Chapter 3  Cleaner Production Opportunities

3 CLEANER PRODUCTION OPPORTUNITIES

Dairy processing typically consumes large quantities of water and energy and discharges significant loads of organic matter in the effluent stream. For this reason, Cleaner Production opportunities described in this guide focus on reducing the consumption of resources (water and energy), increasing production yields and reducing the volume and organic load of effluent discharges.

At the larger production scales, dairy processing has become an extremely automated process and resource efficiency relies, to a large extent, on the efficiency of plant and equipment, the control systems that are used to operate them and the technologies used to recover resources. As a result many Cleaner Production opportunities lie in the selection, design and efficient operation of process equipment. Operator practices also have an impact on plant performance, for example in the areas of milk delivery, plant maintenance and cleaning operations. Therefore there are also opportunities in the areas of housekeeping, work procedures, maintenance regimes and resource handling.

Section 3.1 provides examples of general Cleaner Production opportunities that apply across the entire process, whereas Sections 3.2 to 3.7 present opportunities that relate specifically to individual unit operations within the process. For each unit operation, a detailed process description is provided along with Cleaner Production opportunities specific to that activity. Where available, quantitative data applicable to each unit operation is also provided.

3.1 General

Many food processors that undertake Cleaner Production projects find that significant environmental improvement and cost savings can be derived from simple modification to housekeeping procedures and maintenance programs. Table 3–1 is a checklist of some of these ways. They are generic ideas that apply to the dairy manufacturing process as a whole.

Table 3–1  Checklist of general housekeeping ideas

- Keep work areas tidy and uncluttered to avoid accidents.
- Maintain good inventory control to avoid waste of raw ingredients.
- Ensure that employees are aware of the environmental aspects of the company’s operations and their personal responsibilities.
- Train staff in good cleaning practices.
- Schedule regular maintenance activities to avoid breakdowns.
- Optimise and standardise equipment settings for each shift.
- Identify and mark all valves and equipment settings to reduce the risk that they will be set incorrectly by inexperienced staff.
- Improve start-up and shut-down procedures.
- Segregate waste for reuse and recycling.
- Install drip pans or trays to collect drips and spills.

1 UNEP Cleaner Production Working Group for the Food Industry, 1999
3.1.1 Water

Water is used extensively in dairy processing, so water saving measures are very common Cleaner Production opportunities in this industry. The first step is to analyse water use patterns carefully, by installing water meters and regularly recording water consumption. Water consumption data should be collected during production hours, especially during periods of cleaning. Some data should also be collected outside normal working hours to identify leaks and other areas of unnecessary wastage.

The next step is to undertake a survey of all process area and ancillary operations to identify wasteful practices. Examples might be hoses left running when not in use, CIP cleaning processes using more water than necessary, etc. Installing automatic shut-off equipment and restrictors could prevent such wasteful practices. Automatic control of water use is preferable to relying on operators to manually turn water off.

Once wasteful practices have been addressed, water use for essential process functions can be investigated. It can be difficult to establish the minimum consumption rate necessary to maintain process operations and food hygiene standards. The optimum rate can be determined only by investigating each process in detail and undertaking trials. Such investigations should be carried out collaboratively by production managers, food quality and safety representatives and operations staff. When an optimum usage rate been agreed upon, measures should be taken to set the supply at the specified rate and remove manual control.

Once water use for essential operations has been optimised, water reuse can be considered. Wastewaters that are only slightly contaminated could be used in other areas. For example, final rinse waters could be used as the initial rinses for subsequent cleaning activities, or evaporator condensate could be reused as cooling water or as boiler feed water. Wastewater reuse should not compromise product quality and hygiene, and reuse systems should be carefully installed so that reused wastewater lines cannot be mistaken for fresh water lines, and each case should be approved by the food safety officer.

Table 3–2 Checklist of water saving ideas

| • Use continuous rather than batch processes to reduce the frequency of cleaning; |
| • Use automated cleaning-in-place (CIP) systems for cleaning to control and optimise water use; |
| • Install fixtures that restrict or control the flow of water for manual cleaning processes; |
| • Use high pressure rather than high volume for cleaning surfaces; |
| • Reuse relatively clean wastewaters (such as those from final rinses) for other cleaning steps or in non-critical applications; |
| • Recirculate water used in non-critical applications; |
| • Install meters on high-use equipment to monitor consumption; |
| • Pre-soak floors and equipment to loosen dirt before the final clean; |
| • Use compressed air instead of water where appropriate; |
| • Report and fix leaks promptly. |

1 UNEP Cleaner Production Working Group for the Food Industry, 1999
3.1.2 Effluent

Cleaner Production efforts in relation to effluent generation should focus on reducing the pollutant load of the effluent. The volume of effluent generated is also an important issue. However this aspect is linked closely to water consumption, therefore efforts to reduce water consumption will also result in reduced effluent generation. Opportunities for reducing water consumption are discussed in Section 3.1.1.

Opportunities for reducing the pollutant load of dairy plant effluent focus on avoiding the loss of raw materials and products to the effluent stream. This means avoiding spills, capturing materials before they enter drains and limiting the extent to which water comes into contact with product residues. Improvements to cleaning practices are therefore an area where the most gains can be made. Table 3-4 contains a checklist of common ideas for reducing effluent loads.

Table 3-3 Checklist of ideas for reducing pollutant loads in effluent

| • Ensure that vessels and pipes are drained completely and using pigs and plugs to remove product residues before cleaning; |
| • Use level controls and automatic shut-off systems to avoid spills from vessels and tanker emptying; |
| • Collect spills of solid materials (cheese curd and powders) for reprocessing or use as stock feed; |
| • Fit drains with screens and/or traps to prevent solid materials entering the effluent system; |
| • Install in-line optical sensors and diverters to distinguish between product and water and minimise losses of both; |
| • Install and maintain level controls and automatic shut-off systems on tanks to avoid overfilling; |
| • Use dry cleaning techniques where possible, by scraping vessels before cleaning or pre-cleaning with air guns; |
| • Use starch plugs or pigs to recover product from pipes before internally cleaning tanks. |

1 UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.3 Energy

Energy is an area where substantial savings can be made almost immediately with no capital investment, through simple housekeeping and plant optimisation efforts.

Substantial saving are possible through improved housekeeping and the fine tuning of existing processes and additional savings are possible through the use of more energy-efficient equipment and heat recovery systems.

In addition to reducing a plant’s demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas, purchasing electricity produced from renewable sources, or co-generation of electricity and heat on site. For some plants it may also
be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

**Table 3-4 Checklist of energy saving ideas**

<table>
<thead>
<tr>
<th>Idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implement switch-off programs and installing sensors to turn off or power down lights and equipment when not in use;</td>
</tr>
<tr>
<td>Improve insulation on heating or cooling systems and pipework;</td>
</tr>
<tr>
<td>Favour more energy-efficient equipment;</td>
</tr>
<tr>
<td>Improve maintenance to optimise energy efficiency of equipment;</td>
</tr>
<tr>
<td>Maintain optimal combustion efficiencies on steam and hot water boilers;</td>
</tr>
<tr>
<td>Eliminate steam leaks;</td>
</tr>
<tr>
<td>Capture low-grade energy for use elsewhere in the operation.</td>
</tr>
</tbody>
</table>

1 UNEP Cleaner Production Working Group for the Food Industry, 1999

### 3.2 Milk production

**3.2.1 Receipt and storage of milk**

Raw milk is generally received at processing plants in milk tankers. Some smaller plants may also receive milk in 25–50 L aluminium or steel cans or, in some less developed countries, in plastic barrels. Depending on the structure and traditions of the primary production sector, milk may be collected directly from the farms or from central collection facilities. Farmers producing only small amounts of milk normally deliver their milk to central collection facilities.

At the central collection facilities, operators measure the quantity of milk and the fat content. The milk is then filtered and/or clarified using centrifuges to remove dirt particles as well as udder and blood cells. The milk is then cooled using a plate cooler and pumped to insulated or chilled storage vessels, where it is stored until required for production.

Empty tankers are cleaned in a wash bay ready for the next trip. They are first rinsed internally with cold water and then cleaned with the aid of detergents or a caustic solution. To avoid build-up of milk scale, it is then necessary to rinse the inside of the tank with a nitric acid wash. Tankers may also be washed on the outside with a cold water spray.

Until required for processing, milk is stored in bulk milk vats or in insulated vessels or vessels fitted with water jackets.
Inputs and outputs

Figure 3–1 is a flow diagram showing the inputs and outputs for this process.

![Flow diagram showing inputs and outputs from milk receipt and storage](image)

Environmental issues

Water is consumed for rinsing the tanker and cleaning and sanitising the transfer lines and storage vessels. The resulting effluent from rinsing and cleaning can contain milk spilt when tanker hoses are disconnected. This would contribute to the organic load of the effluent stream.

Table 3–5 provides indicative figures for the pollution loads generated from the receipt of milk at a number of plants. Table 3–6 provides indicative figures for the pollution loads generated from the washing of tankers.

Solid waste is generated from milk clarification and consists mostly of dirt, cells from the cows’ udders, blood corpuscles and bacteria. If this is discharged into the effluent stream, high organic loads and associated downstream problems can result.

