Cleaner Production Assessment in Fish Processing

Prepared by

COWI Consulting Engineers and Planners AS, Denmark

for

UNEP

United Nations Environment Programme
Division of Technology, Industry and Economics

and

Danish Environmental Protection Agency
Danish Ministry of Environment and Energy

CONTENTS

PREFACE

The purpose of the Industrial Sector Guides for Cleaner Production Assessment is to raise awareness of the environmental impacts associated with industrial and manufacturing processes, and to highlight the approaches that industry and government can take to avoid or minimise these impacts by adopting a Cleaner Production approach.

This guide is designed for two principal audiences:

- People responsible for environmental issues at fish processing plants (environmental managers or technicians) who seek information on how to improve production processes and products. In many countries, managers are ultimately responsible for any environmental harm caused by their organisation's activities, irrespective of whether it is caused intentionally or unintentionally.
- Environmental consultants, Cleaner Production practitioners, employees of industry bodies, government officers or private consultants that provide advice to the fish processing industry on environmental issues.

The guide describes Cleaner Production opportunities for improving resource efficiency and preventing the release of contaminants to the air, water and land. The Cleaner Production opportunities described in this guide will help improve production as well as environmental performance.

Chapter 1 provides a brief introduction to the concept of Cleaner Production and the benefits that it can provide.

Chapter 2 provides an overview of the fish processing industry including process descriptions, environmental impacts and key environmental indicators for the industry. The processes discussed in most detail are the filleting of white and oily fish, canning, and fish meal and oil production, as well as cleaning and ancillary operations.

Chapter 3 describes Cleaner Production opportunities for each of the unit operations within the process and examples where these have been successfully applied. Quantitative data is provided for the inputs and outputs associated with each unit operation as an indication of the typical levels of resource consumption and waste generation.

Chapter 4 provides a case study demonstrating the application of Cleaner Production at a fish processing plant.

Chapter 5 describes the Cleaner Production assessment methodology in detail. The methodology can be used as a reference guide for carrying out a Cleaner Production assessment within an organisation.

Annex 1 contains a reference and bibliography list.

Annex 2 contains a glossary and list of abbreviations.

Annex 3 contains a list of literature and contacts for obtaining further information about the environmental aspects of the industry.

Annex 4 contains background information about the UNEP Division of Technology, Industry and Economics (UNEP DTIE).

Monetary figures quoted in this guide are based on 1995–98 figures and presented as US dollars for consistency. As prices vary from country to country and from year to year, these figures should be used with care. They are provided as indicators of capital expenditure and savings only.

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Authors:

- Mr Claus Jespersen, Matcon, Denmark;
- Mr Kim Christiansen, Sophus Berendsen, Denmark;
- Mr Bent Hummelmose, COWI, Denmark.

Contributors:

- Mr Erwin Van den Eede, Danish Environmental Protection Agency (EPA);
- Ms Mariane Hounum, Danish EPA;
- Mr Søren Kristoffersen, Danish EPA;
- Mr John Kryger, DTI/International;
- Mr Sybren de Hoo, UNEP DTIE, now Rabo Bank, the Netherlands;
- Mr Hugh Carr-Harris, BADO, now Enviros-RIS, United Kingdom.

Reviewers and editors:

- Ms Marguerite Renouf, UNEP Working Group for Cleaner Production in the Food Industry, on behalf of Uniquest Pty Ltd, Australia;
- Mr Bob Pagan, UNEP Working Group for Cleaner Production in the Food Industry, on behalf of Uniquest Pty Ltd, Australia;
- Mrs Viera Feckova, Director, National Cleaner Production Centre of Slovak Republic.

Additional comments provided by:

- Mrs Jacqueline Aloisi de Larderel, Director, UNEP DTIE;
- Mr Fritz Balkau, Chief, Production and Consumption Unit, UNEP DTIE;
- Ms Kristina Elvebakken, UNEP DTIE;
- Ms Wei Zhao, Programme Officer, Production and Consumption Unit, UNEP DTIE.

EXECUTIVE SUMMARY

This document is one in a series of Industrial Sector Guides published by the United Nations Environment Programme UNEP Division of Technology, Industry and Economics (UNEP DTIE) and the Danish Environmental Protection Agency. The documents in the series include:

- *Cleaner Production Assessment in Dairy Processing*;
- *Cleaner Production Assessment in Meat Processing*; and
- *Cleaner Production Assessment in Fish Processing*.

This document is a guide to the application of Cleaner Production to the fish processing industry, with a focus on the manufacture of fish fillets, canned fish, fish meal and fish oil at fish processing plants. Its purpose is to raise awareness of the environmental impacts of fish processing, and to highlight approaches that industry and government can take to avoid or minimise these impacts by adopting a Cleaner Production approach.

The life cycle of fish products commences with the capture or growing of fish. Marine fish account for more than 90% of fish production, with the remainder being fresh water fish and fish produced by fish farming.

Fish are processed to produce fresh, frozen or marinated fillets, canned fish, fish meal, fish oil and fish protein products, such as surimi. Approximately 75% of world fish production is used for human consumption and the remaining 25% is used to produce fish meal and oil. Of the fish processed for human consumption, only about 30% is marketed fresh and there is an increasing demand for frozen fish fillets and convenience products.

Fresh fish products are highly perishable and refrigerated storage is required throughout the life of the products to maintain eating appeal and prevent microbiological spoilage. On the other hand, the more highly processed products, such as canned fish, fish meal and fish oil, have a longer shelf life and require less refrigeration. The life cycle ends with consumption by the consumer and disposal or recycling of the packaging.

In this guide, the upstream process of fish capture and farming, and the downstream processes of distribution and post-consumer packaging management are not covered. Instead the guide focuses on the processing of key fish products, namely fish fillets, canned fish, fish meal and fish oil, at fish processing plants.

The guide mainly deals with the processing of fish at on-shore processing facilities. In some of the major fish producing areas, processing can take place at sea on board fishing vessels. While this guide does not cover at-sea processing specifically, some of the basic principles will apply to it.

The processing of fish is a significant contributor to the overall environmental load produced over the life cycle of fish production and consumption. Therefore, the application of Cleaner Production in this phase of the life cycle is important.

As for many food processing industries, the key environmental issues associated with fish processing are the high consumption of water, the generation of effluent streams, the consumption of energy and the generation of by-products. For some sites, noise and odour may also be concerns.

This guide contains background information about the industry and its environmental issues, including quantitative data on rates of resource consumption and waste generation, where available. It presents opportunities for improving the environmental performance of fish processing through the application of Cleaner Production. Case studies of successful Cleaner Production projects are also presented.

Cleaner Production

Cleaner Production is defined as *the continuous application of an integrated, preventive, environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment*. It is different to the traditional ‘pollution control’ approach to environmental management. Where pollution control is an after-the-event, ‘react and treat’ approach, Cleaner Production reflects a proactive, ‘anticipate and prevent’ philosophy.

Cleaner Production has most commonly been applied to production processes, by bringing about the conservation of resources, the elimination of toxic raw materials, and the reduction of wastes and emissions. However it can also be applied throughout the life cycle of a product, from the initial design phase, through to the consumption and disposal phase. Techniques for implementing Cleaner Production include improved housekeeping practices, process optimisation, raw material substitution, new technology and new product design.

The other important feature of Cleaner Production is that by preventing inefficient use of resources and avoiding unnecessary generation of waste, an organisation can benefit from reduced operating costs, reduced waste treatment and disposal costs and reduced liability. Investing in Cleaner Production to prevent pollution and reduce resource consumption is more cost effective than relying on increasingly expensive ‘end-of-pipe’ solutions. There have been many examples that demonstrate the financial benefits of the Cleaner Production approach as well as the environmental benefits.

Water consumption

Water is used for holding and transporting fish, for cleaning equipment and work areas, and for fluming offal and blood. Automated processing equipment generally has permanently installed water sprays to keep equipment clean and to flush offal away.

Rates of water consumption can vary considerably depending on the scale and age of the plant, the type of processing, the level of automation and the ease with which equipment can be cleaned, as well as operator practices. Typical figures for fresh water consumption per tonne of fish intake are 5–11 m^3 for fish filleting, 15 m^3 for canning and 0.5 m^3 for fish meal and oil production. Fish meal and oil production also consumes about 20 m^3 of seawater per tonne of fish intake.

In most parts of the world, the cost of water is increasing as supplies of fresh water become scarcer and as the true environmental costs of its supply are taken into consideration. Water is therefore becoming an increasingly valuable commodity and its efficient use is becoming more important.

Strategies for reducing water consumption can involve technological solutions or equipment upgrade. However substantial benefits can also be gained from examining cleaning procedures and operator practices.

Some key strategies for reducing water consumption are listed below and the use of these techniques would represent best practice for the industry:

- using offal transport systems that avoid or minimise the use of water;
- installing fixtures that restrict or control the flow of water for manual cleaning processes;
- using high pressures rather than high volumes for cleaning surfaces;
- reusing relatively clean wastewaters for other applications; for example, thawing wastewaters could be used for offal fluming or for initial cleaning steps in dirty areas;
- using compressed air instead of water where appropriate;
- installing meters on high use equipment to monitor consumption;
- using closed circuit cooling systems;
- pre-soaking floors and equipment to loosen dirt before the final clean;
- recirculating water used in non-critical applications;
- reporting and fixing leaks promptly.

Effluent discharge

Most water consumed at fish processing plants ultimately becomes effluent. A characteristic of fish processing that has a bearing on the effluent loads is the highly perishable nature of fish and fish products. As the quality of the fish deteriorates over time, product yield decreases and product losses contribute to the waste loads. These losses often find their way into the effluent stream.

Fish processing effluent contains high levels of organic matter due to the presence of oils, proteins and suspended solids. It can also contain high levels of phosphates and nitrates. For the basic fish processing operations, sources of effluent are the handling and storage of raw fish prior to processing, fluming of fish and product around the plant, defrosting, and the cleaning of equipment and work areas throughout the process. For canning operations, effluent is also generated from the draining of cans after precooking and from spillages of sauces, brines and oil. Major sources of effluent from fish meal and fish oil production are bloodwater from the unloading and storage of fish, high-strength effluent from the centrifuges and condensate from evaporators.

Effluent quality is highly dependent upon the type of fish being processed. Pollution loads generated from the processing of oily fish species are much higher than from white fish species, due to the high oil content and the fact that these species are usually not gutted or cleaned on the fishing vessel.

Fish processing effluent contains scraps of flesh, blood and soluble substances from entrails, as well as detergents and other cleaning agents. Effluent from the processing of oily fish can also contain very high levels of oil. Typical ranges for the COD loading in fish processing effluent per tonne of fish intake are 50 kg for the filleting of white fish, 85 kg for the filleting of oily fish, 116 kg for canning and 42 kg for fish meal and oil production.

Strategies for reducing the pollutant load of fish processing effluent focus on avoiding the loss of raw materials and products to the effluent stream. This means capturing materials before they enter drains and using dry cleaning methods.

Some key strategies are listed below:

- sweeping up solid material for use as a by-product, instead of washing it down the drain;
- cleaning dressed fish with vacuum hoses and collecting the blood and offal in an offal hopper rather than the effluent system;
- fitting drains with screens and/or traps to prevent solid materials from entering the effluent system;
- using dry cleaning techniques where possible, by scraping equipment before cleaning, pre-cleaning with air guns and cleaning floor spills with squeegees.

Energy consumption

Energy consumption depends on the age and scale of a plant, the level of automation and the range of products being produced. Processes which involve heating, such as the cooking of canned fish and fish meal and oil production, are very energy intensive, whereas filleting requires less energy. Typical figures for the energy consumption per tonne of fish intake are 65–87 kW.h for the filleting, 150–190 kW.h for canning and about 32 KW.h for fish meal and oil production, plus 32 litres of fuel oil.

Energy is an area where substantial savings can be made almost immediately with little or no capital investment, through simple housekeeping efforts. Some key strategies are listed below:

- implementing switch-off programs and installing sensors to turn off or power down lights and equipment when not in use;
- improving insulation on heating or cooling systems and pipework.;
- favouring more efficient equipment;
- improving maintenance to optimise energy efficiency of equipment;
- maintaining optimal combustion efficiencies on steam and hot water boilers;
- eliminating steam leaks;
- capturing low-grade energy to use elsewhere in the operation.

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

By-product management

An important waste reduction strategy for the industry is the recovery of marketable by-products from fish wastes. Surimi and flaked fish are good examples of products created from previously undervalued fish parts. Hydrolysed fish wastes can be used for fish or pig meal as well as fertiliser components.

The utilisation of by-products is an important Cleaner Production opportunity for the industry since it can potentially generate additional revenue as well as reducing disposal costs for these materials. The transportation of fish residues and offal without the use of water is an important factor for the efficient collection and utilisation of these by-products.

Implementing a Cleaner Production assessment

This guide contains information to help the reader undertake a Cleaner Production assessment at a fish processing plant. A Cleaner Production assessment is a systematic procedure for identifying areas of inefficient resource consumption and poor waste management, and for developing Cleaner Production options. The methodology described in this guide is based on that developed by UNEP and UNIDO, and consists of the following basic steps:

- planning and organising the Cleaner Production assessment;
- pre-assessment (gathering qualitative information about the organisation and its activities);
- assessment (gathering quantitative information about resource consumption and waste generation and generating Cleaner Production opportunities);
- evaluation and feasibility assessment of Cleaner Production opportunities;
- implementation of viable Cleaner Production opportunities and developing a plan for the continuation of Cleaner Production efforts.

It is hoped that by providing technical information on known Cleaner Production opportunities and a methodology for undertaking a Cleaner Production assessment, individuals and organisations within the fish processing industry will be able to take advantage of the benefits that Cleaner Production has to offer.

1 CLEANER PRODUCTION

1.1 What is Cleaner Production?[1]

Over the years, industrialised nations have progressively taken different approaches to dealing with environmental degradation and pollution problems, by:

- ignoring the problem;
- diluting or dispersing the pollution so that its effects are less harmful or apparent;
- controlling pollution using 'end-of-pipe' treatment;
- preventing pollution and waste at the source through a 'Cleaner Production' approach.

The gradual progression from 'ignore' through to 'prevent' has culminated in the realisation that it is possible to achieve economic savings for industry as well as an improved environment for society. This, essentially, is the goal of Cleaner Production.

Definition of Cleaner Production

Cleaner Production is defined as the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment.

- For production processes, Cleaner Production involves the conservation of raw materials and energy, the elimination of toxic raw materials, and the reduction in the quantities and toxicity of wastes and emissions.
- For product development and design, Cleaner Production involves the reduction of negative impacts throughout the life cycle of the product: from raw material extraction to ultimate disposal.
- For service industries, Cleaner Production involves the incorporation of environmental considerations into the design and delivery of services.

Difference between Cleaner Production and pollution control

The key difference between pollution control and Cleaner Production is one of timing. Pollution control is an after-the-event, 'react and treat' approach, whereas Cleaner Production reflects a proactive, 'anticipate and prevent' philosophy. Prevention is always better than cure.

This does not mean, however, that 'end-of-pipe' technologies will never be required. By using a Cleaner Production philosophy to tackle pollution and waste problems, the dependence on 'end-of-pipe' solutions may be reduced or in some cases, eliminated altogether.

Cleaner Production can be and has already been applied to raw material extraction, manufacturing, agriculture, fisheries, transportation, tourism, hospitals, energy generation and information systems.

Changing attitudes

It is important to stress that Cleaner Production is about attitudinal as well as technological change. In many cases, the most significant Cleaner Production benefits can be gained through lateral thinking,

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[1] This chapter has been adapted from a UNEP publication, *Government Strategies and Policies for Cleaner Production*, 1994.

without adopting technological solutions. A change in attitude on the part of company directors, managers and employees is crucial to gaining the most from Cleaner Production.

Applying know-how

Applying know-how means improving efficiency, adopting better management techniques, improving housekeeping practices, and refining company policies and procedures. Typically, the application of technical know-how results in the optimisation of existing processes.

Improving technology

Technological improvements can occur in a number of ways:

- changing manufacturing processes and technology;
- changing the nature of process inputs (ingredients, energy sources, recycled water etc.);
- changing the final product or developing alternative products;
- on-site reuse of wastes and by-products.

Types of Cleaner Production options

Housekeeping	Improvements to work practices and proper maintenance can produce significant benefits. These options are typically low cost.
Process optimisation	Resource consumption can be reduced by optimising existing processes. These options are typically low to medium cost.
Raw material substitution	Environmental problems can be avoided by replacing hazardous materials with more environmentally benign materials. These options may require changes to process equipment.
New technology	Adopting new technologies can reduce resource consumption and minimise waste generation through improved operating efficiencies. These options are often highly capital intensive, but payback periods can be quite short.
New product design	Changing product design can result in benefits throughout the life cycle of the product, including reduced use of hazardous substances, reduced waste disposal, reduced energy consumption and more efficient production processes. New product design is a long-term strategy and may require new production equipment and marketing efforts, but paybacks can ultimately be very rewarding.

1.2 Why invest in Cleaner Production?

Investing in Cleaner Production, to prevent pollution and reduce resource consumption is more cost effective than continuing to rely on increasingly expensive 'end-of-pipe' solutions.

Cleaner Production versus pollution control

When Cleaner Production and pollution control options are carefully evaluated and compared, the Cleaner Production options are often more cost effective overall. The initial investment for Cleaner Production options and for installing pollution control technologies may be similar, but the ongoing costs of pollution control will generally be greater than for Cleaner Production. Furthermore, the Cleaner Production option will generate savings through reduced costs for raw materials, energy, waste treatment and regulatory compliance.

Greener products

The environmental benefits of Cleaner Production can be translated into market opportunities for 'greener' products. Companies that factor environmental considerations into the design stage of a product will be well placed to benefit from the marketing advantages of any future eco-labelling schemes.

Some reasons to invest in Cleaner Production

- improvements to product and processes;
- savings on raw materials and energy, thus reducing production costs;
- increased competitiveness through the use of new and improved technologies;
- reduced concerns over environmental legislation;
- reduced liability associated with the treatment, storage and disposal of hazardous wastes;
- improved health, safety and morale of employees;
- improved company image;
- reduced costs of end-of-pipe solutions.

1.3 Cleaner Production can be practised now

It is often claimed that Cleaner Production techniques do not yet exist or that, if they do, they are already patented and can be obtained only through expensive licences. Neither statement is true, and this belief wrongly associates Cleaner Production with 'clean technology'.

Cleaner Production also covers changing attitudes and management

Firstly, Cleaner Production depends only partly on new or alternative technologies. It can also be achieved through improved management techniques, different work practices and many other 'soft' approaches. Cleaner Production is as much about attitudes, approaches and management as it is about technology.

Cleaner Production techniques already exist

Secondly, Cleaner Production approaches are widely and readily available, and methodologies exist for its application. While it is true that Cleaner Production technologies do not yet exist for all industrial processes and products, it is estimated that 70% of all current wastes and emissions from industrial processes can be prevented at source by the use of technically sound and economically profitable procedures (Baas et al., 1992).

1.4 Cleaner Production and sustainable development

In the past, companies have often introduced processes without considering their environmental impact. They have argued that a trade-off is required between economic growth and the environment, and that some level of pollution must be accepted if reasonable rates of economic growth are to be achieved. This argument is no longer valid, and the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992, established new goals for the world community that advocate environmentally sustainable development.

Economy and environment go hand in hand

Cleaner Production can contribute to sustainable development, as endorsed by Agenda 21. Cleaner Production can reduce or eliminate the need to trade off environmental protection against economic growth, occupational safety against productivity, and consumer safety against competition in international markets. Setting goals across a range of sustainability issues leads to 'win–win' situations that benefit everyone. Cleaner Production is such a 'win–win' strategy: it protects the environment, the consumer and the worker while also improving industrial efficiency, profitability and competitiveness.

Cleaner Production can provide advantages for all countries

Cleaner Production can be especially beneficial to developing countries and those undergoing economic transition. It provides industries in these countries with an opportunity to 'leapfrog' those more established industries elsewhere that are saddled with costly pollution control.

1.5 Cleaner Production and quality and safety

Food safety and food quality are very important aspects of the food industry. While food safety has always been an important concern for the industry, it has received even greater attention over the past decade due to larger scales of production, more automated production processes and more stringent consumer expectations. A stronger emphasis is also being placed on quality due to the need for companies to be more efficient in an increasingly competitive industry.

In relation to food safety, Hazard Analysis Critical Control Point (HACCP) has become a widely use tool for managing food safety throughout the world. It is an approach based on preventing microbiological, chemical and physical hazards in food production processes by anticipating and preventing problems, rather than relying on inspection of the finished product.

Similarly, quality systems such as Total Quality Management (TQM) are based on a systematic and holistic approach to production processes and aim to improve product quality while lowering costs.

Cleaner Production should operate in partnership with quality and safety systems and should never be allowed to compromise them. As well, quality, safety and Cleaner Production systems can work synergistically to identify areas for improvement in all three areas.

1.6 Cleaner Production and environmental management systems

Environmental issues are complex, numerous and continually evolving, and an *ad hoc* approach to solving environmental problems is no longer appropriate. Companies are therefore adopting a more systematic approach to environmental management, sometimes through a formalised environmental management system (EMS).

An EMS provides a company with a decision-making structure and action programme to bring Cleaner Production into the company's strategy, management and day-to-day operations.

ISO 14001

As EMSs have evolved, a need has arisen to standardise their application. An evolving series of generic standards has been initiated by the International Organization for Standardization (ISO), to provide company management with the structure for managing environmental impacts. The UNEP/ICC/FIDIC *Environmental Management System Training Resource Kit*, mentioned above, is compatible with the ISO 14001 standard.

EMS training resources

UNEP DTIE, together with the International Chamber of Commerce (ICC) and the International Federation of Engineers (FIDIC), has published an *Environmental Management System Training Resource Kit*, which functions as a training manual to help industry adopt EMSs.

2 OVERVIEW OF FISH PROCESSING

The fish processing industry is very widespread and quite varied in terms of types of operation, scales of production and outputs. The species of fish processed include cod, tuna, herring, mackerel, pollock, hake, haddock, salmon, anchovy and pilchards. Marine fish account for more than 90% of fish production, with the remainder being fresh water fish and fish produced by aquaculture.

In general, fish processing operations are located close to commercial fishing areas. However in some cases catches may be transported long distances or exported for processing. The Northwest Pacific region is by far the most important fishing area in terms volumes caught and processed. China, Peru, Chile, Japan, the United States, the Russian Federation and Indonesia (in that order) are the top producing countries, together accounting for more than half of world fish production.

Approximately 75% of world fish production is used for human consumption and the remaining 25% is used to produce fish meal and oil. Fish meal is a commodity used as feed for livestock such as poultry, pigs and farmed fish and fish oil is used as an ingredient in paints and margarine.

Currently, only about 30% of fish produced for human consumption are marketed fresh. The supply of frozen fish fillets and fish, in the form of ready-to-eat meals and other convenience food products is growing in both developed and developing countries.

The end products from fish processing may be fresh, frozen or marinated fillets, canned fish, fish meal, fish oil or fish protein products, such as surimi. Surimi is an important fish product, with the majority of catches for some species used solely for its production.

Fish processing most commonly takes place at on-shore processing facilities. However some processing can take place at sea, on board fishing vessels—for example the gutting of oily fish. In some regions of the world, where large sea fleets operate, processing can also take place on board fishing vessels. For some sea fleets, 100% utilisation of the catch may be required by legislation. This means that the entire processing operation, including fish meal and oil production for offal and fish waste, takes place on board the fishing vessels.

Some sectors of the industry are very seasonal. Salmon processing, for example, may operate fewer than 100 days per year during the salmon harvesting season. During this time, plants operate at full capacity with little opportunity for down time and little incentive for waste reduction.

Focus of this guide

It is not possible to cover all aspects of fish processing in this guide. Instead its focus is on the filleting of white and oily fish, the canning industry and the production of fish meal and oil (Figure 2–1).

The production of fish meal has been included in this guide because, in terms of volume, it is a major product and has significant environmental impacts. The processing of seafoods such as squid, cuttlefish, octopus and mussels has not been included because production of these species is relatively small compared to the fish filleting industry.

