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Nordic perspective

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Nordic co-operation has firm traditions in politics, the economy, and culture. It plays an important role in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe.

Nordic co-operation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

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Preface

The Nordic Council of Ministers, the BAT Group under the Working Group for sustainable consumption and production, has requested the consultant Aquateam COWI to prepare a report on Best Available Techniques (BAT) in fish processing industry in the Nordic countries.

The project describes the present status of the used techniques, their emissions and impacts on the environment and technologies that can be considered BAT. The provided information can be utilized by operators, environmental consultants and competent environmental authorities. The report will also be used as an input from the Nordic countries to the EU process under the Industrial Emissions Directive (IED) for preparation of the BAT Reference Document Best Available Techniques in the Food, Drink and Milk Industries (FDM BREF) which started in 2014.

The team of consultants that have contributed to the report

- Eilen Arctander Vik – Aquateam COWI.
- Renata Tomczak-Wandzel – Aquateam COWI.
- Tomasz Wandzel – Aquateam COWI.

The work was supervised by the following Nordic BAT-group members

- Egil Strøm, The Norwegian Environment Agency, Norway.
- Kaj Forsius (Chairman of the group), Finnish Environment Institute.
- Lena Ziskason, Environment Agency of Faroe Islands.
- Sigurdur Ingason, Environment Agency of Iceland.
- Susanne Särs, Environmental and Health Protection Agency of the Aland Islands.
- Birgitte Holm Christensen, Danish Environmental Protection Agency.
- Annika Månsson and Maria Enroth, Swedish Environment.

Summary

The Nordic Council of Ministers, the BAT Group under the Working Group for sustainable consumption and production, has requested the consultant to prepare a report on Best Available Techniques (BAT) in fish processing industry in the Nordic countries. The project describes the present status of the used techniques, their emissions and impacts on the environment and technologies that can be considered BAT. The provided information can be utilized by operators, environmental consultants and competent environmental authorities. The report will also be used as an input from the Nordic countries to the EU process under the Industrial Emissions Directive (IED) for preparation of the BAT Reference Document for Best Available Techniques in the Food, Drink and Milk Industries (FDM BREF) concerning the fish processing sector.

According to the Food and Agriculture Organization of the United Nations (FAO), capture fisheries and aquaculture supplied the world with about 158 million tons of fish and other aquatic species (ca. 136 million tons for human consumption) in 2012, providing an apparent per capita supply 18.9 kg. The Nordic fish processing industry produces around 6.25 million tons per year of fish and fishery products (supply per capita in Nordic countries are much higher than world average consumption).
The waters surrounding the Nordic countries are rich in fish resources. Those nations were always dependent on natural resources. Nordic fish processing industry has been one of the leaders regarding implementation of cleaner production and environmental management systems.

During the last few decades, the fish processing industry has come increasingly into focus as regards environment protection. The industry is characterised by a large consumption of water and a large discharge of organic material. The Nordic fish processing industry is exceptionally large and reducing of water consumption and pollution in wastewater have been extraordinary important. The shortage of marine resources and limited environment capacity calls for the new approach to the fish industry and for the implementation of and new technological processes for providing a less water consumption and better utilization of waste and by-products from fisheries and fish processing activities.

Processing fish involves primarily the application of preservation techniques in order to retain quality and increase shelf life. It may also

deal with value-adding to produce a wide variety of products. The driver for improved profitability in the industry has increased the interest for re-use of residual materials from the fish processing industry. The pelagic fish production has reached the furthest with respect to recovery, but can still improve by producing more valuable products than today. Marine by-products are still considered a huge unexploited potential for increased value in the pelagic industry. Fish proteins is valuable and re-using the by-products is economical beneficial and is expected to move BAT for this industry into some interesting areas in the future.

The fish processing industry is experiencing a large variation in the availability of the raw materials to the industry and the market for their products. The industry is normally active in processing for a few months per year. This is the typical case for the pelagic and white fish industry. The aquaculture industry has increased the availability of fish to the market, but the lack of availability of fish proteins for feed to the fish has increased the demand for the by-products.

The fish processing industry is implementing waste recovery and re-use as well as water saving solutions. Local conditions especially on the North-Atlantic ocean with non-vulnerable recipients to nutrients or organic loading has made the industry head for a level of water treatment technology which is not very sophisticated, but the increased market for more costly by-products might be moving the BAT solutions into another generation where we will see new technologies applied for recovering proteins and fat from the industry. In the future, we might also see that the nutrient recovery (phosphorus and nitrogen) also is becoming more common with higher demand for reduction of releases and raising market as fertilizer (especially phosphorus) prices increases. Focusing on cleaner technology principles and BAT is part of the common Nordic mindset and all the Nordic countries have had for many years an environmental licensing system building upon these principles. Therefore, the Nordic countries were well prepared when the EU approved the IPPC Directive in 1996.

The general objective is to ensure that the fish processing industry in Nordic countries is producing according to technologies and methods that lead to the lowest possible impact to the environment. This aim should be achieved through formulation of conditions in environmental permits and licenses, which are as uniform as possible within the different industrial sector.

Best Available Techniques to ensure the minimum environmental impact without compromising the economic performance of the installation, have a strongly dynamic character, as they are highly affected by scientific and technical progress. One question arising from BAT implementation is which BAT should be chosen in any specific case. BATs are selected based on technical feasibility, environmental benefits and economic profitability. The concept of BAT does not prescribe which specific techniques should be used in order to reach the required environmental levels and does not account for local conditions in the preparation of the EU BREFs. The BREFs are describing the BAT associated emission and performance levels one can reach by using BAT.

BAT is intended to assist in identifying the techniques that are the best for the environment as a whole, and that are economically and technically available for Nordic industry. As there is more and more focus on the environmental impacts from industrial projects, it is of increasing importance to ensure that technologies and practices implemented achieve high level of environmental performance. Investors in Nordic countries try to find the appropriate balance between environmental performance and technical and economical availability.

However, regardless of the IED, in last past decades, the Nordic fish processing has been constantly modernized for improved efficiency, quality and environmental protection. All investments are designed to adapt the Nordic fishing sector to the available resources and environmental conditions. The aim is to minimise all possible sources of pollution from processing plants, as well as to ensure that the best available technology is used, with limit values set, especially for wastewater discharges.

Along with investments, the approach of governments and enterprises to manage processing activities has been changing as well. It must be emphasized that BATs do not only refer to the technology used at an installation, but also to the way the installation is designed, built, operated and maintained. Some BATs are a simple consequence of common sense and do not involve any investment. As a result, significant savings can be achieved thanks to higher productivity, reduced consumption of water and energy and the reduced wastewater pollution to treat.

To ensure that further improvement is taking place in this industry, it is necessary to improve the sampling and analytical procedures for treated wastewater. Sampling and analyses of fat, COD and TSS is associated with large uncertainties in an industry where the water varies greatly from time to time dependent on the catch, the time of year and time of day of the sampling.

List of abbreviations

ADOXPOL	ADvanced OXidation POLishing
ACH	Aluminum chlorohydrate
Al	Aluminum
As	Arsen
ASH	Air Sparged Hydrocyclone Flotation
BAF	Bubble Accelerated Flotation
BAT	Best Available Technique
BAT Group	BAT Group is a sub-group of the Working Group for Sustainable Consumption and Production
BOD	Biochemical Oxygen Demand
BREF	Reference Document on Best Available Techniques in the Food, Drink and Milk Industries
CEFIC	Continuous Flow Intermittent Cleaning
COD	Chemical Oxygen Demand
CT	Cleaner Technology
DAF	Dissolved Air Flotation
DOF	Dispersed ozone Flotation
GEM	Gas Energy Mixing
FAO	Food and Agriculture Organization of the United Nations
Fe	Ferrous, Ferric (Iron)
FPE	Fish Processing Equipment
FOG	Fat, Oil and Grease
HRT	Hydraulic Retention Time
Hg	Mercury
IED	Industrial Emissions Directive
IPPC	Integrated Pollution Prevention and Control
IQF	Individual Quick freezing
LCP	Large Combustion Plants
Ls	Liquid smoke
NVG	Norwegian Vår (Spring) Gyte (Spawn) Herring
PAC	Polyaluminum chloride
PCB	Poly Chlorinated Benzenes
PE	Population Equivalent
PM	Particulate mater
PAH	Polycyclic aromatic hydrocarbons
RAS	Recirculating aquaculture systems
RSW	Refrigerated Sea Water
SPAs	Special Protection Areas
SACs	Special Areas of Conservation
SiC	Silicon carbide
Tot-N	Total Nitrogen
Tot-P	Total phosphorus
TSS	Total suspended solids
TWI	Total Weekly Intake
WI	Waste Incineration Directive
VOC	Volatile Organic Compounds

1. Introduction

1.1 Background

The Nordic Council of Ministers, the BAT Group under the Working Group for sustainable consumption and production, has requested the consultant to prepare a report on Best Available Techniques (BAT) in fish industry in the Nordic countries. The project aims to provide information for operators, environmental consultants and competent environmental authorities on what is considered BAT within the industrial sector, as defined in the context of the EU's environmental legislation.

The purpose of this project is to provide timely information for the BAT reference documents preparation process for fish industry activities covered by the IED (capacity over 75 tons/day), but also as a basis for setting permit conditions for smaller installations in the industrial sector.

1.2 Scope and methodology

Scope
This report covers the following areas:

- Chapter 1 provides an overview of the fish processing industry sectors in Nordic countries, environmental emissions, recipients and local regulation.
- Chapter 2 provides an overview of fish processing and techniques.
- Chapter 3 describes consumption and emissions in fish processing industry, including the water consumption, wastewater generation, wastewater treatment, solid waste generation, energy consumption and air emissions.
- Chapter 4 describes examples of best available techniques case studies from pelagic fish industry, salmon processing industry and from canning industry. The selected, relevant challenges in described industries are presented.

Methodology

Available information on fish processing industry in Nordic countries was reviewed. In the course of the work associations, authorities and operators were contacted and fish processing plants were visited.

The team of consultants that have contributed to the report:

- Eilen Arctander Vik – Aquateam COWI.
- Renata Tomczak-Wandzel – Aquateam COWI.
- Tomasz Wandzel – Aquateam COWI.

Bat Group – The BAT project has been followed and commented on by the Nordic BAT Group. The members of the BAT Group:

- Egil Strøm, The Norwegian Environment Agency, Norway.
- Kaj Forsius (Chairman of the group), Finnish Environment Institute.
- Lena Ziskason, Environment Agency of Faroe Islands.
- Sigurdur Ingason, Environment Agency of Iceland.
- Susanne Särs, Environmental and Health Protection Agency of the Aland Islands.
- Birgitte Holm Christensen, Danish Environmental Protection Agency.
- Annika Månsson and Maria Enroth, Swedish Environmental Protection Agency.

Other experts – The BAT project has also been followed and commented on by fish processing industry specialists in the Nordic countries:

- Helge Blålid, Norway Pelagic, Norway.
- Jarl Knudsen, Nordlaks produkter, Norway.
- Durita á Heygum, Pelagos, The Faroe Islands.
- Mikael Åkerström, Orkla Foods, Sweden.
- Gunnar Þórðarson, Matis, Iceland.