Table 3–5  Indicative pollution loads from the milk receival area

<table>
<thead>
<tr>
<th>Main product</th>
<th>Wastewater (m³/tonne milk)</th>
<th>COD (kg/tonne milk)</th>
<th>Fat (kg/tonne milk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter plant</td>
<td>0.07–0.10</td>
<td>0.1–0.3</td>
<td>0.01–0.02</td>
</tr>
<tr>
<td>Market milk plant</td>
<td>0.03–0.09</td>
<td>0.1–0.4</td>
<td>0.01–0.04</td>
</tr>
<tr>
<td>Cheese plant</td>
<td>0.16–0.23</td>
<td>0.4–0.7</td>
<td>0.006–0.03</td>
</tr>
<tr>
<td>Havarti cheese plant</td>
<td>0.60–1.00</td>
<td>1.4–2.1</td>
<td>0.2–0.3</td>
</tr>
</tbody>
</table>

1 Danish EPA, 1991
Cleaner Production opportunities in this area focus on reducing the amount of milk that is lost to the effluent stream and reducing the amount of water used for cleaning. Ways of achieving this include:

- avoiding milk spillage when disconnecting pipes and hoses;
- ensuring that vessels and hoses are drained before disconnection;
- providing appropriate facilities to collect spills;
- identifying and marking all pipeline to avoid wrong connections that would result in unwanted mixing of products;
- installing pipes with a slight gradient to make them self-draining;
- equipping tanks with level controls to prevent overflow;
- making certain that solid discharges from the centrifugal separator are collected for proper disposal and not discharged to the sewer;
- using ‘clean-in-place’ (CIP) systems for internal cleaning of tankers and milk storage vessels, thus improving the effectiveness of cleaning and sterilisation and reducing detergent consumption;
- improving cleaning regimes and training staff;
- installing trigger nozzles on hoses for cleaning;
- reusing final rinse waters for the initial rinses in CIP operations;
- collecting wastewaters from initial rinses and returning them to the dairy farm for watering cattle.

Case study 3–1: Reduction of water consumption for cleaning

At an Estonian dairy processing plant, open-ended rubber hoses were used to clean delivery trucks. Operators used their fingers at the discharge end of the hose to produce a spray, resulting in ineffective use of water. Furthermore, the hoses were not equipped with any shut-off valve, and the water was often left running.

The operators found that they could reduce water consumption by installing high-pressure systems for cleaning the trucks, the production area and other equipment. Open-ended hoses were also equipped with trigger nozzles.

The cost of this equipment was US$6450 and the saving in water charges was US$10,400 per year; a payback period of less than 8 months. Water consumption has been reduced by 30,000 m³/year.

### Table 3–6 Indicative pollution loads from the washing of tankers

<table>
<thead>
<tr>
<th>Main product</th>
<th>Wastewater (m³/tonne milk)</th>
<th>COD (kg/tonne milk)</th>
<th>Fat (kg/tonne milk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market milk plant</td>
<td>0.08–0.14</td>
<td>0.2–0.3</td>
<td>0.04–0.08</td>
</tr>
<tr>
<td>Havarti cheese plant</td>
<td>0.09–0.14</td>
<td>0.15–0.40</td>
<td>0.08–0.24</td>
</tr>
</tbody>
</table>

¹ Danish EPA, 1991
3.2.2 Separation and standardisation

Dairies that produce cream and/or butter separate fat from the raw milk. Separation takes place in a centrifuge which divides the milk into cream with about 40% fat and skimmed milk with only about 0.5% fat. The skimmed milk and cream are stored and pasteurised separately.

Most dairies standardise all milk, to ensure that their products have a consistent composition. In some cases, products may need to meet certain product specifications in relation to fat content. These specifications vary from one country to the next. However in general, whole milk must contain around 3.5–4.2% fat, semi-skimmed milk around 1.3–1.5% and skimmed milk around 0.5% (Varnam and Sutherland, 1994). Standardisation is achieved by the controlled remixing of cream with skimmed milk, and is common both in cheese plants and in the production of milk powders.

Figure 3–2 is a flow diagram showing the inputs and outputs for this process.

Environmental issues

As in other aspects of dairy processing, water is consumed for rinsing and cleaning of process equipment, resulting in the generation of wastewaters containing milk solids and cleaning agents. Table 3–7 provides indicative figures for the pollution loads generated from the milk separation process at a number of plants.

The centrifugal separators generate a sludge material, which consists of udder and blood cells and bacteria contained in the raw milk. For standard separators the sludge is removed manually during the cleaning phase, while in the case of self-cleaning centrifuges it is discharged automatically. If the sludge is discharged to the sewer along with the effluent stream, it greatly increases the organic load of the effluent.
Table 3-7  Indicative pollution loads generated from milk separation

<table>
<thead>
<tr>
<th>Main product</th>
<th>Wastewater (m³/tonne milk)</th>
<th>COD (kg/tonne milk)</th>
<th>Fat (kg/tonne milk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter plant</td>
<td>0.20–0.30</td>
<td>0.3–1.9</td>
<td>0.05–0.40</td>
</tr>
<tr>
<td>Market milk plant</td>
<td>0.30–0.34</td>
<td>0.1–0.4</td>
<td>0.01–0.04</td>
</tr>
<tr>
<td>Cheese plant</td>
<td>0.06–0.30</td>
<td>0.2–0.6</td>
<td>0.008–0.03</td>
</tr>
<tr>
<td>Havarti cheese plant</td>
<td>0.60–1.00</td>
<td>1.4–2.1</td>
<td>0.2–0.3</td>
</tr>
</tbody>
</table>

1 Danish EPA, 1991

Cleaner Production opportunities specific to this area are related to reducing the generation of separator sludge and optimising its collection and disposal. Ways of achieving this include:

- reducing the frequency with which centrifugal separators are cleaned, by improving milk filtration at the receiving stage or by clarification of the raw milk;
- collecting the sludge and disposing of it along with other waste solids.

Also of importance is the optimisation of cleaning processes, to make them water and energy efficient. Ways of achieving this are discussed further in section 3.6.

3.2.3 Pasteurisation and homogenisation

In large plants, milk is pasteurised in continuous flow pasteurisers, whereas some smaller dairies may use batch-type pasteurisers. In batch pasteurisation processes, milk is typically heated to 62.8–65.6°C for 30 minutes, whereas in continuous pasteurisation processes it is heated to 71.7–78.1°C for at least 15 seconds. The time-temperature relationship is usually prescribed by law, as are certain safeguards to ensure that all milk attains the minimum treatment. For both batch and continuous processes, the milk is cooled to below 10°C immediately after heating.

For some products milk is homogenised using a pressure pump, which breaks up the butterfat globules to a size that keeps them in suspension. In continuous pasteurisation processes homogenisation is usually undertaken in conjunction with pasteurisation, since its efficiency is improved if the milk is warm.
Figure 3–3 is a flow diagram showing the inputs and outputs for this process.

**Figure 3-3 Inputs and outputs for the pasteurisation and homogenisation of whole milk**

**Inputs and outputs**

- Milk
- Steam
- Electricity
- Chilled cooling water
- Pasteurisation
- Condensate return
- Electricity
- Homogenisation
- Pasteurised and homogenised milk

**Environmental issues**

The main environmental issue associated with pasteurisation and homogenisation is the high levels of energy consumed for the heating and cooling of milk.

In addition, water is consumed for rinsing and cleaning of process equipment, resulting in the generation of wastewaters containing milk solids and cleaning agents. In batch pasteurisation, small batches necessitate frequent cleaning, therefore losses of milk and the organic loads in wastewater streams are increased.

**Cleaner Production opportunities**

Cleaner Production opportunities in this area focus on improving energy efficiency. Ways of achieving this include:

- replacing batch pasteurisers with a continuous process incorporating plate heat exchanger (PHE) pasteurisers, where feasible. PHE pasteurisers are more energy efficient than batch pasteurisers because the heat from the pasteurised milk can be used to preheat the incoming cold milk (regenerative counter-current flow);

- installing new manufacturing equipment, which will result in less waste of milk products than the equipment currently used in many dairies;

- avoiding stops in continuous processes. The more constant the production, the less milk will be lost, since most waste comes from cleaning of batch process equipment. In the event of upgrades to process equipment, high-volume pasteurising units should be considered;

- reducing the frequency of cleaning of the pasteuriser. Particularly for small dairies, optimising the size of balance tanks before and after the pasteuriser will allow continuous operation of the pasteuriser and reduce cleaning frequency;

- planning production schedules so that product change-overs coincide with cleaning regimes;

- collecting and recovering the milky wastewater generated at start-up of pasteurisation and supplying it to farmers as animal feed.
Also of importance is optimisation of cleaning processes, to make them water and energy efficient. Ways of achieving this are discussed further in section 3.6.

To make possible the reprocessing of excess milk returned from the market, dairy plants may wish to consider developing policies which allow for the reprocessing of milk without affecting the quality of the freshly pasteurised product.

The introduction of poorer quality milk into the pasteurisation process can result in milk scale and coagulation problems due to higher acidity. This may cause higher milk losses in the pasteuriser due to the need for more frequent cleaning in order to remove milk scale. These issues should be weighed against the benefits of reprocessing returned milk.

The controlled return and reprocessing of milk from the market may require training of sales representatives. Alternatively, penalties could be applied for inappropriate ordering, or bonuses paid for extended periods of no market returns.

### 3.2.4 Deodorisation

**Process description**

Many dairies remove unwanted taints and odours from milk in deodorisation units. In these systems, the odorous substances are drawn-off by injecting steam into the system under vacuum. In situations where the taints and odours are only mild, a vacuum alone may be used.

**Inputs and outputs**

Figure 3-4 is a flow diagram showing the inputs and outputs for this process.