The guide is mainly concerned with the processing of fish at on-shore processing facilities and does not cover at-sea operations specifically. However some of the basic principles will apply to them.

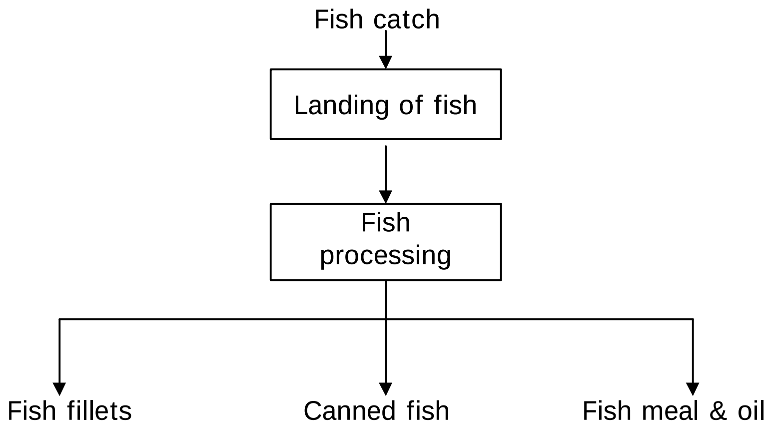

Figure 2–1 General flow diagram for fish processing

2.1 Process overview

2.1.1 Filleting of white fish

Filleting involves a number of unit operations: pretreatment, fish filleting, trimming of fillets, packing and storage. These processes generally take place within separate departments of the fish processing plant.

White fish species have a low oil content and, unlike their oily fish counterparts, are generally gutted, cleaned and sometimes de-headed on board the fishing vessel. The fish are kept on ice in boxes before being delivered to the fish processing plant. On arrival at the plant, fish may be re-iced and placed in chilled storage until required for further processing.

Pretreatment

Pretreatment of the fish involves the removal of ice, washing, grading according to size and de-heading, if this has not been done previously. Large fish may also scaled be before further processing.

Filleting

The next step in the process is filleting, which is generally done by mechanical filleting machines. The filleting department is generally separated from the pretreatment area by a wall, to prevent workers and goods passing from the non-sterile pretreatment area to the sterile filleting area. The filleting machines comprise pairs of mechanically operated knives which cut the fillets from the backbone and remove the collarbone. Some fish fillets may also be skinned at this stage.

Trimming

In the trimming department, pin bones are removed and operators inspect the fillets, removing defects and any parts that are of inferior quality. Offcuts are collected and minced. Depending on the final product, the fillets may be cut into portions according to weight or divided into parts such as loin, tail and belly flap. As a final step before packaging, the fillets are inspected to ensure they meet product standard.

Packaging/storage

Fresh products are packaged in boxes with ice, the ice being separated from the products by a layer of plastic. Frozen products can be packed in a number of ways. Fillets or pieces can be individually frozen and wrapped in plastic, but the most common method is for them to be packed as 6–11 kg blocks in waxed cartons. The blocks are typically frozen and then kept in cold storage.

The steps involved in filleting white fish are summarised in Figure 2–2.

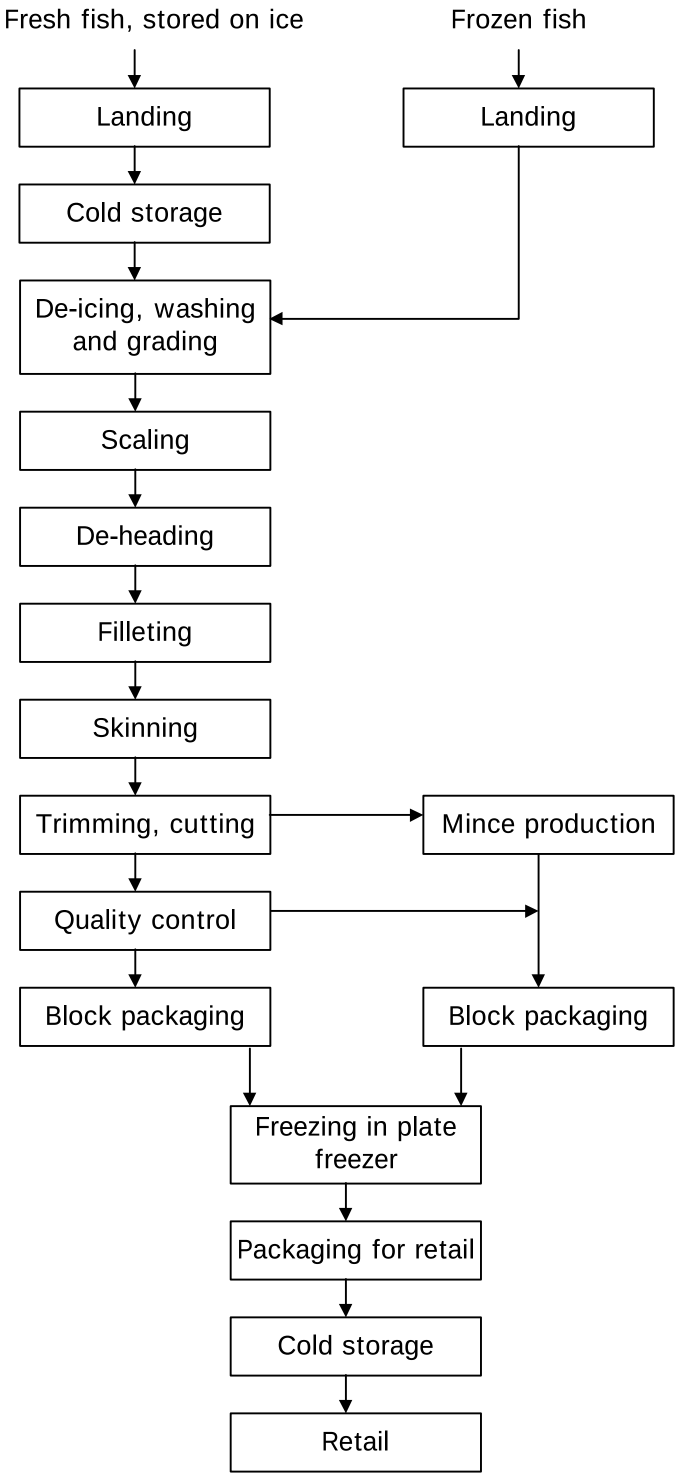

Figure 2–2 Process flow diagram for the filleting of white fish

2.1.2 Filleting of oily fish

Oily fish species are characterised as those having oils distributed throughout the fillet and in the belly cavity around the gut. Fillets from these species may contain up to 30% oil. Oil content varies not only between species but also within species.

Oily fish species are very rarely gutted or cleaned on board the fishing vessels, due to the high oil content and the consequent risks associated with oily surfaces. Keeping the skin of the fish intact also reduces oxidation of the oil and thus maintains flesh quality. Oily species can be filleted like white fish species, but they are also used for canning.

The steps involved in the filleting of oily fish are summarised in Figure 2–3.

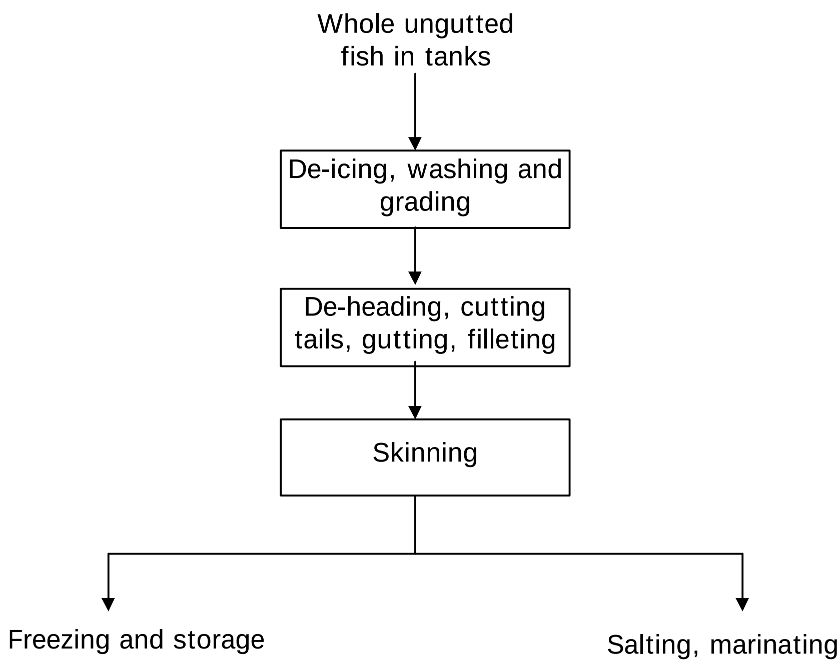

Figure 2–3 Process flow diagram for the filleting of oily fish (herring)

2.1.3 Canning

Off-loading and cutting

The fish are off-loaded at the plant, weighed and loaded into water flumes. The flumes transport the fish to holding vessels, where they remain until required for processing. Fish are flumed, as required, onto cutting tables, where the heads, tails and other inedible parts are removed.

Skinning

Some fish species, such as mackerel, need to have the skin removed by immersion in a warm caustic bath. The effluent generated from this process has a high organic load and has to be neutralised before being discharged.

Can filling and cooking

The canning process depends on the size of the fish. Small fish species such as sardines and pilchards are generally canned whole, with only the heads and tails removed. These whole-fish products are cooked in the can after it has been filled with brine or oil.

Medium-sized fish species are cut into pieces and pre-cooked in the can before the can is filled with brine or oil. For large fish species such as mackerel and tuna, the fish are filleted, cut into pieces of suitable size and also precooked in the can. Bones and inedible parts are removed when large fish species such as tuna are canned. After precooking, the liquid is drained from the cans and oil, brine or sauces are added. The cans are then sealed, sterilised and then stored.

Fish meal production

Most large canneries also operate a fish meal plant, in which fish not suitable for canning is combined with offal and processed into fish meal.

The steps involved in the canning of fish are summarised in Figure 2–4.

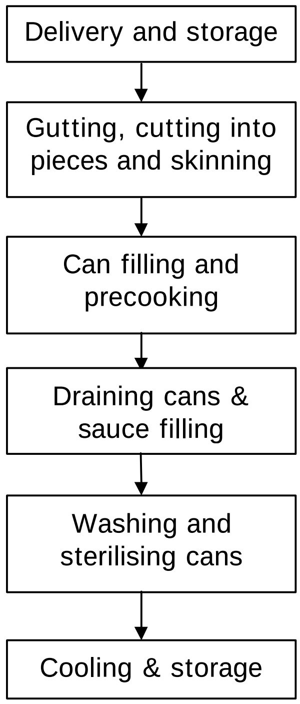

Figure 2–4 Process flow diagram of the canning process

2.1.4 Fish meal and fish oil production

Fish meal and fish oil are produced from fish that are caught specifically for this market, by-catch from fishing activities and solid waste from filleting and canning.

Fish meal and fish oil products have a high nutritional value. Fish meal is used as feed for livestock and farmed fish, and the oil is used as an ingredient in paints and margarine.

Fish meal is derived from the dry components of the fish, and the oil from the oily component. Water, which makes up the rest of the fish matter, is evaporated during the process.

Most fish meal and fish oil production processes are automated and continuous, and comprise several process lines, each with a certain processing capacity. Production rates vary considerably, according to the season and types of fish being processed.

The steps involved in fish meal in fish oil production are summarised in Figure 2–5.

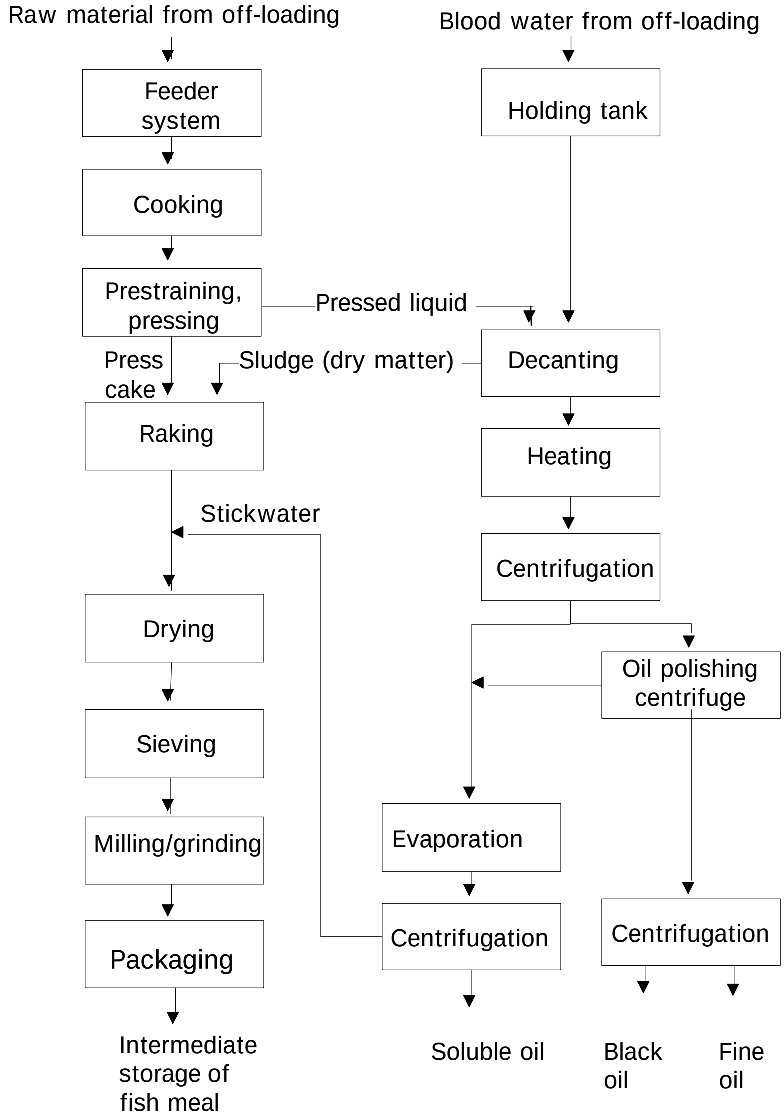

Figure 2–5 Process flow diagram of fish meal and fish oil production

Off-loading

On board the fishing vessels, the catch is normally stored in tanks of water. Upon arriving at the processing plant the fish are pumped to holding bins, where they are stored until required for processing. Extra sea water may need to be added to pump the fish.

Fish meal process

From the storage bins, the fish are transported by screw conveyors to a cooking process which acts to coagulates the protein. The cooked mixture is then screened, using a strainer conveyor or a vibrating screen, and then pressed to remove most of the water from the mixture.

The pressed cake is shredded and dried, using an indirect steam drier or a direct flame dryer. The meal passes through a vibrating screen and on to a hammer mill, which grinds it to the appropriate size. The ground meal is automatically weighed and bagged.

Fish oil process

The pressed liquid generated from the previous processes passes through a decanter to remove most of the sludge, which is fed back to the meal dryer. Oil is separated from the liquid by centrifuges, polished and refined to remove any remaining water and impurities. The separated aqueous phase, referred to as stickwater, is concentrated in an evaporator and then added to the pressed fish meal prior to being sent to the dryer.

2.2 Environmental impacts

As for many other food processing operations, the main environmental impacts associated with fish processing activities are the high consumption of water, consumption of energy and the discharge of effluent with a high organic content. Noise, odour and solid wastes may also be concerns for some plants.

A characteristic of fish that has a bearing on the waste loads generated, is its highly perishable nature compared with other food products. If not properly refrigerated it spoils rapidly, the flesh becomes soft and loose, and pieces are easily lost. As the quality of the fish deteriorates over time, product yield decreases and product losses contribute to the waste loads. These losses often find their way into the effluent stream.

Fish processing plants often have little direct control over the handling of the fish catch before it arrives at the plant, except where the fishing vessels are owned by the processing company. In this case, the processor can set quality standards and expect certain handling practices.

Water consumption

Fish filleting and canning processes consume very large quantities of fresh water. Water is used for transporting fish and offal around the plant in flume systems, for cleaning plant and equipment, for washing raw materials and product, and for de-icing and thawing.

For fish meal and fish oil production, sea water is typically used for cooling and condensing air from the evaporators and scrubbers, and comparatively minor quantities of fresh water are used for the centrifuges, for producing steam and for cleaning.

Energy consumption

Energy is used for operating machinery, producing ice, heating, cooling, and drying. As well as depleting fossil fuel resources, the consumption of energy also produces air pollution and greenhouse gas emissions, which have been linked to global warming.

Production of fish meal and fish oil requires significant amounts of energy for cooking, drying and evaporation. This energy is usually generated by the combustion of fuels on site.

Effluent discharge

Effluent streams generated from fish processing contain high loads of organic matter due to the presence of oils, proteins and suspended solids. They can also contain high levels of phosphates and nitrates.

Sources of effluent from fish processing include the handling and storage of raw fish prior to processing, fluming of fish and product around the plant, defrosting, gutting, scaling, portioning and filleting of fish and the washing of fish products. For operations where skinning is carried out, the effluent can have a high pH due to the presence of caustic.

In canning operations, effluent is also discharged from the draining of cans after precooking, from the spillage of sauces, brines and oil in the can filling process, and from the condensate generated during precooking.

In fish meal and fish oil production, sources of effluent are bloodwater from unloading the vessels, bloodwater from intermediate storage of fish, stickwater from the centrifuges, condensate from the evaporators and cleaning in general.

Effluent quality is highly dependent upon the type of fish being processed. Pollution loads generated from the processing of oily fish species are much higher than from white fish species, due to the high oil content and the fact that these species are usually not gutted or cleaned on the fishing vessel. The entrails from the gutting of oily fish contain high levels of easily soluble substances, which generally find their way to the effluent stream.

Effluent quality also depends on the type of processing undertaken. For example, additional pollution loads arise from the pickling of fish. Brine is used in this process, the wastewaters from which contain salts and acids, making them difficult to treat.

If the effluent streams described above are discharged without treatment into water bodies, the pollutants they contain can cause eutrophication and oxygen depletion. In addition, fish processing industries have been known to pollute nearby beaches and shores by releasing wastewater containing oils. Since oil floats on water, it can end up on the surrounding coastline.

Refrigerants

For operations that use refrigeration systems based on chlorofluorocarbons (CFCs), the fugitive loss of CFCs to the atmosphere is an important environmental consideration, since CFCs are recognised to be a cause of ozone depletion. For such operations, the replacement of CFC-based systems with non- or reduced-CFC systems is thus an important issue.

Emissions to air

Odour generation can be an important environmental issue. The main causes are the storage and handling of putrescible waste materials, and odorous emissions during the cooking and drying processes used in the production of fish meal.

2.3 Environmental indicators

Environmental indicators are important for assessing Cleaner Production opportunities and for comparing the environmental performance of one fish processing operation with that of another. They provide an indication of resource consumption and waste generation per unit of production.

The consumption of resources and the generation of wastes can vary considerably from one plant to the next. Variations are most obvious when different fish species are being processed. Variations also result from the type of equipment used, the extent of processing and the attention paid to optimising resource consumption.

Different species produce different yields by virtue of the amount of edible flesh on the fish. For example, *orange roughie* from Southern Hemisphere fisheries produces relatively low yields (30%), whereas tuna produces higher yields (50%). In addition, the oil content of oily fish species may vary from 2% to more than 25%, depending on the season, and this has a considerable impact on the pollution load generated from the process. There is also a big difference in yield between a small fish canned whole and a large fish that is de-headed, gutted, filleted and skinned.

For the fish processing industry, indicators can be represented either as per tonne of raw material (RM) or per tonne of finished product (FP). The latter takes into consideration the yield of the fish species being processed, but it is often more convenient to calculate the figures per tonne of raw material. Equipment manufacturers often give consumption indicators per tonne of raw material or per hour.

This section contains input and output for each of the processes covered in this guide. The figures are representative of average technology. Also provided are indications of the resource input and waste generation figures that could be achieved by adopting best available technology (BAT).

The figures are derived from Danish plants, and from a few African and American plants. They should be used with care, due to the processing variations discussed above. Rates of resource consumption and waste generation can be much higher than stated in this section.

2.3.1 Filleting white fish

Figure 2–6 below shows the process for filleting white fish including approximate figures for quantities of inputs and outputs.

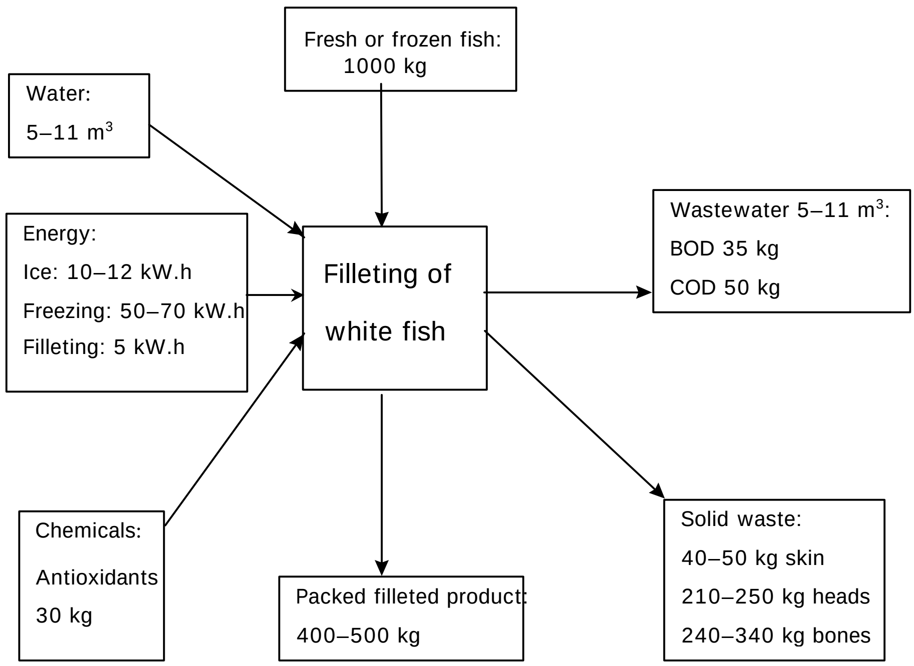

Figure 2–6 Inputs and outputs for filleting of white fish using average technology

By adopting best available technology, the following rates of resource consumption and waste outputs could be achieved:

- Water consumption and wastewater generation could be reduced to 1.2–4.4 m^3 per tonne of raw material.
- Organic loads in the effluent could be reduced to about 12 kg BOD or 17 kg COD per tonne of raw material.
- Energy consumption could also be reduced, especially if the equipment and rooms for freezing were to be improved.
- Product yields would also increase, resulting in a decreased rate of solid waste generation.

2.3.2 Filleting oily fish

Figure 2–7 below shows the process for filleting oily fish including approximate figures for quantities of inputs and outputs.

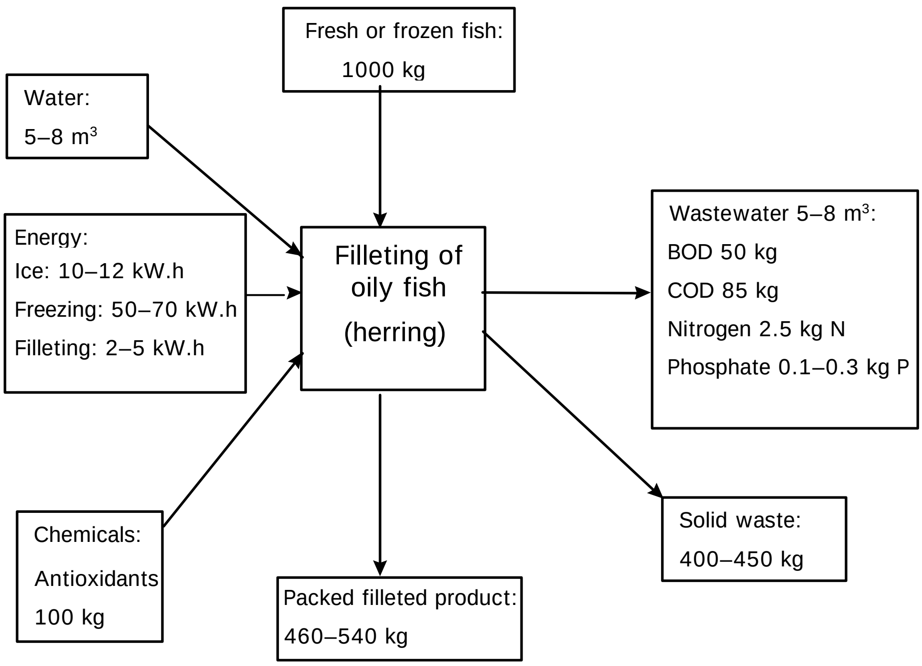

Figure 2–7 Inputs and outputs for filleting of oily fish (herring) using average technology

By adopting best available technology, the following rates of resource consumption and waste outputs could be achieved:

- Water consumption and wastewater generation could be reduced to 2.5–3.0 m^3 per tonne of raw material.
- Organic loads in the effluent could be reduced to about 12–15 kg BOD or 20–21 kg COD per tonne of raw material.
- Nitrogen loads in the effluent could be reduced to 0.4–0.6 kg N per tonne of raw material.
- Phosphate in the effluent could be reduced to 0.02–0.03 kg P per tonne of raw material.

