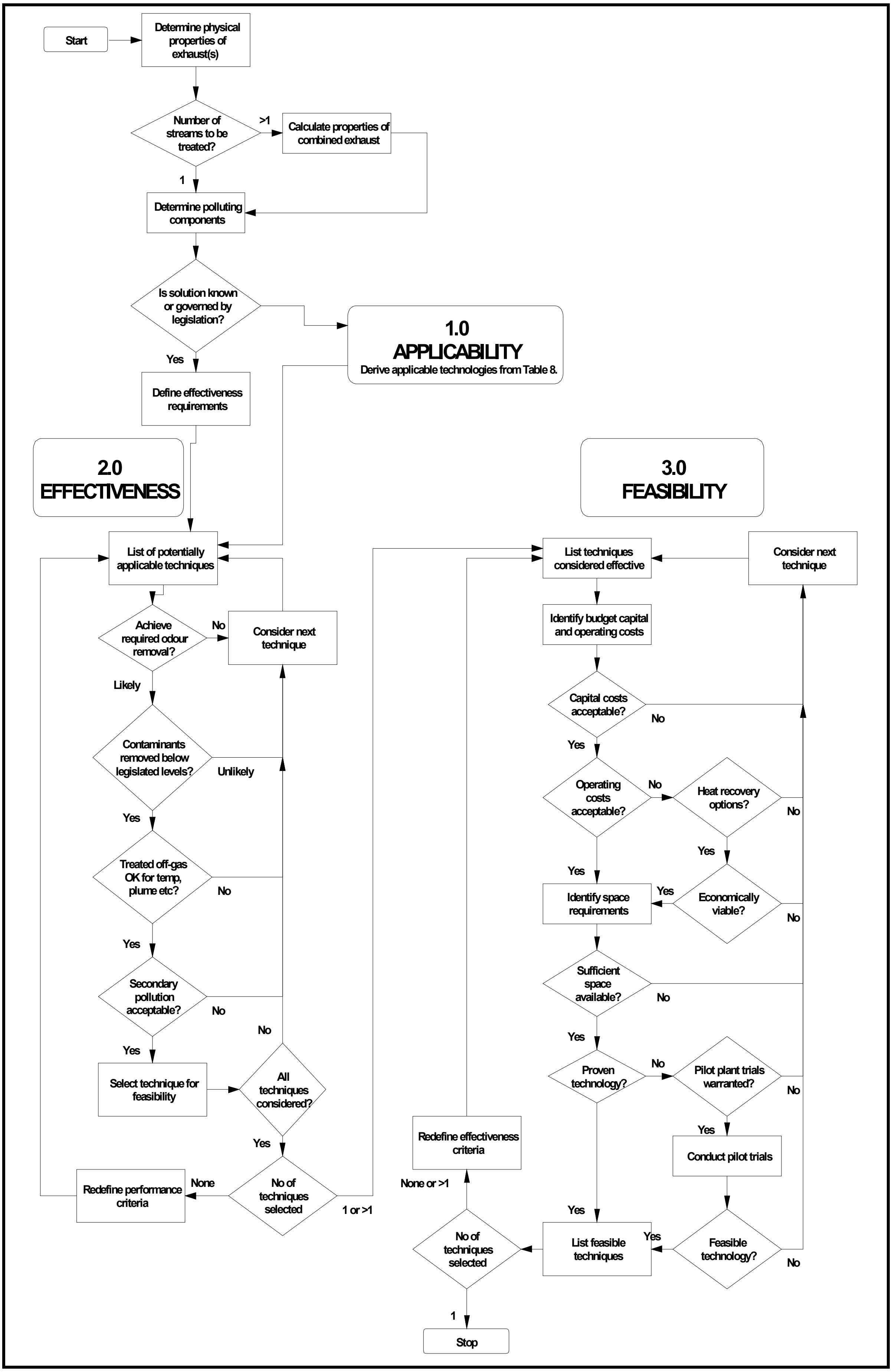

Figure 4.33: Flow sheet for the selection of odour abatement equipment
[Willey A.R.; Williams D. A., 2001 #34]

The development of the flowsheet has been based on three sequential selection stages:

1) applicability
2) effectiveness
3) feasibility.

- Applicability

The first selection stage reviews the properties of the odorous emission in terms of flowrate, temperature, humidity, particulate and contaminant concentrations. This analysis is shown in Table 4.45, where the above-mentioned parameters are shown in a matrix against the generic types of abatement equipment available. Each property of the odorous emission has been segregated into two or three regions, e.g. flowrate above and below 10000 $m^3$/hr. Each cell in the matrix has been assigned a value between 0 and 3 with a value of 3 representing an optimum operating condition.

For each of the abatement techniques the relevant region of each of the odorous emission properties is summed. This allows a simple ranking system to be develop with the most suitable abatement technique, at this stage of the selection process, to be derived by gaining the highest score. Where the properties of the odorous emission result in a zero score then that particular abatement technique is removed from the selection procedure.

This applicability selection procedure typically identifies 3 to 5 suitable abatement techniques that can be carried forward to the next selection procedure.

- Effectiveness

The effectiveness selection procedure is essentially a routine which further selects the optimum abatement technique in terms of assessing whether the required performance can be achieved. This selection procedure would ideally be supplemented by some form of professional guidance rather than a reliance on a general indication or manufacturer's claims.

The flow sheet incorporates a mechanism whereby the effectiveness criteria can be redefined should the procedure identify no suitable techniques. The reader may be wary of adopting a significant change in the performance criteria in order to select a suitable abatement technique.

- Feasibility

The feasibility procedure further assesses the screened abatement techniques from the applicability and effectiveness selection procedures. The parameters used for this screening exercise are capital and operating costs, space requirements and whether the abatement technique applied to the given application represents proven practice, i.e. has it been installed on a similar process previously?

The feasibility selection procedure also incorporates a mechanism whereby the feasibility criteria can be changed should the procedure identify no suitable techniques. This will likely result in a chosen technique with higher capital and/or operating costs.

It should be stressed that the proposed selection flow sheet is used for guidance only and professional advice can be sought to confirm or dispel the derived abatement techniques.

| Treatment | Flowrate (1000 m$^3$/hr) | | Temp (°C) | | Humidity (%RH) | | Particulate (mg/m$^3$) | | | Contaminant conc (mg/m$^3$) | | Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | < 10 | >10 | <50 | >50 | <75 | >75 | 0 | <20 | >20 | <500 | >500 | |
| Physical | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 0 | |
| Absorption-water | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 0 | |
| Absorption - chemical | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | |
| Adsorption | 3 | 1 | 3 | 0 | 2 | 0 | 3 | 0 | 0 | 2 | 1 | |
| Biological | 3 | 2 | 3 | 0 | 2 | 2 | 3 | 1 | 0 | 3 | 0 | |
| Thermal | 3 | 1 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 3 | 3 | |
| Catalytic | 3 | 2 | 1 | 3 | 2 | 1 | 3 | 0 | 0 | 3 | 3 | |

| Score rating | Description |
|---|---|
| 0 | This treatment is not suitable or unlikely to be effective |
| 1 | Worthwhile considering although unlikely to be the best choice |
| 2 | The abatement technique is well suited for this condition |
| 3 | Represents the best operating condition for the given treatment system |

**Table 4.45: Abatement techniques – selection guidelines**

Where a value of zero is indicated, that particular abatement technique is not considered as part of the selection procedure.

### 4.12.8 Introduction to odour treatment techniques

There are a large number of potential options for the treatment of odorous exhaust emissions which can be roughly grouped into absorption, which is inclusive of water and chemical scrubbing; adsorption onto activated carbon or other porous substrate; incineration, including both thermal and catalytic oxidation; and biological oxidation. The variation in treatment efficiency and capital and operating costs between the various options is potentially very high. Furthermore, legislation governing odorous emissions is impact related as opposed to source controlled. For example, the control of $SO_x$ emissions is by measurement prior to discharge, whereas the control of odour is based on the impact on the surrounding environment. Thus it can be seen that there are additional odour control techniques outside the scope of the aforementioned techniques which can minimise the environmental impact of an odorous emission. These techniques fall into a physical dispersion category involving an improvement of the dispersion potential of the emission, e.g. extending the height of the discharge stack or increasing discharge velocity.

The odour abatement techniques that are commercially available are detailed in Sections 4.12.9 - 4.12.15, with an outline given of the design basis, range of applicability, typical performance and advantages and disadvantages. The general format of each section is devoted to a particular abatement technique, with the following subsections of:

i) Principle of operation - details how the technique works, together with any associated theory
ii) Selection of equipment - outlines the various configurations of equipment available and their relevant applications
iii) Design considerations - details the salient design basis of the equipment and identifies what issues need to be considered
iv) Advantages and disadvantages identifies the general applicability of the technique and lists pros and cons

The text is written in order to aid the reader in the selection of the most suitable treatment option for a given application and to allow the reader to make an assessment of manufacturers tenders.

### 4.12.9 Physical treatment

The need for treatment of an odorous emission is governed by the impact it has on the surrounding environment following dispersion in the ambient atmosphere. Ground level odour concentrations, if sufficient in magnitude, will attract complaints from neighbours or fail to satisfy any prevailing legislative controls. Thus any improvements to the dispersion of the emission in the ambient atmosphere will have an ensuing reduction in the magnitude of the ground level odour concentrations. Thus it can be envisaged that improvements to the dispersion of the odorous emission could result in a tolerable or zero level of complaints and hence a solution to the problem. The reduced ground level concentrations would be achieved without any reduction in the magnitude of the odour emission but by merely enhancing its dispersion in the atmosphere. This type of solution can be termed physical treatment and would encompass, *inter alia*, extension of a discharge stack and increasing the discharge velocity.

It should be noted that improvements to the dispersion of a discharge does not effect any removal at source of the magnitude of the odour emission. Thus the effectiveness of this approach will be heavily dependent on such factors as the magnitude of the odour emission, the ground level odour intensity, the location of potential complainants, the nearby land terrain, etc. However, an assessment of the potential effects of improved dispersion is fully warranted as an initial stage based on the potential savings of not having to install and operate an abatement plant.

The use of masking agents represents a further treatment option which could fall into the category of physical treatment. The traditional form of this treatment has been to add a perfumed component into the final discharge stack in an attempt to mask or conceal the more unpleasant odorous nature of the process exhaust. A section on masking agents has also been incorporated.

#### 4.12.9.1 Improving dispersion of odorous emissions

The dispersion of an exhaust emission in the ambient atmosphere and hence its resultant ground level odour concentration will depend upon a whole variety of factors, inclusive of:

- the prevailing climatic conditions
- the height of the discharge
- positioning of nearby buildings or structures
- stack temperature (thermal buoyancy)
- stack discharge velocity
- configuration of the discharge stack.

With the exception of the prevailing climatic conditions, all of the above-mentioned factors can be altered with the desired intention to improve the dispersion potential of the discharge. The influence of the above factors can be easily examined in a computer based dispersion model which incorporates these factors in the computation of ground level odour concentrations. The model allows the sensitivity of increases to the discharge velocity or stack height to be quantitatively judged in relation to ground level concentrations.

### 4.12.9.2 Stack height / effect of nearby buildings

The air dispersion model will allow an assessment of the potential interference associated with buildings or structures within the vicinity of the stack discharge. The effect of these structures is often to cause poor dispersion and in some cases the phenomenon known as plume grounding, where the exhaust is pulled downwards under the influence of the nearby structures. The air dispersion model will allow the potential influence of the nearby building/structure to be assessed. This is typically done using a correlation taking into account the height, width and length of the building. For example, in the Breeze computer model as validated by the Environmental Protection Agency in the United States a correlation is used that incorporates the height and maximum projected width of nearby buildings. The maximum projected width (L) is defined as the diagonal distance between extreme corners of the building at the maximum building elevation. The procedure is then to draw a radius of 5 x L from the building/structure. If the stack discharge falls within 5 x L of the nearby building/structure then the presence of the building will likely have a negative impact on the dispersion from the nearby stack. Similarly, if the stack discharge is outside of the 5 x L radius then the building/structure will have no effect on the dispersion.

The procedure subsequently allows the user to determine the required stack height such that the stack is at a sufficient elevation not to be influenced by the building/structure. The procedure involves comparing the diagonal distance (L) with the building/structure height and the lesser of these two measurements is used in the following equation to determine the stack height required so as not to be influenced by the building/structure.

$$h_e = h_b + 1.5 \times L$$

Where: $h_e$ = required stack height
$h_b$ = height of the building/structure

This procedure can be used as a simple check to ascertain whether an existing discharge stack would be influenced by a nearby building/structure. The analysis would indicate whether or not extensions to the stack height would be a viable option. In this respect reference to any planning restrictions in terms of maximum elevations would need to be considered in addition to the need for increase supports etc. [Willey A.R.; Williams D. A., 2001 #34]

The possibility of ducting an exhaust emission or collection of emissions to a site boiler stack is always considered. The viability of this option would obviously depend upon the distances involved, any increase to the boiler stack backpressure, etc.

### 4.12.9.3 Stack velocity / configuration

The magnitude of the discharge velocity applied to a final emission to atmosphere can have a significant effect on the resultant ground level impact of an odorous emission. An increased discharge velocity will result in an increased momentum or buoyancy of the emission. This implies that the discharge will attain an increased elevation thereby allowing more potential for dispersion in the ambient atmosphere and hence lower ground level concentrations.

A typical design range for final discharge velocities from stacks is between 10 and 20 m/s with an industry standard of 15 m/s. Design velocities of less than 10 m/s are likely to suffer from poor dispersion, whilst velocities above 20 m/s can prove expensive in terms of fanning power and operating costs. Furthermore, discharge velocities greater than 20 m/s can result in significant noise as the discharge generates a "whistling" phenomena.

There may also be restrictions on the design velocity that can be applied to certain installations. In guidance documents it is common for the discharge from a wet arrestment plant such as a water scrubber to be limited to no greater than 9 m/s. This restriction is designed to prevent the carryover of a significant quantity of water droplets resulting in a fountain effect. Typically the restriction would apply within the nearby vicinity of the wet arrestment plant although provision can be incorporated to increase the discharge velocity above 9 m/s a number of pipe diameters away from the wet arrestment plant. This would be achieved by incorporating a venturi or evase to the final discharge configuration.

A final and very important point regarding the stack velocity is to ensure that there are no restrictions in the flowpath. This feature ensures that the momentum energy of the plume is not compromised during discharge. A common feature of many discharge stacks is a "Chinese Hat" arrangement designed to prevent rainfall entering the process via the discharge stack. The discharging process air is thus forced outwards through $90^0$ rather than upwards resulting in a considerable loss of available momentum energy. Thus the use of rainfall protectors are avoided and provision made to offset the discharge to enable satisfactory rainfall collection.

#### 4.12.9.4 Methodology to determine dispersion

This section has so far made reference to the use of computer based air dispersion models in order to identify optimum discharge conditions to minimise the ground level concentrations of odour. There are also calculation procedures available whereby optimum stack heights can be determined without using an expensive air dispersion model. These procedures can be used as a guideline to ascertain the approximate increase in stack height required to improve dispersion to a satisfactory level. This procedure can therefore be used as an initial check to see whether increases to either the stack height or stack velocity are possible. The practicality of carrying out such changes, which may incur the upgrading of fans and significant structural upgrading, can also be assessed.

One such calculation procedure, developed in the UK, is detailed in Annex 2.2. The use of this technique is seen as an ideal screening exercise to identify the approximate increase to the stack height that will be required in order to abate a problem. Whilst the technique does not require the use of a computer based air dispersion model it does require a measurement of the odour concentration of the emission in question. Once the required stack height has been calculated using this methodology an indication of the practicalities of a stack extension can be investigated.

#### 4.12.9.5 Masking agents

The use of masking agents has generated considerable debate for many years and in general masking agents will only be considered in limited detail in a review of this kind. Indeed, in a number of countries the use of masking agents in the conventional sense of the word is outlawed by legislation.

The terminology "masking agents" enables the reader to directly understand what this section of the report is about, although it does not accurately infer the range of potential applications within industry. It certainly does not cover the extent of suppliers' claims concerning their products. There are essentially three areas which have been grouped as masking agents and these are characterised as:

- simple perfuming agents
- counteracting agents
- agents offering a chemical reaction.

#### 4.12.9.6 Perfuming agents

In its simplest form this is effectively a masking agent offering no reduction in the discharged odour concentration but merely attempting to disguise the offensive odour with a "pleasant" odour present at a higher odour threshold than the odour that is being disguised. A typical installation would comprise an aspirator that simply injects a liquid based perfume into the discharged airstream. Alternatively, the motive force of the airstream can be used to induce the liquid perfume into the airstream by a venturi effect.

The use of this type of masking agent can represent an effective control strategy in the short term although its use in the longer term is rather suspect. Indeed, the use of perfuming masking agents is often for a fill-in time gap between the onset of an odour problem and the installation of more effective odour control equipment. The major problem arises in that the perfume may be pleasant to some members of the population although unpleasant to others. Even a pleasant odour can become annoying when it is evident and detectable for 24 hours a day. As such the use of perfuming agents may be not effective.

#### 4.12.9.7 Counteracting agents

As the term implies, counteracting agents are added to the airstream and result in a reduced response to the odour by the human nose by reducing the perceived intensity. Thus effectively, the counteracting agent desensitises the human nose and renders the discharged odour undetectable by the olfactory sensors in the nose. It is well known that some components, such as acetaldehyde, can result in a desensitising of the nose. Needless to say this type of system, which could inhibit the detection of toxic or harmful substances, cannot be recommended.

#### 4.12.9.8 Chemical reaction systems

There are a number of products on the market claiming that odorous emissions can be "neutralised" by the addition of certain components into the airstream. The exact definition of neutralisation in this context is misleading and generally refers to a chemical reaction in which the odorous molecule is rendered non-odorous by chemical reaction with the added ingredient.

The operational process for incorporating neutralising components into an airstream is very similar to that used for masking agents, i.e. by aspiration, venturi, etc. A considerable number of the products on the market refer to the use of "essential oils" derived from plants, trees, grass, wood, flowers, seeds, etc(24). There are a number of mechanisms postulated as to what occurs during the "neutralisation" process, although the exact mechanism or mechanisms are not fully understood. Particular mechanisms suggested include Van der Waals forces where the molecules weakly bond onto the odorous components, Zwaardemaker pairs where an odour is neutralised, or chemical reaction.

### 4.12.10 Absorption

Absorbers or wet scrubbers are used extensively within odour control applications. The terminology is somewhat confusing with the words absorber and scrubber being used simultaneously. By definition absorbers are used for trace gas removal whilst scrubbers are used for particulate abatement. Thus the removal of odour requires the installation of an absorber, so the terminology of absorption will be used in this section.

The absorption process relies on the preferential solubility of the odorous components present in the exhaust stream within the scrubbing medium. There are a number of different types of absorber design and many variations offered by suppliers all claiming enhanced gas-liquid contacting and hence potential improvements to performance in terms of odour removal efficiency. The packed column is the most widely applied absorber design for odour removal offering the advantages of maximised surface area per unit volume and relatively low pressure drop.

There are standard design equations and correlations that can be used to size absorbers for this specific duty. These procedures allow the absorber to be designed around the chemistry of the system and allow the required degree of dissolution, and also the physical structure of the system, the operating pressure drop and the gas velocity to be catered for.

The design equations for determining the physical size of the absorber are based on the relevant gas-liquid equilibria. Whilst this type of information is generally available for binary systems, such as ammonia in water for example, it is not generally available for odorous emissions which in general tend to contain a vast range of components. Thus the design basis becomes one of experience based on information obtained previously within similar industries, or necessitates the need for pilot plant trials. This section outlines the types of absorbers available and provides general design guidelines in relation to their effective sizing for odour control applications. The theory applied to packed beds is illustrated as a reference, although in the vast majority of odour control cases it should be noted that the theory does not provide an effective design basis.

#### 4.12.10.1 Principle of operation

Absorption is the term applied to a process which involves mass transfer between a soluble gas and a liquid solvent in a gas-liquid contacting device. The rate at which an odorous substance is removed from an air stream depends upon its degree of saturation at the solvent surface within the absorber, which in turn depends upon its solubility and its rate of removal from the circulating solvent by reaction and bleed-off. This rate mechanism determines the efficiency of removal for a particular size of absorption plant and a particular air flowrate. Thus the efficiency of removal will be a function of the reaction time, the degree of saturation at the surface of the liquor and the reactivity of the gas components within the absorbing solvent.

Providing the airborne components to be removed are reasonably soluble in water then an absorber can be designed to achieve a desired removal efficiency. The problem arises in the need to maintain a low enough concentration within the absorbing liquor (at the surface) to maintain the driving force for dissolution. This often results in excessive volumes of water being needed to achieve a reasonable efficiency. Thus, it is generally impractical to remove odorants effectively using water alone and other absorbents are typically employed. However, water only systems can be considered as a first stage before other absorbers but much of their effectiveness will be due to mechanisms other than absorption. For example, water absorption of a non-saturated airstream will result in a cooling of the airstream to saturation via the process of adiabatic cooling. This cooling effect, essentially equivalent to the difference between the dry and wet bulb temperatures of the inlet airstream, often incurs a condensation mechanism whereby components are removed from the airstream as they cool to a temperature below their boiling point.

#### 4.12.10.2 Absorbing reagents

The efficiency of absorption can be increased if the absorbing liquid contains a reagent which reacts with the odorants present in the airstream. This effectively reduces the concentration of the airborne components at the liquid surface and thereby maintains the driving force for absorption without the need for vast amounts of absorbing liquid to be required. There are a number of specific reagents that can be employed within absorption systems to remove odorous components from an airstream. These reagents are generally oxidising solutions. The most widely applied include: Sodium Hypochlorite, Hydrogen peroxide, Ozone and Potassium permanganate. The use of acids and alkalis as absorbing mediums is also fairly widespread and often the acid/alkali system is employed in conjunction with an oxidising absorbent. Indeed due to the considerable number of components that can be present in an odorous emission multistage absorbers are often used. Thus, an absorbing system could comprise an initial water scrubber followed by an acid or alkali stage and finally an oxidising stage.

Sodium hypochlorite is perhaps the most widely applied oxidising agent, primarily due to its high reactivity. It is generally used at an alkaline pH in order to prevent dissociation into free chlorine. There is a tendency for the hypochlorite to react with certain components via a chlorination reaction rather than an oxidation. This is a particular concern where an airstream contains aromatic material which could generate chlorinated aromatic compounds in the treated gas stream. Recent advances in the use of hypochlorite under catalysed conditions are discussed in Section 4.12.10.8.1.

Hydrogen peroxide is generally less effective than hypochlorite due to its lower oxidising power. However, it does have the advantage that its reaction product is water and can be used for applications where aromatics are present for reasons mentioned earlier. Hydrogen peroxide is usually employed under acidified conditions, primarily to control its rate of decomposition.

Ozone is also a powerful oxidising agent although its oxidative power is more pronounced in the liquid phase as opposed to the gas phase. A recent application that incorporates ultra violet light to enhance the oxidative performance of ozone is discussed further in Section 4.12.10.8.2.

A number of surfactant based absorbing solutions have been used in recent years, although there is limited information available on their performance. In particular a non-ionic based surfactant system (reduced foaming), such as the material used for dishwasher rinse-aids, has been employed successfully.

The use of oxidising agents is not totally restricted to those in liquid form. There are installations, particularly within Europe, that operate with oxidising agents in solid or particulate form. One such example is the use of a calcium oxide scrubber, where particulate calcium oxide is contacted with the odorous gas stream producing a solid residue of calcium carbonate. However, the feedback from installations of this type has suggested limited odour removal performance and severe operational problems in terms of solids handling. As such, it is strongly recommended that only absorbing agents in liquid form are considered for odour removal applications.

As a final note on the use of oxidising agents, installed systems can suffer from high operating costs in terms of the high use of the oxidising agent. This factor is usually considered at the design stage and alternatives considered if necessary.

#### 4.12.10.3 Selection of absorption equipment

The aim in any absorber is to produce the largest possible liquid surface and good counter-current flow of gas and liquid. The need to have effective liquid and air distribution are fundamental requirements in all absorber designs. There are, broadly speaking, three types of absorber: packed, plate, and spray.

#### 4.12.10.4 Packed bed absorber

The packed bed absorber system layout is shown in Figure 4.34. The airstream to be treated is directed in counter-current fashion to the recirculated liquid stream. The packed bed area comprises a large number of packing pieces, usually of plastic construction, which allow a considerable surface area for gas-liquid contacting. The liquid system can comprise anything from a simple recirculation pump assembly to a sophisticated chemical dosing station together with pH control dosing/control facilities. The liquid distribution is most effectively achieved by a series of nozzles situated symmetrically over the surface area of the unit. The use of one central nozzle, as used in installations in previous years, cannot be recommended due to the resultant poor liquid distribution. Depending upon the vertical length of the packing within the absorber there may be a need to incorporate liquid redistribution systems.

The treated airstream is discharged through a mist eliminator in order to remove any entrained droplets prior to discharge.

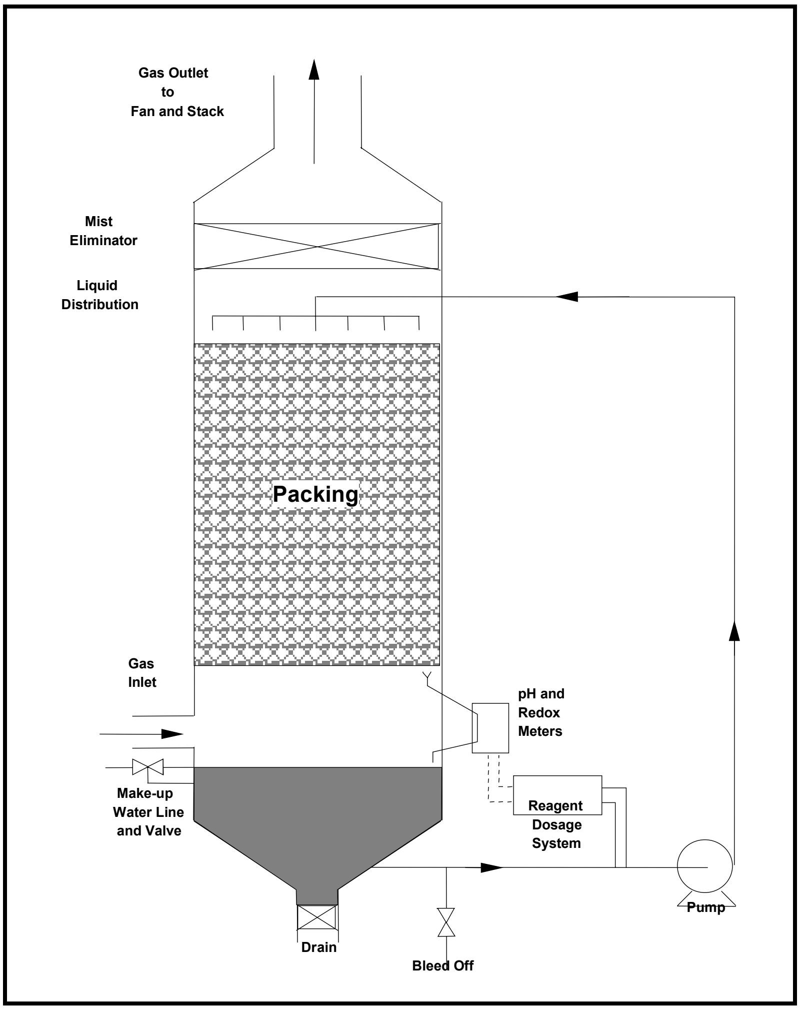

**Figure 4.34: Packed bed reactor**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.10.5 Plate absorber

The plate tower absorber system is shown in Figure 4.35. Plate type absorbers have had widespread application in the chemicals and petrochemicals industries, although only limited application within odour control installations. Plate scrubbers consist of a vertical tower with several horizontal perforated trays or sieve plates stacked in it. Baffles are situated a short distance above the apertures in the plates. Scrubbing liquid enters the top of the tower and successively flows along each of the trays. The airstream to be treated enters the bottom of the tower and flows upwards, passing through perforations in the plates. The velocity of the airstream is sufficient to prevent liquid seeping through the perforations. Essentially, the design incorporates a number of plates within the absorber upon which liquid is held up. The air stream to be treated is directed through the falling curtains of liquid overflowing the trays. There are many variations in the plate design and positioning of the liquid nozzles offered by suppliers.

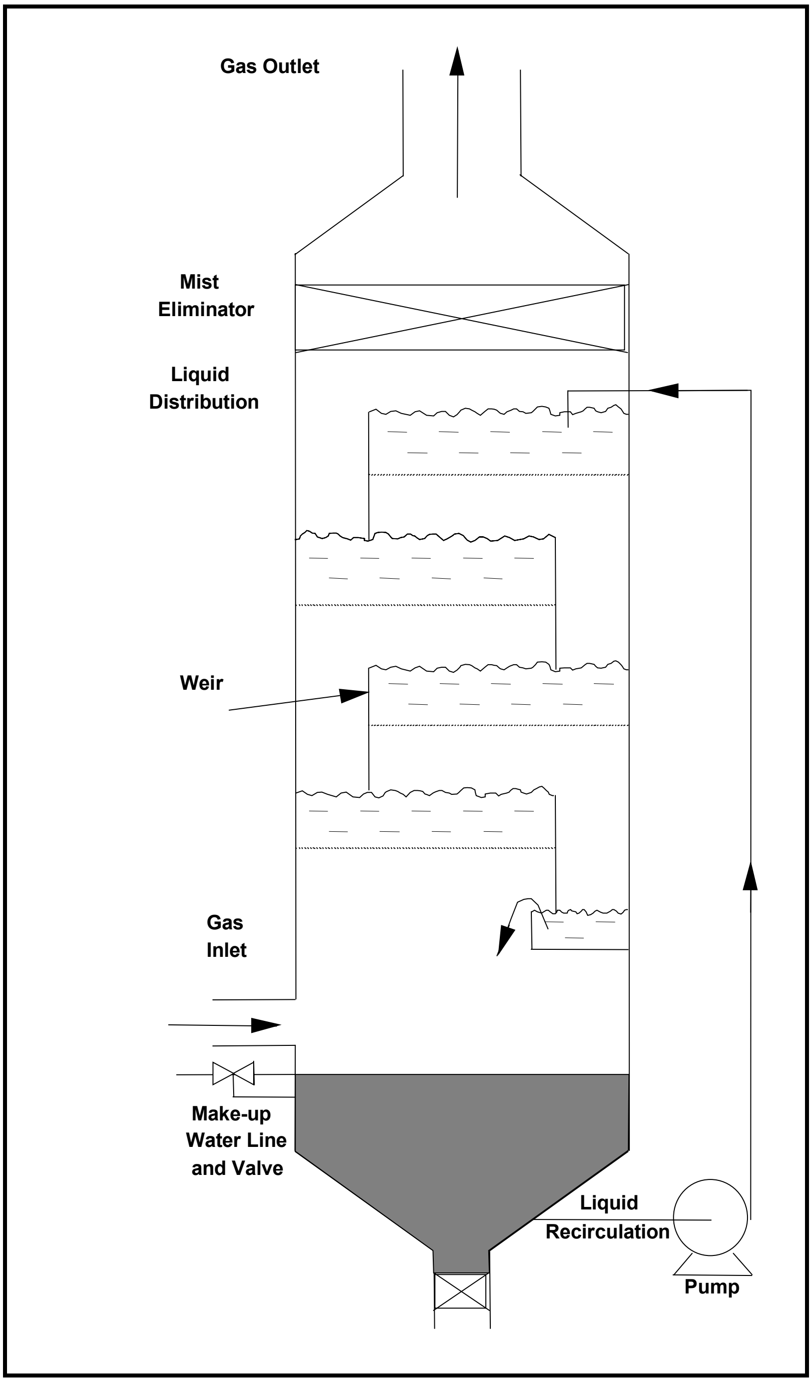

**Figure 4.35: Plate absorber**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.10.6 Spray chamber

A typical spray tower configuration is shown in Figure 4.36. As the name suggests a spray system simply comprises a liquid spray which contacts an upward rising airstream within a vessel. The vessel contains no packing or plates or any device used to enhance gas-liquid contacting. This type of process is not generally suitable for odour control due to the limitations in mass transfer. However, where the airstream to be treated contains a significant level of particulate or condensable material then a simple spray tower may provide an adequate conditioning unit prior to a system with increased gas-liquid contacting, such as a plate or packed bed absorber.

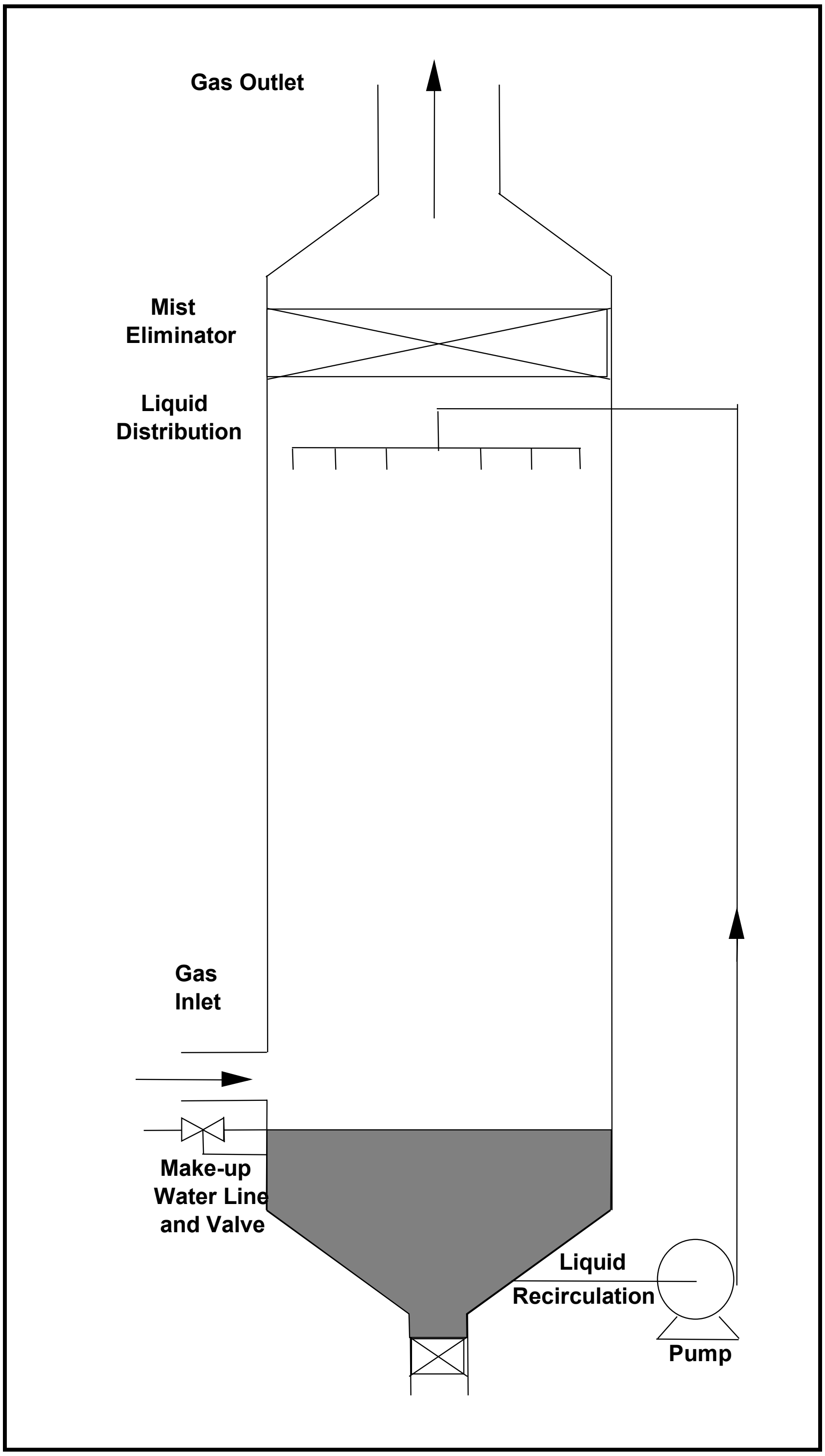

**Figure 4.36: Spray chamber**
**[Willey A.R.; Williams D. A., 2001 #34]**

Where the presence of particulate or condensables is a potential problem and odour removal is required in the same piece of equipment, then the degree of gas-liquid contacting hardware installed within the spray chamber is approached with caution. This can give rise to considerable operational problems and downtime whilst the absorber is cleaned and put back into action. In this respect a wave plate absorber may be a suitable installation. The airstream entering the unit is forced through a series of banks of wave plates, with a liquid spray positioned in front of each wave plate assembly. The wave plate assembly can be designed to be removed in situ, washed and replaced into the unit without having to switch off the plant.

### 4.12.10.7 Design considerations

The most widely used type of absorbing equipment is a packed bed system and this section will review the design guidelines associated with packed beds only. The proper design according to standard chemical engineering principles, requires data on concentration, solubility and mass transfer for the components to be removed from the gas stream. However, as detailed previously, most odorous discharges are complex mixtures for which it is difficult to ascertain the chemical species present and even more difficult to determine their concentrations. The nature and kinetics of the oxidation reactions are not known as a rule and these would be very difficult to determine, even for individual compounds let alone complex mixtures. Thus the design of odour absorption equipment must be empirical rather than scientific.

Thus the volume of packing is chosen according to what volume has been previously found to give reasonably complete absorption of those compounds that can be absorbed. If there is only limited operational experience with the odorous discharge in question then pilot plant trials would be required in order to define the optimal design.

Pilot plant trials or previous experience determine the height of the packing required to achieve a given performance. The required packing height is taken as the height of a transfer unit multiplied by the number of transfer units required. The height of a transfer unit is a measure of the efficiency of diffusion and of the interfacial area of the packing, whilst the number of transfer units is a measure of the performance required. The derivation of the number of transfer units and height of a transfer unit requires a knowledge of factors such as the molar gas and liquid volumes, diffusivity of the odorant in the liquid, physical properties of the liquid and airstream and the characteristics of the packing material.

This information subsequently allows the scrubber to be designed and scaled up in the case of pilot plant investigations. The packing is chosen so as to allow the required number of transfer units for the required efficiency. The packing size and type, the linear gas velocity (which determines the absorber diameter), the linear liquid velocity, the gas pressure drop and the absorber efficiency per unit height (which determines the packed height) are all interrelated. The design procedure therefore looks towards optimising the design in terms of capital and operating costs, taking into consideration the required volumetric throughput, absorption efficiency and constraints such as possible clogging of the packing and the maximum allowable pressure drop. These operating parameters are generally evaluated from design correlations. Typical ranges of the parameters detailed above are shown in Table 4.47. These guidelines can be used in the assessment of the suitability of an absorption plant for odour control purposes.

| Design Parameter | Units | Value |
|---|---|---|
| Gas velocity | m/s | 0.5 - 2.0 |
| Gas flowrate | kg/m$^2$/hr | 2500 - 5000 |
| Liquid flowrate | kg/m$^2$/hr | 25000 - 50000 |
| Gas residence time | sec | 1 - 3 |
| Pressure drop | mm/metre | 20 - 50 |
| Liquid bleed rate | % of recycle flow | 0 -10 |
| Flooding | % of flooding | 40 - 60 |

**Table 4.46: Typical absorber design guidelines**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.10.8 Recent advances in absorption

As detailed previously, there are numerous variations in absorber design. The vast majority of these variations are unlikely to result in significant improvements to the performance or capital and operating costs. There are two recent absorber developments which are worthy of mention in this section. These two developments relate to the enhancement of the performance of the oxidant used in chemical scrubbers and are described below:

#### 4.12.10.8.1 ICI Katalco process

The use of hypochlorite as an effective oxidising agent and its use in chemical absorbers is well documented. Hypochlorite has found particular use in the animal rendering and associated industries, i.e. with emissions generally containing significant levels of sulphur and nitrogen based odorous compounds. As detailed in Section 3.4.2.1, the use of hypochlorite in absorbers is hampered by the potential formation of chlorinated aromatics and the high consumption requirements that are often found. Indeed the chlorination potential is greater at higher hypochlorite concentrations, thereby necessitating a design incorporating lower hypochlorite concentrations in the absorbing liquor than is actually required for optimal absorption.

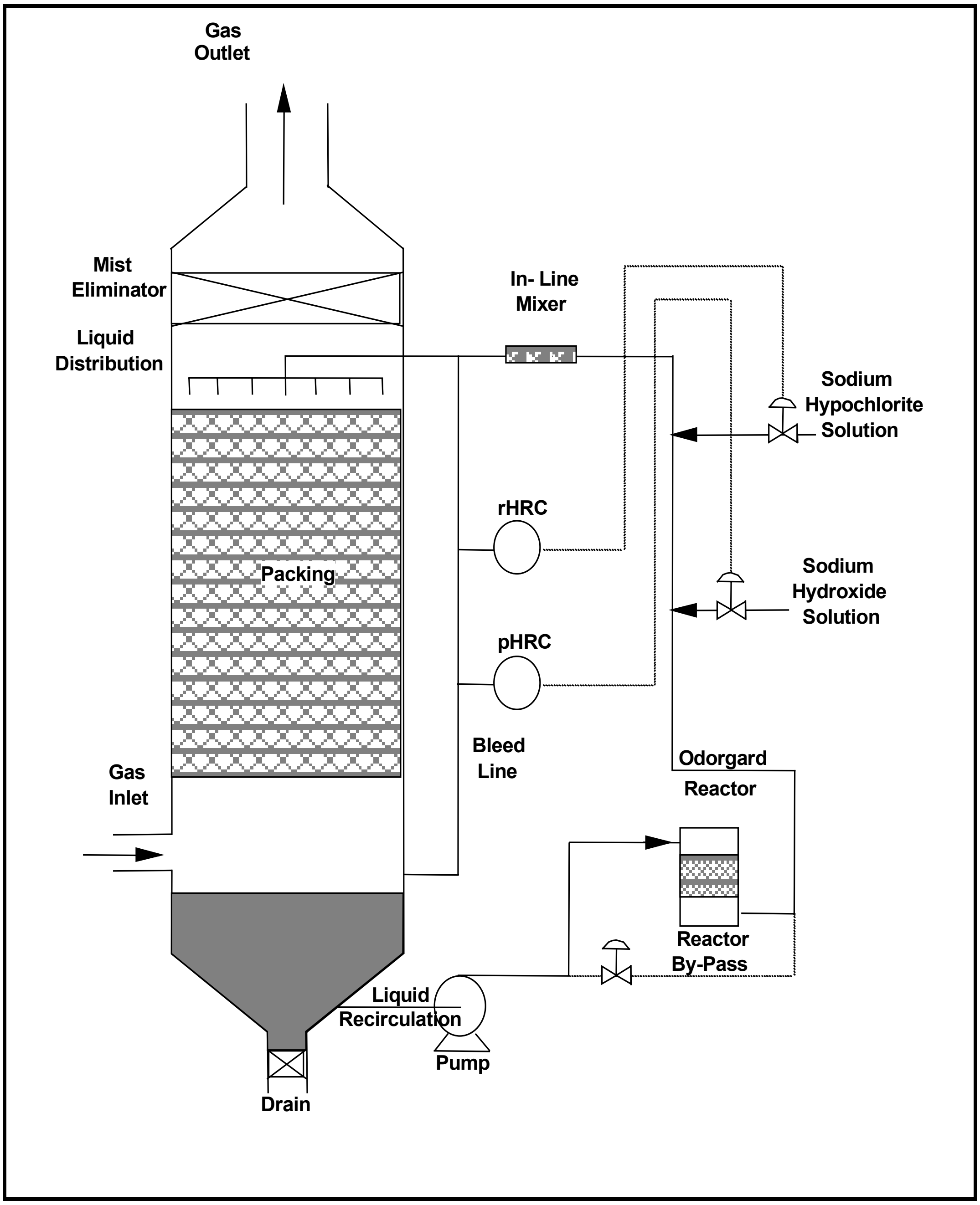

**Figure 4.37: ICI Katalco Odorgard process**
**[Willey A.R.; Williams D. A., 2001 #34]**

In order to address these deficiencies ICI in the UK developed the Katalco process which is essentially a conventional hypochlorite absorber although with a catalyst incorporated into the liquid recycle system. The catalyst is based on nickel oxide and the system is claimed to dramatically increase the hypochlorite reaction rate and prevent any chlorination reactions. The potential chlorination reaction is avoided as the catalyst promotes the decomposition of the hypochlorite into gaseous oxygen and sodium chloride as opposed to free chlorine. This in turn allows the use of increased hypochlorite concentrations in the absorber and hence improved efficiency. The process configuration is illustrated in Figure 4.37 showing the control of pH to approximately pH 9 and the control of redox potential to an optimised voltage.

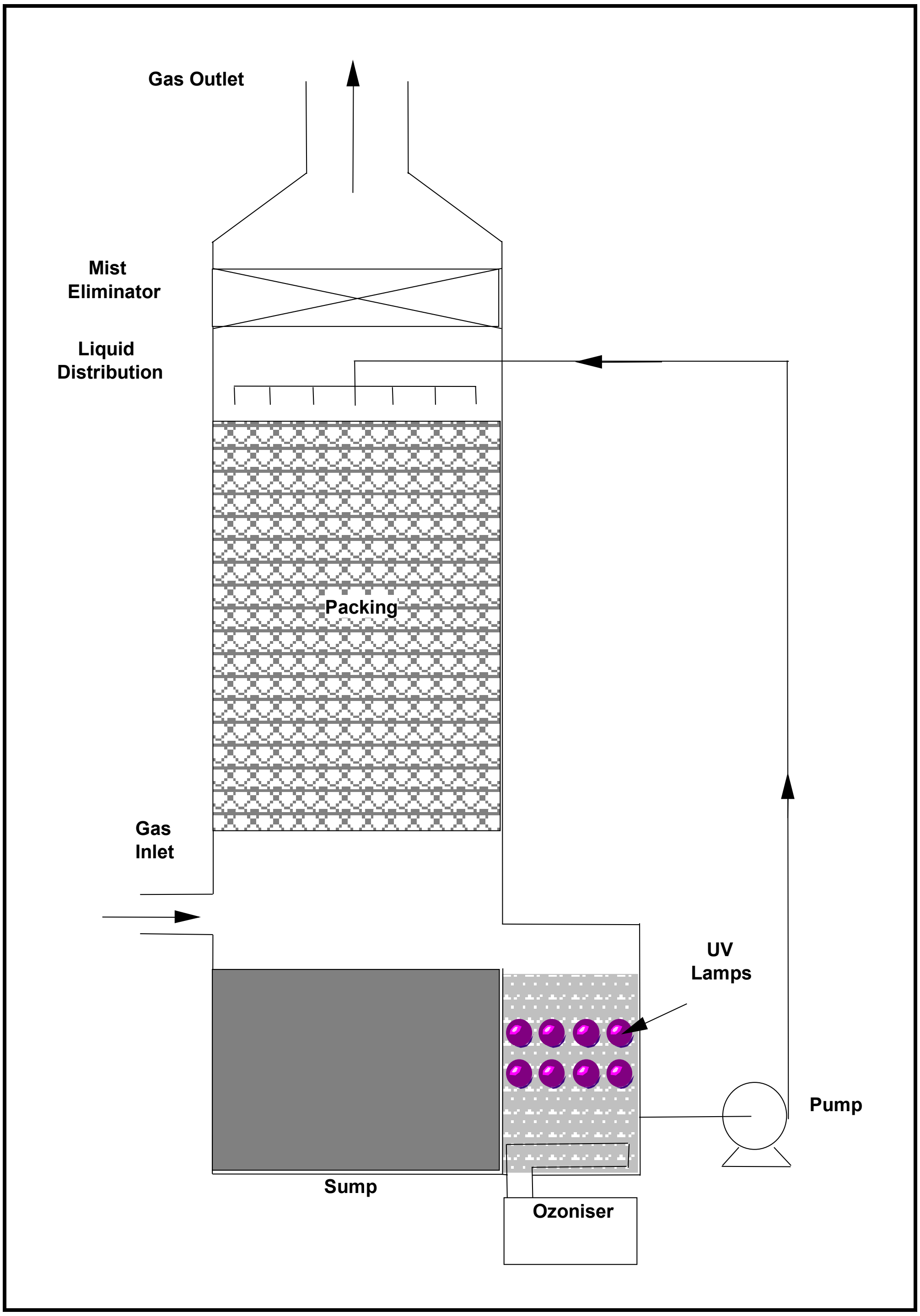

**Figure 4.38: UV/Ozone absorber**
**[Willey A.R.; Williams D. A., 2001 #34]**

#### 4.12.10.8.2 UV / ozone

Ozone has been used historically as an oxidant in only a limited number of odour control applications. This is primarily because, whilst it is extremely reactive in the liquid phase, its reactivity in the gaseous phase is relatively less. A process was developed during the 1980s that enhanced the activity of ozone by the incorporation of ultra violet light. The process is shown in Figure 4.38. The process uses a conventional packed bed system and liquid recycle system. Ozone is bubbled into the sump of the absorber and the ozonated water is passed through a bank of ultra violet lamps. Ozone in the presence of UV light produces hydroxyl radicals which are far more reactive than ozone alone. The dissolved organic compounds in the liquid phase are oxidised to carbon dioxide and water and thus the absorber liquor discharged from the system is relatively clean.

### 4.12.10.9 Absorption systems - Advantages and disadvantages

In general terms absorbers are suitable for a wide range of volumetric airflows which contain odours in relatively low concentration. Absorbers are used extensively within odour control applications, are relatively inexpensive and are considered as possible abatement solutions. The following table of advantages and disadvantages of absorption equipment is used in order to judge the potential for absorption to meet the particular requirements. The use of the word "relatively" in Table 4.47 refers to a comparison with other odour control equipment detailed in this report.

| Advantages | Disadvantages |
|---|---|
| Relatively low capital costs | Likely to generate a waste water discharge |
| Relatively low operating costs | Specific component removal rather than overall |
| Relatively low pressure drop | Limited efficiency typically 70 – 80 % |
| Can treat wide range of airflows | Provision for chemical storage required |
| Compact equipment | Will be likely to generate a visible plume |

**Table 4.47: Advantages and disadvantages of absorption equipment**
**[Willey A.R.; Williams D. A., 2001 #34]**

## 4.12.11 Adsorption

Adsorption is a unit process involving the capture of airborne components onto a fine particulate active surface. There are a number of possible active materials that are used for general applications within industry, including zeolites, silicas, polymeric resins and activated carbon. In virtually 100 % of cases within the control of odorous emissions, activated carbon is presently the chosen absorbent and hence the terminology "carbon adsorption". This review of adsorption will therefore concentrate entirely on carbon adsorption.

Carbon adsorption is utilised for three distinct cases within general air pollution control applications:

i) Air conditioning
ii) Removal of odour from a process exhaust
iii) Removal of components from a process exhaust for subsequent recovery

The design of carbon adsorption equipment for each case is quite different. This section outlines the types of adsorption equipment available and provides general design guidelines in relation to the effective sizing for odour control applications.

### 4.12.11.1 Principle of operation

Adsorption is a dynamic process in which vapour molecules impinge on the surface of the solid and remain there for a period of time before desorbing again into the vapour phase. An equilibrium is established between adsorption and desorption, i.e. a particular concentration of a compound on the carbon surface corresponds to a concentration or partial pressure of that compound in the gas phase. For the majority of odorous emissions, where the organic mass emission is low, the equilibrium amount of adsorbed material increases rapidly for small increases in partial pressure or concentration. Thus the carbon adsorption process allows a positive driving force for adsorption up to a point where the equilibrium position changes and the odour concentration in the outlet exhaust increases. This is the point at which the carbon has been fully utilised and there are insufficient active sites remaining for further adsorption. The carbon bed has thus reached the end of its useful life and will require replacement or regeneration.

The adsorption process, whereby a component is captured within the carbon matrix, can be either physical, in which case the adsorbed molecules are held to the surface by van der Waals forces, or chemical, where chemical bonds are formed between the adsorbed molecules and the surface. Both of these processes release heat, the latter rather more than the former.

Carbon adsorption can be a very effective abatement option, with odour removal efficiencies in the range 80 to 99 % achievable.

### 4.12.11.2 Properties of activated carbon

Activated carbon can be made from a variety of carbonaceous materials including wood, coal, peat, nut shells, lignite, bone and petroleum residues. Shell and coal based products are usually employed in vapour phase applications. The manufacturing process consists of the dehydration and carbonisation of the raw material, which drives off the volatile matter and produces a rudimentary pore structure. This is followed by thermal or chemical activation.

The activated carbons used in odour control applications will have the following typical properties as shown in Table 4.48.

| Parameter | Units | Property |
|---|---|---|
| Particle size | mm | 1.4 - 2.0 |
| Bulk density | Kg/m$^3$ | 400 - 500 |
| Surface area | m$^2$/gram | 750 - 1500 |
| Pore volume | cm$^3$/gram | 0.8 - 1.2 |

**Table 4.48: Properties of activated carbon**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.11.3 Selection of adsorption equipment

There are a number of configurations of adsorber equipment in relation to the three potential duties as outlined in Section 4.12.2. The three major types of adsorber are:

| | | | |
|---|---|---|---|
| i) | fixed bed unsteady state adsorber | - | the contaminated gas passes through a stationary bed of adsorbent |
| ii) | fluidised bed adsorber | - | the contaminated gas passes through suspension of adsorbent |
| iii) | continuous moving bed adsorber | - | the adsorbent falls by gravity through the rising stream of gas. |

In terms of odour control, the major applications are the cleaning of ventilated air and the treatment of odorous process emissions. Carbon beds can be either once used and disposed of, or regenerative. The use of regenerative systems is limited to installations where the recovery of the material being captured is economically attractive. These types of installations are very limited within odour control installations and it is more common for the odour controlling equipment to comprise a single fixed bed adsorber system. Regenerative systems are usually designed with multiple beds so that adsorption and desorption can be conducted simultaneously. It is usually necessary to raise the temperature of the adsorbent bed to release the adsorbate, steam is the most commonly used medium. Thus it can be envisaged that a regenerative system requires an additional capture mechanism for the materials desorbed during the regenerative process.