![Figure 3-4 Inputs and outputs for the deodorisation of milk](image)

**Environmental issues**

An environmental issue specific to the deodorisation process is the large volume of water used to operate water seals on the vacuum pump.

**Cleaner Production opportunities**

Water used for the vacuum pump can be recirculated to reduce or eliminate the necessity to discharge it.
3.2.5 Storage and packaging

Due to the large range of products produced at many dairies (e.g. different fat contents or heat treatment regimes), the bulk storage of these products can involve very extensive storage systems, with associated vessels, piping and valves.

Milk is packaged or bottled in a number of types of containers, including glass bottles, paper cartons, plastic bottles and plastic pouches. In most cases, filling of containers is highly automated. After filling, the packaged milk products are usually stored and transported in wire or plastic crates.

Finished products are held in refrigerated storage until dispatched to retail outlets. The storage temperature depends on the product, but for milk and fresh dairy products, the optimum temperature is usually < 4°C. Refrigerated storage chambers are usually cooled using forced draft evaporators chilled by a primary refrigerant. A secondary refrigerant such as ice water, brine or glycol recirculated in a closed circuit cooling system is also sometimes used. Door openings are usually sealed with rubber swing doors and/or air curtains when open.

Figure 3–5 is a flow diagram showing the inputs and outputs for this process.

![Flow diagram of storage and packaging process](image)

The main environmental issues associated with the storage and packaging operations are the loss of milk products from spills and packaging mistakes, generation of wastewater from cleaning processes and energy consumed for refrigerated storage. However the choice of packaging materials is becoming an increasingly important issue.

Milk products can be lost to the wastewater stream during start-up and shut-down, from residues remaining in storage vessels and from the initial cold water rinses of packaging and storage equipment. Milk products may also be lost due to breakage of packaging material. Generally, incorrectly filled packages are emptied and the milk is returned to the milk receival area.
Considerable work has been undertaken to determine the most suitable form of packaging in terms of overall environmental impacts. Although glass bottles can be cleaned and recycled (thereby creating minimal solid waste), cleaning them consumes water and energy. Glass recycling systems require large capital investments and involve high running costs since the bottles must be collected, then transported and cleaned. Glass bottles can also be inconvenient for consumers because they are heavier and more fragile than cartons.

Cartons, on the other hand, create solid waste that must be transported and disposed of. Solid waste can be disposed of in a landfill, incinerated, or composted. All of these disposal alternatives have environmental impacts, including the generation of leachate from landfills and air pollution from incineration.

Cleaner Production opportunities in this area focus on improving the energy efficiency of refrigeration systems and optimising CIP processes to reduce both water use and the organic load discharged into the effluent stream. Ways of achieving this include:

- clearing milk residues from the pipes using compressed air before the first rinse;
- collecting the more highly concentrated milk wastewater at start-up and shut-down for use as animal feed;
- optimising the accuracy of filling operations. This will not only result in improved efficiency, but will also reduced potential for waste and spillage. Minor variations in filling performance can have significant cumulative effects particularly for small unit fill quantities;
- improving procedures for recovering milk from wrongly filled containers;
- emptying and collecting product from wrongly filled containers for use as animal feed;
- reducing energy consumption through improved insulation, closing of doors to cold areas, good maintenance of room coolers and regular defrosting;
- using direct ammonia-based cooling systems instead of CFC-based systems.

Case study 3–2: Minimising loss of milk in packaging

At a plant producing market milk, the filling of containers was usually undertaken in batches. The product remaining in the bottom of the supply vessel at the end of the batch was discharged to sewer. However, due to increasing effluent discharge costs, the dairy decided to return the residual milk to the production process.

This simple modification prevented 11,500 L/year of product being discharged to sewer. The value of this material was US$4850/year (US$0.42/litre) and annual effluent charges fell by US$1150. Overall the dairy saved US$6000/year with no capital expenditure.
3.3 Butter production

The primary objective of butter making is to conserve the fatty portion of the milk in a form that can be used at a later date. It is essentially a dehydration process, in which the majority of the aqueous phase is removed and the remainder is emulsified into the fat. Milk is an emulsion of milk fat in water, whereas butter is an emulsion of water in milk fat. Butter production involves the conversion from one state to the other.

The evolution of the butter-making process has progressed from the use of skins and gourds for churning, through to the use of wooden-barrelled butter churns, which have since been exchanged for stainless steel churns. Although the development of the continuous process in the 1950s led to the replacement of the batch process in most industrial plants, the batch or churn process may still be used in smaller dairies.

In batch processes, prepared cream is agitated in a specially designed vessel (butter churn) until phase inversion occurs and the fat ‘breaks’ from the cream in the form of butter grains. The surrounding liquid—the buttermilk—is then decanted off. The butter grains are washed in fresh chilled water, salted (if required) and worked by a shearing process to produce a homogeneous mass with a controlled moisture content.

In the more common continuous process, phase inversion of the cream, working of the butter, the addition of salt and moisture control take place in cylindrical, rotating chambers which progressively lead the butter mass to blending augers and final extrusion. The continuous process reduces the amount of waste generated by the process by eliminating the butter grain washing step and also by making use of an internal mechanical system for continuous recovery of butter ‘fines’.

3.3.1 Cream treatment: ripened cream process

Pasteurisation of the cream for making cultured butter is normally carried out at temperatures of up to 110°C. The cream may be subjected to vacuum treatment during cooling in order to improve its spreadability.

In the production of ripened butter, the cream is cooled, inoculated with a culture and ripened. After a ripening period of 12–18 hours at 20°C, the cream is cooled to below 10°C.

The cream treatment process has received considerable attention over many years because it affects the quality of the final product. The quality of the fat before it is churned affects product losses from the process.

The optimum temperature for ageing the cream (allowing all fat to become solid) is generally lower than the temperature required for efficient churning. Cream that is too cold is therefore susceptible to damage, and may result in blocked pipeline and excessive loss.

The most effective churning temperature for cream can be achieved by using heat exchangers with a low pressure drop and a minimum temperature differential between the cream and the water. This avoids localised overheating.
Figure 3–6 is a flow diagram showing the inputs and outputs for this process.

![Flow diagram showing inputs and outputs for the ripened cream process](image)

**Figure 3-6 Inputs and outputs for the ripened cream process**

**Environmental issues**

The main environmental issue associated with this process is the high organic load in wastewaters generated from rinsing and cleaning the pasteuriser. This can be further exacerbated by the requirement for frequent cleaning, which results in a greater loss of milk solids.

**Cleaner Production opportunities**

Cleaner Production opportunities in this area focus on reducing water use and loss of product. Ways of achieving this include:

- minimising the number of times the pasteuriser is cleaned. Particularly in small butter dairies, optimising the size of balance tanks before and after the pasteuriser will allow it to operate continuously, resulting in less need for cleaning;

- installing modern pasteurising equipment. This will reduce waste of cream in many dairies, because improvements in plate design now give a more gentle and constant heat treatment. This decreases the build-up of overheated solids on heating surfaces. In the event of upgrades to process equipment, high-volume pasteurising units should be considered;

- collecting the more highly concentrated milk wastewater generated when starting up the pasteuriser, for use as animal feed.

### 3.3.2 Butter churning

The cream enters the butter maker and the fat globules are disrupted under controlled conditions to destabilise the emulsion and agglomerate the milk fat. This is achieved in the first churning cylinder, which is fitted with a beater driven by a variable-speed motor. The beater speed is adjusted to give the desired butter grain size with minimum fat loss in the buttermilk.

To maintain steady butter-making conditions, it is essential that the cream feed rate be constant. This can be achieved by using a balance tank between the ageing silo and the pump.

The mixture of butter grains and buttermilk falls from the first cylinder into the back section of a second cylinder, where the grains are consolidated. This second cylinder is a larger, perforated, slowly rotating drum which causes the grains to travel along an inclined rotating screen.
with a tumbling action, thus assisting their aggregation at the same time as they are drained of buttermilk. The buttermilk is pumped away from below the cylinder.

From the second cylinder, the moist grains of butter fall into the worker compartment which uses contra-rotating augers to compact the grains into a heterogeneous mass, expelling more buttermilk from the grains as they are squeezed together. Compacted butter grains are fed from the auger through a series of alternating perforated plates and impeller blades. These apply shear forces that further consolidate the butter grains and break up the droplets of buttermilk now remaining in the fat matrix. This forms a dispersed aqueous phase of what is now a water-in-oil emulsion. A second worker compartment, operating under vacuum, may be incorporated to obtain a denser, finer-textured product. A second set of augers removes the butter and forces it through a final set of orifice plates and blades which complete the emulsification before the product is discharged from the butter maker.

Figure 3–7 is a flow diagram showing the inputs and outputs for this process.

![Figure 3-7 Inputs and outputs of the churning process](image)

Inputs and outputs

Environmental issues

Cleaner Production opportunities

Unless the buttermilk is used as a product or as an ingredient in other products, the quantities of buttermilk produced (about 50% of the original cream volume) represent a potential environmental loading. Pollutant discharge is greatest when a continuous butter maker is closed down, due to the loss of the fat remaining in the machine.

Cleaner Production opportunities in this area focus on reducing loss of product. Ways of achieving this include:

- ensuring that the buttermilk is collected separately and hygienically so that it can be used in other processes, such as a base for low-fat spreads;
- collecting all first rinses, and separating the residual fat for use in other processes;
- preventing the build-up of milk scale deposits;
- maintaining butter makers on a regular basis;
- avoiding spills by ensuring that the buttermilk collection facilities are large enough to hold all the liquid.
### 3.3.3 Butter packaging

Butter may be discharged from the butter maker directly into the feed hopper of a bulk butter packer. However, it is more commonly discharged to a butter silo fitted with a pump, thus avoiding any discontinuities in production. From the silo, butter is pumped to the packing machines through pressure compensators, which control the shear forces.