- Product yields would also increase, resulting in a decreased rate of solid waste generation.

2.3.3 Canning

Figure 2–8 below shows the process for canning including approximate figures for quantities of inputs and outputs.

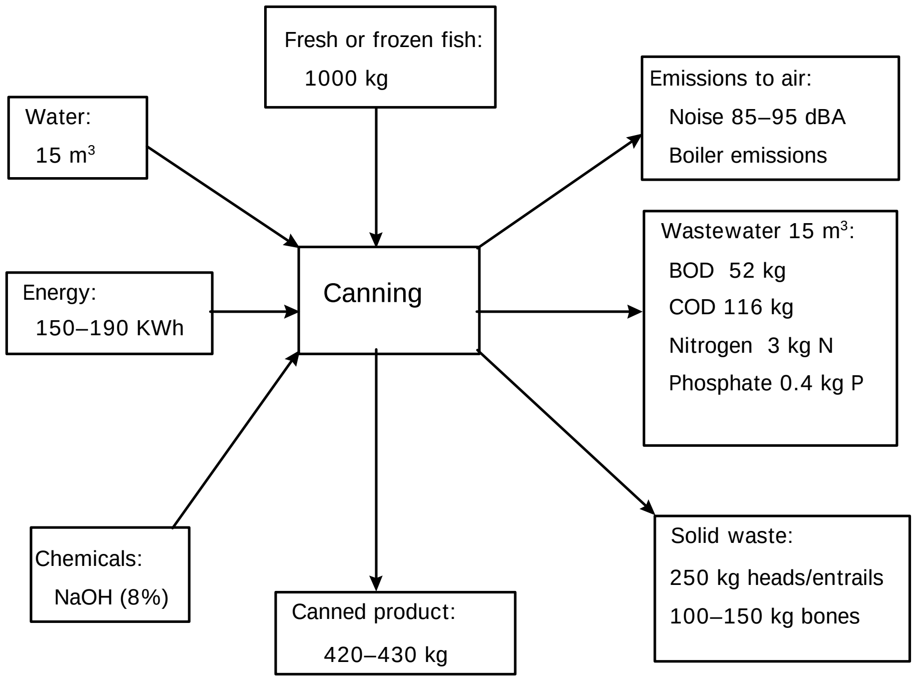

Figure 2–8 Inputs and outputs for canning industry using average technology

By adopting best available technology, the following rates of resource consumption and waste outputs could be achieved:

- Water consumption and wastewater generation could be reduced to 7 m^3 per tonne of raw material.
- Organic loads in the effluent could be reduced to 12 kg BOD or 27 kg COD per tonne of raw material.
- Nitrogen loads in the effluent could be reduced to 0.7 kg N per tonne of raw material.
- Phosphate in the effluent could be reduced to 0.1 kg P per tonne of raw material.
- Energy consumption could also be reduced, especially if the equipment and rooms for freezing were to be improved.
- Product yields would also increase, resulting in a decreased rate of solid waste generation.

Table 2–1 demonstrates the variation in wastewater characteristics that can occur between one fish species and another. In this case the comparison is between the canning of sardines and of tuna.

Table 2–1 Wastewater characteristics for canning of sardines and tuna[1]

Species	**Parameter**	**Range** (per tonne FP)	**Typical value** (per tonne FP)
Sardines	Wastewater (m^3)	NA	9
	BOD (kg)	NA	9
	Suspended solids (kg)	NA	5
	Oil and grease (kg)	NA	2
Tuna	Wastewater (m^3)	6–45	22
	BOD (kg)	7–20	15
	Suspended solids (kg)	4–17	11
	Oil and grease (kg)	2–13	6

NA: not available

[1] UNIDO, 1986

2.3.4 Fish meal and fish oil production

Figure 2–9 below shows the process for fish meal and fish oil production including approximate figures for quantities of inputs and outputs.

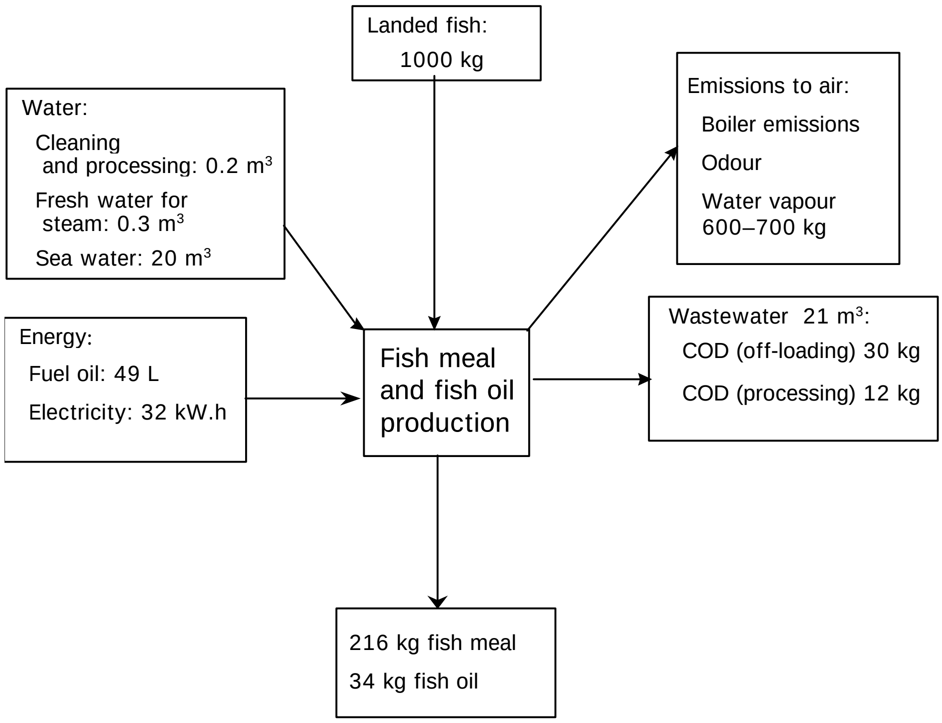

Figure 2–9 Inputs and outputs for fish meal and fish oil production using average technology

By adopting best available technology, the following rates of resource consumption and product and waste outputs could be achieved:

- Product yields for fish meal could increase to approximately 270 kg fish meal per tonne of raw material, but only a minor increase in fish oil yields could be expected.
- Organic loads in the effluent could be reduced to 22 kg COD per tonne of raw material for off-loading processes and to about 9 kg COD per tonne of raw material for processing.
- Fuel oil consumption could be reduced to approximately 35 L per tonne of raw material.

2.3.5 Processing of other seafood species

Table 2–2 below provides indicative figures of water consumption and wastewater generation rates for the processing of a number of other seafood products. If the raw material is frozen, the quantities of water vary enormously depending on thawing method and availability of water.

Table 2–2 Table of wastewater characteristics for various species[1]

Type of processing	Unit	Water (m^3/tonne)	BOD (kg/tonne)	SS (kg/tonne)	Oil and grease (kg/tonne)
Marine finfish					
- conventional plant	FP	5	3	1–2	0.4
- mechanised plant	FP	14	12	9	2.5
Tuna processing					
- range	FP	6–45	7–20	4–17	2–13
- typical value		22	15	11	6
- average of 8 plants	FP	12	137[2]	NA	NA
Canned sardine	FP	9	9	5–6	27
Blue crab					
- conventional plant	FP	1–2	5–6	1	0.2–0.3
- mechanised plant	FP	29–44	22–23	12	4–7
Dungeness crab	FP	14–38	7–15	2–4	NA
Shrimp plant					
- frozen	RM	73	130	210	17
- frozen (without cleaning)[3]	RM	23–30	100–130	NA	NA
- canned	RM	60	120	54	42
- breaded	RM	116	84	93	NA
Shrimp	FP	120–175	250		
Clam plant					
- conventional plant	FP	5	5	10	0.2
- mechanised plant	FP	20	19	6	0.5
Salmon plant					
- conventional plant	FP	4–5	2–3	1–2	0.2–8
- mechanised plant	FP	19–20	45–51	20–25	5–7
Catfish[4]	FP	16–32	6–9	-	4–6
Mussel[4]	FP	20–120	60	NA	NA

[1] UNIDO, 1986 and Danish EPA, 1996A

[2] This value is for chemical oxygen demand (COD)

[3] Author's own data

[4] Water Quality Institute of Denmark

3 CLEANER PRODUCTION OPPORTUNITIES

Fish processing typically consumes large quantities of water and energy and discharges significant quantities of organic material, both as effluent and as solid waste. However, there is very little use of hazardous substances. For this reason, Cleaner Production opportunities described in this guide focus on reducing the consumption of resources, increasing yields and reducing the volume and organic load of effluent discharges.

Although many processes in the industry can be automated, it is difficult to automate the handling of fish and fillets because of the slippery surfaces, variations in size and delicate nature of the product. Therefore, operators generally direct fish and fish products manually through the process. This means that operator practices have a significant impact on the plant performance, particularly in small-scale, less automated operations. As a result, many of the Cleaner Production opportunities described in this section relate to good housekeeping practices, work procedures, maintenance regimes and resource handling.

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

3.1 General

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

Table 3–1 Checklist of general housekeeping ideas [1]

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

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

3.1.1 Water consumption

Water is used extensively in fish processing, so water saving measures are very common Cleaner Production opportunities in this industry. Water is used not only for fish cleaning, but also to flush offal and blood from equipment and floors, and to flume the offal to floor drains and collection sumps. Automated processing equipment generally has permanently installed water sprays to keep the equipment clean and to flush offal away.

The first step in reducing water consumption is to analyse water use patterns carefully, by installing water meters and regularly recording water consumption. Water consumption data should be collected during production hours, especially during periods of cleaning. Some data should also be collected outside normal working hours to identify leaks and other areas of unnecessary wastage. Water consumption data should be presented and discussed at management meetings to formulate strategies for improved water efficiency. Discussion could include whether water needs to be used at all in some processes; for example, could transport systems avoid the use of water?

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, water sprays on process lines operating when no processing is taking place, the continual running of water used for thawing, and so on. Installing automatic shut-off equipment, such as sensors, solenoid valves, timers and thermostats, could prevent such wasteful practices. Automatic control of water use is preferable to relying on operators to manually turn water off.

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

Once water use for essential operations has been optimised, water reuse can be considered. Wastewaters that are only slightly contaminated could be used in other areas. For example, wastewater from fish thawing could be used for offal fluming or for initial cleaning steps in dirty areas. Wastewater reuse should not compromise product quality and hygiene, and reuse systems should be carefully installed so that reused wastewater lines cannot be mistaken for fresh water lines, and each case should be approved by the food safety officer.

Table 3–2 Checklist of water saving ideas [1]

- Use offal transport systems that avoid or minimise the use of water.
- Install fixtures that restrict or control the flow of water for manual cleaning processes.
- Use high pressures rather than high volumes for cleaning surfaces.
- Reuse relatively clean wastewaters for other applications; for example, thawing wastewaters could be used for offal fluming or for initial cleaning steps in dirty areas.
- Use compressed air instead of water where appropriate.
- Install meters on high use equipment to monitor consumption.
- Use closed circuit cooling systems.
- Pre-soak floors and equipment to loosen dirt before the final clean.
- Recirculate water used in non-critical applications.
- Report and fix leaks promptly.

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

3.1.2 Effluent

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

Opportunities for reducing the pollutant load of fish processing effluent principally focus on avoiding the loss of raw materials and products to the effluent stream. This means capturing materials before they enter drains and using dry cleaning methods. Therefore, improvements to cleaning practices are an area where the most gains can be made. Table 3–4 contains a checklist of common ideas for reducing effluent loads.

Table 3–3 Checklist of ideas for reducing effluent loads [1]

- Sweep up solid materials for use as a by-product, instead of washing them down the drain.
- Clean dressed fish with vacuum hoses and collect the blood and offal in an offal hopper rather than the effluent system.
- Fit drains with screens and/or traps to prevent solid materials from entering the effluent system.
- Use dry cleaning techniques where possible, by scraping equipment before cleaning, pre-cleaning with air guns and cleaning floor spills with squeegees.

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

3.1.3 Energy

Fish processing uses electricity to operate machinery, lighting, air compressors and cold storage facilities. Thermal energy in the form of steam and hot water is used for cooking, cleaning and sanitising.

Energy is often an area where substantial savings can be made almost immediately with no capital investment. Significant reductions in energy consumption are possible through improved housekeeping and optimisation of existing processes, and additional savings can be made through the use of more energy-efficient equipment and heat recovery systems.

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

Table 3–4 Checklist of energy saving ideas [1]

- Implement switch-off programs and install sensors to turn off or power down lights and equipment when not in use;
- Improve insulation on heating or cooling systems and pipework.;
- Favour more efficient equipment;
- Improve maintenance to optimise energy efficiency of equipment;
- Maintain optimal combustion efficiencies on steam and hot water boilers;
- Eliminate steam leaks;
- Capture low-grade energy to use elsewhere in the operation.

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

3.1.4 By-products

An important waste reduction strategy for the industry is the recovery of marketable by-products from fish wastes. Surimi and flaked fish are good examples of products created from previously undervalued fish parts.

Chitin and chitosan, chemicals extracted from crab and shrimp shells, produce chitinous polymers similar to cellulose. Chitosan has been used for the manufacture of animal meal products and for various medical applications. Potential uses for fish residue and offal are also being examined in some parts of the world. Hydrolysed fish wastes can be used for fish or pig meal, as well as fertiliser components.

To allow for the efficient collection and utilisation of these by-products, transportation of fish residues and offal without the use of water is very important. Filtering conveyors can be installed under process equipment, or vacuum systems can be used to transport offal directly to storage containers. In plants dominated by manual operations, bins can be provided in suitable locations to collect the offal instead of letting it drop to the floor.

Filleting

3.1.5 Thawing

Process description

In order to be able to produce all year round or to receive sufficient amounts of raw material, some operations use frozen fish. Thawing of frozen fish can be carried out in a number of ways, either in a batch process or using continuous thawing conveyors. The most common method is to immerse the frozen blocks of fish in water.

Inputs and outputs

Figure 3–1 is a flow diagram showing the inputs and outputs for this process and Table 3–5 provides data for the key inputs and outputs.

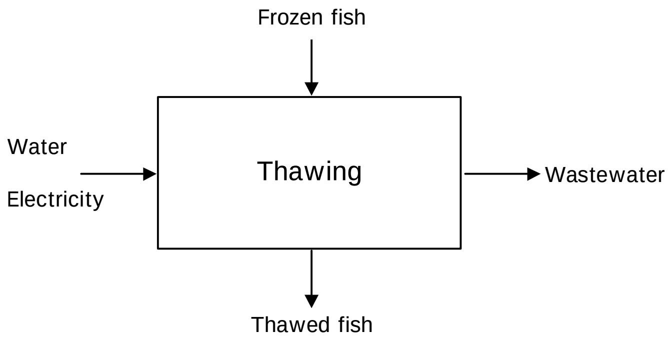

Figure 3–1 Inputs and outputs for the thawing of frozen fish

Table 3–5 Input and output data for thawing of frozen fish

Inputs		Outputs	
Frozen fish	1000 kg[1]	Thawed fish	950–990 kg[1]
Water	5 m^3	Wastewater	5 m^3
		COD	1–7 kg

[1] The weight loss between frozen and thawed fish is attributed to water loss from the fish which occurs as a result of thawing.

Environmental issues

Large amounts of water are used in the thawing process, and can account for around 50% of the total water use when frozen fish are used for filleting. However the amount used depends on the thawing procedure used.

While the fish is thawing in water, the thaw water becomes contaminated with organic material such as intestinal remains, scales and slime. The extent of contamination depends on how well cleaning and gutting were carried out on board the fishing vessels. It can also depend to some extent on the fish species. For example, species such as haddock will contaminate the water with slime and scales more than other species.

Cleaner Production opportunities

Instead of the traditional thawing method, the so-called *Lorenzo method* can be used. In this method, thaw water is heated to 30–35°C to facilitate thawing and the water is agitated with an air sparge, giving a better contact between fish and water. The capital investment is around

US$50,000 and energy is needed for heating the water. However, water consumption is reduced by about 40% to about 3 m^3/t RM.

The *moist air method* utilises a warm, humid air stream and consumes virtually no water. It is therefore a preferred method in terms of water consumption. However, an energy input of about 70 kW.h/t RM is required to heat the moist air. This method has become popular, because less raw material is lost during thawing and the quality of the thawed product is often better. The capital investment for a system with a capacity of 6.5 t/h is around US$230,000. In this case all thawing water, approximately 5 m^3/t RM, will be saved.

3.1.6 De-icing, washing and grading

Process description

The processes described in this section relate to the preparation of fish for filleting. Boxes of fish containing ice and water are emptied into a de-icer tank, in which the contents are stirred to make the fish sink to the bottom and the ice float to the surface. The ice is then skimmed off the surface, assisted by an overflow system.

In a well-functioning operation, fish are graded according to size to optimise yield in subsequent processing steps. An automated grading system operates by passing the fish down an inclined plane, sorting the fish by size along the way.

Inputs and outputs

Figure 3–2 is a flow diagram showing the inputs and outputs for this process and Tables 3–6 and 3–7 provide data for the key inputs and outputs for de-icing and washing fish and for grading fish respectively.

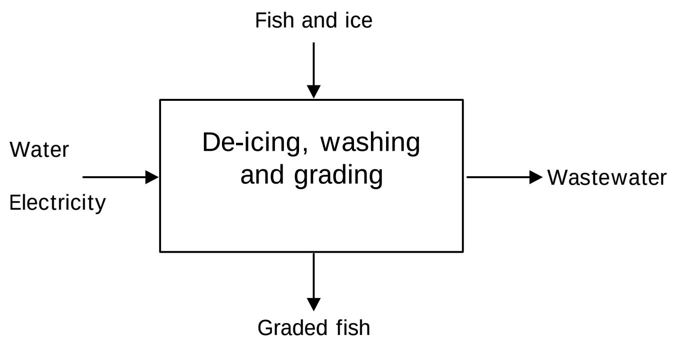

Figure 3–2 Inputs and outputs for de-icing, washing and grading

Table 3–6 Input and output data for de-icing and washing

Inputs		Outputs	
Ice and fish	1000 kg	Fish	980–1000 kg
Water	1 m^3	Wastewater	1 m^3
Electricity	0.8–1.2 kW.h	COD	0.7–4.9 kg
		Solid waste	0–20 kg

Table 3–7 Input and output data for grading fish

Inputs		Outputs	
Fish	1000 kg	Graded fish	980–1000 kg
Water	0.3–0.4 m^3	Wastewater	0.3–0.4 m^3
Electricity	0.1–0.3 kW.h	COD	0.4–1.7 kg
		Solid waste	0–20 kg

Environmental issues

Water is supplied to the de-icer tank to compensate for the water that overflows from the tank. The rate of water consumption is about 1 m^3 per tonne of fish, but depends on the capacity of the machine. Water is also used at the grading equipment to keep the fish lubricated so that they slide down the grading incline. The rate of water consumption for this is about 0.3–0.4 m^3 per tonne of fish.

The wastewater discharged from these processes contains minor amounts of organic matter, the quantity of which depends on fish quality.

Cleaner Production opportunities

Reducing the amount of water that overflows from the de-icing tanks can save water. When the de-icer tanks are topped up, the supply should be shut off when the level is approximately 100 mm below the overflow, to accommodate the water level rise that occurs when the ice melts. The water can be shut off manually, but a level-actuated solenoid valve on the fresh water supply is a more effective means of controlling water use. Using an automated shut-off system could save about 1 m^3/t RM, with an initial investment of about US$800.

The ice/water mixture overflowing from the de-icer tanks may be used for other processes that require chilled water (e.g. scaling operations). The investment for the equipment to do this could be between US$1000 and US$2000. As well as water savings, there will also be some energy savings.

Water consumption at the grading equipment will depend on the quality of the raw fish. Fish of low quality will increase the need for water, to keep the equipment clean. Reductions in water use can be achieved by adjusting consumption rates to meet the actual need. If adjustable valves are installed, the operator can adjust the flow or change to spray nozzles with a lower water consumption. Water savings can be in the order of 50–65%, thus saving about 0.2 m^3/t RM, against an initial investment of about US$200–400.

Case Study 3–1: Water savings on de-icer

In a hake filleting plant, it was calculated that water use at the de-icing equipment could be reduced by 80%. The company has improved housekeeping and installed a level-actuated switch to control water feed. Water savings have been 120 m^3 per day, resulting in a payback time of less than one week.

3.1.7 Scaling

Process description

Scaling equipment consists a perforated, rotating drum, onto which water is applied to flush scales away. If the fillets are to be skinned, it is normally not necessary to scale the fish.

Inputs and outputs

Figure 3–3 is a flow diagram showing the inputs and outputs from this process and Table 3–8 provides data for the key inputs and outputs.

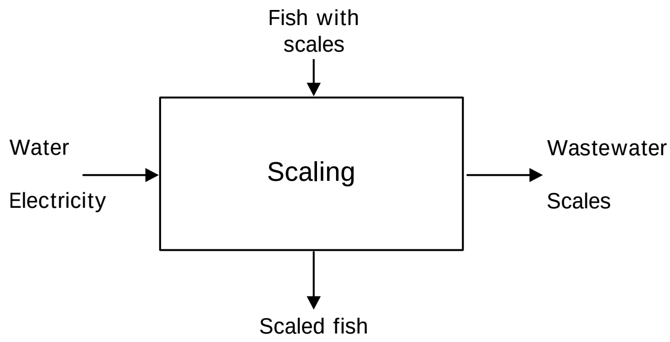

Figure 3–3 Inputs and outputs for scaling

Table 3–8 Input and output data for the scaling of white fish

Inputs		Outputs	
Fish with scales	1000 kg	Scaled fish	960–980 kg
Water	10–15 m^3 [1]	Wastewater	10–15 m^3
Electricity	0.1–0.3 kW.h	Scales	20–40 kg

[1] Water consumed by scaling equipment is typically around 20–30 m^3 per hour. This equates to 10–15 m^3 per tonne of fish, based on 2 tonnes of fish per hour.

Environmental issues

Like most steps in the process, scaling contributes to overall water consumption and to the organic load of the effluent stream. In addition, the scaling process can influence material losses in subsequent processing steps, due to the harsh nature of this treatment.

Cleaner Production opportunities

The necessity for scaling should be assessed on a fish-by-fish basis, bearing in mind that scaling is not required if the fish is to be skinned. If scaling can be avoided, water savings will be in the order of 10–15 m^3 per tonne fish, with no need for capital investment.

Wastewater from the scaling operation can be filtered and recirculated, but the fish must be rinsed with fresh water before leaving the scaler to remove any loose scales and contaminated water. Recirculated water can be chilled with ice from the de-icing operation. The capital investments required for this are very low, while water savings can be about 70%. Water quality must be checked regularly.

Alternatively, proper adjustment of the scaler operation can reduce the quantity of water used in the scaler by 30–60%, with no capital investment. Adjustments should be based on assessments of the performance of the scaler, by weighing the amount of scales and undertaking visual examinations.