1.3 Industrial Emissions Directive (IED 2010/75/EU)

Currently binding act is the Industrial Emissions Directive (IED, 2010/75/EU). The IED (2010/75/EU) recasts seven existing Directives:

- 2008/1/EC (formerly 96/61/EC) – Integrated Pollution Prevention and Control (IPPC).
- 2001/80/EC Large Combustion Plants (LCP).
- 2000/76/EC Waste Incineration Directive (WI).
- 1999/13/EC on Volatile Organic Compounds (VOC) Solvents Directive.
- 78/176 /EEC, 82/883/EEC and 92/112/EEC – Titanium Dioxide Directives.

The IED applies to:

- Activities covered by the IPPC Directive and other activities which are being included in the IPPC code.
- Dry-cleaning and other activities covered by the VOC Solvents Directive; these activities are those listed in Part I of Annex VII to the IED which reach the consumption thresholds set out in Part 2 of that Annex (Article 56) with a solvent consumption of less than 10 tons per year.
- Combustion plants designed for production of energy, the rated thermal input of which is equal to or greater than 50 MW irrespective of the type of fuel used (Article 28).
- Waste incineration plants and waste co-incineration plants which incinerate or co-incinerate solid or liquid waste (Article 42).
- Installations producing titanium dioxide (Article 66).

The aim of IED is to reduce the impact of industry on the environment through a comprehensive approach to the problems arising from the operation of large industrial plants in the European Community. Its scope covered by almost all the major operators and most industries, which activity causes or is likely to cause significant adverse impacts on the environment. The main objectives of the work on the Directive IED was to clarifying and giving a greater role to the best available techniques (BAT). Previously, the BAT reference documents describing (BREF BAT Reference Document) was only as a guidelines and tips to encourage the authorities competent to issue permits in the process of determining the parameters of the installation, recorded in the integrated permit.

The new Industry Emissions Directive (IED) tightens up the principle on use of best available techniques (BAT). In related industry, specific discharge limit levels are adopted in so-called BAT conclusions. Emphasis is also located for greater frequency of inspections, and to update terms and conditions in existing licenses when new and revised BAT conclusions become available. The BAT conclusions will be extract from the BREF and contain the most important elements. Will be accepted by a decision of the European Commission, so as such, will be published in all official languages of the EU and – most importantly – will be directly applicable law. This means that emissions set out therein is to be the rule of law, which should not be exceeded in the integrated permit. Depending on the type of business can result in a significant tightening of environmental protection requirements. This in turn may force entrepreneurs to invest in anti-pollution devices and in many cases generate quite substantial costs.

The essence of this directive in fish processing industry is an integrated approach to environmental issues with an emphasis on the prevention of pollution, and if this is not possible, reducing them by taking technical projects, the introduction of systemic and organizational solutions in the sphere of production activities. The Directive introduced the obligation to obtain an integrated permit, which specifies the conditions for the operation of an installation based on the criteria of best available techniques (BAT) taking into account the specific installation, the local environmental conditions and the technical and economic conditions.

1.4 BAT in fish processing industry

The following general rules are considered BAT in all food, drink and milk industries (BREF, 2006):

- Ensure the employees awareness of environmental aspects of the company's activity.
- Design/select equipment which optimize consumption and emission levels.
- Control noise emission at source.
- Operate regular maintenance.
- Apply and maintain a methodology for preventing and minimising the consumption of water and energy and the production of waste.

- Implement the system for monitoring and reviewing consumption and emission levels for both individual production processes and at the site level.
- Maintain an accurate inventory of inputs and outputs at all stages of the production process.
- Minimize storage time.
- Segregate outputs.
- Apply good housekeeping.
- Use automated water start/stop controls.
- Implement and adhere an environmental management system.
- Seek collaboration with upstream and downstream partners to create a chain of environmental responsibility.

Fish processing industry has to produce according to technologies and methods that lead to the lowest possible impact to the environment. The used cleaner technologies will not influence the quality of the product negatively. The crucial impact on environment is connected with:

- water consumption – all processes in fish processing industry require large volume of high quality of water (transportation, production, cleaning) and as consequence of large demand for water is the generation of large volume of wastewater
- wastewater from different processing steps e.g.: thawing, washing, from primary processing: gutting, filleting, skinning, from the secondary processing: canning, smoke processing, fish-food processing, finally cleaning the equipment and the installation
- solid waste – residue after primary and secondary processing, sludge from wastewater treatment plant
- energy consumption – depends mainly on the installation, the equipment and the type of fish processing. Important is also the source of energy (from fossil fuels or renewable)
- air emissions
- others: noise and odor.

Fish and seafood processing industry is included in the scope of Directive 2010/75/EU in Annex 1 as: "Treatment and processing, other than exclusively packaging, of animal raw materials (other than exclusively milk) with a finished product production capacity greater than 75 t per day, intended for the production of food or feed."

Principles in BAT in fish processing industry:

- quick separation of wastes and process water
- elimination of unnecessary usage of water and energy
- applying the technology which minimising the necessary usage of water and energy
- apply and support developing new technology improving overall environmental performance, but techniques employing a risk of compromising hygiene and food standards should not be applied.

Table 1 summarise achievable consumption and emission benefits, which can be obtained if BAT and/or cleaner technology (CT) measures are implemented (BREF, 2006; Planmiljø, 2009) in the fish processing industry.

Table 1. Achievable consumption and emission (environmental) benefits through implementation of BAT/CT measures

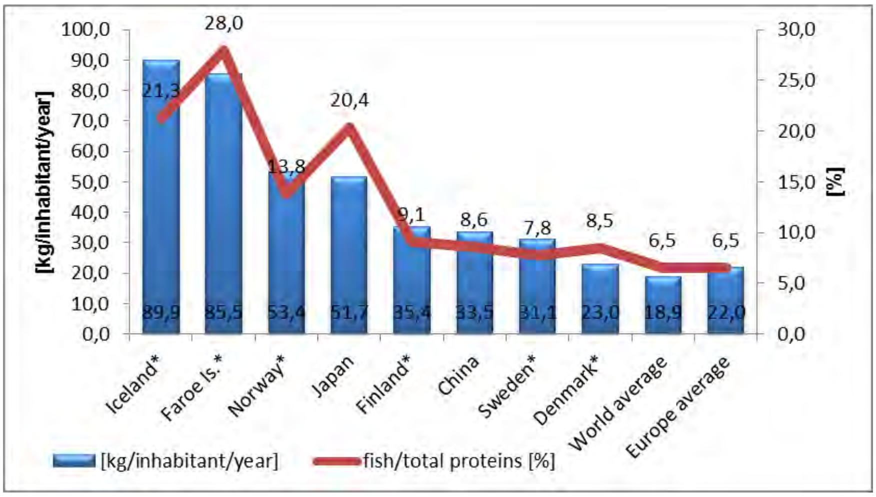
Best available technique	Environmental benefit						
	Reduced waste generation	**Reduced water consumption**	**Reduced wastewater generation**	**Reduced odor**	**Reduced energy consumption**	**Minimize loses of raw material**	**Optimise quality of final product**
Minimize storage time of fresh raw material	x			x	x	x	x
Use only high quality fish though collaboration with upstream suppliers	x					x	
Operate regular maintenance programs	x	x	x		x	x	
Thaw mackerel, whitefish and scrimps in containers with water mixed by bobbling air		x	x				
Avoid scaling of fish if subsequently skinned		10–15 m³/t			x		
When scaling, use filtrated recirculated scaling water for preliminary fish rinsing		Up to 70% reduction can be obtained					
Remove and transport skin and fat from the skinner drum by vacuum suction[1)] [1)] Operational problems related to cleaning has been experienced		~50% reduction can be obtained[1)] [1)] Wash water is needed	COD load can be reduced by95–98%				
Remove and transport fat and viscera from mackerel by vacuum suction[1)] [1)] Operational problems related to cleaning has been experienced	E.g. by-products for fish-meal production	~50% reduction can be obtained[1)] [1)] Wash water is needed	30–50% COD load can be obtained				
Use fine mesh filter conveyor belts to transport solid products, by-products and waste to enable their recovery	E.g. by-products can be sold for fish-meal production	~50% reduction can be obtainedx	Pollution load can be reduced by 30–50%				
For filleting: - Remove frames from fish fillets mechanically - Where possible replace nozzles with mechanical devices - Where nozzles or spray cleaning are needed, install presence-activated sensors		50–90% reduction can be obtained depending on the type of fish processed and which BAT are applied	x				
Apply dry collection of solid waste		x	Amount of organic substances in wastewater is reduced				
Apply dry cleaning of equipment			BOD level can be reduced up to 35% for shellfish				

1.5 The fish processing industry

Increased seafood production is a crucial element of the solution to meeting the global food challenge. According to the Food and Agriculture Organization of the United Nations (FAO), capture fisheries and aquaculture supplied the world with about 158 million tons of fish and other aquatic species (ca. 136 million tons for human consumption) in 2012, providing an apparent per capita supply 18.9 kg (Figure 1). Of this total, aquaculture accounted for 42 per cent. During the past three decades, global aquaculture production has expanded from around five million tons in 1982 to over 66 million tons in 2012. Prognosis shows that in 2030 we can except to grow up to 93.6 million tons (FAO, Fishery statistics, 2012).

In Table 2 the food balance sheet presents a comprehensive picture of the pattern of a country's food supply in 2010. The food balance sheet shows for each food item i.e. each primary commodity availability for human consumption, which corresponds to the sources of supply and its utilization.

Figure 1. Food balance – fish and fishery products in live weight and fish contribution to protein supply



Source: FAO, Fishery statistics, 2012.

Table 2. Food Balance Sheet of fish and fishery products in live weight and fish contribution to protein supply

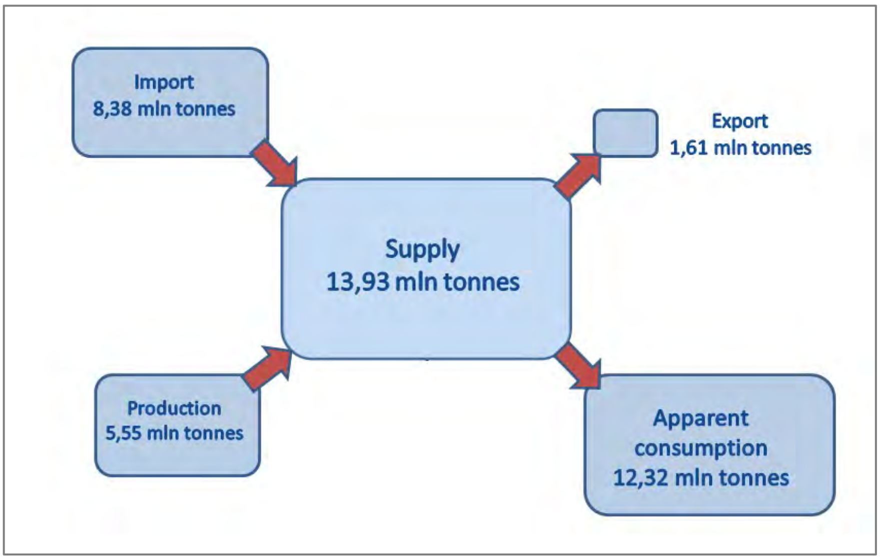
Country	Production	Non-Food Uses	Imports	Exports	Total Food Supply	Population	Per Capita Supply	Fish proteins	Animal proteins	Total proteins	Fish/Animal Proteins	Fish/Total Proteins
	[tones in live weight]					[thousands]	[kg]	[grams per capita per day]			[%]	
World	156,004,443	25,385,725	45,257,802	44,465,230	132,059,737	6,997,991	18.9	5.2	31.1	79.4	16.7	6.5
Europe	16,519,375	2,705,816	17,026,427	14,787,569	16,279,675	741,274	22.0	6.6	57.5	101.8	11.6	6.5
Denmark	867,523	597,593	913,504	1,066,586	128,281	5,575	23.0	9.2	68.1	107.7	13.5	8.5
Faroe Is.	441,450	54,053	3,061	411,488	4,276	50	85.5	22.4	51.9	80.1	43.2	28.0
Finland	170,929	40,035	108,005	47,972	190,928	5,389	35.4	10.2	69.6	112.5	14.7	9.1
Iceland	1,065,690	316,221	75,006	803,872	28,937	322	89.9	28.0	96.2	131.5	29.1	21.3
Norway	3,683,302	707,000	211,342	2,992,012	264,132	4,944	53.4	15.1	64.4	109.0	23.4	13.8
Sweden	222,679	20,042	862,321	781,439	293,520	9,449	31.1	8.4	70.9	107.0	11.8	7.8

Source: FAO, Fishery statistics, 2011.