The fixed bed system comprises a bed of activated carbon through which the gas stream to be treated is passed. The carbon is in either a simple packed bed arrangement or in the form of carbon filters. The filters are essentially paper or cardboard cartridges containing powdered activated carbon. In general the cartridge arrangement is used for general room ventilation whilst the packed bed system is used for odour control from process exhausts. Once the activated carbon has expired, as judged by an increased outlet odour level, the carbon or cartridge arrangement needs to be replaced. The packed bed system has the advantage that in most cases it can be returned to the supplier for regeneration at his premises whilst the cartridge filters will, in most cases, require disposal by the user.

### 4.12.11.4 Design considerations

The design basis for room ventilation using cartridge filters is significantly different than for process odour control using packed beds. In general, cartridge filters will be employed for small vent flows of intermittent or infrequent nature with a very low sorbent concentration. Conversely, the packed bed system would be used where the concentration of components in the air stream to be treated is significantly higher than typical room or factory floor concentrations. The major difference in the design basis of each system is residence time, with room ventilation requiring only 0.1 to 0.2 seconds but process exhaust treatment requiring between 1 and 3 seconds. The choice of residence time is essentially a compromise between the physical volume of the designed bed and the time between renewals.

There are a number of additional design considerations which need to be taken into account which are detailed in the following subsections. These considerations may be viewed in terms of assessing whether carbon adsorption is the most suitable system for the given duty. The considerations are detailed primarily for the application of packed bed adsorbers as applied to the control of process odours.

- Adsorptive capacity

Many literature papers and suppliers catalogues detail the adsorptive capacity of activated carbons for specified components to be removed. The capacity is expressed in a weight % in terms of the amount of the specified material that can be adsorbed per unit mass of carbon. These figures vary considerably from as low as zero to as high as 110 % and are fairly meaningless for an odorous exhaust potentially containing a wide variety of individual components. As a general guideline a value of 30 % can be used in order to estimate the expected lifetime of the carbon bed. In order to conduct this calculation, a knowledge of the mass load of contaminants at the inlet to the bed is required. In the majority of odour cases, with the exception where $H_2S$ is the major odorous contaminant, the organic emission is usually the major problem. This evaluation is further hampered by the inadequacy of analytical techniques to even ascertain the components present in an emission, let alone their individual concentrations. It is normal practice to measure the organic concentration in the gas stream and convert to mg carbon equivalent /$m^3$ of exhaust gas.

The expected life of the carbon bed can be estimated based on a knowledge of the design residence time, the organic load and the airflow to be treated. Thus, consider an airflow of 10000 $m^3$/hr with an organic concentration of 50 mg carbon/$m^3$ and a carbon bed designed with a residence time of 1 second. The organic load is therefore the product of the airflow and concentration at 0.5 kg/hr. A residence time of 1 second implies a carbon bed volume of 2.78 $m^3$. Based on a carbon bulk density of 500 kg/$m^3$ the carbon would be able to adsorb 30 % of 1390 kg which is equivalent to 2780 hours of operation. Thus the bed would require replacement at a frequency of approximately 3 times per year. In this respect the cost of activated carbon at approximately GBP 1500 / tonne needs to be taken into account.

- Temperature

In general, the lower the temperature the greater the amount adsorbed and therefore the longer the penetration time or bed life. As a guideline, a temperature of 40 ºC can be seen as an upper limit for an adsorption process.

- Humidity

In general the efficiency of activated carbon is reduced at a relative humidity above 75 %, except for water soluble compounds such as the lower amines and hydrogen sulphide. This preferential adsorbance of water can lead to condensation within the bed, thereby rendering the carbon inactive. The bed would then require drying out before it could be re-used.

- Packed bed configuration

The height and diameter of a packed bed is largely governed by the choice of linear velocity through the bed and the allowable pressure drop. In practice, linear velocities range from 0.1 to 0.6 m/s with higher linear velocities resulting in higher rates of mass transfer to the carbon surface and therefore higher adsorption rates. This is of course offset against increased pressure drop over the bed.

As a general guideline, a linear velocity of 0.3 m/s is chosen with a minimum bed depth of 0.3 metres and a minimum residence time of 1 second. The pressure drop over the carbon bed will be typically 750 mm water /metre bed based on a carbon particle size of 1.5 mm.

- Particulate

The presence of particulates in the gas stream to be treated can seriously interfere with the efficiency of a carbon bed, as well as increase the operating pressure drop. Thus where particulate or even condensable material is present the use of a carbon bed is questionable. The particulate/condensables can of course be removed in a pre-filter arrangement although this will add to the complexity and cost of the unit as well as adding operational problems in cleaning requirements, particulate breakthrough etc.

#### 4.12.11.5 Adsorption systems - Advantages and disadvantages

The installation of a carbon adsorption system is fairly simple, comprising a fan and vessel to hold the carbon bed. The main limitation to carbon adsorption is the cost of the carbon and the plant downtime that frequent replacements may incur. Regeneration is not normally economical and the carbon bed has to be totally renewed when its adsorption efficiency begins to fall, which might be after only a short period of time depending on the odour emission rate and odorant concentration. Thus adsorption has a definite, if limited, place among odour abatement techniques.

Carbon adsorption systems for process odour control applications are generally suitable for low air throughputs of less than 10000 $m^3$/hr and where the contaminant to be removed is present in a low concentration of say less than 50 mg/$m^3$.

The advantages and disadvantages of carbon adsorption are detailed in Table 4.49.

| Advantages | Disadvantages |
|---|---|
| Relatively low capital cost | Potentially high operating cost |
| Potentially high odour removal ~ 90 – 99 % | Not suitable for high solids loading |
| Simple design | Not suitable where condensables present |
|  | Restricted to a temperature below 40 ºC |
|  | Restricted to below 75 % relative humidity |

**Table 4.49: Advantages and disadvantages of carbon adsorption**

## 4.12.12 Biological treatment

The terminology of biological treatment covers the use of biofilters and bioscrubbers. Biofilters can be further subdivided into soil and non-soil based biofilters. The process of using micro-organisms to breakdown airborne odour emissions was largely developed during the 1960s and is now used extensively within industry. The most popular type of biological treatment is the non-soil biofilter or peat bed scrubber, as it is popularly known. Biological treatment offers potentially high odour removal efficiency at relatively low cost when compared with alternative treatment techniques.

### 4.12.12.1 Principle of operation

The most widely accepted model for the removal of odours in a biological system is the biofilm theory. This theory has been widely applied to explain the mechanisms occurring in a biofilter. The biofilm is the water layer prevailing around individual particles of the filter material where micro-organisms are present. When the airstream to be treated flows around the particles there is a continuous mass transfer between the gas phase and the biolayer. Volatile components present in the exhaust gas, together with oxygen, are partially dissolved in the liquid phase of the biolayer. The second reaction step is the aerobic biological degradation of the components in the liquid phase. In this way a concentration gradient is created in the biolayer which maintains a continuous mass flow of the components from the gas to the wet biolayer.

Transport across the phase boundary and diffusion into the biolayer provide food for the micro-organisms living in the biolayer. Nutrients, required for cell growth, are provided from the filter material and the gas and liquid phase concentrations of each of the components are assumed to be always in equilibrium at the phase boundary and related to Henry's Law.

In terms of reaction kinetics, the biological degradation process follows zero order kinetics, i.e. the degradation rate is independent of the substrate concentration. The zero order kinetics of the elimination process implies that biodegradable compounds may be removed completely providing there is sufficient residence time of the gas phase in the filter bed.

The biofilm model, coupled with zero order kinetics, allows a quantitative description of the basic processes involved in biofiltration and an accurate sizing of biofilters for a one component exhaust gas. Its applicability to a multi component exhaust gas, however, is limited by the increasing mathematical complexity needed for multiple components and by the fact that off-gas constituents will often not be biodegraded independently. Since exhaust gases from industrial sources generally contain a variety of components then pilot plant testing is recommended to ensure that the biofilter is adequately sized.

### 4.12.12.2 Selection of biological equipment

As detailed previously there are essentially 3 types of biological treatment processes. The salient parameters of each system are discussed in the following sub-sections.

- Soil beds

The soil bed was the forerunner of the modern day biofilter and comprises a layer of porous soil underlain by a network of pipes through which the airstream to be treated is passed. An open structured soil is required to keep the pressure drop across the bed to a minimum. Soil beds are normally constructed below ground and care must be taken to ensure that the base of the soil filter is above the water table. The major drawback with the soil biofilter is the excessive residence time required for the biological process, which is in the region of 5 minutes. This results in very large open structures requiring significant land area.

- Biofilters

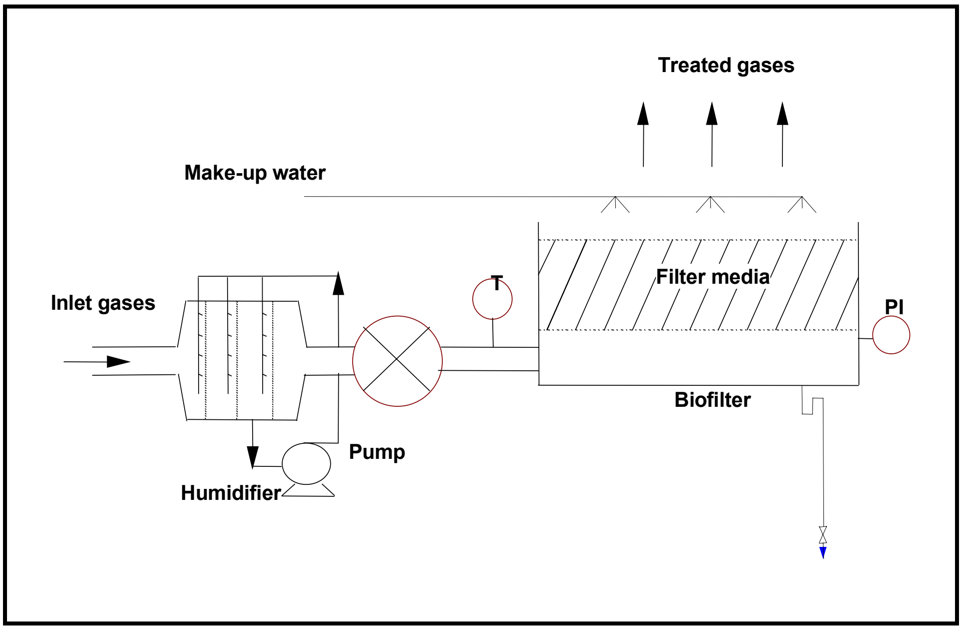

**Figure 4.39: Biofilter layout**
**[Willey A.R.; Williams D. A., 2001 #34]**

A typical layout of a biofilter is illustrated in Figure 4.39. The waste gas to be treated is directed initially into a humidifier, where it is counter-currently contacted with recirculating water. The air exiting the humidifier is subsequently directed to the base of the biofilter. In order to maintain the water balance within the biofilter the relative humidity of the inlet air exiting the humidifier is greater than 95 %.

Exhaust gases entering the biofilter are distributed evenly across the base of the unit and percolate upwards through a distributor plate and subsequently through the filter media. Periodic irrigation of the top of the bed allows the system to maintain the required moisture content in the filter material of 40 - 60 %. Any water falling through the bed, via irrigation or rainfall, can be recycled to the humidifier to avoid a waste water discharge from the system.

There is a wide variety of filter materials that have been used in biofilters. The major requisites of the filter material are a high specific surface area (300 - 1000 $m^2/m^3$), a high water bearing capacity, limited compaction characteristics and a limited resistance to flow. Traditionally, fibrous peat mixed with heather in a 50 % proportion has been used. The microbial activity occurs within the peat whilst the heather provides a stiffening agent to prevent compaction, thereby extending the operating life of the bed.

A variation of the peat/heather mixture is mushroom compost mixed with 5mm diameter polystyrene spheres again in a 50 % proportion. The polystyrene spheres have a similar action to the heather. A filter media that does not require the addition of a stiffening material is "rootwood". The rootwood is typically comprised of tree roots, branches and loose twigs. The rootwood is split into lengths of typically 15 cm by a tearing apart action rather than straight cuts. This action effectively exposes the maximum surface area.

The choice of filter material may largely be restricted to the aforementioned three types which have all been proven in full scale installations. Specific operating experience may be sought if any other materials are proposed.

A typical lifetime of a filter bed of 3 to 5 years is often quoted by suppliers which is probably about the right time period. However, it should be noted that for most filter materials, and particularly for peat/heather, the bed will require topping up within the first 18 months of operation.

Due to reasons of potential compaction, the maximum height of the filter material is restricted to approximately 1.0 to 1.5 metres. Where a greater height is required due to limited land availability then some form of intermediate support would be required within the vertical cross section of the bed.

The distribution of air through the biofilter is an important consideration and a plenum chamber design is recommended. In this respect the vertical height of the plenum chamber is at least 50 % that of the height of the filter material.

A correctly operating biofilter will exhibit an outlet odour concentration of typically 150 to 200 Odour units/m$^3$. The characteristic smell associated with the treated discharge is a musty, moist forest type of smell with very little resemblance to the inlet odour. Odour removal efficiencies of up to 99.5 % can be achieved, although the percentage removal is very dependent upon the inlet concentration. It is unlikely that an outlet odour level of less than 150 OU/m$^3$ can be achieved and thus care need to be exercised in respect of manufacturers claims, i.e. an inlet odour level of 5000 OU/m$^3$, for example, would represent a maximum efficiency of 97 %.

- Bioscrubbers

A typical bioscrubber installation is shown in Figure 4.40. The technique essentially comprises a packed bed absorber containing a bacterial population within the packing and the sump. The contaminated gas is passed up the tower against a flow of water containing a population of bacteria. The bacteria attaches itself to the packing in a similar manner to a trickling filter used for waste water treatment. Nutrients, required for bacterial growth and synthesis, are added to the absorber sump on a periodic basis.

In theory, a bioscrubber can be used wherever bio-oxidation is an appropriate solution to an emission problem and its applications are therefore similar to those for biofilters. A bioscrubber offers operation at a slightly reduced residence time when compared with a biofilter and also requires a much smaller land area. Conversely the bioscrubber is more energy intensive since water is being recirculated in addition to air movement. In terms of application within industry the bioscrubber has only received a limited application when compared with the popular biofilter.

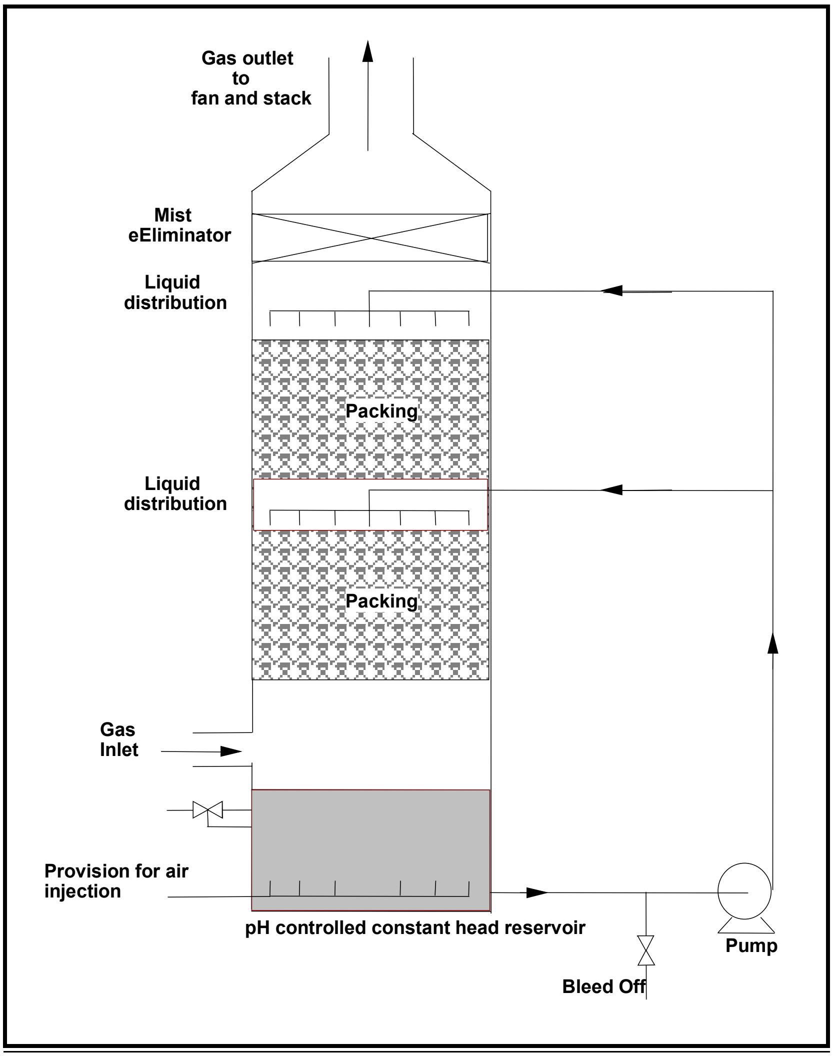

**Figure 4.40: Biosrubber**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.12.3 Design considerations

There are a number of design considerations which need to be taken into account in order to ensure effective operation of a biological treatment plant. The details given in the following subsections primarily relate to the design of biofilters which are by far the most popular biological systems.

- Residence time

The residence time required by a biofilter is dependent upon the level and type of contaminants present in the airstream to be treated. Components that are aromatic in nature will require a longer residence time than more simple organic chemical species. As a general guideline a minimum residence time of 20 seconds is chosen, extended for up to 40 seconds where contaminants with reduced biological degradability are present.

The velocity through the filter bed is typically between 0.02 and 0.05 m/s. The surface loading rate, which is often used to characterise a design, is typically within the range of 100 to 250 $m^3$ gas/$m^2$ filter area/hour.

The design residence time for a bioscrubber is somewhat lower than that for a biofilter, most installations are between 5 and 15 seconds.

- Temperature

No biological process is suitable for airborne temperatures in excess of 40 ºC. If temperatures above 40 ºC are prevalent for significant periods of time, i.e. greater than 4 hours, then the micro-organisms present in the filter become sterilised and the bed requires reseeding. The key temperature is the wet bulb temperature of the airstream to be treated, as this will be the temperature of the airstream following the humidification plant.

At temperatures below 10 °C, the rate of biological degradation falls dramatically. The suitability of biofiltration at temperatures less than 10 °C is therefore questioned.

- Effect of particulate

A significant level of particulates entering the biofilter will have the effect of fouling the porous surface of the filter media, with an ensuing rise in filter pressure drop and a reduction in operational efficiency. A maximum inlet concentration of 10 mg/m$^3$ of insoluble or 20 mg/m$^3$ of soluble particulates is recommended. Thus, one of the functions of the humidifier process is to capture any particulates present in the raw exhaust gas and reduce it down to the above-mentioned concentration, prior to entry into the filter bed.

- Odour loading

A biofilter is best suited to an airstream that exhibits a reasonably constant contaminant loading. In this respect it is ideal for ventilation systems where a constant airflow is extracted from a vessel or process room. Periodic heavily contaminated air streams are avoided unless there is a sufficient dilution from other sources being treated. As a guideline, a maximum organic concentration of 1000 mg/m$^3$ is recommended. Contaminant concentrations above this level will result in a rapid compaction of the filter material.

- Humidifier design

The humidifier, essentially a water scrubber, requires direct contact of the incoming raw gas with water in order to achieve a minimum relative humidity of 95 % at the inlet to the biofilter. There are a number of process alternatives ranging from a simple spray vessel to a packed or trayed column. Each system is generally operated in counter-urrent fashion.

The choice of humidifier configuration is largely dependent upon the level of particulates, if any, in the exhaust gas. Simple spray towers are unlikely to capture a considerable proportion of the particulates, whereas packed columns will likely suffer fouling problems. Additionally some form of internal baffle arrangement is recommended to ensure efficient contacting.

The water reservoir at the base of the humidifier is operated on a level control so that water taken up by the exhaust gas can be continuously replenished. It is not normal practice to operate the humidifier with a continuous fresh supply of make-up water as this would lead to a waste water discharge requirement. A make-up water rate is only envisaged for exhaust gases with heavy particulate loads or where a considerable proportion of the components are likely to condense. The only discharge of waste water from the humidifier arises from periodic cleaning requirements.

#### 4.12.12.4 Process control

The pH of the filter material in a biofilter is typically between 6.5 and 7.5, a range preferred by most bacteria. In some cases the biodegradation of exhaust gas components can generate acidic by-products. This is particularly the case for components such as ammonia, hydrogen sulphide and halogenated hydrocarbons, all potentially yielding dilute acids. A gradual reduction in biofilter pH is typically associated with a reduction in operational efficiency. Additionally, the presence of fungi, visually observed as white coloured moulds, will increase at lower bed pH.

The problem of reducing bed pH can be alleviated via two routes: the addition of an insoluble alkali to the biofilter media, such as calcium carbonate, which effects neutralisation of the dilute acids produced during the biological process. However, the calcium carbonate will effectively have a finite life, following which the onset of acidic conditions in the biofilter will prevail. A maximum calcium carbonate addition to the filter material of 40 kg/m$^3$ has been recommended. The second option is to enhance alkaline conditions in the recirculating water of the humidifier by caustic dosing and pH control. Periodic measurements of filter bed pH is conducted to allow the necessary adjustments to the caustic dosing rate into the humidifier to maintain neutral conditions in the biofilter.

Biofiltration is not a complex process so requires only minimal operator attention. Maintenance requirements are also limited, essentially confined to the exhaust gas fan and humidifier recycle pump. The extent to which process control can be applied to a biofilter installation varies considerably and the degree of control required will depend on such factors as location of biofilter in relation to other processes, planned operator attention etc.
It is recommended as a minimum feature that there are operational running lights for the humidifier duty and standby recycle pumps. Failure of these pumps, without corrective action, could cause potential damage to the filter media.

Depending on the nature of the upstream process an emergency gas vent to atmosphere can be installed linked to a temperature sensor located at the inlet to the biofilter. The control mechanism is set such that if the biofilter inlet temperature exceeds 45 °C over a predetermined period of time, say 4 hours, the exhaust gases will be discharged directly to atmosphere bypassing the biofilter. Local temperature and bed pressure drop indicators are also recommended.

- Upflow / downflow operation

Biofilters can be operated in either upflow or downflow fashion. The relative merits of each mode are uncertain and it is most likely that operational efficiency is the same in each case. The major difference is likely to be reflected in the capital cost where the downflow system will require an airtight top seal. This would be emphasised for a larger biofilter.

The pressure drop over a biofilter is low, typically in the range of 10 to 25 mm per metre of packed height. This low pressure drop infers that proper design of the air distribution for either downflow or upflow installations is a critical design parameter.

- Acclimatisation

As a biofilter is started up there is a finite period of time required for the micro-organisms naturally occurring in the filter material to acclimatise to the particular exhaust gas. This acclimatisation stage is typically between 10 and 30 days depending upon the nature of the exhaust gas. The addition of activated sludge or selective bacterial strains will effectively reduce the acclimatisation period to a matter of a few days. Indeed specific bacterial strains are added to be bed by certain suppliers.

Micro-organisms present in the filter media can survive fairly long periods when the system is not loaded. Shutdown periods of upto 2 weeks have been reported without any loss in microbial activity.

#### 4.12.12.5 Biological systems - Advantages and disadvantages

The biofiltration process is suitable for a wide range of airflows up to and exceeding 100000 $m^3$/hr, providing there is sufficient land space available. Similarly, the size of a bioscrubber is not restricted by the airflow to be treated, although the resultant size of a single packed tower may necessitate two parallel systems. A limit to the maximum concentration of contaminants in the inlet airstream is generally documented as less than 5000 mg/$m^3$ in the literature [Willey A.R.; Williams D. A., 2001 #34], although a concentration limit of 1000 mg/$m^3$ may be used as a guideline when assessing suitability of biofiltration/bioscrubbing.

The advantages and disadvantages of biological treatment methods are detailed in Table 4.50.

| Advantages | Disadvantages |
|---|---|
| Relatively low capital cost | Restricted to wet bulb temperatures < 40 ºC |
| Relatively low operating costs | High land area requirements |
| Potentially high odour removal ~ 90 – 99 % | Potential for visible plume |
| Simple design and operation | Requires control of pH and water content |
|  | Slow adaption to fluctuating concentration |

**Table 4.50: Advantages and disadvantages of biological treatment**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.13 Thermal incineration

A literature review of incineration techniques applied to the control of odorous airstreams will generally examine the relative merits of thermal incineration (this section) and catalytic incineration (see Section 4.12.15). Surprisingly, the potential to use an existing boilerhouse (see Section 4.12.14) to incinerate the odorous emissions is often neglected. Treatment in an existing piece of equipment obviously has economic benefits both in terms of capital costs and operating costs. The following sections outline the principle of operation behind thermal, boiler and catalytic incineration, discusses the type of equipment available and provides general design guidelines in relation to the effective sizing for odour control applications. Due to the importance of each of the treatment techniques each technique has been treated separately.

Thermal incineration has the advantage of being almost universally applicable as a method of odour control because most odorous components can be oxidised to non-odorous products at high temperature whereas the application of other methods are more restrictive. The major considerations when assessing the suitability of thermal incineration is the operating cost in terms of the fuel requirements and the potential of the incineration process to generate unwanted by-products of combustion. In this respect thermal incineration is usually considered as a last resort after other possible less costly abatement techniques have been evaluated.

#### 4.12.13.1 Principle of operation

A typical layout of a thermal incinerator is shown in Figure 4.41. For complete oxidation of odorous compounds it is necessary for them to be in contact with sufficient oxygen for a long enough time at a high enough temperature. Rapid oxidation of organic compounds will occur if the gas temperature in the incinerator can be maintained at 200 - 400 °C above the auto-ignition temperature of the chemical species present. In practice, for odorous compounds, this generally implies an incineration temperature of 750 – 800 °C.

The design of a thermal incinerator allows for adequate time, temperature and turbulence (the three "T's" of incineration). In order to achieve these conditions an incinerator will contain the following equipment stages:

i) Burner - the fuel is burnt with clean air or with a proportion of the contaminated air to produce a flame at a temperature of typically 1350 – 1500 °C
ii) Mixer - to ensure adequate turbulence and hence mixing of the process gas to bring it to uniform temperature
iii) Chamber the gases are held at the combustion temperature until oxidation has been completed typically 0.5 to 1.0 seconds

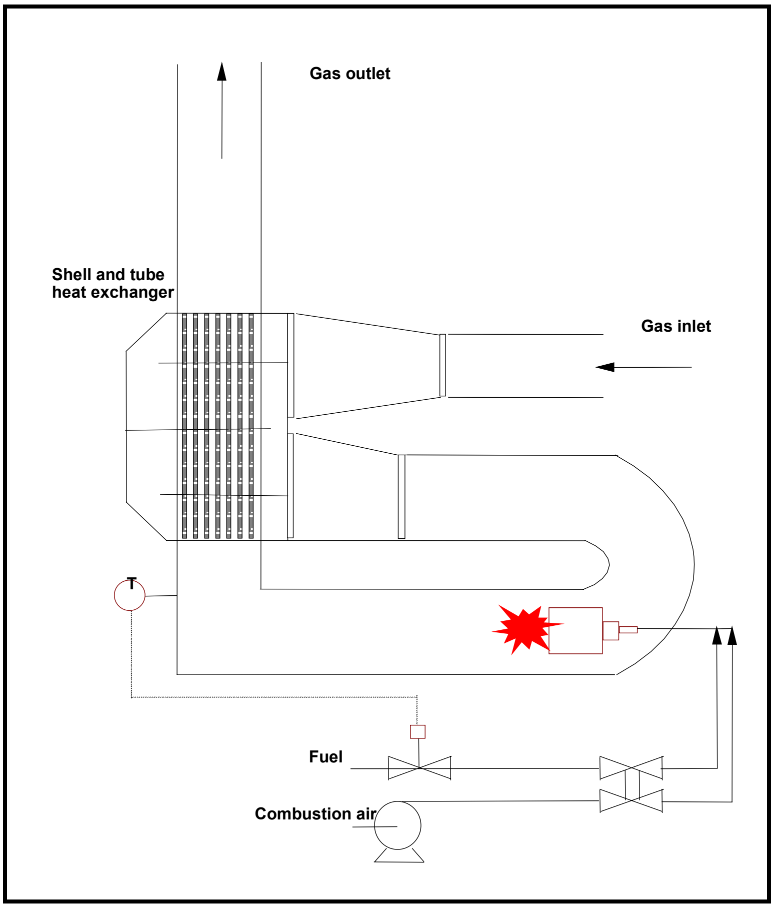

**Figure 4.41: Thermal incinerator layout**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.13.2 Selection of thermal incineration equipment

There are a number of parameters that need to be considered in the selection of thermal incineration equipment. In particular, it is important to consider the recovery of heat from the incineration process to reduce fuel costs. The nature of the components present in the airstream to be treated also play an important role in selection of the optimum system. Most applications for the treatment of odorous streams comprise a direct flame system where the contaminated stream is in direct contact with the combustion flame. In cases where there is a high concentration of organics above relevant explosive limits then a flameless type of system may be required. These systems utilise a heating medium to heat the airstream and thus avoid direct contact of the airstream with the flame. As odorous airstreams seldom have organic concentrations in the region of the lower explosive levels, this section will concentrate on the conventional type of thermal incinerators which have direct flame contact with the airstream to be treated.

The salient points regarding the selection of thermal incineration equipment are detailed in the following subsections:

- Burner type

Burners can be divided into those with a single flame and those in which the fuel is distributed between a large number of jets. The oxygen required for combustion can be taken from the ambient atmosphere, the airstream to be treated or alternatively a proportion of each. Care need to be taken and due vigilance paid to the potential for any water vapour present in the airstream to quench the flame, thereby resulting in poor combustion.

The burner may also be of the pre-mix type where the fuel is mixed with the combustion air prior to passing through the nozzles, or a diffusion type where the fuel is mixed with the combustion air downstream of the nozzles. Most burners are of the diffusion type.

The turndown ratio of the burner may also be specified. The turndown ratio essentially relates to the possible range of fuel flows to the incinerator for heating a range of airflows to a number of incineration temperatures. This factor may be a design consideration if an incinerator is planned for more than one duty as part of a staged installation where a greater airflow may be treated at a later date.

- Mixing section

Mixing of the gas stream may be achieved in a variety of ways, such as natural diffusion, impingement mechanisms and the inclusion of baffles to induce flow changes. Suppliers offering low $NO_x$ systems often incorporate various backmixing sections, with the desired intention of reducing temperature excursions significantly above the mixed temperature.

- Combustion chamber

The dimensions of the combustion chamber are sufficient to achieve the desired residence time and accommodate the physical length of the flame without quenching.

- Heat recovery

Some form of heat recovery is nearly always warranted in order to reduce operating costs. Heat recovery is conventionally conducted in a shell and tube heat exchanger, which allows heat to be continuously transferred to preheat the incoming gas stream. This type of system is termed a recuperative system, 70 - 80 % heat recovery is a typical design level.

Heat recovery can also be achieved in a regenerative system which uses two sets of ceramic bed heat exchangers. One bed is heated by direct contact with the exhaust gas while the other is used to preheat the incoming gases. The system is operated so that the beds alternate between heating and cooling. The heat recovery potential of this system is somewhat higher than the recuperative system, 80 - 90 % heat recovery is a typical design basis. The use of thermal fluids is an alternative to this type of system.

The recovery of heat can also be conducted using a waste heat boiler where the treated exhaust gases are used to produce steam for use in other parts of the factory. The installation of this type of system is reviewed with caution as it requires the incinerator to be operational at all times when there is a steam demand, and aqlso has potential problems in integrating the incinerator with the rest of the factory.

There is also potential for secondary heat recovery, utilising the treated exhaust from the first stage heat recovery for obtaining hot water, space heating etc.

### 4.12.13.3 Design considerations

The major design considerations are the allowance of adequate temperature and residence time to ensure optimal combustion. Additional design considerations together with potential pitfalls are detailed in the following subsections.

- Formation of undesirable components

The major concern in this area is the potential generation of high levels of $NO_x$. Essentially the higher the reaction temperature then the greater the potential for the generation of increased levels of $NO_x$. The guarantee provided by the supplier contains reference to maximum $NO_x$ levels. The purchaser needs to review the pertaining and likely future legislation regarding emissions from incinerators and check these against the suppliers references. It is usually beneficial to opt for a low $NO_x$ burner.

Any compounds containing sulphur present in the odorous gas stream will generate $SO_2$ emissions and the potential for this should be considered against any legislative constraints. In a similar fashion the presence of chlorides in the odorous air stream is reviewed due to the potential formation of acidic gases such as HCl, in terms of any legislative constraints together with potential corrosion problems within the incinerator.

- Pretreatment

Odorous airstreams containing significant quantities of particulate material will likely require pretreatment prior to the incineration process. This is particularly relevant if heat recovery is installed, due to the potential fouling of the heat exchanger.

Whilst the presence of high levels of water vapour in an airstream is not considered a process problem the fuel requirements will increase over and above the heating of dry air. The removal of water vapour from an airstream is unlikely to be an economic option so additional fuel requirements are usually included in the overall economic viability of the proposal.

- Safety requirements

There are a number of safety requirements which in most cases can be addressed adequately by incineration suppliers, in particular:

  - the need for protection against flame flashback between the incinerator and the gas stream to be treated. This can generally be achieved via a flame arrestor or water seal
  - on start-up, before the burner is ignited the incinerator needs to be purged with air by a volume equivalent to 5 times the plant volume. Re-ignition of burners during operation is preceded by a burner purge period. [Willey A.R.; Williams D. A., 2001 #34]

### 4.12.13.4 Thermal incineration - Advantages and disadvantages

A properly designed thermal incinerator will likely achieve odour removal efficiencies of greater than 95 % and approaching 100 %. However, there are number of potential drawbacks which need to be considered. In particular, the planning application to install a thermal incinerator will likely be met with severe opposition by the local community. Whilst this is more prevalent for incinerators burning waste materials, the mere word "incineration" is often sufficient to initiate a strong opposition.

Thermal incineration is generally used for the treatment of low volumes of less than 10000 $m^3$/hr, the driving factor being the increased costs for heating greater volumetric airflows. It is suitable for odorous streams with variable contaminant concentration and is capable of treating a variable volumetric throughput.

The key advantages and disadvantages of thermal incineration are detailed in Table 4.51.

| Advantages | Disadvantages |
|---|---|
| High odour removal efficiency | High capital costs |
| Performance independent of odour intensity | Relatively high operating costs |

**Table 4.51: Advantages and disadvantages of thermal incineration**
**[Willey A.R.; Williams D. A., 2001 #34]**

## 4.12.14 Boiler incineration

Directing the odorous gases to an existing on-site boiler is always considered as a potential treatment option. Indeed boiler incineration is high on the pecking order of suitable treatment options. The obvious advantage is that the equipment, i.e. the boiler, is already present on site and hence big savings can be made in terms of capital expenditure.

### 4.12.14.1 Principle of operation

The principle of operation is essentially the same as for thermal incineration in a purpose built plant.

### 4.12.14.2 Design / operational considerations

There are a number of design implications which need to be addressed as part of the evaluation study:

- Boiler operation and combustion airflow requirements

An important initial consideration is to check whether the boiler would be operating when odorous gas is produced. This, for most factory operations, is likely to be the case. Also a knowledge of the oxygen content of the odorous air, if it is suspected to be less than 21 %, will further help with the initial feasibility exercise.

The odorous exhaust stream would be ducted to the combustion airflow fan of the boiler or boilerhouse. The odorous air would subsequently enter the boiler, provide oxygen to the combustion process, and the odorous components would then be incinerated.

The overall feasibility of boiler incineration largely depends upon the volume of odorous air to be treated in relation to the boiler combustion air requirements under the extremes of load. If the volume of odorous air is significantly less than the combustion air requirements then there should be no problem. The total volume of odorous air could simply be ducted through the combustion fan. However, the vast majority of factory operating conditions result in the boiler operating in a cyclic mode in response to a steam pressure signal.

- Boiler control strategy

The normal operation of a boiler is to generate steam in line with the demand from the factory as judged continuously from the steam pressure signal at the boiler outlet. As the steam pressure increases to its setpoint, the boiler will respond by reducing the fuel flowrate to the burner. The combustion airflow, being electrically or mechanically linked to the fuel feed rate, will also reduce in order to maintain optimum combustion conditions. If the combustion air flowrate at this low firing condition is lower than the volume of odorous air to be treated then the control strategy of the boiler needs to be changed.

Thus, the control strategy would change from being dependent upon the steam pressure to being dependent upon the combustion air flowrate. The combustion air flowrate would be set to a minimum (equivalent to the volume of odorous air to be treated) which in turn would set a minimum fuel flowrate and firing rate. When the steam setpoint pressure is achieved the boiler reverts to operation at the minimum combustion air flowrate and the unwanted heat is discharged through the boiler stack.

Thus, a key part of the evaluation is to ascertain the percentage of time that the boiler operates with a combustion air flowrate lower than the odorous flowrate, in order to calculate additional fuel costs.

##### 4.12.14.2.1 Safety features

The pertinent safety features associated with routing an odorous discharge to a boiler are essentially encompassed within the existing boiler operation. The key omission would be the need to fit flame arrestors or water seals to prevent flame flashback between the boiler and the gas stream to be treated.

##### 4.12.14.2.2 Pretreatment

The need for pretreatment of the odorous airstream to remove particulates prior to the boiler is best assessed in conjunction with the boiler manufacturer as he will know best what the boiler can tolerate.

#### 4.12.14.3 Boiler incineration - Advantages and disadvantages

The advantages and disadvantages of boiler incineration are detailed in Table 4.52.

| Advantages | Disadvantages |
|---|---|
| Low capital costs | Potential implications to boiler operation need to be fully ascertained |
| Potentially low operating costs | Reliance to continuous boiler operation |
| No additional discharge stacks | |

**Table 4.52: Advantages and disadvantages of boiler incineration**
**[Willey A.R.; Williams D. A., 2001 #34]**

### 4.12.15 Catalytic incineration

Catalytic incineration is a process similar to thermal incineration with the fundamental difference being that the oxidation reaction takes place in the presence of a catalyst rather than in free air. The main advantage of catalytic incineration is that significantly lower operating temperatures are required and therefore lower fuel costs result compared to thermal incineration. Catalytic incineration, or catalytic oxidation as it is sometimes called, also does not generally suffer from the connotations of the word "incineration" and the implications associated with thermal incinerators.

#### 4.12.15.1 Principle of operation

A typical layout of a catalytic incinerator is shown in Figure 4.42. The odorous airstream enters the unit and is preheated in a conventional shell and tube-heat exchanger. The preheated inlet stream is then further heated via a burner to the desired oxidation temperature, before passing onto the catalyst. The contaminants present in the odorous airstream, together with oxygen diffuse, onto the surface of the catalyst. Oxidation takes place and the products of oxidation are desorbed back into the gas stream. These transfer processes require a finite time within the catalyst and the rate of reaction is strongly influenced by the operating temperature. The treated gas stream then passes through the heat exchanger, warming the incoming odorous air stream.

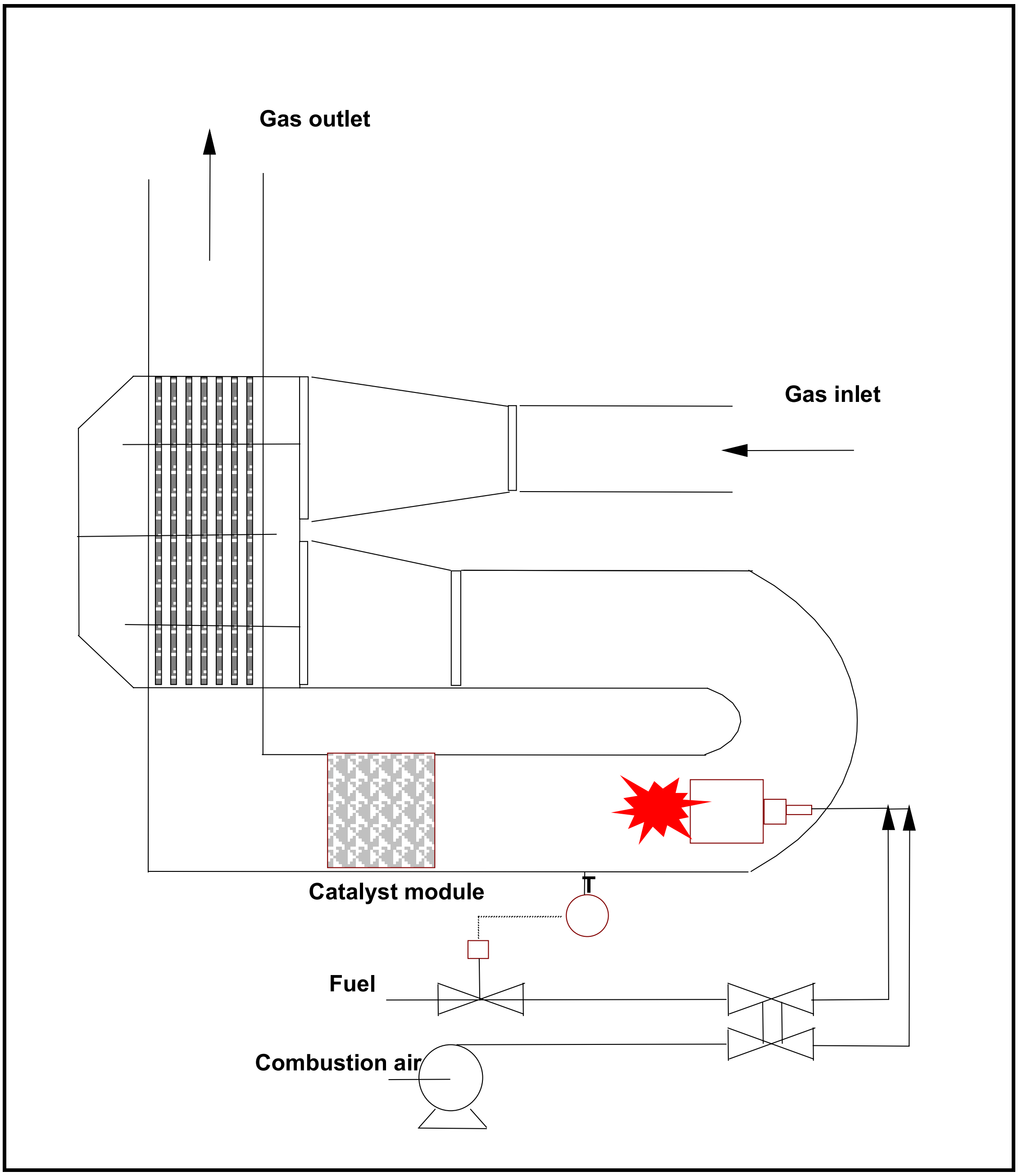

**Figure 4.42: Catalytic incineration layout**
**[Willey A.R.; Williams D. A., 2001 #34]**

The removal rate of odour and organic materials is strongly dependent upon the operating temperature. A graphical plot of increasing temperature versus removal efficiency will have a characteristic "S" shape. At low temperature there is little removal up until a temperature where the removal of organics increases sharply. This temperature is known as the ignition temperature. Successive increases in temperature result in only a gradual increase in the organic removal efficiency. The conversion efficiency with temperature depends upon the type of hydrocarbons present in the odorous air stream. Methane is the most difficult organic to oxidise, requiring operating temperatures of 400 – 450 °C for a 90 % conversion. Similarly, aromatic materials are harder to oxidise than aliphatic, whilst branched molecules are easier than straight chained molecules. For mixtures of organics, as is generally the case for odorous emissions, oxidation temperatures in the region of 300 – 400 °C are required.

### 4.12.15.2 Selection of catalytic incineration equipment

There are a number of factors which need to be considered in the selection of catalytic oxidation equipment.

- Catalyst type

The most important aspect of a catalyst bed is the ratio of surface area to volume and hence the available area for reaction. The catalyst support and bed geometry influence the size and shape of the catalyst bed chamber, which in turn affects the cost and the pressure drop across the bed. Conventional bed geometries include metal ribbons, spherical pellets, ceramic rods and ceramic or metal honeycombs.

The honeycomb structure is perhaps the most common catalyst system and platinum is the most widely used catalyst metal. The honeycomb structure is more effective than other structures in minimising problems of attrition, mechanical stability, excessive pressure drop and chemical stability in oxidising atmospheres.

- Catalyst activity / poisoning

The presence of catalyst poisons in the exhaust stream to be treated is a key consideration(42). Lead is a well known poison in the use of unleaded petrol for cars fitted with catalysts. Lead together with other metals such as phosphorus and mercury are classified as fast acting irreversible poisons. Tin and silicon have similar catalyst deactivating properties but are slow acting. Compounds such as sulphur, halogens, zinc and organic solids tend to coat the catalyst surface but this process is reversible with catalyst activity re-achievable by the application of high temperature. Inert particulate material will also result in a gradual decrease in catalyst activity, although the application of high temperature, approximately 500 °C, will return the catalyst activity.

The presence of particulate in the gas stream tends to accumulate at the front edge of the catalyst, resulting in a gradual increase in catalyst pressure drop. Whilst the literature would suggest that particulate concentrations of up to 115 mg/m$^3$ are possible, in the reference literature [Willey A.R.; Williams D. A., 2001 #34] a maximum concentration of 50 mg/m$^3$ is mentioned as a guideline.

- Catalyst life

The effective lifetime of the catalyst is largely dependent upon the nature of the air stream being treated. Lifetimes reported in the literature vary considerably over a range of 2 to 10 years, although they are more typically between 3 and 5 years. The catalyst replacement cost at approximately GBP 50000/m$^3$ is an important parameter in the calculation of operating costs.

### 4.12.15.3 Design considerations

The following design pointers are considered when evaluating the potential of catalytic incineration as a possible abatement solution.

- Odour removal performance

The likely odour removal performance of a catalytic incinerator will be in the region of greater than 95 %. The odour removal performance is affected by the operating temperature and the design space velocity of the system.

- Space velocity / operating temperature

The space velocity is defined as the reciprocal of the residence time of the gas within the catalyst block, with the volumetric airflow expressed at 0 °C. A typical range of space velocities used in industrial applications is between 20000m/hr and 45000m/hr. This corresponds to a residence time range of 0.03 to 0.1 seconds at typical operating temperatures. Essentially, there is a trade off between the amount of catalyst incorporated into the design and the operational temperature. The more catalyst and hence operation towards a space velocity of 20000m/hr, then the lower the operational temperature required in order to achieve a given performance. Thus, if the airflow to be treated is large then there is scope to incorporate additional catalyst, in order to reduce fuel costs by heating to a lower operational temperature. However, it should be noted that an increased catalyst charge will exhibit an increased pressure drop requiring additional fanning power. Thus, there will be an optimum operational condition for each system in terms of space velocity, temperature, catalyst volume and pressure drop.

- Catalyst pressure drop

The catalyst exhibits a linear relationship between flowrate and pressure drop which is due to the laminar flow within the catalyst. A typical design would allow for a total system pressure drop of approximately 500 mm Wg. The configuration of the catalyst block plays an important role in minimising pressure drop and hence operating costs.

- Heat recovery

Heat recovery is an essential part of the process and usually integrated within the design, using the treated gases to preheat the incoming gases. Heat exchangers are typically designed with an 80 °C heat recovery, which effectively results in a final discharge temperature between 150 and 200 °C for typical oxidation temperatures.

The catalytic oxidation is an exothermic reaction, so an increase in temperature over the catalyst is to be expected. The magnitude of the exotherm is dependent upon the type and concentration of the organic material in the inlet gases. There are installations where the exotherm is of sufficient magnitude to enable the catalytic oxidiser to operate in a self sustaining mode. This means that following the addition of fuel to warm the unit to operating conditions the fuel is no longer required to maintain the operating temperature.

- Safety requirements

There are a number of safety requirements which are effectively similar to those detailed for thermal incinerators:

  - there is a need to protect against flame flashback between the incinerator and the gas stream to be treated. This can generally be achieved via a flame arrestor or water seal
  - on start-up before the burner is ignited, the incinerator needs to be purged with air by a volume equivalent to 5 times the plant volume. Re-ignition of burners during operation are preceded by a burner purge period.

### 4.12.15.4 Catalytic incineration - advantages and disadvantages

Catalytic incinerators are generally suitable for controlling air stream with high odour concentrations in the absence of particulates. They can operate with air streams of variable temperature and odour load. In effect, a catalytic incinerator can be considered as an alternative to a thermal incinerator.

The advantages and disadvantages of catalytic incineration are detailed in Table 4.53. The suggested advantages and disadvantages are judged in comparison with thermal incineration.

| Advantages | Disadvantages |
|---|---|
| Reduced operating temperature required | Not as robust as thermal incineration |
| No need for special construction materials | Catalyst susceptible to poisoning |
| Reduced fuel costs | Relatively low $NO_x$ formation at operating temperatures |

**Table 4.53: Advantages and disadvantages of catalytic incineration**
**[Willey A.R.; Williams D. A., 2001 #34]**

## 4.12.16 New techniques

This review has concentrated on examining the relative merits of the various types of odour abatement techniques. The choice of techniques for review has essentially been based on those techniques that are commercially available and that have been installed for the abatement of odour emissions. The review has attempted to provide the reader with sufficient practical information to allow him to select the most appropriate abatement technique for his particular duty and to provide design guidelines and to identify potential pitfalls to allow him to assess manufacturers designs.

There are a number of possible techniques have not been included in the review. These techniques can be grouped as those techniques that are commercially available, although not used extensively for odour abatement, and those techniques which are currently under development and have not yet reached a commercially exploitable stage. The range of techniques falling within these two groups will not be covered in detail and are simply listed below, together with reasons why they have not been incorporated:

### 4.12.16.1 Techniques commercially available (not included)

| Technique | | Reason |
|---|---|---|
| i) Condensation | - | only applicable where economically beneficial to recover solvents, etc. |
| ii) Electrostatic Precipitation | - | primarily related to the removal of fine solids although potential to remove liquid aerosols. |

#### 4.12.16.1.1 Techniques under development

| Technique | | Reason |
|---|---|---|
| i) Plasma | - | plasma and microwave systems at development stage. At present not applicable to industrial flowrates. |
| ii) Membranes | - | only applicable where economically beneficial to recover solvents, etc. |

## 4.13 End-of-pipe treatment techniques - Waste water treatment

First of all it is important to stress that elimination, i.e. the reduction of water pollution at source, is applied instead of, or before, treating the waste water produced.

Waste minimisation techniques are widely applicable to the sector. Waste minimisation may achieve some or all of the following in relation to a specific waste water stream:

- reduction in the volume
- reduction in the strength
- elimination of, or decrease in, the concentration of certain substances
- suitability for recycling or re-use.

The techniques are discussed in the relevant sections, such as Section 4.3 (waste minimisation), Section 4.4 (water management, including methods for reduction or elimination of water consumption) and even in the section relating to energy efficiency (see Section 4.8). There are also examples in some of the sections relating to special sectors.

Even after undertaking extensive waste minimisation measures, some discharge of waste water from sites is inevitable.

There are many factors, which will influence waste water treatment. The main factors are:

a) volume and composition of effluent being discharged
b) receiver of the discharge, i.e. sewer, river, estuary, lake, sea, land etc
c) local situation, in terms of limits enforced, whether the municipality is supplying
d) cost of treatment, disposal, fees etc.

Points a) and d) will be discussed in the relevant sections for the different techniques. The requirements for the discharge are dictated by the receiving water and the selection from the available options for discharge of final effluents mainly depends on local conditions. However, irrespective of the receiving water, the adequacy of the plant to minimise the emission of specific persistent harmful substances needs to be considered.

### 4.13.1 Discharge of final effluent

The main final effluent discharge options are:

- discharge to public sewer without treatment, or after preliminary treatment only
- discharge to public sewer after partial treatment
- discharge to water course after full treatment.

Other options include:

- off-site treatment or disposal of strong or otherwise problematic waste water streams
- off-site re-use of certain waste water streams (e.g. as a feed stream in another industry, or for irrigation in the agriculture).

In rare cases, all of an installation’s waste water may be tankered or piped to an off-site industrial waste treatment facility or sewage treatment works. [13, **Environment Agency (UK)**, 2000]

Factors affecting choice of discharge option

The choice of discharge option must take into consideration many factors, including but not necessarily limited to:

- availability of suitable space for on-site treatment
- proximity and capacity of sewerage network
- capacity of local sewage treatment works
- proximity and characteristics of potential receiving waters
- availability of other off-site treatment or disposal facilities
- on-site treatment costs versus trade effluent costs and costs of any alternative off-site treatment/disposal
- relative effectiveness(based on reduction of load) of treatment on-site and off-site treatment at a sewage treatment works or elsewhere
- assessment of environmental risks associated with each option (e.g. sewer bypass)
- disposal of secondary wastes arising from on-site treatment
- ability to operate and maintain on-site treatment facilities
- consent negotiations with authority and/or sewerage undertaker and likely consent conditions
- projected trends in waste water volume and composition
- proximity of local residents.