Case Study 3–2: Water reduction through optimised scaling

In a hake filleting plant, the water used in the scaling process was 30 m^3/h. Water was supplied by three jets, spraying water on the fish and the drum from three directions. The performance of the scaler was evaluated by weighing the quantities of scales removed from a batch of fish and by visual examination of the scaled fish. It was found that one water jet performed no useful function and the spray rate from the other two jets could be significantly reduced without reducing the efficiency of the scaling process. Overall, water consumption was reduced by one-third, to 20 m^3/h. The process is now being examined further to identify additional potential savings. It is anticipated that another 5–10 m^3/h can be saved.

3.1.8 De-heading

Process description

In automated processes, fish are fed into the de-heading machine from a buffer storage supply. Water is used in the machine to lubricate the fish as they pass through the machine, to clean the rotating knives and to make sure that the heads are ejected from the machine. The removed heads are either collected in storage containers or transported away from the process in a water flume or by conveyor. In manual processes, the head is cut off with a knife and dropped in a container.

Inputs and outputs

Figure 3–4 is a flow diagram showing the inputs and outputs from this process and Table 3–9 provides data for the key inputs and outputs.

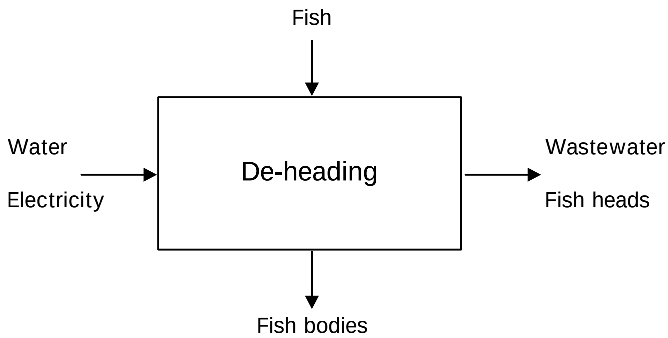

Figure 3–4 Inputs and outputs for de-heading of fish

Table 3–9 Input and output data for the de-heading of white fish

Inputs		Outputs	
Whole fish	1000 kg	Fish bodies	680–730 kg
Water	~ 1 m^3	Wastewater	~ 1 m^3
Electricity	0.3–0.8 kW.h	COD	2–4 kg
		Waste (heads and debris)	270–320 kg

Environmental issues

A typical water consumption rate for de-heading processes is approximately 1 m^3 per tonne of fish, but it can be lower for modern machinery. Water is also used to transport offal using flumes, and this requires a vigorous flow. The organic loading of wastewater generated from the de-heading process is relatively high, due to contamination with blood and flesh pieces.

Cleaner Production opportunities

As mentioned previously, one function of the water in the de-heading machine is to ensure that the removed heads are discharged from the machine and do not pile up on the slide. However, modifying the slide so that it is sufficiently steep will eliminate the need for water. Heads may still accumulate on the horizontal section immediately behind the knives, in which case the operator will have to push the heads out of the machine manually. Water may still be needed for intermittent cleaning, but water savings of about 1 m^3 of water per tonne fish can be achieved with little capital investment.

3.1.9 Cutting of fillets

Process description

The filleting process for white fish differs slightly from that for oily fish. White fish have generally been gutted and cleaned beforehand, so that the filleting processes involves only the removal of the fillet flesh.

Oily fish, on the other hand, have usually not been gutted, cleaned or de-headed prior to this step, so the filleting process involves the gutting and de-heading of the fish as well as the removal of the fillets.

For white fish species, the de-headed fish are manually placed on the filleting machine and rotating knives cut the fillets from the bone and cut off the collar bones. From there, the two fillets are conveyed skin-side down to the skinning machine.

For oily fish, the whole fish is orientated in a forward direction and manoeuvred into position, using water jets, until it is aligned with a stop plate. The head and tail are removed, then the belly flap is cut and the belly cavity cleaned to remove the guts. Two pairs of rotating knives then cut the fillets from the bone. The fillets continue to the skinner.

Inputs and outputs

Figures 3–5 and 3–6 are flow diagrams showing the inputs and outputs from the filleting of white and oily fish respectively. Tables 3–10 and 3–11 provide data for the key inputs and outputs for white and oily fish respectively.

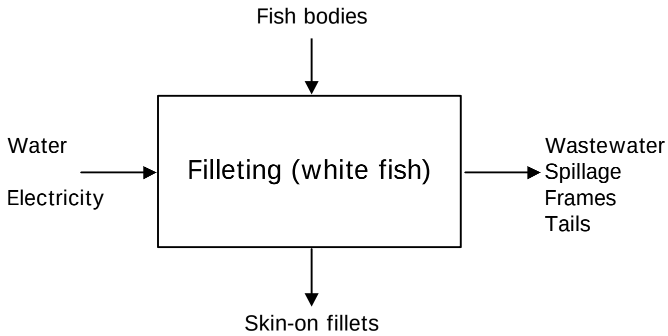

Figure 3–5 Inputs and outputs for filleting white fish

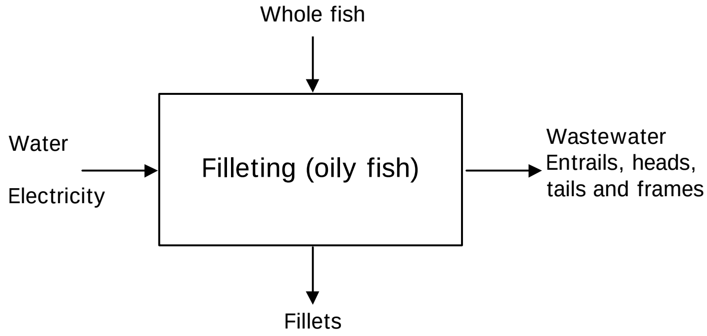

Figure 3–6 Inputs and outputs for filleting oily fish

Table 3–10 Input and output data for filleting of de-headed white fish

Inputs		Outputs	
Fish bodies	1000 kg	Skin-on fillets	700–810 kg
Water	1–3 m^3	Wastewater	1–3 m^3
Electricity	1.8 kW.h	COD	4–12 kg
		Waste (frames and offcuts)	200–300 kg

Table 3–11 Input and output data for filleting of un-gutted oily fish

Inputs		Outputs	
Whole fish	1000 kg	Fillets	550 kg
Water	1–2 m^3	Wastewater	1–2 m^3
Electricity	0.7–2.2 kW.h	COD	7–15 kg
		Waste (entrails, tails, heads and frames)	~440 kg

Environmental issues

The filleting of fish, when done either by hand or by machine, consumes large amounts of water for rinsing the fish and for cleaning knives and equipment. Often continuous rinsing is required to keep work areas free of fish remains. For the filleting of un-gutted oily fish, water is also used for rinsing the belly cavity and for manoeuvring the fish into position before the head is cut off.

Water used for cleaning and rinsing subsequently becomes wastewater, carrying with it fish scraps and entrails. Solids that fall to the floor are also washed to the nearest drain with water.

The entrails and offal from the gutting of oily fish contain high levels of oil and easily soluble matter, and wastewater generated from the filleting of oily fish therefore has a high COD, in the range of 3000–60,000 mg/L. In comparison the COD for wastewater generated from the filleting of white fish is lower, typically 2000–6000 mg/L.

Cleaner Production opportunities

There are various ways of reducing the amount of water consumed in the filleting process. Spray nozzles can be replaced with smaller or more efficient ones, and water pressure can be reduced Sprays can be operated intermittently (e.g. 3 seconds on, 3 seconds off), instead of constantly. In some places, water use can be eliminated by using manual scrapers for removing the build-up of solids on the filleting machines. Solenoid valves should be used to stop water flow when the machines are not in operation.

For oily fish filleting, the water jets that align the fish for removal of the heads can be replaced by a rotating brush. The capital investments for these water saving ideas are all quite low and the water used for filleting can be reduced by 50–90%.

For the highest possible product yields, knives must be correctly aligned and kept sharp. This can be achieved by appropriate operator training, for which capital investment is low.

Stainless steel catch trays placed around the filleting machines can capture solid material that falls from the machines. When filleting is done by hand, most solid wastes end up on the floor and spills occur when offal is transferred to storage containers or onto conveyor belts. Chutes can be installed to capture offal from the filleting tables. These measures can considerably reduce the organic matter discharged in the effluent stream when work areas and floors are cleaned.

The fish frames that remain after filleting can be sold as secondary product to the fish meal industry.

The entrails from the filleting of oily fish can be removed by a vacuum system that sucks and transports the viscera away from the filleting machine. This reduces the consumption of water in this area by about 70%, a reduction of approximately 1.3 m^3 per tonne of fish. It can also reduce the COD of the wastewater stream by about the same proportion, which is a reduction of approximately 4–8 kg per tonne of fish. However the capital investment for such systems is high and energy consumption is high.

Case Study 3–3: Water savings on a filleting machine

A filleting plant installed nozzles on three filleting machines and a simple switch that stopped water when the operator was not at the machine. The investment was only about US$100 and saved 34 m^3 of water was saved per day. The resulting payback period was less than a week.

Case Study 3–4: Optimisation of filleting machine

A Danish company that processes 6000 tonnes of herring every year, on four filleting machines, has introduced a dry gutting process. The water supply to the entrails-cutting wheel was disconnected, and instead the entrails and guts are transported to a container on a conveyor. The investment for four filleting machines was US$35,000. The collected entrails are sold and the water consumption is reduced, saving the company US$7400 every year (after depreciation of the equipment). The environmental benefit is a reduction of organic content in the wastewater in the range of 35%.

3.1.10 Skinning

Process description

In manual processing, the fillets are skinned with a knife at the same work station as the filleting. For automated operations, white fish are skinned by pulling the fillet over a knife, and oily fish are skinned by pulling the fillet over a freezing drum. Water is used for cleaning and lubrication of the machinery.

Inputs and outputs

Figure 3–7 is a flow diagram showing the inputs and outputs from this process. Tables 3–12 and 3–13 provide data for the key inputs and outputs for white and oily fish respectively.

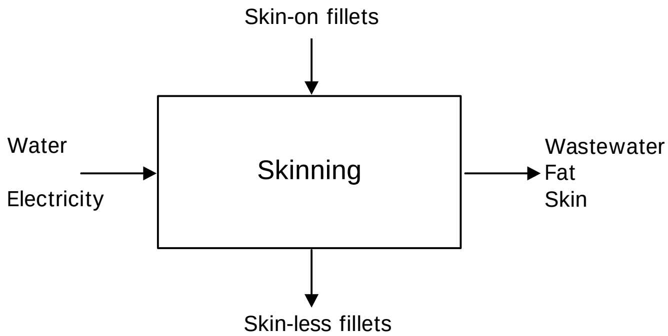

Figure 3–7 Inputs and outputs for skinning

Table 3–12 Input and output data for skinning white fish

Inputs		Outputs	
Skin-on fillets	1000 kg	Skinless fillets	930–950 kg
Water	0.2–0.6 m^3	Wastewater	0.2–0.6 m^3
Electricity	0.4–0.9 kW.h	COD	1.7–5.0 kg
		Waste (skin)	~ 40 kg

Table 3–13 Input and output data for skinning oily fish

Inputs		Outputs	
Skin-on fillets	1000 kg	Skinless fillets	930–950 kg
Water	0.2–0.9 m^3	Wastewater	0.2–0.9 m^3
Electricity	0.2–0.4 kW.h	COD	3–5 kg
		Waste (skin)	~ 40 kg

Environmental issues

The skinning of white fish can contribute significantly to the pollution load of effluent generated from the plant, especially if the quality of the fish is poor. Soft fillets tend to get caught in the skinning equipment and are torn to pieces, reducing yield and increasing waste.

The skinning of oily fish results in the release of large quantities of fish oil to the wastewater stream. The oil comes from the layer of oil just under the skin of the fish and is released during skinning. It is washed away with the water that is constantly applied to the skinning drum to keep it clean. The skinning process contributes about one-third of the overall COD load in the effluent stream.

Cleaner Production opportunities

An important way of reducing the loss of flesh during the skinning operation is to improve the quality of the fish received into the plant, through proper handling from the moment the fish are caught. Secondly, maintenance of machinery is important to ensure that the skinning process is as efficient as possible.

To save water, the number of spray nozzles on the equipment or the size of the nozzles can be reduced. These measures can reduce water consumption by 75%. Additional savings can result by operating the sprays intermittently instead of constantly. The organic load (COD) of the resulting wastewater can also be reduced by 5–10%. For all of the above options, the capital investment is low.

A vacuum system can be used as an alternative to water for removing the skin, fat and flesh pieces from the skinner drum. This will almost eliminate the water consumption from the process. However the high capital cost of such equipment must be considered.

A vacuum system can be mounted on skinning units for oily fish to remove all skin, oil and flesh pieces from the skinner drum. With the exception of a single, small spray nozzle, which sprays water into the drum to keep it moist, water consumption is virtually eliminated. A typical investment for four filleting machines is about US$88,000. The benefits are a reduction in water consumption of about 95%, as well as a reduction in the COD of the wastewater. Across the whole filleting process, total water consumption can be reduced by 17%. This also results in a reduction in overall COD load from filleting and skinning.

3.1.11 Trimming and cutting

Process description

Trimming and cutting are undertaken to remove bones and defects from the fillets and to portion the fillets into smaller pieces. These are often a manual processes, although they can be automated. Any remaining bones are removed, and fins, blood, discoloration and belly membrane materials are cut away. The offcuts from these processes are normally used in the production of fish mince. The trimmed fillets are transported by conveyor belt or in boxes.

Inputs and outputs

Figure 3–8 is a flow diagram showing the inputs and outputs from the trimming and cutting process. Table 3–14 provides data for the key inputs and outputs.

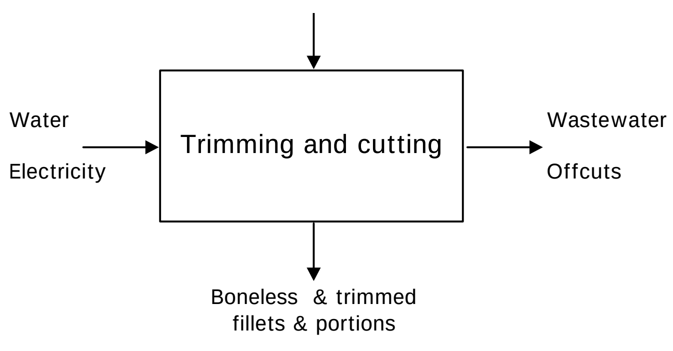

Figure 3–8 Inputs and outputs for trimming and cutting

Table 3–14 Input and output data for trimming and cutting white fish

Inputs		Outputs	
Fillets	1000 kg	Boneless fillets	660–760 kg
Water	0.1 m^3	Wastewater	0.1 m^3
Electricity	0.3–3 kW.h	Waste (bones and cut-off)	240–340 kg

Environmental issues

Water is used for cleaning the fillets and cutting plates, for rinsing the conveyor and boxes, and for cleaning the workplace in general. In some operations, a constant stream of water is used to clean the cutting plates, conveyors and knives. In these situations, water consumption will be much higher than indicated in the above table.

As in many of the other processing areas, losses of materials from the trimming and cutting lines end up on the floor, and if work areas are not well designed, they can be washed to the drain, contributing to the organic load of the effluent stream.

Cleaner Production opportunities

Spray guns can be installed at work areas for occasional cleaning tasks and automatic spray systems can be fitted with solenoid valves so that they operate intermittently. The capital expenditure for these modifications are low and water consumption can be reduced by 50%.

3.1.12 Packaging, freezing and storage

Process description

The fillets are packed in cartons and typically frozen in horizontal plate freezers. Once frozen, the cartons are placed in cold storage until required for distribution and retail.

Inputs and outputs

Figure 3–9 is a flow diagram showing the inputs and outputs from this process. Tables 3–15 and 3–16 provide data for the key inputs and outputs.

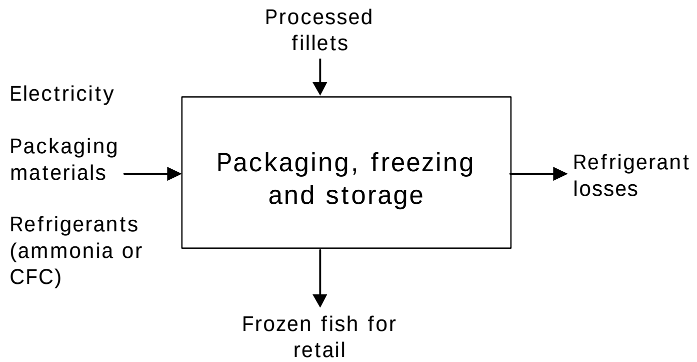

Figure 3–9 Inputs and outputs for packaging, freezing and storage

Table 3–15 Input and output data for packaging of fillets

Inputs		Outputs	
Processed fillets	1000 kg	Fish for retail	~ 1,000 kg
Electricity	5–7.5 kW.h		
Packaging material	NA		

Table 3–16 Input and output data for freezing and storage

Inputs		Outputs	
Packed fish	1000 kg	Frozen fish	~ 1000 kg
Water (for ice)	0.2 m^3		
Electricity	10–14 kW.h		
Additives	various		

Environmental issues

Freezing and refrigeration consume large quantities of energy, and inefficient equipment can result in emission of refrigerant gases, such as ammonia or CFC, depending on which system is used.

Cleaner Production opportunities

The following is a list of possible ways to reduce energy consumption:

- Ensure that the capacity of the cold storage closely matches the production capacity of the operation. It may be convenient to have additional storage capacity, but the extra energy costs of cooling unused capacity may be considerable. This is best addressed during the planning stage of a new development or during refurbishment or upgrades.
- Ensure that cold storage rooms are well insulated and fitted with self-closing doors with tight seals.
- Strictly enforce procedures that ensure cold storage units are defrosted as necessary. If defrosting occurs either too frequently or too infrequently, energy consumption will increase. Such maintenance measures cost little, but require changes in habits.
- Ensure that refrigeration systems are properly maintained. An ongoing maintenance schedule should be established and, whenever leaks or damaged insulation are detected, repairs should be carried out promptly.
- Use non-CFC refrigeration systems, such as those that use ammonia. It can be costly to change refrigeration systems, but it has become necessary due to the Montreal Protocol related to the use of ozone-depleting substances.

3.1.13 Collection and transport of offal

Process description

The conventional method for collecting and removing offal is to allow it to collect in drains adjacent to work areas and then flume it away with water. Generally, water from the filleting and de-heading machines is used for this purpose. It is usually necessary, however, to add some fresh water to transport the solid offal away effectively.

Environmental issues

Fluming of offal is responsible for a considerable proportion of the effluent generated from fish processing plants. During transportation of the offal in the water flume, organic matter is dissolved in the water stream, contributing to high levels of COD and nutrients.

Cleaner Production opportunities

Instead of transporting offal via drains and water flumes, a conveyor with a mesh size of about 1 mm can be installed underneath each filleting line. As well as transporting the offal away, the conveyor acts as a filter.

Wastewaters flowing away from machines and workstations are filtered through the conveyor belt, while the solid offal is retained on the belt, to be transported to the offal collection area. Only particles smaller than 1 mm will pass through the filter, so fish offal is quickly separated from the water stream and contamination of water is limited to small solid particles. The filter conveyor is fitted with a spray system to maintain its filtration capacity and it must also be cleaned thoroughly once a day. In most cases, the filter conveyor can be set up to collect offal from the de-heading, filleting and skinning machines.

In the white fish industry, it is estimated that filter conveyors decrease the total COD of the load from a facility by 5–15% if the factory has a central filter conveyor, or 15–25% if the factory has a rotary sieve. In the herring filleting industry, the reductions in COD that can be achieved are as high as 30–50%, due to the greater pollution that is normally generated from gutted oily fish.

The water used for transport of offal can be filtered and recirculated. This will save water, but there are also drawbacks. When crudely filtered process water is pumped, the oil becomes emulsified in the water. This may cause an increase of consumption of chemicals for flotation or sedimentation at the wastewater treatment plant.

The collection of offal without the use of water will result in a larger quantity of offal being collected, and this will provide increased revenue from the sale of the offal to fish meal plants. The material for processing may also command a higher price, due to its reduced water content.

As a rule of thumb, at least 0.3–0.5% of the raw material weight can be collected if filtering conveyors are installed, but this figure can be as high as 1%, depending on the performance of the plant.

To install a filter conveyor 6m in length under the heading, filleting and skinning machine, the capital expenditure will be approximately as follows:

Filter conveyor with spray system	US$6300
Installation	US$1800
Miscellaneous components	US$400
Total	**US$8500**

These figures do not include the costs for a central conveyor that collects the offal from the filter conveyors. Payback times of 2–3 years have been reported however this depends on the performance of the plant and the prices obtained from the sale of the offal.

For smaller oily fish species, such as herring, the offal can be removed by a vacuum system. After the head is cut off, a vacuum is used to suck out the guts, which are passed directly to collection containers.

The removal of offal from white fish by vacuum has also been investigated. This resulted in about 70% reduction in COD of the discharged wastewater. The reduction in water use was similar, and it was estimated that up to 5% more offal was collected. This can be sold for fish meal production and thus generate an income. The system is being used only at the test plant and more experience is needed.

Case Study 3–5: Vacuum removal of offal

A large herring filleting plant has developed and installed new equipment to vacuum-remove offal from the de-headed herrings. The equipment consists of vacuum pumps, pipes and a cyclone separator. For ten filleting machines the total investment was US$80,000. Despite increased income from sales of offal and reduced costs for water, the additional annual costs are US$3150, including depreciation of the equipment. However, the water consumption has been reduced considerably, as well as the organic content of the wastewater.

3.2 Canning

Fish used for canning include sardine, anchovy, pilchard, tuna and mackerel. They are not generally gutted on board the fishing vessels, owing to the large size of the catches.

3.2.1 Unloading of fish

Process description

On the fishing vessel, the fish are held in a tank of water, referred to as the hold. The common method used for unloading the fish from the hold is the ‘wet’ unloading system. The fish, along with water from the hold, are pumped and conveyed to the processing plant along gravity-fed water flumes. The water is allowed to drain away and the fish are weighed and then returned to water-filled holding pits inside the plant.

Inputs and outputs

Figure 3–10 is a flow diagram showing the inputs and outputs from this process. Table 3–17 provides data for the key inputs and outputs.

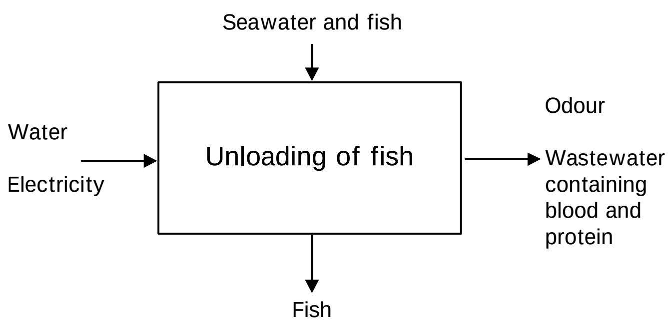

Figure 3-10 Inputs and outputs for unloading fish for canning

Table 3–17 Inputs and outputs for unloading fish for canning

Inputs		Outputs	
Fish and sea water	1000 kg	Fish	980 kg
Water	2–5 m^3	Wastewater	2–5 m^3
Electricity	3 kW.h	COD	27–34 kg

Environmental issues

Sea water is used for transporting and fluming the fish into and around the processing plant, but fresh water is sometimes added to the system to maintain a sufficient water flow.

'Bloodwater' is generated on board the fishing vessels; this term refers to the wastewaters that contain blood from the fish. Depending on fish species and the condition they are in by the time they are unloaded at the processing plant, the bloodwater can represent as much as 20–25% of the total organic load generated from a cannery.

Cleaner Production opportunities

The organic load of the wastewaters generated from the unloading process can be reduced by reducing the contamination of the fish and by chilling the catch. Efficient chilling results in the best-quality fish and reduces losses. Chilling consumes extra energy (approximately 50–60 kW.h/t ice for ice production and 50–70 kW.h for freezing), but the organic load of the wastewater is reduced considerably.