1.5.1 *Fish industry – EU perspective*

The EU is a major consumption market of seafood products in the world with 12.3 million tonnes representing EUR 52.2 billion in 2011. It is the first importer of seafood products, absorbing 24% of total world exchanges in value. EU consumption per capita is 24.5 kg (FAO, 2011). It decreased by 5% between 2008 and 2010 and remained stable between 2010 and 2011. This is a change in trend after a robust growth in per capita consumption since 2000. Seafood consumption varies a lot from one Member State to the other, see Figure 2. Northern Member States are more focused on processed fish while Southern Member States still favour fresh products and devote a larger part of household expenditures to fish. Central and Eastern European countries are below the EU average but register increase in consumption (The EU Fish Market, 2014).

Figure 2. Supply balance in 2011 (live weight equivalent)



Source: EUMOFA based on elaboration of EUROSTAT data (The EU Fish Market, 2014).

EU exports are almost entirely composed of products from captured fisheries, whilst EU aquaculture products stay in the European market. EU exports to third countries increased by 50% in value between 2009 and 2012 to reach EUR 4.1 billion. Spain, the Netherlands and Denmark are the leading exporting Member States to third countries. Table 3 shows the major suppliers of seafood to the European market.

Table 3. The European Union's main suppliers of seafood in 2012

Country	Value in thousands of EUR	Contribution [%]
Norway	3,874,711	20
China	1,565,995	8
Iceland	968,758	5
Ecuador	952,646	5
United States	873,906	5
Other suppliers	11,002,401	57
Total	19,238,417	100%

Source: Common Fisheries Policy, 2014.

The overall value of the output of the processing industry in EU amounts to around EUR 30 billion. The United Kingdom, France, Spain, Italy and Germany are the leading countries in terms of production. The sector employs around 116,000 people. The mainstay of European production is conserves and ready meals of fish, crustaceans and molluscs.

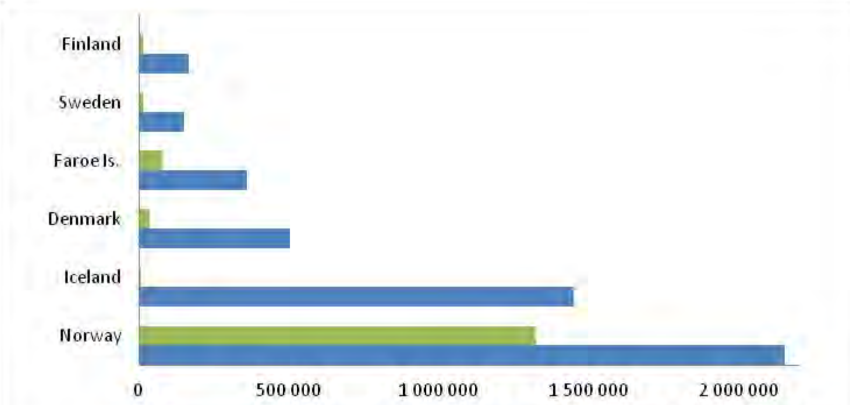
According to Member States DCF data submissions, in 2012 the total number of enterprises in the European fish processing industry was 3,454 in 2012, 54% of which having less than 10 employees, 31% with between 11 and 49 employees and only 15% with more than 50 employees, of which only 1% of enterprises have more than 250 employees (STECF 2014).

Over the period 2008–2012, the total number of enterprises decreased by 5%, although the number of firms employing 10 people or less decreased only by 2%. The number of workers employed in the European fish processing industry in 2012 was ~120,000. The total number of people employed in the sector shrank by 5% from 2008 to 2012, while the average wage increased by 16% (STECF 2014).

1.5.2 Fish industry – Nordic perspective

Economically, the Nordic countries have much in common. They are all small, open economies in which foreign trade has great economic significance. The Nordic countries industrialised late, but quickly. Early industrialisation was often based on the exploitation of rich natural resources. In Finland and Sweden, the forest was the primary source of opportunities for increased exports, while Sweden's large ore deposits also contributed to its early economic growth. With roots that can be traced back to the 1200s, Sweden's Stora Kopparberg, now part of Stora Enso, is believed to be the world's oldest functioning company. Norway has used its many waterfalls to generate power, and the Norwegian economy has been further strengthened by oil exploration in the North Sea. Norway and Iceland have also had an extensive fishing industry. Denmark's economic development was based to a large extent on its fertile agricultural land, and the food industry has been key to Danish economic success. Fishery production in the Nordic countries are shown in Figure 3.

Figure 3. Fisheries production – by capture and aquaculture in 2012 – in tons



	Norway	Iceland	Denmark	Faroe Is.	Sweden	Finland
Total	3 471 674	1 457 018	536 315	437 035	165 366	179 569
Aquaculture	1 321 119	7 431	33 586	76 564	13 757	12 659
Capture	2 150 555	1 449 587	502 729	360 471	151 609	166 910

Source: FAO, Fishery statistics 2012.

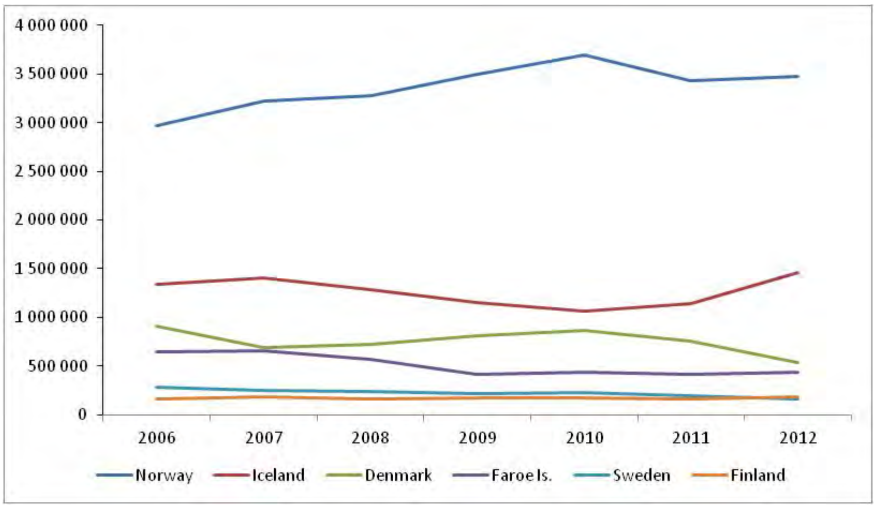
Nordic countries controls some of the world’s most productive marine environments, with excellent conditions for conducting environmentally friendly aquaculture. There are lots of opportunities for developing and maintain seafood production on the highest levels of quantities and qualities. While the numbers of professional fishermen are fairly low across the Nordic region, the fisheries’ industry is of high national and/or regional importance. For example in Iceland and the Faroe Islands, fisheries and fish production make the single most significant economic contribution to the welfare of societies. In terms of size of catches, Norway is the biggest fish producer of the Nordic countries (Eliasen *et al.*, 2009).

The Nordic countries relate to European integration in different ways. Norway and Iceland have chosen to remain outside the EU, but are members of the European Economic Area. Denmark, Finland and Sweden are all EU members, with only Finland being member of the Eurozone.

1.5.3 Overview of the national fish processing industry sectors

Figure 4 presents the total fishery production in Nordic countries – capture and aquaculture, excl. aquatic plants.

Figure 4. Total fishery production – capture and aquaculture, excl. aquatic plants (tons per year)



Source: FAO, Fishery statistics, 2012.

1.5.4 Denmark

The Danish fish processing industry is mainly located around the most important fishing harbors in Denmark. The most important areas in terms of value and volume of landings are the north and western parts of Jutland and most of the processing industry are located in these areas. Denmark is one of the world largest importers and exporter of fish and fish products and the Danish processing industry produces a large variety of products based on many different species. As such, the raw materials for the industry are purchased on the global market for fish and fish products and the dependency on domestic landing is rather limited. Nevertheless, the catches of cod, herring and mackerel are of some importance. The Danish fishmeal and fish oil factories are also dependent on domestic catches, but they are also receiving raw material from countries like Norway, Iceland, UK and Sweden. Furthermore, some Danish regions and islands are heavily depending on the local fisheries and processing industry, because alternative job opportunities in these areas are limited. The Danish import is dominated by salmon from Norway. The salmon processing industry is the most important segment processing fish for human consumption in terms of value (STECF, 2014).

The sector is dominated by small and middle-sized enterprises. In Denmark, 57 enterprises have less than 10 full time employees, corresponding to 54% of the total number of enterprises in 2012. Furthermore, 30 enterprises have between 10 to 49 employees and 19 have between 50 to 249 employees, corresponding to 28% and 18%, respectively. In Denmark, there is no large fish processing company with more than 250 employees. In Denmark, the processing industry can be divided into species dependent segments. In total there are 6 sectors: (1) cod and flatfish; (2) herring and mackerel; (3) molluscs, shrimps and crustaceans; (4) mixed production; (5) salmonoids; (6) fishmeal factories. The most important species for consumption in terms of volume is herring (29%) followed by cod (17%) and salmon (17%). In terms of value the most important species are salmon (28%), herring (17%) and cod (14%). Production of fishmeal and -oil is an important part of the fish processing industry in Denmark, which is based on fish reduction. In 2012, "fish reduction" make up for 64% of the total Danish catch in volume and 33% of the total value. The volume of "fish reduction" has been decreasing from 2008 to 2012, whereas the value has been increasing until 2011 (STECF, 2014).

1.5.5 Faroe Islands

The Faroe Islands are a self-governing territory within the Kingdom of Denmark with a centuries-old and on-going reliance on marine fishing. In 2012, the combined export value of demersal fish products and pelagic products accounted for 48% of total exports (Grétarsson and Danielsen, 2014). Fishery products, including farmed salmon, represent more than 90% of the total Faroese goods export. Additionally, harvesting and processing marine fish stocks is a considerable source of employment, and represents a significant share of the annual gross domestic product (GDP). The fishing industry employs approximately 15% of the labour force (http://www.faroeislands.fo). However, employment within the sector is falling along with an increase in vessel size and improvements in processing efficiency.

