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ЧЕРНІГІВСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНОЛОГІЧНИЙ УНІВЕРСИТЕТ

Промислова екологія харчових виробництв

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Content

Abbreviations

BAFF - Biological aerated flooded filter

BOD - Biochemical oxygen demand: the quantity of dissolved oxygen required by micro-organisms in order to decompose organic matter. The unit of measurement is mg O_2/l. In Europe, BOD is usually measured after 3 (BOD3), 5 (BOD5) or 7 (BOD7) days

CFC - Chlorofluorohydrocarbons

CIP - Cleaning-in-place

COD - Chemical oxygen demand: the amount of potassium dichromate, expressed as oxygen, required to chemically oxidise at approximately 150 °C substances contained in waste water

DAF - Dissolved air flotation

EMAS - Eco-Management and Audit Scheme

EMS - Environmental management system

EC - European Commission

EU - European Union

FBD - Fluidised bed drier

FDM - Food, drink and milk

FOG - Fats, oils and greases

HACCP - Hazard Analysis Critical Control Points

HCFC - Hydrochlorofluorocarbon

HHST - High heat short time (pasteurisation)

HTST - High temperature short time (pasteurisation)

MWWTP - Municipal waste water treatment plant

PE - Polyethylene

PET - Polyethylene terephtalate

PLC - Programmable logic control

RO - Reverse osmosis

SS - Suspended solids

TDS - Total dissolved solids

TS - Total solids

TSS - Total suspended solids

UF - Ultrafiltration

UHT - Ultra-high temperature (sterilization)

UNEP - United Nations Environment Programme

UNIDO - United Nations Industrial Development Organisation

VOC(s) - Volatile organic compound(s) (not limited to the definition of volatile organic compound in Council Directive 1999/13/EC)

WWTP - Waste water treatment plant

Introduction

Subject of course “Industrial ecology of Food Technologies” - materials and energy flows in product systems (including Food, Drink and Milk Industries (FDM) and society, the environmental impacts of these flows, and the influence of technology and socio-economic factors.

Course “Industrial ecology of Food Technologies” consists of 2 modules:

1. Industrial ecology. Strategies for a better environment. Environmental issues for the Food, Drink and Milk Industries sector.
2. Techniques of environmental protection for the FDM sector.

The course aims at presenting the developments in research and application in the field of Industrial ecology and discussing the role of Industrial ecology in strategic sustainable development on a global scale as well as for strategies for manufacturing industries. Environmental problems and their solutions, mainly in the FDM sector, are discussed in this course. The overall aim of the course is to provide theoretical and applied knowledge and understanding of strategies and technologies for a cleaner industrial production for the.

This means that after the course the student should be able to:

1 Describe and explain the concept of Industrial ecology in practice and in research.

2 Describe and explain the similarities and differences between an ecosystem and an industrial system.

3 Propose and motivate strategies and actions for different industrial environmental problems, based on a system analysis perspective.

4 Describe and explain how to use different unit operations as process integrated cleaning stages (as kidney or recovery function) in an industrial production process in order to minimize pollutions to air or water for the FDM.

5 State and describe other process internal solutions to minimize air pollution emissions and emissions through waste water discharges.

6 Describe and explain the function of different process external methods that can be used in order to minimize pollutions to air or water.

7 Discuss advantages and disadvantages for different environmental technical solutions.

8 Propose and motivate the choice of different environmental technical solutions in order to solve or minimize pollutions to air or water from industrial production processes for the FDM.

Students shall develop skills in order to be able to:

1) Explain main aspects material and energy flows for the FDM sector and related environmental impacts;
2) Understand how such methods can be used to improve technological systems for the FDM, and reflect on the differences, strengths and weaknesses of the methods,
3) Outline simple models, carry out simple calculations and interpret results from such analyses, with examples from selected technological systems

(industrial production, energy use, waste management, buildings and infrastructure);

4) Explain requirements for successful implementation in practice;
5) Search information from scientific literature related to industrial ecology and summarize and analyze in written reports;
6) Summarize and orally present own work and critically discuss work done by others.

The course has developed thanks to project Tempus IEMAST: «Establishing Modern Master-level Studies in Industrial Ecology».

TASKS for INDIVIDUAL WORK

I Describe the environmental issues in some individual FDM sectors (on the example of an enterprise):

1. Meat and poultry
2. Fish and shellfish

3 Fruit and vegetables

4 Vegetable oils and fats

5 Bread

6 Confectionery

7 Sugar

8 Coffee

9 Drinks

10 Brewing

When describing the consumption and emission levels in some individual FDM sectors, try to follow the plan:

1.1 General information

- A description of the company's processes should answer the following questions:
- What does the company produce?
- What is the history of the company?
- How is the company organized?
- What are the main processes?
- What are the most important inputs and outputs?

1.2 Water consumption

1.3 Waste water (Quantity of waste water, Composition of waste water)

1.4 Air emissions

1.5 Solid output

1.6 Energy

1.7 Consumption of chemicals

1.8 Noise.

When looking for answers to these questions you should first try to find already existing operational data such as production reports, audit reports and site plans. This checklist would make this step more comprehensive.

Where information is not available you should set up a plan how to obtain the missing data.

II Describe existing techniques for minimizing emissions, which are used in this enterprise.

III Suggest own solution for environmental protection for this enterprise.

Theoretical background

Assessment Methodologies of Cleaner Production.

Cleaner Production assessment is one of the specific Cleaner Production diagnostic tools. This is a systematic procedure for the identification and evaluation of Cleaner Production options for the companies that are launching a Cleaner Production project. The methodology allows us to identify areas of inefficient use of resources and poor management of wastes in production.

Many organisations have produced manuals describing Cleaner Production assessment methodologies with the same underlying strategies. We will follow the UNEP/UNIDO Cleaner Production assessment methodology (UNEP - United Nations Environment Programme; UNIDO - United Nations Industrial Development Organisation).

The five phases in this methodology:

1. Planning and Organizing Cleaner Production.
- Obtain Management Commitment.
- Establish a Project Team.
- Develop Environmental Policy, Objectives and Targets.
- Plan the Cleaner Production Assessment.
2. Pre-assessment.
- Company Description and Flow Chart.
- Walk-through Inspection.
- Establish a Focus.
3. Assessment.
- Collection of Quantitative Data.
- Material Balance.
- Identify Cleaner Production Opportunities.
- Record and Sort Options.
4. Evaluation and Feasibility Study.
- Preliminary Evaluation. Technical Evaluation.
- Economic Evaluation.
- Environmental Evaluation. Select Viable Options.
5. Implementation and Continuation.
- Prepare an Implementation Plan.
- Implement Selected Options.
- Monitor Performance.
- Sustain Cleaner Production Activities.

1. Planning and Organizing Cleaner Production

The objective of this phase is to obtain commitment to the project, allocate resources and plan the details of the work.

1.1 Obtain Management Commitment

Experiences from many companies show that Cleaner Production initiatives results in both environmental improvements and better economic performance. However, this should be recognized by the management of the company. One of the most effective ways for the management to see the benefits of implementation of Cleaner Production is by example of similar companies which already implemented CP programmes. Several sources for study cases around the world are found in the Internet addresses for this chapter.

1.2 Establish a Project Team

The CP project team undertakes the following tasks:

- Analysis and review of present practices.
- Development and evaluation of proposed Cleaner Production initiatives.
- Implementation and maintenance of agreed changes.

The project team should consist of people responsible for the business functions of the major facilities in the company, research & development staff as well as expert consultants in order to facilitate team activities. Members from outside the company would give an independent point of view to Cleaner Production activities.

1.3 Develop Environmental Policy, Objectives and Targets

The environmental policy outlines the guiding principles for the assessment. The policy contains the company's mission and vision for continuous environmental improvement and compliance with legislation. The objectives describe how the company will do this. For example, the objectives could include reducing the consumption of materials and minimizing the generation of waste. Targets are used to monitor if the company is proceeding as planned. An example of a target might be a 20% reduction in electricity consumption within 2 years.

1.4 Plan the Cleaner Production Assessment

The project team should draw up a detailed work plan and a time schedule for activities within the Cleaner Production assessment. Responsibilities should be allocated for each task so that staff involved in the project understands clearly what they have to do.

2 Pre-assessment

The objective of the pre-assessment is to obtain an overview of the production and environmental aspects of a company. Production processes are best represented by a flow chart showing inputs, outputs and environmental problem areas.

2.1 Company Description and Flow Chart

A description of the company's processes should answer the following questions:

- What does the company produce?
- What is the history of the company?
- How is the company organized?
- What are the main processes?
- What are the most important inputs and outputs?

When looking for the answers to the questions the assessment team should first try to find already existing operational data such as production reports, audit reports and site plans. A checklist (Table 1) would make this step more comprehensive.

Table 1 - Checklist

Type of information	Available	Not available	Requires updating	Not applicable
Process Information				
Process flow diagram				
Material balance data				
Energy balance data				
Site plans				
Drainage diagrams				
Operating procedures*				
Equipment list & specifications				
Regulatory Information				
Waste license(s)				
Trade waste agreement(s)				
Environmental monitoring records				
EPA license(s)				
Environmental audit reports				
Raw Material/Production Information				
Material safety data sheets				
Product & raw material inventories				
Production schedules				
Product composition & batch sheets				
Accounting Information				
Waste handling, treatment & disposal costs				
Water & sewer costs				
Product, energy & raw material costs				
Operating & maintenance costs				
Insurance costs				
Benchmarking data				

Where information is not available the project team should set up a plan how to obtain the missing data.