Butter can be packed initially into 25 kg cases, and subsequently repacked into consumer portions. Alternatively, consumer portions can be packed directly from the continuous butter maker. Most consumer portions are packed in a film wrap (either vegetable parchment or a parchment-lined aluminium foil) or in plastic tubs, which are becoming increasingly popular.

Repackaging of bulk butter into consumer portions requires that the frozen butter first be allowed to reach an optimum temperature of 6–8°C, under controlled humidity conditions to avoid excessive condensation. Heat for this process can be provided by carrying out the first stage of thawing in a packed butter store, or low-grade heat from recovery processes.

After temperature adjustment and before repackaging, the butter is re-blended to break down the matrix of fat crystals and to re-introduce plasticity. At this stage, there is the opportunity to adjust salt and moisture content to the maximum permitted by local regulation. For repackaging in large quantities, continuous butter blenders are available which incorporate all functions of chopping and blending and prod for in-line addition of salt, water and culture. Their construction is similar to that of a continuous buttermaker.

Figure 3–8 is a flow diagram showing the inputs and outputs for this process.

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**Figure 3–8 Inputs and outputs of the butter packaging process**

The main environmental issue associated with this process are the high organic loads in the wastewaters generated from rinsing and cleaning the equipment. The greatest potential for environmental loading occurs when machines, such as a continuous butter blender or packing machines, are closed down, because of the residual fat they contain.

In addition, product loss may occur when packaged products containing product residues are discarded.
Cleaner Production opportunities in this area focus on reducing water use and loss of product. Ways of achieving this include:

- collecting first rinses while still warm and separating the milk fat residues for use in other processes;
- reducing the disposal of packaging material by having personnel constantly optimising operation of the packaging machines.

### 3.3.4 Butter storage

Bulk-packed butter is a relatively stable commodity at low temperatures. Commercial freezing stores operate at temperatures down to -30°C, at which temperature the butter should remain in satisfactory condition for more than one year. If storage periods of more than one year are necessary, or if low-temperature refrigerated storage cannot be guaranteed throughout the entire storage life of the butter, the butter can dehydrate below the optimum moisture content.

Factors affecting the ability of butter to withstand long-term storage include:

- the cleanliness and hygiene of butter-making operations at all stages;
- the prevention of post-pasteurisation contamination during the addition of salt, moisture etc., and in particular the absence of micro-organisms that grow at low temperatures in the water used for these purposes;
- the degree to which salt (if added) is dispersed to the aqueous phase;
- the overall quality of the butter in terms of its homogeneity, texture and moisture distribution;
- the type of butter.

In order to standardise its consistency and appearance, butter for immediate consumption is placed in cold storage at 5°C for 24-48 hours. This ensures that fat crystallisation is complete and individual packs are firm enough to withstand subsequent transportation to the market.

For long-term storage, butter freezing facilities must operate at below -15°C, and temperatures down to -30°C are not uncommon. Sufficient space should be allowed between cases and pallets to allow air circulation, which encourages even chilling.

Refrigeration is usually, but not always, provided by direct expansion ammonia evaporators. Chambers are normally equipped with fork-lift truck access doors protected with automatic door or curtain openers.
Figure 3–9 is a flow diagram showing the inputs and outputs for this process.

![Flow diagram of butter storage](image)

**Figure 3-9 Inputs and outputs of butter storage**

The main environmental issue associated with the storage of butter is the energy consumed for refrigeration and the potential loss of refrigerant to the atmosphere.

Cleaner Production opportunities in this area focus on improving the energy efficiency of refrigerated storage. Ways of achieving this include:

- installing insulation;
- keeping doors closed in cold areas;
- undertaking regular defrosting of cold rooms and regular maintenance of refrigeration systems;
- avoiding refrigerants that contain CFCs. Refrigeration systems based on ammonia cooling are preferred.

### 3.4 Cheese production

Cheese making is an art that is more than 5000 years old. The predominantly rural character of everyday life in the past contributed to the evolution of thousands of different types of cheese and each village, or even family, may have had its own variety, some soft and short lived, some harder and more durable.

Modern cheese technology was founded in the nineteenth century when Joseph Harding perceived a need to adopt strict hygiene and control over methods of making cheddar cheese. This represented a step forward in the scientific approach to cheese making.

Cheeses can be categorised according to the following attributes:

- fat content (high-fat, semi-fat and low-fat cheeses);
- consistency (soft cheeses have a moisture content of 45–50% and semi-hard cheese below 40%);
- method of preparation and production (soft cheeses retain whey in the curd matrix and have coagulation temperatures of 20–40°C; semi-hard cheeses receive more draining and the curd is heated to 42–48°C; hard ‘cooked-curd’ cheeses are well drained and heated to 52–55°C).
Some other types of cheese include:

- fresh cheese that can be consumed just after manufacturing and salting (e.g. quark);
- acid-curd cheeses that are coagulated at a higher temperature (e.g. ricotta);
- lactic-curd cheeses which are kneaded or spun (e.g. mozzarella);
- soft cheeses that ripen for only a short time;
- cheeses that develop different tastes due to enzyme action of surface bacteria;
- blue cheeses of many flavours and types;
- semi-hard, mild-tasting, pressed cheeses with holes (e.g. gouda, havarti and tilsit);
- very hard, dry cheeses which are used for grating (e.g. parmesan).

The process description that follows is for the production of cheddar cheese. Cheddar cheese has been used as an example because it is the most widely manufactured and consumed cheese in the world and its industrial manufacturing has been largely automated.

The manufacture of cheddar cheese demonstrates most of the principles of the industrial processing of cheese and provides a good example for discussing the pertinent environmental issues of cheese making.

### 3.4.1 Cheddar cheese production

Process description

Whole or standardised milk is usually pasteurised at 70°C for 15 seconds and then cooled to the inoculation temperature of 30°C before being poured into a cheese vat fitted with internal agitators. If milk is received on one day and held overnight before being used for cheese production, it will be cooled to 4°C after pasteurisation, and warmed up to inoculation temperature for cheese making.

The starter culture is prepared the day before by the laboratory and may be a single-strain or mixed-strain culture, depending on the flavour required and on the cheese makers’ experience. It is important that the mother cultures from which the daily starter is produced be kept under extremely hygienic conditions in order to avoid contamination—especially from bacteriophages. These are viruses that kill bacteria and can stop cheese-making operations without warning. Each is specific to a bacterial strain, and for this reason the type of starter used is ‘rotated’ frequently.

Generally, starter is added at the rate of 1–1.5% of the volume of cheese milk. The quantity, however, is determined on a case-by-case basis, depending on starter activity and the subsequent rate of acid development in the cheese milk.

When the acidity has reached the required level, usually after 45–60 minutes, rennet is added and dispersed evenly throughout the milk, after which curd formation begins. Rennet acts to coagulate the milk solids into curd.

When the curd is firm enough it is carefully cut into cubes the size of large peas. Cutting is done using multiple knives mounted on a frame, which is driven through the curd in two planes.
The mixture of curd pieces and whey is then gradually heated through the walls of the cheese vat to a temperature of 39°C, with slow and careful agitation. Heating assists the process of syneresis, whereby the protein structure shrinks slightly due to the action of the heat, thus expressing whey and creating a firmer curd. During the process of syneresis it is important that the curd pieces not be damaged by the agitators; this could result in a cloudy whey and high losses of fat.

When cooking is complete (determined by acidity development and curd structure) the curd pieces are allowed to settle and the whey is drained off. The curd is now one cohesive mass.

Although the process described applies to cheddar cheese, it is similar to that used for other pressed cheese processes. The primary objective is to force whey out of the curd through the action of acidity development, heat and pressure.

The curd mass is divided with a knife into blocks. These blocks are turned over and rotated regularly and stacked two or three high. They become thinner as a result of the pressing action. The blocks are kept together as much as possible to maintain warmth. This process continues until the curd texture and the acidity of the whey draining out are at optimum levels. The curd blocks are then milled into pieces about the size of large potato chips.

Dry salt is added to the milled pieces and thoroughly mixed, after which the curd pieces are filled into moulds and pressed overnight. The whey that is expelled from the press station is salt whey and is often white. The moulded blocks of cheese are removed from the moulds and allowed to dry. They are then wrapped in an impervious material—usually a plastic shrink-wrap—and transferred to a ripening room where they remain for about two months, under controlled temperature and humidity, before sale.

Due to the airtight wrapping, maturation during storage is minimal. As a result the majority of cheddar cheeses are mild and bland in flavour and since no rind is formed, all of the cheese can be consumed. So-called ‘farmhouse’ cheddar cheese is formed and wrapped in a cheesecloth gauze instead of plastic film and is matured for up to six months. This allows the cheese to mature properly and gas to escape slowly, resulting in a product that has fuller flavour, buttery texture and thin rind.

Figure 3–10 is a flow diagram showing the inputs and outputs for this process.