The quantity of fresh water consumed in the unloading process can be reduced by:

- limiting the amount of water added to the pumping and fluming system to that necessary for efficient transport;
- installing solenoid valves that shut off the flow of water when no fish are being unloaded;
- recirculating flume water (although this requires a filtering conveyor system to separate solid matter from the water stream before reuse);
- installing water meters to check that the unloading crew does not use more water than necessary.

Due to the oil and protein content of the bloodwater, it can be utilised for fish meal production, if there is a plant nearby. Alternatively, it can be treated and discharged to sea. Treatment usually involves passing it through a drum sieve and then through a flotation tank (oil interceptor). Using such a system can reduce COD by 6–25%, depending on the retention time. The capital investment required for such a system is of the order of US$50,000.

Treated water from the above mentioned treatment plant can be reused for unloading fish if it is treated with ultraviolet (UV) light or ozone. Samples of the treated water should be regularly tested to ensure that the water is hygienic. The water saving will be 2–5 m^3/t RM, but capital investment required for ultraviolet or ozone treatment is high.

The quality of the treated bloodwater can be further improved before discharge using a centrifuge system, which can reduce suspended matter and solids by 45% (60 kg/t RM). The capital investment required for such systems, however, is high.

Dry unloading systems, which employ vacuum suction to transport the fish, can be used to avoid the use of water. The fish are discharged onto conveyor belts for conveyance to the processing plant. Modern, dry systems can be as effective as wet unloading systems, but some water is still required occasionally to increase the unloading speed.

Mono-pumps can also be used for unloading, with reasonable performance. The capital investment required is about US$100,000 for the pumps and US$500,000 for the storage tanks. Savings in water are 1–2 m^3 of water per tonne RM and the discharge of organic matter is eliminated.

Unloading using containers or conveyors lowered into the storage hold on the fishing vessels is also possible, but access to the hold is often difficult.

3.2.2 Packing into cans

Process description

This step in the process involves separating the edible parts of the fish, cutting the fish into pieces of appropriate size and packing them into cans. From the unloading area, the fish are transported via water flumes to work stations, where they are sorted and placed onto a belt that feeds them to the cutting and packing machines.

Small-sized fish species are canned whole, whereas medium-sized species are first nobbed and then cut into pieces before canning. Nobbing is the process of simultaneously cutting off the head of the fish and removing the entrails. Tails are then cut off, and the rest of the fish is cut into smaller pieces, according to the size of the can. The fish pieces are then automatically placed in the can. Large fish species are first cooked whole, then the edible parts are removed and canned. Skinning is sometimes carried out using warm lye solutions.

Fish offcuts such as the tails, heads and entrails, are transported to the waste collection area or directly to a fish meal plant via chutes, water flumes or conveyor belt. Tails from the medium and large fish species are sometimes collected separately and used for minced products.

Inputs and outputs

Figure 3–11 is a flow diagram showing the inputs and outputs from this process. Tables 3–18, 3–19 and 3–20 provide data for key inputs and outputs.

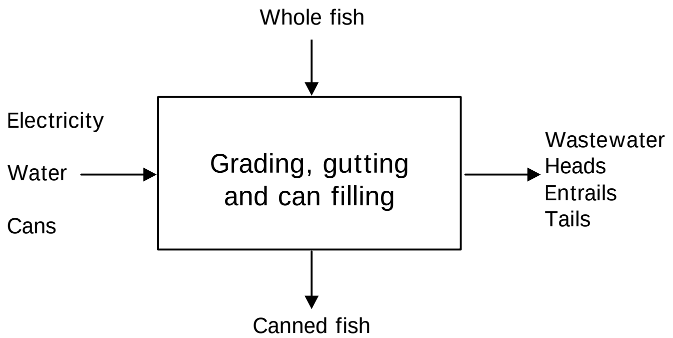

Figure 3–11 Inputs and outputs for grading, gutting and can filling

Table 3–18 Input and output data for grading of fish

Inputs		Outputs	
Whole fish	1000 kg	Graded fish	970–1000 kg
Water	0.2 m^3	Wastewater	0.2 m^3
Electricity	0.15 kW.h	COD	0.35–1.7 kg
		Solid waste	0–30 kg

Table 3–19 Input and output data for nobbing and packing in cans

Inputs		Outputs	
Graded fish	1000 kg	Canned fish	750–760 kg
Water	0.2–0.9 m^3	Wastewater	0.2–0.9 m^3
Electricity	0.4–1.5 kW.h	COD	7–15 kg
Cans	NA	Heads and entrails	150 kg
		Bones and meat	100–150 kg

Table 3–20 Input and output data for skinning of nobbed fish

Inputs		Outputs	
Nobbed fish	1000 kg	Skin-less nobbed fish	940 kg
Water	17 m^3	Wastewater	17 m^3
Chemicals	NaOH (8%)	COD	3–5 kg
Electricity	NA	Waste (skin)	~ 55 kg

Environmental issues

The main environmental issues associated with this aspect of the process are the use of water and the potential for high organic load in the wastewater stream.

Water is used continuously for the cleaning of knives and equipment and, in some instances, to align the fish.

The offal contains oil and easily dissolved organic material that can contribute a significant organic load to the wastewater. If the offal is transported away using water flumes, the potential organic load is even more significant.

Cleaner Production opportunities

Instead of nobbing the fish, the guts can be removed using vacuum suction. The entrails and offal can be transported to collection facilities or to the fish meal plant in an enclosed system instead of using water flumes. This can reduce both water consumption and the COD load of the resulting wastewater by about 67%. However, the capital investment required for this system is high.

Alternatively, installing water-efficient spray nozzles and solenoid-controlled shut-off valves can reduce water consumption by up to 50%. The capital investment required for this option is quite low.

When filling the cans with fish, caution should be taken not to contaminate the outer surface of the cans unnecessarily, because this will necessitate more washing of the cans before retorting. This good housekeeping option costs nothing, and reduces the consumption of water and chemicals for washing the cans.

Case Study 3–6: Sorting of raw material

> In the production of canned smoked sprats a grader was introduced to sort the raw material according to size.
>
> This resulted in:
>
> - fewer fish losses during smoking;
> - higher yield when de-heading;
> - better quality due to more uniform smoking.

Case Study 3–7: Water savings in a cannery

> A cannery with a processing capacity of 35–40 tonnes of fish per hour initially used 210 m^3 water per hour. An assessment revealed that one of the main areas of water use was overflow at the fish pits, because the supply line did not close properly. A 'gooseneck' was fitted to the outlet to stop the excess water flow. In addition, better nozzles were installed at the cutting and filling machines. As a result of these changes, water consumption was reduced to 70 m^3/h.

3.2.3 Precooking and can draining

Process description

Smaller fish species are precooked in the can. However, medium- and large-sized fish species are precooked before being canned to avoid the production of a cloudy sauce or brine. This section discusses the pre-cooking process.

Cooking most often takes place in water-filled cookers. After cooking, the inedible parts of the fish are removed by peeling or by cutting. The edible parts are then packed into the can. The cans are then drained to remove any expelled liquid.

Inputs and outputs

Figures 3–12 and 3–13 are flow diagrams showing the inputs and outputs from these processes. Tables 3–21 and 3–22 provide data for the key inputs and outputs.

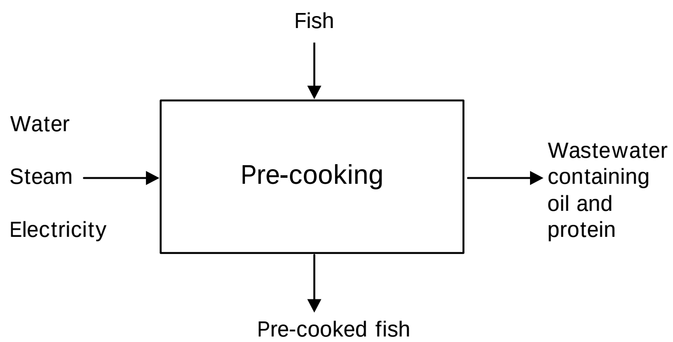

Figure 3–12 Inputs and outputs for precooking

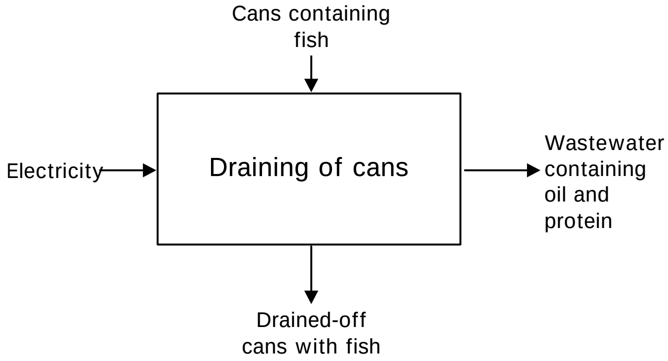

Figure 3–13 Inputs and outputs for draining of cans after pre-cooking

Table 3–21 Input and output data for precooking of fish to be canned

Inputs		Outputs	
Raw fish	1000 kg	Precooked fish (without cans)	850 kg
Steam for heating	35–560 kg	Wastewater	0.07–0.27 m^3
Electricity	0.3–1.1 kW.h	Solid waste (inedible parts)	150 kg

Note that the minimum figure for steam consumption of 35 kg (corresponding to ~28 kW.h) is for precooking of small cans containing no water, in a closed precooker. The high figure of 560 kg (corresponding to ~440 kW.h) is for fish precooked in tall cans containing water.

Table 3–22 Input and output data for draining of cans containing pre-cooked fish

Inputs		Outputs	
Cans with fish	1000 kg	Drained cans with fish	800–900 kg
Electricity	0.3 kW.h	Wastewater	0.1–0.2 m^3
		COD	3–10 kg

Environmental issues

Water is used for filling cookers and for steam production, and is sometimes added to larger cans to assist in the draining of the expelled liquid.

When the larger fish species are precooked in vats of water, oil, protein and pieces of fish are released into the water, with the oil forming a layer on the surface. When the small species of fish are cooked in cans, 10–20% of the fish weight is released as cooking water and is subsequently drained out of the can.

The liquid generated from the cooking process contains dissolved proteins and oil, with the oil content depending on the type of fish. Approximately 3–4 g oil per kilogram of fish can typically be released from oily fish, but it can also be as much as 10 g. Cooking liquids are normally discharged to the drain.

Another environmental issue associated with the cooking process is the large amount of energy used.

Cleaner Production opportunities

The cooking water can be reused repeatedly if the oil is skimmed off and the oil can be sold for fish oil production. The capital investment required for this option is low.

Cookers should always be covered and insulated to reduce heat loss. Proper insulation can be costly, but will normally pay back its costs within a few years.

Cookers should be insulated, and designed so that steam loss is minimised. Installation of a damper in the exhaust of the cooker, combined with automatic or manual control, can also be effective in reducing steam losses.

As an alternative, microwave cooking has been introduced in some plants for pre-cooking processes. The investments required are high, but water consumption is almost eliminated and energy consumption is reduced considerably, especially for fish in tall cans. Microwave cooking may increase product yield, but the process needs careful examination before changes are implemented because it may change the quality of the product.

Skimming of the oil from the cooking liquors will increase the income from selling the oil. This requires no investment, only a change in working procedures. The aqueous phase left after oil skimming can be used for production of fish soup.

As liquid is drained off it should be collected in a storage vessel. The liquid is warm, so the oil separates easily and can be removed from the surface by scraping or suction. This can significantly reduce the pollution load of wastewaters generated from the processing of oily species, and the oil can be sold as fish oil. It is much more efficient to recover the oil from the liquid immediately after draining, rather than at a later stage, as some of it will be emulsified in the water.

For large-scale production it is possible to use a centrifuge to separate the oil, but the investment required is high and requires large volumes to be cost effective.

3.2.4 Sauce filling, sealing and washing of cans

Process description

After being drained, the cans continue to the filling station where they are filled with sauce or brine, and then to the can sealer. The cans are washed to remove fish remains and sauces from the surface, which otherwise could stick when heated in the retort. The amount of water needed for washing depends on how the fish and cans were handled when the fish were packed into the cans. The need for washing increases if the operators touch the outsides of the cans unnecessarily, and when the flesh is soft and breaks easily.

Inputs and outputs

Figure 3–14 is a flow diagram showing the inputs and outputs from this process. Tables 3–23, 3–24 and 3–25 provide data for the key inputs and outputs.

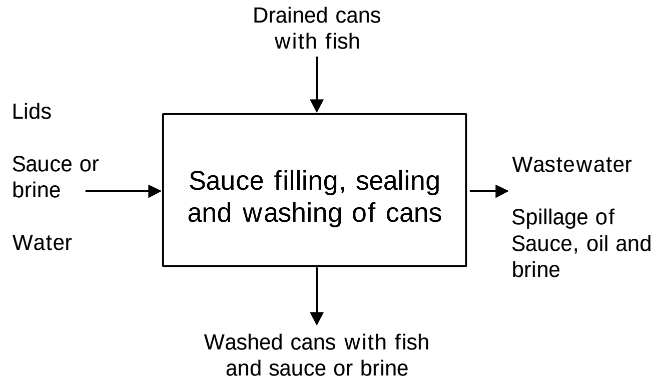

Figure 3–14 Inputs and outputs for sauce filling, sealing and can washing

Table 3–23 Input and output data for sauce filling

Inputs		Outputs	
Drained cans containing fish	1000 kg	Cans containing fish and sauce	1100 kg
Sauce and additives	NA	Waste (spillage of sauce and oil)	varies

Table 3–24 Input and output data for can sealing

Inputs		Outputs	
Cans with fish and sauce	1000 kg	Sealed cans	1000 kg
Electricity	5–6 kW.h		

Table 3–25 Input and output data for washing of cans

Inputs		Outputs	
Sealed cans	1000 kg	Washed cans	1000 kg
Water	0.04 m^3	Wastewater	0.04 m^3
Electricity	7 kW.h		

Environmental issues

The main issues are spillage of sauce, brine or oil added to the cans, and the consumption of water for washing of cans. All losses end up in the wastewater.

Cleaner Production opportunities

A sufficiently large tray to catch spillage from the filling machine should be installed. The filling machine should be well adjusted to minimise the spillage.

Cooling water from the retort or from the flotation plant can be used for washing the closed cans. This necessitates only some piping, so the required capital investment is low. The expected water savings are 0.4 m^3/t RM.

3.2.5 Can sterilisation

Process description

The purpose of sterilisation is to preserve the product. Cans are placed in baskets in a retort and heated to a set temperature for the required time to ensures proper sterilisation. A retort is a vessel that can be sealed and pressurised, containing water which is heated with steam. After sterilisation, cans are cooled to 25°–35°C with chlorinated water.

Inputs and outputs

Figure 3–15 is a flow diagram showing the inputs and outputs from this process. Table 3–26 provides data for the key inputs and outputs.

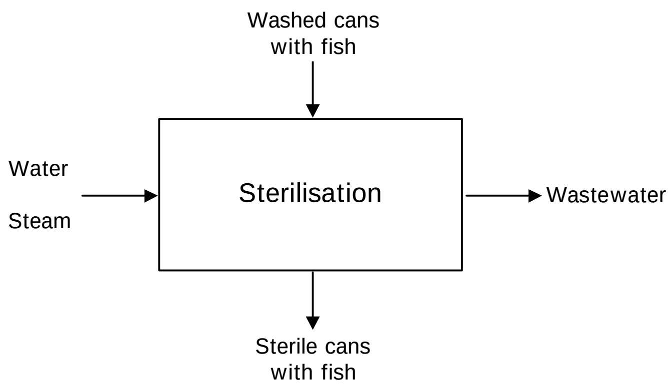

Figure 3–15 Inputs and outputs for can sterilisation

Table 3–26 Input and output data for sterilisation of cans

Inputs		Outputs	
Washed cans with fish	1000 kg	Sterile cans with fish	920–990 kg
Water	3–7 m^3	Wastewater	3–7 m^3
Steam	290 kg (~230 kW.h)	Damaged cans	10–80 kg

Environmental issues

Typically the energy consumption is 200–240 kW.h per tonne of canned product. The energy consumption is a major environmental issue, as it causes resource depletion and air pollution.

Water is used for production of steam and cooling of cans.

Cleaner Production opportunities

Water-filled retorts without a water storage facilities use approximately 75% more energy than retorts with water storage facilities. Therefore the installation of a storage tank should be considered if not already in place. The required capital investment is low, and savings are very substantial: approximately 173 kW.h and 5–6 m^3 of water per tonne RM.

Another energy-saving measure is insulation of the retort, which can save 1.4 kg fuel per tonne of canned product. This measure is costly, at around US$16,000.

Instead of discharging the water to the drain, the water can be directed to a cooling tower and reused for cooling. The number of times water can be reused depends on how clean it is maintained. The water can become contaminated with broken cans and dirt from the surface of the cans. Damaged cans should be removed before placed into the retort to avoid contamination of the water.

When the water can no longer be recirculated, it could be used to clean the sealed cans and for other cleaning activities. The investment required for installation of the necessary pipes and pumps is fairly low, and about 85% of the water can be reused.

3.3 Fish meal and fish oil production

Fish meal production consists of a dry and a wet process. Fish meal is produced in the dry process, and fish oil from the wet process.

3.3.1 Handling and unloading of fish

Process description

Fish for fish meal and fish oil production are caught in large shoals and stored in bulk on the vessel until they can be transported to the plant.

Fish are commonly unloaded from the fishing vessel to the processing plant using a 'wet' unloading method. The fish are pumped out of the vessel's hold and conveyed to the plant in gravity flumes, which float the fish in water. The water, referred to a bloodwater, is drained off, and the fish are weighed and then released into the storage pits inside the plant. Some plants treat the bloodwater through a screen or flotation tank before being discharged to the ocean.

Inputs and outputs

Figure 3–16 is a flow diagram showing the inputs and outputs from this process. Tables 3–27 and 3–28 provide data for the key inputs and outputs for the handling and storage, and unloading of fish respectively.

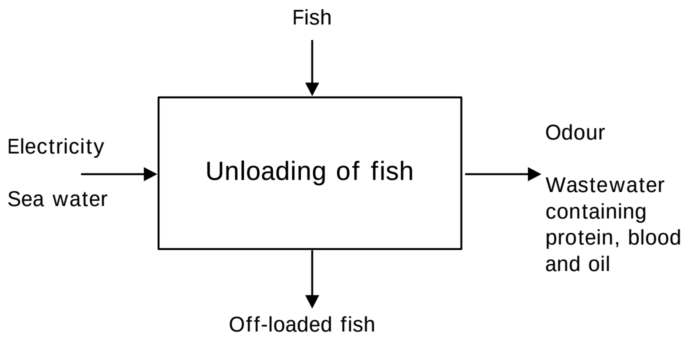

Figure 3–16 Inputs and outputs for unloading of fish

Table 3–27 Input and output data for handling and storage of fish

Inputs		Outputs	
Fish catch	1000 kg	Quantity of fish unloaded	850–870 kg
Electricity	10–12 kW.h	COD	130–140 kg
Ice	200 kg		

Table 3–28 Input and output data for unloading of fish

Inputs		Outputs	
Fish	1000 kg	Off-loaded fish	750–1000 kg
Water	2–5 m^3	Wastewater	2–5 m^3
Electricity	3 kW.h	COD	27–34 kg

Environmental issues

Fish rapidly deteriorate leading to softening of the meat and formation of considerable amounts of bloodwater containing protein and oil. Bloodwater can be heavily contaminated by organic matter, depending on the quality and type of fish. The COD of the bloodwater is normally 15,000–70,000 mg/L but can attain several hundreds of thousands of mg per litre.

Cleaner Production opportunities

Handling of the catch on board the vessel is not under the direct control of the fish meal plants, but has a significant impact on the pollution arising from production.

In some industries, the quality of the raw fish is used to set the price paid and this encourages the fishing companies to take better care of the catch. A higher yield can be expected in processing due to higher quality inputs.

The best way of preserving the catch is by chilling. This can be done using cooling systems that use mechanically refrigerated sea water, or by mixing the fish with ice. Mixing with ice can be done manually, but is better done automatically. The chilling will give a better fish meal quality and the oil yield can be increased up to 50%.

Case Study 3–8: Reduction of pollution from Danish fish meal plants

Fish meal plants in Denmark have over a number of years been forced to reduce their overall pollution by 80% or 6200 tonnes COD/year. Improving the quality of the raw material has been one of the most important ways of achieving this reduction. Other ways of minimising pollution have been to improve the efficiency of the pressing, decanting and centrifuging processes. It has also been necessary to improve filtering and wastewater treatment.

Dry unloading, using pneumatic off-loaders or elevators, can be used instead of wet unloading. The investment required for dry unloading is high, but energy consumption may be reduced by 25–50%.

Bloodwater should, if possible, be evaporated with the stickwater in the evaporation plant (see Section 3.4.9). Alternatively, the bloodwater can be collected and sent to the fish meal and fish oil plant, where the solid material is recovered in the decanter for subsequent recovery as fish meal (see Section 3.4.6).

3.3.2 Cooking

Process description

Fish are conveyed through a continuous cooker by means of a rotary screw conveyor and cooked at a temperature of 95°–100°C as it travels through the cooker. Heat is applied to the cooker indirectly through a steam-heated jacket that surrounding the screw conveyor.

Inputs and outputs

Figure 3–17 is a flow diagram showing the inputs and outputs from this process. Table 3–29 provides data for the key inputs and outputs.

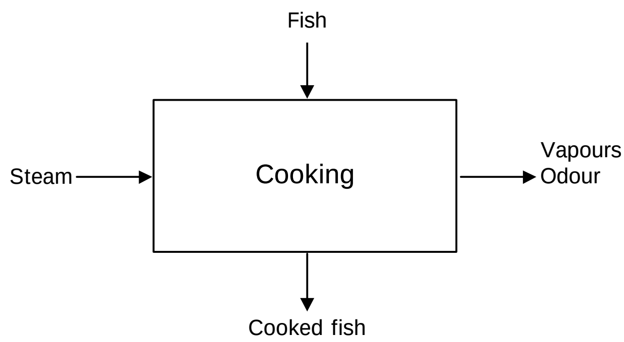

Figure 3–17 Inputs and outputs for cooking fish

Table 3–29 Input and output data for cooking of fish

Inputs		Outputs	
Fish	1000 kg	Cooked fish	1000 kg
Steam	115 kg (~90 kW.h)		

Environmental issues

The process consumes considerable amount of energy and can generate odours.

Cleaner Production opportunities

Energy consumption can be reduced by cleaning the internal surfaces of the cooker at regular intervals to avoid the accumulation of deposits on the heated surfaces, which would otherwise inhibit heat transfer. Energy consumption can be further reduced through careful control of the cooker temperatures.

Waste heat from the evaporators and dryers (used in subsequent processes) can be used to pre-heat the material up to approximately 50°C. The required capital investment is low compared with the savings in energy consumption.

Odorous fumes can be ducted to the boiler and incinerated, which substantially reduces odour problems. The required capital investment is relatively low.

3.3.3 Straining and pressing

Process description

The cooking process releases oil and water from the solid mass. The released liquids are drained from the mass in a strainer. Most of the oil and water can be separated from the solid phase by this straining process, however more can be removed by treating the solid phase in a press or centrifuge. Reducing the moisture content of the solid fish cake helps to reduce fuel consumption during subsequent drying steps.

The products from this process are press cake (the solid material) and the oily water. The subsequent drying and milling of the press cake to produce fish meal are discussed in Sections 3.4.4–3.4.5, and the further processing of the oily water to produce fish oil are discussed in Sections 3.4.6–3.4.8.

Inputs and outputs

Figure 3–18 is a flow diagram showing the inputs and outputs from this process. Table 3–30 provides data for the key inputs and outputs.