The production line to be studied can best be represented using a detailed process flow chart. Producing a flow chart is a key step in the assessment. It will be the basis for material and energy balances which occur later in the assessment. In a process flow chart for a CP assessment, the team should pay particular attention to several activities which are often neglected in traditional process flow charts. These are:

- Cleaning.
- Materials storage and handling.
- Ancillary operations (cooling, steam and compressed air production).
- Equipment maintenance and repair.
- Materials that are not easily recognizable in output streams (catalysts, lubricants etc.).
- By-products released to the environment as fugitive emissions.

The process flow chart is meant to provide an overview and should thus be accompanied by individual input/output sheets for each unit operation or department in the company. Figure 1 provides an example of an input/output worksheet.

Inputs	***Process***	***Outputs***
Raw materials:	*Department:*	*Product:*
Ancillary materials:	*Process:*	*By-products:*
Hazardous materials:		*Air emissions:*
Water:	*Short description:*	*Solid waste:*
Energy:		*Hazardous waste:*
	Occupational health and safety:	*Wastewater discharge:*

Figure 1 - Example of an input/output worksheet

2.2 Walk-through Inspection

Much of the information needed to fill out the input/output sheets, described above, may be obtained during a walk-through inspection of the company. The walk-through inspection should follow the process from start to finish, focusing on areas where products, wastes and emissions are generated.

Below it provides examples of the types of questions which the team may ask operators to facilitate the investigation. During the walk-through all obtained information should be listed, and if there are obvious solutions to the existing problems, they should be noted. Special attention should be paid to no-cost and low-cost solutions. These should be implemented immediately, without waiting for a detailed feasibility analysis.

Questions to be answered during a walk-through inspection:

- Are there signs of poor housekeeping? Are there noticeable spills or leaks?
- Is there any evidence of past spills, such as discolouration or corrosion on walls, work surfaces, ceilings and walls or pipes?
- Are water taps dripping or left running?
- Are there any signs of smoke, dirt or fumes to indicate material losses?
- Are there any strange odours or emissions that cause irritation to eyes, nose or throat?
- Is the noise level high?
- Are there open containers, stacked drums, or other indicators of poor storage procedures?
- Are all containers labelled with their contents and hazards?
- Have you noticed any waste and emissions being generated from process equipment (dripping water, steam, evaporation)?
- Do employees have any comments about the sources of waste and emissions in the company? Is emergency equipment (fire extinguishers etc.) available and visible to ensure rapid response to a fire, spill or other incident?

2.3 Establish a Focus

The last step of the pre-assessment phase is to establish a focus for further work. In an ideal case all processes and unit operations should be assessed. However time and resource constraints may make it necessary to select the most important aspects or process areas. It is common for Cleaner Production assessments to focus on those processes that:

- Generate a large quantity of waste and emissions.
- Use or produce hazardous chemicals and materials.
- Entail a high financial loss.
- Have numerous obvious Cleaner Production benefits.
- Are considered to be a problem by everyone involved.

All information collected during the pre-assessment phase should be well organized so that it is easily accessed and updated.

3 Assessment

The aim of the assessment phase is to collect data and evaluate the environmental performance and production efficiency of the company. Data collected about management activities can be used to monitor and control overall process efficiency, set targets and calculate monthly or yearly indicators. Data collected about operational activities can be used to evaluate the performance of a specific process.

3.1 Collection of Quantitative Data

It is important to collect data on the quantities of resources consumed and wastes and emissions generated. Data should be represented based on the scale of production. Collection and evaluation of data will most likely reveal losses. For instance, high electricity consumption outside production time may indicate leaking compressors or malfunctioning cooling systems. Input/output worksheets are useful documents in determining what data to collect. Most data will already be available within the company's recording systems, e.g. stock records, accounts, purchase receipts, waste disposal receipts and production data.

Where information is not available, estimates or direct measurements will be required.

3.2 Material Balance

The purpose of undertaking a material balance is to account for the consumption of raw materials and services that are consumed by the process, and the losses, wastes and emissions resulting from the process. A material balance is based on the principle of "what comes into a plant or process must equal what comes out". Ideally inputs should equal outputs, but in practice this is rarely the case, and some judgment is required to determine what level of accuracy is acceptable.

Simply expressed, material or mass balance calculations are based on the following equation:

Total material in = material out (product) + material out (wastes) + material out (emissions) + material accumulated.

A material balance makes it possible to identify and quantify previously unknown losses, wastes or emissions, and provide an indication of their sources and causes. Material balances are easier, more meaningful and more accurate when they are undertaken for individual unit operations. An overall company-wide material balance may then be constructed using these partial balances. The material balance sheets can also be used to identify the costs associated with inputs, outputs and identified losses. Presenting these costs to the management of the company often result in a speedy implementation of Cleaner Production options.

While it is complicated to present a complete methodology for establishing a material balance, the following guidelines may be useful:

- Prepare a process flow chart for the entire process, showing as many inputs and outputs as possible.
- Sub-divide the total process into unit operations. Sub-division of unit operations should occur in such a way that there is the smallest possible number of streams entering and leaving the process.
- Do not spend a lot of time and resources trying to achieve a perfect material balance; even a preliminary material balance may reveal plenty of Cleaner Production opportunities.

Environmental performance indicators for the process can be developed from the material balance data. This is achieved by dividing the quantity of a material input or waste stream by the production over the same period. Performance indicators may be used to identify over consumption of resources or excessive waste generation by comparing them with those of other companies or figures quoted in the literature. They also help the company track its performance towards its environmental targets.

It is important to determine the true source of the waste stream. Impurities from an upstream process, poor process control, and other factors may combine to contribute to waste. Unless these sources are identified and their relative importance established, the generation of Cleaner Production options is too limited. It may focus on a piece of equipment that emits the waste stream but produces only a small part of the waste.

3.3 Identify Cleaner Production Opportunities

The Cleaner Production assessment phase starts with making a "diagnosis" of the process to identify shortcomings and their causes, as well as to find options for how to improve it.

The assessment team uses all means possible to identify Cleaner Production options. Ideas may come from:

- Literature.
- Personal knowledge.
- Discussions with suppliers.
- Examples in other companies.
- Specialized databases.
- Further research and development.

It should be noted that during the assessment process, a number of obvious possibilities for immediate improvements may already have been identified. For example one of the simplest and obvious measures is reduction in water use or energy use.

One way to produce ideas for Cleaner Production opportunities is to run a brainstorming session. Brainstorming sessions have proved to be most effective when managers, engineers, process operators and other employees as well as some outside consultants, work together without hierarchical constraints.

Many Cleaner Production solutions are arrived at by carefully analyzing the cause of a problem. Often the temptation is to jump from identifying where wastes and emissions are being generated directly to coming up with solutions how to prevent them. However, adding a middle diagnostic step is often a good idea. It provides additional information, which complements the Cleaner Production options.

Secondly the team focuses on Cleaner Production prevention practices. Here it is important to keep in mind that there are five features which influence the process, and which can serve as focus points for generating options:

1. Input materials.
2. Technology.
3. Execution of the process.
4. Product.
5. Waste and emissions.

Based on these five features that influence the environmental performance of a process, the corresponding points of action can be used to improve the environmental performance of the process.

These are:

1. Input material changes or input substitution.
2. Technology changes or technology modifications.
3. Good housekeeping or good operating practices.
4. Product changes or product modifications.
5. Recycling.

We will briefly comment on each one of these in the following.

Input material changes may contribute to Cleaner Production by reducing or eliminating hazardous materials that enter the production process. Also, changes in input materials can be made to avoid the generation of hazardous wastes within the production processes. Input material changes are either material purification or material substitution.

Technology changes are oriented toward process and equipment modifications to reduce waste, primarily in a production setting. Technology changes range from minor alterations that are possible to implement in a matter of days at low costs, to the replacement of processes involving large capital costs. These may be changes in the production process; introducing new equipment, layout, or piping changes; introducing the use of automation; and implementing changes in process conditions such as flow rates, temperatures, pressures and residence times.

Good housekeeping implies procedural, administrative, or institutional measures that a company can use to minimize waste. Many of these measures are used in larger industries as efficiency improvements and good management practices.

Good housekeeping practices can often be implemented in all areas of the plant, including production, maintenance operations, and raw material and product storage. Good housekeeping or operating practices include the following:

- Cleaner Production programmes.
- Management and personnel practices, including employees training, incentives and bonuses, and other programmes that encourage employees to conscientiously work to reduce waste.
- Material handling and inventory practices, including programmes to reduce loss of input materials due to mishandling, expired shelf life of time-sensitive materials, and proper storage conditions.
- Loss prevention, minimizing wastes by avoiding leaks from equipment and spills.
- Waste segregation, reducing the volume of hazardous wastes by preventing the mixing of hazardous and nonhazardous wastes.
- Cost accounting practices, including programmes to allocate waste treatment and disposal costs directly to the department or groups that generate waste, rather than charging these costs to general company overhead accounts. In doing so, the departments or groups that generate the waste become more aware of the effects of their treatment and disposal practices, and have a financial motivation to minimize their waste.
- Production scheduling, and scheduling batch production runs. This way the frequency of equipment cleaning and the resulting waste can be

reduced. It is at this stage also that the energy efficiency of the process, and of the general plant operations, can be considered.

Product changes are performed by the manufacturer of a product with the intent of reducing waste resulting from a product's use. Product changes include:

- Product substitution.
- Product conservation.
- Changes in product composition.

Product modification is about changing the characteristics of a product such as its shape and material composition.

Recycling via use and/or reuse involves the return of a waste material either to the originating process as a substitute for an input material, or to another process as an input material.