The main fish stocks in the sea around the Faroe Islands are cod, haddock and coalfish. The majority of catches in Faroese waters are landed in the islands for further processing. A significant part of the Faroese fish export value comes from fishing in foreign waters. Fishing in foreign waters is to a large extent reimbursed by reciprocal rights in the Faroese exclusive economic zone. The Faroese commercial fishing fleet comprises long-liners, gill-netters, single and pair trawlers, purse seiners and a number of ocean-going factory vessels, as well as smaller coastal vessels. A large variety of fish stocks is utilised. The most important fish for the Faroese fleet are: the ground fish stocks of cod, haddock, saithe, redfish, ling, tusk, Greenland halibut, anglerfish, greater silver smelt, deep-water stocks like blue ling, roundnose grenadier, black scabbard fish and the pelagic fisheries for herring, blue whiting and mackerel.

Raw material for production is bought at the Faroese Fish Market or directly from boats or fish farms. Catches brought ashore in the Faroe Islands are either exported fresh or processed mainly into fresh or frozen fillets and portions and salted fish. Pelagic fish is also graded and frozen onshore in the Faroe Islands, and dried fish heads and other dried products are also produced, as well as a modern and competitive fish feed production. Salted fish is one of the Faroese fishing industry's trade marks. The Faroese began salting fish in the late 19th century and exporting it to southern Europe (www.industry.fo). Expertise and good quality fish ensure a continued strong position on the market for salted fish products from the Faroe Islands.

Traditionally, the Faroese economy has been largely based upon the export of demersal species, but these have declinedin importance in recent years relative to salmon and pelagic species. The farming of Atlantic salmon and rainbow trout is an important and growing part of total Faroese fish production. In recent years, there has been a clear trend towards fewer companies controlling a large share of the licenses for salmon and trout farming (3 producers; export value: DKK 1.8 billion in 2012, 2.5 billion in 2013. The surplus on the balance of Faroes trade is also due to increased value of exports of pelagic fish (3 processing plants, 11 vessels, value of landings 2013: DKK 1.4 billion (Laksá, 2014).

In order to be certified to process food and additives for export to the European Union, Faroese fish plants, factory vessels and freezer vessels must be approved in line with all relevant EU directives on food safety. The Faroese Environmental Agency is responsible for monitoring environmental quality and issuing environmental approval for fish processing facilities, including salmon and trout processing plants. The aim is to minimise all sources of pollution from processing plants, as well as to ensure that the best available technology (BAT) is used, with limit values set, especially for wastewater outlets.

1.5.6 *Finland*

There were 173 fish processing enterprises operating in Finland in 2012, of which 143 companies were processing fish as their main activity. There were also 27 non main activity enterprises processing fish. Fish processing sector is dominated by micro enterprises employing less than 10 persons. There were 131 micro enterprises in the sector in 2012 and they amounted to 90% of all the main activity enterprises in the industry. There were only 13 enterprises employing 10–49 persons and 2 enterprises employing 50–249 persons. There are no large processing enterprises in Finland employing more than 250 persons (STECF, 2014).

In 2013, fish processing enterprises used around 80,000 tons of fish as raw material, 53,000 tons were domestic fish and 27,000 tons were imported. Total amount of fish processed in 2013 increased from previous years due to increased amounts of Baltic herring and sprat exported deep-frozen and increased amounts of Norwegian salmon and domestic rainbow trout processed.

The main species used in Finnish processing were Baltic herring (31 million kg), salmon (24 million kg) and rainbow trout (18 million kg). The Finnish industry processed also herring and various freshwater fish species. The value of the farmed fish for food industry is bigger than the catch of professional fishermen.

Ninety per cent of the total catch is Baltic herring or sprat. Almost all the sprat and three quarters of the Baltic herring is used for "reduction fisheries" or otherwise as animal feed, leaving less than one third of the total catch for human consumption. Over half of the Baltic herring used for human consumption is deep frozen, whereas half of the rainbow trout is consumed in the form of fillets. Most of the frozen Baltic herring is exported. The majority of fish for human consumption is processed into fillets; deep-frozen fish are the second most frequently consumed form of fish.

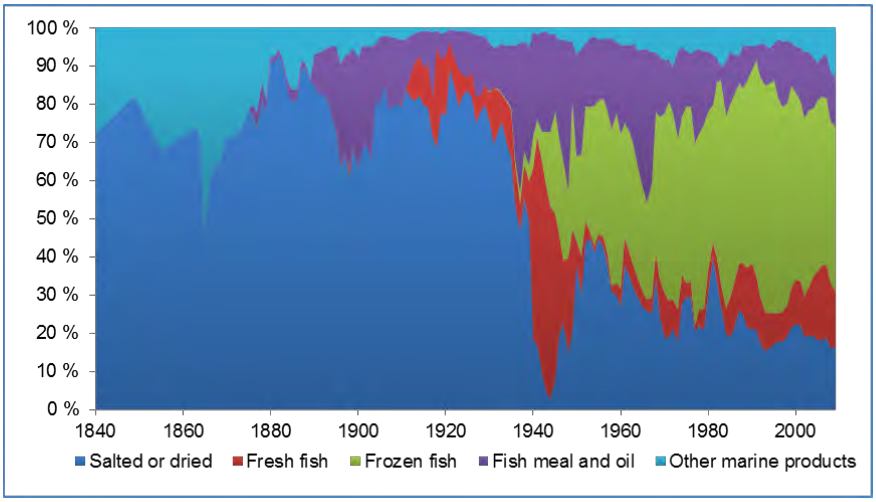
The main processing products are (hot and cold) smoked products of rainbow trout, salmon and herring. There is also a notable production of light-salted rainbow trout. Imported herring is produced as semi-preserved product. There is also some production of ready-to-eat food, in particular of rainbow trout (STECF, 2014).

1.5.7 Iceland

The most of the processing companies in Iceland operate their own fishing vessels to secure supplies for their production. The oldest fish processing method in Iceland was to dry the fish to make the so-called stockfish. Between 1930 and 1950 freezing took over as the main processing method in the industry, and has kept that position ever since although fresh processed fish have increased its portion again in the last decade. The age of quick freezing entered in the 1930s and quickly replaced more primitive methods of freezing, making it possible to export good quality products from a wide range of fish species. Today, three basic methods of processing prevail: quick freezing, salting and preservation of fresh fish in ice.

Figure 5 shows the development in relative export value of different fish products from 1840. In the groundfish fisheries, classified as demersal fish but excluding flatfish, the major trend in recent years has been a proportional increase in fresh fillet processing. Saltfish production has decreased in recent years. Exports of wetfish, i.e. iced whole fish, have increased significantly in the past two years. For various flatfish, the major trends in the past decade have been a proportional increase in fresh fillet exports but also in the export of whole iced fish. In the pelagic fisheries for herring and capelin, industrial processing for fishmeal and oil is still predominant, but frozen processing of whole herring and fillets is increasing rapidly, especially frozen at sea processing. In the shrimp and nephrops fisheries, land based freezing is predominant.

Figure 5. Export value by processing methods since 1840



Source: Statistics Iceland.

Most popular exported species are herring, cod, haddock, redfish, catfish, saithe, plaice and capelin. Quick frozen seafood products have, for a number of years, constituted about 50% of the value of seafood exports from Iceland. Quick freezing is still unrivalled as a method for preserving raw material quality and there are continuous improvements in processing technology. The freezing industry is therefore likely to maintain a strong position. Land based freezing plants are situated around most of the Icelandic coast, but part of the catch is also frozen on board the fishing vessels (Statistics Iceland).

1.5.8 Norway

The Norwegian fishing industry currently supplies seafood to consumers in more than 130 countries worldwide. Norway's coastline, including its islands and fjords, stretches some 57,000 kilometers. Norway's long coastline and seas provide it with catches of between 2.5 and 3 million tons of fish per year. There is little potential for increasing catches in the short term. There are about 10,000 registered fishing vessels in Norway, of which 1,000 are in year-round operation. About 800 facilities are engaged in catch-based aquaculture and the reception and processing of wild fish. Norway is Europe's largest supplier of fish and fish products. In the course of the last 10 years, the landed export value has doubled to over NOK 30 billion. The industry employs about 30,000 people, of whom 14,000 work in fishing, 6,000 in fish farming, and 10,000 in processing (www.regjeringen.no, http://www.invinor.no).

The processing industry mainly consists of a large number of small and medium-sized businesses scattered along the coastline. There are about 800 reception and processing facilities, and about 500 certified exporters, who represent the sales side of the industry. About 600,000 tons of farmed fish and shellfish are produced annually in Norway, and production is increasing. Most of the processing consists of salting, drying, filleting, packing and freezing. However, there is also some production of processed products such as frozen fish fingers, fish balls and fish cakes.

About 1,300 concessions have been issued for fish farming, and about 800 of these are for farming salmon and trout. There are around 100 slaughter/packing facilities, and a significant feed industry has been developed. New farmed species are constantly being introduced to commercial production.

Norway is a world leader in farmed species like Atlantic cod, Atlantic halibut and spotted wolf-fish. Spring cod is probably the most well-known fish after farmed Norwegian salmon. It is caught in the ice-cold waters off the coast of Northern Norway (www.regjeringen.no, http://www.invinor.no)

1.5.9 Sweden

The total number of enterprises operating in the Swedish processing industry increased from 301 to 343 during the period 2008 to 2012, if one includes both enterprises that process fish as their main activity and enterprises that do not. If you separate these two groups, the enterprises that process fish as their main activity increased from 214 to 223, which can be compared to 177 enterprises in 2001.The fish processing industry is located mainly along the west and south coasts of Sweden, as are major parts of the fishing fleet (STECF, 2014).

The Swedish processing industry produces a wide range of fresh, chilled, canned and frozen products. These products are primarily based on herring, whitefish, prawn and roe. In recent years, the processing rate has increased since demand has moved towards products that are almost ready to eat. At the same time, less whole fish is being sold. Farmed salmon from Norway is one of the most imported raw materials used by the Swedish processing industry.

The fish processing industry sector in Sweden is very heterogeneous with small family businesses processing their own landings as well as larger enterprises with large scale industrial production. A majority of the companies, however, are small firms with less than 10 employees. Smaller enterprises are more dependent on local landing and larger enterprises (with industrial production) depend more on imported raw material (STECF, 2014).

1.6 Environmental emissions, recipients and local regulation

1.6.1 EU

In European Union in force is “Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy". In European Union countries, all fish processing companies with production capacity for finished products of more than 75 tons per full day must obtain a separate permit according to the Industry Emissions Directive (IED). The sensitive areas are covered by the additional protection by "Natura 2000" legislation.

The IED is seven directives merged into one; a framework directive that requires the regulating of all pollutant discharges into the air, water and earth from one and the same activity gathered in one permit, granted by one authority. The aim is to achieve a more uniform assessment and regulation of the total pollution impact caused by one activity, and subsequently better protection of the environment. The directive aims for regulation to take place preferentially through individual discharge permits, but also opens for application of general regulations where this is appropriate. To achieve a common practice, the directive includes certain criteria concerning content of the license application, administrative procedure, and terms and conditions of the license. The scope of the directive is specified in a list of categories of industrial activities over a certain size.

1.6.2 The Nordic countries

Discharges of treated water from the fish processing industry, regardless of the recipient (into freshwater, marine waters or municipal sewers) requires an environmental permit. In the permit, the purpose and scope of the present use of water, the amount of wastewater and pollution parameters needs to be specified. The discharge permits describes the company, the production, the process technology applied, any consumption of water, energy, chemicals, materials, etc. and all emissions (to water, air), waste production and waste management. The environmental protection processes applied, including the treatment technology and the amount of sewage determined based on measurements or estimates is also described.