Where it is essential for the installation to be close to the source of its raw material, i.e. in a remote location, there may be no alternative but to carry out full treatment and discharge to a local water course. In most cases, however, two or more options will merit detailed consideration. Waste water disposal may be a major factor in the choice of site for new installations.

The above mentioned are mainly valid for disposals (directly or indirectly) to natural waters. Disposal of waste water (partly or fully treated) to **land** (irrigation) may be the most appropriate environmental option. However this also depends on several factors, e.g. the composition of the waste water, local agricultural requirements and conditions, and on local legislation.

Several aspects are discussed relating to specific techniques. Legal obligations are important in the selection of a specific technique. As an *example*, waste water treatment requirements in Germany are summarised in Table 4.54.

| **Food industrial sector** | **Qualified sample or 2hour composite sample** | | | | |
|---|---|---|---|---|---|
| | $BOD_5$ | COD | $NH_4$-N | $N_{tot}$ | $P_{tot}$ |
| Sugar factories<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 18 | 25 mg/l | 200 mg/l | 10 mg/l | 30 mg/l | 2 mg/l |
| Edible fats and oils (Seed preparation), expectable requirements in future | 5 g/t | 20 g/t | - | 30 mg/l | 0.4 g/t |
| Edible fats and oils (Refining), expectable requirements in future | 38 g/t | 200 g/t | - | 30 mg/l | 4.5 g/t |
| Potato processing<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 8 | 25 mg/l | 150 mg/l | 10 mg/l | 18 mg/l | 2 mg/l |
| Fruit and vegetable processing<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 5 | 25 mg/l | 110 mg/l | 10 mg/l | 18 mg/l | 2 mg/l |
| Slaughtering and meat processing operations<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 10 | 25 mg/l | 110 mg/l | 10 mg/l | 18 mg/l | 2 mg/l |
| Fish processing<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 7 | 25 mg/l | 110 mg/l | 10 mg/l | 25 mg/l | 2 mg/l |
| Processing of milk and dairy products<br>No requirements at present. Following values will probably apply after 3rd revision of Waste water Ordinance | 25 mg/l | 110 mg/l | 10 mg/l | - | 2 mg/l |
| Fruit juice factories, soft drinks production<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 6 | 25 mg/l | 110 mg/l | - | - | 2 mg/l |
| Breweries and malt production<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 11 and Annex 21 | 25 mg/l | 110 mg/l | 10 mg/l | 18 mg/l | 2 mg/l |
| Distilleries, spirits production<br>Waste water Ordinance of 9.2.1999 (2nd revision), Annex 12 | 25 mg/l | 110 mg/l | 10 mg/l | 18 mg/l | 2 mg/l |

**Table 4.54 Requirements currently in force in Germany for discharge of waste water into rivers and lakes**
**[65, Germany, 2002]**

## 4.13.2 Selection in between off-site or on-site treatment of waste water

When technically and economically feasible / justified, decentralised waste water treatment, or treatment, at source may have the following advantages:

Treatment at source
- more flexibility for works enlargement, or for reacting to changing conditions
- facilities for treatment at source are tailor made and thus normally perform better
- operators of the production units demonstrate a more responsible attitude to the effluent when they are made responsible for the quality of their own waste water discharge.

Treatment off site
The main advantages of using a centralised WWTP are:

- making use of mixing effects, such as temperature or pH
- lower capital cost due to economy of scale
- more effective use of chemicals (e.g. nutrients) and equipment, thus decreasing relative operating costs
- dilution of certain contaminants which may be difficult to treat locally (e.g. emulsified fats, sulphate).

For the food industry, the usual scenario is to provide pretreatment (either locally, centrally or a combination of both) prior to discharge to a municipal WWTP or full-centralised treatment prior to discharge to receiving water. [13, **Environment Agency (UK)**, 2000]

Where effluent is treated off-site, the above factors apply, in particular that
- the treatment provided at the sewage treatment works is as good as would be achieved if the emission was treated on-site, based on reduction of load (not concentration) of each substance to the receiving water
- the probability of sewer by-pass, via storm/emergency overflows or at intermediate sewage pumping stations, is acceptably low
- a suitable monitoring programme for emissions to sewer, taking into consideration the potential inhibition of any downstream biological processes.

### 4.13.3 Waste water collection system, segregation

A well designed waste water collection system plays an essential role in effective waste water reduction and/or treatment. The collection system conveys the waste water to their appropriate treatment device and prevents mixing of contaminated and uncontaminated waste water.

There are generally four types of waste water present on a site:
- trade effluent,
- foul waste water (domestic),
- uncontaminated water (e.g. cooling water) and
- surface (storm) water.

For **new** installations the waste water collection system is designed so that the different types of waste water are segregated. However for existing installations this may not be possible to achieve due to the costs involved and the physical or engineering constraints present at specific sites.

The following factors are taken into account when designing a collection system for a new installation:

- segregate process water from uncontaminated rainwater and other uncontaminated water releases. The high volume, low strength streams may then be either re-cycled (following suitable treatment), or discharged directly to sewer (without treatment), or mixed with treated final effluent prior to discharge
- segregate domestic waste water (waste water from toilets, wash basins, canteens, etc.) from process and uncontaminated water that can be directly discharged to the sewer or treated separately.
- consideration needs to be given to the segregation of process water according to its characteristics, e.g. contaminant load.
- install separate drainage for areas of contaminant risk. Depending on the hazard and risk these drains can be either diverted to the main waste water collection system or to a dedicated sump to catch leakage or spillage loss. It may be possible to recycle losses back in the process if technically and economically feasible and justified.

By segregating low strength streams, a treatment facility can be reduced in size. Segregating sanitary waters may facilitate the treated process related waste water use on land. [13, **Environment Agency (UK)**, 2000]

### 4.13.4 Waste water treatment techniques applied – General aspects

The following paragraphs provide general information regarding techniques for the treatment of waste water in the food industry. *Techniques for individual sectors will be covered in Section 4.14.*

The description of the various techniques used in the treatment of the waste waters from the food industry follows the logical sequence that the techniques are likely to be used to achieve a progressively better quality effluent.

Owing to the nature of the raw materials used and the products produced, waste water arising from the food industry is primarily biodegradable in nature. Waste water treatment issues are due to:

- solids (gross and finely dispersed)
- free edible fat/oil
- emulsified material (e.g. edible oil/fat)
- soluble biodegradable organic material (BOD).

Examples of techniques to treat aqueous effluent streams are given below.
(No priority ranking is intended, and the appropriate selection in a particular case will depend on the specifics of the process concerned and on site constraints).

Techniques available

(a) **Primary Treatment**

- screening (F1)
- sedimentation / flotation (F2)
- dissolved air flotation (F3)
- pH Correction/neutralisation (F4)
- centrifugation (F5)

(b) **Secondary Treatment**

Chemical

- coagulation/flocculation/precipitation with sedimentation/filtration/flotation (F6)

Biological

- biofilters (F7)
- anaerobic treatment (F8)
- activated sludge/aeration lagoons (F9)
- extended aeration (F10)
- nitrification/denitrification (F11)
- spraying onto land (F12)

(c) **Tertiary Treatment**

- filtration/coagulation/precipitation (F13)

Application of techniques

The application of these techniques to treat the various aqueous effluent streams is given in Table 4.55.

| Emission Type | Technique |
|---|---|
| Soluble organic material (BOD/COD) | F6, F7, F8, F9, F10, F12 |
| Total suspended solids | F1,F2,F3,F5 |
| Acids/alkali | F4 |
| Oils/fats/greases (free) | F2,F3,F5 |
| Oils/fats/greases (emulsified) | F6,F8 |
| Nitrate, ammonia | F7,F9,F10,F11,F12 |
| Phosphate | F8,F9,F12,F13 |

**Table 4.55: Summary of techniques for treating aqueous effluent streams**
**[1, CIAA, 2002]**

However, waste water produced in different sectors displays considerable variations in composition and pollution levels, and a variety of processes are therefore used to purify it. A summary of the methods used in different sectors is presented in Table 4.56. Combinations of processes are frequently used to treat heavily polluted waste water (e.g. anaerobic preliminary treatment followed by an aerobic biological stage).

| | Breweries | Dairies | Production and processing of vegetable oils and fats | Distilleries and spirits production | Starch production | Sugar production | Soft drinks, fruit juice, mineral waters | Malt production | Meat processing | Wine and sparkling wine production | Sugar confectionery industry | Potato processing industry | Fruit and vegetable processing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mechanical preliminary treatment processes** | | | | | | | | | | | | | |
| Bar rack and screening | x | x | | x | x | | x | x | x | x | x | x | x |
| Filtration | x | | | | | | | | | | | x | x |
| Sedimentation (settling tanks, sand traps) | (x) | (x) | | x | x | x | x | | | | x | x | x |
| Flotation, gasoline separator, fat trap | | x | x | | x | | x | | x | | x | x | |
| Centrifugation (separator, centrifuge) | | | x | | | | | | | | | | |
| Mixing and equalising tanks | x | x | x | | x | x | x | x | x | x | x | | x |
| **Physico-chemical preliminary treatment processes** | | | | | | | | | | | | | |
| Precipitation, flocculation, coagulation filtration | | x | | | x | | | | | | x | | |
| Neutralisation | x | x | x | x | | | x | | | x | x | | x |
| **Biological processes:** | | | | | | | | | | | | | |
| **Biological pretreatment** | | | | | | | | | | | | | |
| Aerobic pretreatment | x | x | | | | | x | | x | x | x | x | x |
| Anaerobic pretreatment | x | x | x | x | x | x | x | | x | x | x | x | x |
| **Full biological treatment** | | | | | | | | | | | | | |
| Single stage activated sludge process | x | x | x | | x | x | x | x | x | x | x | x | x |
| Multi stage activated sludge process | | x | x | x | x | | x | | x | | | x | x |
| SBR (sequencing batch reactor) | x | x | | | | x | x | | | x | | | |
| Biofilters | x | | | | | | x | | x | x | | x | x |
| Sealed aerated lagoons | | x | | x | | x | x | | | | | x | X |

**Table 4.56: Waste water treatment options in different sectors**
**[65, Germany, 2002]**

### 4.13.5 Preliminary treatment

#### 4.13.5.1 Removal of gross solids and fat

For installations with gross solids (bone etc) and large quantities of non-emulsified fats, oils and greases, elimination of these will be required prior to discharge to an effluent treatment system. Gross solids are removed at source, where possible, with coarse screens or basket screens located in drainage points.

Bar racks and screens

The spacing between bars in coarse and fine bar racks in clarification plants is between 60 and 20 mm, or in special cases even less. However, if for example vegetable fragments are to be removed from the waste water from a canned food factory (peas, beans, carrots etc.), the spacing between bars must not exceed 5 mm.

The openings in automatic screens range from 5 mm to 0.5 mm, with openings of 1 to 3 mm in widespread use. Smaller openings (1 - 1.5 mm) are usually less susceptible to blockage than larger ones (2 - 3 mm). Screen types in use include fixed screens, drums, reciprocating screens and filter screens with circular holes or rectangular slots and wire cloth. Micro-screens (drum filters) effect a mechanical separation of solid particles from the waste water by means of microscopically fine fabrics. The most important operating parameter is the headloss (loss of operating pressure), with best separation results likely between 5 and 10 mbar. [65, Germany, 2002]

Filtration

Filtration methods are used to comply with stringent requirements regarding solids content. Unlike sedimentation or flotation, filtration does not require any difference in density between the particles and liquid. The separation of particles and liquid is brought about by a pressure difference between the two sides of the filter, which permits the passage of water through the filter. The particles are held back by the filter medium.

The following filtration methods can be distinguished:

- slow filtration
- fast filtration
- deep-bed filtration
- surface filtration
- biofiltration
- coagulation filtration.

[CIAA 2002, #1]

Gross fats, oils and greases are removed using a grease interceptor by using the imiscibility of the gross fat to separate it from the main body of effluent. The system does not usually require any chemical addition and as such an alternative use for the recovered fats may be investigated. [65, Germany, 2002]

Flotation, gasoline separator, fat trap

Flotation methods are used particularly for oily and fatty waste water in the food industry. The process of flotation is taken to mean the rising of both solid and liquid undissolved substances to the surface of the waste water through the attachment to gas bubbles. Since the separation of light liquids (gasoline), fats and emulsions is based on the same principles as flotation, it is also described in this section.

Flotation methods are classified on the basis of the way the air bubbles are generated:

- mechanical flotation
- dissolved-air flotation
- pneumatic flotation
- dispersion flotation
- electroflotation.

Separators for oils, fats and light hydrocarbons (gasoline) are standardised in DIN standards 4041, 4043 and 1999. According to the DIN standards, their efficiency should never be less than 95 %. A further development of the simple (DIN) separator is the parallel-plate separator. Here the separator chamber contains plates inclined at an angle of 45°[65, Germany, 2002].

#### 4.13.5.2 Flow and load equalisation

Buffer storage or balancing tanks are normally provided to cope with the general variability in flow and composition of waste water, or to provide corrective treatment, e.g. pH control, chemical conditioning.

If no balancing is provided, the operator may show how peak loads are handled without overloading the capacity of the waste water treatment plant. [13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002]

#### 4.13.5.3 Diversion tank

Where appropriate, contingency measures are included for accidental discharges from processes that could prove detrimental to the waste water treatment plant. A diversion tank capable of receiving typically 2 - 3 hours of peak flow is established. The waste water streams are monitored upstream of the waste water treatment plant so they can be automatically diverted to the diversion tank if need be. The diversion tank is linked back to the balance tank or primary treatment stage so that out-of-specification liquors can be gradually introduced back into the waste water stream. Alternatively, provision is made to allow for the disposal off-site of the calamity tank contents.

If a diversion tank is not provided, the operator may show how potentially detrimental streams are handled without them adversely affecting the waste water treatment plant. [13, **Environment Agency (UK)**, 2000]

#### 4.13.5.4 Screens

Coarse solids are normally removed by screening. A screen is a device with openings, generally of uniform size, that is used to retain the coarse solids found in the waste water.
The screening element consists of parallel bars, rods or wires, grating or a wire mesh or perforated plate. The openings may be of any shape but are generally circular or rectangular slots.

The main types of screens used are static (brushed or run-down screens) coarse or fine, vibrating and rotary screens.

1) static screens can be constructed of vertical bars or a perforated plate. This type of static screen requires manual or automatic cleaning

2) vibrating screens depend on a rapid motion for their effectiveness. Normal applications are for pretreatment associated with by-product recovery, particularly of solids with a low moisture content, and preferably not where the waste water contains grease. Vibrating screens operate between 900 rpm and 1800 rpm; the motion can either be circular, rectangular or square, varying from 0.8 to 12.8 mm total travel. The speed and motion are selected by the screen manufacturer for the particular application. Of prime importance in the selection of a proper fine vibrating screen is the application of the proper cloth, that is a cloth with the correct combination of wire strength and percentage of open area. The capacities of vibrating screens are based on the percent of open area of the filter media

3) rotary or drum screens receive the waste water at one end and discharges, the solids at the other. The liquid is passed outward through the screen (usually a stainless steel screen cloth or perforated metal) to a receiving box for forward transfer. The screen is usually cleaned by a continuous spray via external spray nozzles, that are inclined towards the solids discharge end. This type of screen is effective for streams containing relatively high solids contents.

The blinding of screens is a common problem. If it occurs regularly, consideration may be given to increasing the mesh size or improving the cleaning regime. [13, **Environment Agency (UK)**, 2000]

#### 4.13.5.5 Chemical pretreatments

After coarse solids are removed, further separation of the suspended solids is necessary. The efficiency can be enhanced using precipitation, flocculation and coagulation, or destabilisation of emulsion by adjusting pH.

Precipitation, flocculation, coagulation
When the solid particles cannot be separated by simple gravitational means, e.g. when they are too small, their density is too close to that of water or they form colloids / emulsions, then chemicals are added to cause the solids to settle.
Precipitation is used to convert the substance dissolved in the water into insoluble particulates by means of chemical reaction.

The chemical treatment process consists of three major parts:
- coagulation
- flocculation
- adsorption.

The first stage in the process is to destabilise the emulsion/colloidal system by reducing the potential responsible for the system stability. This is generally done by dosing inorganic chemicals such as aluminium sulphate, ferric chloride, or lime ($Ca(HO)_2$). The next step is the flocculation of small particles into larger ones, which can be readily settled or floated. This may entail the addition of polyelectrolytes to form 'bridges' in order to produce large flocs. Apart from coagulation-flocculation some precipitation of the metal hydroxides occurs and these hydroxides adsorb particles of fat. Following chemical treatment, sludges are removed by either settlement or DAF (dissolved air flotation).

Acidification
Another simpler technique to break oil / fat emulsions is acidification of the waste water followed by the addition of an organic polymer and by flotation.
A description of this treatment technique is given below:

1.) The pH of the inlet water is adjusted to approximately 4. The adjustment in pH breaks the emulsion, thereby increasing fat removal. Mineral acid is used for the pH adjustment, e.g. sulphuric acid or hydrochloric acid
2.) polymers/coagulants are added to give a more consistent FOG (fats oils and greases) removal (if this is required to achieve legal limits)
3.) the pH is corrected from acid to neutral (or suitable range) at the outlet of the dissolved air flotation unit.

[65, Germany, 2002]

If applicable, this technique is preferred over chemical treatment for the following reasons:

- chemical treatment plants produce large quantities of a solid waste which is becoming both costly and difficult to dispose of
- due to the addition of chemicals to the waste water, the dissolved solids/salt content may increase significantly in the treated water
- chemical treatment plants are difficult to operate as their performance is very susceptible to changing effluent characteristics and hence requires significant operator manpower
- operation of chemical treatment plants does not lend itself to automation.

In addition to chemical treatment, an alternative method for reducing the level of FOG is anaerobic biological treatment (see Section 4.13.10).

Neutralisation

Strongly acid or strongly alkaline waste water may cause corrosion, a reduction in efficiency of the biological treatment and/or a reduction in the self-purifying properties of lakes and rivers, and may cause operating problems for other water users.

The following are normally used to neutralise waste water which has a low pH:

- limestone, limestone slurry or milk of lime (hydrated lime $Ca(OH)_2$ )
- caustic soda (NaOH) or sodium carbonate ($Na_2CO_3$)
- ion exchangers (cationic).

The following are normally used to neutralise waste water which has a high pH:

- introduction of $CO_2$ (e.g. flue gas, gas from fermentation processes)
- sulphuric acid ($H_2SO_4$) or hydrochloric acid (HCl)
- ion exchangers (anionic).

[65, Germany, 2002]

## 4.13.6 Gravity separation

### 4.13.6.1 Sedimentation

Sedimentation is the separation from water, by gravity settling, of suspended particles that are heavier than water. The settled solids are removed as sludge from the bottom of the device.

### 4.13.6.2 Flotation

Flotation is the removal of material lighter than water (e.g. edible oil / fat). The material collecting on the water surface is removed by skimming. This technique is used widely in the food industry for the removal of free oil /fat from the waste water.

The basic mechanism of air flotation is to introduce small air bubbles into the waste water containing the suspended solids to be floated. The fine air bubbles attach themselves to the chemically conditioned particles and as they rise to the surface the solids float to the surface with them. Here they are accumulated, thickened and removed by mechanical skimming or suction withdrawal. Usually chemicals such as polymers, aluminium sulphate or ferric chloride are used to enhance the adhesion of bubbles. The method of air supply is used to define the process.

1) dissolved air flotation (DAF) occurs when air is injected and dissolved into the liquid under pressure and fine bubbles are released when the pressure in reduced
2) vacuum flotation occurs in a similar manner to DAF, except that the air is dissolved at atmospheric pressure and a sub-atmospheric vacuum is drawn to release the air.
3) induced air flotation occurs when fine air bubbles are drawn into the liquid via an induction device, such as a venturi or orifice plate
4) electroflotation occurs when electrodes placed in the liquid create hydrogen and oxygen bubbles.

DAF is most widely used because of its effectiveness in removing a range of solids. The principle behind DAF is that air is dissolved into effluent under pressure (40 - 80 psig = 3 - 6 bar). The air is normally introduced into a recycle stream of treated effluent which has already passed through the DAF unit. This supersaturated mixture of air and waste water flows to a large flotation tank where the pressure is released, thereby generating numerous small air bubbles. The flocculated particles rise to the surface of the reactor Through a combination of adsorption and entrapment

The choice of chemicals used for coagulation and flocculation will depend upon the intended disposal route for the DAF sludges. Should the sludges be recoverable as a by-product for possible animal feed, then the chemicals used need to be of low toxicity. Typically, sludges recovered from a DAF cell would be in the region of 3 – 4 % dry solids content. [13, **Environment Agency (UK)**, 2000]

Equipment

The equipment used for sedimentation and flotation are similar and can be either:

- rectangular or circular tanks equipped with the appropriate scrapper gear (top scrapper for oil/fat removal, and a bottom scraper for solids removal) and sufficient capacity to provide adequate residence time for separation to occur
- laminar or tube separators where plates are used to increase the surface area for separation.

| Advantages | Disadvantages |
|---|---|
| • Simplicity of installation, not liable to fail | • May occupy large surface area (rectangular or circular tanks) |
| | • Unsuitable for finely dispersed material |
| | • May be prone to blockage with fat (laminar separators) |

**Table 4.57: Advantages and disadvantages of gravity separation**
**[13, Environment Agency (UK), 2000; 65, Germany, 2002]**

| Advantages | Disadvantages |
|---|---|
| • Less land area required | • Higher operating costs |
| • Capital costs lower | • Pressurisation system may be prone to blockage problems. |
| • Higher separation efficiency | |
| • Can absorb shock loads | |
| • System is kept aerobic, thus less likely to create odour problems | |

**Table 4.58: Advantages and disadvantages of air flotation compared to gravity separation**
**[13, Environment Agency (UK), 2000; 65, Germany, 2002]**

### 4.13.6.3 High rate biofiltration

Waste waters from the processing of food and drink are often high in organic strength, generally too high for conventional aerobic treatment. Consequently, pretreatment is necessary to reduce the BOD to an acceptable level prior to discharge to a secondary biological treatment process or to foul sewer.

Roughing filters, or bio-towers can accommodate high organic and hydraulic loading, and are an effective method of reducing BOD to something closer to that of domestic sewage.

Bio-towers are above-ground tanks containing plastic media with a high surface area. Microbial film adheres to the media and consumes the organic material. The effluent is often recycled over the bio-tower to achieve further treatment. The effluent from these units is then discharged to a conventional biological process.

Plastic media of the type used in bio-towers has a surface area ratio of 100 -240 $m^2/m^3$. Loading rates of 0.5kg BOD/$m^3$/day are reported to achieve over 90 % removal; up to 60 % removal is possible with loadings of 2.5 kg BOD/$m^3$/day. [13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002]

Bio-towers can also be used to achieve nitrification but require low BOD loading rates.

#### 4.13.6.4 Centrifuges

There are three main types of centrifuge available;

- solid bowl
- basket
- disk-nozzle.

The disk-nozzle configuration is primarily used for liquid/liquid separation.

The basket and solid bowl centrifuges dewater in a batch process. The solid bowl configuration relies on the supernatant liquors to either be scraped from the surface or over-top a weir arrangement at the top of the centrifuge. The basket system uses a perforated mesh, so that the liquid phase passes through the filter medium during centrifugation. [13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002]

### 4.13.7 Secondary biological treatment

The operator justifies the choice and performance of the plant depending upon the level of treatment required. This is dependent upon the discharge route for the treated waste water (see Section 4.13.1).

Biological treatment is the degradation of dissolved organic substances with micro-organisms. Adsorption of pollutants to the organic sludge produced will also remove non -biodegradable materials such as heavy metals. Organic nitrogen and phosphorus can also be (partially) removed from the waste water.

There are essentially three types of metabolic processes:

- anaerobic processes, without oxygen supply
- aerobic, using dissolved oxygen
- anoxic processes, using the biological reduction of oxygen donors.

[13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002]

### 4.13.8 Aerobic processes

Common aerobic biological treatment techniques include:

- completely- mixed activated sludge process
- sequencing batch reactors
- trickling or percolating filter process
- high rate filters
- biologically aerated flooded filters (BAFFs)
- lagoons.

[13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002; 65, Germany, 2002]

#### 4.13.8.1 Suspended growth processes

**Activated sludge**

The biomass is aerated and maintained in suspension within a reactor vessel. It is the most commonly used method in the food industry. After a given residence time, based on an organic loading rate of about 0.1 kg BOD/kg MLSS/d (MLSS = mixed liquor suspended solids), the mixed suspension of micro-organisms is passed to a settlement facility. Here settlement of microbial flocs occurs and a clear effluent is passed over a weir to a watercourse. Settled sludge is produced and mostly returned to the aeration tank. However, a proportion (the excess sludge [or surplus activated sludge, SAS] due to growth and reproduction of organisms), is wasted in order to maintain MLSS at a reasonable level, e.g. 3000 mg/l.

Plants can use air, oxygen or a combination of the two. The use of oxygen improves control and performance and can be retrofitted to existing plants. However it would normally be preferable, on the grounds of minimising overall running costs, to size a plant to use air.

**Sequencing Batch Reactors**

The sequencing batch reactor is a variant of the activated sludge process. It is operated on the fill and draw principle and normally consists of two identical reaction tanks. The various stages of the activated sludge process; balancing, aeration, clarification are all carried out within the same reactor. Each of the three stages are carried out in sequence. In stage 1, waste water is fed into the reactor while aeration is taking place. In stage 2, waste water is diverted to a 2nd reactor whilst continuous mixing and aeration takes place in the 1st reactor. In the third stage, the aeration and mixing is stopped and the biomass is allowed to settle. After the settling period, a proportion of the treated effluent is decanted from the reactor. The time taken for each stage of the process can be adjusted to suit local circumstances

The main advantages of the sequencing batch reactor over the conventional activated sludge is capital cost and simpler and more robust operation (fill and draw system). The process sequence is independent of any influences caused by hydraulic input fluctuations. Another benefit is that batch-wise filling leads to the formation of a readily settling activated sludge, which means this process is also suitable for industrial waste waters that have a tendency to form bulking sludge.[65, Germany, 2002]

The process is very flexible but requires a greater degree of operator involvement, as a number of process changes are possible within the operating cycles (e.g. enhanced denitrification during the idle phase). [1, **CIAA**, 2002]

**Sludge bulking**

The most common problem associated with aerobic suspended growth processes is that of **bulking** activated sludge. This term is used to describe biological sludge of poor settling characteristics and is generally due to the presence of filamentous bacteria and/or excessive bound water within the biological floc. Filamentous bacteria are the most common cause of bulking sludge.

One important and fundamental point to emphasise regarding bulking sludge is that prevention is better than cure. A number of plants exist that are currently operating a ‘quick fix’ control of the problem, rather than understanding and solving the root cause of the problem. The operator ensures that the optimum balance of added nutrients is maintained, minimising both the release of nutrients and the occurrence of overproduction of filamentous bacteria or bulking.

The operator will usually have procedures in place to deal with bulking when it occurs including reducing load if necessary. The operator confirms whether *ammonia* is present as a breakdown product, provides evidence of the levels and states whether de-nitrification is needed. The hydraulic residence time, the sludge age and the operating temperature are the most important parameters to consider The parameters are to be justified in terms of the breakdown of the more resistant organic substances.

Generally aerobic activated sludge plants are designed to have hydraulic retention times in the order of 1 day and sludge loads below 0.15 kg BOD/kg MLSS/day (F:M ratio) in order to give high removal efficiencies, good stability and adequate breakdown of the more complex compounds present in the waste water. Higher operating temperatures will also aid degradation. Some aerobic plants are currently planned to operate at around 30 °C, but higher temperatures may be detrimental for the biological degradation. [1, **CIAA**, 2002]

**Lagoons**

In their simplest form, aerobic lagoons are large shallow earthen basins that are used for the treatment of waste water by natural processes, involving the use of both algae bacteria, sun and wind. Oxygen in addition to that produced by algae, enters the liquid through atmospheric diffusion. The contents of the lagoon are normally mixed periodically using pumps or surface aerators.

Lagoon systems offer the following advantages [65, Germany, 2002]:

- buffer capacity due to large areas and volumes
- volume and concentration equalisation in seasonal operations
- establishment of adapted biocoenoses given very long residence times.

A variation on the aerobic lagoon is the facultative lagoon, where stabilisation is brought about by a combination of aerobic, anaerobic and facultative bacteria.

Oxygen can be maintained in the upper layer of a facultative lagoon by surface re-aeration.

This process is widely used in the sugar industry.

### 4.13.8.2 Fixed film aerobic processes

In trickling and submerged aerated filter processes, the biomass grows on the surface of packing media and the waste water is distributed to flow evenly across the biomass film.

The trickling filter medium normally consists of rocks or various types of plastic. The treated liquid is collected under the media and passed to a settling tank from where part of the liquid can be recycled to dilute the strength of the incoming waste water. Variations include alternating double filtration (ADF) or permanent double filtration.

This type of process is applicable where the waste water is less concentrated. It tends to be used as a polishing stage after an activated sludge process or high rate biofiltration. Its use within the food industry has decreased because of the relatively large land area required and because of operational problems due to blockage.

### 4.13.8.3 Activated sludge configuration for nitrogen removal

**[65, Germany, 2002]**

Removal of plant nutrients may be needed. Phosphorus removal is generally made by chemical treatment. (Precipitation of insoluble phosphate compounds and their removal together with the excess sludge.) Nitrogen is removed in the form of ammonia or by a nitrification/denitrification process.

The following variants of the activated sludge process are used in the food industry:

a) Preceding denitrification

In preceding denitrification, the incoming waste water first enters the denitrification basin. $NH_4$-N passes through the basin unchanged, whereas organic N is partially hydrolysed to $NH_4$-N. In the subsequent nitrification basin, the hydrolysis is completed and the ammonium in particular is nitrified. The nitrate formed is transported via the return sludge and also via intensive recirculation from the nitrification basin outlet to the denitrification basin, where it is reduced to nitrogen by endogenous respiration.

b) Simultaneous denitrification
In a system with simultaneous denitrification, aerobic and anoxic zones are created on a targeted basis by controlling the input of oxygen into the basin. Simultaneous denitrification systems are mostly designed as circulation basins or carousel basins.

c) Intermittent denitrification
In intermittent denitrification, fully stirred activated sludge basins are periodically aerated. In the activated sludge basin, aerobic and anoxic processes take place successively in the same basin. The extent of nitrification and denitrification can largely be adjusted to the feed conditions by varying the operating times.

d) Cascaded denitrification
In cascaded denitrification, several basin compartments consisting of anoxic and aerobic tones (preceding denitrification) are arranged in series without intermediate clarification. The untreated water is fed into the first cascade to ensure optimum utilisation of the substrate present in the waste water. The return sludge flow is fed into the first basin. Here, there is no need for internal recirculation within the individual stages.

## 4.13.9 Further waste water treatment options

Developments in treatment techniques are traditionally slow, with the techniques presently in use, having been in use for many years. Presently, the main developments taking place which may have application within the food industry are: [1, **CIAA**, 2002]

- development of high rate aerobic systems
- development of ultra high rate aerobic systems
- membrane bioreactor
- use of membranes, ultrafiltration, microfiltration etc.

The first two operations give the potential for increasing the loading rates applied to aerobic systems and hence possibilities for reducing plant size and capital investment. However, most, if not all of the high rate systems suffer, in that they do not give a quality of effluent suitable for river discharge when operated at these higher loading rates. Hence a second aerobic stage, which is more conservatively loaded is required to meet river discharge standards. However, the combination of high and low rate systems reduce space requirements and reduce investment.

### 4.13.9.1 High rate systems

Systems, which are marketed as high rate systems, include:

- Bayer tower, Hoechst tower
- deep shaft, multi-reactor, Lurghi deep tank
- submerged biological aerated filters (SBAF, BAFF)
- membrane solids separation (ESMASP)
- suspended immobilised biomass reactors (Catir, Limpis, Ringlace)
- biological fluidised bed (air lift suspension reaction, oxitron)
- oxygen reactor (Vitox)
- Jet aeration systems
- multi-stage reactors (Böhnke A/B process)
- sequencing batch reactors (SBR), Omniflow, Unitank, CASS.

These systems operate across a range of loading rates, but can achieve a higher rate in a number of ways, i.e. increased static pressure increases the amount of dissolved oxygen thereby aiding mass transfer, using oxygen instead of air, using multi-stage to optimise the process etc.

If any of these systems are to be used, then very careful consideration and practical evaluation is undertaken.

### 4.13.9.2 Biological aerated flooded filters (BAFF) and submerged biological aerated filters (SBAF)

Biological aerated flooded filters (BAFF) and submerged biological aerated filters (SBAF) are hybrid suspended/attached growth systems, which are best described as activated sludge plants which contain high voidage media to encourage bacterial growth. Generally they also allow a certain amount of physical filtration within the same structure.

Backwashing takes place approximately every 24 hours to remove surplus biomass. As such, secondary clarification is not required. [13, **Environment Agency (UK)**, 2000]

### 4.13.9.3 Ultra high rate aerobic systems

Very high rate aerobic systems offer the potential for loading aerobic systems, up to 50 - 100 times greater than is presently the case. The process employs a high waste water recycle rate, directed through an integral nozzle assembly. Air is induced through the nozzle, providing a high shear force on the bacteria and an intense degree of turbulence/oxygenation. It is this high shear undergone by the bacteria which makes this process so different from other aerobic techniques, i.e. micro-organisms are passed through the nozzle resulting in the existence of only very small bacteria in the system, which differs from other systems where bacteria are not subjected to such shear and hence higher life forms also exist.

The very high loading rates that may be attainable with such a system make this extremely attractive with options that include reduced reactor size and reduced capital.

### 4.13.9.4 Membrane bioreactor

Membrane bio-reactors (MBR) are a variation on conventional activated sludge systems whereby a number of membrane modules, or ‘cartridges’, are placed within the body of the reactor vessel. Clarified effluent passes through the membranes, under static head pressure, to separate the treated effluent from the MLSS (mixed liquor suspended solid). The membrane can be either located within the aerated activated sludge tank or in an external loop.

The use of membranes allows a higher concentration of biomass to be retained in the aerated tank. A membrane bioreactor is a compact unit that produces less sludge. However the energy consumption (pumping) is significantly higher than conventional activated sludge.

Fouling of the membranes may be a major problem. Aeration and backwashing are used to try and control this problem, which may result in additional waste water being produced.
[13, **Environment Agency (UK)**, 2000]

Two distinct advantages are that no secondary clarifiers are required and also very high MLSS can be achieved (typically 12 - 17000 mg/l). Diffused air is used to scour and clean the membrane surfaces to prevent biofouling.

### 4.13.9.5 Membranes

The use of membranes as a means of waste water treatment within the food industry has not yet been used, but it does offer the following potentials:

- concentration of effluent streams to reduce volumes prior to further treatment/disposal, e.g. possible concentration of dilute waste to concentrations suitable for rework
- possible recovery of expensive ingredients for re-use or return/sales to suppliers
- recovery of ingredients/materials at source
- recovery of water for re-use.

The major problem over the use of membranes, as an alternative to traditional effluent treatment, is that of the fouling of the membranes, gel polarisation etc. The flux rates through the membrane are relatively low, meaning extensive membrane area (and capital) is required to recover material, which often only has a low/moderate economic value. The operating cost associated with the use and cleaning of membranes can be very high and additional waste water may be produced.

The only general application of membranes in the food industry is as part of the manufacturing process, e.g. concentration of whey from cheese manufacture.

#### 4.13.9.6 Multi-stage activated sludge systems

Multi-stage systems are combinations of processes arranged in series. Waste water treatment takes place successively in individual stages, which are kept separate from each other by means of separate sludge circuits. The following process combinations are used:

1. Activated sludge - Activated sludge
2. Trickling filter - Trickling filter
3. Trickling filter - Activated sludge
4. Activated sludge - Trickling filter
5. Combined lagoon systems

[65, Germany, 2002]

| Advantages | Disadvantages |
|---|---|
| • Cost effective treatment of soluble organic matter (activated sludge, BAFF reactors) | • High energy usage (activated sludge and fixed bed reactor) |
| • Degradation into harmless compounds | • Large quantities of sludge produced |
| • Widely used in food industry (activated sludge) | • Can be difficult to operate (e.g. bulking sludge with activated sludge) |
| | • Stripping affects resulting in fugitive releases often the cause of odours/aerosols |
| | • Large land area required (activated sludge) |

**Table 4.59: Advantages and disadvantages of aerobic treatment processes**
**[13, Environment Agency (UK), 2000; 1, CIAA, 2002; 65, Germany, 2002]**

### 4.13.10 Anaerobic processes

Anaerobic treatment, as with aerobic treatment, is an intensification of a natural process. Organic matter is broken down, in the absence of oxygen, producing methane ($CH_4$) as a by-product.

The biological treatment of effluent by anaerobic processes is beginning to be accepted as an appropriate technique within industry. In this respect, the UK is somewhat lagging behind other countries where anaerobic treatment has been used successfully for a number of years.

Anaerobic effluent treatment is generally only applicable (and cost effective) for those effluents which are more readily biodegradable. The strength of the effluent is also an important factor and is generally applicable where the COD is greater than 1500 - 2000 mg/l. The limiting factor here is economics. Higher BOD loadings are achievable with anaerobic technique (in terms of kg BOD/$m^3$ of reactor volume) meaning that the size of the reactor for weaker effluents is still relatively large hence the installation becomes economically un-viable.

The applications for anaerobic waste water treatment are largely confined to fairly heavily polluted waste water with a COD between 3000 and 40000 mg/l from the food industry (sugar, starch, yeast, fruit and vegetable factories, distilleries). There has recently been some success in using certain anaerobic systems even for less heavily polluted waste water with a COD between 1500 and 3000 mg/l, for example in breweries, dairies and in the fruit juice, mineral water and soft drinks industry. [65, Germany, 2002]

One of the most fundamental aspects of anaerobic effluent treatment is that the vast majority of organic carbon associated with the influent BOD is converted to methane as opposed to new cell growth. The opposite is true with aerobic processes, which convert most of the organic carbon to new cells which eventually form waste biosolids that require either further treatment or off-site disposal. Anaerobic processes produce much less waste sludge. Also the methane produced has a high calorific value and as such can be re-used as fuel elsewhere in an installation.

An anaerobic system alone would not achieve a final effluent quality high enough for discharge to a watercourse. Anaerobic installations are followed by an aerobic system as the latter achieves lower absolute release levels, will remove hydrogen sulphide and ensure that the final effluent is well aerated to assist in the breakdown of the remaining BOD. The energy gained from the anaerobic plant can be equivalent to that consumed by the aerobic plant. In certain circumstances the aerobic treatment may be the local sewage treatment works operated by the Water Company. This will depend upon the receiving works and the balance between trade effluent charges and an on-site aerobic treatment stage. The anaerobically treated effluent may be flash aerated on-site prior to transfer to a sewage treatment works. This is normally carried out in a post treatment holding tank providing positive dissolved oxygen levels before being discharged to sewer.

The methanogenic bacteria (essentially the final stage of the anaerobic process producing methane gas) need to be protected from excessive chlorinated and sulphur compounds, pH and temperature fluctuations and the plant made more robust by an acidification stage in which other bacteria will predominate and break down many of the substances which cause the problems.

For those sites producing higher strength effluent that do employ anaerobic treatment, it is worth considering the main advantages and disadvantages of the anaerobic treatment process.

| Advantages | Disadvantages |
|---|---|
| • Low specific surplus sludge production; the lower growth rates mean lower macro/micro nutrient requirements | • Can generally only be utilised as a pretreatment stage; no nitrogen and phosphorus elimination |
| • Low energy requirements due to lack of forced ventilation | • Mesophillic bacteria (which thrive at temperatures between 20 and 45 ºC,) may require external source of heat |
| • Generally lower running costs associated with decreased sludge production and lower mixing costs | • Generally higher capital build cost |
| • Produces biogas that can be used for power or heat generation | • Low growth rate requires good biomass retention |
| • Small space requirements | • Initial commissioning/acclimatisation phase can be long |
| • Particularly suitable for seasonal industrial operations (e.g. sugar industry), as the anaerobic biomass can be reactivated in only few days after a break of several months. | • Anaerobic systems are more sensitive than aerobic systems to fluctuations in temperature, pH, concentration and pollution loads. |
| • Some substances that cannot be degraded by aerobic means can be degraded anaerobically (e.g. pectin, betain). | • Some constituents of treated effluent can be toxic / corrosive (e.g. $H_2S$) |
| • Less odour problems (if appropriate abatement techniques are employed) | • Generally require more ‘steady state’ conditions and are less tolerant to toxic shock |
| • Can be easily decommissioned for extended periods and remain in a dormant state (useful for seasonal manufacturing processes e.g. sugar beet) | |

**Table 4.60: Advantages and setbacks of anaerobic waste water treatment compared to aerobic treatment**
**[13, Environment Agency (UK), 2000; 1, CIAA, 2002; 65, Germany, 2002]**

Anaerobic techniques are generally utilised in those industries where there is a **high level of soluble and readily biodegradable organic material**. As the organic content is readily available as a substrate for the anaerobic bacteria, the time required for biodegradation is much less, and this therefore also reduces the required hydraulic retention time (HRT).

Anaerobic plants are usually designed to maximises methane production for collection and burning for energy production.

Modern reactor designs permit higher loading rates, increase biogas production and offer greater stability. Once the bacterial populations in such systems are adapted to the waste water then increased stability occurs.

Every on-site treatment facility that relies upon an anaerobic reactor as the main treatment process, possesses a similar layout. All must have a factory waste water collection sump/vessel or balancing tank from which the waste is pumped/flows to a primary treatment tank. The primary treatment processes are as described above for aerobic systems.

From the primary treatment stage the effluent is passed to a conditioning or buffer tank where the waste water is "conditioned" (pH correction, nutrient addition) before it is passed via the influent distribution system through to the bioreactor. Early anaerobic reactors allow the initial stages of the anaerobic metabolism to be initiated in the conditioning tank (often referred to as the acidification tank). Modern reactor designs allow all the metabolic pathways to take place in the reactor. The conditioning tank is therefore generally only required for pH correction and nutrient addition.

Treatment occurs in the reactor, producing biogas which must be collected and disposed of by burning in a flare or boiler facility. Other components often included are a sludge storage tank, vent gas disposal and post or pretreatment facilities.

There are three main types of basic anaerobic reactor configurations.

### 4.13.10.1 Anaerobic contact processes

The anaerobic contact process can be likened to the aerobic activated sludge process as separation and recirculation of the biomass is incorporated into the design. Since the anaerobic sludge continues to produce gas outside the reactor and the gas volume continues to rise, there is frequently a need for a degasification unit between the methane reactor and the separator unit. This degasification may, for example, be achieved by means of vacuum degassing, stripping, cooling or slowly rotating agitators. This feature allows the process to be operated at 6 - 14 hr retention times.

Compared with the high-performance processes described below (UASB, fixed bed, fluidised bed), contact stabilisation processes do not produce such high biomass concentrations in the reactor and are therefore run at comparatively lower space loadings (usually around 5 kg COD/m$^3$d). Their main advantage, however, lies in relatively trouble-free operation and, in particular, their lack of clogging problems. [13, **Environment Agency (UK)**, 2000]

### 4.13.10.2 Anaerobic filter

**[13, Environment Agency (UK), 2000; 1, CIAA, 2002; 65, Germany, 2002]**

In the anaerobic filter the growth of anaerobic bacteria is established on a packing material. The packing retains the biomass within the reactor, it also assists in the separation of the gas from the liquid phase. The system can be operated in the upflow or downflow mode.
Anaerobic filters are, in particular, suitable for treating heavily polluted waste waters having COD of 10 - 70 thousand mg/l.

### 4.13.10.3 Upflow Anaerobic Sludge Blanket (UASB)

In the upflow anaerobic sludge blanket system, the waste water is directed to the bottom of the reactor for uniform distribution. The waste water passes through a blanket of naturally formed bacterial granules having good settling characteristics so that they are therefore not easily washed out of the system. The bacteria carry out the reactions and then natural convection raises a mixture of gas, treated effluent and sludge granules to the top of the reactor. Patented 3-phase separator arrangements are used to separate the final effluent from the solids (biomass) and the biogas.

This process is particularly suitable for waste water with a low solid content and with relatively low (COD < 20000 mg/l) pollution levels.
Sludge-bed reactors are currently the most widespread reactors in the food and milk industry. A particular advantage of the process lies in the formation of pellets. This permits not only rapid reactivation after month-long breaks in operation, but also the sale of surplus sludge pellets (e.g. for inoculation of new systems).

Loadings of up to 60 kg COD/m$^3$/day have been reported, but more typical would be a loading rate of 10 kg COD/m$^3$/day with an HRT of 4hr. [13, **Environment Agency (UK)**, 2000]

### 4.13.10.4 Fluidised bed reactors

Fluidised-bed reactors are reactors in which the carrier material (usually sand, sometimes pumice or plastic pellets) is kept in suspension by means of high recirculation rates. The recirculation must be strong enough to keep the carrier material in suspension, but care must be taken to ensure that excessive circulation does not cause the biomass to become detached from the carrier material. In the fluidised-bed reactor the carrier material is constantly in motion, with a bed expansion of 50 % or more. To achieve high volume-time yields of 20 kg COD/m$^3$ per day and over, it is absolutely essential to fill the methane reactors with as constant a volume of adequately acidified solids-free waste water as possible. For this reason all large-scale systems have been built as two-stage systems, i.e. with a separate acidification stage. In operational large-scale systems the waste water for treatment has relatively low pollution loads with an average COD of between 1500 and 3600 mg/l. [65, Germany, 2002]

### 4.13.10.5 The IC reactor (internal circulation)

The IC Reactor (internal circulation) is based on the proven UASB technique and is an up-flow granular sludge bed system. The IC reactor consists of two UASB reactor compartments on top of each other, one high loaded and one low loaded. The biogas collected in the first stage drives a gas-lift resulting in internal recirculation of waste water and sludge, hence the process name.

One of the main advantages of the IC reactor is that it can undergo a certain amount of 'self-regulation', irrespective of the variations in incoming flows and loads. As the load increases, the quantity of methane generated also increases, and further increases the degree of recirculation and hence dilution of the incoming load. Typical loading rates for this process are in the range: 15 - 35 kg COD/m$^3$d. [13, **Environment Agency (UK)**, 2000]

### 4.13.10.6 Expanded Granular Sludge Blanket (EGSB)

An expanded Granular Sludge Blanket (EGSB) is similar to the aerobic filters reviewed previously. The EGSB process also incorporates a support media, often no more than sand or synthetic plastic materials. Light materials are often used in order to minimise the up-flow velocities required to fluidise the beds, particle sizes are typically in the range: 0.3 - 1.0 mm.

If the particles and biomass are completely mixed, the process is known as a fluidised bed, whereas a partially mixed system is known as an expanded bed. Typical loading rates for this process are in the range: 15 - 35 kg COD/m$^3$d. [13, **Environment Agency (UK)**, 2000]

### 4.13.10.7 The Hybrid process

The Hybrid process is a further variation of the conventional UASB, incorporating a packed media zone above the main open zone. This allows for the collection and retaining of non-granulated bacteria which, in conventional UASB reactors, would be lost from the process.

The lower sludge zone acts in exactly the same way as within a conventional UASB reactor and is responsible for the majority of the biodegradation of the organic material.

The role of the micro-organisms and media in the packed zone is to provide a certain amount of polishing treatment, to hold biological solids in reserve, and to prevent the biomass from washing out of the reactor.

Anaerobic hybrids are high rate systems with typical loading rates in the region of 10 - 25 kg COD/m$^3$ per day. [13, **Environment Agency (UK)**, 2000]

#### 4.13.10.8 Operational problems

Common operational problems experienced with anaerobic treatment processes are;

| | | |
|---|---|---|
| **Lack of macro-nutrients** | ⇒ | BOD:N:P ratios are normally maintained at 500:5:1 |
| **pH** | ⇒ | In the reactor, the pH is maintained at 6.8 - 7.5 |
| **Temperature** | ⇒ | In the reactor, the optimum temperature for mesophillic bacteria is 35 – 37 ºC. |
| **Lack of micro-nutrients** | ⇒ | Minimum quantities of micro-nutrients are maintained, especially for Fe, Ca, Mg and Zn, according to the specific process employed |
| **Waste water composition** | ⇒ | Significant quantities of fats, oil (especially mineral oil) and greases are removed prior to the reactor |
| **Physical blockage of the reactor inlet pipework** | ⇒ | Effective screening and primary treatment is essential |
| **Overloading** | ⇒ | Care needs to be taken to ensure the original hydraulic, solid and organic loading design rates do not exceed the manufacturers recommendations. |

Some recent advances in the anaerobic treatment technique have led to a number of variations of the process developed and successfully marketed in the UK. [13, **Environment Agency (UK)**, 2000]

### 4.13.11 Tertiary treatment techniques

Tertiary treatment refers to any process that is considered a "polishing" phase after the secondary treatment techniques, up to and including disinfection and sterilisation systems. The need for tertiary treatment is dictated by two potential factors:

- consent to discharge conditions as set down by the local Water Company (sewer discharge) or the Environment Agency (discharge to water course)
- recycling of effluent back into the factory, either as process water or low grade wash water.

Tertiary treatment can be employed to meet stringent consent standards for discharge to controlled waters. In addition to the 'standard' consented parameters (COD/BOD, suspended solids, pH, temperature, flow) there are a number of other parameters which may need specialised (i.e. tertiary) treatment techniques, depending on the nature of the manufacturing processes and the quality of the receiving waters.

'Special' consent conditions can apply for the following:

Ammonia: Usually removed in the secondary biological stage by allowing for extended sludge time periods to facilitate the proliferation of nitrifying bacteria. However, it is also fairly common to install separate tertiary biological nitrifying filters. These are usually variations on the standard percolating or high rate aerobic filters and may follow activated sludge plants or attached growth systems.

Dangerous Substances Directive: the Framework Directive on pollution caused by certain dangerous substances discharged into the aquatic environment (76/464/EEC), establishes the List I (particularly dangerous) and List II (less dangerous) groups of substances, on the basis of their toxicity, persistence and bioaccumulation. List I and II substances are controlled by setting Environmental Quality Standards, which must be respected when setting discharge permits.

List I substances (or "Black List"): 17 accredited substances, established in Daughter Directives to 76/464/EEC. Pollution by these substances must be eliminated under the Directive.

List 2 substances (or "Grey List"): Substances identified by Member States (about 50 substances identified in the UK), pollution from which must be reduced.

Removal of many complex organic and inorganic compounds can be implemented through the appropriate use of membrane technique.

Suspended Solids: A tertiary solids removal filter may be required in order to achieve the consent to discharge. Depending on the severity of the problem and the nature of the solids, a standard sand or dual media filter (sand/anthracite) may be acceptable.

There are now a number of constantly 'self cleaning' sand filters available which have proven to be extremely effective at polishing suspended solids from the final effluent. [13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002; 65, Germany, 2002]

### 4.13.11.1 Macrofltration

Macro filtration describes the tertiary removal of suspended solids, usually through the use of sand filtration or mixed media (e.g. sand/anthracite blends). Filters may be either gravity filters or pressure filters.

More specialised types of filtration media, such as Granular Activated Carbon (GAC), are used to remove certain chemicals, tastes and odours. GAC works by adsorbance of the contaminants onto and within the carbon granules. [13, **Environment Agency (UK)**, 2000]

### 4.13.11.2 Membrane techniques

Membrane techniques are a group of processes that can be used to separate suspended, colloidal and dissolved solutes from process waste water. Membrane filtration processes use a pressure driven, semi-permeable membrane to achieve selective separations. Much of the selectivity is established by designations relative to pore size. The pore size of the membrane will be relatively large if precipitates or suspended materials are to be removed (crossflow microfiltration), or for very small for the removal of inorganic salts or organic molecules (ultrafiltration or reverse osmosis). During operation, the feed solution flows across the surface of the membrane, clean water permeates through the membrane, and the contaminants and a portion of the feed remain. The clean or treated water is referred to as the permeate or product water stream, while the stream containing the contaminants is called the concentrate, brine or reject.

The techniques employed depend on the level of 'filtration' that is actually required, and generally consist of:

- micro filtration
- ultra filtration
- nano filtration
- reverse Osmosis.

Cross-flow Microfilters use membranes with pore sizes in the range of 0.1 - 1.0 micron. The feed stream does not require extensive pretreatment, while the membrane is relatively resistant to fouling and can be easily cleaned. A CMF system would be effective for removing gross contaminants from feed streams, but would not be an effective pesticide treatment unless the active ingredients were relatively insoluble or were attached to the suspended material. CMF is also a process which has found application in the UK to remove heavy metals from industrial waste waters.

Ultrafiltration is similar to CMF, but the UF membrane has smaller pores (0.001 - 0.02 micron). The smallest pore size UF membrane has the capacity to reject molecules with diameters greater than 1 nm or nominal molecular weights greater than 2000. Some pretreatment may be necessary to prevent membrane fouling. For most UF designs the introduction of adsorbents or flocculants to the feed stream is not recommended since they may plug the membrane module. OF systems are also capable of recovery of up to 90 to 95 % of the feed as product water.