3.4 Record and Sort Options

Once a number of Cleaner Production opportunities have been suggested and recorded, they should be sorted into those that can be implemented directly and those that require further investigation. It is helpful to follow the steps:

- Organize the options according to unit operations or process areas, or according to inputs/outputs categories (e.g. problems that cause high water consumption).
- Identify any mutually interfering options, since implementation of one option may affect the other.
- Opportunities that are cost free or low cost, that do not require an extensive feasibility study, or that are relatively easy to implement should be implemented immediately.
- Opportunities that are obviously infeasible, or cannot be implemented should be eliminated from the list of options for further study.

4. Evaluation and Feasibility Study

The objective of the evaluation and feasibility study phase is to evaluate the proposed Cleaner Production opportunities and to select those suitable for implementation. The opportunities selected during the assessment phase should all be evaluated according to their technical, economic and environmental merits.

4.1 Preliminary Evaluation

The quickest and easiest method of evaluating the different options is to form a group, consisting of the project team and management personnel, and discuss the possible solutions one by one. This process should give a good indication of which projects are feasible and what further information is required.

4.2 Technical Evaluation

The potential impacts on products, production processes and safety concerns of the proposed changes need to be evaluated before complex and costly projects can be decided upon. In addition, laboratory testing or trial runs may be required when options significantly change existing practices. A technical evaluation will determine whether the opportunity requires staff changes or additional training or maintenance.

4.3 Economic Evaluation

The objective of this step is to evaluate the cost effectiveness of the Cleaner

Production opportunities. Economic viability is often the key parameter that determines whether or not an opportunity will be implemented.

When performing the economic evaluation, costs of the change are weighed against the savings that may result. Costs can be broken into capital investments and operating costs.

Investment capital estimates can be broadly classified in three types according to the accuracy and purpose of the estimate.

1. Preliminary feasibility estimates are used for initial feasibility studies and to make rough choices between design alternatives. The accuracy of theses estimates is in the order of ± 30%. Feasibility estimates are often made on capital cost information for a complete process taken from previously built plants. The cost information is adjusted using scaling factors for capacity and for inflation to obtain the estimated capital cost.

$C_2 = C_1 (S_2/S_1)_n$

where

C_1 = capital cost of the project with capacity S_1.

C_2 = capital cost of the project with capacity S_2.

n = cost factor. The empirical value for process plants, for individual units of equipment the value varies from ca 0.3 to 0.8.

Major equipment estimates provide more accurate (± 30%) capital estimates. In this method all major process equipment is roughly sized and the approximate purchased equipment cost is calculated. The total cost of the equipment is then factored for installation, piping, instrumentation, electrical installations, utilities, buildings, foundations etc. to give the total estimated process cost. The so called Lang factor for a mixed fluids-solids processing plant indicates that the total capital investment is 3.6 times the cost of the major process equipment.

2. Budget (or Authorisation) estimates, with accuracy of ± 10-15%, are used for authorisation of funds to proceed with the design to the point where a more accurate estimate can bemade. made. This type of estimate requires preliminary specifications of all the equipment, utilities, instrumentation, electrical and off-site installations of the process.

3. Detailed (Quotation) estimates, accuracy ± 5-10%, are used for project cost control and for contractor negotiations. This type requires complete, detailed process design, firm quotations for equipment and detailed breakdown and estimation of construction cost.

Operating costs include direct manufacturing costs such as raw materials, waste treatment, utilities, labour costs, maintenance and repairs,fixed manufacturing costs which include capital costs (interest), depreciation of the installed equipment, taxes, insurance and plant overhead costs. The operating costs also include general costs shared with other parts of the company such as administration, distribution and sales costs and costs for research and development.

Standard parameters used to evaluate the economic feasibility of a project are payback period, net present value (NPV), or internal rate of return (IRR).

As an example we can take a tannery, which will have to spend USD 351,120 for the installation of four special drums in order to use a Cleaner Production process for un-hairing hides, rather than using a chemical method. The annual savings is estimated to be USD 87,780 in reduced chemical costs. The payback period is therefore 4 years.

4.4 Environmental Evaluation

The objective of the environmental evaluation is to determine the positive and negative environmental impacts of the proposed Cleaner Production option. In many cases the environmental advantages are obvious: a net reduction in toxicity and/or quantity of wastes or emissions. In other cases, it may be necessary to evaluate whether an increase in electricity consumption, for instance, would outweigh the environmental advantages of reducing the consumption of materials.

For a good environmental evaluation, the following information is needed:

- Changes in amount and toxicity of wastes or emissions.
- Changes in energy consumption.
- Changes in material consumption.
- Changes in degradability of the wastes or emissions.
- Changes in the extent to which renewable raw materials are used.
- Changes in the reusability of waste streams and emissions.
- Changes in the environmental impacts of the product.

In many cases it will be impossible to collect all the data necessary for a good environmental evaluation. In such cases a qualified assessment will have to be made on the basis of the existing information. Given the wide range of environmental issues, it will probably be necessary to prioritise those issues of greatest concern. In line with the national environmentalpolicy of the country or the company, some issues may have a higher priority than others.

4.5 Select Viable Options

The most promising options must be selected in close collaboration with the management of the company.

A comparative ranking analysis may be used to prioritise opportunities for implementation. The concept of such a method is shown below in Table 4.2. An option can be assigned scores, say from 1 to 10, based on its performance against a set of evaluation criteria. By multiplying each score by a relative weight assigned to each criterion, a final score can be arrived at. The options with the highest scores will probably be best suited for implementation. However, the results of this analysis should not be blindly accepted. Instead, they should form a starting point for a discussion. All simple, cost-free and low-cost opportunities should of course be implemented as soon as possible.

Table 2 **-** Example of a weighted sum method for evaluating alternative options

Evaluation criterion	**Weight**	**Score***					
		Option A		Option B		Option C	
		score	weighed score	score	weighed score	score	weighed score
Reduced hazardous waste treatment							
Reduced wastewater treatment costs							
Reduced amount of solid waste							
Reduced exposure to chemicals							
Reduced amount of water consumption							
Reduced odours problems							
Reduced noise problems							
Easy to install and maintain							
Weighted sum							

-3 = lowest rank, 0 = no change, +3 = highest rank (preferred)

5. Implementation and Continuation

The objective of the last phase of the assessment is to ensure that the selected options are implemented, and that the resulting reductions in resource consumption and waste generation are monitored continuously.

5.1 Prepare an Implementation Plan

To ensure implementation of the selected options, an action plan should be developed, detailing:

- Activities to be carried out.
- The way in which the activities are to carried out.
- Resource requirements (finance and manpower).
- The persons responsible for undertaking those activities.
- A time frame for completion with intermediate milestones.

Table 3 - Implementation plan

Problem	Solution	What?	Who?	When?

5.2 Implement Selected Options

As for other investment projects, the implementation of Cleaner Production options involves modifications to operating procedures and/or processes and may require new equipment. The company should, therefore, follow the same procedures as it uses for implementation of any other company projects. However, special attention should be paid to the need for training of the staff. The project could be a failure if it is not backed up by adequately trained employees. Training needs should have been identified during the technical evaluation.

5.3 Monitor Performance

It is very important to evaluate the effectiveness of the implemented Cleaner Production options. Typical indicators for improved performance are:

- Reductions in wastes and emissions per unit of production.
- Reductions in resource consumption (including energy) per unit of production.
- Improved profitability.

There should be periodic monitoring to determine whether positive changes are occurring and whether the company is progressing toward its targets. Examples of the types of aspects that could be checked to evaluate improvements are shown in Table 4.4.

Table 4 - Evaluation checklist

	Yes	No
Overall Cleaner Production assessment check Are the opportunities implemented according to the action plan? Are new procedures being followed correctly by the employees? Where do problems occur and why? Do licenses or permits require amendments? Which ones? Has compliance with legislation been maintained as a result of the changes? **Environmental performance check** Are the opportunities cost effective? Is the cost effectiveness as expected? Has the number of waste and emission sources decreased? By how many? Has the total amount of waste and emissions decreased? By how much? Has the toxicity of the waste and emissions decreased? By how much? Has the energy consumption decreased? By how much?		

Have the Cleaner Production goals been achieved? Which have and which have not? Have there been any technical ramifications? What are they and why? **Documentation check (The following items should be included in the files.)** Statements of the company's objectives and targets and the environmental policy Company description and flow diagram with input and outputs Worksheets completed during the Cleaner Production assessment Material balances List of Cleaner Production opportunities generated during brainstorming sessions Lists of opportunities that are technically, economically and environmentally feasible Implementation action plan Monitoring data Before-and-after' comparisons Post-implementation evaluation reports		
By how much? Have the Cleaner Production goals been achieved? Which have and which have not? Have there been any technical ramifications? What are they and why? Documentation check (The following items should be included in the files.) Statements of the company's objectives and targets and the environmental policy Company description and flow diagram with input and outputs Worksheets completed during the Cleaner Production assessment Material balances List of Cleaner Production opportunities generated during brainstorming sessions Lists of opportunities that are technically, economically and environmentally feasible Implementation action plan Monitoring data Before-and-after' comparisons Post-implementation evaluation reports		

5.4 Sustain Cleaner Production Activities

Sustained Cleaner Production is best achieved when it becomes part of the management through a formal company environmental management system or a total environmental quality management approach. An environmental management system provides a decision-making structure and action plan to support continuous environmental improvements, such as the implementation of Cleaner Production. If a company has already established an environmental management system, the Cleaner

Production assessment can be an effective tool for focusing attention on specific environmental problems. If, on the other hand, the company establishes a Cleaner Production assessment first, this can provide the foundations of an environmental management system.