To illustrate the diversity for wastewater treatment and discharge permits for fish processing plants in the Nordic countries, Figure 6 shows the differences in the final recipient of the treated wastewater. Figure 6 shows the location of some selected fish processing plants. The 4 case studies described in the current report have been enumerated as 1–4, A-F are cases of which discharge permits in Åland, Finland and Denmark have been given.

Figure 6. Location of the selected fish processing plants in Nordic countries

Source: http://www.zonu.com

Case studies described:

1. P/F Pelagos, Faroe Island.
2. Norway Pelagic AS, Måløy, Norway.
3. Nordlaks Produkter AS, Norway.
4. Orkla Foods, Sweden.

Discharge permits described:

A. Åland.
B. Finland, Kuopio.
C. Finland, Kasnäs.
D. Denmark, example 1.
E. Denmark, example 2.
F. Denmark, example 3.

1.6.3 Norway

The Industry Emissions Directive (IED) is implemented in Norwegian legislation. In Norway fish processing companies with production capacity for finished products of more than 75 tons per full day, and factory ships and activities that produce fish oil, fishmeal or fish feed must obtain a separate permit from the County Governor according to the Pollution Act, which also includes the Industry Emissions Directive (IED) (Environmental report, NSF 2013).

The majority of fish processing plants in Norway discharge to marine recipients, where no major challenges related to over-fertilization and pollution have been seen. The inspection action that the Norwegian Environment Agency carried out in 2012 to several plants nonetheless exposed certain deviations from the applicable regulations, particularly in emission control, wastewater treatment, waste disposal and environmental risk assessment. A particular challenge reported by many fish processing plant is related to the sampling and monitoring of fat in treated water.

The companies will strive continuously to improve and close these deviations. The companies that are covered by the IED regulations may report emissions of nitrogen (Total N), phosphorous (Total P), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), fat and water quantity. Reports are uploaded to the website of the Norwegian Environment Agency.

The examples of fish processing plants in Norway and the discharge requirements is described in detail in chapter 4.1.2. and 4.2.1.

1.6.4 Åland

Åland adopted in 2014 new regulation for the discharge permits from fish slaughterhouse. The new limits are established for BOD, total P and total N, for fish slaughterhouse equipped with internal, small treatment plants. The wastewater after treatment are discharged into the Baltic Sea. The limits for fish slaughterhouse correspond to maximum levels for municipal wastewater treatment plants between 100–400 p.e. In the other cases, the wastewater should be discharge to the municipal wastewater treatment plants. In Table 4 the discharge limits for fish slaughterhouse is presented.

Table 4. Discharge permits in Åland

Parameter	Limited concentration [mg/l]	Removal [%]
BOD	15	90
Tot-P	1	90
Tot-N	35	50

1.6.5 Finland

There are no specific regulations in Finland as far as the fish processing sector is concerned. As an EU member Finland has implemented into national legislation the regulations, regarding wastewater discharged (IED directive and the obligation to implement BAT). As BAT does not take into consideration, the type of the final recipient, authorities have to take into account the location of the installation and the foreseen impact. More strict requirements can be established in case the recipient is very sensitive for pollution (lakes, Baltic Sea).

In Finland there is a lack of fish processing plants that meet the IED regulation regarding size of plants. Nevertheless, smaller plants have to adhere to the very strict regulations due to special type of recipients.

Example 1

As an example of discharge permits for small fish processing plants can be listed the factory, that produces smoked and salted salmon in Kuopio. The capacity of produced final product is less than 600 tons per year. Table 5 show the discharge permit. The permit concerns the volume over the 25 m^3 per day of generated wastewater.

Table 5. Discharge permits in the smoked and salted salmon in Kuopio (Finland)

Parameter	Required concentration [mg/l]	Removal [%]
BOD	30	90
COD	250	-
Tot-P	-	85
Tot-N	-	40

Example 2

Another example of discharge permits is for a small fish processing plant, a salmon farm in Kasnäs with fish preprocessing (slaughterhouse and fish cleaning processes). The majority, about 75% of the blood is frozen with the other waste at the fish processing plant, the residual part of blood dissolves in the rinse water. Water for fish cleaning is taken from a private drilled well. Water consumption during cleaning of the fish is 2 liter per kg of gutted fish. The capacity of processed fish (fish cleaned by hand and washed by machine) is about 600 tons per year.

Environmental impact per year (600.000 kg of fish cleaned by hand and washed by machine):

BOD	1,596 kg
Total phosphorus (Tot-P)	15 kg
Total nitrogen (Tot-N)	204 kg

Processing wastewater should be treated at least to the level of treatment required in the government act on municipal wastewater treatment in areas without connection to sewer networks.

The amount of wastewater may not exceed 25 m^3 per day. Permits concerning the discharge wastewater:

BOD	300 g / ton gutted fish
Total phosphorus (Tot-P)	10 g / ton gutted fish
Total nitrogen (Tot-N)	200 g / ton gutted fish

In some particular plants, the problem with brine can appear. If the plant would like to meet the requirements for wastewater discharges, the brine separation from the main stream of wastewater is needed. The brine is separated and transported to the external treatment plant, where followed by more effective treatment. That solution generate additional cost but the requirements are met.

1.6.6 Denmark

Figure 7. Nature protection and Natura2000 areas in Denmark where BAT may be insufficient to protect the habitats

Source: http://arealinformation.miljoeportal.dk

Denmark is a member of EU and thus environmental permits for fish industries producing food from fish shall be based on BAT as described in the BREF-document for food drink and milk (2006). The BAT associated emission levels in the existing BREF-document form a basis for the local authority when they set limits in permits and proportionality may be a part of the assessment behind the permits. In the future, when new

BAT-conclusions have been published, the BAT associated emission levels will be more strictly binding, thus the local authority can only set limits in the permits that are stricter than the interval of the BAT associated emission levels, if public health or recipient surrounding nature requires it. Denmark has implemented into national legislation the EU regulations, e.g.: "The Water Frame Directive" and "Natura 2000". These regulations can lead to stricter limits than those based only on BAT, depending on where the company is situated. Figure 7 shows nature protection areas and Natura 2000 areas in Denmark where BAT may be insufficient to protect the habitats.

Example 1

The fish processing company has an environmental permit from 2006 and a permit for connection to the municipal wastewater treatment plant from 2013. The company has emission of wastewater from the industrial process. The wastewater is pre-treated on-site in a flotation process without addition the chemicals. After pretreatment the wastewater are discharged to the municipal sewer. Part of the treated wastewater is re-used as dispersion water in the flotation system. The wastewater discharged into the municipal wastewater treatment plant have to meet the permits shown in Table 6.

Table 6. Emission limits for wastewater discharged to municipal wastewater treatment plant situated in the northern part of Jutland

Parameter	Max discharge concentration (average)	Max. discharge concentration (max)	Unit
COD	6,000	10,000	mg/l
TSS	3,000	5,000	mg/l
Oil and grease	1,500	3,000	mg/l
Chloride	4,500	5,500	mg/l
Flow (per hour)	-	200	m^3/h
Flow (per day)	-	1,500	m^3/day
Flow (per year)	-	200,000	m^3/year
pH	6.5–9.0	6.5–9.0	-
Temperature	50	50	°C

Example 2

The fish processing company has an environmental permit and a permit for connection to the municipal wastewater treatment plant from 2011. The company has emission of wastewater from the industrial process. The wastewater, before discharging to the municipal wastewater sewer system, is filtered in a rotation filter and treated in an oil and grease separator. The wastewater discharged into the municipal wastewater treatment plant have to meet the permit shown in Table 7.

Table 7. Emission limits for wastewater discharged to municipal wastewater treatment plant situated in northeastern part of Jutland

Parameter	Max. discharge concentration (average)	Max. discharge concentration (max)	Unit
COD	20,000	40,000	mg/l
TSS	2,000	4,000	mg/l
Oil and grease	2,000	5,000	mg/l
Flow (per day)	70	100	m^3/day
Flow (per year)	5,000	6,000	m^3/year
pH	6.5–9.0	-	-
Temperature	50	50	°C

Example 3

In Table 8 the discharge permit for a fish processing plant, which is operating a biological wastewater treatment plant is presented. The recipient is the sea east of Jutland (Kattegat).

Table 8. Emission limits from a wastewater treatment plant emitting to the sea eastern part of Jutland (Kattegat)

Parameter	Max discharge concentration (average)	Max discharge per year
Water	-	110,000 m^3
COD	100 mg/l	11 tons
Total Nitrogen	19 mg/l	2,100 kg
Total Phosphorus	1.5 mg/l	105 kg

1.6.7 The Faroe Islands

The Faroe Islands are not member of European Union and has therefore not implemented EU legislation for wastewater into national regulations (IED directive and the obligation to implement BAT). The Faroe Islands does not have any specific regulations for fish processing industry on wastewater treatment, but the requirements are set out in the environmental approval for each plant.

The requirements for wastewater treatment in the fish processing industry is that wastewater before discharge must be filtered by sieves (minimum 1 mm); the factory should be equipped with a fat separator (with retention time minimum 15 min. and a maximum surface loading of 10 $m^3/m^2/h$).

The processed wastewater must be discharged directly into the sea where the water current prevents accumulation of organic matter. The discharge must be minimum 1 m below the sea surface, and there shall not be any visible trace on the sea surface. The wastewater discharge should not have any negative impact on the environment.

2. Overview of fish processing and techniques

2.1 General

Processing fish involves primarily the application of preservation techniques in order to retain quality and increase shelf life. It may also deal with value-adding to produce a wide variety of products.

The primary objective of any handling method is to preserve the quality of the fish by bringing down the temperature near to 0 °C as quickly as possible. The factors such as: delay in handling and chilling, poor temperature control in the fish hold, damage from rough handling, poor standards of gutting, bleeding and washing the fish and mechanical damage due to the overfilling of the containers, have a deleterious effect on the quality of fish, and result in reduction of shelf life and loss of weight.

A number of methods are used to preserve fish. Some employ techniques based on temperature control, using ice, refrigeration or freezing; others on the control of water activity and include drying, salting, smoking and freeze-drying. Techniques may rely on the physical control of microbial fish loads, such as through microwave heating or ionizing irradiation or on chemical control of microbial activity and loads by adding acids, for example, to fish products. Techniques are also used that are based on decreasing of oxygen level, such as vacuum packaging. Most often, a combination of different techniques is used to preserve fish.

Finally, fish processing operations include proper waste management techniques. The further processing of fish into a wide variety of value-added products is now common with the increase in demand for food products that are ready to eat or require little preparation before serving. For the transportation of chilled and frozen fish products by road, rail, sea or air, it is essential that the cold chain is maintained throughout. This requires the use of insulated containers or transport vehicles and adequate quantities of coolants or mechanical refrigeration. Container technology now makes possible the combination of refrigeration combined with a modified or controlled atmosphere (FAO, Processing fish and fish products, 2015).