![Figure 3–10 Inputs and outputs for Cheddar cheese production](image)
The major environmental issue associated with the cheese-making process is the disposal of whey. There are generally three types of whey:

- **sweet whey**, which is generated when enzymes, principally rennet, are used to coagulate the milk. Sweet whey typically contains 0.6–0.9% soluble protein, up to 0.3% fat and large quantities of lactose (up to 5%). The pH value of sweet whey from cheddar cheese manufacturing is generally 5.1–5.3;

- **acid whey**, which is generated when acid is used to coagulate the milk, for example in the production of cottage cheese. Acid whey typically contains the same proportion of soluble proteins as sweet whey, but less fat and somewhat less lactose (4.5%), since some of the lactose is converted to lactic acid. It has a low pH value, between 4.5 and 4.7;

- **salt whey**, which is the product expressed during the pressing of salted cheese curd, such as in the manufacturing of cheddar cheese. This whey should be collected separately from other types of whey.

Whey produced from natural cheese-making operations contains approximately 6% solids. In the past, whey was perceived merely as an insurmountable problem for the dairy industry because of the high costs of disposal using traditional effluent treatment processes. All too often dairies have taken the easy way out by simply dumping it on land, into rivers or down boreholes. Because of its lactose and protein content, untreated whey has a very high concentration of organic matter which can lead to pollution of rivers and streams and can create bad odours.

A number of opportunities exist for the recovery of the valuable high-grade protein from sweet whey. However it has only been in recent years that they have become technically and economically viable. The method used is ultrafiltration (UF), followed by spray drying of the protein. This process is costly, so is only worthwhile when large quantities of fresh whey are available. Spray-dried whey powder contains between 25% and 80% protein and is used in food products, where it performs a similar function to egg proteins. Whey powder is highly soluble, even at high acidity, and is capable of forming stable foams and gels when heated. Whey protein powder is therefore used in the manufacturing of bakery and meat products, where its gelatinous properties are particularly useful.

Other options available for whey utilisation are:

- Evaporation followed by spray drying to produce whey powder

  One of the problems associated with this solution is that the lactose tends to caramelise, making any heating process difficult. Unless special precautions are taken, the resulting product is very hygroscopic due to the high concentrations of lactose (70–75%). Whey powder in this form is not suitable for use as a food ingredient because it is very sticky and absorbs moisture during storage, forming hard lumps.

  Non-hygroscopic whey powder can be produced by precrystallising the lactose before drying. In this way, most of the lactose is present in the alpha-crystalline form, which is non-hygroscopic. Higher-quality whey powder can be produced by incorporating a secondary crystallisation step after spray drying.
Powder is removed from the drying chamber at 8–14% moisture. The moisture remaining in the powder permits almost complete crystallisation of the lactose and the residual moisture can then be removed in a secondary drying system (e.g. a fluid bed) before the powder is cooled and packaged.

- Feeding it to animals
  
  In most countries where this is practised, the whey is normally fed to pigs or cows. This is a low-cost solution but the price obtained for whey, after transport costs are considered, is often only a very small fraction of the cost of the original milk. The advantages are that there are no capital costs and no effluent charges.

- Demineralisation, or reduction of the mineral content of whey
  
  This increases the range of opportunities for its use as a food ingredient. Ion exchange treatment or electrodialysis is used in the demineralisation process, and demineralised whey is spray-dried in the same way as whey powder. The main use of demineralised whey powder is in the manufacture of infant milk formulations, where it is used in combination with skimmed milk powder to give a similar composition to that of human milk. Another use of demineralised whey powder is in the manufacture of chocolate. Electrodialysis, or ion exchange technology, is comparatively expensive but it does give an end product with a higher value.

- Anaerobic digestion and fermentation
  
  Whey can be anaerobically digested to produce methane gas, which can be captured and used as a supplementary fuel on site. Whey can also be fermented to produce alcohol.

In addition, there are a number of Cleaner Production opportunities for reducing the loss of product from the process, which include:

- preventing the loss of curds by not overfilling cheese vats;
- completely removing whey and curds from the vats before rinsing;
- segregating all whey drained from the cheese;
- sweeping up pressings instead of washing them to drain;
- screening all liquid streams to collect fines.

Case study 3–3: Recovery of lactose from sweet whey

<table>
<thead>
<tr>
<th>To reduce the organic load of effluent on its wastewater treatment plant, a New Zealand dairy expanded its whey protein concentrate plant to process all the sweet whey on site and recover all permeate for lactose.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The company increased sweet whey treatment from 1400 m³/day to 2200 m³/day. This meant that the quantity of lactose discharged was reduced by 50–70 tonnes, and could be used in making new products.</td>
</tr>
<tr>
<td>Although there were some cost savings from reducing the load on the wastewater treatment plant, the most significant economic gain was the income generated from increased production. This was estimated at US$3 million a year.</td>
</tr>
</tbody>
</table>
Case study 3–4: Recovery of cheese solids by installation of screens and settling tanks

An Australian dairy wanted to reduce the amount of cheese solids it discharged to its wastewater treatment plant. To accomplish this, the company installed screens in the cheese room wastewater outlet and built two large settling tanks in the whey room. The settling tanks were intended to remove cheese solids from the process rinse water. Recovered solids could then be reused in the cheese-making process.

The total suspended solids in the effluent decreased significantly and there was a subsequent increase in cheese production of 1%, or 17,700 kg/year. This increased production generated an additional revenue of US$70,000. The total cost of these changes was US$21,000, giving a payback period of less than 4 months.

3.4.2 Cheese packaging

After maturation cheeses are packed, either as entire cheeses (in the case of small varieties), or in consumer portions for larger cheeses such as cheddar. Packaging usually involves a combination of manual and automated processes. Packaging materials include natural wax, laminated paper/foil, shrink-wrap plastic, cartons and pre-formed plastic boxes.

In some cases it is necessary to clean the surface of the cheese and dry it before packaging. This is most common with cheeses that require a longer maturing time, during which there may be considerable mould growth on the surface. These growths are harmless but not aesthetically pleasing to the consumer.

Cleaning, together with stripping of the cheesecloth bandage, is often a manual process. The process of dividing larger cheeses into smaller portions and then shrink-wrapping them is often a semi-manual operation. Wrapping and boxing of small varieties is normally fully automated. Farmhouse cheddar cheeses, edam, gouda and a few other varieties are often dipped in wax to protect and seal the natural rind.

Figure 3–11 is a flow diagram showing the inputs and outputs for this process.

![Figure 3–11 Inputs and outputs for cheese packaging](image-url)
### Environmental issues

The major wastes from the cheese packing area are solid wastes, including discarded cuts and small pieces of cheese and damaged packaging material.

In addition there are liquid discharges from the cleaning of packaging machines, work surfaces and conveyors.

### Cleaner Production opportunities

All cheese scraps should be collected separately from other waste and either used as raw material for processed cheese manufacturing (where possible) or sold as animal feed.

Liquid wastes should be treated, together with other effluent streams.

### 3.4.3 Cheese storage

**Process description**

Cheese storage at the processing plant is limited mainly to the ripening period, as cheeses are normally dispatched for sale immediately after final preparation and packing.

The temperature of storage varies for different types of cheese. Quick-ripening soft cheeses require a low temperature of 4.5°C whereas the harder cheeses, requiring longer ripening periods, are normally stored at up to 18°C.

The most important aspect of cheese storage during the ripening stage is humidity control. Humidity may vary from 75% to 85% for hard, dry-rind cheeses (such as farmhouse cheddar) to over 90% for soft, rindless cheese or surface-ripened soft cheeses.

**Inputs and outputs**

Figure 3–12 is a flow diagram showing the inputs and outputs from this process.

![Figure 3-12 Inputs and outputs for cheese storage](image)

**Environmental issues**

The main environmental issues associated with cheese storage are the energy and refrigerants consumed in refrigerated cold stores.

**Cleaner Production opportunities**

Methods for reducing energy consumption and minimising the impacts of refrigerant use are:

- installing good insulation;
- keeping doors to cold rooms closed;
- undertaking regular defrosting and maintenance of refrigeration systems;
- avoiding refrigerants that contain CFCs. Refrigeration systems based on ammonia cooling are preferred.
3.5 Evaporated and dried milk production

For many centuries, the only known way to conserve the valuable solids of milk was to manufacture butter and cheese. In the mid-1800s, however, it was found that milk could be preserved by boiling it with sugar to form a thick conserve (sweetened condensed milk) which was protected from spoilage by its high sugar content. This discovery was followed at the end of the century by the development of unsweetened condensed milk. Commonly known as ‘evaporated milk’, this product was sterilised in the can, using a revolving retort.

The manufacturing of condensed milk products grew steadily until about 1950, but has since declined. The last major markets for these products are in South-east Asia and South America, which are now mainly being supplied by companies that reconstitute skimmed milk powder.

The period of development of the milk conserves coincided with a major development of private and co-operative dairies in the United States, in which butter and cheese were made on a large scale. The skimmed milk resulting from the separation of cream for butter making was, at best, returned to farmers for cattle feed, but was often dumped in rivers and lakes. This practice continued up until the 1930s, at which time it became possible to dry skimmed milk.

Drying of milk was introduced at the beginning of the 20th century on a very small scale, but many years went by before equipment and processes were developed for extensive commercial use in the 1930s. At this time spray drying processes were introduced in parallel with the earlier roller-drying process.

Further development did not take place to any major extent, however, until after the Second World War. During the past 30 years in particular, milk drying has become recognised as an essential link between the dairy farmer and the consuming public. This is because it allows milk to be stored for long periods in times of surplus, and for the powder to be reconstituted or recombined in times of shortage. Extensive research and practical experience in the techniques of recombining have led to the development of a wide range of dairy products. The availability of milk powders has allowed the developed world to help counter the increasing shortage of proteins in many countries. Milk powder is one of the food products most widely used in relief programs.