Study Questions

1. Describe the Cleaner Production assessment methodology of UNEP/UNIDO.
2. How may the implementation of Cleaner Production assessment methodologies in companies give environmental and economic benefits?
3. Which company specialists should be included in a project team for the analysis and review of present practices and development of Cleaner Production initiatives? Which questions should first be considered? Determine the sources of information.
4. What does the material balance mean?
5. How is it possible to accomplish a Cleaner Production programme in a company? Give some examples of good housekeeping in companies, product changes and so on. In which way may the environmental, economic and technical effectiveness of a project be evaluated?
6. Write the formula for calculating the NPV and other methods of evaluation.
7. What should be included in an action plan for Cleaner Production implementation?

Example of the task solution

1 Environmental issues for the Dairy products industry

1 Water

1.1 Water consumption

Water consumption is mainly associated with cleaning operations. The factors affecting water consumption in European dairies are:

- availability of surface and groundwater for cooling
- time and amount of water used for rinsing
- characteristics of CIP programmes
- maintenance, e.g. reparation of leaks.

A reasonably efficient consumption of water is reported to be around 1 – 5 l/kg milk, however, it is reported that a water consumption of 0.8 – 1.0 l/kg milk can be achieved by using advanced equipment and a good operation. According to a German survey, 132 dairies used, on average in 1999, 2.06 l/kg of milk. Table 1.1 shows water consumption in European dairies. Table 1.2 shows water consumption for some Nordic dairies.

Table 1.1 - Water consumption in European dairies

Product	**Water consumption* (l/kg processed milk)**	
	Min	**Max**
Market milk and yoghurt	0.8	25
Cheese and whey	1.0	60
Milk powder, cheese and/or liquid products	1.2	60
*Cooling water is included		

Table 1.2 - Water consumption for some Nordic dairies

Product	**Water consumption (l/l processed milk)**			
	Sweden	**Denmark**	**Finland**	**Norway**
Market milk and yoghurt	0.96 – 2.8 (8)	0.60 – 0.97 (3)	1.2 – 2.9 (8)	4.1 (1)
Cheese and whey	2.0 – 2.5 (4)	1.2 – 1.7 (5)	2.0 – 3.1 (2)	2.5 – 3.8 (2)
Milk powder, cheese and/or liquid products	1.7 – 4.0 (7)	0.69 – 1.9 (3)	1.4 – 4.6 (2)	4.6 – 6.3 (2)
Figures in brackets show the number of dairy installations in each category				

In the UK dairy industry, there is a wide variation in the water consumption/amount of milk processed ratio, compared to the volume of the milk received for processing per installation, as shown in Figure 1.1.

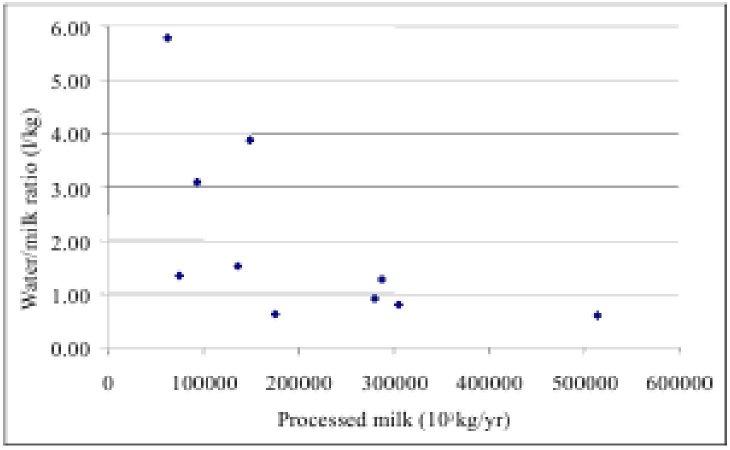

Figure 1.1 - Water consumption/processed milk ratio as a function of the quantity of processed milk

Seven ice-cream installations in Nordic countries have reported a water consumption in the range 3.6 – 10.3 l/kg of produced ice-cream. For ice-cream installations where no water recycling is applied in the cooling system, a water consumption of 10 – 325 l/kg of product has been reported.

1.2 Waste water

Waste water is the main environmental issue in the dairy sector. The sector uses a vast amount of water, and generates a huge amount of waste water in maintaining the required level of hygiene and cleanliness. Data reported for specific waste water discharge for dairy activities in Austria are shown in Table 1.3. Waste water volume in a well managed installation is reported to be about 1 – 2 l/kg of milk processed.

Table 1.3 - Approximate volumes of waste water in dairy activities

Type of product	Waste water volume (l/kg of milk processed)
“White” products, e.g. milk, cream and yoghurt	3
“Yellow” products, e.g. butter and cheese	4
“Special” products, e.g. concentrates of milk or whey and dried milk products	5

In the UK, around 14 million m^3 of milk is produced for processing each year. It is reported that a new dairy in the UK is achieving a 1:1 volume of milk processed: waste water volume ratio, i.e. one litre of waste water for each litre of milk litre processed and that a 1.5:1 ratio is achievable in existing dairies. A comparison is reported between a dairy generating 2 liters of waste water per litre of milk processed. This would produce around 28 million m^3/year of waste water for disposal to a WWTP. If this waste water is considered to have an average COD strength of 3000 mg/l, then the total loading would be around 84000 t COD/yr, equivalent to the waste of more than two million people. Also, if 1 m^3 of milk is released into a watercourse, its oxygen depleting potential, in terms of BOD5 load, is equivalent to the daily raw sewage of 1500 – 2000 people.

Untreated dairy waste waters have an average BOD load ranging from 0.8 to 2.5 kg BOD/t milk. Other significant pollutants present in the waste water are phosphorus, nitrogen and chloride. Individual waste water streams of a wide pH range are produced. The temperature of the waste water streams may also need to be considered. The waste water may contain pathogens from contaminated materials or production processes. Table 1.4 gives data on the typical untreated waste water from dairy processing.

Table 1.4 - Reported untreated dairy waste water contamination levels

Component	**Range**
SS	24 – 5700 mg/l
TSS	135 – 8500 mg/l
COD	500 – 4500 mg/l
BOD5	450 – 4790 mg/l
Protein	210 – 560 mg/l
Fat	35 – 500 mg/l
Carbohydrate	252 – 931 mg/l
Ammonia -N	10 – 100 mg/l**
Nitrogen	15 – 180 mg/l
Phosphorus	20–250 mg/l
Sodium	60 – 807 mg/l
Chloride	48 – 469 (up to 2000) mg/l
Calcium	57 – 112 mg/l
Magnesium	22 – 49 mg/l
Potassium	11 – 160 mg/l
pH	5.3 – 9.4 (6 – 10)
Temperature	12 – 40 °C
Actual levels will depend on the use of in-process techniques to prevent water contamination reported)	

Volume and pollution levels of dairy waste water in Europe are shown in Table 1.5. The typical BOD of various milk products is shown in Table 1.6.

Table 1.5 - Volume and pollution levels of dairy waste water in Europe

Product	**Waste water volume (l/kg)**	**Parameters (mg/kg of processed milk)**		
		COD	**Total N**	**Total P**
Market milk and yoghurt	0.9 – 25	2.0 – 10	0.05 – 0.14	0.01 – 0.02
Cheese	0.7 – 60	0.8 – 13	0.08 – 0.2	0.01 – 0.05
Milk and whey powder	0.4 – 60	0.5 – 6	0.03 – 0.3	0.01 – 0.2
Ice-cream	2.7–7.8			

Table 1.6 - Typical BOD levels of various milk products

Product	BOD_5 (mg/kg of product)
Whole milk	104000
Skimmed milk	67000
Double cream	399000
Yoghurt	91000
Ice-cream	292000
Whey	34000

The largest proportion of waste water is cleaning water. This is used for equipment cleaning, e.g. line purging at product change-over, start-up, shut-down and change-over of HTST pasteurisation units as well as some product washing. Product loss during milk manufacture can be as high as 3 – 4 %, with normally 0.5 – 1.5 % of product being wasted. These milk losses can occur during cleaning; the run-off during the start-up, shut-down or change-over of an HTST unit; or from accidental spills. Product losses to waste water can contribute greatly to the COD, nitrogen and phosphorous content. Typical milk losses are shown in Figure 1.2.

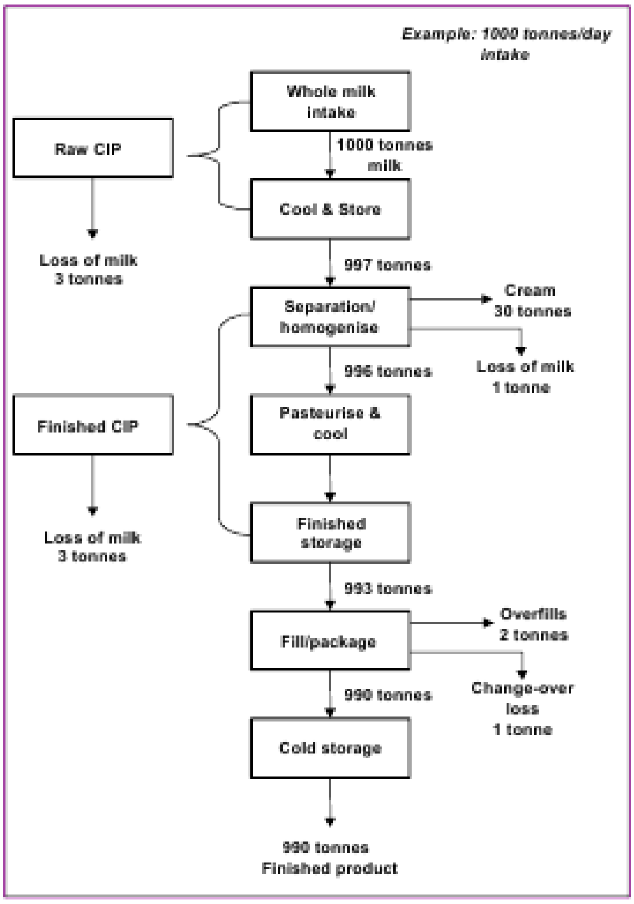

Figure 1.2 - Typical losses of milk in the dairy industry

Although CIP operations contribute to saving water, energy and chemicals, they still generate large volumes of waste water, which may have a high or low pH due to the use of acid and alkaline cleaning solutions. The use of phosphoric and nitric acids will increase the phosphate and nitrate content of the waste water. Badly designed CIP systems and inadequate product removal prior to the start of the CIP cycle cause large quantities of product to enter the cleaning water. Some UK dairy sites have achieved a reduction of 40 – 65 % in their waste water COD as a result of improvements in this area. Waste water with high concentrations of dissolved solids is produced by the regeneration of ion exchange resins and from membrane backwashing.