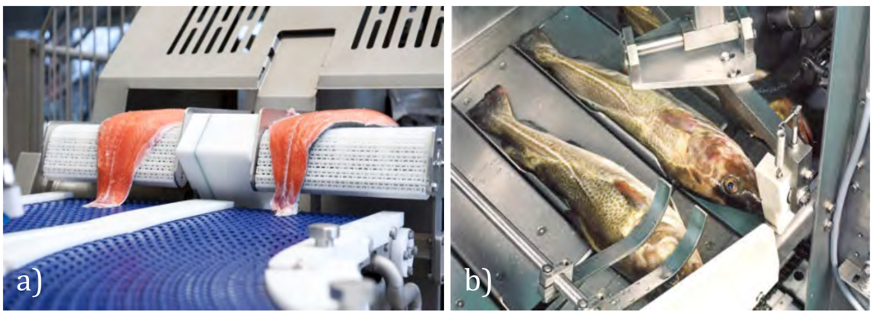
2.2 Preliminary processing

Fish are processed both onboard the ships catching it and in land based plants. The main objective of preliminary processing is the full or partial separation of edible parts from inedible ones. As a result, semi products are obtained of the shape, size, and quality approved by the consumers and meets the needs of the further processing. It also allows for efficient utilization of inedible parts e.g. for animal feed production. Isolating the highly perishable parts extends the life of the parts used in further processing. The decrease of the mass of the raw material affords economy in the transport of the semi products or the final products.

There are a few major semi products of fish preprocessing from the least to the most labor intensive – headed and gutted fish fillets, V-cut fillets, butterfly fillets, fish after nobbing. Subsequent operation result in the growing degree of the edible/inedible part separation. The choice of the particular form of preprocessing depends on the requirements of the technology, the kind and size of the material and the technical potential of the producer. The economic and marketing aspects have also a great importance.

In the modern fish industry, preliminary processing is mainly mechanized. There are special machines to scaling, gutting, deheading, nobbing, filleting, skinning, cutting and meat separation. In preprocessing process, other machines are also used e.g. freezers, deicers or graders.
There are many types of the above mentioned machinery. They differ in output capacity, size and species range of the processed material, the way in which the operation is performed, the technological yield etc. (Sikorski, 1990).

Figure 8. BAADER 581 salmon filleting machine



(a) BAADER 192 HR heading, gutting and roe recovery machine .
(b) – http://www.baader.com/

Most fish processing machinery installations, used during preliminary processing, depend for their operation on using large quantities of water. Beyond this necessary use of water, the flow of water to these installations is often uncontrolled and excessive (Þórðarson *et al.* 2013). The waste is often cut or mashed up and mixed with the water by the action of the machines, which produces a high strength effluent. This is a particular problem when processing ungutted and high oil content pelagic fish. The solid waste from the machines is often not effectively separated at source. It often ends up on the floor around the installations. The faults lie not only in the processing machines themselves but also in the systems of catch trays, chutes, conveyors and flumes commonly built around them to transport the fish, products and waste (Seafish, 1999; Þórðarson *et al.,* 2013).

2.2.1 Thawing/freezing

The process of commercial freezing as a means of preserving seafood has been in place since the early 1900's. The freezing process alone is not a method of preservation. It is merely the means of preparing the fish for storage at a suitably low temperature. In order to produce a good product, freezing must be accomplished quickly. A freezer requires to be specially designed for this purpose and thus freezing is a separate process from low temperature storage. The three basic methods of freezing fish are: (i) blowing a continuous stream of cold air over the fish – air blast freezers; (ii) direct contact between the fish and a refrigerated surface – contact or plate freezers; (iii) immersion in or spraying with a refrigerated liquid – immersion or spray freezers. The majority of frozen fish semi products require thawing before further processing.

Thawing is the process of changing a product from frozen to unfrozen. It involves transferring heat to a frozen product to melt the ice that was formed within the flesh during the freezing process. Fish processing industry use a large quantity of frozen fish and shellfish every year. Much of this product requires thawing before further processing or use. Companies typically thaw seafood in-house using a range of different methods. These vary from using water (immersion or spray), air or steam through to microwave and radio frequency systems. The type of thawing method used is dependent on many factors including cost, throughput, timescale, size, efficiency and effect on quality amongst other things.

2.2.2 Grading

Processing begins with the grading of raw material according to species and size, as well as isolating the fish, which are unfit for consumption or damaged. Fish grading is an absolute prerequisite for efficient industrial fish processing. Actual catch often contains fish of different sizes and species. Grading by size and separation of species ensures uniform flow for next processes thus increasing capacity and quality.

Fish grading is used extensively for small, pelagic fish e.g. herring, mackerel, sprat and sardines. The material is graded according to maximum thickness, as this is correlated with the length of the fish. Most frequently, the grading take place in an opening slit formed by some vibrating elements, or between rotating rollers.

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Figure 9. Rotating elements in grading machine and vibrating grading machine

Source: http://www.timars.se

2.2.3 Scaling

For some fish species, hand scaling amounts nearly 50% of the time of initial processing. Machines used in mechanized scaling should not damage the skin or weaken the texture of the muscular tissue. Two types of scaling machines are used in fish preliminary processing; drum machines in which the material is scaled by grazing past the rough walls of the rotating drum, and machine scrapers in which fish is passed through a system of stationary or moving scrapers.

2.2.4 *Deheading and gutting*

The fish head constitutes up to 20% of its weight (Ghalyet *et al.,* 2013) and is usually considered as an inedible part. The fish can be deheaded manually or mechanically. Manual cutting is easier for small fresh water fish. Larger fish ranging from 20–40 cm can be deheaded using mechanical devices. Fish can be cut in three different ways: round cut, straight cut and contoured cut. In most fish plants, manual deheading is performed because it causes minimal flesh loss. A cut around the operculum is a called a round cut and it results in the lowest meat loss. The contour cut runs perpendicular to the fish backbone and then at an angle of 45°. This cut is mainly used when the final product is a boneless and skinless fillet (Borderías and Sánchez-Alonso, 2011). Machines with a guillotine cutter are suitable for larger fish under-going round or contour cuts. Machines with a manually operated circular saw are suitable for larger fish undergoing straight cuts. The amount of deheaded waste produced from fish processing is 27–32% (Arvanitoyannis and Kassaveti, 2008).

Gutting of the fish is the removal of internal organs and optionally cleaning the body cavity of the peritoneum, kidney tissue and blood. In the gutting process, the fish is cut longitudinally to remove the internal organs on a table made of special material, which is easy to wash and does not absorb fluids. The table is rinsed and periodically disinfected. There are some mechanical gutting machines used for trout, eel and other fish, but their use increases the fish processing cost (Jonatansson and Randhawa, 1986). The internal organs constitutes around 5–8% of the fish weight Ghaly *et al.*, 2013).

2.2.5 *Filleting and skinning*

Filleting can involve a number of unit operations: pretreatment, fish filleting, trimming of fillets, packing and storage. The fillet is the block of meat composed of the dorsal and abdominal muscles and the most popular forms of fish-obtained culinary raw material on the market. The technological yield of filleting, e.g., gutting depends of the fish species, its sex, size, alimentation etc. Hand filleting is labor intensive and high productivity requires much skill and experience from the workers. For this reason, filleting machines have been implemented in fish processing on a wide scale. The growing demand for fish fillets increases interest in simple and inexpensive single-purpose machines for filleting of deheaded and/or gutted fish. Different species can be processed in these devices as long as they are in the same size range and similar body shape. The simplest filleting machine for gutted and deheaded fish has two disc knives set from each other at a distance equal to the thickness of the fish's backbone.

Following the wide application of filleting machines, skinning machines were introduced. The fish skinning machines are designed to scrape the fish skin from fish fillets and must ensure high output and effectiveness of the operation. A correctly skinned fillet must not be damaged on the skinned side, where the silvery pellicle connecting monomers must be left.

2.3 Canning

The canning process is a sterilization technique that kills microorganisms already present on the fish, prevents further microbial contamination, and inactivates degradable enzymes. In this process fish are hermetically sealed in containers and then heated to high temperatures for a given amount of time. The fish canning production process begins with the reception of raw materials. The processes in fish canning industry varies significantly depending on traditions, fish species and character of final products. However, the main processes are following: 1) the fresh fish are offloaded at the plant, 2) the skins are eventually removed and the fish are eventually filleted and cut into pieces, 3) the fish are precooked in the cans, 4) brine, oil or sauce is added and 5) the cans are sealed and autoclaved. The fish canning industry consumes a large amount of water in operations such as cleaning, washing, cooling, thawing, ice removal, etc. (AWARENET, 2005). Consequently, this sector also generates large quantities of wastewater in which the treatment is particularly difficult due to the high content of organic matter and salts and to the significant amount of oil and grease they present (UNEP, 2000).

2.4 Salting

Salting is the process that lowers the moisture or water content of fish and other fishery products to a point where microorganisms cannot live and grow. Sodium chloride, or salt, improves fish texture because it firms up the fish. Salt partially dehydrates the fish and kills the bacteria. Three basic methods of applying salt to preserve fish:

Pickle Salting – cover the fish with salt and pack them in layers in watertight containers. This forms the pickle that serves as the saturated brine solution that covers the fish completely.

Brine Salting – immerse the fish in a saturated solution made up of 25 parts of salt and 100 parts of water. Brine salting is done only as a temporary way to preserve fish before they are dried, smoked, or processed.

Dry Salting – run granular salt on the fish. The proportion of salt to fish varies from 10% to 35% of the fish weight.

2.5 Smoking

Smoked seafood is prepared with two basic procedures. Hot smoking cooks the product; cold smoking does not. Cold smoking devices have one basic function: to apply smoke to the product. Hot smoking devices have the added function of applying heat. And because preservation of fish usually requires moisture removal, systems designed for hot or cold smoking fish may have the added function of dehydration. Modern fish smoking equipment is usually designed to produce either hot or cold smoked products, but in either case they are usually designed to have adequate airflow and exchange to remove large quantities of water from the product (and eject it from the system) (Hilderbrand, 2001).

Fresh fish received shall be inspected and adequately washed with potable water before processing. All fish received in a frozen state shall be either thawed promptly and processed or stored at a temperature that will maintain the fish in a frozen state. Thawing shall be carried out in as rapid a manner as possible so that the internal temperature of the fish does not exceed 3.3 degrees Celsius. After thawing, the fish shall be adequately washed with potable water before processing. Before smoking, fish shall be dry-salted or brined in a manner that will ensure an adequate and consistent water phase salt content of the finished product. After removal from a brining solution, fish shall be rinsed with potable water. Immediately after the thermal process, the smoked fish shall be cooled to a temperature ca. 3.3 degrees Celsius or below and shall remain at or below that temperature at all times, including through all storage, marketing, and sales channels.

2.6 Drying

This method is also known as natural dehydration. Like the salting method, it lowers the water content of the fish to a point where microorganisms, bacteria, enzymes, and yeasts cannot grow and multiply. The most popular fish preservation method is solar drying. It is done in combination with salting. Fish dried under the sun looks and tastes better.

2.7 Fish meal/oil production

Fishmeal and oil processing is based on technology that has been developed through most of this century. Each consignment is subject to comprehensive regulatory controls to safeguard its integrity from factory to farm. Raw material quality, heat treatment and separation processes must therefore be well monitored.

Fishmeal and fish oil are produced by a continuous process which involves cooking, pressing, drying and milling. Fishmeal factories use raw material fully. The following summary is a step by step guide to the production process:

- Intake – raw fish is sampled and analysed on intake to check for freshness.
- Cooking – the raw fish is conveyed through a steam heated continuous cooker, where it is heated to 90°C–95°C. This sterilizes the fish, coagulates the proteins and disrupts the cell membranes, to facilitate the separation of the solubles and the oil from the dry matter.
- Press – the cooked raw material is fed to a screw press where much of the liquid is squeezed out to form a presscake which is conveyed to the drier.
- Separator – the press liquid contains, apart from water, most of the oil from the fish, and also dissolved proteins, salts and fine particles. The latter are removed in a decanter and transported to the drier to be mixed in with the presscake. The liquid from the decanter is fed to separators where the oil is removed and subsequently stored for export.
- Evaporator – the water phase from the separators is fed to the evaporators where it is concentrated before being blended with the presscake during the drying stage.
- Drier – the water in the presscake, sludge and concentrate is removed by rapid hot air drying after which the fishmeal is cooled, milled and stored for export (FAO, Fisheries Technical Paper, 1986).