Reverse osmosis (RO) systems have the ability to reject dissolved organic and inorganic molecules. The osmotic pressure difference between the feed and the product is exploited to split the feed solution adjacent to the membrane wall. The purified solution permeates through the membrane. Typically, membranes with a pore size of 0.1 to 1 nm are used to remove pesticides and heavy metals. RO membranes have been used to remove pesticides whose active ingredient molecular weights are greater than 200.

RO membranes are very susceptible to fouling and may require an extensive degree of pretreatment. Oxidants which may attack the membrane and particulates, oil, grease and other materials which may cause a film or scale to form, must be removed by pretreatment or the membrane must be subjected to frequent cleaning cycles. RO product streams are normally of very high quality and suitable for discharge, or more importantly, re-use in the manufacturing process. Standard practice is to dispose of the reject stream or to apply a suitable treatment to the concentrated brine. The recovery that can be obtained as well as the operating pressure required, will be a function of the type of dissolved solids and their concentrations.

Electrodialysis is also a membrane filtration process. It enables ionic separation by using an electrical field as a driving force as opposed to a hydraulic force. The membranes utilised are adapted to make them ion selective (for cations and anions). A number of cells are required to make up the complete electrodialysis unit. [13, **Environment Agency (UK)**, 2000]

### 4.13.11.3 Sterilisation and disinfection techniques

Sterilisation and disinfection techniques all operate on the same basic principle, they affect the cell structure within bacteria and prevent their replication. There are three main techniques for achieving this.

1) oxidising biocides, which oxidise the bacterial cells walls in order to prevent replication. They rely on the use of strong oxidising agents such as chlorine/bromine, ozone and hydrogen peroxide

2) the use of chlorine compounds (chlorine gas, chlorine dioxide, sodium hypochlorite), which rely upon the formation of hypochlorous acid (the active biocide) in aqueous solution

3) bromine based biocides, which are becoming more prevalent in industrial applications due to the hypobromous acid species dissociating at a higher pH than the equivalent chlorine based compounds.

The main disadvantage of chlorine based chemistry is the ability of chlorine to react with a wide number of other compounds which can cause a reduction in the ‘effective’ chlorine dose rate.

This situation is further complicated by the formation of ‘chloramines’ and other organo-halogen compounds, many of which are dangerous to living organisms, so the discharge which will be tightly controlled within the receiving water.

The use of ozone is also increasing for disinfection purposes.

Non-oxidising biocides operate by chemically altering the cell structure in order to prevent bacterial cell replication. They are becoming more common, some examples are quaternary ammonium salts and formaldehyde/glutaraldehyde.

UV Light is perhaps the most significant advancement in disinfection technique over the past 10 years. UV light at 254nm is readily absorbed by the cellular genetic material within bacteria and viruses, which prevents the cell from replicating.

The main advantages of UV disinfection over other techniques includes, no storage or use of dangerous chemicals, the absence of harmful by-products (no organohalogens) and it is a simple technique with relatively low capital and operating costs.

The dose rate is measured in milliwatts per square centimetre multiplied by the contact time in seconds. The actual dose is dependant on the transmittance (i.e. compounds which can absorb and reduce UV light effectiveness) of the waste water stream.

The main disadvantage of UV disinfection, is that a direct line of sight must be maintained between the lamp and the bacteria/virus. Any appreciable levels of suspended solids or turbidity (hence decreasing transmisivity) will actually shield the bacteria and prevent their disinfection.

UV light is also an immediate reaction which therefore does not impart any residual effect of treated waters being liable to re-infection. [13, **Environment Agency (UK)**, 2000]

| Advantages | Disadvantages |
|---|---|
| **Chlorination**<br>• Effective disinfectant<br>• Relatively low cost<br>• Oxidises organic matter | • Organic compounds present in waste water may react with chlorine to form toxic compounds |
| **Ozonisation**<br>• Effective disinfectant<br>• Oxidises organic matter | • Moderately high cost<br>• Unstable, must be generated as used<br>• Toxic ozonides may be formed |
| **UV Radiation**<br>• Effective disinfectant provided if low solids content present and turbidity low | • Moderately high cost<br>• Efficiency effected by presence of solids or turbidity<br>• Must be generated as used |

**Table 4.61: Advantages and disadvantages of disinfection techniques**
**[13, Environment Agency (UK), 2000; 1, CIAA, 2002]**

## 4.13.12 Sludge treatment and disposal

Sludge treatment and disposal is quite often left until last when companies consider on-site effluent treatment. However, in terms of capital expenditure and operating costs, sludge treatment and disposal can prove as expensive (if not more so) than the rest of the effluent treatment plant. Whilst environmental legislation continues to limit the disposal options available, or significantly increase the associated cost, the management and disposal of solid waste will remain one of the most fundamental issues facing the effluent plant operator.

Before considering on-site sludge treatment and potential disposal routes, the plant operator may be more concerned with how to reduce the cost of disposal. This is generally associated with a reduction in sludge volume rather than the optimisation of an on-site treatment process.

It is assumed that any product recovery that can take place has already been achieved, and as such, any solid material that cannot be recovered must be disposed of in an environmentally acceptable way and the costs absorbed into the overall running cost. In addition, any aerobic biological treatment process employed will, by its very nature, convert a high proportion of the organic load to new bacteria cells, the wasting of which (as surplus activated sludge) will further contribute to the solid material that requires disposal. The quantity of sludges produced for disposal from an anaerobic system are significantly less. [13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002; 65, Germany, 2002]

### 4.13.12.1 Sludge treatment techniques

Sludge treatment techniques are generally employed to either:

- reduce the volume of sludges produced for disposal, or to
- change the nature of the sludge
    - to a form suitable for re-use (e.g. land application) or
    - for landfill (highly biodegradable sludges are no longer encouraged at landfill sites and, as with all materials going to landfill, will attract landfill tax and disposal charges.).

Typically, volume reduction through dewatering can occur on-site, whereas further sludge treatment would be carried out elsewhere.

The main cost savings are made by reducing the volume of sludge for disposal. This will lead to a cost saving in terms of:

(a) reduced tankering charges
(b) reduced landfill reception charge (if going to landfill).
[13, **Environment Agency (UK)**, 2000]

The main emphasis will be on reducing these costs by thickening the sludge. It should be noted that the final disposal route for sludges liberated from an effluent treatment plant will dictate the level of treatment required, hence the disposal options for sludges are investigated during the early stages of design.
The ultimate disposal /use of the treated sludge (e.g. landfill, landspreading, incineration, etc) has not been included in this document.

The treatment techniques normally applied in the food industry are detailed below.

### 4.13.12.2 Conditioning

The purpose of conditioning is to improve the characteristics of the sludge so that it is easier to thicken and/or dewater. The techniques generally used are:

- chemical
- thermal.

### 4.13.12.3 Sludge thickening

Sludge thickening can be applicable to both secondary biological surplus sludge and primary sludge. Primary solids consist mainly of inorganic material and/or primary organic solids. They are able to settle and compact generally without chemical supplementation. As such associated water is not excessively ‘entrained’ within the sludge. The opposite occurs for secondary biological sludge, whereby the water is bound within the flocs and hence is generally more difficult to dewater and conditioning is generally applied.

Sludges that are taken from the bottom of primary and secondary settlement tanks will generally be around 0.5 - 1.0 % dry solids content, with slightly higher values (up to 4 % dry solids) for dissolved air flotation. The most straightforward dewatering technique is to allow the sludges to consolidate further in sludge settlement tanks. A number of key design points are considered when opting for this technique:

- The efficiency of the dewatering process is affected by the height of the sludge layer and not by the volume of supernatant above it. Therefore, the tank may have a specific aspect ratio favouring a tall and narrow tank rather than a low tank with a large surface area.

- Depending upon the details of the primary solids/surplus sludge removal pattern, consideration is given to two tanks to allow for quiescent settling of one tank whilst the second is in the fill cycle. If this is not possible, arrange the sludge inlet to be near the top of the tank, possibly onto a baffle plate, to minimise hydraulic disturbance.

- Allow for gentle agitation within the tank (a picket fence thickener within the tank is most commonly used) to help reduce stratification of the sludge and to assist in the release of any entrained gases and water.

- Residence time within the tank will be entirely dependent upon the nature of the sludges and excessive retention must be avoided to minimise the possibility of anaerobic conditions occurring with consequent odour and corrosion problems.

- Addition rates to the thickener are in the range of 20 - 30 $m^3$ of feed/$m^2$ of surface area/day.

A conventional gravity/picket fence thickener is capable of thickening the sludge up to 4 – 8 % dry solids, again dependent on the nature of the raw sludge and in particular the relative content of primary sludge.

The techniques generally used to achieve the above are:
- gravity
- centrifugal
- flotation.

For many sites, sludge thickening alone is sufficient to reduce the volume of sludge to a level that enables off-site disposal to be undertaken in a sufficiently cost effective manner. For larger sites, the thickening process is a first stage prior to further dewatering.
[13, **Environment Agency (UK)**, 2000; 1, **CIAA**, 2002; 65, Germany, 2002]

### 4.13.12.4 Sludge dewatering

The objective is the same as that is of thickening but the solid content is much higher. Sludge over 10 % dry solids becomes difficult and expensive to pump. Dewatering produces a sludge ‘cake’, which may be between 20 - 50 % dry solids, which will in turn significantly reduce disposal costs.

In most cases, further dewatering will first require some form of chemical conditioning, to assist in the separation of the bound and entrained water from within the sludge.

A number of sludge dewatering processes exist and selection will depend upon the nature and frequency of the solids produced, and the sludge cake required:

Dewatering techniques generally used are:
- centrifuge
- belt filter press
- filter press
- vacuum filters.

Centrifuges are continuous processes which produce a cake of up to 40 % dry solids for certain sludges. Because of the ‘closed’ nature of the centrifuge, associated odour problems are minimal.

Filter (or plate) presses are batch processes, and can be manually intensive. The “plates” are covered with a suitable filter cloth (dependent upon the application) and the sludge is fed into the plate cavity. The sludge is dewatered under pressure with the filtrate passing through the filter cloth. Once the pressure is released and the plates separated, the cake is either manually scraped off or vibration mechanisms are employed to automate the process. A filter press can produce up to 40 % dry solids cake.

The belt press and vacuum filters are continuous processes with the filter cloth continually running through rollers that forcefully dewater the sludge. Performance optimisation requires regular and specialised maintenance. A belt press can produce up to 35 % dry solids cake. Chemicals costs are generally quite high.

Advantages and Disadvantages of Sludge Treatment Techniques
Thickening / Dewatering

| Advantages | Disadvantages |
|---|---|
| **Gravity Thickening** | |
| • Low cost<br>• Low energy consumption | • Low solids concentration with waste activated sludge |
| **Centrifugal thickening/dewatering** | |
| • Good capture of solids that are difficult to filter<br>• Low space requirements<br>• Easy installation | • High consumption of energy<br>• Noise and vibration generation<br>• Skilled maintenance personnel required<br>• Low solids concentration in cake |
| **Dissolved air flotation thickening** | |
| • Good for waste biological sludge<br>• Sludge kept aerobic | • Blockage problems<br>• Possible release of odours (stripping effect) |
| **Belt filter press dewatering** | |
| • High dewatering efficiency<br>• Relatively easy maintenance | • Hydraulic limitations<br>• Belt may blind and short life<br>• Sensitive to sludge feed characteristics |
| **Filter Press Dewatering** | |
| • High solids concentration in cake and low suspended solids in filtrate<br>• Robust operation | • Essentially batch operation<br>• Labour costs high<br>• Limited filter cloth life |
| **Vacuum Filtration** | |
| | • Complex system<br>• High operating and maintenance costs<br>• Maximum differential pressure 1 bar<br>• Filtrate may have high suspended solids |

**Table 4.62: Advantages and disadvantages of sludge thickening and dewatering techniques**
**[13, Environment Agency (UK), 2000; 1, CIAA, 2002; 65, Germany, 2002]**

### 4.13.12.5 Stabilisation of sludge

Stabilisation is used to: [1, **CIAA**, 2002]
- reduce or eliminate the amount of odorous constituents
- reduce the quantity of biodegradable sludge solids
- reduce the quantity of biodegradable soluble matter, converting mineralised nitrogen/organic matter into humic rich material.
- improve dewatering
- reduce pathogens
- reduce or eliminate the potential for putrefaction.

The techniques generally used to achieve the above are:

- chemical
- thermal
- anaerobic
- aerobic.

The reader is referred to a suitable textbook on waste water treatment for a detailed description of the above techniques.

| Advantages | Disadvantages |
|---|---|
| **Chemical stabilisation and conditioning** | |
| • Low technical requirements<br>• Good method to improve downstream dewatering (conditioning) and to abate odours and pathogens | • Increases solids content of the sludge |
| **Thermal stabilisation and conditioning** | |
| • Low space requirements<br>• Effective treatment for producing good sludge for dewatering and destruction of bacteria | • High capital cost<br>• High energy usage<br>• Odours may be released |
| **Aerobic digestion** | |
| • Produces odourless humus like biologically stabilised sludge<br>• Lower capital cost compared to anaerobic<br>• Relatively easy operation | • High energy requirement for stirring and supply of oxygen<br>• Process significantly affected by temperature<br>• Sludge poor mechanical dewatering characteristics |
| **Anaerobic digestion** | |
| • Gas produced, source of energy<br>• Long residence time, good mineralisation of sludge | • Big installations due to relatively high capital costs |

**Table 4.63: Advantages and disadvantages of sludge stabilisation techniques**
**[13, Environment Agency (UK), 2000; 1, CIAA, 2002; 65, Germany, 2002]**

## 4.14 Waste water treatment in sectors

This section provides information on waste water management guidance for specific subsectors and individual categories within those subsectors. Only those identified as high priority are addressed in the current draft.

### 4.14.1 Meat processing

#### 4.14.1.1 Treatment for discharge to sewer

Screening to remove gross solids is essential for installations in this subsector. Static wedge screens are cleaned several times a day to remove build-up. Self-cleaning screens are preferable, otherwise regular chemical cleaning takes place to dissolve fatty deposits. A hot water supply for cleaning purposes is also recommended in order to reduce fatty deposits. However, these can re-congeal lower down the system. Therefore, grease and fat must be retained in a trap close to the source.

Due to the nature of the processes, the washdown regime and use of shift work, flow and load balancing are required. Adequate mixing and aeration is allowed for. The formation of scum on the surface of the balance tank is minimised and, where necessary, scum removal arrangements installed. A balance tank typically has a retention time of 6 - 12 hours.

High trade effluent charges will make it cost-effective for most installations covered by IPPC to carry out some form of primary treatment. Dissolved air flotation is widely used in this sub-sector for the removal of fats, oils and greases and suspended solids. The separated material can generally be re-used as animal feed if suitable coagulants and flocculants have been chosen.

In some instances, discharge to sewer could occur downstream of a dissolved air flotation process, depending upon the efficiency of the process and the receiving sewage treatment works. In this case operators must allow for a contingency strategy for failure of the dissolved air flotation process or the chemical conditioning process associated with it, e.g. a diversion tank.

Following primary treatment, further stages may be required, either to achieve the required effluent quality or to minimise trade effluent charges. For waste water streams with a BOD concentration greater than 1000 – 1500 mg/l anaerobic treatment processes may be considered. If an anaerobic technique is used, operators must ensure that fats, oils and greases are not allowed to reach the anaerobic reactor, as well as minimising any biocides from reaching this stage of the process. Final effluent from the anaerobic process could be discharged directly to sewer, following flash aeration.

For lower strength waste water streams aerobic treatment would be the preferred option, provided that the necessary BOD:N:P ratios are achieved. Conventional activated sludge systems have been used for such waste water streams, and (where economics allow) activated sludge variants (pure oxygen, SBR, MBR) would also be applicable. Hybrid aerobic reactors, such as the submerged biological aerated filter are also gaining popularity in this field. [13, **Environment Agency (UK)**, 2000]

#### 4.14.1.1.1 Treatment for discharge to watercourse or for recycling

For discharges to watercourses, or for treating effluent to a quality suitable for re-use, further treatment stages would be required.

For high strength waste waters that have passed through an anaerobic treatment plant a further aerobic plant will be required. Typically anaerobic reactors are followed by conventional activated sludge systems for further treatment. A two stage biological system (anaerobic followed by aerobic), if designed correctly, achieves a quality of effluent suitable for discharge to a water course. Should suspended solids consent be low a tertiary macrofiltration system (sandfilter) would be required.

Further tertiary treatment would be required for recycling all or part of the final effluent. Due to the nature of the waste, GAC filters and/or crossflow microfiltration would be required. Disinfection would also be recommended should recycled water be used in hygienic areas. [13, **Environment Agency (UK)**, 2000]

Figure 4.43 shows a typical schematic for a process flow diagram for effluent treatment applicable to meat and poultry processing waste water.

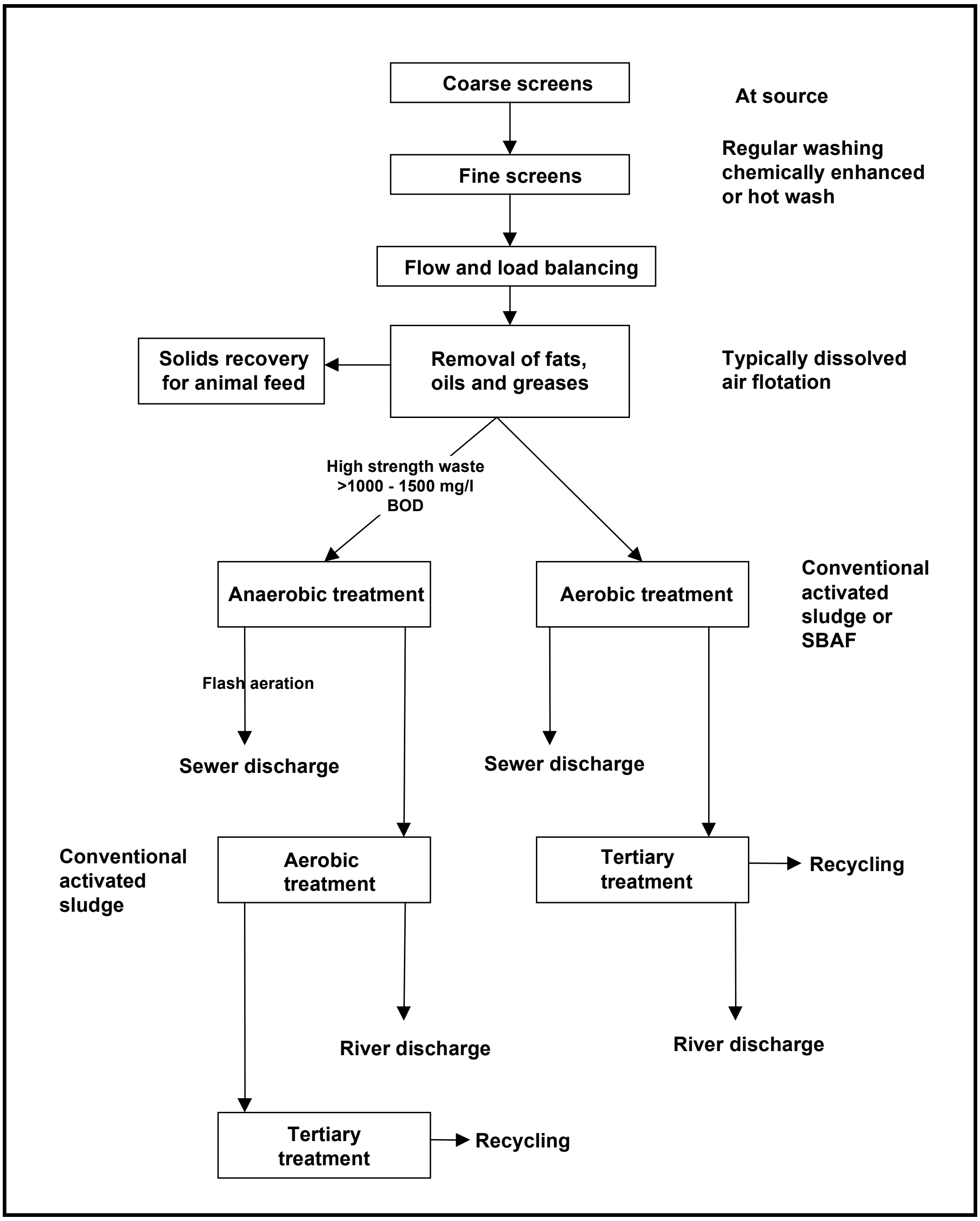

**Figure 4.43: Flow sheet of the treatment for meat and poultry processing waste waters [13, Environment Agency (UK), 2000]**

### 4.14.2 Fish processing

To be completed using input from [Nordic #28] and [27, **Austermann-Haun**, 2000]

### 4.14.3 Fruit & vegetable processing

#### 4.14.3.1 Segregation

Segregation of waste water streams according to their composition is generally desirable, however, it may be uneconomical to segregate small, isolated streams. Water that has only been used for washing incoming produce has low levels of BOD and might be screened to remove solids rather than receiving full treatment. The same applies to freezer defrost water.
[13, **Environment Agency (UK)**, 2000]

#### 4.14.3.2 Treatment for discharge to sewer

The following unit processes can be considered [13, **Environment Agency (UK)**, 2000]:

Screening to remove gross solids is essential for installations in this subsector. Static wedge screens are cleaned several times a day to remove build-up. Self-cleaning screens are preferable.

Due to the nature of the processes, the washdown regime and the use of shift work, flow and load balancing would be required. Adequate mixing and aeration are allowed for. A balance tank would typically have a retention time of 6 - 12 hours.

High trade effluent charges will make it cost-effective for most installations covered by IPPC to carry out some form of primary treatment. Waste water streams liberated from fruit and vegetable processing lends itself to settlement as opposed to flotation. Dissolved air flotation would be applicable to those waste waters with appreciable levels of fats, oils and greases.

Those waste waters that are colloidal in nature will require chemical conditioning in order to facilitate settlement at the primary stage.

Installations with a high degree of starch in the waste water (potato starch processing) would benefit from recovery of the starch. Typically this is achieved through centrifuges without the addition of chemicals.

In some instances, discharge to sewer could occur downstream of the primary settlement tanks, depending upon the receiving sewage treatment works.

Following primary treatment, further stages may be required, either to achieve a consent to discharge or minimise trade effluent charges. For waste water streams with a BOD concentration greater than 1000 – 1500 mg/l anaerobic treatment processes are considered. Anaerobic treatment has been applied in the UK to various potato processing facilities. If an anaerobic technique is used, operators need to ensure that fats, oils and greases are not allowed to reach the anaerobic reactor, as well as minimising any biocides from reaching this stage of the process. Final effluent from the anaerobic process could be discharged directly to sewer, following flash aeration.

Fruit and vegetable processing waste waters are often deficient in nitrogen and phosphorus and will require supplements of these nutrients to support adequate biological activity.

For lower strength waste water streams, aerobic treatment would be the preferred option. Conventional activated sludge systems have been used for such waste water streams, and hybrid aerobic reactors, such as the submerged biological aerated filter have been used within this sector. Advanced forms of activated sludge (pure oxygen, SBR and MBR) can be considered should space be at a premium and if economics allow.

#### 4.14.3.3 Treatment for discharge to watercourse or for recycling

For discharges to watercourses, or for treating effluent to a quality suitable for re-use, further treatment stages would be required.

For high strength waste waters that have passed through an anaerobic treatment plant a further aerobic plant will be required. Typically anaerobic reactors are followed by conventional activated sludge systems for further treatment. A two stage biological system (anaerobic followed by aerobic) if designed correctly achieves a quality of effluent suitable for discharge to a water course. Should suspended solids consent be low a tertiary macrofiltration system (sandfilter) would be required. [Environment agency, UK, 2000 # 13]

Further tertiary treatment would be required for recycling all or part of the final effluent. Due to the nature of the waste, GAC filters and/or crossflow microfiltration would be required. Disinfection would also be recommended should recycled water be used in hygienic areas.

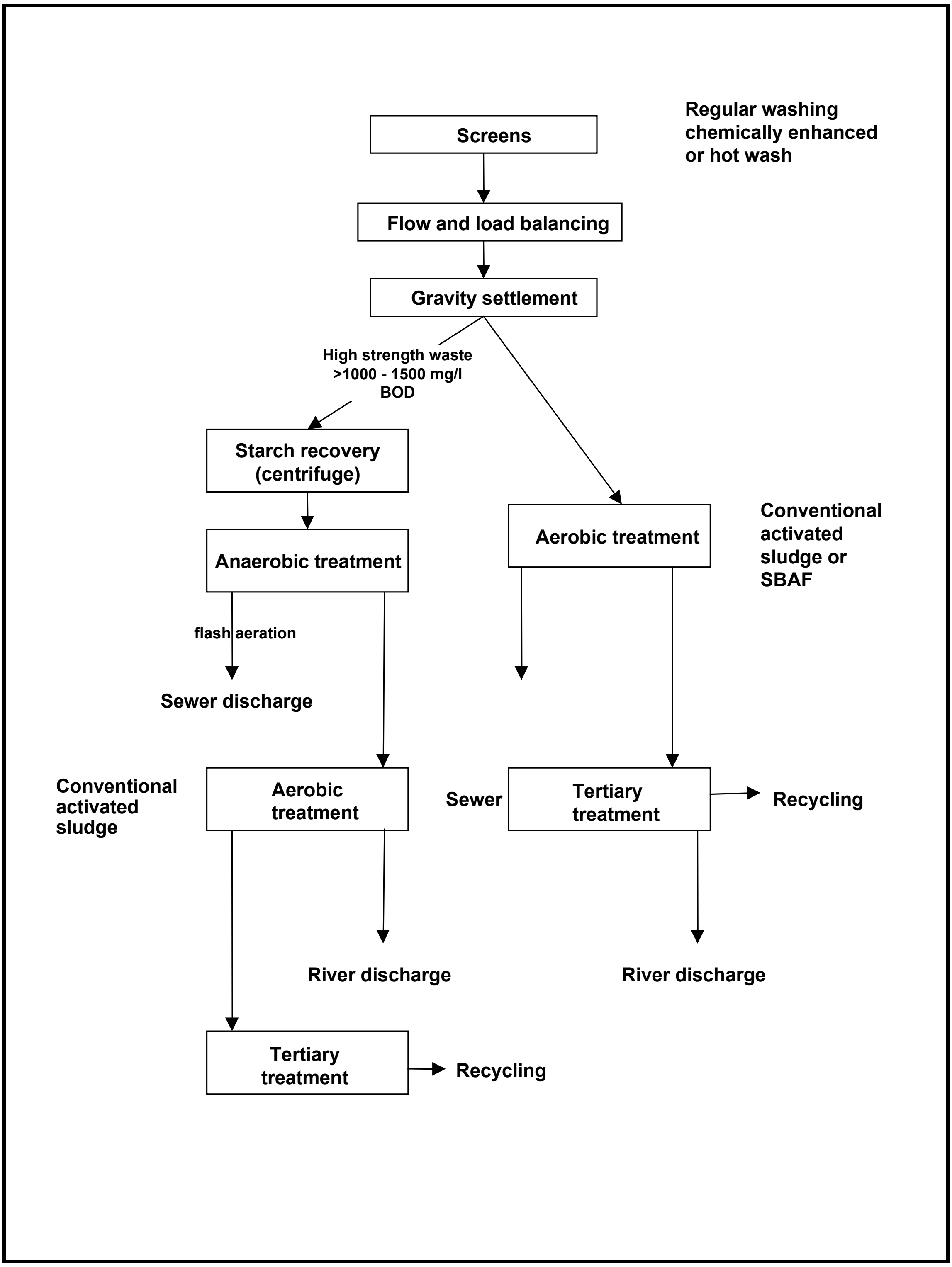

**Figure 4.44: Flow sheet of the treatment for fruit and vegetable processing [Environment agency, UK, 2000 # 13]**

Figure 4.44 shows a typical schematic for a process flow diagram for effluent treatment applicable to fruit and vegetable processing waste waters.

Potato processing industry

Although the organic constituents of the waste water from the potato processing industry are readily biodegradable, problems may arise during waste water treatment. These are largely due to the following factors: [65, Germany, 2002]

- pollution loads that fluctuate substantially in the course of the day, week, year
- mostly high concentrations of impurities
- imbalanced composition of waste water (preponderance of carbohydrates and sometimes imbalanced mineral nutrient supply)
- presence of foam-producing substances (protein)
- risk of bulking sludge formation
- temperature of production waste water sometimes exceeds 35 to 40°C, which may make it necessary to use evaporation coolers
- the rapid onset of the anaerobic fermentation process may give rise to undesirable odours. Moreover, the acids present during the fermentation processes may result in the pH being reduced to between 4 and 4.5. This acidification takes place within about 2 hours.

In anaerobic/aerobic treatment systems it is necessary to investigate whether, in view of the $N_{tot}$ load, it is possible to treat the entire production waste water or only a sub-stream in order to ensure that the aerobic stage still has enough carbon for nitrogen elimination. If the above considerations are taken into account, it is certainly possible to use biological processes to clean the highly concentrated waste water from potato processing facilities.

#### 4.14.3.4 Techniques to consider for the fruit and vegetable processing industry in drainage and effluent treatment

**[31, An Derden, 2001]**

| | Technique | Comments |
|---|---|---|
| 75 | Maintaining an effluent log book | |
| 76 | Match size of effluent treatment plant to the amount of effluent to be treated | |
| 77 | Separate collection and transport of industrial effluent | |
| 78 | Separate collection and transport of water from toilets and washbasins | |
| 79 | Separate collection and transport of rainwater | |
| 80 | Spread production with high pollution of water (organic material, pH, etc.) | Low profitability |
| 81 | Remove coarse particles (organic material) from the effluent using "sieves" (grilles, sieve, drum sieve) | |
| 82 | Removal of heavy particles from the effluent by "sedimentation" (sand trap) | |
| 83 | Clean sand trap regularly, so that it can remove sand effectively from the effluent | |
| 84 | Remove floating particles from the effluent during primary treatment by means of "flotation" (air flotation, blade separator) | Can be applied for removal of fats, applied only in potato processing sector |
| 85 | Collect primarily cleaned effluent before further secondary treatment in a mixing tank (correct of pH and temperature), neutralisation tanks (correction of pH), buffer tanks (continuous feed biological treatment unit ) or pre-sedimentation tanks (deposit of sinkable particles by use of the force of gravity) | |

| | | |
|---|---|---|
| 86 | Anaerobic pre-cleaning of the effluent (natural fermentation, anaerobic integrated into the aerobic cleaning stage UASB ) | May not be suitable for potato peeling firms |
| 87 | Aerobic cleaning of the effluent (active sludge process) | |
| 88 | Stimulate nitrification process by controlling the aeration process during aerobic cleaning of the effluent | May not be suitable for potato peeling firms |
| 89 | Stimulate dephosphatation process by controlling the aeration process during aerobic cleaning of the effluent | May not be suitable for potato peeling firms |
| 90 | Dimension the aerobic cleaning to achieve low sludge content | |
| 91 | Anoxic post-cleaning of the effluent (denitification process) | May not be suitable for potato peeling firms |
| 92 | Separate secondary sludge and effluent into a sedimentation tank | |
| 93 | Effluent cleaning by means of "coagulation / flocculation", followed by "sand filtration" | Not suitable for any case, its use depends on the receiving surface water |
| 94 | Effluent cleaning using "active carbon filtration" | High energy costs, waste production |
| 95 | Effluent cleaning using "microfiltration" | High energy costs, waste production |
| 96 | Effluent cleaning by "reverse osmosis" | High energy costs, waste production |
| 97 | Clean effluent by application of primary cleaning alone | If water is to be re-used |
| 98 | Clean effluent by application of primary cleaning + aerobic | If water is to be re-used and for potato processing |
| 99 | Clean effluent by application of primary cleaning + anaerobic + aerobic without stimulation of biological denitrification/dephosphatation | |
| 100 | Clean effluent by primary cleaning + anaerobic + aerobic + denitrification + dephosphatation | Not suitable for potato peeling firms |
| 101 | Clean effluent using primary cleaning + anaerobic + aerobic + denitrification / dephosphatation + coagulation / flocculation + filtration | Waste production. Its use depends on requirements of the protection of the receiving water;<br>not suitable for potato peeling firms |
| 102 | Clean effluent using primary cleaning + anaerobic + aerobic + denitrification / dephosphatation + coagulation / flocculation + filtration + active carbon filtration | If water is to be re-used |
| 103 | Clean effluent using primary cleaning + anaerobic + aerobic + denitrification / dephosphatation + coagulation / flocculation + filtration + active carbon filtration + microfiltration | If water is to be re-used |
| 104 | Clean effluent using primary cleaning + anaerobic + aerobic + denitrification / dephosphatation = coagulation / flocculation + filtration + active carbon filtration + microfiltration + reverse osmosis | If water is to be re-used |
| 105 | Cover over the anaerobic system (+ possibly extract air and feed it back to the aeration tanks, in which the odour components are then broken down) | If odour is a nuisance |
| 106 | Treat the air in the anaerobic tanks with a biofilter (packaging material e.g. turf, compost, wood bark, etc.) | If odour is a nuisance |

| | | |
|---|---|---|
| 107 | The system must be completely waterproof to avoid contamination of the soil and groundwater | |
| 108 | Valorisation of biogas, formed during anaerobic cleaning (e.g. heating a reactor, generating electricity via a gas engine, etc. | |
| 109 | Dewater sludge by means of mechanical compression via a sieve belt press | |
| 110 | Dewater sludge by means of gravity compression via a sedimentation tank | |
| 111 | Dewater sludge by means of gravity compression via sludge storage | |
| 112 | Dewater sludge via flotation compression by means of bubbling air | |
| 113 | Stabilise sludge chemically by treating with lime | |
| 114 | Stabilise sludge biologically by mineralisation | |
| 115 | Stabilise sludge biologically by fermentation | |
| 116 | Stabilise sludge biologically by composting | |
| 117 | Stabilise sludge thermally by drying | |
| 118 | Stabilise sludge thermally via pasteurisation | |

**Table 4.64: List of techniques to consider for drainage and waste water treatment in the fruit and vegetable processing industry**
**[31, An Derden, 2001]**

## 4.14.4 Starch manufacturing

Aerobic waste water treatment:
For cost-effectiveness reasons, in cases of large seasonal fluctuations and in view of the risk of bulking sludge formation, starch industry waste water with a COD in excess of 10 g/l is best not subjected to aerobic treatment alone. The aerobic technique is perfectly suitable for less polluted waste water, e.g. condensed vapours from concentration systems or washing and flume water from potato starch production.
In particular, when treating condensed vapours, it is important to ensure a balanced nutrient ratio (N/P). Moreover, waste water from starch modification can be expected to have extremely imbalanced, carbohydrate-based organic loads with considerable problems due to rising and bulking sludge. [65, Germany, 2002]

## 4.14.5 Dairies

### 4.14.5.1 Segregation

In addition to segregating storm water, it is desirable to segregate waste water on some or all of the following criteria:

- high solids content
- very high BOD
- high salinity.

It may be appropriate to bleed high solids content waste water (e.g. CIP sludge) into the main waste water stream from a holding tank.

Waste water balancing and neutralisation facilities may be able to cope with extreme pHs resulting from occasional acid or caustic spills.

Condensate that cannot be re-used may be suitable for discharge direct to sewer. [Environment agency, UK, 2000 # 13]

#### 4.14.5.2 Treatment for discharge to sewer

Important characteristics of dairy waste water for the purposes of treatment are:

- large diurnal variation in flow rate
- variable pH
- generally nitrogen deficient
- may be high in phosphorus if phosphoric acid used for clean-up (risk of phosphorus release in final effluent if treatment process becomes anaerobic).

In general, when applying techniques for the treatment of waste waters liberated form dairy processing installations, the following unit processes may be considered:

- **Screening.** Screens are installed to remove gross solids (including gloves, hats, etc.) as a protective measure for downstream processes. Self-cleaning screens are preferable, otherwise regular chemical cleaning is needed to dissolve fatty deposits. A hot water supply for cleaning purposes is also recommended for this purpose.

- **Balancing**. Due to the large diurnal variation in waste water discharge volumes, flow and load balancing are required. Adequate mixing and aeration are allowed for to prevent stratification within the balance tank and to maintain a positive dissolved oxygen level. A balance tank would typically have a retention time of 6 - 12 hours, pH correction would also be required at this stage.

- **Primary Treatment**. If there are high trade effluent charges it is cost-effective for most installations covered by IPPC to carry out some form of primary treatment. Dissolved air flotation is widely used in this subsector for the removal of fats, oils and greases, and of suspended solids. The separated material can generally be re-used as animal feed if suitable coagulants and flocculants have been chosen.

  In some instances, discharge to sewer could occur downstream of a dissolved air flotation process, depending upon the efficiency of the process and the receiving sewage treatment works. In this case, operators allow for a contingency strategy for failure of the dissolved air flotation process or the chemical conditioning process associated with it, e.g. a diversion tank.

Following primary treatment, further stages may be required either to achieve a consent to discharge or to minimise trade effluent charges.

- For waste water streams with a BOD concentration greater than 1000 – 1500 mg/l BOD **anaerobic treatment** processes may be considered. Anaerobic techniques are widespread across Europe and are gaining popularity in the UK. If an anaerobic technique is used, operators ensure that fats, oils and greases are not allowed to reach the anaerobic reactor. Final effluent from the anaerobic process can be discharged directly to sewer, following flash aeration.

- For lower strength waste water streams **aerobic treatment** would be the preferred option. High rate trickling filters have been used at some dairies throughout the UK. The high rate trickling filter uses a high voidage filter packing media and can allow for a high rate of flow and load across the process. Systems are typically designed to remove 50 – 60 % BOD. It is essential that the levels of fats, oils and greases have been minimised prior to feed onto a high rate filter. Secondary settlement is required following a high rate filter and (depending upon the consent to discharge conditions) discharged direct to sewer. [13, **Environment Agency (UK)**, 2000]

For a higher degree of treatment conventional activated sludge systems have been used for such waste water streams, and (where economics allow) activated sludge variants (pure oxygen, SBR, MBR) can also be applicable. Hybrid aerobic reactors, such as the submerged biological aerated filter are also popular due to the historical use of biofiltration processes in the dairy industry.

#### 4.14.5.2.1 Treatment for discharge to watercourse or for recycling

For discharges to watercourses, or for treating effluent to a quality suitable for re-use, further treatment stages would be required.

**Figure 4.45: Anaerobic digestion of whey**
**[Energy Efficiency Office, 1987 #36]**

For the high strength waste waters that have passed through an anaerobic treatment plant a further aerobic plant will be required. Typically anaerobic reactors are followed by conventional activated sludge systems for further treatment. A two stage biological system (anaerobic followed by aerobic), if designed correctly, achieves a quality of effluent suitable for discharge to a water course. Should suspended solids consent be low a tertiary macrofiltration system (e.g. sandfilter) would be required.

Further tertiary treatment would be required for recycling all or part of the final effluent. Due to the nature of the waste, GAC filters and/or crossflow microfiltration would be required. Disinfection would also be recommended should recycled water be used in hygienic areas.

Figure 4.46 shows a typical schematic for a process flow diagram for effluent treatment applicable to dairy processing waste waters.

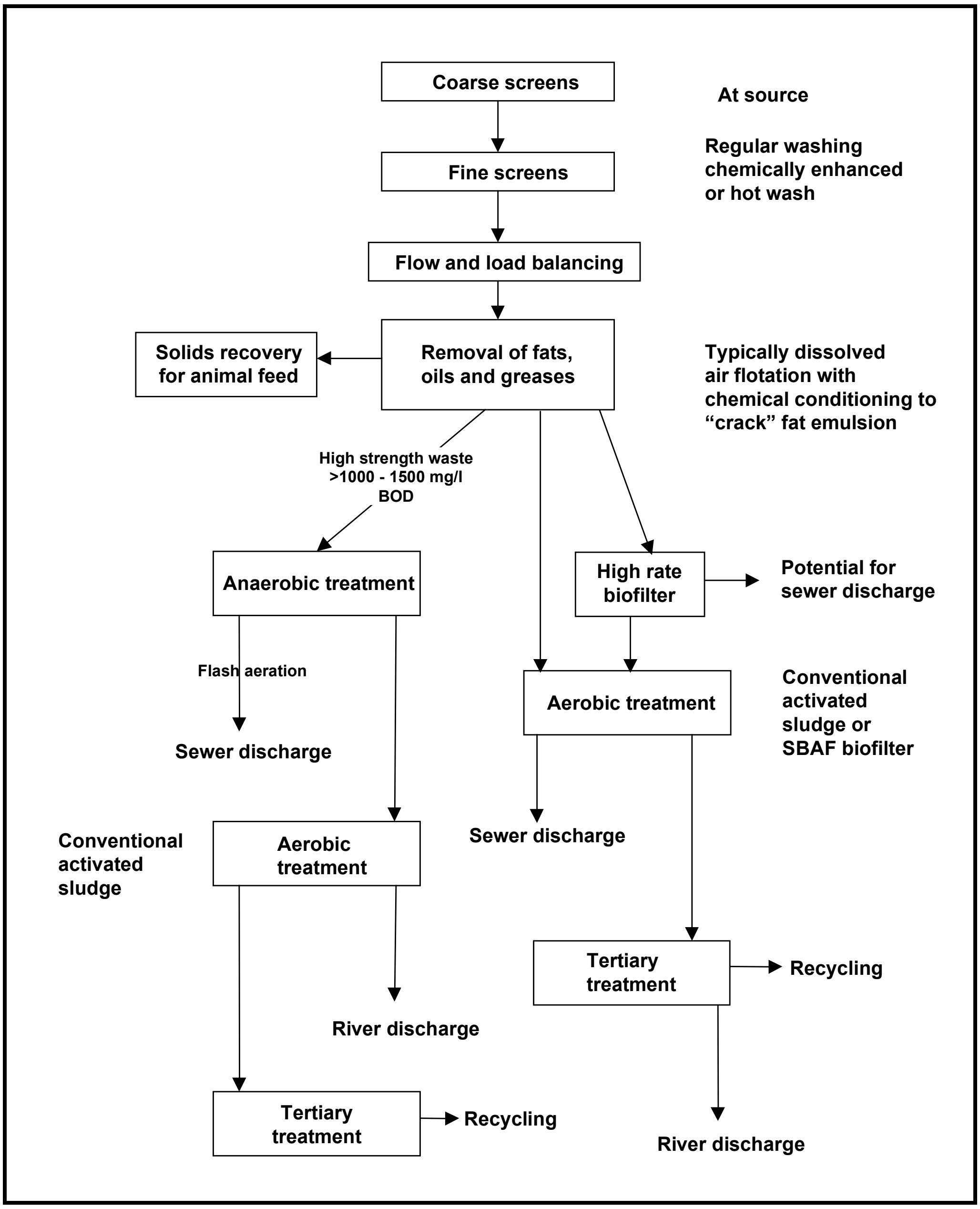

**Figure 4.46: Flow sheet of the treatment for dairy waste water**
**[13, Environment Agency (UK), 2000]**

<u>Problems in waste water management in dairy industry</u>
Waste water from dairies is generally readily biodegradable, but there are a number of specific conditions that need to be observed to ensure reliable purification results [65, Germany, 2002]:

- As a result of the cleaning cycles, there are considerable fluctuations in pH, waste water concentrations and flow volumes. A mixing and equalisation basin is therefore recommended.
- In order to deal with problems during operation it may make sense to provide an emergency tank.
- Despite preceding equalisation basins it is necessary to allow for peak loads when designing the oxygen supply.
- Widely differing conditions with regard to phosphorus are encountered at the individual facilities. Some factories use phosphate-rich cleaners on a considerable scale, resulting in substantial phosphate loads. In view of the necessary precipitation measures, this has a major impact on sludge production.

- In the case of dairy waste water, surplus sludge production is considerably lower than with domestic waste water, for instance, owing to the lower content of filterable substances and the higher waste water temperatures.
- Dairy waste water has a considerable bulking sludge potential. Activated-sludge systems with light loads are less at risk in this respect than systems subject to heavy loads. System design makes use of the so-called "contact basin effect" or "selector effect", in which the sludge is briefly subjected to a very heavy load and then once again to a low load. When designing a final clarification basin, special attention must be paid to the sludge index.
- The installation of a sand or grit trap is particularly necessary in cases where washing water from vehicle washing units and rainwater from sealed surfaces pass into the factory waste water treatment system. A screen or fine bar rack is also recommended, as this simplifies later removal of the sludge and avoids problems with operation of the treatment system (clogging, deposits).
- In milk processing facilities there may be substantial nitrate concentrations in the untreated waste water as a result of the nitric acid used for cleaning purposes.

## 4.14.6 Sugar manufacture

The UK Environment Agency used the "Guidance Note for Establishing BAT in the European Sugar Industry; Comite European des Fabricants de Sucre" document as the main reference for this Section. [13, **Environment Agency (UK)**, 2000]

### 4.14.6.1 Scope

This subsector includes:

- sugar beet processing and manufacture of beet sugar products
- cane sugar refining and manufacture of cane sugar products.

There are nine factories which process the UK sugar beet crop on a campaign basis. Five of these factories store thick sugar juice for processing between the beet campaigns. The UK has the largest sugar beet factory in Europe and which is often regarded as a showpiece for the British beet processing industry.

The largest cane sugar refinery in the world is also situated in the UK.

### 4.14.6.2 Sources & nature of waste water

#### 4.14.6.2.1 Sugar beet processing

75 % of the sugar beet itself can be attributed to water, and the extraction process, by definition, aims to release a high proportion of that water. Approximately half of this water is lost due to evaporation or inclusion in various product streams. The remainder is a source of high strength waste water. "Process waste water" is deemed to be the excess condensate from the concentration and crystallisation stages. This surplus condensate is high in ammonia and relatively low in COD content. [13, **Environment Agency (UK)**, 2000]

Another major source of waste water comes from fluming water and washing of the incoming beets. These are floated through the cleaning stage where stones, weeds and other gross contaminants are removed. The beets then enter the factory, where they are washed before being sliced into cossettes in order to the maximise surface area for the extraction process.

The combined waste water has a high BOD and is produced in large volumes.

Figure 4.47 shows a typical process flow diagram of the waste water treatment for a sugar beet processing plant.

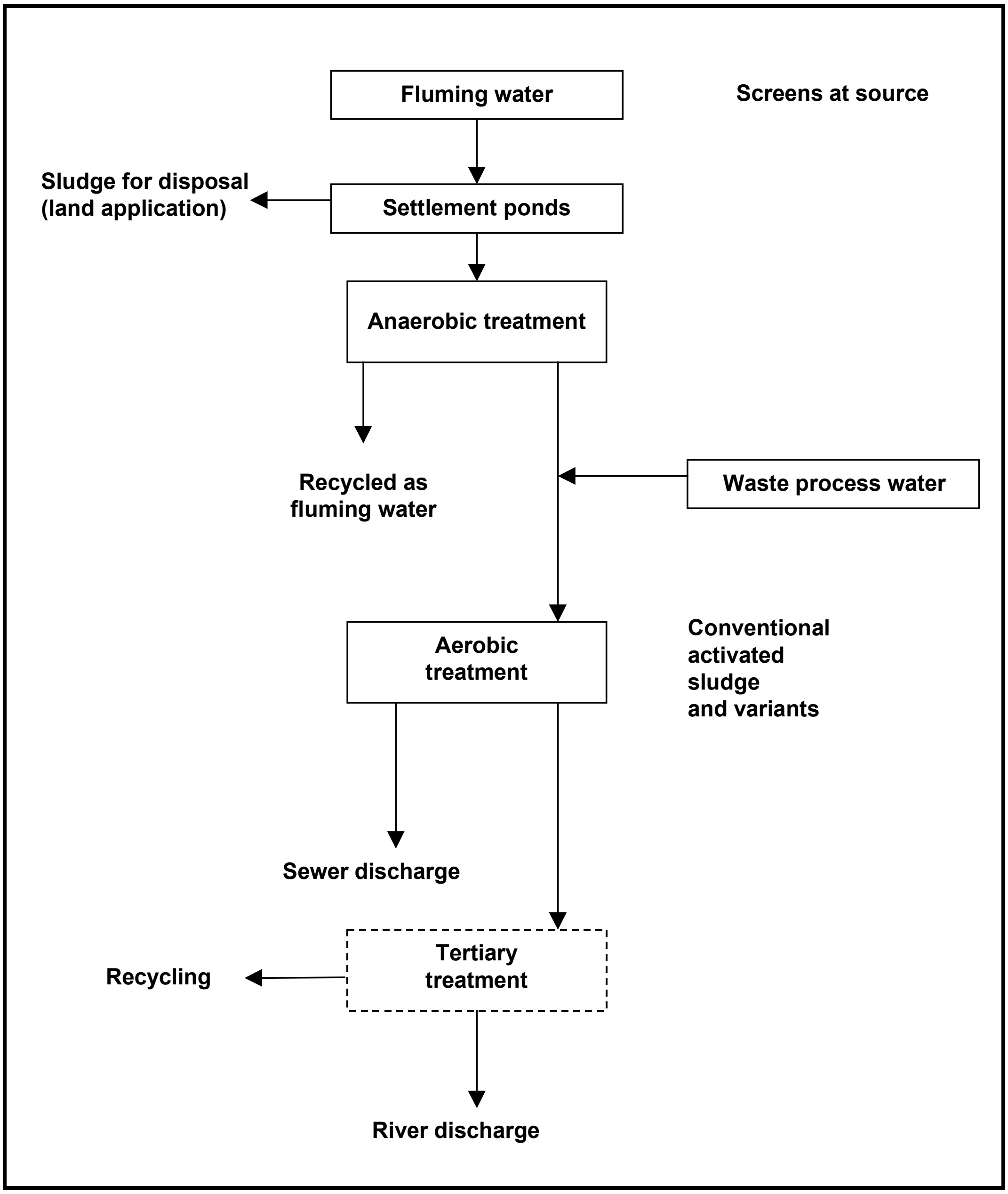

**Figure 4.47: Flow sheet of the treatment for sugar beet processing waste water**
**[13, Environment Agency (UK), 2000]**

#### 4.14.6.2.2 Cane sugar refining

As the starting point is raw sugar, less water is required than in sugar beet processing.

Regeneration of the ion exchange resin cells used in the decolourisation process every 40 - 50 hours generates a difficult waste water. Caustic brine is used as the regenerant. [13, **Environment Agency (UK)**, 2000]

There may be excess condensate and sweet water although these can be eliminated – see Section 4.14.6.3.

Waste water will be generated from steam cleaning of the bulk road tankers that are used to transport liquid sugar products.

#### 4.14.6.3 Water/waste water recycling

For sugar beet processing, one of the major sources of waste water is the flume water used for transporting beet through the initial stages of the process. The flume water can be recycled approximately 20 times before it is discarded. The ultimate goal for transport water may be zero abstraction from external water sources. Due to the formation of organic acid compounds within the flume water, it has been historical practice to pH correct (usually with lime). However, those plants using anaerobic treatment for waste water have found that recycling anaerobically treated effluent as flume water has eliminated the need for pH correction.

Cooling water is used on-site for electricity generating turbines. Typically, cooling water will have been abstracted from a river and will make a single pass around a turbine before being discharged back to the river. Recycle of suitable cooled water is considered.

Condensate may also be considered as a source of low grade water.

Sugar refineries can be made very water efficient so that all the sweet water is used in the process and a total recycling of condensate is achieved. [13, **Environment Agency (UK)**, 2000]

#### 4.14.6.4 Waste water minimisation

For sugar beet processing there are three main areas to be optimised in order to help reduce waste water production;

- reducing soil on incoming beet in order to reduce load in transport water
- minimise beet damage during transport and consequently reduce sugar leaching into the transport water
- reduce product losses e.g. by careful control of boiling pans.

[13, **Environment Agency (UK)**, 2000]

#### 4.14.6.5 Waste water treatment

Sugar Beet Processing

Sugar beet processing is dictated by crop production hence processing occurs on an intensive campaign basis. The level of treatment required is dictated by the discharge to consent conditions.

It is essential that waste water segregation is carried out at sugar beet processing installations. The “process water” (surplus condensate) remains separate from the high strength fluming water.

The fluming (transport) water contains mud, stones and waste vegetation, as well as high COD from damaged sugar beet. The heavy particulates require settlement, and it is common to use large settlement ponds for this purpose. The sludge taken from the settlement ponds can be further dewatered and the liquors recovered from the dewatering process can be returned to the factory, either via the diffusers or as fluming water.

The high strength supernatant passing from the settlement ponds is ideally suited for treatment using **anaerobic technique**. Also the betains from the sugar beet (organic nitrogen compounds) can only be degraded anaerobically, not aerobically. Consequently about half the sugar factories in Germany are currently equipped with anaerobic systems. [65, Germany, 2002]
The organic material in the fluming water breaks down into shorter chain organic acids. Historically pH correction has occurred using additives such as lime. However, this “acidification” of the waste water stream is ideally suited for anaerobic treatment. “Acidogenesis” is an essential reaction that takes place in anaerobic conditions to break the

longer chain organic material into more treatable organic acids. A number of anaerobic installations require an acidification tank upstream of the anaerobic reactor in order to initiate the acidogenesis stage. Hence pH correction of the fluming water is no longer required.