Large evaporators are used in the production of milk concentrate, which is the first stage in the production of milk powder, and dried whey. The evaporated water is condensed, giving rise to large quantities of condensate. Normally this is clean, but vacuum leaks on the condensers can lead to contamination with product. Condensate may be used in other processes, such as preheating incoming milk or as cleaning water after suitable treatment, e.g. RO followed by disinfection.

There are smaller contributions to the waste water from the non-dairy ingredients used in some of the products and from lubricants. SS are associated with coagulated milk, particles of cheese curd and non-dairy ingredients.

For cheese manufacturing, about 90 % of the milk used ends up as whey. Sweet whey is often recovered and used as a food grade additive. Salt whey, produced after salt has been added to the curd to remove additional liquid, is not suitable for this application unless the salt is removed by RO. The RO permeate is highly saline. Unless whey is processed quickly it becomes acidic due to lactic acid formation. If acid whey is discharged to a WWTP, it may cause low pH levels.

This waste water has an extremely variable composition, depending on the technology applied and whether whey is segregated. The characteristics of a typical waste water from cheese manufacturing are shown in Table 1.7.

Table 1.7 - Composition of cheese manufacturing waste water

Parameter	**Installation with whey recovery**	**Installation without whey recovery**
	mg/l	
BOD5	2397	5312
COD	5312	20559
Fats	96	463
N total	90	159
P total	26	21

1.3 Air emissions

Many dairies produce thermal energy on site. Emissions of carbon dioxide, sulphur dioxide and nitrogen oxides derive from the energy production in the boiler plants and are not discussed here. Many dairies still use halogenated compounds in their cooling systems, mostly HCFCs, but small amounts of CFCs are still used in some countries. The interaction of halogen refrigerants with ozone in the air has resulted in the progressive prohibition of the placing on the market and use of ozone depleting substances and of products and equipment containing those substances. There is currently a proposal for a Regulation of the European Parliament and of the Council on certain fluorinated greenhouse gases.

Ammonia used in cooling systems may leak or accidental releases may occur which also result in odour complaints. Odour problems are usually related to waste water treatment operations. Dairy installations situated in urban areas usually receive complaints regarding noise, e.g. associated with vehicle movements, refrigeration and UHT installations.

Bag filters can be used to reduce dust emissions to <5 mg/Nm^3. Filters use significantly less energy than cyclones and produce less noise. If filtering installations suitable for CIP are used for outgoing air, it is not necessary to use cyclones allowing huge energy savings and noise reductions to be achieved. The filter powder of food quality can be used for other purposes.

1.4 Solid output

Packaging waste such as paper, wooden pallets, big bags and plastic films, and other wastes need to be re-used or disposed of. Wastes are also produced in fat traps, and in flotation and biological WWTPs. As well as these wastes, major solid or liquid wastes and by-products are also produced, e.g. whey residues, non-conforming products, sludge from separation during milk clarification and filtration, product loss on the heat transfer surface and discharged in the waste water during the cleaning of the equipment, curd waste, and small pieces of cheese. Whey may be segregated and processed to make further useful products. The non-conforming products are used as animal feed or sent for landfill and the sludge produced in the WWTP is sent for landfill.

Product losses in the dairy industry, expressed as a percentage of the volume of milk or fat or whey processed, are summarized in Table 1.8.

Table 1.8 - Product losses in some processes in the dairy industry

Type of processing	**Product losses (%)**		
	Milk	**Fat**	**Whey**
Butter/transport of skimmed milk	0.17	0.14	–
Butter and skimmed milk powder	0.60	0.20	–
Cheese	0.20	0.10	1.6
Cheese and whey evaporation	0.20	0.10	2.2
Cheese and whey powder	0.20	0.10	2.3
Consumer milk	1.9	0.7	–
Full-cream milk powder	0.64	0.22	–

Reported solid outputs per tonne of processed milk are shown in Table 1.9.

Table 1.9 - Solid output per tonne of processed milk

	Solid output (kg)	**WWTP sludges**
Liquid milk and yoghurt	1.7 – 45.0	0.2 – 18.0
Cheese	1 – 20	0.2 – 24
Milk and whey powder	0.5 – 16	3 – 30

Table 1.10 gives the reported total amounts of waste produced in Nordic dairy installations and their disposal. The figures do not include waste that is intended for animal feed. Non-conforming products sent for landfilling are included.

Table 1.10 - Production and disposal of solid wastes from some Nordic dairies

Products	Total solid waste (kg/1000 l)	Of which			
		Recycled	**Incinerated**	**Composted**	**Sent for landfilling**
Market milk, cultured products	1.7 – 14 (13)	5 – 41 %	0 – 48 %	0 – 14 %	14 – 95 %
Cheese, whey, powder	0.5 – 10 (17)	1 – 91 %	0 – 80 %	0 – 2 %	9 – 88 %
Ice-cream (kg/1000 kg)	35 – 48 (4)	4 – 33 %	0 – 6 %	0 %	67 – 95 %
* The figures in brackets show the number of dairy installations in each category					

The overall solid output for ice cream manufacturing reported for Europe is in a wider range, i.e. 30 – 150 kg/t product.

1.5 Energy

Dairies have a significant energy consumption. Around 80 % of the energy is consumed as thermal energy from the combustion of fossil fuels to generate steam and hot water. It is used for heating operations and cleaning. The remaining 20 % is consumed as electricity to drive machinery, refrigeration, ventilation, and lighting. The most energy consuming operations are the evaporation and drying of milk. In pasteurisation, e.g. significant energy is also needed for the heating and cooling steps. Recovery of heat by heat-exchangers can be applied. Evaporation is normally combined with vapour recompression. A wide range of energy consumption data has been reported for the European dairy industry. Figures are included in Table 1.11.

Table 1.11 - Energy consumption in European dairies

	Energy consumption (GJ/t processed milk)		
Products	**Electricity**	**Fuel**	**Remarks**
Market milk and yoghurt	0.15 – 2.5	0.18 – 1.5	Minimum for liquid milk, maximum for specialities
	0.09 – 1.11*		
Cheese	0.08 – 2.9	0.15 – 4.6	Depends on the type of cheese and production run. Maximum fuel for whey evaporation
	0.06 – 2.08*		
Milk and whey powder	0.06 – 3.3	3 – 20	Maximum fuel for whey products
	0.85 – 6.47*		
* approximate kWh/l (assuming milk has a density of 1 kg/l)			

More energy is used in dairies where butter, as well as drinking milk, is produced and where the production of powdered milk is greater. Four installations of the ice-cream industry in Nordic countries have reported to have a total energy consumption in the range 0.75 - 1.6 kWh/kg of ice-cream produced. Other reports show an energy consumption of 2 – 10 GJ/t ice-cream produced.

1.6 Consumption of chemicals

Most of the chemicals are used for the cleaning and disinfection of process machinery and pipelines. Fresh product dairies mainly use caustic and nitric acid and some disinfectants, such as hydrogen peroxide, peracetic acid and sodium hypochlorite. Disinfection agents are also used in a range of 0.01 – 0.34 kg/t processed milk. Table 1.12 shows the consumption of cleaning agents used in European dairies. Of the total chemical consumption in Nordic dairies, 55 % is caustic and 30 % nitric acid.

Table 1.12 - Consumption of cleaning agents used in European dairies

Products	**Consumption of cleaning agents (kg/t processed milk)**		
	NaOH, 100 %	**HNO_3, 100 %**	**Detergents**
Market milk and yoghurt	0.2 – 10	0.2 – 5. 0	*
Cheese	0.4 – 5.4	0.6– 3.8	0.1– 1.5
Milk and whey powder	0.4 – 5.4	0.8 – 2. 5	*
Values vary with the length and capacity of production runs *Not applicable			

Whey processing involving electrodialysis, ion exchange, ultra and nanofiltration, requires large amounts of phosphoric, sulphuric and hydrochloride acid as well as potassium hydroxide and sodium hypochlorite. Chelating agents are widely used in dairy cleaning operations

1.7 Noise

Noise is caused by the movement of milk tankers and distribution lorries; evaporators, spray driers, and cooling condensers. Bag filters use significantly less energy than cyclones and produce less noise. If filtering installations suitable for CIP are used for outgoing air, it is not necessary to use cyclones allowing huge energy savings and noise reductions to be achieved.

Study Questions

1. List the key environmental issues for Dairy products sector.
2. What are the main air pollutants emitted into the environment from Dairy products sector?
3. List the most common sources of waste water in the Dairy products sector.
4. Describe the composition of waste water in the Dairy products sector.
5. Give examples of the sources of emissions in the Dairy products sector.
6. Describe the loss of materials during the processes in the Dairy products sector.
7. Describe the energy consumption in the Dairy products sector.

2 Waste water treatment for Dairy products

General

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 focus on reducing the consumption of resources (water and energy), increasing production yields and reducing the volume and organic load of effluent discharges.