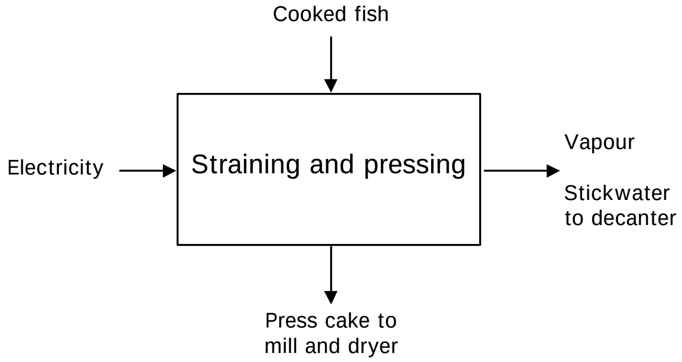

Figure 3–18 Inputs and outputs for pre-straining and pressing

Table 3–30 Input and output data for pressing the cooked fish

Inputs		Outputs	
Cooked fish	1000 kg	Stickwater	750 kg water
Electricity	NA		150 kg oil
		Press cake	100 kg dry matter

Cleaner Production opportunities

For most raw materials, apertures of 4–6 mm diameter in the strainer are suitable. Substantially larger diameters will cause problems, as the large particles allowed to pass through the strainer will tend to block the pump conveying the liquid. The presence of solid material in the screened liquid will also reduce the efficiency of subsequent steps. By ensuring the optimum diameter for the screen apertures, better performance and higher yield will be obtained.

Problems may occur when soft, partly deteriorated fish are processed. Poor quality materials contain large amounts of fine particulate matter (sludge), which tend to clog up the outlets of the press. If better raw material cannot be obtained, the size of the holes in the pre-strainer should be increased.

Increasing the pressure of the press will improve the recovery of liquid.

3.3.4 Drying of press cake

Process description

The purpose of drying is to convert the wet press cake into a stable, preserved meal. The sludge from the decanter (see Section 3.4.6) is also added to the press cake before drying.

Drying may take place using either direct-fired drying or indirect steam drying. For direct-fired drying, hot air is passed through the dryer and comes in direct contact with the press cake. This is the most efficient mode of heat transfer, but it is more difficult to control than other methods. For the indirect steam drying, the press cake is fed continuously into a rotary apparatus containing steam-heated elements (tubes, discs, coils etc.). A counter-current stream of air is blown through the dryer to remove water vapour. Indirect steam drying is less energy efficient than direct-fired drying.

Odourous gases released from the drying process, along with those from other parts of the process (cookers, strainers, presses etc.), are often treated before being released.

Inputs and outputs

Figure 3–19 is a flow diagram showing the inputs and outputs from this process. Table 3–31 provides data for the key inputs and outputs.

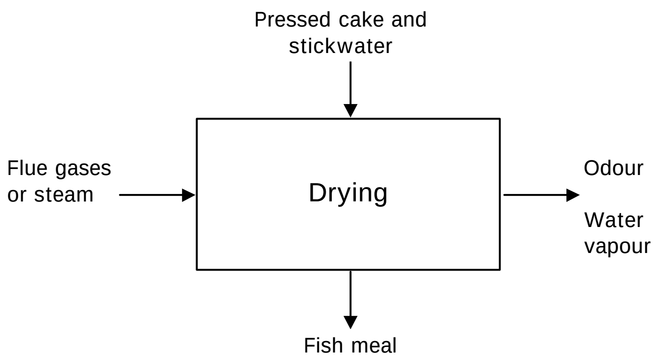

Figure 3–19 Inputs and outputs for drying

Table 3–31 Input and output data for drying

Inputs		Outputs	
Press cake and stickwater	1000 kg	Fish meal	480 kg (12% moisture)
Steam	430 kg (~340 kW.h)	Vapour	~520 kg

Environmental issues

The process uses large amounts of energy for heating, and can cause highly objectionable odours.

Cleaner Production opportunities

In modern indirect steam dryers, heat can be recovered and used in the evaporation plant (see Section 3.4.9). This saves considerable amounts of energy, but requires installation of piping and heat exchangers.

The temperature in indirect steam dryers should be carefully controlled to avoid scorching of the fish meal, which greatly exacerbates odour problems.

High-temperature combustion of the odourous gases from the dryers is a very efficient and relatively cheap method for dealing with odourous emissions. The gaseous emissions can be collected and burnt in the boiler. This method is most easily used at plants which use dry indirect steam dryers, since there is usually a boiler on site.

Saltwater scrubbers can also be used to reduce odour. Cool waters recirculated in the scrubber acts to condense the vapours and reduces the gas volume by some 40%. The gases exiting the scrubber may also be chemically denatured using hypochlorite as the oxidising agent.

3.3.5 Milling and packaging of fish meal

Process description

Dried fish meal first passes through a sieve to remove extraneous matter and is then milled before being automatically weighed into bags for distribution and sale.

Inputs and outputs

Figure 3–20 is a flow diagram showing the inputs and outputs from this process. Table 3–32 provides data for the key inputs and outputs.

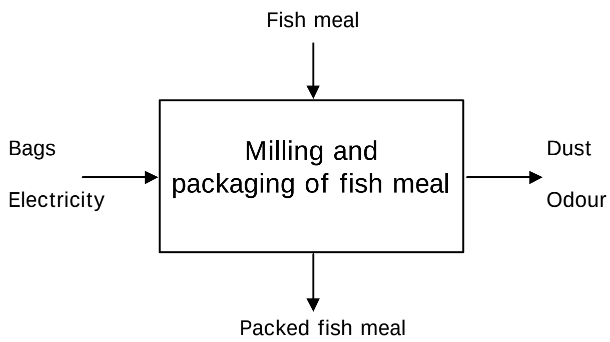

Figure 3–20 Inputs and outputs for milling and packing of fish meal

Table 3–32 Input and output data for milling and packing of fish meal

Inputs		Outputs	
Fish meal	1000 kg	Packed fish meal	1000 kg
Electricity	NA	Dust	NA
Bags	NA	Odour	NA

Environmental issues

Dust and odour emitted from the milling processes may cause some localised annoyance as well as an unhealthy work environment for operators.

Cleaner Production opportunities

The mill should be regularly cleaned to avoid clogging and regularly maintained to help avoid spillages.

Odour gases from the milling process should be extracted for treatment along with the other odourous steams before being released.

3.3.6 Decanting of press liquid

Process description

Press liquid from the straining and pressing process (see Section 3.4.3) is transferred to a decanter, along with bloodwater from the unloading of fish (see Section 3.4.1). The decanter is a horizontal centrifuge with two- or three-phase separation.

The first phase removes about half of the dry matter from the press water (which contains approximately 10% dry matter before decanting) which is sent to the dryer (see Section 3.4.4). In the second phase, water containing sludge is removed. In the third phase, decanter liquid (impure oil) is separated. The liquids flow through a closed system and no pollution should occur from this step.

Figure 3–21 is a flow diagram showing the inputs and outputs from this process. Table 3–33 provides data for the key inputs and outputs.

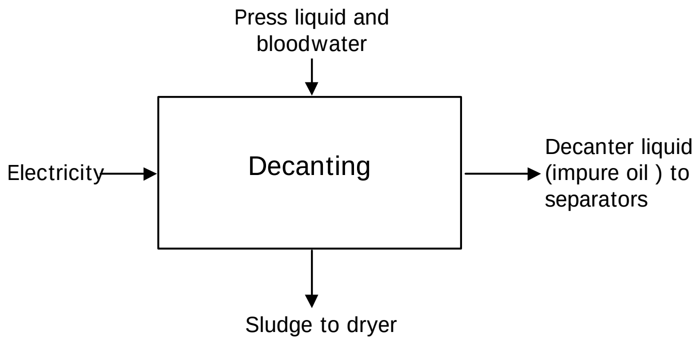

Figure 3–21 Inputs and outputs for decanting of press liquid

Table 3–33 Input and output data for decanting of press liquid

Inputs		Outputs	
Press liquid and bloodwater	1000 kg	Impure oil (decanter liquid)	900 kg
Electricity	NA	Sludge to dryer	100 kg

Cleaner Production opportunities

If the decanter and pumps are old, changing to newer, more energy-efficient equipment should be considered. Equipment specifications can be obtained from various suppliers in order to compare the stated energy consumption rates.

3.3.7 Centrifugation of decanter liquid

Process description

In this step, decanter liquid (impure oil) is centrifuged further to separate the fish oil from the aqueous phase. The resulting wastewater from the process is referred to as stickwater.

After centrifugation, the stickwater contains 5–10% dry matter and 1% oil. The stickwater is then pumped to the evaporators and the oil is sent for further processing.

Inputs and outputs

Figure 3–22 is a flow diagram showing the inputs and outputs from this process. Table 3–34 provides data for the key inputs and outputs.

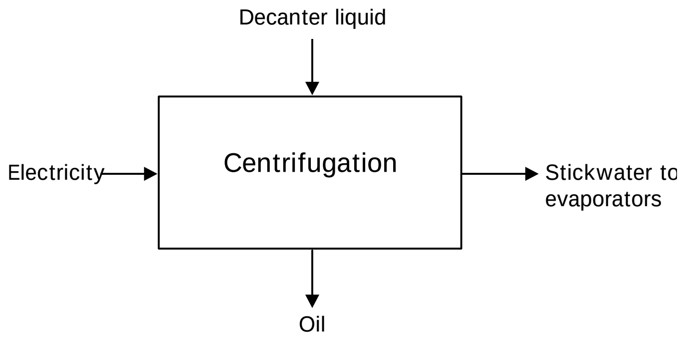

Figure 3–22 Inputs and outputs for heating and centrifugation

Table 3–34 Input and output data for centrifuging of the decanter liquid

Inputs		Outputs	
Decanter liquid	1000 kg	Oil	10 kg
Electricity	NA	Stickwater	900–950 kg water
			50–100 kg dry matter

Environmental issues

The average COD of stickwater is more than 100,000 mg/L and causes significant pollution if discharged. In some places or under some conditions, stickwater is discharged to sewer.

Cleaner Production opportunities

Since stickwater represents a substantial pollution load and a loss of product, it is important to ensure that all stickwater is transferred to the evaporators and used in production. This does not require any capital investment—just a good knowledge of the equipment and processes.

3.3.8 Fish oil polishing

Process description

The purpose of this process is to refine or 'polish' the oil extracted from the decanting process. Polishing is carried out by extracting impurities from the oil using hot water at about 95°C.

Figure 3–23 is a flow diagram showing the inputs and outputs from this process. Table 3–35 provides data for the key inputs and outputs.

Environmental issues

Hot water is used for polishing, thus this process is energy consuming. The energy consumption depends on the amount of water used and whether the hot water is generated from waste heat (e.g. from drying) or from steam.

The polishing process generates a low-volume, high-strength effluent. The volume of this effluent is about 0.07 m^3 per tonne processed and the effluent quality, measured as COD, varies between 20,000 and 200,000 mg/L.

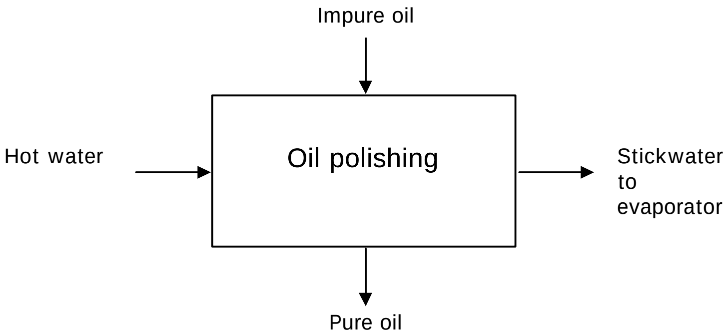

Figure 3–23 Inputs and outputs for oil polishing

Table 3–35 Inputs and outputs for oil polishing

Inputs		Outputs	
Impure oil	1000 kg	Pure oil	~1000 kg
Water	0.05–0.1 m^3	Wastewater	0.05–0.1 m^3
Energy	hot water	COD	~5 kg

Cleaner Production opportunities

The use of waste heat for this and other processes will reduce energy consumption, and will also help to reduce the temperature of the wastewater. Waste heat recovery requires a heat exchanger, an insulated hot water tank and the necessary piping.

The effluent should be collected and sent to the evaporators, to prevent the discharge of highly polluted liquid.

3.3.9 Stickwater evaporation

Process description

The stickwater from the centrifuges and oil polishing process is concentrated in an evaporation unit. Normally, a multi-stage evaporator is used, where the pressure is successively lowered and waste heat from the previous phases is reused. From each phase, stickwater concentrate or condensed fish solubles are drawn off. The remaining solution
(50–60% water) is added to the press cake in the dryer from where the end product, fish meal, is produced.

Two types of evaporators are used:

- Falling film evaporators, with no recirculation and short retention times, are effective at handling heat-sensitive products.
- Circulating evaporators can operate over a wide range of concentrations in a single unit. Self-circulating evaporators are normally less energy efficient than forced-circulation and falling film evaporators.

The stickwater plant needs to be cleaned at regular intervals, either mechanically or by using caustic soda.

Inputs and outputs

Figure 3–24 is a flow diagram showing the inputs and outputs from this process. Table 3–36 provides data for the key inputs and outputs.

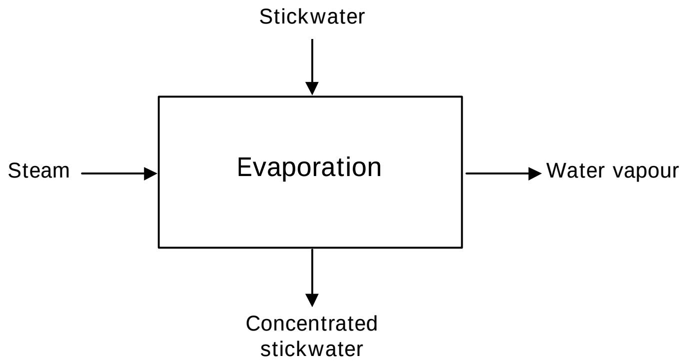

Figure 3–24 Inputs and outputs for evaporation

Table 3–36 Material balance for evaporation of stickwater

Inputs		Outputs	
Stickwater	1000 kg	Concentrated stickwater	250 kg
Steam	600 kg (~475 kW.h)	Dry matter	up to 50 kg
		Water vapour	~700 kg

Environmental issues

As the water evaporates, the viscosity of the stickwater increases and this in the end determines how high a concentration can be obtained. If bumping occurs during heating, there is a risk that material will be carried away with the steam, thus resulting in increased air emissions. Approximately 25% of the dry matter from the fish will pass through the evaporators. The pollution is thus increased greatly when the stickwater plant is not running. Processing 1000 kg of fish with a dry matter content of 20% will yield 200 kg of dry matter. If the stickwater is not used, 50 kg of dry matter will be discharged.

Significant quantities of energy are used to evaporate the water. Typically, figures for steam consumption are 0.40–0.45 kg steam per kilogram of water evaporated in a triple effect evaporator.

Cleaner Production opportunities

The nature of the stickwater is such that the evaporator tubes are easily fouled, with consequent reduction in thermal efficiency and capacity. The evaporators should therefore be cleaned frequently to restore efficiency. When a processing plant is operated at full capacity for many hours, declining performance and cleaning of the evaporators result in an accumulation of stickwater and bloodwater, which ultimately must be discharged if the plant is not shut down during the cleaning process. Stickwater condensate can be used for flushing and cleaning before and after caustic soda treatment. The liquid can be collected and evaporated in the evaporation plant. Thus, discharge of highly polluting stickwater is avoided without capital investment.

Modern falling film evaporators have a shorter retention time and low hold-up volumes. This makes them more efficient to start up for small-scale production. The investments necessary for reusing the surplus heat are low (the requirements are a heat exchanger, a hot water storage tank and piping). It is more costly to install new evaporators; however, both options will reduce energy consumption.

3.3.10 Acid hydrolysis to produce silage

Instead of using fish waste to produce fish meal and oil, it can be converted into silage, which can be used as a nutritious animal feed. Fish silage is a liquefied fish product produced by grinding and acid hydrolysis of fish or fish scrap. The acid hydrolysis process breaks the fish proteins down to single amino acids and small peptide fragments.

Production of silage is a good option when there is animal farming nearby. The feed can be used for pigs, poultry and ruminants. The silage is added to the feed mixture in different amounts (5–20% by weight) depending on species and age of the animal.

Besides its high nutritional value, an advantage of silage is that the processing is simple, with no requirement for specialised equipment, and required capital investment is low. It can be carried out at small and large installations.

3.3.11 Protein hydrolysates

An alternative to producing silage by acid hydrolysis is to use enzymatic hydrolysis to produce protein hydrolysates. This process allows the hydrolysis to be controlled so that not all the proteins are hydrolysed down to single amino acids, producing a better and more palatable feed ingredient.

Enzymatic hydrolysis also operates under acid conditions. However proteolytic enzymes are added to the minced fish along with minerals or organic acids. The mixture is heated to 65ºC to solubilise the protein.

Compared with acid hydrolysis, this process involves considerable capital and technical investment, which might not be attractive for small or seasonal operations.

3.4 Cleaning

Process description

In a fish processing plant work areas and equipment that are in contact with fish must be cleaned and sanitised regularly to maintain hygienic conditions. Cleaning requirements are normally stipulated by regulation. All production areas and equipment are cleaned daily, and the floors and machinery are also rinsed during production.

A common cleaning routine at fish processing plants is to first hose down equipment and floors roughly, to enhance the effect of detergents. Detergents and sanitising agents are then applied, followed by washing and scrubbing. The detergents used are normally alkaline, in order to remove oil and protein. There is a final rinse with clean water to remove all detergent and sanitising agents.

Inputs and outputs

Figure 3–25 is a flow diagram showing the inputs and outputs from this process.

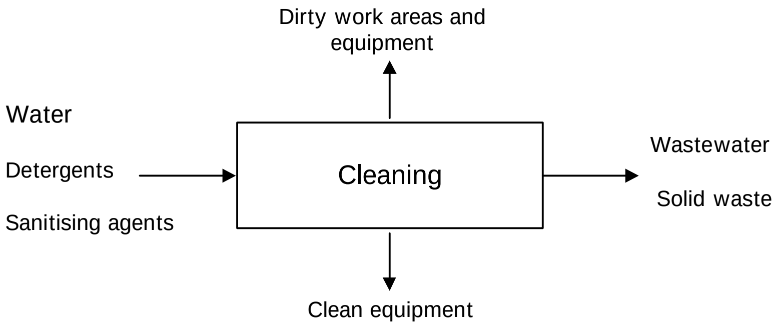

Figure 3–25 Inputs and outputs for cleaning

Environmental issues

The water consumption for cleaning can be very high accounting for 25–40% of the total water used at a fish processing plant.

The organic load contained in cleaning wastewater is high, containing fish wastes which have been washed to the drain. Cleaning wastewaters also contain detergents and disinfectants. In addition, hazardous substances such as sodium hydroxide and sodium hypochlorite are sometimes used in conjunction with cleaning.

Cleaner Production opportunities

A large part of the water for cleaning—about 70%—is consumed during the initial rinse step. Therefore this is an areas where significant water savings can be made The best way of reducing water consumption for cleaning is to undertake dry cleaning before washing with water.

Solid materials should first be scraped and swept from all surfaces and floors. Following thorough dry cleaning, work surfaces, walls and floors can be washed down in preparation for cleaning and sanitising. The following measures will help reduce water consumption for this step:

- hoses should be fitted with spray nozzles, since a pressurised spray is far more effective for cleaning surfaces and therefore uses less water. A pressure of 25–30 bar is advisable.
- flat-jet nozzles provide maximum impact and velocity for any given pressure. Spray angles of up to 60° provide wide coverage and a sweeping effect to propel remaining solids towards floor drains.
- the first rinse should be with cold water, because warm water will make protein materials stick to the surfaces. The temperature of the water for the subsequent cleaning depends on the kind of contamination; however cold water is often sufficient.
- the wastewater from the final rinse can be collected and used for the initial rinse on the following day.

Detergents and disinfectants can be a significant source of pollution if the amounts used are too great. It is very important, therefore, to monitor their consumption.

The following measures will help reduce detergent consumption:

- determining the required amount or concentration for effective cleaning;
- scraping followed by an initial rinse. This will reduce the consumption of detergents for dissolving organic matter and oil;
- applying detergents in a certain ratio with water, so a reduction in water consumption will reduce the consumption of detergents;
- using newer detergents, some of which are more effective and more environmentally friendly than older ones. alternative detergents should be evaluated on the basis of their cleaning performance as well as their cost and environmental attributes.

Sanitisers should be applied as a fine spray to cleaned surfaces, instead of a final rinse with hot water (about 82ºC). Chemical sanitisers can be more effective in bacteriological control, less damaging to the building and safer for personnel than large quantities of hot water (McNeil and Husband, 1995).

Spray nozzles, commonly used for cleaning operations, are subject to wear that causes deterioration of the orifice and distortion to the spray pattern. This results in an increased flowrate of water and reduced effectiveness. In general, 10% nozzle wear will result in a 20% increase in water consumption (McNeil and Husband, 1995).). Nozzles made from different materials have varying abrasion resistance, as shown in Table 3–37.

Table 3-37 Abrasion wear index for nozzle materials [1]

Material	Abrasion wear index
Brass	1 (poor)
Stainless steel	4–6 (good)
Hard plastics	4–6 (good)
Ceramic	90–200 (excellent)

[1] McNeil and Husband, 1995

Regular monitoring of spray nozzle wear should be incorporated into maintenance programs. Nozzles in service can be compared with new nozzles to determine the extent of wear, and the flowrate of a nozzle can be determined by measuring the time taken to fill a container of known volume.

Case Study 3–9: Cleaning in a herring processing factory

At a Danish herring processing plant, cleaning equipment consists of two 500 L water storage containers, two pumps, a flow meter, a timer and various valves. One of the two containers is first filled with clean water and used to commence cleaning of plant equipment. The cleaning wastewaters drain through the filter conveyor and are pumped back into the water storage container. When the flow meter has measured consumption of four times the container volume (about 2 m^3), the second water storage container, which has been filled with clean water in the meantime, is used as the water supply. The first container is then refilled with clean water, and so on, so that the cleaning process proceeds uninterruptedly.

The use of this system has reduced fresh water consumption for cleaning in the herring processing plant by 75%. This type of cleaning system could be used for plants processing white fish as well.

3.5 Ancillary operations

3.5.1 Compressed air supply

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

Inputs and outputs

Figure 3–26 is a flow diagram showing the inputs and outputs for this process.

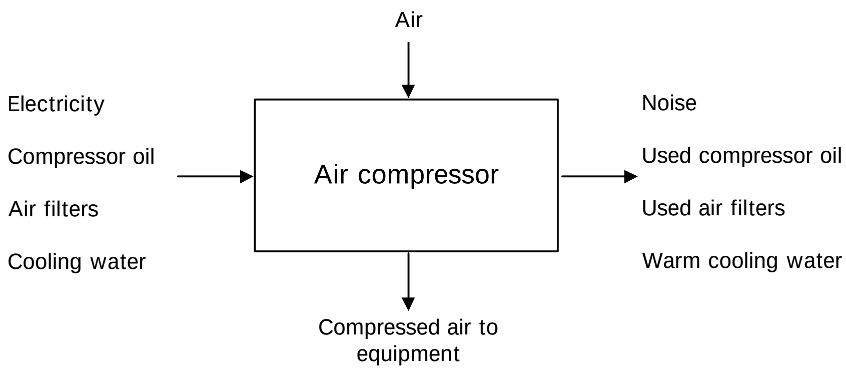

Figure 3–26 Inputs and outputs for production of compressed air

Environmental issues

With just a few small holes in the compressed air system (pipes, valves etc.), a large amount of compressed air is continuously lost. This results in a waste of electricity because the compressor has to run more than is necessary. Table 3–38 lists unnecessary electricity consumption that can be caused by leaks in the compressed air system.

Table 3–38 Electricity losses from leaks in 6 bar compressed air system [1]

Hole size (mm)	Air losses (L/s)	kW.h/day	MW.h/year
1	1	6	3
3	19	74	27
5	27	199	73

[1] UNEP, 1996

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

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

Cleaner Production opportunities

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

Maintenance (e.g. change of compressor oil) and the keeping of accurate log-books will often help identify the onset of system leaks.

A great deal of energy can be saved through these simple measures. It pays to implement procedures that ensure the compressed air system is leak free and well maintained.

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

Case Study 3–10: Reuse of cooling water

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

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

3.5.2 Steam supply

Process description

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

Inputs and outputs

Figure 3–27 is a flow diagram showing the inputs and outputs for this process.