The systems that are used for anaerobic waste water treatment in the sugar industry can be considered to belong to the contact-sludge process, the upflow anaerobic sludge blanket (UASB) process or the fluidised-bed process.
Operating problems may occur as a result of changes in the composition of the organic constituents of the waste water and also its high calcium content.

In the methane reactor, the presence of calcium from the carbonation process (present in the waste water) in combination with carbon dioxide (formed in the reactor) leads to the precipitation of calcium carbonate. Experience shows that regardless of the concentration on the incoming waste water and regardless of the process used, the calcium content is reduced to around 0.3 - 0.7 kg/m$^3$. This means annual calcium carbonate loads of 300 to 1000 tonne remain in the reactor. This gives rise to problems with mixing in the system, and also to additional work and cost to keep the relevant pumps, heat exchangers and pipes in good working order. [65, Germany, 2002]

To eliminate lime during operation, some factories use hydrocyclones that remove the more lime-laden bacterial sludge from the system. In nearly all factories it is, nevertheless, necessary at regular intervals (every 2 - 5 years) to open the reactors during the off-season period and mechanically remove the lime that has formed. This is not necessarily the case with fluidised beds; lime is precipitated almost entirely on the carrier material, which can then be drawn off during operation. The lime concentrations on removal are around 800 - 1000 kg/m$^3$ of carrier material.

Since such operations are seasonal, the aerobic system downstream of the anaerobic system must be activated accordingly at the start of the season.

A portion of the anaerobically treated effluent can be recycled as fluming water.

The methane produced as part of the anaerobic process is used for drying beet pulp intended for use as animal feed. Low grade heat is used to preheat the waste water entering the anaerobic reactor. [13, **Environment Agency (UK)**, 2000]

The waste process water is considered to be high in ammonia content, yet low in COD. The recommended process for reducing the ammonia levels would be to use **aerobic biological** processes configured to allow for the nitrification of the ammonia. In order for this to take place, the waste water stream requires dosing with an external carbon source. For those installations using anaerobic technique for treating the fluming water, combining the effluent from the anaerobic process with the excess process water is usually sufficient to provide a feed of adequate balance onto the aerobic treatment stage.

The aerobic treatment stage is typically an activated sludge type plant or a variant of. Coarse bubble aerated lagoons, extended aeration (oxidation ditch) and conventional forms of activated sludge are acceptable.

The final effluent from this stage may be of a high enough quality to be discharged to water course. Alternatively discharge would be to sewer.

For potential recycling of final effluent, tertiary treatment techniques could be employed on a portion of the final effluent.

#### 4.14.6.6 Waste water treatment in the sugar industry

The water on site, which has been, minimised both in volume and organic loading will require treatment before discharge. Several treatment methods make it possible to achieve very high levels of pollution control. The choice of the most appropriate one will take into account the geographical and human aspects in order to satisfy the local environmental requirements, which are best, suited to the technical characteristics of the existing plants. The various methods are explained below.

The following options indicate the techniques, which are used successfully to achieve the appropriate level of environmental protection, having taken into account the environmental needs of the area, the geographical and weather conditions and the legal requirements. In general, the costs increase with the level and sophistication of the plant and equipment and the numbers of people required to make it operate. [1, **CIAA**, 2002]

**Option 1 Land spreading**

In areas, which permit it, transport water can be spread directly onto suitable land. When it is correctly managed, this technique, which recycles those natural elements previously exported with the crop, may be considered to be a good option. As an example, the approach used in France is presented. It consists of three steps.

Step 1: Preliminary studies

There must be an impact study to exhaustively analyse the mixture of soil and water, geology, hydrogeology, climate and agricultural techniques of the proposed land. If the impact study concludes that this technique is feasible, and excluding areas for which it is not suitable, an expert may recommend the exact operational details.

Step 2: The operations

The spreading operations must be carried out according to the expert specifications. The principle of water purification results from both the digestion of organic compounds by the micro-organisms of the soil and from the absorption of the inorganic salts by the plants. This latter part prevents soil pollution and ground water pollution by salts and nitrogen. It controls the amount of water to be sprayed and the timing of the interval between sprayings. There will need to be other operational controls to ensure even distribution of spraying and to prevent spraying during frosts etc.

This agronomical balance requires a high level of co-operation between the farmer and the sugar factory and requires a high standard of supervision.

Step 3: Monitoring

Every predicted effect are verified by analysis of soils, ground profiles and ground waters to ensure full control.

**Option 2**

The soil is settled out from the transport water in settling ponds. The decanted water can then be treated through extensive or intensive methods.

- Extensive methods
  The water decanted from the soil settling ponds can be stored in treatment lagoons to allow for natural treatment to meet appropriate standards. Note that the use of lagoons can make it possible to use the water to irrigate the land during dry weather, which also reduces the need for abstracting water from the rivers or from the ground.

For the treatment of process waters in southern Europe, it may be possible to use lagoons for natural water evaporation due to the high average temperatures.

The technique of lagoons is as follows. The bacterial population in large lagoons will, under the appropriate conditions of temperature and time, degrade the biological oxygen demand of stored water. Surface area and depth are key elements in the rate of degradation of the biological oxygen demand. Degradation of the biological oxygen demand relies on natural processes such as the carbon, nitrogen and sulphur cycles, with both anaerobic and aerobic bacteria responsible for this degradation.

- Intensive treatments
  If there is a risk of offensive odour or should the needs of the environment dictate a more stringent level of treatment, then there are two main alternatives:

  - primary soil settlement followed by natural treatment in lagoons enhanced by surface aeration, and
  - preceding the above with aerobic treatment.

Surface aeration
Surface aeration uses the lagoon as the basis. To increase the rate of aerobic bacterial activity, additional oxygen is diffused into the water by electrically driven "free" or "fixed" floating aerators. Occasionally wind powered aerators are used where weather conditions are favourable. Indeed, mixed wind and electrical systems are now available. The same limitations as for lagoons prevail. At low temperatures bacterial activity is reduced. The additional oxygen, whilst increasing bacterial food, is derived from air at ambient temperature. Hence during the winter bacterial activity is reduced. Nevertheless, they can be, under the right conditions, both efficient and cost effective.

Injection of pure oxygen is an extension to the surface aeration technique. However, the running costs of purchasing the liquid oxygen are high.

Aerobic treatment
Aerobic treatment is commonly referred to as activated sludge plants. These operate by mixing waste water with a mixture of micro-organisms, nutrients and air (oxygen), which then oxidise the organic impurities in the waste water. The activated sludge consists of aerobic bacteria, which break down the organics in the waste, and protozoa and rotifers which feed on the bacteria. The activated sludge is settled out in settlement tanks or clarifiers and part of it is returned to the aeration tank for mixing with the waste water. The clear, treated water is decanted off from the settlement tank or clarifier.

Aerobic treatment plants can receive the oxygen input from either surface injection or sub-surface injection. Surface injection of oxygen is by means of either surface aerators or oxygenation cages. This type of plant will treat low BOD water highly efficiently and cost effectively. Low winter air and water temperatures will, however, depress the treatment capacity as bacterial activity is reduced. However, low-grade waste heat from the sugar process can usually be used to increase temperatures in the system and enhance bacterial activity.

Sub-surface aerobic treatment plants are usually categorised as either fine or medium / large bubble aeration systems. They can be used to treat high or low BOD waste waters. Fine bubble systems can be highly efficient, cost effective systems. Oxygen uptake into the waste water from fine bubble diffusers is high and therefore fewer units and less air is required to remove a fixed biological load compared to medium / large bubble diffusers. Both systems need a large input of air and power, and as such can be expensive to operate. Fine bubble aeration is more cost effective than medium bubble aeration in terms of operation, but both systems can be highly efficient in degrading biological oxygen demands. The type of system installed depends upon the constituents in the waste water. High calcium waters will quickly scale up fine bubble diffusers. The heat of compression from the air can increase the water temperature by up to 80 ºC, which increases the rate of bacterial activity during this period.

Aerobic treatment will convert the biological oxygen demand of the water by bacterial action but will leave organic waste, usually termed effluent sludge. This sludge will require removal from the plant and can often be put to a beneficial use. It should also be noted that there are a large number of designs of this system. The selection of the most appropriate one must take many factors into account, such as availability of space and costs.

**Option 3**

Should the environmental needs dictate that further levels of treatment are required, primary soil settlement, anaerobic treatment followed by oxygenation and/or aerobic digestion with a final sludge settlement process may be considered.

Anaerobic treatment is carried out in the absence of "free" oxygen. Anaerobic bacteria breakdown the organics in the waste water in the simultaneously occurring stages; Hydrolysis, Acidification and finally Methanogenesis. The final breakdown products are methane and carbon dioxide. This reaction is optimised at 370 ºC, although a lower rate of digestion can take place at 200 ºC or less.

Anaerobic digestion is normally used for high BOD waste waters and sludges, but recent designs are more flexible. Technological advances have greatly altered both the size and performance of anaerobic treatment plants. The methane gas can either be used to heat the waste water or used as a fuel in the main process. They also require less nutrient addition compared to aerobic systems and produce far less surplus sludge (approximately 5 % by volume versus 50 % by volume for aerobic systems). Most anaerobic plants will remove about 95 % of the influent BOD. If the influent BOD rises, the effluent BOD rises. But, if the influent BOD rises too much, the removal rate may decrease. In practice, anaerobic effluents always need subsequent aerobic treatment.

**Option 4**

For those circumstances which demand additional control of nitrogen and its compounds, it will be necessary to install suitable designed nitrification and denitrification systems. There are many designs of such systems, they can be either batch or continuously operated. In essence the effect is to nitrify the ammonium ions into nitrites and nitrates. These are then denitrified into elemental nitrogen gas, which is then harmlessly discharged to air.

There are several biological and non-biological techniques available for reducing levels of ammonium ($NH_4$+) ions in discharged effluents.

## 4.14.7 Soft drinks and alcoholic beverages

### 4.14.7.1 Scope

This sub-sector includes:

- production of ethyl alcohol by fermentation
- manufacture of wine from grapes and from concentrated grape must
- manufacture of grape juice
- manufacture of fruit wines and other fermented fruit beverages
- manufacture of cider and perry
- manufacture of distilled alcoholic beverages
- production of mineral waters
- manufacture of soft drinks
- manufacture of malt.

The manufacture of beer is the subject of a separate project and will not be discussed here, except in the context of common or transferable techniques. Tea and coffee and their substitutes belong to another sub-sector. [13, **Environment Agency (UK)**, 2000]

### 4.14.7.2 Sources & nature of waste water

#### 4.14.7.2.1 General

Processes for the manufacture of different beverages share common sources of waste water, including:

- plant and equipment cleaning
- washing of containers (bottles, cans, casks)
- pasteurisation of containers
- floor washing
- once-through cooling water or bleed from closed loop cooling systems
- boiler blowdown
- backwash from water treatment systems
- "chase" water purged from pipework between uses.

The preparation and cleaning of equipment is the largest source of waste water in this sector.

The cleaning of fermenter vessels in particular is a major source of COD/BOD and suspended solids load. In breweries they are the source of almost half the COD load and about 70 % of the suspended solids load in the waste water. Proprietary products used in the cleaning process (e.g. clay, disinfectants, detergents, sanitising agents) contribute to the waste water loadings. Dilute solutions of peracetic acid, a widely used sanitising agent, have a COD of approximately 1000 mg/l. When one soft drinks manufacturer changed the lubricant they used on their conveyors, they reduced soap usage by 75 % and substantially reduced COD discharges associated with the soap.

In addition to these point sources, overflowing vessels and tanks often make a significant contribution to the waste water strength. [13, **Environment Agency (UK)**, 2000]

#### 4.14.7.2.2 Soft drinks, fruit juice, mineral waters

Waste water treatment in biological treatment systems has proved successful in both the fruit juice industry and the soft drinks industry. Only where bottling is confined exclusively to mineral water can biological treatment cause problems owing to the lack of a substrate.
Buffering and smoothing (mixing and equalisation basins) before the biological treatment is always advisable. Depending on the product range and packaging system (returnable or non-returnable), constant or intermittent addition of nutrient salts may be necessary. However, cleaning and disinfecting measures may lead to temporary peaks in P concentrations, which may then cause problems for direct dischargers in spite of the equalisation measures. In the case of returnable bottle systems and the associated bottle cleaning operations, the nitrogen contained in the label adhesive may make it necessary to design the treatment system for targeted nitrogen elimination. [65, Germany, 2002]

#### 4.14.7.2.3 Production of ethyl alcohol by fermentation

The major sources of waste water are the cooling water system, which serves the condensers and fermentation tanks, and the residues (vinasses) from the distillation towers.

Manufacture of Cider and Perry

There are two main processes which liberate waste water at cider and perry manufacturing installations;

- production of final product from juice
- milling of fruit.

The production of the final product occurs all year round, whereas the milling of fruit is dictated by the harvesting of the fruit itself.

The waste water from the production of the final product is generally generated from wash water, waste product (kept to a minimum), and spillages from storage areas etc.

During the milling season the waste water volumes and strengths increase significantly. The main sources of waste water during this period are:

- transport water (conveying the fruit through the process)
- surplus evaporator water (from juice concentrating)
- general waste (wash water etc).

The transport water is recycled as often as possible, however, this waste water is high in strength. Towards the middle of the milling season, flows and loads increase due to the quantity of fruit entering an installation. Towards the end of the milling season the volume of waste water decreases. However, the BOD and solids content of the waste water increases due to the deteriorating quality of the fruit being received. [13, **Environment Agency (UK)**, 2000]

#### 4.14.7.2.4 Production of malt

The main sources of waste water are the discharge from the steeping tanks and the cooling system for the germination stage.

### 4.14.7.3 Water/waste water recycling

Waste water with a high sugar/fermentable content may be reusable in other industries, such as yeast production.

If water-cooled refrigeration compressors are used, the cooling water is on a closed loop, if practicable. It may be possible to integrate the compressors in the fermenter cooling water loop. Otherwise the cooling water is re-used for washing purposes.

Careful management of steam and condensate can significantly reduce waste water discharges and conserve energy.

When washing bottles, cans or other containers the final rinsewater is used for the pre-rinse or other stages. Where liquid ring vacuum pumps are used in the filling operation, contamination of the seal water is minimised so that it can be re-used as rinsewater.

Where possible, water used in pasteurisers and boilers is recirculated. [13, **Environment Agency (UK)**, 2000]

Some typical waste water production figures for the soft drinks industry are shown below:

| Product | Specific waste water discharge ($m^3$ water/$m^3$ of product) |
|---|---|
| Bottled waters | 0.8 |
| Fruit juices | 1.5$m^3$ |
| Carbonates/dilutables | 1.4 $m^3$ |
| Carbonates/fruit juices | 3.6 $m^3$ |

**Table 4.65: Average specific waste water discharges**
**[51, Envirowise (UK), 1998]**

### 4.14.7.4 Waste water minimisation

In addition to the general advice on waste water minimisation in Sections 4.4 - 4.5, the following minimisation techniques specific to this sub-sector may be adopted where applicable:

- avoid overfilling of process vessels, as contents can have very high COD (e.g. in beer making every 1 % of wort going to drain adds about 5 % to the trade effluent COD)
- use fine mesh baskets over floor drains to keep grain, fruit skins, etc. out of the drainage system
- return strong liquors to the process, or recover them for animal feed or other re-use where practicable
- avoid disposing of yeast to drain because of its very high COD and propensity to form organic acids
- use cross-flow filtration rather than conventional product filters, to reduce volume of chase water and product losses
- meter volume of product into containers rather than filling them to capacity, to avoid overfilling or fit fob return systems to the filling heads
- collect spillage in returned containers rather than washing it to drain.

[13, **Environment Agency (UK)**, 2000]

### 4.14.7.5 Waste water treatment

Segregation
In general, where possible, waste water segregation is investigated. Potential may exist for high volume low strength streams to be either:

- recycled (following suitable treatment)
- discharged directly to sewer (without treatment)
- mixed with treated final effluent prior to discharge.

The options available will be dependent upon the receiving water and hence the consent to discharge. By segregating low strength streams, a treatment facility can be reduced in size by designing on high strength waste waters liberated from an installation. [13, **Environment Agency (UK)**, 2000]

Fermentable and non-fermentable wastes are kept separate to maximise potential for re-use.

Treatment for Discharge to Sewer
The level of treatment required prior to discharge to sewer is dependent upon the consent to discharge conditions. An economic balance needs to be achieved taking into account trade effluent charges and the capital and operating costs of a new effluent treatment plant.

The soft drinks and beverages sub-sector is a diverse sector on its own, however, for the purposes of effluent treatment, the waste waters generated can be categorised as follows:
- low strength high volume

- high strength low volume
- continuous regular discharges
- campaign/seasonal discharges.

In general, when applying techniques for the treatment of waste waters liberated from the soft drinks and beverages sub-sector, the following unit processes may be considered: [13, **Environment Agency (UK)**, 2000]

- **Screening** to remove gross solids is recommended for installations in this sub-sector. Static wedge screens are cleaned several times a day to remove build-up. Self-cleaning screens are preferable, otherwise regular manual cleaning takes place. Vibrating screens have also been used successfully within this sub-sector.

Due to the batch-wise nature of the processes and washdown regimes, flow and load balancing would be required. The waste water from this sub-sector tends to be highly biodegradable and contain active bio-organisms. Excessive retention in the balance tank are avoided to ensure that the contents do not become anaerobic, leading to acidity and odour. The balance tank is agitated to prevent sludge accumulation, minimising the potential for methane build-up. A balance tank would typically have a retention time of 6 - 12 hours. [13, **Environment Agency (UK)**, 2000]

- High trade effluent charges will make it cost-effective for most installations covered by IPPC to carry out some form of **primary treatment**. Dissolved air flotation is widely used in this sub-sector for the removal of fats, oils and greases and of suspended solids. The separated material can generally be re-used as animal feed if suitable coagulants and flocculants have been chosen.

In some instances, discharge to sewer could occur downstream of a primary process, depending upon the efficiency of the process and the receiving sewage treatment works. In this case operators must allow for a contingency strategy for failure of the primary treatment process, e.g. a diversion tank.

- Following primary treatment, further stages may be required, either to achieve a consent to discharge or to minimise trade effluent charges. For waste water streams with a BOD concentration greater than 1000 – 1500 mg/l BOD **anaerobic treatment** processes are considered. Anaerobic techniques are widespread across Europe. If anaerobic technique is used, operators ensure that fats, oils and greases are not allowed to reach the anaerobic reactor as well as minimising any biocides from reaching this stage of the process. Final effluent from the anaerobic process could be discharged directly to sewer, following flash aeration.

- For lower strength waste water streams **aerobic treatment** would be the preferred option. Conventional activated sludge systems have been used for such waste water streams, and (where economics allow) activated sludge variants (pure oxygen, SBR, MBR) would also be applicable. High rate trickling filters have also been employed as well as the standard rate configuration.

Hybrid aerobic reactors, such as the submerged biological aerated filter are also gaining popularity in this field.

For installations affected by seasonal produce, a number of options exist. Installations such as these will have general waste water generated all year round from the continuous production on-site. During the season or campaign, further waste water is generated from intensive processes. The nature of the general waste water and the campaign waste water will dictate the technique for the installation.

Typically the campaign waste water will be higher in strength than the general waste water and a number of factors will affect an operators choice of techniques under these conditions, e.g. the discharge points for the waste water streams may not be close to each other and there may be little or no process benefit in combining the streams.

The main choice facing operators here will be whether to treat the waste water streams separately or together. This will be site-specific and will be dependent upon the nature of the streams, the nature of the streams when combined, and the economics of constructing an effluent treatment plant capable of receiving significantly higher loads during a campaign.

If treated separately, the general waste water stream may require primary treatment only (prior to discharge to sewer), however, secondary treatment requirements would be aerobic biological treatment, typically conventional activated sludge, trickling filters and hybrid reactors, such as the submerged biological aerated filter.

The campaign/seasonal waste water is typically high in strength and comparatively low in volume. As the waste water stream is generated during certain times of the year only, anaerobic treatment would be considered for the treatment of the stream. Final effluent from the anaerobic process could be discharged directly to sewer, following flash aeration.

For treating the streams together, a treatment plant must be of modular construction with two or more reactors working in parallel. This will allow for one reactor to be used out of season with the plant brought up to full capacity during the seasonal production. A technique to consider for this configuration would be a conventional activated sludge process with pure oxygen supplementation during the high loads associated with the seasonal production. The plant may require artificial feeding in preparation for the increased flows and loads.

Treatment for discharge to water course or for recycling
For discharges to water courses, or for treating effluent to a quality suitable for re-use, further treatment stages would be required.

- For high strength waste waters that have already passed through an **anaerobic treatment** plant, **a further aerobic plant** will be generally required. Typically anaerobic reactors are followed by conventional activated sludge systems for further treatment. A two stage biological system (anaerobic followed by aerobic) if designed correctly achieves a quality of effluent suitable for discharge to a water course. Should suspended solids consent be low a tertiary macrofiltration system (sandfilter) would be required.

Further tertiary treatment would be required for recycling all or part of the final effluent. Due to the nature of the waste, GAC filters and/or crossflow microfiltration would be required. Disinfection would also be recommended should recycled water be used in hygienic areas.

### 4.14.8 Production and processing of vegetable oils and fats

Biological waste water treatment
In recent years there have been extensive investigations into biological treatment of refinery waste water from oil mills, with the aim of eliminating the hitherto unavoidable waste water loads. Tests have been performed on a laboratory and pilot-plant scale. Treatment strategies developed as a result have hitherto been implemented in two prototype production-scale systems. Both examples are tailored to the special operating conditions of the factories and their local situation. Optimisation of the prototypes is still in progress. Therefore, as yet, one cannot speak of a fully developed technique for biological waste water purification in this industry.

Industry-specific factors:

- Influence of low-volatile lipophilic substances
- Influence of sulphate on biological waste water purification
- Influence of elevated phosphatide levels on biological waste water purification
- Influnce of pH on biological waste water purification.

In view of the residual oil content, it makes sense to use flotation rather than sedimentation for separation of solids – both in preliminary clarification and in final clarification. In general the waste water lends itself well to biological treatment. One problematic aspect is the elimination of P from the waste water. In the untreated water, phosphate is present in organic form and cannot therefore be precipitated during preliminary treatment. Simultaneous precipitation is not practicable either, because the treatment systems are too sensitive to peak loads. Subsequent precipitation with aluminium salts is possible, but P concentrations of less than 2 mg/l have yet to be achieved. [65, Germany, 2002]

## 4.15 Waste water treatment – Case studies

**[CIAA 2002, #1]**

### 4.15.1 Waste water treatment in the sugar industry: Cleaner beets

Every year large quantities of soil, gravel and stones are transported to Danisco's sugar factories as part of beet deliveries. Handling of this unwanted material consumes a lot of resources at the site, such as energy and water. Danisco Sugar has focused on reducing this soil tare since the early 1980s.

A 'Clean Beats' project, combining technical, economic, and plant breeding measures, has resulted in a reduction of 150000 tonnes of soil coming to factories in Sweden. In Denmark, the figure is even higher, due to larger beet growing area. Levels are now 50 % below those typical of 10 years ago.

A special bonus system is used in Sweden and Denmark to promote harvesting in good weather conditions and the use of harvesters in the best possible manner. Tests run by Danisco Sugar indicate that once new harvesters are used appropriately it is possible to achieve a 5 % soil tare (95 % purity) under almost all weather conditions.

Reduction of soil amount (tare) in Sweden:

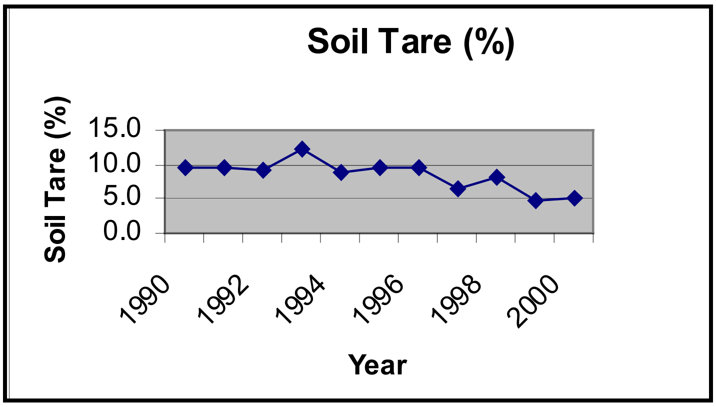

**Figure 4.48: Reduction of soil tare in Sweden**
**[1, CIAA, 2002]**

Parallel to this work, Danisco Seed is working on improving the shape of sugar beet to ensure that less soil attaches to the tuber. Breeding using traditional breeding techniques has focused on the root groove of the beet, which is the main problem in beet cleaning.

Once the soil has settled in the ponds the water is cleaned in waste water treatment plants having an anaerobic step producing biogas used as fuel and an aerobic step degrading nitrogen and phosphorus.
After cleaning, the water is either re-used in the factory or drained into rivers or the open sea.

The efficiency of waste water treatment plants is illustrated by the figures for the amount of biodegradable compounds (BOD), nitrogen and phosphorus in the inlet and after the various treatments:

| Treatment | BOD mg/l | Total N mg/l | Total P mg/l |
|---|---|---|---|
| Before treatment | 3300 | 120 | 10 |
| After anaerobic treatment | 100 | 80 | 8 |
| After anaerobic and aerobic treatment | 2 | 10 | 0.4 |

**Table 4.66: Waste water treatment figures in sugar industry**

## 4.15.2 Multi-stage waste water treatment for vegetable oils and fats manufacturing plant

**[65, Germany, 2002]**

Multi-stage waste water system with mechanical, chemical and full biological stages.
The technique is used for on-site treatment of the production waste water from the processing of oils and fats at the facility. The system in question is a demonstration system. It was implemented with assistance from the programme run by the Ministry for the Environment, Nature Conservation and Nuclear Safety. The waste water comes from soap splitting (acid water), the storage sector and plant cleaning.
The system comprises the following stages: fat separation, mixing and equalisation system, dissolved-air flotation with and without preceding flocculation, neutralisation, cascaded biological stage, activated sludge flotation.
The following Table shows the operating data and dimensions of the system:

| Operating data (maxima) | |
|---|---|
| Waste water input | < 25 $m^3/h$ |
| Untreated waste water: | |
| COD | 2500 mg/l |
| Lipophilic substances (H 17) | 100 mg/l |
| $Phosphorus_{total}^{*}$ | < 140 mg/l |
| Sulphate up to | 12000 mg/l |
| Unit 1: | Cooling, NaOH neutralisation, coagulation aid admixture, urea admixture |
| Flotation in acid environment: | A = 25 $m^2$ |
| Flotation in neutral environment: | A = 25 $m^2$ |
| Unit 2: | Aerobic activation + flotation (intermediate clarification) |
| Cascaded activated sludge basins | V1= 630 $m^3$<br>V2 = 1 270 $m^3$<br>Residence time: approx. 35 h |
| Flotation | A = 45 $m^2$ |
| Unit 4: | Clear water tank, clarified waste water storage tank for sedimentation of residual suspended matter, buffer for rinsing purposes, outfeed pump station |
| Clear water tank | V = 279 $m^3$ |

| Unit 5: | Sludge treatment |
|---|---|
| | Sludge storage tank with fine-bubble aeration for aerobic stabilisation of the surplus sludge. Sludge storage tank for fatty sludge from chemical/physical pretreatment, with coarse-bubble aeration for aerobic stabilisation of sludge. |
| System performance | |
| Operating values at outlet | < 150 mg/l COD<br>< 5 mg/l $BOD_5$<br>< 70 mg/l P |
| Consumption data | |
| Energy consumption | |
| Steam | 16 kg/t unrefined oil |
| Electricity | 3.2 kWh/t unrefined oil |
| * Source of phosphorus: phospholipids/lecithins | |

**Table 4.67: Description of waste water treatment system at an oil and fat processing facility [65, Germany, 2002]**

### Applicability and characterisation of technique

**Availability**: Good

Achieved environmental benefits

- Reduction in waste water COD by more than 95 %
- phosphorous elimination through biological absorption: approx. 50 %.

Cross-media effects

- increased use of operating resources: caustic soda, coagulation aids for fat elimination
- increased use of energy for physical and biological process steps
- waste for energy production results from fat elimination and aerobic biological stage.

Applicability

Area of application: Universal

| Restrictions: | Low organic loads |
|---|---|
| | Good preliminary fat separation |
| | No preceding precipitation of phospholipids possible |
| | Simultaneous precipitation with high P concentrations harmful to biocenosis |
| | Subsequent precipitation to ensure reliable compliance with P levels only possible with substantial overdosing |
| Operating reliability: | Limited owing to substantial unavoidable fluctuations in quality of untreated waste water |
| | Reliable control of system only possible by disproportionate means |

Economics

- Substantial investment for development and construction of system
- cost due to increased input of energy and operating resources
- cost of maintenance and repair
- cost due to greater demands on operating personnel
- costs due to increased waste production.

Driving forces for implementation

- More stringent official requirements regarding waste water volume and quality
- local situation regarding gravitational flow into receiving body of water (water conditions)
- timing of decision on availability of other alternatives
- demonstration system assisted by public funds.

## 4.15.3 Waste water treatment of a distillery

**[65, Germany, 2002]**

Waste water treatment system at a molasses distillery

Description

The condensed vapours from the facility's condensation unit and the singlings from distillation / rectification are cleaned in a two-stage waste water treatment system (anaerobic/aerobic). At the heart of the system is a biobed reactor (expanded granular sludge bed – EGSB – reactor) in which the organic load is largely degraded to methane gas under anaerobic conditions. There is a further reduction in COD load and nitrogen load in the downstream activated sludge unit. The methane gas is burned in a CHP plant to generate electricity and heat. In view of the high efficiency of the biobed reactor, only small quantities of aerobic surplus sludge are produced. This is concentrated in a decanter and used for agricultural purposes or disposed of via the municipal sewerage system. The following schematic diagram shows the process sequence in the factory waste water treatment system.

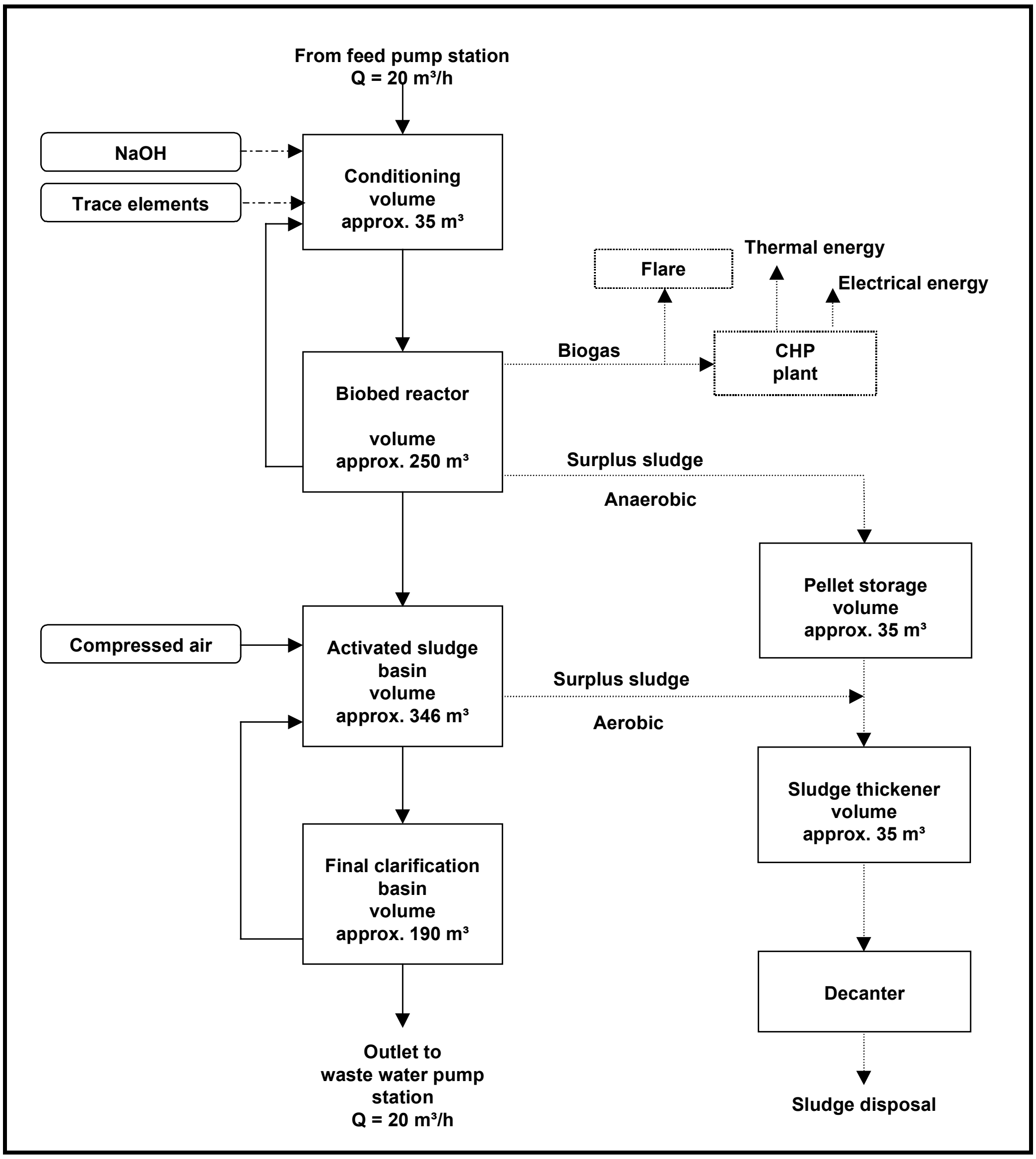

**Figure 4.49: Flow chart and dimensions of the anaerobic/aerobic waste water treatment system at a distillery**
**[65, Germany, 2002]**

Achieved environmental benefits

- reduction in organic load in waste water and nitrogen level.

Cross-media effects

- reduction in waste water emissions
- reduction in electrical energy requirements of waste water treatment system
- reduction in emissions thanks to power generation by burning methane in CHP unit.

Operational data

Applicability

Economics

Driving forces for implementation

- reduction in waste water levy
- reliable compliance with discharge parameters under regulations.

Example plants

### 4.15.4 Production and use of biogas in a dairy plant

**[1, CIAA, 2002]**

Description

The company produced cheese, yoghurt, butter, cream, etc. The plant typically produced some 20 - 22 thousand m$^3$ of whey per year as a by–product of their manufacturing processes.

A two step waste water treatment facility was built. The first part consisted of a 2200 m$^3$ digester of an UASB type which anaerobically digests the bulk of organic material contained in whey (up to 95 % at 35 °C). The second part is an aerobic treatment which is used to `polish` the final effluent before passing this into a nearby grade one river.

The anaerobic digester produced 775000 m$^3$/yr of a biogas containing 55 - 60 % methane. The biogas was primarily used for raising steam in the plant`s boilers, which were fitted with dual fuel (heavy oil/biogas) burners, but it was also used to generate electricity via a 135 kWh gas engine. Waste heat from the generator cooling water and exhaust was used to heat water in the two insulated storage tanks and used the following day as boiler feed water and wash water in the Creamery.

Achieved environmental benefits

- industrial effluent ready to discharge into the river
- energy savings: 15000 GJ/yr.

Cross-media effects

Operational data

Applicability

Dairy, brewing, other food processing industries with readily degradable and heavily polluted waste waters.

Economics

Investment cost: GBP 470000 (1987). Payback period: 5 - 6 years. (Energy saving.)

Driving forces for implementation

Disposal of whey containing waste water was increasingly difficult and expensive.

Example plant

South Caernarvon Creameries Ltd, Chwilog, Pwlheli, Gwynedd LL53 6SB, UK

## 4.16 End-of-pipe techniques - Techniques for the treating, recovering and disposing of solid output

Examples of methods to treat, recover and dispose of solid emissions are given below.

No priority ranking is intended, and the appropriate selection in a particular case will depend on the specifics of the process concerned and on site constraints.

The interpretation of the symbols is given in Table 3.29.

Techniques available

(a) Treatment

| | |
|---|---|
| gravity thickening | (G1) |
| dissolved air flotation | (G2) |
| filtration | (G3) |
| centrifugation | (G4) |
| drying | (G5) |

(b) Recovery (see also Section 4.3)

| | |
|---|---|
| landspreading (as fertiliser) | (R1) |
| re-use in downstream processing | (R2) |

(c) Disposal

| | |
|---|---|
| landfill | (D1) |
| Incineration with energy recovery | (D2) |

Application of techniques

The application of these techniques to handle the various solid residues various emissions identified in Section 3.6 is given in Table 4.68.

| Sources | Technique |
|---|---|
| Organic (waste product / processing material) | G3,G4,G5; R1, R2; D1,D2 |
| Oils / fats / greases | G1,G2; R1,R2 |
| Inorganic (e.g. soil, calcium carbonate, bleaching earth) | G3,G4,G5; R1; D1,D2 |
| Solvent | D2 |
| Metals e.g. nickel catalyst | R2 |
| Packaging from process operations | R2, D1,D2 |

**Table 4.68: Summary of techniques for handling solid output**
**[1, CIAA, 2002]**

## 4.17 Noise abatement measures in the food industry

### 4.17.1 Traffic noise

Noise sources
Noise emissions by traffic are largely determined by engine and exhaust noise and by tyre and road noise.
Engine noise covers not only the noise emitted by the engine itself, but also the noise from all auxiliary equipment, the transmission, the pipes, the fan, the pressure system and the exhaust.
Rolling noise covers all noise emissions arising from the rolling of the tyres on the road surface. These emissions increase rapidly at higher speeds.

Possible miscellaneous noise sources in HGV traffic include, flow noises, rattling sounds, incidental noise emanating from the chassis, body etc.

Drive noises depend primarily on engine speed, while tyre and road noises depend on the speed of the truck and the properties of the road surface. In general it is true to say that traffic noise is to a large extent determined by the way the vehicle is driven. High engine speeds and rapid acceleration can increase noise levels by up to 15 dB(A) compared with normal driving.

If one assumes that an accelerating HGV with an engine power in excess of 150 kW has a sound level of around 90 dB(A), it becomes clear that traffic noise is a significant factor in compliance with the immission limit values specified separately for heavy industrial areas in TA-Lärm 98. The TA-Lärm lists immission values that are graduated by area use categories (industrial area, residential area etc.), with different values for day and night. The immission guide value for outdoor immission locations in heavy industrial areas is 70 dB(A). In heavy industrial areas no distinction is made between day and night values. [65, Germany, 2002]

Noise abatement measures

For the noise sources there are a variety of measures that can be used singly, or in combination, to achieve noise reductions which may in some cases be substantial:

| | |
|---|---|
| Constructional measures | • Noise control structures (embankments, walls)<br>• Plants<br>• Placing roads lower than surrounding land<br>• Noise-reducing road surfaces |
| HGV-related measures | • Sound insulation of engine |
| Driving-related measures | • Reducing speed<br>• Steady driving |
| Organisational measures | • Access to factory on the side facing away from the use that is to be protected |

Constructional measures can be extremely effective in reducing noise propagation. The abatement effect of a noise barrier primarily depends on its height. No effect is achieved until the line of sight between source and recipient is interrupted. It is also important to ensure that no gaps in the structure cancel out the noise reduction otherwise achieved. The closer the wall or embankment to the road, the greater is the effect. Sound-absorbing noise barrier designs prevent reflection and any resulting increase in the sound level on the other side of the road. Noise barriers in the form of walls or embankments can bring reductions of 10 dB(A) or more.

Plants, like noise barriers, can reduce traffic noise, though to a lesser extent. Where sound is propagated through dense leafy vegetation one can expect a maximum sound level reduction of 1.5 dB(A) per 10 m depth of vegetation. The psychological effect here must not be overlooked. For example, people affected by traffic noise may perceive a subjective noise reduction as a result of trees, dense vegetation, e.g. with hedges to interrupt the line of sight between the sound source and the recipient, even if this reduction is small in measurable terms.

If the road is placed lower than the adjacent land, the road is below the highway boundary, cycle path, pavement or adjacent buildings. The direct propagation path of the sound is thus interrupted. It does, however, have the disadvantage that it is more difficult for pedestrians and cyclists to cross such roads, because they can only cross at certain places.

At higher speeds the vehicle rolling noise, or rather the tyre/road surface noise, outweighs the drive noise. The structure of the road surface thus acquires great importance. For example, a mastic asphalt with chippings is 2 dB(A) quieter than a rolled asphalt surface and 4 dB(A) quieter than a concrete surface. Open textured asphalt cappings, known as “whispering asphalt”, can reduce noise levels by a further 3 dB(A) [ARS 14/1991]. However, open-textured asphalts run into technical problems. Their noise reduction effect is due to the fact that the tyre/road noise is “intercepted” by the cavities in the road surface. The cavities fill up with dirt in the course of time, however, and quickly lose their effect as a result. Other disadvantages are their short life (some 6 - 8 years compared with 20 years for normal asphalt surfaces) and expensive drainage. Great potential undoubtedly exists here for achieving permanent noise reductions in future by means of improved road surfacings that also meet the requirements for road safety, durability and maintenance costs. In general it is important to keep highways in good repair.

Irregularities in the road surface cause additional noise and cause vibrations in HGV bodies and loose loads.

In Annex 1 to the 16th Ordinance implementing the Federal Immission Control Act [16. BImSchV – Verkehrslärmschutzverordnung], Table B lists correction data in dB(A) for various road surfaces. The correction data are used when calculating the assessed noise level. The assessed level in dB(A) is then compared with the immission limit values.

Noise-reducing road surfaces not only bring about a reduction in road noise, but also absorb engine noise and inhibit reflections.

According to RLS-90, a speed reduction from 50 km/h to 30 km/h brings a sound level reduction of approx. 2.5 dB(A). In addition, driving style and habits play an important role in noise emissions. Smooth steady driving creates less noise than frequent changes between acceleration and braking, and driving at lower engine speeds is quieter than high engine speeds. Driving an HGV at high engine speeds generates 5 dB(A) more noise than driving at low engine speeds. [65, Germany, 2002]

### 4.17.2 Ventilation systems and fans

Noise sources

The noise generated by ventilation systems can be transmitted over considerable distances through the air. The noise mainly escapes via the duct system as airborne noise. For noise abatement purposes, it is important to reduce the noise input into the duct system from the fan and any additional noise flows that arise during passage through the duct system.

The principal cause of fan noise is turbulence phenomena and local flow retardation due to vortex shedding. Noise may be caused by excitement of the duct walls at their natural frequency and by cross resonances between the duct walls. Other notable noise sources, particularly at high air speeds, include branches, bypasses, dampers and air passages.

Noise abatement measures

Noise levels in ventilation systems can be reduced by means of silencers. The most commonly used are absorption-type silencers. It is also possible to encapsulate sound sources. A capsule usually consists of a metal jacket lined with absorber material, which wholly or partially encloses the sound source. The noise level reduction that can be achieved depends on the insulation of airborne sound by the walls and the absorption capacity of the internal lining.

The connections between the fans and the ducts or housings are effected using elastic linkages.

Fan noises are transmitted over long distances; the higher frequencies tend to die away faster. In the following example (Figure 4.50) the roof-mounted fan is therefore modified to produce higher-frequency noise.

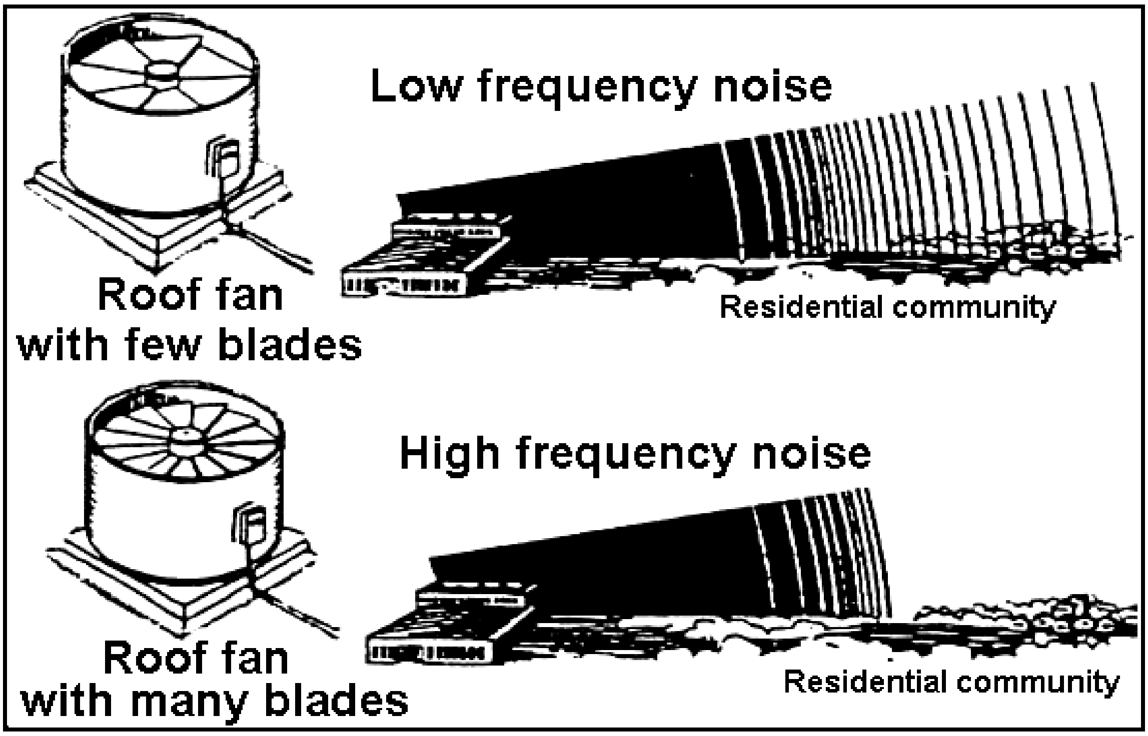

**Figure 4.50: Influencing noise transmission by a roof fan**
**[65, Germany, 2002]**

### 4.17.3 Pipework

Noise sources

Pipes are used to transport gases, vapours and liquids. It is also possible to transport solids with the aid of a carrier liquid. The noise emissions arising from pipes are many and various. They include noise formation in the flowing media, transmission of noise by the fluids and solids, and airborne noise transmission.

Virtually no noise results from laminar flow, but with increasing turbulence the noise level within the pipe increases.

Cavitation also causes intensive noise. Cavitation occurs when the static pressure is locally equal to or less than the vapour pressure, e.g. where the direction of flow is changed.

When solids are transported with the aid of carrier fluids, additional noise results from contact of the solid particles with each other and with the walls of the pipe. Such noise is particularly marked where hard particles are transported using a gaseous fluid. The sound pressure level depends on the flow rate, the material of the pipe, and the type of solid. Sound pressure levels may reach between 85 dB(A) and 100 dB(A) at a distance of 1 m from straight pipe elements. Some 10 dB(A) to 15 dB(A) more can be expected in the vicinity of bends.

Noise abatement measures

To ensure compliance with the immission limit values of the TA-Lärm, the pipes can be enclosed within walls or laid in special ducts. In such cases it is necessary to line the cavities or fill them with sound absorbing material to achieve optimum results. One can also consider laying pipes and ducts underground.

Sound insulation can be improved by the following means: [65, Germany, 2002]

- use a different pipe material with better sound insulating properties (e.g. cast iron instead of plastic)
- increase the thickness of the pipe wall
- enclose the pipe in jacket attachments.

Damping the vibrations in the pipe wall that gives rise to airborne noise causes a reduction in sound energy by absorption as the sound spreads through the fluid. This damping effect is not important at low frequencies, but increases as the frequency rises. The damping effect falls off as the pipe diameter increases, and irregularities in the surface of the pipe increase the damping effect. If pipes have a sound-absorbing inner lining, then at higher flow speeds the damping is considerably reduced for sound propagation in the direction of flow and increased for sound propagation against the direction of flow.

When dimensioning pipes it is important to ensure that the principal excitation frequency of the sound power level entering the pipe is sufficiently far from the natural frequencies and pass frequencies of the pipes. All natural frequencies are influenced by the way the pipes are mounted, the route taken by the pipe (bends) and any internal baffles etc.

### 4.17.4 Industrial structures

Noise sources

The acoustic output of machines and the acoustic properties of the rooms determine the sound pressure levels inside an industrial building close to the external shell of the building. These sound pressure levels (internal) and the sound insulation provided by the external shell (walls, roofs, windows, doors, openings) result in the airborne sound power of the elements.

Other examples of noise sources in industrial structures include towers and chimneys.

Noise abatement measures

One means of reducing noise is to insulate parts of the industrial building against airborne noise. A distinction is made between single-shell and double-shell components.

The sound insulation of components of more or less homogeneous structure depends largely on their weight per unit area. The nature of the material is also important.

Double-shell building elements consist of two dense shells separated by an air gap or a resilient insulating layer. Under certain conditions the sound insulation provided by such elements is greater than that of single-shell elements of the same weight. The most important requirement for better sound insulation is that the air gap between the shells be sufficiently large or that any insulating layer stuck between the shells is sufficiently resilient and open textured. It is of the utmost importance for the insulating effect that the cavity between the shells be filled with sound-absorbing materials, e.g. mineral fibre panels. Rigid connections between the shells have an adverse effect on sound insulation.

Shielding the industrial building has the effect that the sound pressure level at immission sites without a direct line-of-sight connection with the noise source is lower than at immission sites with a direct line-of-sight connection. Shielding may be effected by other buildings in the industrial complex or by additional barriers such as walls or embankments. These can achieve a shielding effect of 5 dB(A) if they at least interrupt the line-of-sight connection. The higher the barrier and the closer it is to the noise source and/or immission site, the greater the shielding effect. [65, Germany, 2002]

Organisational measures may also achieve noise reductions. These include not working with doors or windows open, and not working outside.

Air flowing past chimneys creates noise due to eddies and excites vibrations in the chimney. One possible measure is a spiral turbulence generator to interfere with eddy formation and hence sound generation. The gradient of the turbulence generator is not constant.

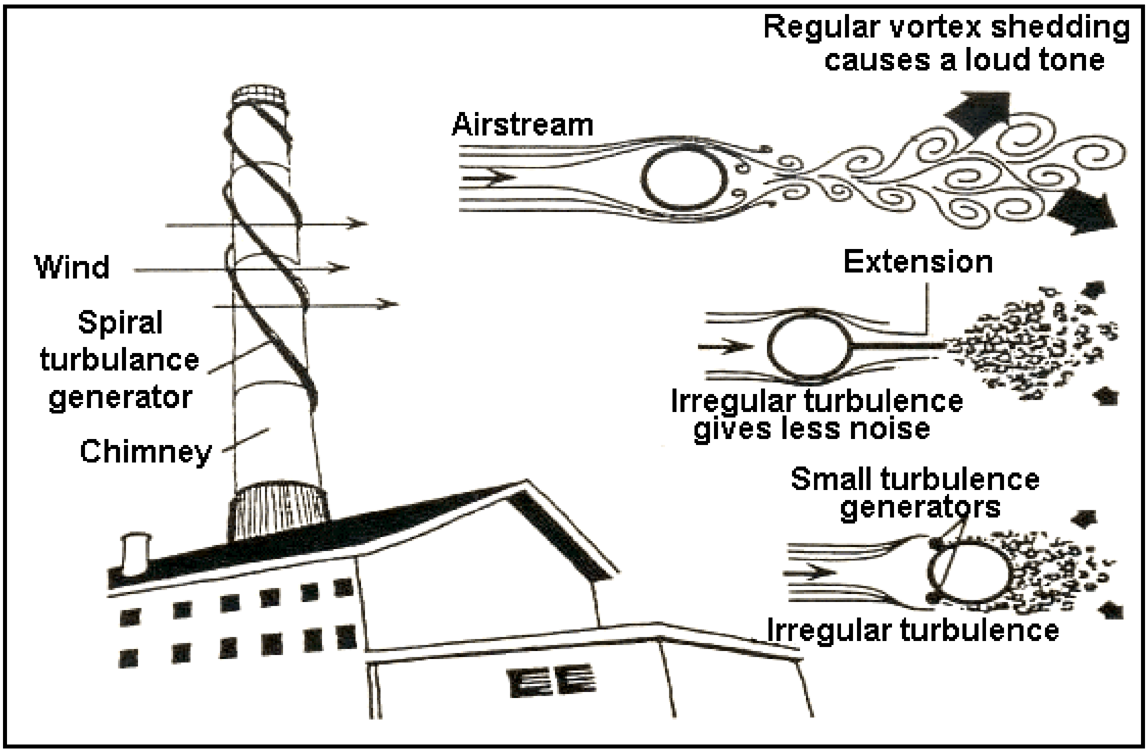

**Figure 4.51: Noise reduction on an industrial chimney**
**[65, Germany, 2002]**

## 4.17.5 Case studies

### 4.17.5.1 Noise reduction in a large brewery

**[65, Germany, 2002]**

A large brewery was requested to measure noise levels in the neighbourhood of the brewery. The following tasks were to be performed:

- measuring the immission levels caused by the brewery at the nearest immission detection sites
- calculating the noise levels at the nearest immission detection sites caused by traffic to and from the brewery (incoming malt etc., outgoing bottled beer, canned beer, yeast and brewery residues) and within the facility (fork-lift trucks, employee car parks).

Six parcels of land were considered as immission detection sites. With the exception of one site (storage and workshop buildings), the parcels of land are not built on.