There are also opportunities in the areas of housekeeping, work procedures, maintenance regimes and resource handling.

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 analyze 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 restricters 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 optimized, water reuse can be considered. Waste-waters 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.

A checklist of water saving ideas follows:

Use continuous rather than batch processes to reduce the frequency of cleaning.

Use automated cleaning-in-place (CIP) systems for cleaning to control and optimize 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.

Exp., reduction of Water Consumption for Cleaning at an Estonian Dairy Processing Plant:

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 USD 6,450 and the saving in water charges was USD 10,400 per year; a payback period of less than 8 months. Water consumption has been reduced by 30,000 m^3/year.

Reducing Effluent Pollution Loads

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 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 residue. Improvements to cleaning practices are therefore an area where the most gains can be made.

A checklist of ideas for reducing pollutant loads in effluents:

- Ensure that vessels and pipes are drained completely and using pigs and plugs to remove product residue 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 minimize 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.

2.1 Waste water characteristics

Some important characteristics of dairy waste water for the purposes of treatment are:

• large daily variation in flowrate

• variable pH

• waste water may be nitrogen deficient, unless the raw water has a high nitrate content or nitric acid is used

• waste water may be high in phosphorus if phosphoric acid is used for clean-up. Milk also has a high phosphorus content, e.g. 93 mg P/100 g whole milk

• the treatment of dairy waste water results in lower surplus sludge than domestic waste water treatment, owing to, e.g. the lower content of suspended solids, the lower F/M ratio used and the higher waste water temperatures

• despiteutilising preceding equalisation basins, it is still prudent to allow for peak loads when designing the oxygen supply.

2.2 Waste water treatment

In the dairy sector, solids from washing water from vehicle washing units are generally removed at source. This may be carried out by using sand or grit traps, or the rainwater from the sealed surfaces is generally passed into the on-site waste water treatment system. Next, segregation of waste water is generally applied, by high solids content, very high BOD and high salinity. After segregation, primary treatment is required and the following techniques can be used:

• screening

• flow and load equalisation

• neutralisation

• sedimentation

• DAF

• centrifugation

• precipitation.

Following primary treatment, secondary treatment may be required. For waste water with a BOD concentration greater than 1000 – 1500 mg/l, anaerobic treatment processes are used. Anaerobic techniques are widespread across Europe for dairy waste water when BOD is greater than 3000 mg/l. Following surface aeration, the resultant final waste water from the anaerobic process can be discharged directly to a MWWTP. Nevertheless, there may be a risk of phosphorus release in the final waste water if anaerobic processes are used. For lower strength waste water streams, aerobic treatment is applied.

Figure 2.1 shows a typical waste water treatment flow sheet applied to dairy waste waters.

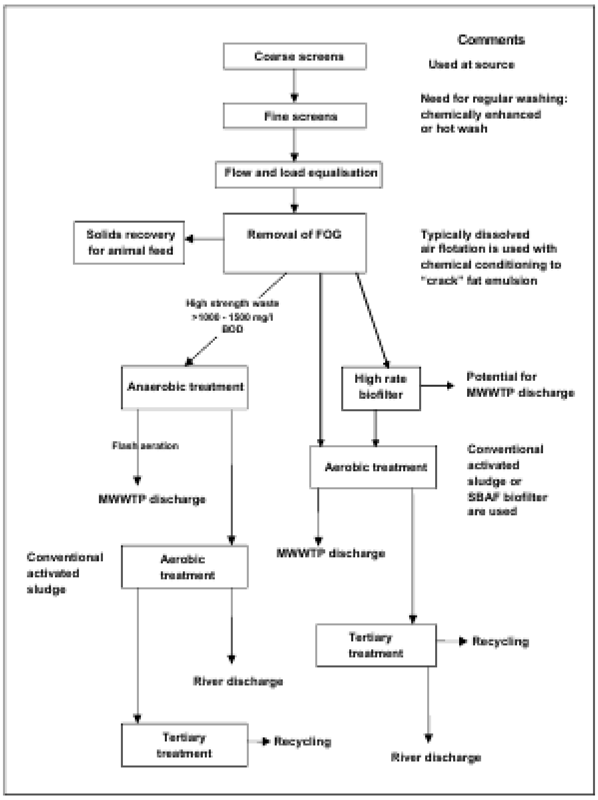

Figure 2.1 - Typical waste water treatment applicable to a dairy

2.3 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. Figure 2.2 is a flow diagram showing the inputs and outputs for this process.

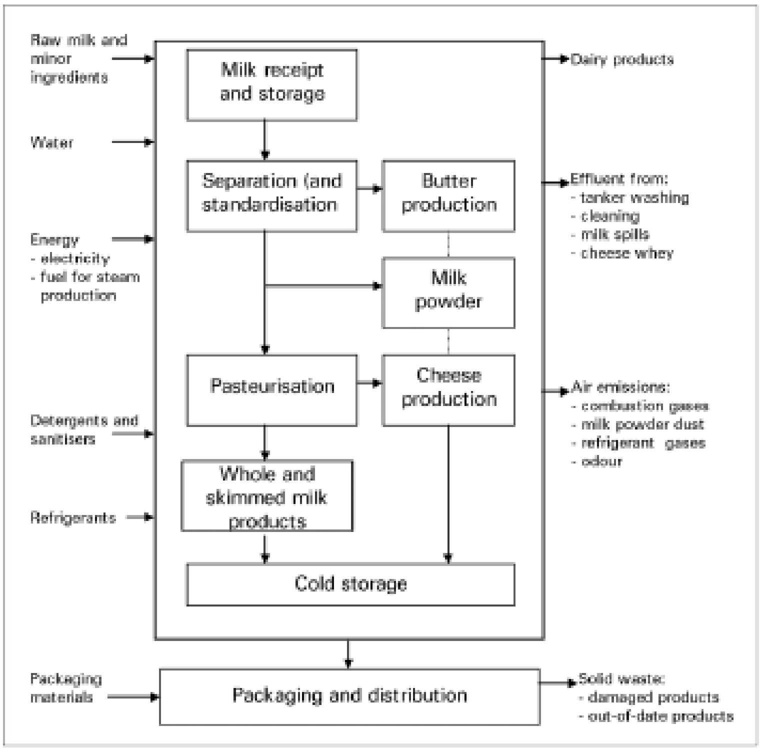

Figure 2.2 - Inputs and outputs from milk receipt and storage vessels.

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 2.1 provides indicative figures for the pollution loads generated from the receipt of milk at a number of plants.

Table 2.1 - Indicative pollution loads from the milk receival area.

Main product	**Wastewater (m^3/tonne milk)**	**COD (kg/tonne milk)**	**Fat (kg/tonne milk)**
Butter plant	0.07 – 0.10	0.1 – 0.3	0.01 – 0.02
Market milk plant	0.03 – 0.09	0.1 – 0.4	0.01 – 0.04
Cheese plant	0.16 – 0.23	0.4 – 0.7	0.006 – 0.03
Havarti cheese plant	0.60 – 1.00	1.4 – 2.1	0.2 – 0.3

Table 2.2 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 2.2 - Indicative pollution loads from the washing of tankers

Main product	**Wastewater (m^3/tonne milk)**	**COD (kg/tonne milk)**	**Fat (kg/tonne milk)**
Market milk plant	0.08 – 0.14	0.2 – 0.3	0.04 – 0.08
Havarti cheese plant	0.09 – 0.14	0.15 – 0.40	0.08 – 0.24

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 'cleaning-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.

Study Questions

1. In what ways can the amount of pollutants in the Dairy products sector waste stream be reduced? List the most important strategies.
2. Give examples of use of level sensors in Dairy products processing.
3. In what way can improved process control reduce the emissions of pollutants in the Dairy products sector?
4. Explain how raw material waste and waste water generation can be reduced by controlling the temperature.
5. Describe how a pressure control can be applied to minimize of waste in Dairy products sector.
6. Describe the typical applications of flow measurements in the Dairy products sector.

3 General techniques applicable in Dairy products sector

3.1 Segregation of outputs, to optimize use, re-use, recovery, recycling and disposal (and minimize water use and waste water contamination)

In the dairy industry, examples of materials which can be collected separately for optimal use or disposal include the drainings of yoghurt and fruit throughout the dairy; first rinses of buttermilk and residual fat in butter churning operations, for use in other processes, e.g. for low fat spreads and whey, e.g. for making mitzithra cheese.

Reported examples of where the technique is applied

There are likely to be many other opportunities to apply this technique within the sector.

- collect leaked and spilt ingredients and partly and fully processed materials
- collect whey which is not intended for making mitzithra cheese, baby food or other products
- collect milky waste water generated at the start-up of pasteurisers
- keep the solid waste obtained after centrifugation from entering the waste water
- collect and recover product/product mixtures from product change-overs
- separate and collect buttermilk, first rinses and residual fat in butter churning oprations, to use it in other processes, e.g. as a base for low fat spreads
- collect rinsings from yoghurt vats
- collect the drainings of yoghurt and fruit throughout the dairy
- collect and empty the products from wrongly filled containers for use as animal feed, e.g. by maceration of packaging.

3.2 Dry cleaning

As much residual material as possible can be removed from vessels, equipment an dinstallations, before they are wet cleaned. This can be applied both during and at the end of the working period. All spillages can be cleaned up, by, e.g. shovelling or vacuuming spilt material or by using a squeegee, prior to wet cleaning, rather than hosing them down the drain. This is enhanced further by transporting materials such as ingredients, by-products and waste from processing as dry as possible.

As well as manual dry cleaning of equipment an dinstallations, other measures can be used, such as letting materials drain naturally, by gravity, by using pigging.

The cleaning procedure can be managed to ensure that wet cleaning is minimized. For example, the use of hoses can be prohibited until after dry clean-up.