The bulk of the world's fish meal and oil is today manufactured by the wet pressing method. The main steps of the process are cooking for coagulation of the protein thereby liberating bound water and oil, separation by pressing of the coagulate yielding a solid phase (presscake) containing 60–80% of the oil-free dry matter (protein, bones) and oil, and a liquid phase (press liquor) containing water and the rest of the solids (oil, dissolved and suspended protein, vitamins and minerals). The main part of the sludge in the press liquor is removed by centrifugation in a decanter and the oil is subsequently removed by centrifuge. The stickwater is concentrated in multi-effect evaporators and the concentrate is thoroughly mixed with the presscake, which is then dehydrated usually by two-stage drying. The dried material is milled and stored in bags or in bulk. The oil is stored in tanks (FAO, Fisheries Technical Paper, 1986).

2.8 Cleaning

Clean and disinfected fish contact surfaces are of the utmost importance in the fish processing industry to control the risk of microbiological contamination in the processing line. The hygiene in the industry is usually guaranteed by cleaning and disinfecting the processing plant such as the working area, processing equipment and fish contact surfaces. There are different methods for cleaning and disinfecting a processing plant. Cleaning-in-place (CIP) is the most commonly used practice for cleaning and sanitizing food processing plants. After each processing day, the plant and all equipment should be cleaned with using different cleaning agents. Most frequently used agents in fish industry are: water, detergents and sanitizers.

The detergents are the most important type of cleaning agent, and are usually mixed with water before use. They can be divided into three broad groups, dependent on the kind of solution they form, whether acidic, neutral or alkaline.

Acid detergents are generally based on phosphoric or sulphuric acid, and their use is rather limited. They are extremely effective in removing salts precipitated from water in hard water areas, and in cleaning aluminium where the acids readily remove the white scale that forms on the surface of the metal.

Neutral detergents comprise a wide range of materials that are mainly suitable for light duty cleaning. They are generally similar to household detergents, and their good wetting ability makes them ideal for the dispersal of grease and oil.

Alkaline detergents can vary in strength from those that are only a little stronger than the neutral types to ones that are strongly alkaline, consisting almost entirely of caustic soda, and requiring extreme care in use (Martowitono, 2011).
The most commonly used sanitizer in food processing is chlorine, in its various forms. Commonly used chlorine compounds include liquid chlorine, hypochlorite, inorganic chloramines, and organic chloramines. Chlorine is active at low temperature, is relatively cheap, and leaves minimal residue or film on surfaces. The major disadvantage of chlorine compound is corrosiveness of many metal surfaces (especially at higher temperatures) (Martowitono, 2011).

As a priority in cleaning operation should be usage the readily biodegradable surfactants and their commercial composition.

Keeping the plant in clean & tidy condition, according to safe food quality standards and minimizing the amount of chemicals needed for cleaning in the plant is the principle role in modern factories. In some factories for fish processing the target is to avoid or minimize using chemicals which can deteriorate the waste by-products. Especially in case of using fish by-product for production of human consumption product.

2.9 Environmental challenges

In fish processing industry, the most important issue is to operate in a manner that protects human health and the environment while maintaining the highest food safety standards. If not minimised and properly managed, these operations can create enormous negative impacts on the environment. The primary environmental issues associated with fish processing industry are water use, high-strength effluent discharge and energy consumption. Noise, odor and solid wastes are additional significant impacts that can detrimentally affect the environment if not adequately addressed. In Table 9 the impact of the processing processes on the environment is summarised.

Table 9. Environmental challenges in particular processes in fish processing industry

Process	Environmental challenges						
	Water con-sumption	Wastewater generation	Energy consumption	Waste generation	Odor	Noise	Chemicals consumption
Preliminary processing	+	+	+	+		+	
- Thawing and frizzing	+	+	+				
– Grading			+				
– Scaling	+	+	+	+			
- Deheading and gutting	+	+	+	+			
- Filleting and skinning	+	+	+	+			
Canning	+	+	+	+	+		+
Salting	+	+					+
Smoking	+	+	+		+		
Drying			+		+		
Fish meal/oil production	+	+	+	+	+	+	
Cleaning	+	+		+			+

3. Consumption and emissions

3.1 Environmental overview

In fish processing industry, the large quantities of water and energy are consumed, which cause that significant quantities of organic material, both as liquid waste and as solid waste are generated. The consumption and emission of the utilities (water, energy) varies in wide range, depending on the process technology, product characteristics, plant location, equipment characteristics and source of utilities. Figure 10 presents the environmental balance in fish processing industry. Tables 10–12 present the inputs and outputs of fish production processing, canning process and fishmeal production (Arvanitoyannis and Kassaveti, 2008; Ghaly *et al.*, 2013). Data presented in Tables 10–12 are mostly similar to BREF, but the table is organized differently. Over the past years no significant changes in the value of inputs and outputs in fish processing industry has been reported.

Figure 10. Consumption and emission in fish processing industry

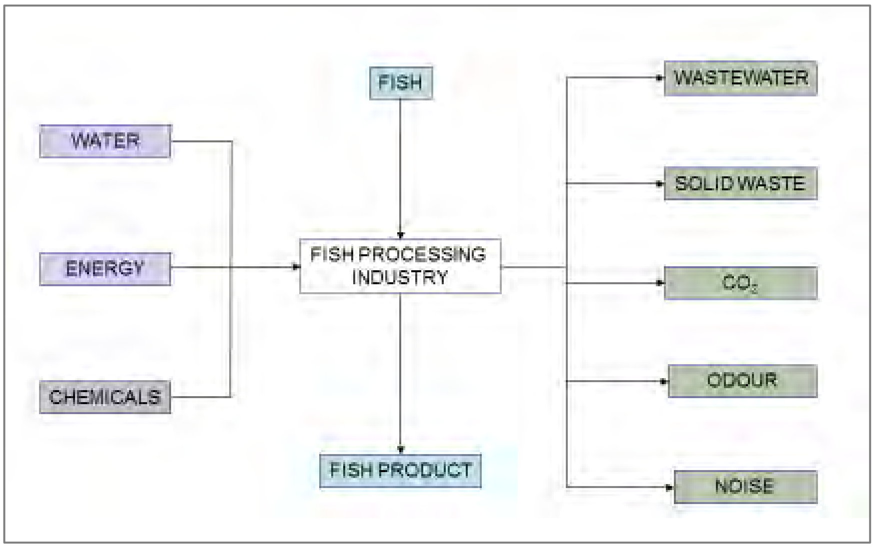


Table 10. Inputs (1000 kg of fish) and outputs of the different fish production processes

Process	Inputs	Outputs					
	Energy [kW h]	Wastewater [m³]	BOD [kg]	COD [kg]	Nitrogen [kg]	Phosphorus [kg]	Solid waste [kg]
White fish filleting	Ice: 10–12 Freezing: 50–70 Filleting: 5	5–11	35	50	-	-	Skin: 40–50 Heads: 210–250 Bones: 240–340
Oily fish filleting	Ice: 10–12 Freezing: 50–70 Filleting: 2–5	5–8	50	85	2.5	0.1–0.3	400–450
Frozen fish thawing	-	5	-	1–7	-	-	-
De-icing and washing	0.8–1.2	1	-	0.7–4.9	-	-	0–20
Grinding	0.1–0.3	0.3–0.4	-	0.4–1.7	-	-	0–20
Scaling of white fish	0.1–0.3	10–15	-	-	-	-	Scales: 20–40
Deheading of white fish	0.3–0.8	1	-	2–4	-	-	Head and debris: 270–320
Filleting of deheaded white fish	1.8	1–3	-	4–12	-	-	Frames and off cat
Filleting of ungutted oily fish	0.7–2.2	1–2	-	7–5	-	-	Entrails, tails, heads and frames: 400
Skinning white fish	0.4–0.9	0.2–0.6	-	1.7–5	-	-	Skin: 40
Skinning oily fish	0.2–0.4	0.2–0.9	-	3–5	-	-	Skin: 40
Trimming and cutting of white fish	0.3–3	0.1	-	-	-	-	-
Packaging of fillets	5–7.5	-	-	-	-	-	-
Freezing and storage	10–14	-	-	-	-	-	-
Handling and storage of fish	10–12	-	-	130–140	-	-	-
Unloading of fish	3	2–5	-	27–34	-	-	-

Source: Ghaly et al. 2013.

Table 11. Inputs (1000 kg of fish) and outputs of the fish canning process

Process	Inputs	Outputs					
	Energy [kW h]	Wastewater [m³]	BOD [kg]	COD [kg]	Nitrogen [kg]	Phosphorus [kg]	Solid waste [kg]
Canning	150–190	15	52	116	3	0.1–0.4	Heads: 250 Bones: 100–150
Unloading fish for canning	3	2–5	-	27–34	-	-	-
Precooking of fish to be canned	0.3–11	0.07–0.27	-	-	-	-	Inedible parts: 150
Nobbing and packing in cans	0.4–1.5	0.2–0.9	-	7–15	-	-	Heads and entrails: 150 Bones and meat: 100–150
Draining of cans containing precooked fish	0.3	0.1–0.2	-	3–10	-	-	-
Sauce filling	-	-	-	-	-	-	Spillage of sauce and oil: varies
Can sealing	5–6	-	-	-	-	-	-
Washing of cans	7	0.04	-	-	-	-	-
Sterilization of cans	230	3–7	-	-	-	-	-

Source: Ghaly et al. 2013.

Table 12. Inputs (1000 kg of fish) and outputs of the fish meal production process

Process	Inputs	Outputs		
	Energy [kW h]	Wastewater [m³]	COD [kg]	Solid waste [kg]
Fish meal and fish oil	Electricity: 32	-	-	-
Cooking of fish	90	-	-	-
Pressing the cooked fish	-	750kg water 150kg oil	-	Press cake: 100 dry matter
Drying of press cake	340	-	-	-
Fish oil polishing	Hot water	0.05–0.1	5	-
Stick water evaporation	475	-	-	Concentrated stick water: 250 Dry matter: 50

Source: Ghaly et al. 2013.

3.2 Water consumption

Fish processing requires large amounts of water, primarily for washing and cleaning purposes, but also as a media for storage and refrigeration of fish products before and during processes. Water is also an important medium for transportation in the particular handling and processing steps. The processing industry for marine species often uses seawater in part of the cleaning process, and cleaning the fish filet with seawater is considered important to improve the quality of the finished product. Seawater used for this purpose is normally filtered and treated with UV disinfection to inhibit spreading of bacteria.

The water consumption depends also on the water prices. High prices of water can encourage development and implementation of novel technology. The level of achieved potential savings, in case of application of new, emerging technology will be different in terms of water price.

In Faroe Islands, where the water is available for free, the companies very seldom take into consideration in plans of their development, the possibility of buying new, expensive technologies for water saving. Conversely, in Denmark, where the water price is very high, the companies are interested in solutions, that allow for the water saving and thus savings of the funds. In such countries, there is an opportunity for significant growth of markets for fish processing equipment that give the real water savings.