Under the Federal Immission Control Act, breweries are installations requiring authorisation. Noise originating from industrial facilities is measured and assessed in accordance with the TA-Lärm. The following immission guide values apply:

For exposure sites in the vicinity of mainly light industrial sites (applies to all six parcels of land considered):

| | | |
|---|---|---|
| by day | (06.00 AM – 10.00 PM) | 65 dB(A) |
| by night | (10.00 PM – 06.00 AM) | 50 dB(A) |

Individual events are also subject to the requirement that brief noise peaks must not exceed the immission guide values by more than 30 dB(A) by day or more than 20 dB(A) by night.

The brewery operates a full 24 hours a day on working days. Traffic to and from the brewery is confined to daytime hours.

The measurements of the immissions caused by the brewery at the nearest immission detection sites (the noise sources used were the operating noise of fans and compressors and brief blow-off noises from valves) yielded the results shown in Table 4.69:

| Measuring site | LAFm [dB(A)] | LAF95 [dB(A)] | Noise source |
|---|---|---|---|
| Parcel 1 | 43.3 | 42.0 | Fans of waste water system |
| Parcel 2 | 48.0 | 46.5 | Fans of CIP system, roof fans |
| Parcel 3 | 49.7 | 48.0 | Fans of CIP system, roof fans |
| Parcel 4 | 48.6 | 46.0 | Fans of CIP system, compressor unit |
| Parcel 5 | 45.8 | 44.5 | Compressor unit |
| Parcel 6 | 46.9 | 45.5 | Compressor unit |

**Table 4.69: Measurements (mean of three independent measurements)**

The measurements in Table 4.70 characterise the noise emissions from production by day and by night without internal site traffic and supplier traffic. These sound immissions were calculated for day operation (Lrt2) and night operation (Lrn2) (Table 4.70, columns 2 and 3).

| Site | Partial rating level – night Lrn2 [dB(A)] | Partial rating level – day Lrt2 [dB(A)] | Rating level [dB(A)] | | Immission guide value [dB(A)] | |
|---|---|---|---|---|---|---|
| | | | Day | Night | Day | Night |
| Parcel 1 | 43.5 | 52.9 | 53.7 | 46.4 | 65 | 50 |
| Parcel 2 | 41.2 | 51.0 | 53.7 | 49.0 | 65 | 50 |
| Parcel 3 | 30.9 | 44.3 | 52.8 | 49.7 | 65 | 50 |
| Parcel 4 | 24.4 | 37.3 | 51.2 | 48.6 | 65 | 50 |
| Parcel 5 | 31.7 | 41.7 | 49.1 | 46.0 | 65 | 50 |
| Parcel 6 | 35.9 | 44.9 | 50.1 | 47.2 | 65 | 50 |

**Table 4.70: Calculated partial rating levels for materials transport and transhipment processes, derived rating level and comparison with guide values of TA Lärm**

Columns 2 and 3 of Table 4.70 show the partial rating levels for transport and transhipment processes at the individual immission sites. The day and night rating levels (columns 4 and 5, Table 4.70) result from the "energy-oriented" addition of the measured partial emission levels and the calculated levels at the individual immission sites. When calculating the daytime rating levels, the values in Table 4.69 were raised by a rest-period mark-up of 2.4 dB.
The measured values at all six sites were well below the immission guide values during the day and comply with the immission guide value during the night.

# 5 BEST AVAILABLE TECHNIQUES

# 6 EMERGING TECHNIQUES

# 7 CONCLUDING REMARKS

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# GLOSSARY

## Glossary of terms

| | |
|---|---|
| Activated sludge process | A sewage treatment process by which bacteria that feed on organic wastes are continuously circulated and put in contact with organic waste in the presence of oxygen to increase the rate of decomposition. |
| Aeration | A biological process that occurs in the presence of oxygen. |
| Anaerobic | A biological process which occurs in the absence of oxygen. |
| AOCl | Adsorbable organic chlorine compounds. |
| AOX | Adsorbable organic halogen compounds. The total concentration in milligrams per litre, expressed as chlorine, of all halogen compounds (except fluorine) present in a sample of water that are capable of being adsorbed on activated carbon. |
| Aquifer | A water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring. |
| Asbestos | A mineral fibre that can pollute air or water and cause cancer or asbestosis when inhaled. |
| Assimilative capacity | The ability of a natural body of water to receive waste waters or toxic materials without harmful effects and without damage to aquatic life. |
| Bactericide | A pesticide used to control or destroy bacteria. |
| Biochemicals | Chemicals that are either naturally occurring or identical to naturally occurring substances. Examples include hormones, pheromones and enzymes. Biochemicals function as pesticides through non-toxic, non-lethal modes of action, such as disrupting the mating pattern of insects, regulating growth or acting as repellants. |
| Biodegradable | That can be broken down physically and/or chemically by micro-organisms. For example, many chemicals, food scraps, cotton, wool and paper are biodegradable. |
| Biodiversity | The number and variety of different organisms in the ecological complexes in which they naturally occur. Organisms are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species and genes that must be present for a healthy environment. A large number of species must characterize the food chain, representing multiple predator-prey relationships. |
| Eutrophication | The pollution of a body of water by sewage, fertilizers washed from the land, and industrial wastes (inorganic nitrates and phosphates). These compounds stimulate the growth of algae, reducing the oxygen content in the water, and so killing animals with a high oxygen requirement. |

## Glossary of abbreviations

| **Currency** | |
|---|---|
| | |
| ATS | Austrian schilling |
| BEF | Belgian franc |
| CZK | Czech koruna |
| DEM | German mark |
| DKK | Danish krone |
| EEK | Estonian kroon |
| ESP | Spanish peseta |
| EUR | Euro |
| FIM | Finish markka |
| FRF | French franc |
| GBP | Pound sterling |
| GRD | Greek drachma |
| HUF | Hungarian forint |
| IEP | Irish pound |
| ITL | Itialian lira |
| NLG | Dutch guilder |
| PLN | Polish złoty |
| PTE | Portuguese escudo |
| SEK | Swedish krona |

## Other terms

| | |
|---|---|
| ADMS | Atmospheric dispersion modelling system. |
| BAFF | Biological aerated flooded filter. |
| BAT | Best Available Technique(s). |
| BOD | Biochemical oxygen demand: the quantity of dissolved oxygen required by micro-organisms in order to decompose organic matter. The unit of measurement is mg $O_2$/l. In Europe, BOD is usually measured after 3 ($BOD_3$), 5 ($BOD_5$) or 7 ($BOD_7$) days. |
| BREF | BAT reference document. |
| BSE | Bovine spongiform encephalopathy. |
| $C_1$, $C_2$ etc. | Organic compounds indicated by the number of carbon atoms. |
| CaO | Calcium oxide. |
| $Ca(OH)_2$ | Calcium hydroxide. |
| CBP | Chorleywood Bread Process. |
| $CCl_4$ | Carbon tetrachloride. |
| CEN | The European Committee for Standardization. |
| CFC | Chlorofluorohydrocarbons. |
| $CH_4$ | Methane. |
| $CHCl_3$ | Trichloromethane (chloroform). |
| CHP | Co-generation of heat and power (combined heat and power). |
| CIAA | Confederation of the food and drink industries of the EU. |
| CIP | Cleaning-in-place. |
| $Cl_2$ | Chlorine. |
| CMF | Cross flow microfilter. |
| CO | Carbon monoxide. |
| $CO_2$ | Carbon dioxide. |
| COD | Chemical oxygen demand: the amount of potassium dichromate, expressed as oxygen, required to chemically oxidize at ca. 150 °C substances contained in waste water. |
| DAF | Dissolved air flotation. |

| | |
|---|---|
| ED | Electrodialysis. |
| EDTA | Ethylene-diamine-tetra-acetate. |
| e.g. | For example (Latin: exempli gratia). |
| EGSB | Expanded granular sludge blanket (reactor). |
| EIPPCB | European IPPC Bureau. |
| EMS | Environmental management system. |
| EP | Electrostatic precipitator. |
| EPA | USA Environment Protection Agency. |
| ESP | Electrostatic separators. |
| ETBPP | Environmental Technology Best Practice Programme (UK). |
| $FeCl_3$ | Iron trichloride. |
| FFA | Free fatty acids. |
| FOG | Fats, oils and greases. |
| GAC | Granular activated carbon. |
| GMO | Genetically modified organisms. |
| HACCP | Hazard Analysis Critical Control Points. |
| HCFC | Hydrochlorofluorocarbon. |
| HCH | Hexachlorocyclohexane (lindane). An insecticide. |
| HCl | Hydrochloric acid. |
| HDPE | High density poly-ethylene. |
| HP | High pressure. |
| HPP | (margarine). |
| HRT | Hydraulic retention time. |
| $H_2SO_4$ | Sulphuric acid. |
| HTST | High temperature short time (pasteurisation). |
| IBC | Belt blancher/water freezer combination. |
| ISCST | Industrial source complex short term (model). |
| ISO | International Organisation for Standardization. |
| IPPC | Integrated pollution prevention and control. |
| LAS | Linear alkylated benzenesulphonacids. |
| $LC_{50}$ | Lethal concentration. The lowest concentration of a substance in water or ambient air in milligrams per litre sufficient to cause death in 50 % of the test population within a defined period (e.g. 96 hours for fish, 48 hours for daphnia). |
| LDPE | Low density poly-ethylene. |
| LOEC | Lowest observed effect concentration. The lowest experimentally determined concentration of a test substance at which adverse effects can be observed. |
| LP | Low pressure. |
| LTDM | Long-term frequency distribution model. |
| MAP | Modified atmosphere packing. |
| MBR | Membrane bio-reactor. |
| MF | Microfiltration. |
| MLSS | Mixed liquor suspended solids. |
| MS | Member state(s) of the European Union. |
| MVR | Mechanical vapour recompression. |
| n/d | No data. |
| NF | Nanofiltration. |
| NGO | Non-governmental organisation. |
| $NH_3$ | Ammonia. |
| $NH_4$ | Ammonium. |
| $NH_4$-N | Ammonium nitrogen |
| N-tot | Total nitrogen. |
| PAH | Polyaromatic hydrocarbons. |

| | |
|---|---|
| PET | Polyethylene terephtalate. |
| Pid | Process and instrumentation diagrams. |
| PM | Particulate matter. |
| PP | Polypropylene. |
| PS | Polystyrene. |
| PTFE | Polytetrafluorethylene. |
| PVC | Polyvinyl chloride. |
| QAC | Quaternary ammonium compounds. |
| RO | Reverse osmosis. |
| SBAF | Submerged biological aerated filter. |
| SBR | Sequencing batch reactor. |
| SEC | Specific energy consumption. |
| SME | Small and medium enterprise(s). |
| SNF | Solids not fat. |
| $SO_x$ | Sulphur oxides. |
| $SO_2$ | Sulphur dioxide. |
| $SO_3$ | Sulphur trioxide. |
| SS | Suspended solids. |
| TDS | Total dissolved solids. |
| TOC | Total organic carbon. |
| TS | Total solids. |
| TSE | Transmissible spongiform encephalopathy. |
| TSS | Total suspended solids. |
| TVR | Thermal vapour recompression. |
| TWG | Technical working group. |
| UASB | Upflow anaerobic sludge blanket (reactor). |
| UF | Ultrafiltration. |
| UHP | Ultra high pressure. |
| UHT | Ultra high temperature (sterilisation). |
| UV | Ultraviolet. |
| VOC | Volatile organic compounds. |
| WFE | Wiped film evaporator. |
| WHB | Waste heat boiler. |
| WWTP | Waste water treatment plant |

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# ANNEX 1 RELEVANT LEGISLATION IN EU AND IN SOME COUNTRIES

## 1.1. STATUS REPORT ON FOOD LEGISLATION IN THE EUROPEAN UNION

### 1.1.1 General principles and structures

| **Reference** | **Published (OJ L)** | **Content** | **Application date** | **Modified by** |
|---|---|---|---|---|
| 68/361/EEC Decision | 255/68 | Sets up the Permanent Veterinary Committee. | Entry into force 15.10.68 | |
| 69/414/EEC Decision | 291/69 | Sets up the Standing Committee for Foodstuffs which is made up of representatives of the Member States and a representative of the Commission. During - its meeting of 28-29.09.93 the Standing Committee adopted its own rules of procedure (III/3939/93). | Entry into force 13.11.69 | |
| 69/1119 Resolution | 148/69 (OJ C) | Council Resolution on the intervention procedures of the Standing Committee on Foodstuffs. | Entry into force 13.11.69 | |
| 75/420/EEC Decision | 182/75 | Decision setting up an Advisory Committee on Foodstuffs. | Entry into force 26.06.75 | 78/758 (251/78); **80/1073** |
| 77/505/EEC Decision | 206/77 | Sets up the Permanent Zootechnical Committee. | Entry into force 25.07.77 | |
| 80/1073/EEC Decision | 318/80 | Decision establishing a new statute for the ACF to comprise 30 members representing the following sectors: agriculture, industries, employees, commerce and consumers. The Committee is consulted by the Commission on any draft related to legislation on foodstuffs. | Entry into force 26.11.80 | |
| 81/651/EEC Decision | 233/81 | Decision which sets up the Scientific Veterinary Committee. | Entry into force 30.07.81 | **86/105** |
| 85/591/EEC Directive | 372/85 | Directive which makes the Standing Committee on Foodstuffs procedure more general regarding decisions on methods of sampling and analysis intended for the inspection of foodstuffs. | Implementation date 23.12.87 | |
| 86/105/EEC Decision | 93/86 | Amends Decisions 76/791, 78/436 and 81/651 with respect to the number of members of the Scientific Committee. | Entry into force 25.02.86 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 87/89/EEC Decision | 45/87 | Decision concerning the setting up of the Consultative Veterinary Committee. | Entry into force 01.01.87 | |
| 93/5/EEC Decision | 52/93 | Directive on assistance to the Commission and co-operation by the Member States in the scientific examination of questions relating to food. | Implementation date 01.06.93 | |
| 93/72/EEC Decision | 26/93 | Decision concerning the setting up of an Advisory Committee for co-ordination within the field of the Internal Market. | Entry into force 01.01.93 | |
| 94/458/EC Decision | 189/94 | Commission Decision on the administrative management of co-operation in the scientific examination of questions relating to food. | Entry into force 07.07.94 | |
| No reference | 245/94 | Commission Decision establishing the composition of the Scientific Veterinary Committee. | | |
| No reference | 246/94 (OJ C) | List of competent authorities nominated y Member States, responsible for co-operation with the Commission on the scientific examination of questions relating to food. | | |
| 94/652/EC Decision | 253/94 | Commission Decision establishing the inventory and distribution of tasks to be undertaken within the framework of co-operation by Member States in the scientific examination of questions relating to food. | Entry into force 22.09.94 | **957124; 95/492; 96/460; 97/174; 98/177; 98/479; 99/134; 99/634** |
| 95/142/EC Decision | 92/95 | Commission Decision amending Decision 94/652 | Entry into force 02.04.95 | |
| 95/260/EC Decision | 162/95 | Commission Decision creating a Consumers Committee, repealing Decision 90/55 creating a Consultative Consumer Council. | Entry into force 13.06.95 | |
| 95/273/EC Decision | 167/95 | Commission Decision relating to the institution of a Scientific Committee for Food, repealing Decision 74/234 creating a Scientific Committee for Food. | Entry into force 06.07.95 | |

**Table I - Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| No reference | | Composition of the Scientific Committee for Food. | | |
| 95/492/EC Decision | 282/95 | Commission Decision amending Decision 94/652. Establishing the inventory and distribution of tasks to be undertaken within the framework of co-operation by Member States in the scientific examination of questions relating to food. | Entry into force 16.11.95 | **96/460** |
| No reference | 99/96 | Nomination of new members of the Scientific Veterinary Committee. | | |
| 96/460/EC Decision | 191/96 | Commission Decision modifying Decision 94/652 and 95/492, establishing the inventory and distribution of tasks to be undertaken within the framework of co-operation by Member States in the scientific examination of questions relating to food. | Entry into force 09.07.96 | |
| 97/174/EC Decision | 70/97 | Commission Decision modifying Decision 94/652, establishing the inventory and distribution of tasks to be undertaken within the framework of co-operation by Member States in the scientific examination of questions relating to food. | Entry into force 20.02.97 | |
| 97/404/EC Decision | 169/97 | Commission Decision creating a Scientific Steering Committee. | Entry into force 27.06.97 | **2000/443** |
| 97/579/EC Decision | 237/97 | Commission Decision setting up eight Scientific Committees in the field of food safety, animal nutrition, animal health and animal welfare, veterinary public health, plants, cosmetic and other non-food consumer products, toxicity and eco-toxicity and the environment, medicinal products and medical devices. | Entry into force 23.07.97 | **2000/443** |
| 98/177/EC Decision | 65/98 | Commission Decision replacing the Annex of Decision 94/652 on the inventory and distribution of tasks to be undertaken within the framework of co-operation by Member States in the scientific examination of questions relating to food. | Entry into force 05.03.98 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 98/479/EC Decision | 215/98 | Commission Decision amending Decision 94/652 establishing the inventory and distribution of tasks to be undertaken within the framework of co-operation by Member States in the scientific examination of questions relating to food. | Entry into force 01.08.98 | |
| 98/34/EC Directive | 204/98 | European Parliament and Council Directive laying down a procedure for the pro- vision of information in the field of technical standards and regulations. | Entry into force 11.08.98 | **98/48** |
| 98/48/EC Directive | 217/98 | European Parliament and Council Directive amending Directive 98/34 laying down a procedure for the provision of information in the field of technical standards and regulations | Implementation date 05.08.99 | |
| 99/134/EC Decision | 44/99 | Commission Decision amending Decision 94/652 establishing the inventory and distribution to be undertaken within the framework of co-operation by Member States in the examination of questions relating to food. | Entry into force 27.01.99 | |
| 99/634/EC Decision | 249/99 | Commission Decision amending Decision 94/652 establishing the inventory and distribution of tasks to be undertaken within the framework of cooperation by Member States in the scientific examination of questions relating to food. | Entry into force 22.09.99 | |
| 2000/443/EC Decision | 179/00 | Commission Decision amending Decision 97/404 setting up a Scientific Steering Committee and Decision 97/579 setting up scientific committees in the area of consumer health and food safety. | Entry into force 18.07.00 | |

**Table I – Adopted legislation (continued)**

**Table II - Proposed legislation: none**

**Table III - Draft proposals: none**

### 1.1.2 Official control of foodstuffs

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 85/374/EEC Directive | 210/85<br>307/88 | The Directive approximates Member States' legislation on liability for defective products. The Directive applies to all "movables " except unprocessed agricultural goods. The manufacturer of a product is liable for any damage caused by any defect in the product - except in a number of situations that are specified in the Directive. | Implementation date 30.07.88 | |
| 89/397/EEC Directive | 186/89 | Lays down the general principles governing the verification of the compliance of foodstuffs, and materials and articles intended to come into contact therewith, with legislation. | Implementation date 20.06.90<br>Implemented in all Member States | |
| 92/59/EEC Directive | 228/92 | The Directive complements Directive 85/374 on product liability and creates general standards and powers for removing hazardous products from the market place. | Implementation date 29.06.94 | |
| 93/99/EEC Directive | 290/93 | The Directive supplements Directive 89/397 and lays down additional rules designed to improve the control procedures in force in the Community and to strengthen co-operation between the authorities responsible for the official control of foodstuffs. The additional measures proposed concern training of staff, quality standards for laboratories and an increase in the exchange of information between Member States and Commission officials. | Implementation date 01.05.95<br>For Article 3: 01.01.98 | |
| 96/290/EC Recommendation | 109/96 | Commission Recommendation concerning the coordinated programme for the official control of foodstuffs for 1996. | Entry into force 18.04.96 | |
| 97/77/EC Recommendation | 22/97 | Commission Recommendation concerning a coordinated programme for the official control of foodstuffs for 1997. | Entry into force 13.01.97 | |
| 99/34/EC Directive | 141/99 | Directive of the European Parliament and of the Council amending Directive 85/374 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for the defective products. | Implementation date 04.12.00 | |

**Table I – Adopted legislation**

**Table II - Proposed legislation: none**

**Table III - Draft proposals: none**

### 1.1.3 Methods of sampling and analysis for the monitoring of foodstuff

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 85/591/EEC Directive | 372/85 | Defines the criteria with which the methods of sampling or analysis for the determination of the composition, conditions of manufacture, packaging or labelling of a foodstuff must comply. | Implementation date 22.12.87<br>Implemented in all Member States | Implementation 22.12.87 |

**Table II - Proposed legislation: none**

**Table III - Draft proposals: none**

### 1.1.4 Food labelling

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 87/250 Directive | 107/91113/87 | Deals with the compulsory listing of actual alcoholic strength by volume and specific tolerances. | Implementation dates 01.05.88 and 01.05.89<br>Implemented in all Member States | |
| 89/396/EEC Directive | 186/89 | Deals with marks identifying the lot to which a foodstuff belongs. | Implementation dates 20.06.90 and 20.06.91 - extended to 01.07.92 by 92/11<br>Implemented in all Member States | **91/238; 92/11** |
| 90/496/EEC Directive | 276/90<br>79/93,<br>51/92,<br>140/91,<br>76/91 | Nutrition labelling rules for foodstuffs for sale to the consumer | Implementation dates 01.04.92 and 01.10.93<br>Implemented in all Member States | |
| 91/238/EEC Directive | 107/91 | Amends 89/396 Article 2 with regard to lot marking of individual portions of ice cream. | Implementation date 21.04.91<br>Implemented in all Member States | |
| 92/11/EEC Directive | 65/92 | Amends 89/396 on lot marking to prohibit trade in products not in compliance as of 01.07.92. | Implementation date 01.07.92<br>Implemented in all Member States | |
| 94/54/EC Directive | 300/94<br>34/95 | The Directive provides for the indication of the use of packaging gases where these gases have been used to extend the durability of the product concerned.<br>The Standing Committee for Foodstuffs met on 20.12.94 and agreed that packaging gases used in beers and non alcoholic beverages should not be mentioned on the labelling. | Implementation dates 01.07.95 and 01.01.97 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 96/21/EC Directive | 88/96 | Modifies Directive 94/54 concerning the compulsory indication on the labelling of certain foodstuffs (containing sweeteners) other than those provided for in Directive 79/112. | Implementation dates 01.07.96 and 01.07.97 | |
| 1141/97/EC Regulation | 165/97 | Commission Regulation laying down detailed rules for the application of Council Regulation 820/97 as regards the labelling of beef and beef products. | Entry into force 24.06.97 | **2406/97** |
| 2406/97/EC Regulation | 332/97 | Commission Regulation amending Regulation 1141/97, laying down detailed rules for the application of Council Regulation 820/97 as regards the labelling of beef and beef products. | Entry into force 11.12.97 | |
| 824/98/EC Regulation | 117/98 | Commission Regulation laying down detailed rules for the application of Council Regulation 820/97 as regards the labelling of beef and beef products. | Entry into force 22.04.98 | |
| 2071/98/EC Regulation | 265/98 | Council Regulation on publicity measures on the labelling of beef and veal | Entry into force 07.10.98 | |
| 1468/99/EC Regulation | 170/99 | Commission Regulation laying down certain detailed rules for the application measures for the Community beef and veal labelling system in 1999/2000. | Entry into force 07.07.99 | |
| 2772/99/EC Regulation | 334/99 | Council Regulation providing for the general rules for a compulsory beef labelling system. | Entry into force 29.12.99 | |
| 2000/13/EC Directive | 109/00<br>124/00 | Directive of the European Parliament and of the Council on the approximation of laws of the Member States relating to the labelling, presentation and advertising of foodstuffs. | Implementation date 26.05.00 | |
| 1760/2000/EC Regulation | 204/00 | Regulation of the European Parliament and of the Council establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products and repealing Council Regulation 820/97. | Entry into force 14.08.00 | **1825/2000** |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1825/2000/EC Regulation | 216/00 | Commission Regulation laying down detailed rules for the application of Regulation 1760/2000 of the European Parliament and of the Council as regards the labelling of beef and beef products. | Entry into force 29.08.00 | |

**Table I – Adopted legislation (continued)**

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposal for a Directive of the European Parliament and the Council amending Directive 79/112/EEC COM (97) 20 final (OJ C 106/97). | First reading on the report was taken in the European Parliament on 25.02.99. The EP's amendments mainly concern avoiding discrimination between the different alcoholic beverages and how the list of ingredients should be displayed. | The ESC endorsed the proposal on 28.05.97. Its opinion called for specific labelling rules to be adopted by the Standing Committee on Foodstuffs, an independent body whose role is to assess rules governing foodstuffs. | Council's Common Position is presently awaited. | The proposal is to make the list of ingredients compulsory for alcoholic beverages. The Schnellhardt report aims to bring about one consolidated set of legislation for all alcoholic beverages, which are presently covered by different institutional procedures from comitology through to co-decision - and with the resulting varying degrees of EP participation. In the EP, however, there is fundamental disagreement between the rapporteur and the Agricultural Committee drafts man about whether this directive should apply to all alcoholic beverages. Whilst the rapporteur believes that this should be the case, the latter is actively seeking differentiation between "industrial" products, such as beer and alco-pops, and "agricultural" products such as wine, as regards both labelling requirements and the timespan under which to introduce a label. The amended proposal COM (99) 0339 takes up 12 amendments adopted by the EP including extension of the deadline from 3 to 5 years, a more specific reference to aromatised beverages and the consultation of the SCF where issues relating to |

**Table II – Proposed legislation**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft proposal for a European Parliament and Council Directive amending Directive 2000/13/EC. | | Proposes the compulsory statement in the list of ingredients of certain substances scientifically recognised as sources of allergy and intolerance, without the possibility of granting derogation and proposes the removal of the rule for the labelling of compound ingredients. | Advisory Committee: 13.07.00 | A2 |

**Table III – Draft proposals**

## 1.1.5 Pre-packing and unit pricing

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 75/106/EEC Directive | 42/75<br>324/75 | Deals with the making-up by volume of certain pre-packaged liquids. Specifies the maximum negative error between actual content and the quantity indicated on the pre-package. Reference methods are also specified. | Implementation dates 19.06.76 and 31.12.79<br>Implemented in all Member States | **78/891; 79/1005; 85/10; 88/316** |
| 75/107/EEC Directive | 42/75 | Applies to bottles used as measuring containers. Specifies the maximum error tolerated compared with the nominal capacity of the bottle. Reference methods are also specified. | Implementation date 20.06.76<br>Implemented in all Member States | **78/891** |
| 76/211/EEC Directive | 46/76 | Applies to the making-up by weight or by volume of certain pre-packaged products. Specifies the maximum negative error tolerable between the actual content and the quantity indicated on the pre-package. Reference methods are also specified. | Implementation dates 22.07.77 and 31.12.79<br>Implemented in all Member States | |
| 78/891/EEC Directive | 311/78<br>6/79 | Modifies 75/106 and 76/211 on pre-packaged liquid foodstuffs as regards tolerances, labelling and official verification of compliance. | Implementation date 01.01.80<br>Implemented in all Member States | |
| 79/1005/EEC Directive | 308/79 | Harmonises the text of the basic Directive 75/106 (on pre-packaged liquid foodstuffs) with that of Directive 76/211 (on pre-packaged non-liquid foodstuffs). | Implementation date 01.01.81<br>Implemented in all Member States | |
| 80/181/EEC Directive | 39/80,<br>89/80,<br>296/81,<br>185/84,<br>276/84 | Council Directive on the approximation of the laws of the Member States relating to units of measurements and on the repeal of Directive 71/354. | Implementation date 01.10.81<br>Implemented in all Member states | **89/617; 99/103** |
| 80/232/EEC Directive | 51/80<br>99/80,<br>81/80,<br>72/80 | Lists the ranges of nominal quantities and nominal capacities permitted for certain pre-packaged products. | Implementation date 17.01.82<br>Implemented in all Member States | **86/96; 87/356** |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 85/10/EEC Directive | 4/85 | Modifies Annex III of the basic Directive 75/106 on pre-packaged liquid foodstuffs (Annex III - ranges of nominal volumes allowed for certain product categories). | Implementation date 20.12.85 Implemented in all Member States | |
| 86/96/EEC Directive | 80/86 | Modifies Directive 80/232. Specifies certain types of products and the regime for products sold as aerosols. | Implementation date 19.09.87 Implemented in all Member States | |
| 87/356/EEC Directive | 192/87 | Council Directive amending Annex I of Directive 80/232. | Implementation date 30.06.88 Implemented in all Member States | |
| 88/315/EEC Directive | 142/88<br>219/88 | Exempts pre-packaged foodstuffs from unitpricing labelling. Member States may waive the obligation to indicate the unit price for specific products or quantities. The Directive provides for a transitional period which expires on 07.06.97. At the Edinburgh Council in December '92 the Commission was asked to simplify the existing legislation on unit pricing. | Implementation date 07.06.90 Implemented in all Member States | |
| 88/316/EEC Directive | 143/88<br>112/89,<br>189/88 | Modifies Article 1 and 5 and Annex III of Directive 75/106 on pre-packaged liquid foodstuffs. | Implementation date 30.06.88 Implemented in all Member States | |
| 89/617/EEC Directive | 357/89 | Council Directive amending Directive 80/181 on the approximation of the laws of the Member States relating to units of measurement. | Implementation date 07.12.91 | |
| 89/676/EEC Directive | 398/89 | Modifies Articles 1 and 5 and Annex III of Directive 75/106 on pre-packaged liquid foodstuffs. | Implementation date 01.07.90 Implemented in all Member States | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 95/58/EC Directive | 299/95<br>71/97 | European Parliament and Council Directive amending Council Directive 79/581 on consumer protection in the indication of the prices of foodstuffs as amended by Council Directive 88/315 and Council Directive 88/314 on consumer protection in the indication of the prices of non-food products. The Directive extends the transitional period for the application of unit pricing in Directive 88/315 which expires on 6.06.95, for 2 extra years. | Implementation date 07.06.95 | |
| 98/6/EC Directive | 80/98 | Directive of the European Parliament and the Council on consumer protection with respect to the indication of prices of products offered to consumers. | Implementation date 18.03.00<br>Implementation date 09.02.01 | |
| 99/103/EC Directive | 34/00 | Directive of the European Parliament and of the Council amending Directive 80/181 on the approximation of the laws of the Member States relating to units of measurement. | | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

**Table III – Draft proposals: none**

## 1.1.6 Additives

### 1.1.6.1 Framework directive 89/107 and specific directives

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 89/107/EEC Directive | 40/89 | Framework Directive which provides a basis on which lists of authorised additives and the conditions for their use may be drawn up. It paves the way for the adoption of a comprehensive Directive in the field, and for Directives determining the criteria of purity for food additives and the relevant methods for analysing and sampling them. Also lays down also general labelling requirements. | Implementation dates 28.12.90 and 28.12.91 Implemented in all Member States | **94/34** |
| 94/34/EC Directive | 237/94 | Council Directive amending Directive 89/107 concerning food additives authorised for use in foodstuffs. | Entry into force 10.09.94 | |
| 94/35/EC Directive | 237/94 | Council Directive on sweeteners for use in foodstuffs. | Implementation dates 31.12.95 and 30.06.96 | **96/83** |
| 94/36/EC Directive | 237/94<br>252/96,<br>259/94 | Council Directive on colours for use in foodstuffs. | Implementation dates 31.12.95 and 30.06.96 | |
| 95/2/EC Directive | 61/95<br>248/95 | Council Directive on additives other than colours and sweeteners. | Implementation dates 25.09.96 and 25.03.97 | **96/85; 98/72** |
| 95/31/EC Directive | 178/95 | Commission Directive establishing specific purity criteria for concerning sweeteners used in foodstuffs. | Implementation date 01.07.96 | **98/66** |
| 95/45/EC Directive | 226/95 | Commission Directive establishing specific purity criteria for colours used in foodstuffs. | Implementation date 01.07.96 | **99/75** |
| 96/77/EC Directive | 339/96 | Commission Directive establishing specific purity criteria for food additives other than colours and sweeteners, as permitted by Directive 95/2. | Implementation date 01.07.97 | **98/86** |
| 96/83/EC Directive | 48/97 | EP and Council Directive amending Directive 94/35 on sweeteners for use in foodstuffs. | Implementation dates 19.12.97 and 19.06.98 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 96/85/EC Directive | 86/97 | EP and Council Directive amending Directive 95/2 on additives other than colours and sweeteners. This Directive adds E407a to the list of additives. | Implementation date 28.06.97 | |
| 97/292/EC Decision | 48197 | EP and Council Directive on the maintenance of national laws prohibiting the use of certain additives in the production of foodstuffs. | Entry into force 26.03.97 | |
| 98/66/EC Directive | 257/98 | Commission Directive amending the Annex of Directive 95/31 regarding the purity criteria of isomalt (E 953). | Implementation date 01.07.99 | |
| 98R2/EC Directive | 295/98 | European Parliament and Council Directive amending Directive 95/2 on other additives than colours and sweeteners. | Implementation dates 04.05.00 and 04.1 1.00 | |
| 98/86/EC Directive | 334/98 | Commission Directive amending Commission Directive 96/77 laying down specific purity criteria on food additives other than colours and sweeteners. | Entry into force 29.12.98 | |
| 99/75/EC Directive | 206/99 | Commission Directive amending Commission Directive 95/45 laying down specific purity criteria concerning colours for use in foodstuffs. | Implementation date 01.07.00 | |

**Table I – Adopted legislation (continued)**

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposals for European Parliament and Council Directive amending Directive 95/2/EC ...<br>COM (1999) 329 Final.<br>COD/1999/0158 | The Lannoye report rejected the Commission proposal which sought to authorise new additives and processing aids. This position was carried in the Committee and the Parliament. | The ESC adopted its opinion on 08.12.99. | | Proposal to allow the use of some new additives recently evaluated by the SCF and to extend the use of some additives already authorised to be used in new applications. |

**Table II – Proposed legislation**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft amendment to Directive 96/77/EC laying down specific purity criteria on food additives other than colours and sweeteners. | WGA/002/00/ Rev. 1 | | CWP: 19-20.01.99<br>11-12.10.99<br>24-25.01.00 | A4 |
| Draft amendment to Directives on purity criteria (95/31/EC, 95/45/EC, 96/77/EC) concerning food additives from genetically modified organisms. | SANCO/1796 /2000 | This draft establishes provisions for safety evaluation of food additives prepared by a technique that involves genetic modification of from a starting material derived from genetically modified organisms. | CWP: 19-20.01.99<br>11-12.10.99<br>24-25.01-00<br>03-04.07.00 | A4 |
| Draft European Parliament and Council Directive amending the additives framework Directive 89/107/EC. | WGA/003/00 Rev. 1 | This draft intends to give power to the Commission on adjusting the specific Directives and sets provisions on labelling of food additives containing GMO sold as such to the manufacturer or to the ultimate consumer. | CWP: 24-25.01.00<br>03-04.07.00 | A4 |
| Draft amendment to Directive 95/31/EC laying down specific criteria of purity concerning sweeteners for use in foodstuffs. | WGA/004/00 | This draft sets purity criteria for mannitol and maltitol syrup. | CWP: 24-25.01.00<br>The Standing Committee gave its favourable opinion on 26.06.00. | A3 |
| Draft amendment to Directive 95/31/EC laying down specific criteria of purity concerning sweeteners for use in foodstuffs. | WGA/008/00 | This draft sets purity criteria for acesulfame K. | CWP: 03-04.07.00 | A4 |
| Draft amendment to Directive 95/45/EC laying down specific purity criteria concerning colours for use in foodstuffs. | WGA/009/00 | This draft sets purity criteria for algal betacarotene. | CWP: 03-04.07.00 | A4 |

**Table III – Draft proposals**

### 1.1.7 Directives on food additives prior to the framework directive 89/107 (emulsifiers, stabilisers, thickeners and gelling agents, preservatives, antioxidants, colours)

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 67/427/EEC Directive | 148/67<br>263/80,<br>249/67 | Regulates control measures to be used for the analysis of preservatives in and on citrus fruits. | Implementation date 01.07.68 Implemented in all Member States | |
| 78/663/EEC Directive | 223/78<br>91/79,<br>11/79,<br>296/78 | Establishes the specific purity criteria for emulsifiers, stabilisers, thickeners and gelling agents. | Implementation date 31.02.80 Implemented in all Member States | **82/504; 90/612; 92/4** |
| 81/712/EEC Directive | 257/81 | First Commission Directive laying down Community methods of analysis for verifying that certain additives used in foodstuffs satisfy purity criteria. | Implementation date 20.02.83 | |
| 82/504/EEC Directive | 230/82<br>269/82 | Amends 78/663 by adding specific purity criteria for xanthan gum and powdered cellulose and amends certain other criteria. | Implementation date 01.01.84 | |
| 90/612/EEC Directive | 326/90 | Commission Directive amending the Annex of Directive 78/663. | Implementation date 12.11.91 | |
| 92/4/EEC Directive | 55/92 | Amends the specific purity criteria for E473 sucrose esters in the Annex of Directive 78/663. | Implementation date 01.06.93 | |

**Table I – Adopted legislation**

### 1.1.8 Flavourings

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 88/388/EEC Directive | 184/88<br>89/96,<br>345/88 | Framework Directive on flavours used in foodstuffs and on their source materials. This Directive sets general purity criteria, definitions and principles. | Implementation dates 22.06.90 and 22.06.91 Implemented in all | **91/71** |
| 88/389/EEC Decision | 184/88 | Council Decision which invites the Commission to draw up before mid-1990 an inventory of the source materials and substances used in the preparations of flavourings. | Entry into force 22.06.88 | |
| 91/71/EEC Directive | 42/91 | Inserts Article 9a into Directive 88/388 on labelling of flavourings intended for sale to the final consumers. | Implementation dates 30.06.92 and 01.01.94 | |
| 2232/96/EC Regulation | 299/96 | European Parliament and Council Regulation laying down a Community procedure for flavouring substances used or intended for use in or on foodstuffs. | Entry into force 23.11.96 | |
| 99/217/EC Decision | 84/99 | Commission Decision adopting a register of flavouring substances used in or on foodstuffs drawn up in application of Regulation 2232196 of the European Parliament and of the Council | Entry into force 27.03.99 | **2000/489** |
| 2000/489/EC Decision | 197/00 | Commission Decision amending Decision 99/217 adopting a register of flavouring substances used in or on foodstuffs. | Entry into force 03.08.00 | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft European Parliament and Council Regulation laying down the list of food additives for use in flavourings. | WGF/005/00 | The draft proposal would permit only food additives mentioned in the Annex of the Regulation and lays down maximum limits in flavours and foodstuffs. | CWP: 05.07.99<br>15.10.99<br>26.01.2000<br>28.06.2000 | A4 |
| Draft Proposal for an EP and Council Directive amending Directive 88/388/EEC. | SANCO/1184/2000 | The draft proposal aims at amending Article 1 of the Directive 88/388/EEC in order to clarify its scope and to update the definition of process flavourings and smoke flavours. It also aims at amending Annex II to reduce the maximum levels of active principles such as coumarin following the opinion of the SCF on the safety of coumarin. In addition, furfural, capsaicin, menthofuran are added to Annex II. | CWP: 15.10.99<br>26.01.2000<br>28.06.2000 | A4 |
| Draft Commission Decision on an evaluation programme for the flavouring substances of the register of Commission Decision 1999/217/EC. | III/5621/99 Rev. 1 | The draft Decision lays down the methodology and priorities for the evaluation of the substances. The substances of the register will be classified into 36 chemical groups (Annex I) and into 2 lists: one list of substances that have been positively evaluated by SCF, JECFA, Council of Europe and another list of substances that were classified as not acceptable by SCF or JECFA. These lists will be updated on a yearly basis.<br>Annex II gives the chemical specifications to be provided for the evaluation and Annex IV (which is still empty) will provide a standard format for the transmission of the information to the SCF.<br>Other information related to the use of the molecule has to be provided: volume of use, food categories in which the substance is used (Annex III), levels of use, toxicological data if available.<br>If no data is given, the substance will be removed from the list.<br>Adopted on 18.07.00 and published in OJ L 197 of 03.08.00. | CWP: 15.10.99<br>26.01.2000<br>28.06.2000 | A4 |

**Table III – Draft proposals**

### 1.1.9 Processing aids

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 88/344/EEC Directive | 157/88 | Lists the extraction solvents which may be used during the processing of raw materials for foodstuffs or food ingredients. The conditions for use are specified for a number of these solvents. | Implementation date 12.06.91 | **92/115; 94/52; 97/60** |
| 92/115/EEC Directive | 409/92 | Amends Articles 1 and 2 and the Annex of Directive 88/344. | Implementation dates 01.07.93 and 01.01.94 | |
| 94/52/EC Directive | 331/94 | European Parliament and Council Directive amending for the second time Directive 88/344, reinstalling cyclohexane in the list of solvents to be used in the production of foodstuffs or ingredients. | Implementation date 07.12.95 | |
| 97/60/EC Directive | 331/97 | European Parliament and Council Directive amending for the third time Directive 88/344. | Implementation dates 27.10.98 and 27.04.99 | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

**Table III – Draft proposals: none**

### 1.1.10 Fortified foods and food supplements

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposal for a Directive of the European Parliament and of the Council on food supplements.<br>COM (2000) 222 final<br>COD/2000/0080 | Rapporteur: Emilia Müller (D, EPP)<br>Probable Plenary session: November 2000 | Rapporteur: Mr. Jaschick | | The aim of the directive is the approximation of laws relating to food supplements. |

**Table II – Proposed legislation**

**Table I: Adopted legislation: none**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft EC proposal for a European Parliament and Council Directive on the addition of nutrients to foods. | SANCO/1478/2000 | This draft intends to set provisions for the voluntary addition of nutrients to foods. | Advisory Committee: 13.07.00 | A3 |

**Table III – Draft proposals**

## 1.1.11 Food for particular nutritional uses

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 89/398/EEC Directive | 186/89<br>275/90 | Framework Directive on foodstuffs intended for particular nutritional uses, (which repeals and replaces the former Directive 77/94). Provides various elements of definitions and lays down certain measures for the protection of the consumer against fraud. Serves as a basis for future specific Directives on various foodstuff categories listed in Annex / which are: 1. Infant formulae,- 2. Follow-up milk and other follow-up foods,- 3. Baby foods, 4. Low-energy and energy-reduced foods intended for weight control,- 5. Dietary foods for special medical purposes, 6. Low-sodium foods, including low-sodium or sodium-free dietary salts, 7. Gluten-free foods,- 8. Foods intended to meet the expenditure of intense muscular effort, especially for sportsmen, 9. Foods for persons suffering from carbohydrate-metabolism disorders (diabetes). | Implementation dates 16.05.90 and 16.05.91 | **96/84; 99/41** |
| 91/321/EEC Directive | 175/91<br>101/95 | Vertical Directive on infant formulae and follow-on formulae. | Implementation dates 01.12.92 and 01.06.94 | **96/4; 99/50** |
| 92/52/EC/Euratom Directive | 179/92 | Extends Community rules or international standards on composition of infant formulae and follow-on formulae and Community rules on the labelling of those products intended for export to third countries. | Implementation date 01.06.94 | |
| 96/4/EC/Euratom Directive | 49/96 | Commission Directive amending Directive 91/321 on infant formulae and follow-on formulae. | Implementation dates 01.04.97 and 31.03.99 | |
| 96/5/EC/Euratom Directive | 49/96 | Commission Directive on processed cereal-based foods and baby foods for infants and young children. | Implementation dates 01.10.97 and 31.03.99 | **98/36; 99/39** |
| 96/8/EC Directive | 55/96 | Commission Directive on foods intended for weight-controlled diets. Specific Directive based on the general guidelines provided by Directive 89/398. | Implementation date 01.10.97 | |
| 96/84/EEC Directive | 48/97 | EP and council Directive amending Directive 89/398 on the approximation of the laws of Member States relating to foodstuffs intended for particular nutritional uses.<br>Provides for a procedure allowing on a temporary basis to put goods, resulting from technological innovation, on the market, pending modification of the specific Directive. | Implementation date 30.09.97 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 98/36/EC Directive | 167/98 | Commission Directive amending Directive 96/5 on processed cereal-based foods and baby foods for infants and young children. | Implementation dates 01.01.99 and 01.01.2000 | |
| 99/21/EC Directive | 91/99<br>2/00 | Commission Directive on dietary foods for special medical purposes. | Implementation dates 01.05.2000 and 01.11.2001 | |
| 99/39/EC Directive | 124/99 | Commission Directive amending Directive 96/5 on processed cereal-based foods and baby foods for infants and young children. | Implementation dates 30.06.2000 and 01.07.2002 | |
| 99/50/EC Directive | 139/99<br>290/99 | Commission Directive amending Directive 91/321 on infant formulae and follow-on formulae. | Implementation dates 30.06.2000 and 01.07.2002 | |
| 99/41/EC Directive | 172/99 | Directive of the European Parliament and of the Council amending Directive 89/398 on the approximation of the laws of the Member States relating to foodstuffs intended for particular nutritional uses. | Implementation dates 08.07.2000 and 08.07.2001 | |
| 2001/15/EC Directive | 052/01 | Commission Directive on substances that may be added for special nutritional purposes in foods for particular nutritional uses.<br>The purpose of this Directive is to establish a positive list of nutritional uses (as defined by Directive 89/398/EEC) | Implementation date 31.03.02 | |

**Table I – Adopted legislation (continued)**

**Table II – Proposed legislation: none**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft Commission Directive on substances that may be added for specific nutritional purposes in foods for particular nutritional uses. | EN-SANCO/996-1/00 | The purpose of this Directive is to establish a list of nutritional substances that may be used in the manufacture of all other foods intended for weight control, foods for special medical purposes, foods for persons making intense muscular effort (e.g. athletes). Nutritional substances are described rather than defined in Directive 89/398/EEC as " ...vitamins, mineral salts, amino acids and other substances... ". Today it is still not possible to define nutritional substances as a distinct category or to list all possible categories of nutritional substances for the purpose of this directive. Therefore it has to be accepted that this directive will establish a positive list of substances. However, some categories of nutritional substances are not included in the Annex and will be legislated at national level. | CWP: 17.01.99 The Standing Committee adopted the proposal on 26.06.00 with minor changes. | A3 |
| Proposal for a draft Commission directive amending Directive 91/321/EEC on infant formulae and follow on formulae. | SANCO/969/2000 | | | |
| Proposal for a draft Commission directive amending Directive 96/5/EC on processed cereal-based foods for infants and young children. | SANCO/967/2000 | | | |

**Table II – Draft proposals**

### 1.1.12 Novel foods

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 90/219/EEC Directive | 117/90<br>7/91 | Council Directive which applies to the confined use of genetically modified micro-organisms. | Implementation date 23.10.91 | **94/51; 98/81** |
| 90/220/EEC Directive | 117/90<br>7/91<br>74/99 | Council Directive concerning the deliberate release of genetically modified organisms in the environment. Part C and Annex /I/ of the Directive, which refer to the procedures and notifications in view of the placing on the market of products containing GMO, are not applicable to foodstuffs since provisions are foreseen in the specific Directive (i.e. proposed Regulation on Novel Foods and Novel Food Ingredients). | Implementation date 23.10.91 | **94/15** |
| 91/448/EEC Decision | 239/91<br>322/91 | Commission Decision establishing the guidelines for further interpretation of Annex II of Directive 90/219. | Entry into force 28.08.91 | **96/134** |
| 91/596/EEC Decision | | Council Decision concerning the Summary Notification Information Format referred to in Article 9 of Directive 90/220. | Entry into force 26.11.91 | **94/211** |
| 92/146/EEC Decision | 60/92 | Commission Decision concerning the Summary Notification Information Format referred to in Article 12 of Council Directive 90/220. | Entry into force 05.03.92 | |
| 93/572/EEC Decision | 276/93 | Commission Decision concerning the placing on the market of a product containing genetically modified organisms, in accordance with Article 13 of Directive 90/220. | Entry into force 09.03.92 | |
| 94/15/EC Directive | 103/94<br>131/96 | Commission Directive adapting Directive 90/220 to technical progress. | implementation date 30.06.94 | |
| 94/51/EEC Directive | 297/94 | Commission Directive adapting Council Directive 90/219 to technical progress. | Implementation date 30.04.95 | |
| 94/211/EC Decision | 105/94 | Commission Decision amending Council Decision 91/596. | Entry into force 19.04.94 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 94/730/EC Decision | 292/94 | Commission Decision establishing simplified procedures concerning the deliberate release into the environment of genetically modified plants pursuant to Article 6 (5) of Council Directive 90/220. | Entry into force 07.11.94 | |
| 96/134/EC Decision | 31/96 | Commission decision amending Decision 91/448 concerning guidelines for classification referred to in Article 4 of Council Directive 90/219 on the confined use of genetically modified micro-organisms. | Entry into force 09.02.96 | |
| 96/158/EC Decision | 37196 | Commission Decision concerning the placing on the market of a genetically modified herbicide-tolerant swede-rape seed in accordance with Directive 90/220. | Entry into force 0702.96 | |
| 96/281/EC Decision | 107/96 | Commission Decision concerning the placing on the market of genetically modified soyabean (Glycine max L.) resistant to the glyphosate herbicide, in accordance with Council Directive 90/220. | Entry into force 03.04.96 | |
| 96/424/EC Decision | 175/96 | Commission Decision concerning the placing on the market of a genetically modified chicory (Chicorium intybus L.) partially resistant to the herbicide glyfosinate-ammonium in accordance with Council Directive 90/220. | Entry into force 11.07.96 | |
| 97/98/EC Decision | 31/97 | Commission Decision concerning the placing on the market of genetically modified maize (Zea mays L.) with the combined modification for insecticidal properties conferred by the Bt-endotoxin gene and increased tolerance to the herbicide glufosinate ammonium pursuant to Council Directive 90/220. | Entry into force 24.01.97 | |
| 258/97/EC Regulation | 43/97 | Regulation concerning Novel Foods and Novel Food Ingredients. | Entry into force 15.05.97 | |
| 97/35/EC Directive | 169/97 | Commission Directive adapting for the second time Directive 90/220 to technical progress. | Entry into force 28.06.97 | |
| 97/392/EC Decision | 164/97 | Commission Decision concerning the placing on the market of genetically modified swede-rape (Brassica napus L. oleifera Metzg. MS1, RFl), pursuant to Council Directive 90/220. | Entry into force 21.06.97 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 97/393/EC Decision | 164/97 | Commission Decision concerning the placing on the market of genetically modified swede-rape (Brassica napus L. oleifera Metzg. MS1, RF2), pursuant to Council Directive 90/220. | Entry into force 21.06.97 | |
| 98/291/EC Decision | 131/98 | Commission Decision concerning the placing on the market of genetically modified spring swepe rape (Brassica napus oleifera), pursuant to Council Directive 90/220. | Entry into force 22.04.98 | |
| 98/292/EC Decision | 131/98 | Commission Decision concerning the placing on the market of genetically modified maize (Zea mays L. line Bt-1 1), pursuant to Council Directive 90/220. | Entry into force 22.04.98 | |
| 98/293/EC Decision | 131/98 | Commission Decision concerning the placing on the market of genetically modified maize (Zea mays L. T25), pursuant to Council Directive 90/220. | Entry into force 22.04.98 | |
| 98/294/EC Decision | 131/98 | Commission Decision concerning the placing on the market of genetically modified maize (Zea mays L. line MON 810), pursuant to Council Directive 90/220. | Entry into force 22.04.98 | |
| 1139/98/EC Regulation | 159/98 | Council Regulation concerning the compulsory indication on the labelling of certain foodstuffs produced from genetically modified organisms of particulars other than those provided in Directive 79/112. | Entry into force 01.09.98 | **49/00** |
| no reference | 200/98 (OJ C) | Summary of notifications received in 1997 by the Commission in application of Article 5 of Regulation 258/97 of the European Parliament and the Council. | | |
| 98/44/EC Directive | 213/98 | European Parliament and Council Directive on the legal protection of biotechnological inventions. | Implementation date 30.07.00 | |
| 98/81/EC Directive | 330/98 | Council Directive amending Directive 90/219 on the contained use of genetically modified micro-organisms. | Implementation date 05.06.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 49/00/EC Regulation | 6/00<br>45/00<br>54/00 | Commission Regulation amending Council Regulation 1139/98 concerning the compulsory indication on the labelling of certain foodstuffs produced from genetically modified organisms of particulars other than those provided for in Directive 79/112. | Entry into force date 10.04.00 | |
| 50/00/EC Regulation | 6/00<br>47/00 | Commission Regulation on the labelling of foodstuffs and food ingredients containing additives and flavourings that have been genetically modified or have been produced from genetically modified organisms. | Entry into force date 10.04.00 | |
| 2000/608/EC Decision | 258/00 | Commission Decision concerning the guidance notes for risk assessment outlined in Annex III of Directive 90/219 on the contained use of genetically modified micro-organisms. | Entry into force 12.10.00 | |
| 2000/500/EC Decision | 200/00 | Commission Decision on authorising the placing on the market of “yellow fat spreads with added phytosterol esters” as a novel food or novel food ingredient under Regulation 258/97/EC of the European Parliament and of the Council. | Entry into force 10.08.00 | |
| 2001/17/EC Decision | 004/01 | Commmission Decision on refusing the placing on the market of “Nangai nuts (Canarium indicum L.)” as a novel food ingredient under Regulation 258/EC of the European Parliament and of the Council. | Entry into force 09.01.01 | |
| 2001/122/EC Decision | 044/01 | Commission Decision on authorising the placing on the market of a dextran preparation produced by Leuconostoc mesenteroides as a novel food ingredient in bakery products under Regulation 258/97/EC of the European Parliament and of the Council. | Entry into force 18.02.01 | |