Reported examples of where the technique is applied

There are likely to be many other opportunities to apply this technique within the sector.

• adopt dry cleaning methods to collect the solid residues from cheese production

• sweep curd losses instead of washing them to the drain

• treat spills of curd, yoghurt or ice-cream mix as waste rather than just washing them to the drain

• use dry processes to collect excess salt rather than just washing it to the drain

• fit drains with screens and/or traps to prevent any solid material from entering the waste water.

3.3 Partial homogenization of market milk

The cream is homogenized together with a small proportion of skimmed milk. The optimum fat content of the mixture is 12 %. The rest of the skimmed milk flows directly from the centrifugal separator to the pasteurization section of the pasteuriser. The homogenized cream is remixed into the skimmed milk stream before it enters the final heating section. Using this technique, the size of the homogenizer can be significantly reduced, leading to energy savings.

Achieved environmental benefits

Reduced energy consumption.

Economics

Smaller homogenizers are cheaper in terms of investment costs and operational costs. The price of the smaller homogenizer is about 55 % of the price of a piece of equipment with the capacity to treat the nominal capacity of the line.

3.4 Use of computer controlled milk transfer, pasteurization, homogenization and CIP equipment

An example dairy installation receives 450000 liters of milk, at a quality complying with the Directive 92/46/EEC. The installation requires its suppliers to use mechanical milking, have proper refrigeration capacity and to apply HACCP.

The milk reception is via two parallel PLC-controlled closed systems. The introduction of a technique using special valves, has significantly reduced the milk losses. It is reported that where the valves have been introduced, milk losses during transfer between pipes, when filling tanks and human errors have been totally eliminated, thus waste water pollution from that source, has decreased.

The milk is also pasteurized by computer controlled plate heat-exchangers, which have a greater surface area for heat-exchange than others and are equipped with automatic fat standardizing and homogenizing units.

The processing is carried out in a closed system. The control for storing and pumping the raw materials, intermediaries, and products to the different processing units of the installation is carried out by a computer aided system. Using this system, the losses have been minimized. The same control system operates the CIP system. Here, the last rinsing water is used for the next cleaning circle.

The pasteurized fresh milk is packed in PE bags or PET bottles.

Achieved environmental benefits:

Reduced milk wastage and waste water contamination. The computerised CIP system also led to reduced water and reagent savings.

Operational data:

During pasteurization, the greater surface area for heat-exchange and the recirculation of warm water reportedly results in about 25 % savings in energy consumption and about 50 % savings in water consumption, in comparison with the old pasteurizer previously used.

The computerized process control avoids or decreases milk losses in reception and during further processing.

The automatic dosing reportedly results in about 15 % savings both in water and in the consumption of cleaning and disinfecting agents.

Economics:

Investment costs are high.

Driving force for implementation

Reduced costs for energy and water.

3.5 Use of continuous pasteurizers

In continuous pasteurization, flow-through heat-exchangers, e.g. tubular, plate and frame, are used. These have heating, holding and cooling sections. To reduce energy consumption and waste water generation, continuous pasteurizers are used instead of batch pasteurizers.

Achieved environmental benefits:

Reduced energy consumption and waste water production, compared to batch pasteurizers.

Batch wise pasteurization uses a temperature of 62 to 65 ºC for up to 30 minutes. Continuous pasteurizers include high temperature short time pasteurization (HTST) and high heat short time pasteurization (HHST). HTST uses a temperature of 72 to 75 ºC for 15 to 240 seconds. HHST applies a temperature of 85 to 90 ºC for 1 to 25 seconds.

3.6 Regenerative heat-exchange in a pasteurization process

Pasteurizers are normally equipped with some regenerative countercurrent flow heating sections. The incoming milk is preheated with the hot milk leaving the pasteurization section.

It is widely applied in dairies. In older dairies, heating and cooling energy can be further reduced by replacing the old plate exchangers by more effective ones.

3.7 Reduce cleaning requirements of centrifuges by improved preliminary milk filtration and clarification

By improving the preliminary milk filtration and clarification processes, the deposits in the centrifugal separators are minimized, leading to a reduction of the frequency of cleaning.

3.8 Two-stage drying in milk powder production

After the milk has been thickened from 11 % to 50 – 60 % dry matter in an evaporator, the condensed milk may further be dried to 95 – 97 % dry matter content. Spray driers or roller driers are used in milk powder processing. Although roller driers may be found in the dairy sector and are sometimes useful for specialized products, spray driers with downstream or integrated FBDs have become more common. This is due to their lower energy usage, the primarily dust-free product, and due to their reduced thermal stress.

When using two-stage drying, lower residual product moisture with less harm to product quality as well as more efficient energy utilization can be achieved. The solids leave the spray drier with 3 – 5 % residual moisture. The final drying step takes place under mild conditions with low energy usage.

Achieved environmental benefits:

Reduced energy and water consumption. Reduced dust emissions.

Economics

High capital costs.

Example plants - A large dairy making powdered milk in Germany.

3.9 Use of an aseptic packaging system not requiring an aseptic chamber

An example dairy installation receives 450000 liters of milk, at a quality complying with the Directive 92/46/EEC. The installation requires its suppliers to use mechanical milking, to have proper refrigeration capacity and to apply HACCP.

UHT milk processing is applied, followed by homogenization and online aseptic packaging. High efficiency tubular type heat-exchangers are used in this process. The brick-shaped packages are made of paper-based laminated material, which includes several layers of plastic film and aluminum foil. The packages are formed from a continuous strip of the material, which enters the filling machinery through a hydrogen peroxide sterilizing bath. Subsequently, the strip is formed into a tube around the sterilized product feed line, and appropriate longitudinal and cross seams are made by heat-sealing the plastic inner surfaces as the package is filled. This continuous aseptic packaging system does not require an aseptic chamber.

Achieved environmental benefits:

Energy saving in heat treatment, lower packaging waste and lower milk losses.

The spoilage, when this system is used, is reportedly below 0.5 %.

Example plants - At least one dairy in Hungary.

3.10 Online detection of transition points between the product and the water phases

Pipelines are usually filled with water before start-up. Water is then pushed out by the product through a drain valve. Traditionally, drain valves were closed manually according to visual observation or automatically by counting the time needed to fill the pipeline with the product. To achieve an accurate detection of transition points between the product and the water phases, online methods are now used for fully automated production lines, e.g. measuring the volume using flow or density transmitters; measuring the density using conductivity transmitters and using optical sensors to differentiate water from the product.

These techniques can be used to recover product from CIP initial rinses, HTST start-up, shut-down and change-over and from the rinsing of other equipment and pipework.

Optical sensors are reportedly the most reliable, accurate and have a shorter response time compared to the other online methods. It is reported that when using optical sensors, the amount of rinse-water containing milk that goes to the WWTP can be reduced to a couple of liters per start-up. In addition, product losses can be reduced by 50 %. In filling lines used for liquid milk products, the use of these sensors reduced the amount of change-over mixtures by 30 – 40 %.

In an example installation using conductivity transmitters, the BOD load in the waste water decreased by 30 %. Regular calibration of the density transmitter is needed.

Economics

The price of an optical sensor is about EUR 2700 (2001). The cost of implementing process control includes, not only the price of sensors, but also other associated hardware and software, e.g. transmitters and display equipment.

Driving force for implementation

Product losses and waste water treatment costs are reduced.

Example plants - An example dairy in Finland has installed 61 online optical sensors in its process lines. Conductivity transmitters and flow transmitters are widely used in Nordic countries.

3.11 Provision of in-line storage tanks to minimize product recirculation in pasteurizers

A production line can be designed in such a way that the capacities of the individual components are optimized with respect to the others, in order to prevent product build-up or shortage in some parts of the line. Later changes in the production line or in the filling schedule might, however, disturb the balance causing interruptions in the continuous operation.

For instance, if the capacity of the in-line storage tanks is too small compared to the output of the pasteurizer in a pasteurization line, the milk has to be recirculated in the pasteurizer several times during the day. This consumes energy and harms the quality of the product and is regulated by Council Directive 92/46/EEC. Furthermore, longer interruptions increase the frequency of cleaning the pasteurizer.

Interruptions in the line and recirculation of the milk in the pasteurizer can be avoided or minimized by adapting the size/number of in-line storage tanks to the

In an example dairy, supplying a pasteurization line with in-line storage tanks before filling, together with automation of the product change-overs, resulted in a 30 % reduction of the processing time. The annual energy savings in this dairy amounted to 250 MWh in electrical energy and 230 MWh in thermal energy. The estimated payback period is 4.5 years.

3.12 Just-in-time mixing "component filling"

A filling machine concept called "component filling" enables milk products to be diversified as late as possible, preferably immediately prior to filling. In this machine there are two pipelines, one with skimmed milk and the other with milk of a standardized fat content. These are mixed at the filling machine to the ratio required for each particular product. For example, a dairy might produce three types of milk, with three different fat contents and these would be achieved by changing the amount supplied from the two pipelines. Losses of product and packaging materials caused by change-overs in production can be eliminated using this technique. Component filling also reduces the need for in-line storage tanks and the corresponding cleaning requirements.

Normally, 75 – 100 liters of milk can easily be lost because of the change-over of production in a traditional filling operation.

The price of a new component filling machine with a filling capacity of 12000 – 12500 packs/h is approximately EUR 1 million (2001), not including any process modification that may be needed. In many cases, one component filling machine may replace several ordinary fillers.

Example plants - There are a total of three component filling machines in the Nordic countries, including one in Finland.

3.13 Re-use and recycling of water for cleaning in dairies

Cooling water, condensates generated in evaporation and drying operations, permeates generated in membrane separation processes and cleaning water can be re-used in dairy installations.