In the drying process the removal of water takes place in two stages. In the first stage, the milk is concentrated by vacuum evaporation to remove up to 90% of the water, and the second drying stage removes much of the remaining moisture. The reason for this two-stage approach is that the energy required per kilogram of water evaporated in the drying process is up to twenty times as much as that required in the evaporation process.

In order to maximise the effectiveness of the two stages of the process, multiple-effect evaporators with up to six effects and mechanical vapour re-compression, as well as double-stage dryers with energy-saving devices, have been developed. There has been considerable progress in energy efficiency since the major increase in price of fossil fuels that resulted from the energy crisis of 1973.
3.5.1 Evaporation

Falling film evaporators are the most commonly used evaporators in the dairy industry. They are long, tubular structures made from stainless steel. Milk is introduced at the top of the evaporator and flows as a thin film, down the outside surface of heated tubes or plates, which are packed into the evaporator. The surfaces within the evaporator are heated by steam, which is injected into the top of the evaporator.

In most dairies, multiple-effect evaporation is used, in which a number of evaporators are operated in series. The vapour generated from milk evaporated in the first evaporator is used as the steam input in the next evaporator and so on. Up to seven effects can be operated in series, but three to five is more common. Operating evaporators in this way provides for greater steam efficiency and therefore reduced energy consumption.

In order to attain further steam efficiency, the vapour exiting each evaporator can be recompressed to increase its energy before it is used as the heating medium the subsequent evaporator. Traditionally, thermal recompression, also referred to as thermal vapour recompression (TVR), was the most common recompression system in use. It involved the mixing of high pressure steam with the vapour to compress the mixture to a higher pressure. A single evaporator with a thermocompressor is as efficient as a two-effect unit without one. Therefore thermocompression is often used together with multiple-effect evaporation systems.

The effect on energy efficiency of multiple-effect evaporation and thermal recompression is shown in Table 3-8. TVR evaporators are inexpensive, have no moving parts and provide considerable savings in steam consumption.

Table 3-8  Steam consumption for different evaporation systems

<table>
<thead>
<tr>
<th>Type of falling film evaporator</th>
<th>Specific steam consumption (kg steam/kg water evaporated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without TVR</td>
</tr>
<tr>
<td>Two-effect evaporator</td>
<td>0.60</td>
</tr>
<tr>
<td>Five-effect evaporator</td>
<td>0.40</td>
</tr>
<tr>
<td>Seven-effect evaporator</td>
<td>-</td>
</tr>
</tbody>
</table>

1 Bylund, 1995

Another form of vapour recompression is mechanical vapour recompression (MVR). MVR evaporators were developed in Switzerland during the Second World War when there was a lack of fuel for raising steam. The pressure increase of the vapour is accomplished by the mechanical energy that drives the compressor.

The advantage of the MVR evaporator is that all of the vapour is recompressed, rather than just a portion of it, as is the case with TVR evaporators. This makes for a high degree of heat recovery. In addition, MVR systems are driven by electricity rather than steam, which means that operating costs are considerably lower. The operating cost of a three-effect MVR evaporator are approximately half that of a
conventional seven-effect TVR plant. As a result, it is reasonable to expect that older TVR plants will be replaced with MVR technology.

A disadvantage of MVR systems is that it is not possible to attain high temperatures and thus a steam-heated ‘finisher’ is required. Furthermore, cleaning of the compressor is difficult, although these problems have been alleviated by the recent introduction of high-volume fans instead of compressors.

It is important to note that another option has become available for pre-concentration of the liquid to be dried. Reverse osmosis (RO), which is a hyper-filtration concentration process, can remove some of the water from the milk mechanically without the application of heat. Electrical power is used to drive pumps, which causes liquid migration through a semi-permeable membrane. However it is only possible to increase the solids concentration to a certain extent. A two fold concentration for milk and whey is common.

Figure 3–13 is a flow diagram showing the inputs and outputs for this process.

![Figure 3-13 Inputs and outputs for evaporation](image)

**Figure 3-13 Inputs and outputs for evaporation**

The main environmental issue associated with the evaporative concentration of milk is the very high level of energy consumption. For example, milk powder is a highly energy-intensive product.

TVR evaporators generate noise and have high energy consumption, especially if the condensate is not reused. The condensate from an evaporator will normally be sufficiently pure to allow direct disposal. However, it is often used for cleaning instead of hot water and thus the environmental loading is, in theory, very limited.

Contamination of the condensate by milk, through improper adjustments, carryover and backflows, can result in losses of milk solids and pollution of the considerable quantities of water produced during the evaporation process.

Cleaning of MVR compressors is difficult and produces liquid wastes. So, to some extent, does the cleaning of the high-volume fans that have begun to replace mechanical compressors. MVR evaporators use large amounts of electrical energy, which can create a secondary environmental loading.
Cleaner Production opportunities in this area focus on ensuring the efficient operation of the evaporators, including:

- maintaining a liquid level low enough to prevent product boil-over;
- using entrainment separators to avoid carry-over of milk droplets during condensation of evaporated water;
- recirculating low concentration milk and other feedstocks until a required concentration is reached;
- prior to scheduled shut-downs, processing rinse waters with solids content greater than 7% or evaporating them during the next run rather than discharging them to the effluent stream;
- draining equipment thoroughly before starting rinsing and washing;
- collecting the first rinse water for animal feed;
- reducing the frequency of cleaning operations as much as possible;
- reusing condensate as cooling water after circulation through a cooling tower, or as feed water to the boiler.

Case study 3–5: Conversion to mechanical vapour recompression (MVR)

A Japanese dairy upgraded its milk powder process and installed a four-effect MVR evaporator to replace its existing four-effect TVR evaporator. The cost of the new MVR evaporator was US$1.5 million, compared with US$1.3 million for a new TVR evaporator.

At an evaporation rate of 30 tonnes/hour, the annual operating cost of the MVR evaporator was US$680,000, compared with previous annual operating costs of US$175,000 for the TVR evaporator, a saving of nearly 75%. The savings were a result of greatly reduced steam consumption.

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, to maintain design evaporation capacity. As a result, an automated control system was installed to control operating parameters such as flowrate, temperature and pressure.

(CADDET, 1992)

3.5.2 The drying process

Although roller dryers may still be found in the dairy industry and are sometimes useful for specialised products, the use of spray dryers is now almost universal. The trend towards fewer yet larger dairies, coupled with technical advances in drying techniques since the Second World War, and the need for major economies in the use of energy over the past two decades, have made spray dryers the more practical choice. Roller dryers will thus not be discussed other than to say that they have always had severe environmental problems. They generate fine milk flakes in the vapours that are exhausted through a hood and stack placed immediately over the heated rollers and led outside the building. This has necessitated the use of external vapour cleaners.
After concentration, the milk to be dried is atomised into a fog-like mist, which increases the overall surface area of the milk. The atomised mist is created in a chamber through which high-volume, hot air is being pumped or drawn in a spiral pattern from entry to exit. The milk spray thus evaporates instantly to powder particles. These particles either separate out on the walls and bottom of the chamber due to the cyclonic action or, if they are too fine to react to the centrifugal force, are carried out in the co-current air flow and subsequently collected in smaller cyclones and/or in final fabric filters.

The powder is usually cooled in a fluid bed cooler, especially in areas of high ambient temperatures. This is particularly necessary when powders containing high levels of fat are being dried, to avoid lumping and deterioration of the fat.

Cleaning of the spray tower is normally a dry operation. Wet cleaning should be restricted to a minimum to reduce the risk of bacterial contamination, as moisture is a growth requirement for most bacteria.

Spray drying creates a fire and explosion hazard due to the presence of hot, dry air and a fine, flammable dust. All modern dryers have explosion release mechanisms and fire prevention systems built in.

Figure 3–14 is a flow diagram showing the inputs and outputs for this process.

**Figure 3-14 Inputs and outputs for the drying process**

<table>
<thead>
<tr>
<th>Process description</th>
<th>Environmental issues</th>
<th>Cleaner Production opportunities</th>
</tr>
</thead>
</table>
| After concentration, the milk to be dried is atomised into a fog-like mist, which increases the overall surface area of the milk. The atomised mist is created in a chamber through which high-volume, hot air is being pumped or drawn in a spiral pattern from entry to exit. The milk spray thus evaporates instantly to powder particles. These particles either separate out on the walls and bottom of the chamber due to the cyclonic action or, if they are too fine to react to the centrifugal force, are carried out in the co-current air flow and subsequently collected in smaller cyclones and/or in final fabric filters. | A possible source of pollution is the emission of fine milk powder from the air exhaust of drying systems. This can cause acidic deposits on surrounding roofs and open areas. | Methods for avoiding the release of fine milk powder to surrounding areas include:

- minimising emissions to air by using fabric filters or wet scrubbers;
- undertaking wet cleaning only when absolutely necessary, and plan for it to coincide with a change of product;
- controlling air emissions and taking corrective action if levels are beyond acceptable limits. |
3.5.3 Packaging and storage of milk powder

Milk powder is generally packed into bulk containers as soon as it is cool. For export markets and sometimes for domestic markets, milk powders are packaged into coded, multi-layer kraft paper bags with a separately sealed polythene lining, each containing 25 kg of product. The linings are immediately sealed after filling and the bags are then sewn shut.