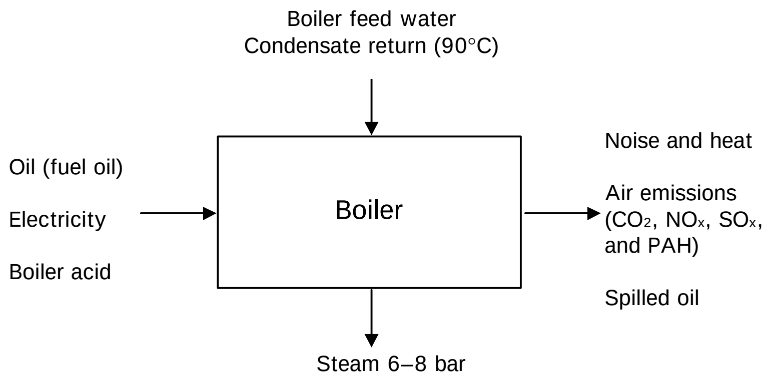

Figure 3–27 Inputs and outputs for supply of steam

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

Environmental issues

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

Combustion of fuel oil results in emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and polycyclic aromatic hydrocarbons (PAHs). Some fuel oils contain 3–5% sulphur and result in sulphur dioxide emissions of 50–85 kg per 1000 litres of fuel oil.

Sulphur dioxide converts to sulfuric acid in the atmosphere, resulting in the formation of acid rain. Nitrogen oxides contribute to smog and can cause lung irritation.

If the combustion is not adjusted properly, and if the air:oil ratio is too low, there are high emissions of soot from the burners. Soot regularly contains PAHs that are carcinogenic. Table 3–39 shows the emissions produced from the combustion of various fuels to produce steam.

Table 3–39 Emissions from the combustion of fuel oil

Input		**Outputs**	
Fuel oil (1% sulphur)	1 kg	Energy content	11.5 kW.h
		Carbon dioxide (CO_2)	3.5 kg
		Nitrogen oxides (NO_x)	0.01 kg
		Sulphur dioxide (SO_2)	0.02 kg

1 kg of oil = 1.16 litre of oil (0.86 kg/L)

1 kW.h = 3.6 MJ

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

Cleaner Production opportunities

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

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

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

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

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

- valves, flanges;
- scalding vats/tanks;
- autoclaves;
- cooking vats;
- pipe connections to machinery.

Through proper insulation of this equipment, heat losses can be reduced by 90%. Often the payback period for insulation is less than 3 years.

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

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

Case Study 3–11: Biogas production from fish waste

A New Zealand fish processor decided to look for an alternative to landfill for disposal of its fish wastes. After considerable research, the company installed a fish biodigester. Using anaerobic digestion, the plant now produces two useful by-products: methane and fertiliser. Methane (biogas) is used to heat the digester and to supplement the energy requirements of the plant. Sales of the by-products of what previously was waste are US$9000 per month. Energy savings amount to US$4000 per year and annual disposal charges of US$12,500 have been saved. The overall payback period is estimated at 6 years.

Case Study 3–12: Poorly operated coal-fired boiler

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

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

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

3.5.3 Water supply

Process description

High-quality domestic water supplies may not need any treatment before use in the plant. However if the available water is of poor quality it may be necessary to treat it to meet hygiene requirements. Treatment normally consists of aeration and filtration through gravel or sand and chlorination may also be necessary.

Inputs and outputs

Figure 3–28 is a flow diagram showing the inputs and outputs from this process.

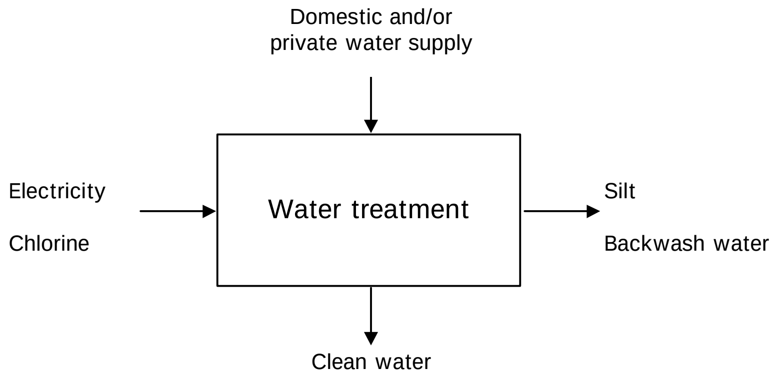

Figure 3–28 Inputs and outputs for water treatment

Environmental issues

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

The losses that occur due to holes in water pipes and running taps can be considerable. Table 3–40 shows the relationship between size of leaks and water loss.

Table 3–40 Water loss from leaks at 4.5 bar pressure [1]

Hole size (mm)	**Water loss** (m^3/day)	**Water loss** (m^3/year)
0.5	0.4	140
1	1.2	430
2	3.7	1300
4	18	6400
6	47	17,000

[1] UNEP, 1996.

Cleaner Production opportunities

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

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

3.5.4 Refrigeration and cooling

Process description

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

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

Inputs and outputs

Figure 3–29 is a flow diagram showing the inputs and outputs from this process.

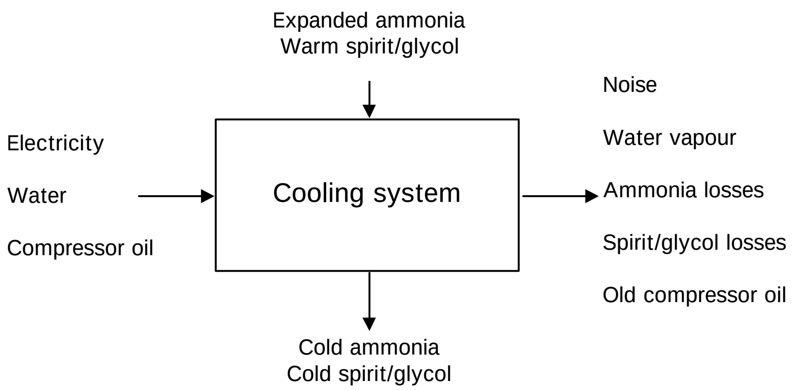

Figure 3–29 Inputs and outputs for cooling system

Environmental issues

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

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

Cleaner Production opportunities

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

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

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

4 CLEANER PRODUCTION CASE STUDY

This case study originates from a Cleaner Production assessment carried out at a Polish herring filleting plant. It shows what the company did and what the assessment achieved. The description below follows the Cleaner Production assessment methodology described in Chapter 5.

4.1 Phase I: Planning and organisation

Obtain management commitment

The company was under pressure from the local authorities because the organic load in the wastewater was too high; and the neighbours complained about odour and effluent from the plant. For these reasons, the managing director committed the company to a project aimed at reducing the company's emissions to the environment.

Set up a project team

A team was established, consisting of the managing director, the technical engineer and supervisors from the various departments. In addition, consultants were commissioned to assist with the project.

Develop environmental policy

The company decided on the following environmental policy:

Overall aim:

- to upgrade production whilst meeting the demands of the local and central authorities;
- to address the complaints of residents nearby.

Objectives:

- to increase yield;
- to decrease pollution load in effluent;
- to reduce odour; and
- to improve work environment.

Targets:

- to increase yield by 3%;
- to reduce water consumption and wastewater volumes by 50%;
- to receive no complaints from neighbours.

Plan the Cleaner Production assessment

The project team decided to focus the Cleaner Production assessment on the filleting line. The timeframe set for implementing the Cleaner Production initiatives was 2 years. They decided on the following steps:

4.2 Phase II: Pre-assessment

Describe the process

The project team first prepared a short description and flow chart of the production processes.

The company processes both herring and cod. However this project involved the herring processing lines only. The company processes 4000 tonnes of raw herring per year and produces frozen and marinated fillets. The production of herring takes place in two mechanical filleting lines and a hand filleting line. The solid waste is treated in a fish meal plant owned by the same company.

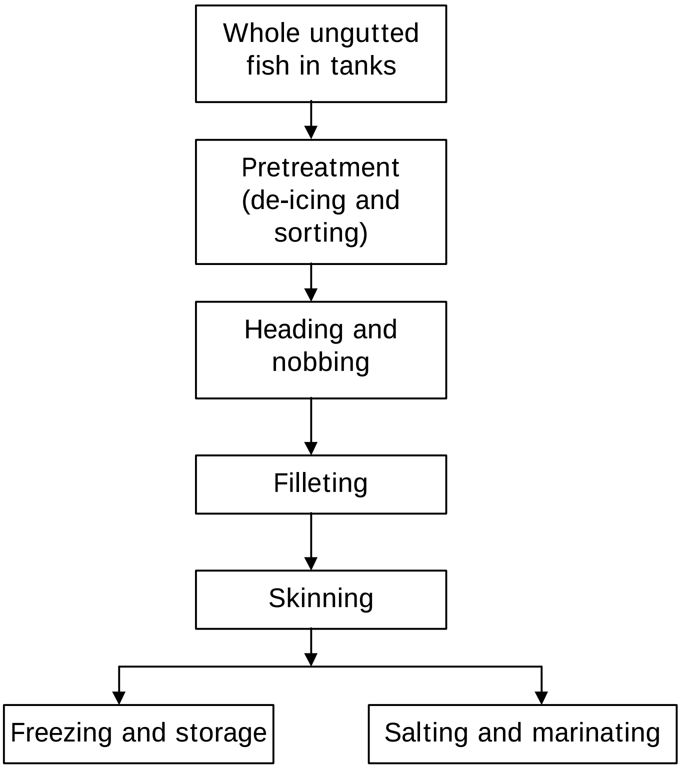

Figure 4–1 Process flow chart of the operation

Undertake walk-through site inspection

A site inspection revealed the following problems:

- poor housekeeping, resulting in excessive waste on floors;
- running hoses;
- poor hygiene;
- insufficient monitoring of yields;
- poor maintenance of equipment;
- a very damp, cold work environment, with waste making the floors wet and slippery;
- an overall impression of untidiness.

Plan assessment phase

The project team decided to focus the Cleaner Production assessment on the herring filleting department because it generates a large quantity of wastewater with a high content of organic matter and it causes economic losses. The yield had earlier been estimated to be 3–5% lower than optimum levels.

In addition, it was felt that quality, hygiene and waste treatment could be improved significantly.

4.3 Phase III: Assessment

Collect data

The team made a sketch of the plant, showing the water and wastewater reticulation system. On the basis of this sketch, the team decided where to install water meters and where to take samples of the wastewater stream. For each key process are, the following were measured:

- water consumption;
- organic load (COD) and suspended solids content of the wastewater;
- energy consumption; and
- product yields.

Operators read water meters regularly and, when necessary, took manual measurements of flow rates. Effluent samples were sent to a laboratory.

This data was tabulated for each process, resulting in key figures that could then be used as benchmarks against which to track improvement.

Identify Cleaner Production options

Cleaner Production pitons were identified for every process and problem. Team members met with the consultants to discuss solutions to the various problems. Those that were considered feasible are listed in Table 4–1.

4.4 Phase IV: Evaluation and feasibility study

Undertake preliminary evaluation

The project team went through a long list of possible options—far more than those shown in Table 4–1. As most of the possible options had been implemented at other plants in the past, the preliminary evaluation was quickly done.

The option for producing silage from offal had to undergo some testing to determine whether a viable market existed. Farmers were called upon to conduct feeding trials to verify the nutritional value of the silage and a promote a market for the product.

Undertake technical evaluation

The staff member responsible for technical and production issues examined the reduced list of options. This was done to exclude options that had a negative impact on product quality and to ensure that selected options were not restricted by site-specific or technical conditions.

Undertake economic evaluation

The project team estimated the investment required for each option, including equipment costs, the cost of construction and the time needed for making changes. If the estimated yield improvement and increased earnings on the silage were valid, the pay-back time would be approximately 2 years. The technical team made a prioritised action list and presented this to the managing director for final approval.

Undertake environmental evaluation

By implementing the options, the project team expected a 50% reduction in water use and a similar reduction in organic load in effluent.

Table 4–1 List of Cleaner Production options

Problem	Description	Proposed solution	Expected improvement	Time span	Capital cost	Operational cost
Low yield	Yield and quality were estimated to be 3–5% lower than expected. The excessive flesh on the skeleton adds to the pollution due to fluming and pumping of offal in excessive water.	Introduce grading of raw material. Introduce production control system, weighing input and output from important processes, in order to minimise waste and continuously check performance. Introduce a daily production report showing all key figures. Refurbish existing filleting machines, including the purchase of new knives and other spare parts. Undertake machinery tests. Introduce regular maintenance of machinery. Train operators and produce short manuals for checking individual machines to improve operation.	Yield increase of 3–5% Less solid waste Less waste in effluent	6 months	Total US$65,000	Low
Excessive water use	Water was used unnecessarily, both on machines and by operators. The plant used 32 m^3 water per tonne of raw material.	Stop all running hoses by installing spray guns. Reduce consumption on filleting machines by installing solenoid valves and nozzles using less water. Reduce or stop overflow from bins by installing valves. Avoid unnecessary washing of fillets. Change transport of offal (see next). Monitor consumption on installed water meters.	Reduction of 50% in water use from 32 m^3/t to 16 m^3/t raw material	1 month	US$2500	Low

Table 4–1 List of Cleaner Production options

Problem	Description	Proposed solution	Expected improvement	Time span	Capital cost	Operational cost
Highly polluted effluent	The load in the effluent exceeded the maximum limits set by the municipal wastewater treatment plant. The limits were: BOD: 700 mg/L COD: 1000 mg/L Suspended solids: 330 mg/L Fat/oil: 50 mg/L The measured maximum values were: BOD: 3500 mg/L COD: 10,000 mg/L Suspended matter: 2000 mg/L Fat/oil: 2900 mg/L	Reduce water use as follows: • Stop transport of offal in water by installing filtering conveyor (mesh 1 mm) under machines to collect offal. • Stop pumping offal in water by changing the flow of wastewater into a soft flow. • Install a screen (mesh 0.2 mm) for mechanical pre-treatment of wastewater.	Lower wastewater load able to be treated in the existing plant. Increased amounts of solid waste to be used for secondary products.	6–12 months	US$35,000 plus construction costs	Relatively low
Solid waste	The offal was processed in the neighbouring fish meal plant. The production: • was not profitable; • caused complaints about the odour; • emitted highly polluted wastewater.	Instead of producing fish meal the waste offal could be used to produce silage in a silage plant.	Odour problems minimised. No wastewater from silage production. Larger amount of secondary products.	6 months	US$40,000 plus construction costs.	Labour Acid and other additives.

Select options

Of the options listed in Table 4–1, the following were selected for implementation:

- introduction of new process systems to improve product yield;
- dry collection of offal;
- water saving opportunities;
- production of silage from offal.

4.5 Phase V: Implementation and Continuation

Prepare an action plan

Based on the evaluation, an implementation plan was drawn up. The plan took into account the seasonal variation in raw material supplies in order to disturb normal production as little as possible. Those persons responsible for technical design, construction, assessment of training needs and training of staff were appointed.

The following options were implemented:

Yield improvements:

- A system for grading fish was introduced. A belt grader was installed to remove fish that were either too small or too large. This enabled the correct adjustment of the filleting machines for fish of uniform size.
- A production control system was installed and the staff and managers underwent training.
- Equipment monitoring procedures were put in place which included the sharpening and changing of knives at each shift.
- Product yield monitoring procedures were also introduced for each filleting line. Machines are adjusted or overhauled based on the feedback from the monitoring results.

Dry collection of offal:

- Small chutes guide the offal and water to a filtration belt with 1 mm mesh size for rapid separation of the offal from the water. The separated water then flows to floor drains that take it to a microfiltration belt with a narrower mesh size.
- The solid offal separated from the filtration belt is taken to a main belt conveyor for transport to a silage plant.
- Wastewater containing offal that has fallen to the floor is transported by gravity to the main filtration belt for screening. The screened offal is added to the main offal stream and also used for silage.

Water saving activities:

- Water meters were installed to record consumption.
- Trigger nozzles were fitted to all cleaning hoses.
- Solenoids valves were installed on all filleting machines to shut off water during shutdown periods.
- Operators are now made aware of water consumption figures in order to increase awareness.

Production of silage:

- Instead of sending the offal to a fish meal plant, the offal is now used to produce silage. The production of silage is less energy consuming than production of fish meal, and is used as fodder.

Monitor performance

As part of the implementation process, a monitoring programme was established to document improvements. After more than 6 months of production, it was found that:

- product yield improved by 5–7%;
- water consumption fell from 32–20 m^3/hour, which is equivalent to a 37% reduction;
- the volume of effluent generated also decreased by a similar amount;
- the organic load of the wastewater reduced by 41–88%.

Silage is being sold and produces an income for the company and no pollution arises from this process. The fish meal plant has been closed and the associated nuisance eliminated.

The Cleaner Production activities are sustained by regular monitoring, and by an annual review of the implementation plan.

4.6 Contacts

For more information on this case study please contact:

PPiUR Szkuner
Ul. Portowa 5
84–120 Wladyslawowo
Poland
Phone: + 48 58 74 00 66
Fax: + 48 58 74 14 85

or

Matcon
Parallelvej 15
DK-2800 Lyngby
Denmark
Phone: +45 45 97 27 75
Fax: +45 45 97 21 14

5 CLEANER PRODUCTION ASSESSMENT

A Cleaner Production assessment is a methodology for identifying areas of inefficient use of resources and poor management of wastes, by focusing on the environmental aspects and thus the impacts of industrial processes.

Many organisations have produced manuals describing Cleaner Production assessment methodologies at varying levels of detail. However, the underlying strategies are much the same. The basic concept centres around a review of a company and its production processes in order to identify areas where resource consumption, hazardous materials and waste generation can be reduced. Table 5-1 lists some of the steps described in the more well-known methodologies.

Table 5-1 Methodologies for undertaking a Cleaner Production assessment

Organisation	**Document**	Methodology
UNEP, 1996	*Guidance Materials for the UNIDO/UNEP National Cleaner Production Centres*	1. Planning and organisation 2. Pre-assessment 3. Assessment 4. Evaluation and feasibility study 5. Implementation and continuation
UNEP, 1991	*Audit and Reduction Manual for Industrial Emissions and Wastes. Technical Report Series No. 7*	1. Pre-assessment 2. Material balance 3. Synthesis
Dutch Ministry of Economic Affairs, 1991	*PREPARE Manual for the Prevention of Waste and Emissions*	1. Planning and organisation 2. Assessment 3. Feasibility 4. Implementation
USEPA, 1992	*Facility Pollution Prevention Guide*	1. Development of pollution prevention programme 2. Preliminary assessment

The rest of this chapter describes the steps within a Cleaner Production assessment as outlined in the UNEP/UNIDO document, *Guidance Materials for UNIDO/UNEP National Cleaner Production Centres*. (UNEP, 1995). The steps from this methodology are detailed further in Figure 5—1.

See section 5.1

Phase I: Planning and organisation

- Obtain management commitment
- Establish a project team
- Develop policy, objectives and targets
- Plan the Cleaner Production assessment

↓

See section 5.2

Phase II: Pre-assessment (qualitative review)

- Company description and flow chart
- Walk-through inspection
- Establish a focus

↓

See section 5.3

Phase III: Assessment (quantitative review)

- Collection of quantitative data
- Material balance
- Identify Cleaner Production opportunities
- Record and sort options

↓

See section 5.4

Phase IV: Evaluation and feasibility study

- Preliminary evaluation
- Technical evaluation
- Economic evaluation
- Environmental evaluation
- Select viable options

↓

See section 5.5

Phase V: Implementation and continuation

- Prepare an implementation plan
- Implement selected options
- Monitor performance
- Sustain Cleaner Production activities

Figure 5—1 Overview of the Cleaner Production assessment methodology *(UNEP, 1996)*

5.1 Planning and organisation

The objective of this phase is to obtain commitment to the project, initiate systems, allocate resources and plan the details of the work to come. A project has more chance of success if this groundwork is done well.

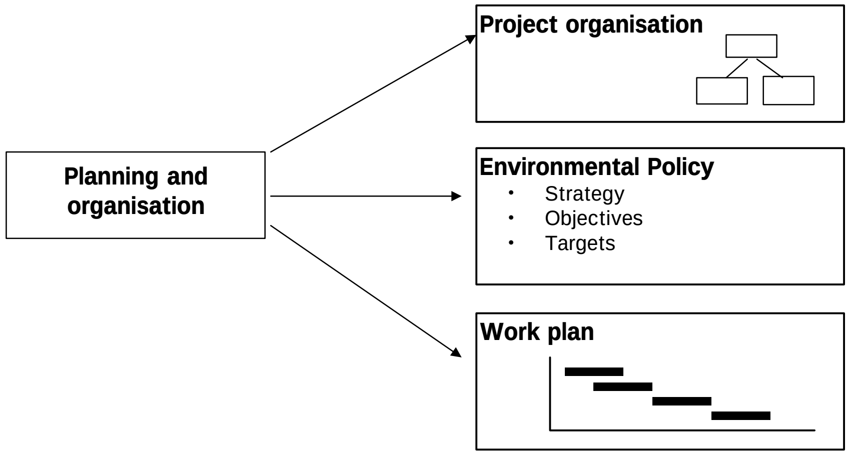

Figure 5—2 Planning and organisation phase

5.1.1 Obtain management commitment

Experience from companies throughout the world shows that Cleaner Production results in both environmental improvements and better economic performance. However, this message has to reach the management of the company. Without management commitment the Cleaner Production assessment may be only a short-term environmental management tool.

5.1.2 Establish a project team

It is best to establish a project team as early in the process as possible. The project team is responsible for progressing the assessment and will normally undertake the following tasks:

- analysis and review of present practices (knowledge);
- development and evaluation of proposed Cleaner Production initiatives (creativity);
- implementation and maintenance of agreed changes (authority).

5.1.3 Develop environmental policy, objectives and targets

The environmental policy outlines the guiding principles for the assessment. It acts to focus efforts in a way considered most important by management. The environmental policy can be refined as the project team gains more insight into the Cleaner Production possibilities within the company.

The policy contains the company's mission and vision for continuous environmental improvement and compliance with legislation. Objectives describe how the company will do this. For example, objectives could include reducing consumption of materials and minimising the generation of waste. Targets are measurable and scheduled, and 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.

In general, objectives and targets should be:

- acceptable to those who work to achieve them;
- flexible and adaptable to changing requirements;
- measurable over time (targets only);
- motivational;
- in line with the overall policy statement.

5.1.4 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 understand clearly what they have to do. It is also wise to anticipate any problems or delays that may arise and plan for them accordingly. Lengthy delays and problems arising out of poor planning erode motivation at both the worker and management level.

5.2 Pre-assessment

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

5.2.1 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 organised?
- What are the main processes?
- What are the most important inputs and outputs?

Processes which take place as part of the company's activities can be represented using a detailed process flow chart. Flow chart production is a key step in the assessment and forms the basis for material and energy balances which occur later in the assessment. Process flow charts should pay particular attention to activities which are often neglected in traditional process flow charts, such as:

- cleaning;
- materials storage and handling;
- ancillary operations (cooling, steam and compressed air production);
- equipment maintenance and repair;
- materials that are not easily recognisable in output streams (catalysts, lubricants etc.);
- by-products released to the environment as fugitive emissions.

The process flow chart is meant of providing an overview and should thus be accompanied by individual input/output sheets for each unit operation or department. Figure 5—3 provides an example of an input/output worksheet, however it may be arranged in various ways.