In some cases, cross-contamination risks will need to be considered when re-using water, for instance between starter batches in cheese making.

Avoiding an unnecessary contamination of condensate maximizes the potential for water re-use, sometimes without any treatment, depending on the intended use. The cleanest condensate may be suitable for use as boiler feed-water.

Example plants - At least one milk producing dairy in the UK uses treated evaporator condensate for cleaning. At least one cheese making dairy in the UK produces demineralized water from RO and uses it as boiler feed-water or membrane CIP.

3.14 Re-using warm cooling water for cleaning

Cleaning is the most water consuming process in the dairy sector and large savings are possible in this area. Many dairy operations involve cooling with cold water in heat-exchangers, which results in warm cooling water. Usually the warm cooling water from the process is re-used for cleaning purposes, mainly for cleaning milk tankers. Warm cooling water can generally be used for the intra-plant cleaning, regardless of its temperature. In the dairy industry, water above 50 °C can be re-used for the cleaning of milk tankers or for the manual cleaning or CIP of equipment. Achieved environmental benefits

The water and energy savings depend on the amount of re-usable warm cooling water used and its temperature.

Example plants - Two dairies, one in Sweden and the other in Finland.

Butter

Minimization of losses during buttermaking. Due to the high viscosity of cream, the cream heater may be rinsed with with skimmed milk, which is then retained and used, before the cleaning. This reduces fat losses. Buttermilk which results as a by-product can be used as a product and not disposed of, e.g. into the waste water. These savings may be used, e.g. as a base for low fat spreads.

In addition to the BAT for buttermaking, BAT is to do the following:

- remove residual butter from pipework using a cooled butter block pushed by compressed air
- rinse the cream heater with skimmed milk before cleaning it.

Cheese

Using ultrafiltration (UF) for protein standardization of cheese milk

Ultrafiltration (UF) can be used for protein standardization of cheese milk. The milk flows under pressure over a membrane that withholds the protein molecules, thus increasing the protein content of the retentate. The membrane pore size ranges from about 10 to 100 nm.

As using UF leads to an increase in the cheese yield per processed milk unit, the generated quantity of whey is smaller compared to traditional standardization. Furthermore, even when UF requires additional electrical power, thermal energy and water compared to traditional standardization, in large scale production, the increase in cheese yield compensates for the increased consumption of energy and water.

The permeate from the UF unit is further treated by RO. The RO water, which is of drinking water quality, can be used for cleaning purposes.

Economics

The investment cost is high. Payback periods are acceptable only if the capacity is large enough. For example, the investment cost in the example Danish dairy is estimated to be EUR 430000 and the payback period 5.9 years.

Example plants - A dairy in Denmark.

Reduction of fat and cheese fines in whey

To accomplish the reduction of fat and cheese fines in whey, first, during the processing of the curd, the highest possible yield of fat and protein is achieved and after, the whey is screened to collect remaining fines.

Minimize the production of acid whey and its discharge to the WWTP

In cheese manufacturing, about 90 % of the milk used ends up as whey. For acid type cheeses, actic acid mother cultures are grown on media and then bulk cultures are propagated and added to milk to make cheese. Acid whey is separated after curd formation. If acid whey is discharged to a WWTP, it may cause low pH levels. To prevent this, spillages are avoided by draining the top or platform of the salting vats. In addition, whey can be processed quickly so less acid whey is produced due to lactic acid formation.

Recovery and use of whey

In cheese manufacturing, about 90 % of the milk used ends up as whey. Sweet whey is produced during the making of rennet type hard cheeses, e.g. cheddar or Swiss cheese. Salt whey is produced after salt has been added to the curd to remove additional liquid. Sweet whey is collected and re-used in the process or in other processes to make by-products, e.g. for protein recovery, as animal feed, in the production of mitzithra cheese, as a food supplement and as baby food. Even when salt whey cannot be re-used in the process without the removal of the salt, it can either be collected as it is, or concentrated by evaporation and used as animal feed.

Recovery of salt whey by evaporation

In cheese manufacturing, about 90 % of the milk used ends up as whey. Salt whey is produced after salt has been added to the curd to remove additional liquid. Salt whey can be re-used in the process or used as animal feed either directly or after drying by evaporation. The condensed water may be used for cleaning.

Recovery of whey by removal of salt using RO

In cheese manufacturing, about 90 % of the milk used ends up as whey. Salt whey is produced after salt has been added to the curd to remove additional liquid. Salt whey can be re-used in the process, along with sweet whey, only after the salt is removed by RO.

Utilisation of heat from warm whey for preheating cheese milk

The incoming milk is preheated with warm whey, which is simultaneously strained off from another vat. Heat-exchangers and tanks are needed for circulating the water. Savings in energy for heating the incoming milk and cooling energy for the processed whey are achieved.

In a Danish example dairy, the cheese milk is heated from 12 to 32 ºC with heat from a closed system with circulating water at 34.5 ºC. The temperature of the water decreases to 13 ºC and it is subsequently reheated in the cooling section of the whey pasteuriser, where the whey is cooled from 36 to 14.5 ºC. In addition to the plate heat-exchangers, two buffer tanks of 150 m^3 were installed for the circulating water. Savings, assuming 250 million kg/yr whey, were estimated to be 1200 MWh/yr electrical energy, 6065 MWh/yr heat energy and 4200 m^3/yr water.

High temperature cheese ripening with later humidification and ionisation of the ventilation air

In cheese manufacturing, the temperature of the air is increased to shorten ripening times. This leads to a reduction in the demand for storage facilities, cooling power and ventilation energy. As a higher temperature increases the risk of dehydrating the cheese and of contamination by mould, the ventilation air is humidified and cleaned by a discharge tube which ionises the air which is passed through ventilation ducts. As ions in the ventilation air react with dust particles, micro-organisms and viruses, the air is effectively cleared of these sources of contamination.

Operational data:

In an example cheese installation, a project was started in January 1994 to reduce energy consumption. Before the project, the manufacturer stored cheese at 12 ºC to allow ripening to take place. The temperature was increased to 15 ºC. The ventilation air was humidified and cleaned of dust and micro-organisms by ionisation prior to entering the warehouse. The new equipment allows the air temperature to rise to 16 ºC at 85 % relative humidity. Energy savings amounting to 272000 kWh/yr, or 85000 m^3/yr of natural gas, were reported. A shortening of the ripening time by 50 %, an improvement of the product quality and a reduction of the consumption of plastics and fungicidal agents were also reported.

Economics:

In the example installation, considerable savings were achieved in labour costs, maintenance and in the use of materials for cleaning the ventilation system. The payback period is around two years.

Example plants - A cheese warehouse in the Netherlands.

In addition to the BAT for cheese making, BAT is to do the following:

- use the heat from warm whey for preheating cheese milk
- maximize whey recovery and use
- segregate salt whey (not to be mixed with sweet or acid whey)
- reduce fat and cheese fines in whey and screen liquid streams to collect fines
- minimize the occurrence of acid whey and drain the top or platform of the salting vats to avoid brine spillage to the WWTP
- to produce whey powder use multi-effect evaporators,
- optimizing vapour recompression related to heat and power availability in the installation, to concentrate whey before spray drying, followed by FBD, e.g. integrated FDB.

Ice-cream

Heat recovery from pasteurization in ice-cream production

Heat and water can be recovered from the ice-cream pasteurization process. The ice-cream mix enters the pasteurizer at a temperature of 60 ºC and is then heated to 85 ºC, followed by cooling to 4 ºC prior to ageing. The cooling phase consists of two steps. In the first step, the ice-cream is cooled to 70 ºC by regenerative heat-exchange and in the second step, cooling water is used for further cooling to approximately 20 ºC. The final temperature of 4 ºC is achieved by cooling with ice-water.

The heat released to the water, from the ice-cream mix in the second cooling step can preheat the water for various purposes, mainly for cleaning operations. This requires a number of storage tanks for the hot water.

Example plants - At least one ice-cream installation in Sweden.

In-process environmental management at a dairy

The example dairy processes 1.2 million liters of milk per week, producing around 200 tons of yoghurt and 15 tons of cottage cheese per week. The balance of the milk is used for pasteurized and UHT milk and cream production. Waste water is discharged to a MWWTP.

The installation operator decided to upgrade the existing on-site WWTP, which comprised sedimentation of a proportion of the waste water, prior to discharge to sea. The estimated waste water treatment costs were halved by introducing and operating in-process techniques for minimizing waste water generation and contamination.

All the staff were involved in completing the following actions:

• for cottage cheese, the whey was already collected for animal feed, but the number of tanks installed was increased to allow for the collection of curd wash-water and yoghurt residues, also each tank was fitted with high level alarms

• yoghurt pipelines were modified by incorporating 135° bends to improve drainage

• drainage times on emptying yoghurt vats were increased by 5 minutes

• burst rinsing was introduced for yoghurt vats, with all rinsings collected for animal feed

• a requirement to collect all the drainings of yoghurt and fruit throughout the dairy, for use as animal feed, was more rigidly enforced.

The waste water treatment charges were EUR 125000/yr instead of the expected EUR 500000/yr with very little investment cost.

Study Questions

1. Explain how the training of the staff can optimize operation for environmental benefits.

2. In what ways can improve equipment design to minimize consumption and emission levels including noise emissions?

3. List the main steps for the successful methodology for preventing and minimizing the consumption of water and energy and the production of waste.

4. Explain how production planning can minimize associated waste production and cleaning frequencies.

5. How is it possible to avoid problems with shelf-life by managing the control of receipt, storage and use of materials in the FDM sector?

6. Give examples of materials which can be collected separately for optimal use or disposal in the FDM sector.

7. List and discuss briefly different measures for modifying a production process in the FDM sector.

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