In order to improve stacking ability and store utilisation, fully sealed bags are generally passed through a bag flattener before being placed on a pallet. Full pallets are often shrink-wrapped to keep the bags clean, improve structural stability, reduce the possibility of theft and make stocktaking easier. Pallets are then transferred to a store, where powders with different codes are usually kept separate.

Figure 3–15 is a flow diagram showing the inputs and outputs for this process.

![Figure 3-15 Inputs and outputs for packaging and storage of milk powder]

**Environmental issues**

Dust from the exterior surfaces of sacks and/or from sacks that are leaking or not closed properly can deposit on surrounding surfaces. When wet, these deposits become acidic and can cause corrosion.

**Cleaner Production opportunities**

The Cleaner Production opportunities in this area focus on the prevention of emissions of milk powder dust, including:

- ensuring the proper management of storage operations;
- installing exhaust ventilation to minimise dust in the work place.

3.6 Cleaning

Areas and equipment that are in contact with milk and dairy products must be cleaned regularly to maintain hygiene standards. Furthermore, sanitising must be carried out frequently. The relevant regulatory authority normally defines specific cleaning requirements.

**Process description**

Production equipment is typically cleaned by pumping rinse water and cleaning solution through all the equipment components. Some equipment has built-in cleaning nozzles that improve the utilisation of the cleaning solution. The cleaning solution that leaves the vessel can be either discharged or pumped to another vessel. With the use of cleaning-in-place (CIP) equipment, however, it is possible to use less clean
solution and to recirculate cleaning waters to a significant extent. This allows for savings in both detergent and water.

The design of CIP equipment can vary greatly, from simple systems where a batch of cleaning solutions is prepared and pumped through equipment and then drained, to fully automated plants with tanks for water and cleaning solutions.

Modern CIP systems often involve the use of three tanks: one for hot water rinsing, one for alkaline cleaning solution (caustic soda) and one for acidic rinses (nitric acid). Steam is often used to heat the cleaning solutions. The items of equipment to be cleaned are isolated from product flows and the prepared cleaning solutions are pumped through the vessels and pipes. Simpler CIP systems can consist of only one tank and a pump.

Cleaning cycles are often automated according to set sequences and cleaning times, and usually consist of the following steps:

- rinse with cold water (discharged to sewer);
- addition of detergents and/or caustic soda;
- circulation of cleaning solution through the equipment with turbulent flow to loosen and suspend soils (discharged to sewer);
- rinse with water (discharged to sewer);
- nitric acid rinse to prevent build-up of milk scale (discharged to sewer);
- rinse with water (discharged to sewer).

Figure 3–16 is a flow diagram showing the inputs and outputs for this process.

![Flow diagram showing inputs and outputs for cleaning processes](image)

Environmental issues

Cleaning is one of the most water-consuming operations, typically accounting for 25–40% of the total water consumption in a dairy.

The pollution load of cleaning wastewaters is considerable, due to the presence of milk fat and proteins as well as detergents and disinfectants.

Cleaner Production opportunities

For dairies without CIP systems, consideration should be given to their installation. CIP systems make the recovery and reuse of cleaning solutions possible, and systems equipped with in-line monitoring can control the quality of cleaning solutions, thereby maximising the use of detergents and minimising water use. For dairies with CIP equipment, it is important to determine and maintain optimum operational settings to reduce the consumption of both water and detergents.
Further water reductions can be achieved by providing facilities for the collection of final rinse waters so that they can be reused as the initial rinse water in the next CIP cycle.

Detergents and disinfectants can be significant sources of pollution if too much is used. It is very important, therefore, to monitor their consumption. An optimum detergent concentration for cleaning should be determined.

Operators should ensure that tanks, pipes and hoses are as completely empty as possible before they are cleaned. Empty pipelines can be blown with compressed air before cleaning in order to reduce any milk film that may have adhered to the walls of vessels and pipelines.

Cleaning of floors and equipment often consumes large quantities of water, due to the traditional cleaning method in which the operator directs a jet of water from a hose onto equipment and floors until the milk and solids float down the drain. Solid wastes, such as curd particles in the cheese making process, can be collected using a brush or broom rather than being rinsed down the drain.

The use of pigging systems to remove product residues from the internal surfaces of pipeline prior to cleaning can help to reduce the pollutant load of cleaning wastewaters and also allow for product recovery.

Spray nozzles are subject to wear that causes deterioration of the orifice and distortion to the spray pattern. This results in an increased flowrate of water and reduced effectiveness. In general, 10% nozzle wear will result in a 20% increase in water consumption (McNeil and Husband, 1995). Nozzles made from different materials have varying abrasion resistance, as shown in Table 3–9.

### Table 3–9 Abrasion wear index for nozzle materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Abrasion wear index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass</td>
<td>1 (poor)</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>4-6 (good)</td>
</tr>
<tr>
<td>Hard plastic</td>
<td>4-6 (good)</td>
</tr>
<tr>
<td>Ceramic</td>
<td>90-200 (excellent)</td>
</tr>
</tbody>
</table>

1 McNeil and Husband, 1995

Regular monitoring of spray nozzle wear should be incorporated into maintenance programs. Nozzles in service can be compared with new nozzles to determine the extent of wear, and the flowrate of a nozzle can be determined by measuring the time taken to fill a container of known volume.
Case study 3–6: Improved monitoring and operation of CIP equipment

In a Dutch dairy, an analysis of the custard preparation and filling units found that a significant cause of product loss was the cleaning of the pipes and machines. Consequently, monitoring equipment was installed in the cleaning circuits to measure the conductivity and temperature of the rinse waters. The company modified its procedure by installing a level controller, lowering the temperature of the heat exchanger, shortening the cleaning program by 20 minutes, and buying a new software program to monitor the system.

As a result of these changes, consumption of cleaning agents was reduced by 23% and the organic load of effluent discharged to sewer fell significantly. Expenditure on detergents fell by US$28,500/year and effluent charges by US$4,200 a year. The capital outlay required for the system was US$3,150, so the payback period was only one month.

Case study 3–7: Replacement of nitric and phosphoric acids

An Australian dairy was using a mixture of nitric and phosphoric acids for its CIP operations. The company found that 200 litres of these acids were being used each day, eventually ending up in surface drains. The potential risks to the nearby river motivated the company to look for other cleaning agents.

The company found a new cleaning compound that, when used with caustic soda, virtually eliminated the need for an acid wash. Only 150 litres of the new compound was needed and the wash time was reduced by 25%. The reduction in wash time meant an increase of 1.5 production hours a day. Overall savings from switching cleaning chemicals amounted to US$220 per day.

Case study 3–8: Improved operation procedure in yoghurt production

In a Dutch dairy, rinsing after each batch of yoghurt was resulting in significant product loss and an over-consumption of water. To improve this situation, the dairy modified its process by allowing each batch to drain out and then mixing the remaining product with the next batch. Only 50 litres of ‘mixed’ product had to be sold as cattle feed, compared to 110 litres ending up as wastewater.

By not rinsing between batches, 12,500 litres of product a year was recovered, resulting in a cost saving of US$4,600. Effluent treatment costs fell by US$2,100 and water charges by US$800. The dairy saved US$7,400 per year with no capital investment or loss of product quality.
### 3.6.1 Crate washing

**Process description**
Plastic crates (and to some extent wire crates) are washed in a crate washer. The typical washing sequence is: rinsing with cold and warm water, washing with a washing soda solution, and final rinsing with cold water.

**Inputs and outputs**
Figure 3–17 is a flow diagram showing the inputs and outputs for this process.

![Figure 3–17 Inputs and outputs for crate washer operation](image)

**Environmental issues**
The crate washer uses large amounts of water and detergents. This causes the discharge of large quantities of water as well as dirt and some organic matter from milk. Leaks often go undetected as the area is generally wet.

**Cleaner Production opportunities**
Cleaner Production opportunities in this area therefore focus on reducing the consumption of water. Ways of achieving this include:

- optimising water consumption by monitoring the water pressure and the condition of the water spray nozzles;
- installation of spray nozzles of the optimum dimensions;
- fixing leaks promptly;
- turning off the crate washer when not in use;
- recirculating wash water through a holding tank.
3.7 Ancillary operations

3.7.1 Compressed air supply

Air is compressed in an air compressor and distributed throughout the plant in pressurised pipes. Normally, the compressor is driven by electricity and cooled with water or air.

Figure 3–18 is a flow diagram showing the inputs and outputs for this process.

![Figure 3–18 Inputs and outputs for production of compressed air](image)

With just a few small holes in the compressed air system (pipes, valves etc.), a large amount of compressed air is continuously lost. This results in a waste of electricity because the compressor has to run more than is necessary. Table 3–10 lists unnecessary electricity consumption that can be caused by leaks in the compressed air system.

Table 3–10  Electricity loss from compressed air leaks

<table>
<thead>
<tr>
<th>Hole size (mm)</th>
<th>Air losses (L/s)</th>
<th>kW.h/day</th>
<th>MW.h/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>74</td>
<td>27</td>
</tr>
<tr>
<td>5</td>
<td>27</td>
<td>199</td>
<td>73</td>
</tr>
</tbody>
</table>

1 UNEP, 1996

Air compressors are usually very noisy, causing serious risk of hearing damage to the workers in the area.

If the air compressor is water cooled, water consumption can be quite high.

It is very important to check the compressed air system frequently. The best method is to listen for leaks during periods when there is no production.

Maintenance (e.g. change of compressor oil) and the keeping of accurate log-books will often help identify the onset of system leaks.
A great deal of energy can be saved through these simple measures. It pays to implement procedures that ensure the compressed air system is leak free and well maintained.