**Table I – Adopted legislation (continued)**

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposal to amend Directive 90/220/EEC on the deliberate release of GMOs into the environment.<br>COM (1998) 85 final<br>(OJ C139/98). | Parliament adopted the Bowe report with amendments in its first reading on 11.02.99. Twenty-nine amendments were adopted at second reading on 16.05.00. The Commission accepted only four fully and nine in principle. Hence the Conciliation procedure was opened on 08.11.00 and the Conciliation Committee reached agreement on the joint text of the directive on 14.12.00.<br>Parliament adopted the joint text at third reading on 14.02.01. | The ESC adopted its opinion on the Directive on 09.09.98. | Council formally adopted the EP/Council text on 15.02.01.<br>Member States have 18 months from the day of publication in the OJ to transpose the legislation into national law. | The objective of the directive is to extend and clarify the scope of Directive 90/220/EEC and to harmonise the decision-making procedures between Member States on the basis of common principles of risk assessment while maintaining a high level of protection for consumer health and the environment. |

**Table II – Proposed legislation**

**Table III – Draft proposals: none**

### 1.1.13 Organic production

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2092/91/EEC Regulation | 198/91<br>138/92,<br>297/91,<br>220/91 | Council Regulation on the organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 22.07.91<br>For Articles 8 and 9: 22.04.92<br>For Articles 5, 8(l) and 11(1):22.07.92 | **94/92; 1535/92; 2083/92; 3457/92;** 3713/92 (378/92); **2608/93; 468/94; 1469/94; 2381/94, 529/95; 1201/95; 1202/95; 1935/95; 418/96; 1900/98; 330/99; 1804/99; 331/2000; 1073/2000;** |
| 94/92/EEC Regulation | 11/92 | Commission Regulation laying down detailed rules for implementing the arrangements for imports from third countries provided for in Regulation 2092/91. | Entry into force 24.01.92 | **522/96; 314/97; 349/01** |
| 1535/92/EEC Regulation | 162/92 | Commission Regulation amending Annexes I and III of Council Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 06.07.92 | |
| 2083/92/EEC Regulation | 208/92 | Council Regulation amending Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 24.07.92 | |
| 3457/92/EEC Regulation | 350/92 | Commission Regulation establishing clauses concerning the application of the importing regime of a third country, as foreseen in Regulation 2092/91. | Entry into force 16.12.92 | |
| 207/93/EEC Regulation | 25/93<br>44/94 | Commission Regulation defining the content of Annex VI to Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs and laying down detailed rules for implementing the provisions of Article 5(4) thereto. | Entry into force 17.02.93 | **345/97** |
| 2608/93/EEC Regulation | 239/93 | Commission regulation amending Annexes I, II, III of Council Regulation 2092/91 on organic production of agricultural products. | Entry into force 01.10.93 and 24.03.94 | |
| 468/94/EC Regulation | 59/94 | Commission Regulation amending Annex VI of Regulation 2092/91. | Entry into force 18.03.94 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1468/94/EC Regulation | 159/94 | Council Regulation amending 2092/91 to change the date in Article 5 (5) from 1.07.94 to 1.07.95. | Entry into force 28.06.94 and 01.07.94 | |
| 2381/94/EC Regulation | 255/94<br>21/95 | Council Regulation amending Annex II of Regulation 2092/91. | Entry into force 08.10.94 | |
| 529/95/EC Regulation | 54/95 | Commission Regulation extending the delay for implementation of Article 11 (1) of Regulation 2092/91. | Entry into force 01.03.95 | |
| 1201/95/EC Regulation | 119/95 | Commission Regulation amending Annex VI to Regulation 2092/91 on organic production of agricultural products and foodstuffs. | Entry into force 06.06.95 | |
| 1202/95/EC Regulation | 119/95 | Commission Regulation amending Annexes I and III to Regulation 2092/91 on organic production of agricultural products and foodstuffs. | Entry into force 14.06.95 | |
| 1935/95/EC Regulation | 186/95 | Council Regulation amending Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 12.08.95 | |
| 418/96/EC Regulation | 59/96 | Commission Regulation amending Annex VI of Regulation 2092/91 on the organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 15.03.96 | |
| 522/96/EC Regulation | 77/96 | Commission Regulation amending Regulation 94/92 laying down detailed rules for implementing the arrangements for imports from 3rd countries provided for in Regulation 2099/91 and amending Regulation 529/95, extending the delay for implementation of Article 1 1 (1) of Regulation 2092/91 on the organic production of agricultural products and indications referring thereto on agricultural products or foodstuffs. | Entry into force 01.03.96 and 01.03.97 | |
| 314/97/EC Regulation | 51/97 | Commission Regulation amending Regulation 94/92 implementing the arrangements for imports from third countries provided for in Council Regulation 2092/91 on organic production of agricultural products. | Entry into force 01.03.97 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 345/97/EC Regulation | 58/97 | Commission Regulation amending Article 3 of Regulation 207/93 defining the content of Annex VI to Council Regulation 2092/91 on organic production of agricultural products. | Entry into force 29.03.97 | |
| 1488/97/EC Regulation | 202/97 | Commission Regulation amending Council Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 06.08.97 | |
| 1900/98/EC Regulation | 247/98 | Commission Regulation amending Annex I of Council Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 05.09.98 | |
| 330/99/EC Regulation | 40/99 | Commission Regulation amending Section C of Annex VI of Council Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 13.02.99 | |
| 1804/99/EC Regulation | 222/99 | Council Regulation supplementing Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production. | Entry into force 24.08.2001, with the exception of the interdiction to use GMOs (Article 3): 24.08.99 | |
| 331/2000/EC Regulation | 48/00 | Commission Regulation amending Annex V to Council Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 19.04.00 | |
| 1073/2000/EC Regulation | 119/00 | Commission Regulation amending Council Regulation 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. | Entry into force 27.05.00 | |
| 1616/2000/EC Regulation | 185/00 | Commission Regulation amending Regulation 94/92 laying down detailed rules for implementing the arrangements for imports from third countries provided for in Council Regulation 2092/91. | Entry into force 24.08.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 349/2001/EC Regulation | 052/01 | Commission Regulation amending Regulation 94/92/EEC laying down detailed rules for implementing the arrangements for imports from third countries provided for in Council Regulation 2092/91/EEC. | Entry into force 25.02.01 | |

**Table I – Adopted legislation (continued)**

**Table II – Proposed legislation: none**

**Table III – Draft proposals: none**

## 1.1.14 Hygiene

### 1.1.14.1 General rules

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 93/43/EEC Directive | 175/93<br>208/95,<br>176/93 | Council Directive on the hygiene of foodstuffs. | Implementation date 14.12.95<br>Until 01.08.99<br>Implemented in all<br>Member States except | **96/3; 98/28** |

**Table I – Adopted legislation**

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposal for a Directive on hygiene.<br>COM(2000) 0438<br>(OJ C 365/00). | The ENV COM (Mr. Schnellhardt, D, EPP) was initially made responsible for all of the hygiene package, but in November responsibility for the animal health rules part was handed over to the AGRI COM (Mr. Kindermann, D, PES). Mr. Schnellhardt organised a hearing with stakeholders on 06.02.01 to discuss all aspects of the dossier. | Paul Verhaeghe was nominated rapporteur. Adopted of his report is scheduled for the March Plenary session.. | | The proposals aim at harmonising, simplifying and amalgamating the 17 existing Directives on hygiene.. |

**Table II – Proposed legislation**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft proposal for a European Parliament and Council Regulation on the hygiene of foodstuffs. | III/5227/98 Rev. 4<br>VI/1881 Rev.2 | This draft text has been prepared by the services of DG III in conjunction with DG VI. The text will form the foundation for the general hygiene measures for all foodstuffs regardless of whether these are of animal or non-animal origin. | CWP: 15-16.06.98<br>31.05-01.06.99<br>22-23.07.99<br>The proposal was adopted by the Commission on 14.07.00 | A4 |

**Table III – Draft proposals**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft Commission Decision on control on Listeria monocytogenes in ready-to-eat food. | SANCO/594/2000 Rev. 3 final | This draft sets provisions on the control by the operators of food processing establishments of the presence of Listeria monocytogenes. | | A4 |

**Table III – Draft proposals (continued)**

### 1.1.14.2 Health rules concerning foodstuffs of animal origin

**Explanatory note:** The Commission has set out to implement a programme which has resulted in a set of requirements, already adopted or submitted to the Council for adoption, which cover the range of products of animal origin contained in Annex II of the Treaty.

This results in a number of texts which apply partly in a horizontal way to all products of animal origin, and partly in a vertical way, covering specific problems in special products or groups of products.

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 77/99/EEC Directive | 26/77<br>153/77,<br>76/77,<br>68/77 | Meat products:<br>Deals with the health conditions to be respected when processing meat for the production of meat products. It defines the approval conditions for processing establishments and hygiene conditions during all stages of production and marketing. There are special requirements for sensitive products such as canned meat and ready-to-cook meals. | Implementation date 01.07.79<br>Implemented in all Member States | 80/214 (47/80); 81/476 (186/81); **83/201;** 85/327 (168/85); 85/328 (168/85); 85/586 (327/85); 3768/85 (362/85); 3805/85 (357/85); 89/227 (93/89); **89/662; 92/5;** 92/116 (62/93); 92/45 (268/92); **92/118; 92/120; 95/68; 97/76** |
| 83/201/EEC Directive | 112/83 | Establishes exceptions from Council Directive 77/99 for certain products which contain other foodstuffs and only a small percentage of meat or meat product. | Implementation date 01.01.84 | 83/577 (334/83) |
| 89/384/EEC Directive | 181/89 | Directive fixing the modes of control of the freezing point of raw milk provided for in Annex A of Directive 85/397. | Implementation date 01.07.90<br>Implemented in all Member States | **89/662; 91/684** |
| 89/437/EEC Directive | 212/89 | Egg products:<br>Concerns hygiene and health problems affecting the production and the placing on the market of egg products. Egg products, which are obtained by recuperating the egg contents after removal of the shell, are particularly sensitive to contamination. During production, strict hygiene rules must be observed in order to ensure that the end product complies with the required microbiological standards. The conditions laid down in this Directive apply in the same way to national production and the production for intra-Community trade. | Implementation date 31.12.91 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 89/662/EEC Directive | 395/89<br>51/90,<br>38/90 | Amending Directive 77/99, this Directive concerns veterinary checks in intra-Community trade with a view to the completion of the internal market. | Implementation date 31.12.92 | **90/675; 91/67;** 91/492 (268/91); **91/493; 91/494, 91/495; 91/496;** 92/45 (268/92); |
| 90/425/EC Directive | 224/90 | Council Directive concerning veterinary and zootechnical checks applicable in intra-Community trade in certain live animals and products with a view to the completion of the internal market. | Implementation dates 18.10.90 and 31.12.91 | 90/539 (303/90); 90/667 **(363/90); 90/675;** 91/68 (46/91); 91/174 (85/91); **91/496;** 91/628 (340/91); 92/60 (268/92); 92/6 (268/92); **92/118;** 94/338 (151/94)5 |
| 90/675/EEC Directive | 373/90<br>168/92 | Amending Directive 89/662, this Directive concerns veterinary checks on products entering the Community from third countries. | Implementation date 01.07.92 | **91/496; 92/118;** 92/438 (243/92); 1601/92 (173/92); 94/360 (158/94); 94/958 (371/94); 95/157 (103/95); 95/52 (265/95); **96/43** |
| 91/67/EEC Directive | 46/91 | Council Directive amending Directive 89/662, on animal health conditions for the placing on the market of aquaculture animals and products. | Implementation date 31.12.92 | **93/54,** 95/55 (14/93); **95/22;** 95/70 (332/95); **97/79; 98/45** |
| 91/493/EEC Directive | 268/91<br>189/92,<br>82/92,<br>30/92,<br>305/91,<br>248/91 | Amending Directive 89/662, this Directive lays down the health conditions for the production and the placing on the market of fishery products. | Implementation date 01.01.93 | **94/356;** 94/941 (366/94); **95/71;** 96/23 (125/96); **97/79** |
| 91/494/EEC Directive | 268/91 | Amending Directive 89/662, this Directive lays down the health conditions governing into community trade in and imports from third countries of fresh poultry meat. | Implementation date 01.05.92 | 92/116 (62/93); 93/121 (340/93); 95/117 (80/95) |
| 91/496/EEC Directive | 268/91<br>50/92 | Council Directive on veterinary checks on animals entering the Community from third countries and amending Directives 89/662, 90/425 and 90/675. | Implementation dates 01.12.91 and 01.07.92 | 92/438 (340/91): 92/527 (332/92); 94/957 (371/94); 94/970 (371/94); 95/157 (103/95); **96/43** |
| 91/684/EEC Directive | 376/91 | Council Directive amending Directive 89/437 on hygiene and health problems regarding the production and the placing on the market of egg products. | Implementation date 31.12.91 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 92/5/EEC Directive | 57/92 | Amends Directive 77/99 on health problems affecting intra-Community trade in meat products. | Implementation date 01.01.93 with exceptions by 01.01.95 | 95/1 (1/95) |
| 92/46/EEC Directive | 268/92<br>41/93 | Council Directive laying down the health rules for the production and placing on the market of raw milk, heat treated milk and milk-based products. (See also documents V1/8972/93 and V1/1030/93 in Table III). | Implementation date 31.12.93<br>Implemented in all Member States | **92/118; 94/330; 94/695; 94/71;** 95/165 (108/95); 96/23 (125/96) |
| 92/47/EEC Directive | 268/92 | Council Directive on the conditions for granting temporary and limited derogations from specific Community health rules on the production and placing on the market of milk and milk-based products. | Implementation date 01.01.94<br>For Art. 2 (2): 01.01.93<br>Implemented in all Member States | **94/695** |
| 92/48/EEC Directive | 187/92<br>208/92 | Council Directive laying down the minimal rules of hygiene to be applied to fishery products produced on certain ships as laid down in Article 3 paragraph 1 point a) i) of Directive 91/493. | Implementation date 01.01.93 | |
| 92/67/EEC Directive | 268/92 | Council Directive amending Directive 89/662, on veterinary checks in intra-Community. | Implementation date 01.07.92 | |
| 92/117/EEC Directive | 62/93<br>244/93 | Council Directive concerning measures for protection against specified zoonoses and specified zoonotic agents in animals and products of animal origin in order to prevent outbreaks of food-bome infections and intoxications. | Implementation date 01.01.94 | **97/22; 99/72** |
| 92/118/EEC Directive | 62/93 | Council Directive laying down animal health and public health requirements governing trade in and imports into the Community of products not subject to the said requirements laid down in specific Community rules referred to in Annex A (I) to Directive 89/622 and, as regards pathogens, to Directive 90/425. | Implementation date 01.01.94<br>For Articles 12 (2) and 17.01.01.93 | 94/466 (190/94); **94/723;** 95338 (200/95); **95/339;** 96/103 (24/96); 96/340 (129/96); **96/90; 96/405; 97/79; 99/724** |
| 92/120/EEC Directive | 62/93 | Council Directive derogating Directive 77/99 on the conditions for granting temporary and limited derogations from specific Community health rules on the production and marketing of certain products of animal origin. | Implementation date 01.01.93 | 94/70 (368/94); **95/5** |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 93/51/EEC<br>Decision | 13/93<br>129/93,<br>117/93 | Commission Decision concerning the microbiological criteria applicable to the production of cooked crustacea and molluscs. | Entry into Force 22.02.97 | |
| 93/52/EEC<br>Decision | 13/93 | Commission Decision establishing the conformity of certain Member States or of some regions to conditions relating to brucellose (Br melitensis) and recognising the statute of a Member State or a region not officially affected by this disease. | Entry into Force 06.01.93 | 94/877 (352/94);<br>94/965 (371/94);<br>94/972 (371/94);<br>97/315 (137/97) |
| 93/54/EEC<br>Directive | 175/93 | Council Directive amending Directive 91/67 laying down health rules for the placing on the market of aquaculture products. | Implementation date 30.06.93 | |
| 94/65/EC<br>Directive | 368/94 | Council Directive 94/65, abrogating Directive 88/657, lays down the requirements for the production and placing on the market of minced meat and meat preparations. | Implementation date 20.01.95 | |
| 94/71/EC<br>Directive | 368/94 | Amends Directive 92/46. The amendments concern the collection temperatures for raw milk, the rules on equipment in treatment or processing establishments and the manufacture of heat-treated milk and milk based products. | Implementation dates 01.07.95 and 01.07.97 | |
| 94/278/EC<br>Decision | 120/94<br>115/96 | Commission Decision establishing the list of third countries from which Member States may authorise the importation of certain products referred to in Directive 92/118. | Entry into force 01.07.94 | 94/453 (187/94);<br>95/134 (589/95);<br>95/444 (258/95);<br>96/116 (39/96);<br>96/285 (107/96);<br>**96/344; 01/158** |
| 94/330/EC<br>Decision | 146/94 | Commission Decision modifying Article 5 point 9 of Council Directive 92/46 concerning the freezing point. | Entry into force 26.05.94 | |
| 94/356/EC<br>Decision | 156/94 | Commission Decision laying down detailed rules for the application 91/493, as regards own health checks on fishery products. | Entry into force 02.06.94 | |
| 94/474/EC<br>Decision | 194/94 | Commission Decision concerning certain protection measures relating to bovine spongiform encephalopathy and repealing Decisions 89/469 and 90/200. | Entry into force 27.07.94 | 94/794 (329/94);<br>95/287 (181/95);<br>**98/256; 98/272;**<br>00/418 (158/00) |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 94/695/EC Decision | 282/94 | Commission Decision listing the Community establishments for which temporary and limited derogations are granted from specific Community health rules on the production and placing on the market of raw milk, heat-treated milk and milk-based products. | Entry into force 20.10.94 | |
| 94/723/EC Decision | 288/94 | Commission Decision amending Annex I chapter 3 of Council Directive 92/118 laying down animal health and public health requirements governing trade in and imports of products not regarded by community rules (89/662) and concerning pathogens (90/425). | Entry into force 01.12.94 | |
| 95/5/EC Directive | 51/95 | Council Directive amending Directive 92/120 on limited derogations from specific Community health rules on the production of certain products of animal origin. | Implementation date 28.02.95 | |
| 95/22/EC Directive | 243/95 | Council Directive amending Directive 91/67 concerning the animal health conditions governing the placing on the market of aquaculture animals and products. | Implementation date 01.07.96 | |
| 95/68/EC Directive | 322/95 | Council Directive amending Directive 77/99 on health problems affecting the production and marketing of meat products and certain other products of animal origin. | Implementation date 01.10.96 | |
| 95/71/EC Directive | 332/95 | Council Directive amending the Annex of Directive 91/493 fixing the sanitary rules governing the production and the placing on the market of fisheries products. | Implementation date 01.07.97 | |
| 95/149/EC Decision | 97195 | Commission Decision fixing the total volatile basic nitrogen (TVB-N) limit values for certain categories of fishery products and specifying the analysis methods to be used. | Entry into force 09.03.95 | |
| 95/339/EC Decision | 200/95 | Commission Decision amending Chapter 1 of Annex I to Council Directive 92/118 laying down animal health and public health requirements governing trade in and imports into the Community of products not subject to the said requirements laid down in specific Community rules referred to in Annex A (1) | Entry into force 02.02.96 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 95/340/EC Decision | 200/95 | Commission Decision drawing up a provisional list of third countries from which Member States authorise imports of milk and milk based products and revoking Decision 94RO. | Entry into force 02.02.96 | |
| 95/341/EC Decision | 200/95 | Commission Decision concerning animal health conditions and veterinary certification for imports of milk and milk-based products not intended for human consumption from third countries | Entry into force 02.02.96 | |
| 95/342/EC Decision | 200/95 | Commission Decision on treatment of milk and milk-based products for human consumption from third countries or parts of third countries where there is a risk of foot-and-mouth disease. | Entry into force 02.02.96 | |
| 95/343/EC Decision | 200/95 | Commission Decision providing for the specimens of the health certificate for the importation from third countries of heat-treated milk, milk-based products and raw milk for human consumption intended to be accepted at a collection centre, standardisation centre, treatment establishment or processing establishment. | Entry into force 01.01.97 | |
| 96/3/EC/ ECSC/Euratom Directive | 21/96 | Commission Directive granting derogations from the hygiene provisions of Directive 93/43 concerning the bulk transport of liquid oils and fats for human consumption in sea-going vessels. | Implementation date 12.02.96 | |
| 96/43/EC Directive | 162/96 | Council Directive modifying and codifying Directive 85/73 ensuring the financing of veterinary inspections and controls of live animals and certain animal products, and modifying Directives 90/675 and 91/496. | Implementation dates 01.07.97 and 01.07.99 | |
| 96/90/EC Directive | 13/97 | Council Directive modifying Article 10 and Annex II of Directive 92/118. | Implementation date 30.06.97 | |
| 96/203 Resolution | 203/96 (OJ C) | Council Resolution on measures to be implemented under veterinary policy. The Council invites the Commission to submit an action plan on the implementation of this Resolution to the Council and the European Parliament before 1 December '96. | Entry into force 05.03.95 | |

**Table I –Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 96/239/EC Decision | 78/96 | Commission Decision on emergency measures to protect against bovine spongiform encephalopathy | Entry into force 27.03.96 | **96/362** |
| 96/344/EC Decision | 133/96 | Commission Decision modifying Decision 94/278 establishing the list of third countries from which Member States may authorise the importation of certain products referred to in Directive 92/118. | Entry into force 22.05.96 | |
| 96/345/EC Decision | 133/96 | Commission Decision laying down modalities concerning the veterinary checks, done by Commission experts, in the different Member States. | Entry into force 23.05.96 | |
| 96/362/EC Decision | 139/96<br>140/96 | Commission Decision modifying Decision 96/239 on emergency measures to protect against bovine spongiform encephalopathy. | Entry into force 11.06.96 | |
| 96/381/EC Decision | 149/96 | Commission Decision approving the measures enforced in Portugal concerning bovine spongiform encephalopathy | Entry into force 20.06.96 | |
| 96/385/EC Decision | 151/96 | Commission Decision approving the plan for the control and eradication of bovine spongiform encephalopathy in the United Kingdom. | Entry into force 25.06.96 | |
| 96/405/EC Decision | 165/96 | Commission Decision modifying Annex I of chapter 7 of Directive 92/118 laying down animal health and public health requirements governing trade in and imports into the Community of products not subject to the said requirements laid down in specific Community rules referred to in Annex A (1) to Directive 89/622 and, as regards pathogens, to Directive 90/425. | Entry into force 01.07.96 | |
| 96/449/EC Decision | 184/96 | Commission Decision on the approval of thermal treatment systems for the spongiform encephalopathy agents. | Entry into force 01.04.97 | |
| 97/22/EC Directive | 113/97 | Council Directive modifying Directive 92/117 on zoonoses. | Implementation date 01.09.97 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 97/29/EC Decision | 12/97 | Commission Decision laying down the health conditions and the public health certification for the importation of minced meat and meat preparations from third countries. | Entry into force 01.01.97 | |
| 97/38/EC Decision | 14/97 | Commission Decision laying down the public health requirements for the importation of egg products intended for human consumption. | Entry into force 01.01.97 | |
| 97/76/EC Directive | 10/98 | Council Directive mainly amending Annexes B and C of Directive 77/99 on rules applicable to minced meat, meat products and certain other product of animal origin. | Entry into force 16.01.98 | |
| 97/79/EC Directive | 24/98 | Council Directive modifying Directives 71/118, 72/462, 85/73, 91/67, 91/492, 91/493, 92/45 and 92/118 concerning veterinary checks on products entering the Community from third countries. | Implementation date 01.07.99 | |
| 97/94/EC Decision | 29/97 | Commission Decision on certain measures necessary for the application of certification rules to certain animal products. | Entry into force 09.01.97 | |
| 97/131/EC<br>97/132/EC Decision | 57/97 | Council Decisions on the conclusions of the agreement between the European Community and New Zealand on the sanitary and phytosanitary measures applicable to live animals and animal products. | Entry into force 17.02.97 and 26.02.97 | 99/837 (337/99) |
| 97/134/EC Decision | 51/97 | Commission Decision fixing certain modalities for the veterinary controls of Commission experts in third countries. | Entry into force 26.02.97 | |
| 97/312/EC Decision | 133/97 | Commission Decision approving the measures to be enforced concerning bovine spongiform encephalopathy in Ireland. | Entry into force 13.05.97 | |
| 98/45/EC Directive | 189/98 | Council Directive amending Directive 91/67 concerning the animal health conditions governing the placing on the market of aquaculture animals and products. | Implementation date 01.07.99 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 97/29/EC Decision | 12/97 | Commission Decision laying down the health conditions and the public health certification for the importation of minced meat and meat preparations from third countries. | | |
| 97/38/EC Decision | 14/97 | Commission Decision laying down the public health requirements for the importation of egg products intended for human consumption. | Entry into force 01.01.97 | |
| 97/76/EC Directive | 10/98 | Council Directive mainly amending Annexes B and C of Directive 77/99 on rules applicable to minced meat, meat products and certain other product of animal origin. | Entry into force 16.01.98 | |
| 97/79/EC Directive | 24/98 | Council Directive modifying Directives 71/118, 72/462, 85/73, 91/67, 91/492, 91/493, 92/45 and 92/118 concerning veterinary checks on products entering the Community from third countries. | Implementation date 01.07.99 | |
| 97/94/EC Decision | 29/97 | Commission Decision on certain measures necessary for the application of certification rules to certain animal products. | Entry into force 09.01.97 | |
| 97/131/EC<br>97/132/EC<br>Decision | 57/97 | Council Decisions on the conclusions of the agreement between the European Community and New Zealand on the sanitary and phytosanitary measures applicable to live animals and animal products. | Entry into force 17.02.97 and 26.02.97 | 99/837 (337/99) |
| 97/134/EC Decision | 51/97 | Commission Decision fixing certain modalities for the veterinary controls of Commission experts in third countries. | Entry into force 26.02.97 | |
| 97/312/EC Decision | 133/97 | Commission Decision approving the measures to be enforced concerning bovine spongiform encephalopathy in Ireland. | Entry into force 13.05.97 | |
| 98/45/EC Directive | 189/98 | Council Directive amending Directive 91/67 concerning the animal health conditions governing the placing on the market of aquaculture animals and | Implementation date 01.07.99 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 99/724/EC Decision | 290/99 | Commission Decision amending Annex II to Council Directive 92/118 laying down animal health and public health requirements governing trade in imports into the Community of products not subject to the said requirements laid down in specific Community rules referred to in Annex A (1) to Directive 89/662 and, as regards pathogens, to Directive 90/425. | Entry into force 01.06.2000; for part 11, point 2, and part IV, point 1 of the annex, see procedure laid down in article 18 of Directive 92/118. | |
| 99/788/EC Decision | 310/99 | Commission Decision on protective measures with regard to contamination by dioxins of certain products of porcine and poultry origin intended for human or animal consumption. | Entry into force 04.12.99 | |
| 2000/374/EC Decision | 135/00 | Commission Decision amending Decision 98/272 on epidemio-surveillance for transmissible spongiform encephalopathies. | Entry into force 01.01.01 | |
| 2000/585/EC Decision | 251/00 | Commission Decision laying down animal and public health conditions and veterinary certifications for import of wild and farmed game meat and rabbit - meat from third countries and repealing Commission Decisions 97/217, 97/218, 97/219, 97/220. | Entry into force 05.12.00 | |
| 2001/7/EC Decision | 002/01 | Commission Decision amending Annex I, Chapter 14 of Council Directive 92/118/EEC laying down animal health and public health requirements governing trade in and imports into the Community of products not subject to the said requirements laid down in specific Community rules referred to in Annex A(l) to Directive 89/662/EEC and, as regards pathogens, to Directive 90/425/EEC. | Entry into force 01.01.01 | |
| 2001/158/EC Decision | 057/01 | Commission Decision amending Decision 94/278/EC drawing up a list of third countries from which Member States authorise imports of certain products subject to Council Directive 92/118/EEC, with respect to imports of honey. | Entry into force 01.03.01 | |

**Table I – Adopted legislation (continued)**

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposal for a Directive of the European Parliament and of the Council amending Council Directives 90/425/EEC and 92/118/EEC as regards health requirements for animal by- products COM(2000)573 final (JO C 62E/2001) -2000/0230(COD) | Rapporteur: Mrs Paulsen; First reading scheduled for May Plenary session | Rapporteur: Mr Nielsen; Discussion scheduled for April Plenary session | | |

**Table II – Proposed legislation**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Concept of "milk-based products"; Directive 92/46/EEC laying down the health rules for the production and placing on the market of raw milk, heat-treated milk and milk-based products. | VI/8972/93 | This interpretative document, adopted by the DGVI legal services, clarifies the concept of milk-based products defined in Article 2 (4) of Directive 92/46/EEC. | | These two documents have not been published in the Official Journal but have been sent to the 12 Permanent Representations in Brussels under a cover letter to explain that additional specific problems due to different interpretations at national level need to be resolved in order to avoid unnecessary burdens on the industry. |
| Rules applicable to composite products covered by Article 18 of Directive 92/46/EEC. | VI/1030/93 | This interpretative document, adopted by the DGVI legal services, relates to the hygiene rules applying to products covered by Article 18 of Directive 92/46/EEC. | | |
| Revised working document concerning VI/8765/96 Rev. 2 certain rules governing production, marketing and importation of products of animal origin intended for human consumption. | VI/8765/96 Rev. 2 | The text, revised following the 2nd round of consultation, is being submitted for internal consultation within the Commission, prior to its submission to Council and EP. | First round of consultation within A4 the AVC: 30.05.96; 04.06.96; 11.06.96; 18.06.96; 25.06.96; 15.07.96; 01.10.96 2nd round of consultation 18.02.97; 24.03.97; 22.04.97; 25.06.97 | A4 |
| Draft Council Regulation laying down the detailed rules for the organisation of the official checks, investigations and controls on products of animal origin destined for human consumption. | VI/8655/96 Rev. 1 | | AVC : 28.11.97<br>12.05.9 | A4 |

**Table III – Draft proposals**

### 1.1.15 Ionisation

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 99/2/EC Directive | 66/99 | Directive of the European Parliament and of the Council on the approximation of the laws of the Member States concerning foods and food ingredients treated with ionising radiation. | Implementation dates 20.09. 00 and 20.03. 01 | |
| 99/3/EC Directive | 66/99 | Directive of the European Parliament and of the Council on the establishment of a Community list of foods and food ingredients treated with ionising radiation. | Implementation date 20.09.00 | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Proposal for completing the positive list as laid down in Directive 99/3/EC. | SANCO/1335/2000 Rev. 2 | | CWP: 22.06.00 | A4 |

Table III – Draft proposals

### 1.1.16 Material and articles in contact with foodstuffs

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 78/142/EEC Directive | 44/78<br>163/78 | Lays down the maximum vinyl chloride monomer level permissible in materials and articles in contact with foodstuffs. Criteria for future analysis methods are also specified. | Implementation date 26.11.79 Implemented in all Member States | |
| 80/590/EEC Directive | 151/80 | Introduces a symbol which can be used in place of the words "for food use or in place of the specific indication of the use of the materials and articles in question. | Implementation date 01.01.81 Implemented in all Member States | |
| 80/766/EEC Directive | 213/80 | Defines the method of analysis to be used for the official determination of the level of vinyl chloride monomer in materials and articles in question. | Implementation date 11.01.82 Implemented in all Member States | |
| 81/432/EEC Directive | 167/81 | Defines the method of analysis used for the official determination of the level of vinyl chloride in foodstuffs in contact or which have been in contact with materials and articles. | Implementation date 01.10.82 Implemented in all Member States | |
| 82/711/EEC Directive | 297/82<br>332/82 | Defines the terms "plastic materials and articles" and "plastics". Lays down the basic rules for determining the migration of constituents of these materials and articles to foodstuffs. | Implementation date 04.11.82 Implemented in all Member States | **93/8; 97/48** |
| 83/229/EEC Directive | 123/83<br>159/83 | Lists the substances whose use is authorised, within limits, in the manufacture of regenerated cellulose film to be used in contact with foodstuffs. | Implementation dates 01.01.85 and 01.01.86 Implemented in all Member States | 86/388 (228/86); **92/15; 93/10** |
| 84/500/EEC Directive | 227/84<br>181/89,<br>114/89 | Defines the term "ceramic articles" and lays down the limits for migration of two of their constituents, namely lead and cadmium. The analysis methods are also laid down. | Implementation dates 17.10.87 and 17.10.89 Implemented in all | |

Table I – Adopted legislation

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 85/572/EEC Directive | 372/85 | Lists the simulants which can be used for determining the migration of constituents of plastic materials and articles in contact with foodstuffs. | Implementation dates 01.01.91 and 01.01.93<br>Implemented in all Member States | |
| 89/109/EEC Directive | 40/89<br>347/89 | Framework Directive which paves the way for the adoption of specific Directives on particular types of materials and articles in contact with foodstuffs. This Directive consolidates and repeals the former Directive 76/893. | Implementation dates 10.07.90 and 10.01.92<br>Implemented in all Member States | |
| 90/128/EEC Directive | 75/90<br>349/90 | Specific Directive on plastic materials and articles in contact with foodstuffs. | Implementation date 31.12.90.<br>Implemented in all Member States | **92/39; 93/9; 95/3; 96/11; 99/91** |
| 92/39/EEC Directive | 168/92 | Commission Directive amending Directive 90/128 relating to plastics materials and articles intended to come into contact with foodstuffs. | Implementation dates 31.03.94 and 01.04.95 | |
| 93/8/EEC Directive | 90/93 | Commission Directive amending Articles 2 and 3 of Directive 82/71 1. | Implementation date 01.04.94 | |
| 93/9/EEC Directive | 90/93 | Commission Directive amending Article 5 and Annex II of Directive 90/128. | Implementation dates 01.04.94 and 01.04.96 | |
| 93/10/EEC Directive | 93/93<br>176/93 | Commission Directive concerning regenerated cellulose film intended to come into contact with foodstuffs. | Implementation dates 01.01.94 and 01.01.95 | 93/111 (310/93) |
| 93/11/EEC Directive | 93/93<br>164/93 | Commission Directive concerning the release of the N-nitrosamines and N-nitrosatable substances from rubber teats and soothers. | Implementation dates 01.04.94 and 01.01.95 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 95/3/EC Directive | 41/95 | Commission Directive amending for the third time Directive 90/128. Annex II (list of monomers and other starting materials) has been modified. An Annex III (incomplete list of additives which may be used in the manufacture of plastic materials and articles) has been adopted. Until this list is complete, additives not appearing on the list will be regulated by national legislation. | Implementation dates 01.04.96 and 01.04.98 | |
| 96/11/EC Directive | | Commission Directive amending for the fourth time Directive 90/128. This amendment postpones until 01.01.2002 the time limit for the application of the positive list of monomers. | Implementation dates 01.01.97 and 01.01.99 | |
| 97/48/EC Directive | 222/97 | Commission Directive amending for the second time Council Directive 82/711 laying down the basic rules necessary for testing migration of the constituens of plastic materials and articles intended to come into contact with foodstuffs. | Implementation date: 01.07.98 | |
| 99/91/EC Directive | 310/99 | Commission Directive amending Directive 90/128 relating to plastic materials and articles intended to come into contact with foodstuffs. | Implementation dates: 31.12.00, 01.01.02 and 01.01.03 | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft Commission Directive concerning the use of BADGE and NOGE in materials and articles intended to come into contact with foodstuffs. | SANCO/2874/2000 Rev. 6 | This draft establishes temporary migration limit of 1 ppm for BADGE and BFDGE until 01.01.05 for all applications. It also bans the use of NOGE as an additive from 01.12.02. Until this date, its use is permitted provided it cornplies with a migration level of 1 ppm. The Commission unit in charge is to transmit the draft proposal for adoption to the standing Committee ON 04-05.04.01. | CWP: 29.02.00 - 01.03.00 27-28.07.00 23-24.10.00 | A3 |

**Table III – Draft proposals**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft Commission Directive amending for the 6th time Directive 90/128/EEC relating to plastic materials and articles intended to come into contact with foodstuffs. | SANCO/2872/2000 Rev. 7 | This draft intends to include all the additives for plastics which have been evaluated by the SCF. The Commission unit in charge is to transmit the draft proposal for adoption to the standing Committee on 04-05.04.01. | CWP: 10-11.11.99/29.02.00-01.03.00 / 27-28.07.00<br>23-24.10.00 | A4 |
| Draft Council Directive amending for the first time Directive 89/109/EEC. | SANCO/2873/2000 Rev. 5 | | CWP: 10-11.11.99/29.02.00-01.03.00 / 27-28.07.00<br>23-24.10.00 | A4 |

**Table III – Draft proposals (continued)**

### 1.1.17 Contaminants and residues

| Reference | Published (OJ L) | Content | Application | Modified by |
|---|---|---|---|---|
| 76/895/EEC Directive | 340/76<br>83/95 | Directive relating to the fixing of maximum levels for pesticide residues in and on fruits and vegetables. | Implementation date 26.11.78<br>Implemented in Member States | **880/428; 81/36; 82/528;** 3762/85 (362/85); **88/298; 89/186; 93/58; 96/32; 2000/24; 00/82** |
| 80/778/EEC Directive | 229/80<br>224/93,<br>76/91,<br>220/81,<br>69/81,<br>54/81 | Directive on the approximation of the laws of the Member States relating to the quality of water intended for human consumption. | Implementation date 17.07.82 | 81/858 (319/81); 90/656 (353/90); **91/692** |
| 80/428/EEC Directive | 102/80<br>122/80 | Council Directive amending Annex II to the Council Directive 76/895 relating to the fixing of maximum levels for pesticide residues in and on fruit and vegetables. | Implementation date 31.03.81<br>Implemented in all Member States | |
| 81/36/EEC Directive | 46/81<br>220/81 | Council Directive amending Annex II to the Council Directive 76/895 relating to the fixing of maximum levels for pesticide residues in and on fruit and vegetables. | Implementation date 01.01.82<br>Implemented in all Member States | |
| 82/528/EEC Directive | 234/82 | Council Directive amending Annex II to the Council Directive 76/895 relating to the fixing of maximum levels for pesticide residues in and on fruit and vegetables. | Implementation date 01.07.84<br>Implemented in all Member States | |
| 86/362/EEC Directive | 221/86<br>83/95 | Council Directive fixing the maximum levels for pesticide residues in and on cereals. | Implementation date 17.07.82<br>Implemented in all Member States | **88/298;** 90/654 (353/90); **93/57; 94/29; 95/39; 96/33; 97/41; 97/71; 98/82; 99/65; 99/71; 645/2000; 2000/24; 2000/48; 00/82** |
| 86/363/EEC Directive | 221/86<br>83/95 | Council Directive fixing the maximum levels for pesticide residues in and on foodstuffs of animal origin. | Implementation date 30.06.88<br>Implemented in all | **93/57; 94/29; 95/39; 96/33; 97/41; 97/71; 98/82; 99/71; 2000/24; 00/82** |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 87/800/Euratom Decision | 371/87 | Council Decision on Community arrangements for the early exchange of information in the event of a radiological emergency. | Entry into force 21.12.87 | |
| 3954/87/Euratom Regulation | 371/87<br>281/88,<br>18/88 | Council Regulation which applies to radioactive contamination of foodstuffs.<br>This Regulation lays down maximum permitted levels of radioactive contamination of foodstuffs and of feeding stuffs following a nuclear accident or any other case of radiological emergency. | Entry into force 02.01.88 | **2218/89** |
| 88/298/EEC Directive | 126/88<br>83/95 | Council Directive amending Annex 11 to Directive 86/362 and 86/362 relating to the fixing of maximum levels for pesticide residues in and on fruit and vegetables and cereals respectively. | Implementation dates 01.07.88 and 01.01.89<br>Implemented in all Member States | |
| 89/186/EEC Directive | 66/89<br>86/89 | Council Directive amending Annex 11 to the Directive 76/895 relating to the fixing of maximum levels of pesticide residues in and on fruit and vegetables. | Implementation date 01.08.89 | |
| 944/89/ Euratom Regulation | 101/89 | Commission Regulation laying down maximum permitted levels of radioactive contamination in minor foodstuffs, following a nuclear accident or any other case of radiological emergency. | Entry into force 16.04.89 | |
| 2218/89/ Euratom Regulation | 211/89<br>223/89 | Council Regulation amending Article 7 and the Annex to the Regulation 3954/87. | Entry into force 25.07.89 | |
| 2219/89/Euratom Regulation | 211/89 | Regulation on the special conditions for exporting foodstuffs and feeding stuffs following a nuclear accident or any other case of radiological emergency. | Entry into force 25.07.89 | |
| 90/642/EEC Directive | 350/90<br>83/95,<br>26/91 | Council Directive fixing the maximum levels for pesticide residues in and on certain products of plant origin, including fruits and vegetables. | Implementation date 31.12.92 | **93/58; 94/30; 95/38; 95/61; 96/32; 97/41; 97/71; 98/82; 99/65; 99/71; 645/2000; 2000/24; 2000/48; 00/82** |
| 737/90/EEC Regulation | 82/90 | Council Regulation on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power-station. | Entry into force 01.04.90 | **95/686** |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2377/90/EEC Regulation<br>Also modified by: | 224/90<br>87/92 | Council Regulation establishing community procedures for fixing maximum limits for veterinary drug residues in foodstuffs of animal origin. | Entry into force 01.01.92 | 675/92 (73/92);<br>3092/92 (311/92);<br>895/93 (93/93);<br>2697/93 (245/93);<br>2901/93 (264/93);<br>3425/93 (312/93);<br>3426/93 (312/93);<br>955/94 (108/94);<br>1430/94 (156/94) |
| 762/92/EEC Regulation | 83/92 | Commission Regulation modifying Annex V to Council Regulation 2377/90. | Entry into force 28.03.92 | |
| 2701/94/EC Regulation | 287/94 | Commission Regulation modifying Annexes I, II, III and IV to Council Regulation 2377/90. | Entry into force 07.01.95 | |
| 2703/94/EC Regulation | 287/94 | Commission Regulation modifying Annexes I, II and III to Council Regulation 2377/90. | Entry into force 07.01.95 | |
| 3059/94/EC Regulation | 323/94 | Commission Regulation modifying Annexes I, II and III to Council Regulation 2377/90. | Entry into force 14.02.95 | |
| 1102/95/EC Regulation | 110/95 | Commission Regulation modifying Annexes I, II and III to Council Regulation 2377/90. | Entry into force 16.07.95 | |
| 1441/95/EC Regulation | 143/95<br>217/95 | Commission Regulation amending Annexes I, II and III of Regulation 2377/90. | Entry into force 25.08.95 | |
| 1442/95/EC Regulation | 143/95<br>316/96,<br>222/95,<br>159/95 | Commission Regulation amending Annexes I, II, III and IV of Regulation 2377/90. | Entry into force 25.08.95 | |
| 1798/95/EC Regulation | 174/95 | Commission Regulation amending Annex IV of Regulation 2377/90. | Entry into force 24.09.95 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2796/95/EC Regulation | 290/95 | Commission Regulation modifying Annex II of Regulation 2377/90. | Entry into force 03.02.96 | |
| 2804/95/EC Regulation | 291/95 | Commission Regulation modifying Annex II of Regulation 2377/90. | Entry into force 04.02.96 | |
| 281/96/EC Regulation | 37/96 | Commission Regulation amending Annex I and III of Regulation 2377/90. A number of new substances are added to Annex I and the provisional maximum limit for trimethoprim in Annex III is extended. | Entry into force 15.04.96 | |
| 282/96/EC Regulation | 37/96 | Commission Regulation adding a number of substances to Annex I, II and III of Regulation 2377/90. | Entry into force 15.04.96 | |
| 1140/96/EC Regulation | 151/96 | Commission Regulation modifying Annex Ill of Council Regulation 2377/90. | Entry into force 25.08.96 | |
| 1147/96/EC Regulation | 151/96 | Commission Regulation modifying Annexes II and III of Council Regulation 2377/90. | Entry into force 07.09.96 | |
| 1311/96/EC Regulation | 170/96 | Commission Regulation modifying Annexes I, II, III and IV of Council Regulation 2377/90. | Entry into force 25.08.96 | |
| 1312/96/EC Regulation | 170/96 | Commission Regulation modifying Annex III of Council Regulation 2377/90. | Entry into force 25.08.96 | |
| 1433/96/EC Regulation | 184/96 | Commission Regulation amending Annex II and III of Council Regulation 2377/90. | Entry into force 23.09.96 | |
| 1742/96/EC Regulation | 226/96 | Commission Regulation modifying Annexes I, II and III of Council Regulation 2377/90. | Entry into force 06.11.96. | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1798/96/EC Regulation | 236/96 | Commission Regulation modifying Annex III of Council Regulation 2377/90. | Entry into force 17.11.96 | |
| 2010/96/EC Regulation | 269/96 | Commission Regulation modifying Annex II of Regulation 2377/90. | Entry into force 21.12.96 | |
| 2017/96/EC Regulation | 270/96 | Commission Regulation modifying Annex III of Regulation 2377/90. | Entry into force 22.12.96 | |
| 2034/96/EC Regulation | 272/96 | Commission Regulation modifying Annexes I, II and III of Council Regulation 2377/90. | Entry into force 24.12.96 | |
| 17/97/EC Regulation | 5/97 | Commission Regulation amending Annexes I, II, III and IV of Regulation 2377/90. | Entry into force 10.03.97 | |
| 211/97/EC Regulation | 35/97 | Commission Regulation modifying Annex II of Council Regulation 2377/90. | Entry into force 06.04.97 | |
| 270/97/EC Regulation | 45/97 | Commission Regulation modifying Annexes I, II, III and IV of Council Regulation 2377/90. | Entry into force 16.04.97 | |
| 434/97/EC Regulation | 7/97 | Council Regulation modifying Article 14 of Regulation 2377/90. | Entry into force 07.03.97 | |
| 716/97/EC Regulation | 106/97 | Commission Regulation modifying Annexes II and III of Council Regulation 2377/90. | Entry into force 23.06.97 | |
| 748/97/EC Regulation | 110/97 | Commission Regulation modifying Annexes I and II of Council Regulation 2377/90. | Entry into force 24.06.97 | |
| 749/97/EC Regulation | 6110/97 | Commission Regulation modifying Annex III of Council Regulation 2377/90. | Entry into force 24.06.97 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1850/97/EC Regulation | 264/97 | Commission Regulation modifying Annexes I, II and III of Council Regulation 2377/90. | Entry into force 26.11.97 | |
| 121/98/EC Regulation | 11/98 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90. | Entry into force 18.03.98 | |
| 426/98/EC Regulation | 53/98 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90. | Entry into force 25.04.98 | |
| 613/98/EC Regulation | 82/98 | Commission Regulation amending Annexes II, III and IV of Council Regulation 2377/90. | Entry into force 18.05.98 | |
| 1000/98/EC Regulation | 142/98 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90. | Entry into force 13.07.98 | |
| 1076/98/EC Regulation | 154/98 | Commission Regulation amending Annex II of Council Regulation 2377/09. | Entry into force 27.07.98 | |
| 1191/98/EC Regulation | 165/98 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90. | Entry into force 09.08.98 | |
| 1568/98/EC Regulation | 205/98 | Commission Regulation amending Annexes I, II, III and IV of Council Regulation 2377/90. | Entry into force 20.09.98 | |
| 1916/98/EC Regulation | 250/98 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90. | Entry into force 09.11.98 | |
| 1917/98/EC Regulation | 250/98 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90. | Entry into force 09.11.98 | |
| 1958/98/EC Regulation | 254/98 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90. | Entry into force 15.11.98 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2560/98/EC Regulation | 320/98 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 27.01.99 | |
| 2686/98/EC Regulation | 337/98 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 10.02.99 | |
| 508/99/EC Regulation | 60/99 | Commission Regulation amending Annexes I and IV of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 08.05.99 | |
| 804/99/EC Regulation | 102/99 | Commission Regulation amending Annexes I, II and III to Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 16.06.99 | |
| 953/99/EC Regulation | 118/99 | Commission Regulation amending Annexes II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 05.07.99 | |
| 954/99/EC Regulation | 118/99 | Commission Regulation amending Annex III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 05.07.99 | |
| 997/99/EC Regulation | 122/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 11.07.99 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 998/99/EC Regulation | 122/99 | Commission Regulation amending Annexes I and II of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 11.07.99 | |
| 1308/99/EC Regulation | 156/99<br>9/00 | Council Regulation amending Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medical products in foodstuffs of animal origin. | Entry into force 26.06.99 | |
| 1931/99/EC Regulation | 240/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 01.11.99 | |
| 1942/99/EC Regulation | 241/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 10.11.99 | |
| 1943/99/EC Regulation | 241/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 10.11.99 | |
| 2385/99/EC Regulation | 288/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 10.01.00 | |
| 2393/99/EC Regulation | 290/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 11.01.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2593/99/EC Regulation | 315/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 07.02.00 | |
| 2728/99/EC Regulation | 328/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 25.12.99 | |
| 2757/99/EC Regulation | 331/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 26.12.99 | |
| 2758/99/EC Regulation | 331/99 | Commission Regulation amending Annexes I, II and III of Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 26.12.99 | |
| 1295/2000/EC Regulation | 146/00 | Commission Regulation amending Annexes II and III to Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 24.06.00 | |
| 1960/2000/EC Regulation | 234/00 | Commission Regulation amending annexes I and III to Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 19.09.00 | |
| 2338/2000/EC Regulation | 269/00 | Commission Regulation amending annexes I and III to Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 24.10.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2391/2000/EC Regulation | 276/00 | Commission Regulation amending annexes I, II and III to Council Regulation 2377/90 laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 31.10.00 | |
| 2535/2000/EC Regulation | 291/00 | Commission Regulation amending Annex I of Council Regulation 2377/90/EEC laying down a Community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. | Entry into force 21.11.00 | |
| 91/414/EEC Directive | 230/91<br>170/92 | Council Directive concerning the placing of plant protection products on the market. Point 8.7 of Annex III concerns the information to be brought in the technical dossier to be submitted for the authorisation of a plant protection product on the proposed maximum residue levels (MRLS) in or on treated products, food and feed and on the justification of the acceptability of these residues. | Implementation date 26.07.93 | 3600/92 (366/92); 93/71 (221/93); 94/37 (194/94); **94/43;** 94/79 (354/94); 95/35 (172/95); 95/36 (172/95) **96/12; 96/46; 96/68; 99/462; 99/73; 99/80; 99/555; 99/610; 00/251; 00/49; 00/51; 00/626; 00/66; 00/67; 00/68; 00/80** |
| 91/692/EEC Directive | 377/91 | Council Directive standardising and rationalising reports on the implementation of certain Directives relating to the environment. | Implementation dates 01.01.93, 01.01.94, 01.01.95 | |
| 93/57/EEC Directive | 211/93<br>146/94 | Council Directive amending the Annexes to Directives 86/362 and 86/363 on the fixing of maximum levels for pesticide residues in and on cereals and foodstuffs of animal origin respectively. | Implementation date 31.12.93 | |
| 93/58/EEC Directive | 211/93<br>83/95,<br>219/94 | Council Directive modifying Annex 11 of Directive 76/895 relating to the fixing of maximum levels for pesticide residues in and on fruits and vegetables and the Annex to Directive 90/642 relating to the fixing of maximum levels for pesticide residues in and on certain products of plant origin, including fruits and vegetables, and providing for the establishment of a first list of maximum levels. | Implementation date 31.12.93 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 315/93/EEC Regulation | 37/93 | Council Regulation laying down community procedures for contaminants in food. | Entry into force 01.03.93 | |
| 94/29/EC Directive | 189/94<br>83/95 | Council Directive amending for the second time the Annexes to Council Directives 86/362 and 86/363 on the fixing of maximum levels for pesticide residues in and on cereals and foodstuffs of animal origin. | Implementation date 30.06.95 | |
| 94/30/EC Directive | 189/94<br>83/95 | Council Directive amending for the second time Annex II to Directive 90/642 relating to the fixing of maximum levels for pesticide residues in and on certain products of plant origin, including fruits and vegetables and providing for the establishment of a first list of maximum levels. | Implementation date 30.06.95 | |
| 94/43/EC Directive | 227/94 | Council Directive establishing Annex VI to Directive 91/414. | Implementation date 01.09.95 | **2000/159** |
| 94/787/EC Decision | 321/94 | Commission Decision inviting Denmark to defer until 01.05.95 the adoption of its draft legislation concerning maximum levels of some mycotoxins in foodstuffs. | Entry into force 08.12.94 | |
| 95/38/EC Directive | 197/95<br>155/96 | Council Directive amending for the third time Annexes I and II of Directive 90/642. | Implementation date 01.07.96 | |
| 95/39/EC Directive | 197/95<br>164/96 | Council Directive amending for the third time the Annexes to Directives 86/362 and 86/363. | Implementation date 22.08.96 | |
| 95/61/EC Directive | 292/95 | Council Directive modifying Annex II of Directive 90/642. | Implementation date 07.12.95 | |
| 95/156/EC Recommendation | 103/95 | Commission Recommendation concerning a coordinated programme of inspections in 1995 to ensure compliance with maximum levels of pesticides in and on certain products of plant origin, including fruits and vegetables. | Entry into force 09.03.95 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 96/12/EC Directive | 65/96 | Amends Annexes II and III to Directive 91/414 on the marketing of plant protection products. | Implementation date 31.03.97 | |
| 96/23/EC Directive | 125/96 | Directive on measures to monitor certain hormonal substances and their residues in live animals and animal products. This Directive repeals Directives 85/358 and 86/469 and Decisions 89/187 and 91/664. | Implementation date 01.07.97 | **2000/159** |
| 96/32/EC Directive | 144/96 | Council Directive amending Annex II of Council Directive 76/895 regarding the setting of maximum levels for pesticide residues on and in fruit and vegetables and Annex II to Council Directive 90/642 regarding the setting of maximum levels of pesticides on or in certain products of vegetable origin, including fruit and vegetables, and establishing a list of maximum contents. | Implementation date 30.04.97 | |
| 96/33/EC Directive | 144/96 | Council Directive amending the Annexes to Directives 86/362 and 86/363 on maximum levels for pesticide residues in cereals and foodstuffs of animal origin. | Implementation date 30.04.97 | |
| 96/46/EC Directive | 214/96 | Commission Directive modifying Directive 91/414 on the marketing of plant protection products. | Implementation date 30.04.96 | |
| 96/68/EC Directive | 277/96 | Commission Directive modifying Annex II and III of Directive 91/414. | Implementation date 30.11.97 | |
| 96/199/EC Recommendation | 64/96 | Commission Recommendation concerning a coordinated programme for controlling the maximum levels of pesticide residues in products of vegetable origin, including fruits and vegetables. | Entry into force 05.03.96 | |
| 96/738/EC Recommendation | 335/96 | Commission Recommendation concerning a coordinated programme of inspection in 1997 to ensure compliance of maximum levels of pesticide residues in or on certain products of vegetable origin, including fruits and vegetables. | Entry into force 03.12.96 | |
| 97/41/EC Directive | 184/97 | Council Directive amending Directives 76/895, 86/362, 86/363 and 90/642 setting maximum levels for pesticide residues in fruits and vegetables, cereals and foodstuffs of animal and vegetable origin. | Implementation date 31.12.98 | **1525/98;<br>864/99;<br>1566/99** |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 194/97/EC Regulation | 31/97 | Commission Regulation setting maximum levels for certain contaminants (nitrates) in foodstuffs. | Entry into force 15.02.97 | |
| 97/71/EC Directive | 347/97 | Commission Directive amending the Annexes to Council Directives 86/362, 86/363 and 90/642 on the fixing of maximum levels for pesticide residues in and on cereals, foodstuffs of animal origin and certain products of plant origin, including fruits and vegetables respectively. | Implementation date 31.12.97 | |
| 97/822/EC Recommendation | 337/97 | Commission Recommendation concerning a co-ordinated Community monitoring programme for 1998 to ensure compliance with maximum levels of pesticide residues in or on certain products of vegetable origin, including fruits and vegetables. | Entry into force 09.12.97 | |
| 98/151/EC<br>98/152/EC<br>98/153/EC<br>98/154/EC<br>98/155/EC<br>Decision | 47/98 | Commission Decisions approving the monitoring plan for the detection of residues or substances in live animals and animal products presented by France, United Kingdom, Austria, Finland and Sweden respectively. | Entry into force 18.02.98 | |
| 98/179/EC Decision | 65/98 | Commission Decision laying down detailed rules on official sampling for the monitoring of certain substances and residues thereof in live animal products. | Entry into force 05.03.98 | |
| 98/47/EC Directive | 191/98 | Commission Directive including an active substance (azoxystrobin) in Annex I to Council Directive 91/414. | Entry into force 01.07.98 | |
| 1525/98/EC Regulation | 201/98 | Commission Regulation amending Article 2 and the Annex of Commission Regulation 194/97. | Entry into force 01.01.99 | |
| 98/53/EC Directive | | Commission Directive laying down the sampling methods and the methods of analysis for the official control of the levels for certain contaminants in foodstuffs | Implementation date 31.12.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 98/82/EC Directive | 290/98<br>175/99 | Commission Directive amending the Annexes to Council Directives 86/362, 86/363 and 90/642 on the fixing of maximum levels for pesticides residues in and on cereals, foodstuffs of animal origin and certain products of plant origin, including fruits and vegetables. | Implementation date 01.08.99 | |
| 98/83/EC Directive | 330/98 | Council Directive on the quality of water intended for human consumption. | Entry into force 25.12.98 | |
| 99/237/EC Decision | 87/99 | Commission Decision recognising in principle the completeness of the dossier submitted for detailed examination in view of the possible inclusion of CGA 277 476 (oxasulfuron) in Annex I to Council Directive 91/414 concerning the placing of plant-protection products on the market. | Entry into force 31.03.99 | |
| 864/99/EC Regulation | 108/99 | Commission Regulation amending Regulation 194/97 setting maximum levels for certain contaminants in foodstuffs. | Entry into force 17.05.99 | |
| 99/333/EC Recommendation | 128/99 | Commission Recommendation concerning a coordinated Community monitoring programme for 1999 to ensure compliance with maximum levels of pesticide residues in and on cereals and certain products of plant origin, including fruits and vegetables. | Entry into force 21.05.99 | |
| 99/65/EC Directive | 172/99 | Commission Directive amending Council Directives 86/362 and 90/642 on the fixing of maximum levels of pesticide residues in and on cereals and certain products of plant origin including fruits and vegetables respectively. | Implementation date 31.12.99 | |
| 99/462/EC Decision | 180/99 | Commission Decision recognising in principle the completeness of the dossier submitted for detailed examination in view of the possible inclusion of alanycarbe in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 15.07.99 | |
| 1566/99/EC Regulation | 184/99 | Commission Regulation amending Regulation 194/97 setting maximum levels for certain contaminants in foodstuffs. | Entry into force 17.07.99 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 99/71/EC<br>Directive | 194/99 | Commission Directive amending the Annexes to Council Directives 86/362, 86/363 and 90/642 on the fixing of maximum levels for pesticide residues in and on cereals, foodstuffs of animal origin and certain products of plant origin, including fruit and vegetables respectively. | Implementation date 31.01.00 | |
| 99/73/EC<br>Directive | 206/99<br>221/99 | Commission Directive including an active substance (spiroxamine) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Implementation date 01.01.00 | |
| 99/80/EC<br>Directive | 210/99 | Commission Directive including an active substance (azimsulfuron) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Implementation dates 01.04.00 and 01.04.01 | |
| 99/555/EC<br>Decision | 210/99 | Commission Decision recognising in principle the completeness of the dossiers submitted for detailed examination in view of the possible inclusion of BAS 656H (dimethenamid-p), AC 900001 (picolinafen), ZA 1963 (picoxystrobin) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 10.08.99 | |
| 99/610/EC<br>Decision | 242/99 | Commission Decision recognising in principle the completeness of the dossier submitted for detailed examination in view of the possible inclusion of L91105D (carvone) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 14.09.99 | |
| 2000/43/EC<br>Recommendation | 14/00 | Commission Recommendation concerning a coordinated Community monitoring programme for 2000 to ensure compliance with maximum levels of pesticide residues in and on cereals and certain products of plant origin, including fruit and vegetables. | Entry into force 21.01.2000 | |
| 2000/159/EC<br>Decision | 51/00 | Commission Decision on the provisional approval of residue plans of third countries according to Council Directive 96/23. | Entry into force 31.03.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2000/251/EC Decision | 78/00 | Commission Decision recognising in principle the completeness of the dossier submitted for detailed examination with a view to the possible inclusion of RPA407213 (fenamidone) in Annex I to Council Directive 91/414 concerning the placing of plant-protection products on the market. | Entry into force 29.03.00 | |
| 645/2000/EC Regulation | 78/00 | Commission Regulation setting out detailed implementing rules necessary for the proper functioning of certain provisions of Article 7 of Directive 86/362 and of Article 4 of Directive 90/642 concerning the arrangements for monitoring the maximum levels of pesticide residues in and on cereals and products of plant origin, including fruit and vegetables, respectively. | Entry into force 01.04.00 | |
| 2000/24/EC Directive | 107/00 | Commission Directive amending the Annexes to Directives 76/895, 86/362, 86/363 and 90/642 on the fixing pf maximum levels for pesticides residues in and on cereals, foodstuffs of animal origin and certain products of plant origin, including fruit and vegetables respectively. | Implementation date 01.01.01 | |
| 2000/358/EC Decision | 127/00 | Commission Decision extending the possible time period for provisional authorisations of the new active substances flupyrsulfuron methyl, carfentrazone ethyl, prosulfuron, flurtamone, isoxaflutole. | Entry into force 27.05.00 | |
| 2000/412/EC Decision | 155/00 | Commission Decision recognising in principle the completeness of the dossier submitted for detailed examination with a view to the possible inclusion of IKF916 (cyazofamid) in Annex I to Council Directive 91/414/EEC concerning the placing of plant protection products on the market. | Entry into force 28.06.00 | |
| 2000/463/EC Decision | 183/00 | Commission Decision recognising in principle the completeness of the dossier submitted for detailed examination with a view to the possible inclusion of MKH 65 61 (propoxycarbonazone-sodium) in Annex I to Council Directive 91/414/EEC concerning the placing of plant protection products on the market. | Entry into force 22.07.00 | |
| 2000/48/EC Directive | 197/00 | Commission Directive amending the Annexes to Council Directives 86/362 and 90/642 on the fixing of maximum levels for pesticide residues in and on cereals and certain products of plant origin, including fruit and vegetables respectively. | Implementation date 01.04.01 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2000/49/EC Directive | 197/00 | Commission Directive including an active substance (metsulfuron-methyl) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Implementation date 31.12.01 | |
| 2000/50/EC Directive | 198/00 | Commission Directive including an active substance (prohexadione-calcium) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 01.10.00 | |
| 2000/626/EC Decision | 263/00 | Commission Decision concerning the non-inclusion of chlozolinate in Annex I to Council Directive 91/414 and the withdrawal of authorisation for plant protection products containing this active substance. | Entry into force 18.10.00 | |
| 2000/66/EC Directive | 276/00 | Commission Directive including an active substance (triasulfuron) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 01.08.01 | |
| 2000/67/EC Directive | 276/00 | Commission Directive including an active substance (esfenvalerate) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 01.08.01<br>Implementaion date 31.01.02 | |
| 2000/68/EC Directive | 276/00 | Commission Directive including an active substance (bentazone) in Annex I to Council Directive 91/414 concerning the placing of plant protection products on the market. | Entry into force 01.08.01<br>Implementaion date 31.01.02 | |
| 2000/725/EC Decision | 292/00 | Commission Decision concerning the non-inclusion of tecnazene in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant protection products containing this active substance. | Entry into force 21.11.00 | |
| 2000/80/EC Directive | 309/00 | Commission Directive amending Annex I to Council Directive 91/414/EEC concerning the placing of plant protection products on the market, so as to consolidate that Annex and include a further active substance (lambdacyhalothrin) | Entry into force 29.12.00<br>Implementation date 01.01.02 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2000/801/EC Decision | 324/00 | Commission Decision concerning the non-inclusion of lindane in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant-protection products containing this active substance. | Implementation date 20.12.00 | |
| 2000/816/EC Decision | 332/00 | Commission Decision concerning the non-inclusion of quintozene in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant-protection products containing this active substance. | Entry into force 28.12.00 | |
| 2000/817/EC Decision | 332/00 | Commission Decision concerning the non-inclusion of permethrin in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant-protection products containing this active substance. | Entry into force 28.12.00 | |
| 2000/82/EC Directive | 003/01 | Commission Directive 2000/82/EC amending the Annexes to Council Directives 76/895/EEC, 86/362/EEC and 90/642/EEC on the fixing of maximum levels for pesticide residues in and on fruit and vegetables, cereals, foodstuffs of animal origin and certain products of plant origin, including fruit and vegetables respectively. | Entry into force 26.01.00<br>Implementation date 01.07.01 | |