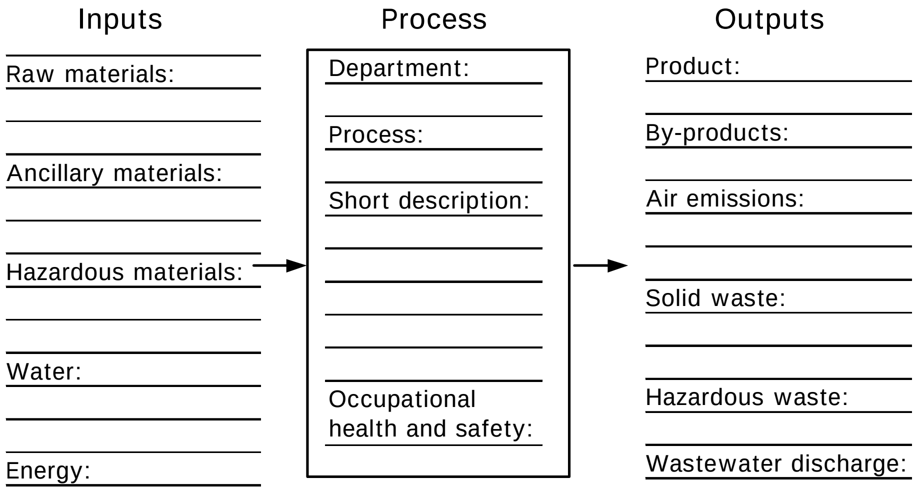

Figure 5—3 Example of an input/output worksheet

5.2.2 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, if possible, follow the process from the start to the finish, focusing on areas where products, wastes and emissions are generated. During the walk-through, it is important to talk to the operators, since they often have ideas or information that can be useful in identifying sources of waste and Cleaner Production opportunities. The text box over page provides examples of the types of questions that may be asked to prompt the investigation.

During the walk-through problems encountered along the way should be listed, and if there are obvious solutions to these they should also 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.

5.2.3 Establish a focus

The last step of the pre-assessment phase is to establish a focus for further work. In an ideal world, all processes and unit operations should be assessed. However time and resource constraints may make it necessary to select the most important aspect or process area.

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

Questions to be answered during a walk-through inspection

Are there signs of poor housekeeping (untidy or obstructed work areas etc.)?

Are there noticeable spills or leaks? Is there any evidence of past spills, such as discoloration 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?

5.3 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.

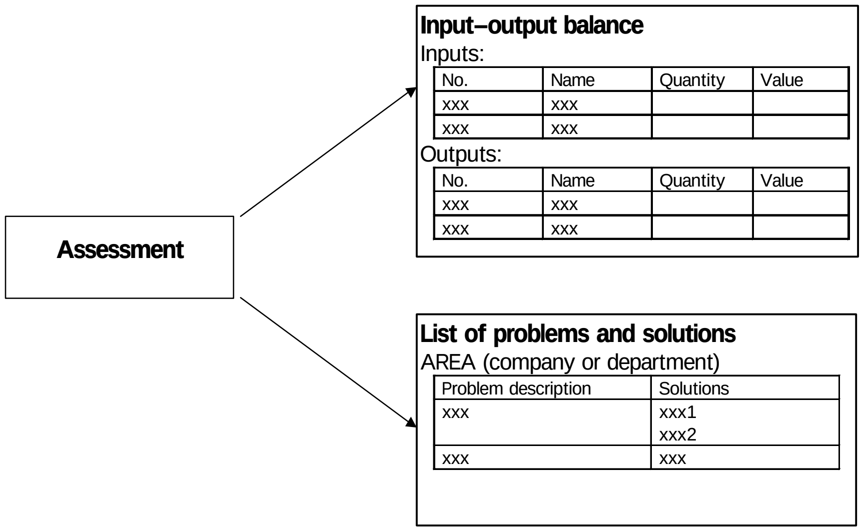

Figure 5—4 Assessment phase

5.3.1 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: for example: water consumption per tonne of live carcass weight (LCW) processed or mass of organic matter (COD) generated per tonne of live carcass weight (LCW) processed. 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.

In determining what data to collect, use the input/output worksheets, described previously, as a guide. Most data will already be available within the company recording systems, e.g. stock records, accounts, purchase receipts, waste disposal receipts and the production data. Where information is not available, estimates or direct measurements will be required.

5.3.2 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.

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 operation. An overall company-wide material balance can then be constructed with these.

The material balance can also be used to identify the costs associated with inputs, outputs and identified losses. It is often found that presenting these costs to management can result in a speedy implementation of Cleaner Production options.

While it is not possible to lay down a precise and complete methodology for undertaking 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 rescues trying to achieve a perfect material balance; even a preliminary material balance can 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.

5.3.3 Identify Cleaner Production opportunities

Identifying Cleaner Production opportunities depends on the knowledge and creativity of the project team members and company staff, much of which comes from their experience. Many Cleaner Production solution are arrived at by carefully analysing the cause of a problem.

Another way of identifying Cleaner Production opportunities is to hold a ‘brainstorming’ session, where people from different parts of the organisation meet to discuss solutions to specific problems in an open and non-threatening environment.

Some other sources of help from outside the organisation could be:

- this guide;
- external industry personnel or consultants;
- trade associations;
- universities, innovation centres, research institutions, government agencies;
- equipment suppliers;
- information centres, such as UNEP or UNIDO;
- literature and electronic databases.

5.3.4 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 following steps:

- Organise 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 unfeasible, or cannot be implemented should be eliminated from the list of options for further study.

Table 5—2 Example of information recorded for identified options

Problem type	**Problem description**	**Cleaner Production options**
Examples: • resource consumption • energy consumption • air pollution • solid waste • wastewater • hazardous waste • occupational health and safety	Examples: • name of process and department • short background of problem • amount of materials lost or concentration of pollutants • money lost due to lost resources	Examples: • how the problem can be solved • short-term solution • long-term solution • estimated reductions in resource consumption and waste generation

5.4 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 merit. However, the depth of the study depends on the type of project. Complex projects naturally require more thought than simple projects. For some options, it may be necessary to collect considerably more information. An important source of this information may be employees affected by the implementation.

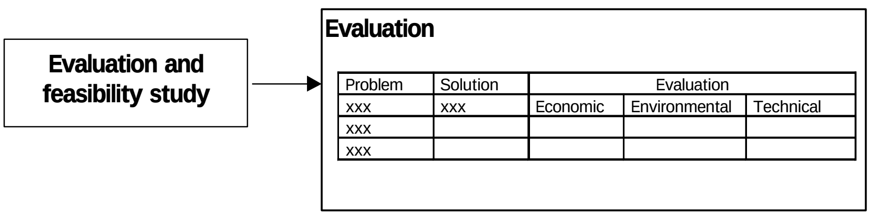

Figure 5—5 Evaluation and feasibility study phase

5.4.1 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.

5.4.2 Technical evaluation

The potential impacts on products, production processes and safety from 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.

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

Capital investment is the sum of the fixed capital costs of design, equipment purchase, installation and commissioning, costs of working capital, licenses, training, and financing. Operating costs, if different to existing conditions will need to be calculated. It may be that operating costs reduce as a result of the change, in which case, these should be accounted for in the evaluation as an ongoing saving.

5.4.4 Environmental evaluation

The objective of the environmental evaluation is to determine the positive and negative environmental impacts of the option. In many cases the environmental advantages are obvious: a net reduction in toxicity and/or quantity of wastes or emissions. In other cases it may be necessary to evaluate whether, for example, an increase in electricity consumption 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 environmental policy of the country, some issues may have a higher priority than others.

Aspects to be considered in the evaluation

Preliminary evaluation

- Is the Cleaner Production option available?
- Can a supplier be found to provide the necessary equipment or input material?
- Are consultants available to help develop an alternative?
- Has this Cleaner Production opportunity been applied elsewhere? If so, what have been the results and experience?
- Does the option fit in with the way the company is run?

Technical evaluation

- Will the option compromise the company's product?
- What are the consequences for internal logistics, processing time and production planning?
- Will adjustments need to be made in other parts of the company?
- Does the change require additional training of staff and employees?

Economic evaluation

- What are the expected costs and benefits?
- Can an estimate of required capital investment be made?
- Can an estimate of the financial savings be made, such as reductions in environmental costs, waste treatment costs, material costs or improvements to the quality of the product?

Environmental evaluation

- What is the expected environmental effect of the option?
- How significant is the estimated reduction in wastes or emissions?
- Will the option affect public or operator health (positive or negative)? If so, what is the magnitude of these effects in terms of toxicity and exposure?

5.4.5 Select options

The most promising options must be selected in close collaboration with management. A comparative ranking analysis may be used to prioritise opportunities for implementation. The concept of such a method is shown below in Table 5-3.

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 discussion.

All simple, cost-free and low-cost opportunities should of course be implemented as soon as possible.

Table 5-3 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	3	+ 3	9	+ 2	6	+ 3	9
Reduced wastewater treatment costs	3	+ 1	3	0	0	+ 2	6
Reduced amount of solid waste	3	+ 3	9	+ 2	6	+ 3	9
Reduced exposure to chemicals	2	+ 3	6	0	0	–1	-2
Reduced amount of water consumption	1	+ 1	1	0	0	+ 2	2
Reduced odour problems	1	0	0	–1	–1	0	0
Reduced noise problems	1	–2	–2	0	0	0	0
Easy to install and maintain	3	–1	–3	-1	-3	+ 1	3
Weighted sum			23		8		27

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

5.5 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.

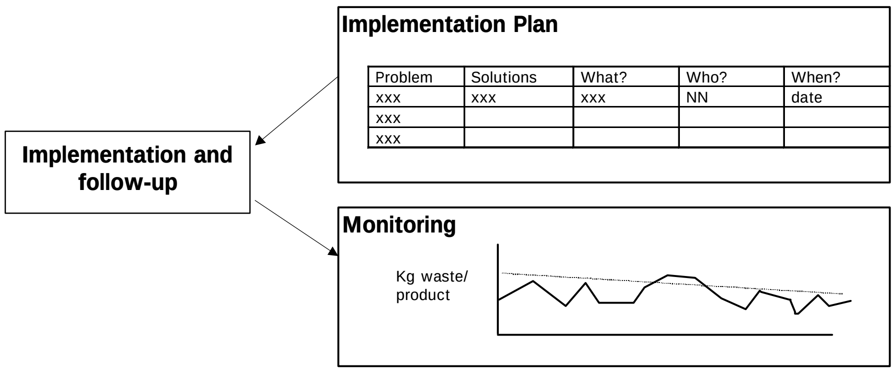

Figure 5—6 Implementation and continuation phase

5.5.1 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.

5.5.2 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 staff. The project could be a failure if not backed up by adequately trained employees. Training needs should have been identified during the technical evaluation.

5.5.3 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 5-4.

5.5.4 Sustain Cleaner Production activities

If Cleaner Production is to take root and progress in an organisation, it is imperative that the project team does not lose momentum after it has implemented a few Cleaner Production options. Sustained Cleaner Production is best achieved when it becomes part of the management culture 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.

Regardless of which approach is undertaken, Cleaner Production assessment and environmental management systems are compatible. While Cleaner Production projects have a technical orientation, an environmental management system focuses on setting a management framework, but it needs a technical focus as well.

To assist industry in understanding and implementing environmental management systems, UNEP, together with the International Chamber of Commerce (ICC) and the International Federation of Engineers (FIDIC), has published an *Environmental Management System Training Resource Kit*. This kit is compatible with the ISO 14001 standard.

Like the Cleaner Production assessment, an environmental management system should be assessed and evaluated on an ongoing basis and improvements made as required. While the specific needs and circumstances of individual companies and countries will influence the nature of the system, every environmental management system should be consistent with and complementary to a company's business plan.

Table 5—4 Evaluation checklist

Overall Cleaner Production assessment check	**YES**	**NO**
• 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? Which 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		

Evaluation Questionnaire

CLEANER PRODUCTION ASSESSMENT IN FISH PROCESSING

As part of its continuing review of the quality and impact of publications it supports, the United Nations Environment Programme's Division of Technology, Industry and Economics would appreciate your co-operation in completing the following questionnaire.

1. Quality

Please rate the following quality aspects of the publication by ticking the appropriate box:

	Very good	*Adequate*	*Poor*
Presentation	❑	❑	❑
Structure of content	❑	❑	❑
Subject coverage	❑	❑	❑
Ease of reading	❑	❑	❑
Level of detail	❑	❑	❑
Rigour of analysis	❑	❑	❑
Up-to-date	❑	❑	❑

2. Usefulness

In general, how much of the publication is:

	Most	*About half*	*Little*
Of technical/substantive value to you?	❑	❑	❑
Relevant to you?	❑	❑	❑
New to you?	❑	❑	❑
Will be used by you?	❑	❑	❑

What would make the manual more useful for you?

____

3. Effectiveness in achieving the objective

The objective of this publication is to provide the reader with an appreciation of how Cleaner Production can be applied to the fish processing industry as well as providing resources to help undertake a Cleaner Production assessment at a fish

processing facility. In your opinion, to what extend does this document fulfil this objective?

Please tick one box ❑ Fully ❑ Adequately ❑ Inadequately

Please state reasons for your rating:

____

____

4. Uses

a. Please state how the publication will affect or contribute to your work, illustrating your answer with examples.

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b. Please indicate, in order of importance (first, second or third), the usefulness of the publication to you:

	First	***Second***	***Third***
For your own information	❑	❑	❑
As reference material	❑	❑	❑
As guidelines for on-the-job application	❑	❑	❑

5. Distribution

Will others read your copy of this publication? ❑ Yes ❑ No ❑ Unknown

If 'yes', how many?

Did you receive this publication directly from UNEP? ❑ Yes ❑ No ❑ Unknown

If 'no', who forwarded it to you?

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6. General Observations

a. Please indicate any changes in the publication that would increase its value to you.

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b. Please indicate, in order of importance (first, second or third), which of the following items might increase the value of the publication to you.

	First	***Second***	***Third***
Translation into your own language	❑	❑	❑
Specific regional information	❑	❑	❑
Additional technical information	❑	❑	❑

7. The following data would be useful for statistical analysis

Your name (optional) ______________________________

Professional background ______________________________

Position/function/occupation ______________________________

Organisation ______________________________

Country ______________________________

Date ______________________________

UNEP would like to thank you for completing this questionnaire. Please return to:

The Director

UNEP Division of Technology, Industry and Environment

Tour Mirabeau 39-43, quai André Citroën

75739 Paris Cedex 15, France

Fax: +33 (1) 44 37 14 74

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United Nations Industrial Development Organisation (UNIDO), 1986. *Environmental Assessment of the Fish Processing Industry*. UNIDO Sector Studies Series No. 28.

ANNEX 2 GLOSSARY

BAT	Best available technology and best available techniques (from an environmental viewpoint). BAT covers both equipment and operational practice.
Best practice	The practice of seeking out, emulating and measuring performance against the best standard identifiable.
BOD	Biochemical oxygen demand: a measure of the quantity of dissolved oxygen consumed by micro-organisms as the result of the breakdown of biodegradable constituents in wastewater.
Bloodwater	The general term for all liquid separated from fish prior to cooking.
CFC	Chlorofluorocarbon. CFCs have very good technical properties as coolants; however, they are implicated in causing depletion of the ozone layer, which protects humans, animals and crops against ultraviolet radiation. CFCs and HCFCs (hydrogenated chlorofluorocarbons) are being phased out according to the Montreal Protocol. CFC-11 is commonly known as Freon.
CIP	Cleaning in place: circulation of a cleaning solution through or over the surface of production equipment
CO_2	Carbon dioxide
COD	Chemical oxygen demand: a measure of the quantity of dissolved oxygen consumed during chemical oxidation of wastewater
CP	Cleaner Production
CPA	Cleaner Production assessment
Effluent	The liquid discharged from a process or treatment system
EMS	Environmental management system
Eutrophication	Excessive growth of algae, reducing penetration of light through water and consuming large amounts of oxygen, resulting in a high risk of fish death due to lack of oxygen.
FP	Final (or finished) product. See also RM below.
HCFC	Hydrogenated chlorofluorocarbon; see CFC.
ISO 14001	International Standard ISO 14001 Environmental Management Systems: specification with guidance for use. International Organization for Standardization
N	Nitrogen
NO_x	Nitrogen oxides; covers both NO_2 (nitrogen dioxide) and NO (nitrogen monoxide)
Nobbing	A process of cutting the head from a fish while simultaneously removing the entrails

P	Phosphorus
PAH	Polycyclic aromatic hydrocarbons: occur in flue gases from combustion of fuel. Some PAHs are carcinogenic.
RM	Raw material, in this case fish arriving at a certain process. Most key statistics in the fish processing industry are based on RM or final product.
SO_x^-	Sulphur oxides; covers the various forms of gaseous sulphur oxide compounds found in combustion gases.
SS	Suspended solids
TS	Total solids
UN	United Nations
UNEP DTIE	United Nations Environment Programme Division of Technology, Industry and Economics
UNIDO	United Nations Industrial Development Organization
US$	US dollars
VOC	Volatile organic compounds, e.g. solvents with a low boiling point

Units

bar	unit for measuring pressure (1 bar = 0.987 atmosphere)
J	joule (1 W = 1 J/s)
kg	kilogram
kW.h	kilowatt hour (1 kW.h = 3.6 MJ)
L	litre
lb	pound (1 lb = 0.454 kg)
m	metre
m^2	square metre
m^3	cubic metre (= 1000 L)
MJ	1 million joules (1 MJ = 0.278 kW.h)
MW.h	megawatt hour (1 MW.h = 1000 kW.h)
Nm^3	Normal cubic metre
t/tonne	tonne (= 1000 kg)

ANNEX 3 FURTHER INFORMATION

Journals

Fishing News International

Emap Heighway
Meed House, 21 John Street
London WC1N 2BP
United Kingdom
Phone: +44 171 470 6200
Fax: +44 171 831 9362
Email: ians@meed.emap.co.uk

World Fishing Magazine

Royston House, Caroline Park
Edinburgh EH5 1QJ
United Kingdom
Phone: +44 131 551 2942
Fax: +44 131 551 2938

Seafood International

Quantum Publishing Ltd
Quantum House
19 Scarbrook Road
Croydon, Surrey CR9 1LX
United Kingdom
Phone: +44 181 565 4200
Fax: +44 181 565 4340

Food Technology

Institute of Food Technologists
221 N. La Salle St. Ste. 300, Chicago, Il. 60601
United States of America
Phone: +1 31 27 82 84 24
Fax: +1 31 27 82 83 48
Email: info@ift.org

Organisations

UNEP DTIE

United Nations Environment Programme
Division of Technology, Industry and Economics
39–43, Quai André Citroën
F-75739 Paris Cedex 15
France
Phone: +33 1 44 37 14 50
Fax: +33 1 44 37 14 74
Email: unep.tie@unep.fr
Website: http://www.uneptie.org

This organisation publishes a number of useful resources, including the UNEP Technical Report Series, Cleaner Production and environmental management training packages and UNEP periodicals such as UNEP *Industry and Environment Review*. It also maintains the International Cleaner Production Information Clearinghouse (ICPIC) database which contains Cleaner Production case studies (see Cleaner Production on the Web section).

UNEP Cleaner Production Working Group for the Food Industry

Environmental Management Centre
The University of Queensland
Brisbane, QLD 4072
Australia
Phone: +61 7 33 65 15 94
Fax: +61 7 33 65 60 83
Email: r.pagan@mailbox.uq.edu.au
Website: http://www.geosp.uq.edu.au/emc/CP/default.HTM

The aim of the group is to promote Cleaner Production in the food industry. The group's activities include maintaining a network of food industry and Cleaner Production experts, maintaining a library and database of information related to Cleaner Production in the food industry, delivering workshops and seminars and producing a newsletter.

United Nations Industrial Development Organization (UNIDO)

Vienna International Centre
P.O. Box 300
A-1400 Vienna
Austria
Phone: +43 1 21 13 10
Fax: +43 1 23 21 56
Email: zcsizer@unido.org
Website: http://www.unido.org/doc/f50135.htmls

UNIDO provides seminars, conferences, workshops, media coverage, demonstration projects, training and information dissemination. It also offers support in establishing National Cleaner Production Centres. Fifteen such centres had been set up by October 1998, with several more on the way.

Information manuals available from UNIDO include the *UNEP/UNIDO Audit and Reduction Manual for Industrial Emissions and Wastes* and UNIDO's DESIRE kit (Demonstration in Small Industries for Reducing

Wastes). In addition, nine of the National Cleaner Production Centres have their own country-specific manuals. UNIDO has also prepared seven manuals specific to particular industry sub-sectors and has contributed to 26 UNEP Technical Reports on specific Cleaner Production options. All these publications can be obtained through UNIDO.

International Fish Meal and Oil Manufacturers Association (IFOMA)

2 College Yard, Lower Dagnall Street
St Albans, Hertfordshire
AL3 4PA
United Kingdom
Phone: +44 17 27 84 28 44
Fax: +44 17 27 84 28 66
Website: http://www.ifoma.com/

This organisation meets annually to discuss current problems in the industry.

Food and Agriculture Organization of the UN (FAO)

Via delle Terme di Caracalla
00100 Rome
Italy
Phone: +39.0657051
Fax: +39.0657053152
Website: http://www.fao.org/

The FAO's aim is to raise levels of nutrition and standards of living, to improve agricultural productivity, and to better the condition of rural populations. It is active in the areas of land and water development, plant and animal production, forestry, fisheries, economic and social policy, investment, nutrition, food standards and commodities and trade.

It provides regular and comprehensive statistics on world food production and also commissions projects and publication related to the environmental sustainability of food production.

Danish Institute for Fish Technology (DIFTA)

The North Sea Centre
Box 59,
DK-9850 Hirtshals
Denmark
Phone: +45 98 94 43 00
Fax: +45 98 24 22 26

The main activities of DIFTA are to carry out research, development and consultancy services in fishing and fish processing technology within Denmark.

Fishery Industrial Technology Centre

900 Trident Way
Kodiak, Alaska 99615-7401
United States of America
Phone: +1 (907) 486 1500
Fax: +1 (907) 486 1540
Website: http://www.sfos.uaf.edu:8000/FITC/

Cleaner Production on the web

UNEP International Cleaner Production Information Clearinghouse (ICPIC)

ICPIC is a Cleaner Production database containing case studies, publication abstracts, lists of expert organisations, and information on the resources available from UNEP DTIE. It is an electronic reference tool that is searchable by key word.

The database can be accessed via the internet at the site indicated below. A CD–ROM version of the database can also be ordered through the same website.

UNEP, Division of Technology, Industry and Economics
39–43, Quai André Citroën
F–75739 Paris Cedex 15
France
Phone: +33 1 44 37 14 50
Fax: +33 1 44 37 14 74
Email: unep.tie@unep.fr
Website: http://www.unepie.org/Cp2/info_sources/icpic_data.html

US EPA Enviroene

Enviroene is a database of information provided through the United States Environmental Protection Agency's website. It provides information on pollution prevention, compliance and enforcement. The information available includes pollution prevention case studies, pollution control technologies, environmental statutes and regulations, compliance and enforcement policies and environmental guidelines.

Website: http://es.epa.gov/

National Technology Transfer Centre, USA

At the National Technology Transfer Centre website you can search the internet for Cleaner Production cases.

Wheeling Jesuit University
316 Washington Avenue
Wheeling, WV 26003
United States of America
Phone: +1 80 06 78 68 82
Website: http://endeavor.nttc.edu/

EnviroNET Australia

The EnviroNET Australia website contains a wide range of Cleaner Production case studies from Australia.

Environment Australia
Environment Protection Group
40 Blackall Street
Barton ACT 2600
Australia
Phone: +61 2 62 74 17 81
Fax: +61 2 62 74 16 40
Email: environet@ea.gov.au
Website: http://www.erin.gov.au/net/environet.html

ANNEX 4 ABOUT UNEP DTIE

The mission of United Nations Environment Programme is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

The activities of UNEP DTIE, located in Paris, focus on raising awareness, improving the transfer of information, building capacity, fostering technology transfer, improving understanding of the environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and promoting global chemical safety. The division is composed of one centre and four units, as described below.

The **International Environmental Technology Centre** (Osaka) promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins in developing countries and countries with economies in transition.

The **Production and Consumption Unit** (Paris) fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

The **Chemicals Unit** (Geneva) promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety worldwide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).

The **Energy and OzonAction Unit** (Paris) supports the phase-out of ozone-depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of this unit.

The **Economics and Trade Unit** (Geneva) promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

For more information contact:

UNEP, Division of Technology, Industry and Economics
39–43, Quai André Citroën
F–75739 Paris Cedex 15
France
Phone: +33 1 44 37 14 50
Fax: +33 1 44 37 14 74
Email: unep.tie@unep.fr
Internet: http://www.uneptie.org