The consumption of cooling water should be regulated by a temperature-sensitive valve, ensuring the optimum cooling temperature and minimum use of water. Furthermore, the cooling water can be recirculated via a cooling tower. Alternatively, the cooling water can be reused for other purposes such as cleaning, where the hygiene requirements are low.

**Case study 3-9: Reuse of cooling water**

An air-cooled system for an air compressor was replaced with a water-cooled one. The water absorbs the heat from the compressor and is then reused in the boilers. Energy is saved in the boilers because the water preheated.

The installation of the water cooling system cost US$18,000 and had a payback period of less than two years.

### 3.7.2 Steam supply

**Process description**

Steam is produced in a boiler and distributed throughout the plant by insulated pipes. Condensate is returned to a condensate tank, from where it is recirculated as boiler feed water, unless it is used for heating in the production process.

**Inputs and outputs**

Figure 3–19 is a flow diagram showing the inputs and outputs for this process.

![Boiler diagram](image)

**Figure 3-19 Inputs and outputs for supply of steam**

The amount and pressure of the steam produced depend on the size of the boiler and how the fuel is injected into the combustion chamber. Other parameters include pressure level, fuel type, and maintenance and operation of the boiler.

**Environmental issues**

Inefficiencies in boiler operation of boilers and steam leaks leads to the waste of valuable fuel resources as well as additional operating costs.

Combustion of fuel oil results in emissions of carbon dioxide (CO\textsubscript{2}), sulphur dioxide (SO\textsubscript{2}), nitrogen oxides (NO\textsubscript{x}) and polycyclic aromatic hydrocarbons (PAHs). Some fuel oils contain 3–5% sulphur and result in sulphur dioxide emissions of 50–85 kg per 1000 litres of fuel oil.
Sulphur dioxide converts to sulfuric acid in the atmosphere, resulting in the formation of acid rain. Nitrogen oxides contribute to smog and can cause lung irritation.

If the combustion is not adjusted properly, and if the air:oil ratio is too low, there are high emissions of soot from the burners. Soot regularly contains PAHs that are carcinogenic.

Table 3–11 shows the emissions produced from the combustion of various fuels to produce steam.

**Table 3–11  Emissions from the combustion of fuel oil**

<table>
<thead>
<tr>
<th>Input</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel oil (1% sulphur) 1 kg</td>
<td>Energy content 11.5 kW.h</td>
</tr>
<tr>
<td></td>
<td>Carbon dioxide (CO₂) 3.5 kg</td>
</tr>
<tr>
<td></td>
<td>Nitrogen oxides (NOₓ) 0.01 kg</td>
</tr>
<tr>
<td></td>
<td>Sulphur dioxide (SO₂) 0.02 kg</td>
</tr>
</tbody>
</table>

1 kg of oil = 1.16 litre of oil (0.86 kg/L)
1 kW.h = 3.6 MJ

Oil is often spilt in storage and at the boiler. If the spilt oil is not collected and reused or sold, it can cause serious pollution of soil and water.

Instead of using fuel oil with a high sulphur content, it is advantageous to change to a fuel oil with a low sulphur content (less than 1%). This increases the efficiency of the boiler and reduces sulphur dioxide emissions. There are no investment costs involved, but the running costs will be higher because fuel oil with a lower sulphur content is more expensive.

It is essential to avoid oil spills and, if they occur, to clean them up properly and either reuse or sell the oil. A procedure for handling oil and oil spills should be instituted and followed.

If the boiler is old, installation of a new boiler should be considered. Making the change from coal to oil, or from oil to natural gas, should also be considered. In some burners it is possible to install an oil atomiser and thereby increase efficiency. Both options (new boiler and atomiser) will often pay back the investment within 5 years. The actual payback period depends on the efficiency of the existing boiler, the utilisation of the new boiler, the cost of fuel, and other factors.

Steam leaks should be repaired as soon as possible when identified. Even small steam leaks cause substantial losses of steam and corresponding losses of oil and money.

Insulation of hot surfaces is a cheap and very effective way of reducing energy consumption. The following equipment is often not insulated:

- valves, flanges;
- scalding vats/tanks;
- autoclaves;
- cooking vats;
- pipe connections to machinery.
Through proper insulation of this equipment, heat losses can be reduced by 90%. Often the payback period for insulation is less than 3 years.

If steam condensate from some areas is not returned to the boiler, both energy and water are wasted. Piping systems for returning condensate to the boiler should be installed to reduce energy losses. The payback period is short, because 1 m$^3$ of lost condensate represents 8.7 kg of oil at a condensate temperature of 100°C.

The efficiency of boilers depends on how they are operated. If the air to fuel ratio is wrongly adjusted incineration will be poor, causing more pollution and/or poorer utilisation of the fuel. Proper operation of the boiler requires proper training of employees and, if the expertise not is available within the company, frequent visits of specialists.

**Case study 3-10: Poorly operated coal-fired boiler**

Samples of coal and waste ash were taken from coal-fired boilers and were measured for specific energy (kJ/kg), ash percentage and moisture percentage. Results showed that up to 29% of the total fuel supply was not being combusted in the boilers, with the least efficient boiler generating an additional 230 kg of unburnt material per tonne of coal. This unburnt material was retained in the ash and disposed of in landfill.

To improve performance, the company trained employees in efficient boiler operations, so that boilers could be run on automatic control. After this training boiler efficiency increased by 25%, and the specific energy fell to 6 kJ/kg.

Coal use has been reduced by 1500 tons, making an annual saving of US$45,000. Improved boiler operation has also reduced annual landfill disposal by 275 tonnes. The company has hired a specialist company to monitor boiler efficiency on an ongoing basis. The cost of this service is US$2100 per month.

**3.1.3 Water supply**

High-quality domestic water supplies may not need any treatment before use in the plant. However if the available water is of poor quality it may be necessary to treat it to meet hygiene requirements. Treatment normally consists of aeration and filtration through gravel or sand and chlorination may also be necessary.
Figure 3–20 is a flow diagram showing the inputs and outputs from this process.

Figure 3–20  Inputs and outputs for water treatment

Environmental issues

Water is a valuable resource, so its use should be minimised wherever possible. Since electricity is needed for pumping water, energy consumption also increases with increasing water consumption.

The losses that occur due to holes in water pipes and running taps can be considerable. Table 3–12 shows the relationship between size of leaks and water loss.

Table 3–12  Water loss from leaks at 4.5 bar pressure

<table>
<thead>
<tr>
<th>Hole size (mm)</th>
<th>Water loss (m³/day)</th>
<th>Water loss (m³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.4</td>
<td>140</td>
</tr>
<tr>
<td>1</td>
<td>1.2</td>
<td>430</td>
</tr>
<tr>
<td>2</td>
<td>3.7</td>
<td>1300</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>6400</td>
</tr>
<tr>
<td>6</td>
<td>47</td>
<td>17,000</td>
</tr>
</tbody>
</table>

¹ UNEP, 1996.

Cleaner Production opportunities

To ensure that water consumption is optimised, consumption should be monitored on a regular basis. It is helpful to install water meters for separate departments and even for individual processes or pieces of equipment. Whether this is feasible depends on the level of water consumption and the expected savings in each instance. Water consumption can be reduced by 10–50% simply by increasing employees’ awareness and by educating them on how to reduce unnecessary consumption.

Energy-efficient pumps should be installed to reduce the energy consumed for pumping of water. New and efficient pumps can reduce energy consumption by up to 50% compared with standard pumps. It is very important to select a pump with optimum pumping capacity and position it close to the required pump work.
3.1.4 Refrigeration and cooling

Process description

In refrigeration and cooling systems a refrigerant, typically ammonia or a chlorofluorocarbon (CFC)-based substance, is compressed, and its subsequent expansion is used to chill a closed circuit cooling system. The refrigerant itself can act as a primary coolant, recirculated directly through the cooling system, or alternatively, it can be used to chill a secondary coolant, typically brine or glycol.

CFCs were once extensively used in refrigeration systems, but they are now prohibited in most countries, and their use is being phased out as a result of the Montreal Protocol on ozone-depleting substances. All cooling systems should be closed circuit systems and free of leaks. However, due to wear and tear and inadequate maintenance, leaks may occur.

Figure 3–21 is a flow diagram showing the inputs and outputs from this process.

![Flow diagram of a cooling system](image)

Environmental issues

The consumption of electricity and of water can be quite high.

If CFC-based refrigerants are used there is a risk that refrigerant gases will be emitted to the atmosphere, contributing to the depletion of the ozone layer. There is also a risk of ammonia and glycol leaks, which can be an occupational, health and safety problem for workers, but can also result in environmental problems.

Cleaner Production opportunities

CFC-based refrigerants should be replaced by the less hazardous hydrogenated chlorofluorocarbons (HCFCs) or, preferably, by ammonia. In the long run both CFCs and HCFCs should be replaced by other refrigerants according to the Montreal Protocol. Replacing CFCs can be expensive, as it may require the installation of new cooling equipment.

Minimising the ingress of heat into refrigerated areas can reduce energy consumption. This can be accomplished by insulating cold rooms and pipes that contain refrigerant, by closing doors and windows to cold areas, or by installing self-closing doors.

If water and electricity consumption in the cooling towers seems high, it could be due to algal growth on the evaporator pipes. Another reason could be that the fans are running at too high a speed, blowing the water off the cooling tower. Optimising the running of the cooling tower can save a lot of water.