**Table I – Adopted legislation (continued)**

**Table II – Proposed legislation: none**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft Commission Regulation setting maximum limits for certain contaminants in foodstuffs. | SANCO/0453/00 Rev. 5 | This draft sets limits for Ochratoxin A in certain foodstuffs. | CWP: 20.09.00; 21-22.02.00 31.05.00<br>St. Com: 26.06.00; 18-19.10.00 14-15.12.00 | A3 |
| Draft Commission Directive on sampling methods and methods of analysis for Ochratoxin A. | SANCO/0476/00 Rev. 2 | | CWP: 20.09.00; 21-22.02.00 31.05.00<br>St. Com: 26.06.00; 18-19.10.00 14-15.12.00 | A3 |

**Table III – Draft proposals**

| Subject matter | Reference | Comments | Consultations | Status |
|---|---|---|---|---|
| Draft Commission Regulation setting maximum limits for certain contaminants in foodstuffs. | SANCO/890/2000 Rev. 5 | This draft sets maximum limits for lead, cadmium, mercury and 3-MPCD in certain food categories | CWP: 17.12.99; 01.03.00<br>15-16.05.00<br>St. Corn: 18-19.10.00<br>14-15.12.00 | |
| Draft Commission Directive laying down sampling method and the method of analysis for certain contaminants in foodstuffs. | SANCO/1045/2000 Rev. 5 | | CWP: 15-16.05.00<br>St. Corn: 18-19.10.00<br>14-15.12.00 | |
| Draft Commission Decision repealing Commission Decision 93/351/EEC on analysis methods, sampling plans and maximum limits for mercury in fishery products. | SANCO/1046/2000 | | CWP: 15-16.07.00 | A4 |
| Draft Commission Regulation amending Commission Regulation 194/97/EC setting maximum limits for certain contaminants in foodstuffs. | SANCO/3347/2000 Rev.3 | This draft sets maximum levels for aflatoxins in spices. | St. Corn: 18-19.10.00 | A3 |
| Draft Commission Directive amending Directive 98/53/EC laying down the sampling methods and the methods of analysis for the official control of the levels of certain contaminants in foodstuffs. | SANCO/3348/2000 Rev.3 | This draft includes sampling methods for the determination of the level of aflatoxins in spices. | St. Corn: 18-19.10.00 | A3 |
| Draft Commission Recommendation on the reduction of the presence of deoxynivalenol in certain cereals and cereal products. | SANCO/1630/2000 Rev. 1 | | St. Corn: 18-19.10.00 | A3 |

**Table III – Draft proposals (continued)**

## 1.1.18 Environment

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 85/339/EEC Directive | 176/85 | Directive that provides for a series of measures relating to the production, marketing, use, recycling and refilling of containers of liquids for human consumption. | Implementation date 03.07.87 | **94/62** |
| 90/656/EEC Directive | 353/90 | Directive on the transitional measures applicable in Germany with regard to certain provisions relating to the protection of the environment. | Implementation dates 31.12.92,31.12.93, 31.12.95 | 93/80 (256/93) |
| 94/62/EC Directive | 365/94 | Directive on packaging and packaging waste. | Implementation date 30.06.96 | **177/99** |
| 96/61/EC Directive | 257/96 | Directive on integrated pollution prevention and control. | Implementation date 30.11.99 | |
| 97/129/EC Decision | 50/97 | Commission Decision establishing the identification system for packaging materials pursuant to European Parliament and Council Directive 94/62 on packaging and packaging waste. | Entry into force 29.01.97 | |
| 97/138/EC Decision | 52/97 | Commission Decision establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/62 on packaging and packaging waste. | Entry into force 04.02.97 | |
| 99/177/EC Decision | 56/99 | Commission Decision establishing the conditions for a derogation for plastic crates and plastic pallets in relation to the heavy metal concentration level established in Directive 94/62. | Entry into force 27.02.99 | |
| 99/391/EC Decision | 148/99 | Commission Decision concerning the questionnaire relating to Council Directive 96/61 concerning integrated pollution prevention and control (IPPC). | Entry into force 31.05.99 | |
| 2001/171/EC Decision | 062/01 | Commission Decision establishing the conditions for a derogation for glass packaging in relation to the heavy metal concentration levels established in Directive 94/62/EC on packaging and packaging waste. | Entry into force 04.03.01 | |

**Table I – Adopted legislation**

| Title of Proposal | EP | ESC | EU Council | Comments |
|---|---|---|---|---|
| Proposal for a European Parliament and Council Directive on the marking of packaging and the establishment of a conformity assessment procedure for packaging.<br>COM (96) 191 final (OJ C 382/96) | The EP voted on the Grossetète report at lst reading, adopting amendments that replaced recyclable and reusable marks with material identification symbol , and also amendments that gave shared responsibility for the conformity assessment procedure to both the packaging manufacturer and the packer/filler. | The ESC opinion was adopted at the Plenary Session of 28.05.1997 (ENV/1/429). | Awaiting Council's Common Position. | This draft proposal contains provisions on the marking of recyclable and reusable packaging on a voluntary basis. it also provides for a conformity assessment procedure for packaging. |

**Table II – Proposed legislation**

**Table III – Draft proposals: none**

## 1.1.19 Food “quality” policy

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2081/92/EEC Regulation | 208/92<br>27/97 | Council Regulation on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 24.07.93 | **2037/93;<br>535/97;<br>1068/97** |
| 2082/92/EEC Regulation | 208/92 | Council Regulation on certificates of specific character for agricultural products and foodstuffs. | Entry into force 24.07.93 | **1848/93** |
| 93/53/EEC Decision | 13/93 | Commission Decision setting up a Scientific Committee for designations of origin, geographical indications and certificates of specific character | Entry into force 21.12.92 | **94/437** |
| 1848/93/EEC Regulation | 168/93<br>15/94 | Commission Regulation laying down detailed rules of application of Council Regulation 2082/92 on certificates of specific character for agricultural products and foodstuffs. | Entry into force 26.07.93 | |
| 2037/93/EEC Regulation | 185/93<br>15/94 | Commission Regulation laying down detailed rules of application of Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 26.07.93 | **1726/98** |
| Communication (no reference) | 273/93 (OJ C) | Communication to enterprises which use designations of origin and geographical indications for agricultural products and foodstuffs on the simplified Community registration procedure provided for in Article 17 of Regulation 2081/92. The Commission is working on drawing up a centralised list of such indications and designations in order to submit it upon completion to the regulatory committee. | Entry into force 26.01.94 | |
| 94/437/EC Decision | 180/94 | Modifies Commission Decision 93/53 and specifies that the work of the Committee is only valid if at least 5 of its members are present. | Entry into force 14.06.94 | |
| 2515/94/EC Regulation | 275/94 | Commission Regulation amending Regulation 1848/93 laying down rules for the application of Council Regulation 2082/92 on certificates of specific character for agricultural products and foodstuffs. The Regulation contains the Community symbol which may only be applied to those products in conformity with the detailed Community rules of application laid down by Regulation 1848/93. | Entry into force 07.11.94 | |

**Table I – Adopted legislation**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1107/96/EC Regulation | 148/96<br>290/96<br>299/96 | Commission Regulation on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 21.06.96 | **1263/96; 123/97; 1065/97; 2325/97; 134/98; 83/99; 590/99; 1070/99; 1509/00; 2703/00** |
| 1263/96/EC Regulation | 163/96<br>291/96 | Commission Regulation completing the Annex of Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 02.07.96 | |
| 2400/96/EC Regulation | 327/96 | Commission Regulation on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92. | Entry into force 18.12.96 | **2396/97; 195/98; 1265/98; 1576/98; 2088/98; 2139/98; 378/99; 872/99; 1645/99; 2107/99; 547/00; 1187/00; 1576/00; 1651/00; 1903/00; 1904/00; 2446/00; 138/01** |
| 123/97/EC Regulation | 22/97 | Commission Regulation supplementing the Annex to Commission Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 24.01.97 | |
| 535/97/EC Regulation | 83/97 | Council Regulation modifying Articles 1.1, 5.5, 7.4, and 13 of Regulation 2081/92. | Entry into force 28.03.97 | |
| 1065/97/EC Regulation | 156/97 | Commission Regulation supplementing the Annex of Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 13.06.97 | |
| 1068/97/EC Regulation | 156/97 | Commission Regulation modifying Annex II of Council Regulation 2081/92. | Entry into force 13.06.97 | |
| 1875/97/EC Regulation | 265/97 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the 'Register of protected designations of origin and protected geographical indications' provided for in Council Regulation 2081/92. | Entry into force 27.09.97 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 2301/97/EC Regulation | 319/97 | Commission Regulation on the entry of certain names in the "Specific Character Register" provided for in Regulation 2082/92. | Entry into force 21.11.97 | **954/98;<br>2527/98;<br>2419/99;<br>1482/2000** |
| 2325/97/EC Regulation | 322/97 | Commission Regulation supplementing the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 25.11.97 | |
| 2396/97/EC Regulation | 331/97 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Regulation 2081/92. | Entry into force 03.12.97 | |
| 134/98/EC Regulation | 15/98 | Commission Regulation supplementing the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 21.01.98 | |
| 195/98/EC Regulation | 20/98 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Regulation 2081/92. | Entry into force 27.01.98 | |
| 644/98/EC Regulation | 87/98 | Commission Regulation supplementing the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Regulation 2081/92. | Entry into force 21.03.98 | |
| 954/98/EC Regulation | 133/98 | Commission Regulation supplementing the Annex to Regulation 2301/97 on the entry of certain names in the "Specific Character Register" provided for in Regulation 2082/92. | Entry into force 07.05.98 | |
| 1265/98/EC Regulation | 175/98 | Commission Regulation supplementing the Annex of Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Regulation 2081/92. | Entry into force 19.06.98 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1576/98/EC Regulation | 206/98 | Commission Regulation supplementing the Annex of Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92. | Entry into force 23.07.98 | |
| 1726/98/EC Regulation | 224/98 | Commission Regulation amending Articles 5 and 6 and the Annex of Regulation 2037/93 laying down detailed rules of application of Council Regulation 2081/92 on the protection of geographical indications and designa- tions of origin for agricultural productions and foodstuffs. | Entry into force 11.08.98 | |
| 2088/98/EC Regulation | 266/98 | Commission Regulation supplementing the Annex of Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92. | Entry into force 01.10.98 | |
| 2139/98/EC Regulation | 270/98 | Commission Regulation supplementing the Annex of Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92. | Entry into force 07.10.98 | |
| No reference | 332/98 (OJ C) | Inspection structures notified by the Member States in accordance with Article 10(2) of Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | | |
| 2527/98/EC Regulation | 317/98 | Commission Regulation supplementing the Annex to Regulation 2301/97 on the entry of certain names in the "Register of certificates of specific character" provided for in Council Regulation 2082/92 on certificates of specific character for agricultural products and foodstuffs. | Entry into force 26.11.98 | |
| 83/99/EC Regulation | 8/99 | Commission Regulation amending the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Council Regulation 2081/92. | Entry into force 14.01.99 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 378/99/EC Regulation | 46/99 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Regulation 2081/92. | Entry into force 20.02.99 | |
| 590/99/EC Regulation | 74/99 | Commission Regulation supplementing the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Council Regulation 2081/92. | Entry into force 19.03.99 | |
| 872/99/EC Regulation | 110/99 | Commission Regulation supplementing Regulation 2400/96 on the entry of cerain names in the "Register of Protected Designations of Origin and Protected - Geographical Indications" provided for in Council Regulation 2081/92 on the Protection of Geographical Indications and Designations of Origin for Agricultural Products and Foodstuffs. | Entry into force 28.04.99 | |
| 1070/99/EC Regulation | 130/99 | Commission Regulation amending the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Council Regulation 2081/92. | Entry into force 26.05.99 | |
| 1645/99/EC Regulation | 195/99 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the Register of protected designations of origin and protected geographical indications provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 28.07.99 | |
| 2107/99/EC Regulation | 258/99 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the Register of protected designations of origin and protected geographical indications provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 05.10.99 | |
| 2419/99/EC Regulation | 291/99 | Commission Regulation supplementing the Annex to Regulation 2301/97 on the entry of certain names in the Register of certificates of specific character provided for in Council Regulation 2082/92 on certificates of specific character | Entry into force 01.03.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 547/2000/EC Regulation | 67/00 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 15.03.00 | |
| 1187/2000/EC Regulation | 133/00 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 06.06.00 | |
| 1482/2000/EC Regulation | 167/00 | Commission Regulation supplementing the Annex to Regulation 2301/97 on the entry of certain names in the Register of protected designations of origin and protected geographical indications provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 07.07.00 | |
| 1509/2000/EC Regulation | 174/00 | Commission Regulation amending items in the specifications for several names listed in the Annex to Regulation 1107/96 on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Council Regulation 2081/92. | Entry into force 13.07.00 | |
| 1576/2000/EC Regulation | 181/00 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 20.07.00 | |
| 1651/2000/EC Regulation | 189/00 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 27.07.00 | |

**Table I – Adopted legislation (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 1903/2000/EC Regulation | 228/00 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 08.09.00 | |
| 1904/2000/EC Regulation | 228/00 | Commission Regulation supplementing the Annex to Regulation 2400/96 on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 08.09.00 | |
| 2446/2000/EC Regulation | 281/00 | Commission Regulation supplementing the Annex to Regulation 2400/96/EC on the entry of certain names in the Register of protected designations of origin and protected geographical indications provided for in Council Regulation 2081/92/EEC on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 07.11.00 | |
| 2703/2000/EC Regulation | 311/00 | Commission Regulation amending items in the specifications for several names listed in the Annex to Regulation 1107/96/EC on the registration of geographical indications and designations of origin under the procedure laid down in Article 17 of Council Regulation 2081/92/EEC | Entry into force 12.12.00 | |
| 138/2001/EC Regulation | 023/01 | Commission Regulation supplementing the Annex to Regulation 2400/96/EC on the entry of certain names in the "Register of protected designations of origin and protected geographical indications" provided for in Council Regulation 2081/92/EEC on the protection of geographical indications and designations of origin for agricultural products and foodstuffs. | Entry into force 25.01.01 | |

**Table I – Adopted legislation**

## 1.1.20 Miscellaneous

### 1.1.20.1 Elimination of technical barriers

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| Resolution (no reference) | 117/73 | Council Resolution of 17.12.73 on industrial policy with a timetable for the elimination of technical barriers to trade in foodstuffs and industrial products. | | |
| White Paper COM (85) 310 | Not published in OJ | White Paper from the Commission to the European Council (Milan 28-29 June 1985). | | |
| COM (85) 603 | Not published in OJ | Completion of the Internal Market Community legislation on foodstuffs. | | |
| Communication (no reference) | 271/89 | Communication on the free movement of foodstuffs within the Community. | | |
| Communication (no reference) | 270/91 | Commission interpretative communication on the trade descriptions of foodstuffs further to the '89 Communication on free movement. Examines and clarifies specific cases where an importing Member State may impose a different trade description on a product. | | |
| Communication (no reference) | 345/93 | Commission interpretative Communication on the use of language further to the '89 Communication on free movement. Examines the use of language for the marketing of foodstuffs following the Peeters case (369/89). | | |
| Communication COM (93) 430 final | Not published in OJ | Communication from the Commission to the Council, the EP and ECOSOC on the handling of urgent procedures in the context of implementation of Community rules. It forms part of the follow-up to the Sutherland Report. It was discussed by the Internal Market Council of 10.03.94. | | |
| Communication (no reference) | 353/94 | Communication from the Commission to the Council and the EP; Management of the mutual recognition of national rules after 1992. It sets out operational conclusions reached in the light of the inventory drawn up pursuant to Article 100 b of the EC Treaty. | | |

**Table I – Adopted measures**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| Communication COM (94) 29 final | Not published in OJ | Communication from the Commission to the Council and the EP on the development of administrative co-operation in the implementation and enforcement of Community legislation in the Internal Market. It has been drawn up in the context of the strategic programme for the Internal Market and considers the current state of administrative co-operation in the Community and steps necessary to ensure its effectiveness and further development. | | |
| Resolution (no reference) | 179/94 | Council Resolution on the development of administrative co-operation in the implementation and enforcement of Community legislation in the Internal Market. It welcomes the Commission Communication in the same field and sets out a recommended programme of topics for administrative co-operation. | | |
| Resolution (no reference) | 181/94<br>(OJ C) | This Council Resolution sets out objectives and recommendations for the Commission and Member States in the area of information exchange. It sets out objectives and recommendations for the Commission and Member States in the area of information exchange. | Entry into force 01.01.97 | |
| Report COM (94) 567 final | Not published in OJ | Report from the Commission to the Council and the European Parliament on the application of Article 14 of Directive 89/397 on the official control of foodstuffs. It consists of three parts: i) Inspection programmes, ii) Coordinated inspection programmes, iii) Conclusions and Commission recommendations. | | |
| Decision (no reference) | 321/95 | European Parliament and Council Decision establishing a procedure for the exchange of information on national measures derogating from the principle of the free movement of goods within the Community. | | |
| Resolution (no reference) | 188/95<br>(OJ C) | Council Resolution on the effective uniform application of Community law on the penalties applicable for breaches of Community law in the Internal Market. | | |
| Communication COM (95) 162 final | Not published in OJ | Communication from the Commission to the Council and the European Parliament on the role of penalities in implementing Community Internal Market legislation. | | |

**Table I – Adopted measures (continued)**

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| Report COM (96) 20 final | Not published in OJ | Report from the Commission to the Council and the European Parliament on the co-operation between administrations for enforcement of internal Market law. | | |
| Report COM (96) 51 final | Not published in OJ | Report from the Commission to the Council and the European Parliament on the Single Market in 1995. This is the third Commission report on the operation of the Single Market. | | |
| 95/3052/EC Decision | 321/95 | Decision of the European Parliament and of the Council establishing a procedure for the exchange of information on national measures derogating from the principle of the free movement of goods within the Community. | Entry into force 01.01.97 | |
| Communication COM (96) 392 final | Not published in OJ | Communication of 30.08.96 from the Commission to the Council, the European Parliament and the Economic and Social Committee on regulatory transparency in the internal market for information society services. | Entry into force 07.12.98 | |
| 2679/98/EC Regulation | 337/99 | Council Regulation relating to the functioning of the internal market regarding the free movement of goods among Member States. | | |

**Table I – Adopted measures (continued)**

**Table II – Proposed measures: none**

**Table III – Draft measures: none**

### 1.1.20.2 Good laboratory practice

| Reference | Published (OJ L) | Content | Application date | Modified by |
|---|---|---|---|---|
| 87/18/EEC Directive | 15/87 | Council Directive on the harmonisation of laws, regulations and administrative provisions relating to the application of the principles of good laboratory practice and the verification of their applications for tests on chemical substances. | Implementation date 30.06.88<br>Implemented in all Member States | |
| 88/320/EEC Directive | 145/88<br>174/88 | Directive on the inspection and verification of the organisational process and conditions under which laboratory studies are planned, performed, recorded and reported for the non-clinical testing of chemicals. | Implementation date 01.01.89 | **90/18** |
| 90/18/EEC Directive | 11/90 | Adapting to technical progress the Annex of Council Directive 88/320 on the inspection and verification of Good Laboratory Practice. | Implementation date 01.07.90 | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

**Table III – Draft proposals: none**

### 1.1.20.3 Food machinery

| **Reference** | **Published (OJ L)** | **Content** | **Application** date | **Modified by** |
|---|---|---|---|---|
| 89/392/EEC Directive | 183/69<br>296/89 | Council Directive on machinery. This Directive contains detailed health and safety requirements relating to the design and construction of machinery, including additional requirements for agri-foodstuffs, machinery for the preparation and processing of foods (cooking, refrigeration, thawing, washing, handling, storage, packaging, transport or distribution). | Implementation date 31.12.92 | **91/368;**<br>**93/44;** 93/68 (220/93) |
| 91/368/EEC Directive | 198/91<br>305/91 | Council Directive amending Directive 89/392 on the approximation of the laws of the Member States relating to machinery. | Implementation date 01.01.93 | |
| 93/44/EEC Directive | 175/93 | Council Directive amending Directive 89/392 on the approximation of the laws of the Member States relating to machinery. | Implementation dates 01.01.95 and 01.07.94 | |

**Table I – Adopted legislation**

**Table II – Proposed legislation: none**

**Table III – Draft proposals: none**

## 1.1.21 Legislation in Denmark

Environmental Protection Act, cf. Consolidated Act No. 698 of 22 September 1998, as last amended by Act No. 373 of 2 June 1999, and by section 2(3) of Act No. 369 of 2 June 1999; Statutory order No. 807 of 25 October 1999 on permits for listed activities and installations[1] as last amended by statutory order No. 107 of 1 February 2000, Ministry of Environment and Energy.

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[1] This Order implements:

- Council Directive 96/61/EU of 24 September 1996 concerning integrated prevention and control of pollution, *Official Journal of the European Communities*, **L 257**(10 October 1996): 26–40; and
- Council Directive 96/82/EEC of 9 December 1996 on the control of major-accident hazards involving dangerous substances, *Official Journal of the European Communities*, **L 010**(14 January 1997): 13–33.

## 1.1.22 Legislation in Finland

The Environment Protection Act by which Finland implements the IPPC directive came into force 1 March 2000. The Act and the list of plants for which a permit is required cover much smaller plants than the IPPC Annex 1. Within the food sector, IPPC plants will, as a rule, be permitted by the Regional Environment Centres while smaller plants will be permitted by the municipalities. So far, hardly any plant is permitted according to the new Act. The Act obliges all plants in the food sector to apply for a permit by the end of 2003. There are no standards for the food sector. Most plants are nowadays connected to the municipal waste water treatment plant and thus waste waters are regulated only by an agreement. Plants discharging to a water course have a permit according to the old Water Act, they have a self-monitoring programme and they are supervised. Wastes are to a large extent sorted at source and recycled or treated according to general rules.

### 1.1.23 Legislation in France

Arrêté du 2 février 1998 modifié relatif aux prélèvements et à la consommation d'eau ainsi qu'aux émissions de toute nature des installations classées pour la protection de l'environnement soumises à autorisation

### 1.1.24 Legislation in Greece

**Greek legal requirements for industrial sectors**

**i. Liquid effluent standards**

Prefectural Decision 17823/5.11.79 (Government Gazette 1132 B/21.12.79) & its modification A3/6533/22.6.81

Effluent Limit Values have been issued for many of the prefectures in Greece. The limits are applied for any kind of discharges, including those from food industries. A typical sample is presented in Table Greece-1.

Prefectural Decision for discharges to Saronikos Golf -Athens, 17823/5.11.79 (Government Gazette 1132 B/21.12.79)

| **Liquid effluents standards for industrial installations** | |
|---|---|
| PH | 6.0 - 9.0 |
| Temperature | 35$^{o}$C |
| Color | Not visible in a 1:20 dilution and layer thickness of 10 cm |
| Floating materials (larger than 1cm) | Nil |
| Sediment | 0.5 ml/l (measured at an IMHOFF cone after 2 hours) |
| Separated | 0.5 ml/l (measured at an IMHOFF cone after 2 hours) |
| Total suspended solids | 40 mg/l |
| Total dissolved solid | 1500 mg/l |
| $BOD_5$ | 40 mg/l |
| COD | 150 mg/l |
| Detergents (80 % biodegradable) | 5 mg/l |
| Greases and oils (animal-vegetable) | 20 mg/l |
| Mineral Oils - Hydrocarbons | 15 mg/l |
| Total toxic metals | 3 mg/l |
| Aluminium | 5 mg/l |
| Arsenic | 0.5 mg/l |
| Barium | 20 mg/l |
| Boron | 2 mg/l |
| Cadmium | 0.1 mg/l |
| Chromium (3 valence) | 2 mg/l |
| Chromium (VI) | 0.2 mg/l |
| Iron | 2 mg/l |
| Manganese | 2 mg/l |
| Mercury | 0.005 mg/l |
| Nickel | 2 mg/l |
| Lead | 0.1 mg/l |
| Copper | 1.5 mg/l |
| Selenium | 0.1 mg/l |
| Tin | 10 mg/l |
| Zinc | 1 mg/l |
| Cyanides | 0.5 mg/l |
| Chlorine (free) | 0.7 mg/l |
| Sulphites | 1 mg/l |
| Sulphides | 2 mg/l |
| Fluorides | 6 mg/l |
| Phosphorous | 10 mg/l |
| Total Ammonia | 15 mg/l |
| Nitrogen as N in ($NO_3$) | 20.0 mg/l |
| Total Phenols | 0.5 mg/l |
| Aldehydes | 1 mg/l |
| Aromatic solvents | 0.2 mg/l |
| Nitrogenous solvents | 0.1 mg/l |
| Chloride solvents | 1 mg/l |
| Total amount of toxic substances [As,Cd, Cr (VI), Hg, Ni, Pb, Cu, Se, Zn, $CN^-$, $C_6H_5OH$] | must be:<br>$\frac{Y_1}{E_1} + \frac{Y_2}{E_2} + \ldots + \frac{Y_n}{E_n} \leq 3$<br>where $Y_1$,$Y_2$,...,$Y_n$= Concentration of the corresponding substance, and $E_1$,$E_2$,..., permitted concentration of the corresponding substance |

**Table Greece – 1.: Emission limit values for effluents**

The allowed deviations of the above limits for one average sample in every three, are specified as follows:

| Standards range | | Deviation |
|---|---|---|
| From | To | |
| – | 0.1 | none |
| 0.11 | 0.5 | 0.2 |
| 0.51 | 0.9 | 0.4 |
| 1 | 5 | 2 |
| 6 | 10 | 4 |
| 11 | 30 | 8 |
| 31 | 50 | 20 |
| 51 | 150 | 30 |
| 1500 | – | 200 |

**Table Greece – 2.: Standard deviation from emission limit values for effluents**

## Other limitations:

- All liquid effluents from any industrial installation must be effectively sterilised before discharge into the final recipient, according to Hygienic Decree E1b/221/65.

- Industrial liquid effluents should be analysed in the lab. in a 24 hour representative average sample, composed from various samples, collected in a frequency determined by the total flow of the effluents and the variability of their composition.

- No sludge from liquid effluent treatment installations should be discharged in the Saronikos Gulf.

- The above pollutant limits should be achieved by treatment and not by dilution.

## ii. Air pollution emission standards

a) Presidential Decree 1180/81 (Government Gazette 293 A/6.10.81)

Article 2: Emission standards

- The allowable emission limits for gaseous pollutants are specified as follow:

| Pollutant | ELV | Comment |
|---|---|---|
| a. Smoke: | 1 | (Ringelmann scale) |
| b. F, HF, Fluorides: | 100 mg/Nm$^3$ | (old installations) |
| | 80 mg/Nm$^3$ | (new installations*) |
| c. Pb, As, Cd: | 20 µg/Nm$^3$ | (old installations*) |
| | 10 µg/Nm$^3$ | (new installations) |
| d. Dust: | 100 mg/Nm$^3$ | (old installations) |
| | 150 mg/Nm$^3$ | (new installations) |
| e. $H_2S$: | 10 mg/Nm$^3$ | (refineries) |
| **at 1981* | | |

**Table Greece – 3.: Emission limit values for off-gases**

b) Common Ministerial Decision 11294/93 (Government Gazette 264 B/15.4.93)

Article 2: Fuel oil burner - Emission limits

- The smoke index should be less than 3 (Bacharach scale).
- Exhaust gases should contain $CO_2$ at more than 10 % per volume, when operating at 50 - 100 % of the nominal boiler capacity.
- Alternatively, the $O_2$ measurements should not exceed 7.5 % per volume, when operating at 50 – 100 % of the nominal boiler capacity.

Article 3: Diesel oil burner - Emission limits

- The smoke index should be less than 1 (Bacharach scale).
- Exhaust gases should contain $CO_2$ at more than 10 % per volume, when operating at 50 – 100 % of the nominal boiler capacity.
- Alternatively, the $O_2$ measurements should not exceed 7.5 % per volume, when operating at 50 – 100 % of the nominal boiler capacity.

### iii. Ambient air and noise quality standards

### Air quality

Ministerial Council Act 99/10/87 (Government Gazette 135 A/28.7.87) in accordance with the Directive 80/779/CEC concerning $SO_2$ limit values:

| **Time period** | **$SO_2$ limit value** | | **Combination value for suspended particles** | |
|---|---|---|---|---|
| | | | | |
| Year | 80<br>or<br>120 | Median of 24 hrs average values | >40<br><40 | median of 24 hrs average values |
| Winter (1 Oct. - 31 March) | 130<br>or<br>180 | Median of 24 hrs average values | >60<br><60 | median of 24 hrs average values |
| Year | 250<br>or<br>350 | 98 % of 24 hrs average values | >150<br><150 | 98 % of 24 hrs average values |

**Table Greece – 4.: Ambient air quality requirements for $SO_2$**

Ministerial Council Act 25/88 (Government Gazette 52 A/22.3.88) in accordance with the Directive 85/203/CEC concerning $NO_2$ limit values

Article 7: $NO_2$ concentration limit value

| **Reference Period:** | | **$NO_2$ concentration limit value:** |
|---|---|---|
| year | the 98 % of the values which are collected yearly, at an 1 hr basis (or less) average value measurement, should not exceed | 200 $\mu g/m^3$ |

Ministerial Council Act 11/97 (Government Gazette 19 A/19.2.97) in accordance with the Directive 92/72/CEC concerning $O_3$ limit values

Ministerial Council Act 98/87 (Government Gazette 135 A/28.7.87) in accordance with the Directive 82/84/CEC concerning Lead (Pb) limit values

Lead: 2µg/$m^3$, mean annual concentration

Directive 96/62 concerning Ambient Air Quality Assessment and Management"

**Noise**

Presidential Decree 1180/81 (article 2, Government Gazette 293 A/81)

- The allowable noise limit is specified at 65 dBA at the boundaries of the installation

### iv. Toxic and solid wastes

**Solid and non-toxic waste disposal**

Ministerial Decision 69728/824/96 (Government Gazette 358 B/17.5.96)

**Dangerous wastes**

Ministerial Decision 19396/1546/97 (Government Gazette 604 B/18.7.97) in accordance with the CEC Directives 91/689/EU & 94/904/EU & 96/350/EU concerning dangerous wastes

Article 7:

For temporary storage, storage, handling and exploitation, a prefectural permission is required. The requirements for this permission is:

- feasibility study which should prove that alternative solutions are not possible
- safety and risk management study.

ANNEX: Dangerous wastes list

crude oil distillation wastes
natural gas refinement wastes
oil sludges and solid wastes
tank sludges
oil stains
oil regeneration wastes
alkaline wastes
ammonia
filter plates and exhausted absorbent materials
acid tars.

**Used mineral oils and non-lead sludge management**

Ministerial Decision 98012/2001/96 (Government Gazette 40 B/19.1.96)

## 1.1.25 Legislation in Italy

**Air**: DPR 203/88, D.P.C.M. 21/7/89, D.M. 12/7/90, D.P.R. 25/7/91, D.P.R. n. 412 del 26/8/1993, D.P.C.M. 2/10/95, D.M. 21/10/95, D.M. 25/2/2000, D.M. 25/8/2000

**Noise**: D.P.C.M. 1/3/1991, L. 447/95, D.P.C.M. 14/11/97, D.P.C.M. 5/12/97, D.M. 16/3/98

**Ground and underground**: D.M. 392/96, D.L.gs. 22/97, D.M. 20/10/1998, D.M. 471/99

**Waste**: L. 475/88, D.L.gs. 95/92, D.L.gs. 99/92, D.L.gs. 508/92, L. 70/94, D.M. 22/2/1994, D.M. 392/96, D.L.gs. 22/97, , D.P.C.M. 21/3/97, D.M. 370/98, D.M. 5/2/98, D.M. 145/98, D.M. 148/98, D.M. 372/98, D.M. 219/2000,

**Water**: T.U. 1775/33, R.D. 1265/34, D.P.R. 236/88, L. 36/94, D.P.C.M. 4/3/96, D.L.gs. 152/99, D.L.gs. 31/2001

**Waste Water**: D.L.gs. 152/99, D.L.gs. 18/8/2000

**Dangerous Substances**: D.P.R. 547/55, D.L.gs. 52/97, D.Lgs. 285/98, L. 40/2000

**Asbestos**: D.L.gs. 277/91, L. 257/92, D.M. 6/9/94, D.M. 14/5/1996

**Ozone protection**: L549/93, D.M. 26/3/96, L. 179/97, D.M. 10/3/99

**PCB**: D.P.R. 216/88, D.M. 11/02/1989, D.L.gs. 95/92, D.L.gs. 22/97, D.L.gs. 209/99, L. 25/2/2000

**Ammonia**: R.D. 147/27, D.P.R. 547/55, D.M. 10/6/80

**Energy**: L. 10/91

NOTE: This is the national legislation. There are also regional and local regulations. You can find the full text of this legislation in the web-site http://www.ecoserver.cima.unige.it/norm/homenorm.html

## 1.1.26 Legislation in Portugal

National Legislation (Decreto-Lei 194/200¸ Portaria nº 1047/2001; Portaria nº 1252/2001 (2ª Série))

# ANNEX 2. SOME RELEVANT STANDARDS AND GUIDELINES

## 1. VDI Air Quality Guidelines

**[Germany, 2002 #65]**

| Title | VDI Guideline |
|---|---|
| Testing of filter media for cleanable filters – Standard test for comparative assessment of cleanable filter media | 3926 Sheet 1 |
| Waste gas purification – Separation of oxides of sulphur, oxides of nitrogen and halogenides from waste gases (flue gases) from combustion processes | 3927 Sheet 1 |
| Waste gas treatment by chemisorption | 3928 |
| Collection of foreign bodies from air | 3929 |
| Cooling and heating of waste gas | 3930 |
| Determination of expenditure on operational environmental protection measures | 3800 |
| Dynamic separators | 3676 |
| Filter separators – Surface filters | 3677 Sheet 1 |
| Filter separators – Three-dimensional fibre filters | 3677 Sheet 2 |
| Electrofilters – Cleaning of process gas and waste gas | 3678 Sheet 1 |
| Electrofilters – Cleaning of process air and room air | 3678 Sheet 2 |
| Wet separators for particulate substances | 3679 Sheet 1 |
| Wet separators – Waste gas purification by absorption (scrubbers) | 3679 Sheet 2 |
| Wet separators – Mist collectors | 3679 Sheet 3 |
| Pressure relief for dust explosions | 3673 Sheet 1 |
| Waste gas purification by adsorption – Cleaning of process gas and waste gas | 3674 |
| Catalytic processes for waste gas purification | 3476 |
| Biological waste gas / exhaust air purification; biofilters | 3477 |
| Biological waste gas purification – Bioscrubbers and packed bed reactors | 3478 |
| Waste gas purification by direct-flame incineration | 2442 |
| Waste gas purification by oxidising gas scrubbing | 2443 |
| Technical guarantees for separator systems; separation of solid and liquid impurities from air | 2260 |
| Workplace air quality; reducing exposure to impurities in air; general requirements | 2262 Sheet 1 |
| Workplace air quality – Reducing exposure to impurities in air – Process measures and organisational measures | 2262 Sheet 2 |
| Workplace air quality; reducing exposure to impurities in air; ventilation measures | 2262 Sheet 3 |
| Dust fires and dust explosions; dangers, assessment, preventive measures | 2263 |
| Dust fires and dust explosions; dangers, assessment, safety measures; test methods for determining safety parameters of particulate materials | 2263 Sheet 1 |
| Dust fires and dust explosions; dangers, assessment, safety measures; inertification | 2263 Sheet 2 |
| Dust fires and dust explosions; dangers, assessment, safety measures; explosion pressure proof containers and equipment; calculation, construction and testing | 2263 Sheet 3 |
| Dust fires and dust explosions; dangers, assessment, safety measures; suppressing dust explosions | 2263 Sheet 4 |
| Commissioning, operation and maintenance of separator systems for removing gaseous and particulate substances from gas streams | 2264 |

**VDI Air Quality Guidelines**

## 2. Requirement of odour measurement standards

**[Willey A.R.; Williams D. A., 2001 #34]**

National Standards relating to the methodology for odour quantification exist predominantly in Europe and USA. The standards are essentially similar with the common aim being to standardise the procedures for sampling, testing and screening of panellists. The CEN standard on dynamic olfactometry, which is about to be adopted, will bring together all of the above mentioned standards in one document covering both the yes/no and forced choice olfactometers. The key requirements of the testing methodology are summarised below:

i) Sampling

- sampling can be either “dynamic” where the odorous gas is led directly to the olfactometer or ”static” where sample containers are used
- the interval between sampling and measurement must not exceed 30 hours
- sampling hoods should be used for non-point discharges, e.g. a biofilter
- the number of samples taken per discharge should cover the likely fluctuations in odour concentration of the discharge

ii) Olfactometer accuracy

- the performance of the olfactometer should be assessed at least annually
- the accuracy should be determined using a tracer gas and an accurate monitor
- the olfactometer should be testes for accuracy, repeatability an instability

iii) Panellist screening / selection

- panellists must be screened using 60 ppm n-butanol as a reference gas
- the screening exercise assesses variability and sensitivity of panellists
- panellists must be capable of smelling n-butanol within the range 20 - 80 ppm

iv) Odour measurement

- a minimum panel size of 4 people is stated although at least 8 people is recommended in order to produce at least 8 threshold estimates
- analysis to be done in a ventilated room
- presentations can be random or in increasing odour strength
- retrospective screening to remove panellists responding to blank samples and whose threshold dilution is greater than 5 times the geometric mean of the entire panel.

## 3. Methodology to determine dispersion

**[Willey A.R.; Williams D. A., 2001 #34]**

In the UK there is a Technical Guidance Note as issued by Her Majesty's Inspectorate of Pollution(1) which describes a technique to determine the required stack height to achieve adequate dispersion. This basis of the procedure is detailed below.

The technique was designed to enable calculation of effective stack heights to achieve adequate dispersion so as not to increase significantly the existing ground level pollutant concentrations of the component concerned. The technique has also been applied to emissions of odour by incorporating a methodology to account for short term fluctuations in ground level concentrations which by definition are applicable to odorous emissions, i.e. odorous emissions can be detected over a period of seconds rather than hourly averages or other used timescales.

The calculation procedure comprises three stages of evaluation. The calculation procedure for each stage is detailed as:

1) Determine the Pollution Index

The Pollution Index is defined as:

Pollution Index = 10 * D * 1000/$G_d$

Where: D is the discharge rate of odour in Odour Units/second
Gd is the tolerable ground level concentration of odour which could be set as 1 OU/$m^3$, being the point at which 50 % of a panel of observers can detect an odour and 50 % cannot.

The factor of 10 is introduced to account for the potential fluctuations of odour levels within the short term averaging period of the technique of up to 1 hour.

2) Determine the Discharge Stack Height

The required stack height is determined using the Pollution Index together with basic information about the discharge and the surrounding buildings. Two uncorrected discharge stack heights are calculated, Ub and Um, based upon the buoyancy and momentum in the discharge respectively. Then a final stack height is calculated, corrected for downwash due to nearby buildings.

The buoyancy ($U_p$) calculation is essentially related to the heat release of the discharge and is given by:

$$U_b = 10^a \; * \; P_i^b$$

for a heat release, Q of <= 1 MW then

$a = - 1.11 - 0.19 * \log_{10}Q$ $b = 0.49 + 0.005 \text{ x } \log_{10}Q$

and when the heat release, Q > 1 MW then

$a = -0.84 - 0.1 * \exp(Q^{0.31})$ $b = 0.46 + 0.011 * \exp(Q^{0.32})$

To calculate the uncorrected stack height accounting for momentum (Um)

$$\log_{10}U_m = x + (y * \log_{10}P_i + z)^{0.5}$$

where $x = -3.7 + (\log_{10}M)^{0.9}$
and $y = 5.9 - 0.624 * \log_{10}M$
and $z = 4.24 - 9.7 \text{ x } \log_{10}M + 1.47 * (\log_{10}M)^2 - 0.07*(\log_{10}M)^3$

The discharge momentum, M, can be calculated from

$$M = (283/T_d)*V * w \quad (m^4/s^2)$$

where $T_d$ is the temperature of the discharging gases (K)
V is the volumetric rate of discharge in $m^3/s$
w is the discharge velocity in m/s

3) Determine the Corrected Stack Height

Calculation of the corrected stack height takes into account the presence of nearby buildings which could potentially affect the dispersion. This procedure is not too dissimilar to the guidelines detailed in Section 4.13.2.

The overall uncorrected stack height becomes the lesser of $U_m$ and $U_b$. The calculation of the corrected stack height, C, is given by the following equation:

For a building which is wider than it is high:

$$C = H + 0.6 *(U + (2.5*H - U)* (1 - A^{-U/H}))$$

| | | |
|---|---|---|
| where | A | is the ratio of Um/Ub, A=1 if Ub> Um |
| | H | is the building height in metres |
| | C | is the final discharge stack height in metres. |

The technique effectively considers all buildings within a range of 5 times the uncorrected stack height potentially affect the dispersion. Similarly, if the uncorrected stack height is less than 2½ times the height of the tallest nearby building within a range of 5 times the uncorrected stack height then a correction for stack height is not required.

The use of this technique is seen as an ideal screening exercise to identify the approximate increase to the stack height that will be required in order to abate the problem. Whilst the technique does not require the use of a computer based air dispersion model it does require a measurement of the odour concentration of the emission in question. Once the required stack height has been calculated using this methodology an indication of the practicalities of a stack extension can be investigated.

References:

(1) Technical Guidance Note D1. Guidelines on Discharge Stack Heights for Polluting Emissions. Her Majesty’s Stationary Office, London. June 1993.