3.3 Wastewater generation

In fish processing plants, large quantities of wastewater is generated. The quality of wastewater discharged from fish processing plants depends on the water management system exploited in the plants. One of the indicators, which allow estimating the correctness of the management of water and wastewater in the plant, is the water consumption for the particular processing operation and fish products. Saving water while maintaining the technological and sanitary standards reduces the volume of wastewater but increases the concentrations of the pollutants. The total amount of pollutants per amount of fish processed (kg/ton fish processed) is, however, reduced. As an example of water savings and thereby reduction of wastewater generation can be modification of the smoking of fish from dry smoking to condensate smoking (liquid smoke). Smoking without tar and ash reduces up to 50% the level of water requirements for cleaning work. The wastewater volume is smaller and less contaminated with harmful substances.

Most of the water consumed during the different fish processing steps (thawing, washing, head cutting, filleting, skinning, trimming, canning and fish-food processing) ends in the wastewater.

The wastewater contains high levels of organic substances (fat, soluble proteins, acetic acid, and carbohydrates), phosphorus, nitrogen and remains from the cleaning process.

3.3.1 Wastewater treatment

Water consumption in fish processing industry and the production of high strength wastewaters are of great concern worldwide (Chowdhury *et al*., 2010). In fact, in this type of industries, a huge amount of water is used throughout all steps, including cleaning, cooking, cooling, sanitization and floor washing. Fish processing wastewater are known to contain organic contaminants in soluble, colloidal and particulate form. The biodegradable organic matter is mainly in the form of proteins and lipids. The concentration and volume of wastewater from fish processing varies widely, depending on the fish to be processed, the additives used (e.g. brine, oil, tomato sauce), the unit processes involved and the source of the water, among other factors.

There is a need, for both economic and environmental sustainability reasons, to consider the wastewater treatment in order to obtain water with the quality requirements established by the European Directive 98/83/EC, which allows its reuse into the industrial process.

Fish processing wastewaters are generally treated using physical-chemical methods (primary treatment) biological methods (secondary treatment), or a combination of both.

Within the primary treatment, can be listed processes as equalization, screening, sedimentation, pH adjustment, flocculation, flotation, and microfiltration. The biological processes (aerobic and anaerobic) are known to be the more appropriate for removal of dissolved organics and nutrients (Cristóvão *et al.,* 2015).

A stepwise approach to wastewater treatment commonly yields the best results in the most economical way. The primary treatment deals with the removal of suspended solids, colloidal materials and large screenable and settleable solids. In the treatment of fish processing wastewater solids and colloids, they should be removed fast and with low shear technologies in order to avoid dissolution of oil and organics (COD) into the water. Wastewater treatment is a provision to collect the substances lost during the process as the last possibility of pollution control and a good opportunity for recovering valuable substances.

It is a general experience that higher temperature improves efficiency of wastewater treatment including, coagulation, flocculation and flotation processes, but also biological processes. Temperature affects the solubility of the metal hydroxide precipitate and the rate of formation of the metal hydrolysis products. Low temperature affect's coagulation and flocculation processes by altering coagulant solubility, increasing water viscosity, and retarding the kinetics of hydrolysis reactions and particle flocculation. Higher coagulant doses, the addition of flocculation or filter aids, longer flocculation times, and lower flotation, sedimentation, and/or filtration rates are often required to achieve the proper quality of treated wastewater (Sahu and Chaudhari, 2013). When the flotation is used for removal valuable products (protein and fat) from wastewater, low temperature is conducive to maintaining a high quality of the by-products. High quality of by-products results in a high price on a market.

Equalization

Proper equalization of fish processing wastewater can provide a more constant and homogeneous flow to the treatment plant. This can improve the effectiveness of the chemical treatment program used for coagulation and flocculation prior to flotation. Equalization also allows for installations of screens with smaller capacities (average as opposed to peak flow).

Screening

By screening, relatively large solids (0.7 mm or larger) can be removed in a primary treatment facility. This is one of the treatments most commonly used by food processing plants as it quickly reduces the amount of solids being discharged. The simplest configuration is that of flow-through static screens, which have openings of about 1 mm. The tangential screens are static but less prone to clogging due to their flow characteristics, since the wastewater flow tends to avoid clogging. Rotary drum screens are mechanically more complex. Screens with perforated sheets are less prone to fouling with scales or small fish bones. Such screens are therefore more often used in fish processing plants. Screens used in fish processing wastewater treatment often can remove between 30% and 80% of solids (Colic *et al.,* 2007). This can substantially reduce load to subsequent primary treatment steps such as flotation. Savings in amount and cost of treatment chemicals such as coagulants and flocculants can also be achieved.

Fisheries wastewaters contain variable amounts of oil and grease which depend on the process used, the species processed, and the operational procedure. To remove oil and grease, gravity separation may be used, provided the oil particles are large enough to float towards the surface and are not emulsified. If this is the case, the emulsion must be first broken, which in fish wastes may be achieved by adjustment of the pH-value. Heat may also be used.

Coagulation and Flocculation

Coagulation and flocculation are among the most effective approaches to remove fats, oils and grease, suspended solids and colloidal materials. Oil and grease particles are often emulsified and charge is present in the surfactants used as emulsifying agents.

Once the pH is adjusted, coagulation and flocculation process follow. Coagulation is addition of oppositely charged ions or molecules in order to neutralize surface charge and destabilize colloidal suspensions. Inorganic coagulants such as sulfate or chloride salts of trivalent iron (Fe [III]) or aluminum (Al [III]) have been quite popular in food processing wastewater treatment. Pre-hydrolyzed inorganic polymeric aluminum reagents such as poly-aluminum chloride (PAC) or aluminum chlorohydrate (ACH) are more efficient in charge neutralization. Such salts also produce less bulky sludge. Cationic polyelectrolytes (organic low molecular weight polymers) such as quaternary polyamines produce less sludge that is easier to dewater. Such reagents are also much more efficient in coagulation process (Colic *et al.,* 2007).

Flocculation is a process of formation of large stable flocs that either sediment or float. Flocculants are reagents that achieve flocculation. Flocculants are large polymeric molecules that bind together smaller flocs produced by coagulation. Synthetic high molecular weight polyacrylamides are the most commonly used flocculants.

Selection of coagulants and flocculants depends on the further use of the post-coagulation sludge. In circumstance for use the sludge as a by-product for e.g. food production, the principle is to avoid using any chemicals.

Flotation

Flotation is one of the most effective removal systems for suspensions that contain fats, oil and grease mixed with low density organic suspended solids. Flotation is a process in which one or more specific particulate (particular) constituents of a slurry or suspension of finely dispersed particles or droplets become attached to gas bubbles so that they can be separated from water and/or other constituents.

Flotation processes in water and wastewater treatment are designed to remove all suspended particles, colloids, emulsions, and even some ions or soluble organics that can be precipitated or adsorbed on suspended solids. In this case, the process is optimized by the maximum recovery of cleaned water with the lowest concentration of contaminants. It is also often desired that the recovered sludge contain a high percentage of solids. Such solids can sometimes be recycled and reused. The removal of valuable substances from wastewater should be carry out by using only flotation system (without chemical addition).

This procedure allows for achieving a good quality by-product (sludge with high content of oil and protein for further utilization), nevertheless the quality of effluent (wastewater after treatment) deteriorates. Additional steps of treatment might be needed. The design features and operating conditions of flotation equipment used for this purpose must be modified accordingly (Rubio *et al.*, 2002).

DAF units have been somewhat successful in the treatment of the seafood processing wastewater (Tay *et al.*, 2006). When used without coagulants and flocculants, DAF units can remove up to 50% of suspended solids and 80% of Fat, oil and grease (FOG). Addition of coagulants and flocculants increased separation efficiencies to between 80 and 95%. Removal of COD/BOD depends on the amount of dissolved materials and separation efficiencies can vary between 15 and 65%. When chemical are used to improve removal of fat and oil to meet strict environmental regulations, the recovery of fat and oil is not easy to achieve. DAF units used in seafood processing wastewater treatment are usually operated around pH 5 to minimize protein solubility.

Despite that, the DAF systems have some serious limitations, they are commonly used in fish processing wastewater treatment. However, different modifications and improvements of flotation system appear nowadays. The new developments in flotation systems are listed below:

- Centrifugal Flotation Systems
- Air Sparged Hydrocyclone Flotation (ASH)
- Bubble Accelerated Flotation (BAF)
- The Hybrid Centrifugal – Dissolved Air Flotation System: Gas Energy Mixing Management (GEM)
- The ozone flotation system- dispersed ozone flotation (DOF, ADOXPOL) – ADOXPOL is described in Chapter 4.5.

Biological treatment

After suitable primary treatment, the wastewater is treated through a biological wastewater treatment system where microorganisms are involved in degradation of organic matter. Types of biological systems used in treating fish processing wastewater can be divided into two general types: aerobic and anaerobic. Commonly apply aerobic systems: activated sludge systems, aerated lagoons, trickling filters, rotating biological contactor and rotating biological contractors. Commonly used anaerobic systems: anaerobic filter, anaerobic digester, anaerobic fixed film reactor, anaerobic fluidized bed reactor, anaerobic fixed filter reactor, and upflow anaerobic sludge blanket reactor.

Depending on law regulation, the biological treatment can be only one option to meet the strict regulations due to very sensitive recipients. It is especially important if it has to adhere to very strict limitations regarding removal of nutritious substances (phosphorus and nitrogen) from wastewater. The capital and operational expenditures of biological wastewater treatment plant could be extremely high. Therefore, very often the fish processing plants deliver the wastewater into municipal wastewater treatment plants for final treatment. In certain cases in municipal wastewater treatment plants, the high concentration of brine can have negative impact on the activated sludge conditions. It can cause the deterioration of the efficiency of wastewater treatment. The solution is to separate the brine in source to avoid the mixing with the rest of wastewater stream, and treat the brine in dedicate special installation. Such approach to the wastewater treatment is consistent with the BAT assumption, although the additional cost of wastewater handling is generated. The newest developments in biological treatment systems applied by the food industry is CFIC (Continous Flow Intermittent Cleaning) which is described in Chapter 4.5.

Other methods

In recent years, new methods and technologies complement existing systems. Appear a new research and application of treatment fish processing wastewater using microfiltration and ultrafiltration via ceramic membranes (Kuca and Szaniawska 2009) (Pérez-Gálveza *et al.,* 2011). Ceramic membrane can be used not only for wastewater treatment, however also for valuable by-product recovery from treated effluents (e.g. fish oil). The ultrafiltration emerging technique is described in Chapter 4.5.

3.4 Waste, solid generation and recovery

The amount of waste from fish varies with fish species, size, season and fishing ground. The solid waste are generated when the fish is gutted, headed and further processed into fillets. Depending on the efficiency of the production process, only 50–60% of total fish catch goes for human consumption. The waste include heads, viscera, skin, trimmings and fish rejects. They are often dumped, used as animal feed or as fertilizer. Due to the worldwide decline of fish stocks, a better use of by-catch and by-products is important. These biomasses have great potential as a source of high valued products due to their high protein content, high levels of essential nutrients such as vitamins, minerals, and fish oils.

For example, waste from farmed salmon are used to produce fish oil of a quality that is well suited for human consumption. Besides salmon, waste from other fish species such as herring, cod, mackerel and sardine are used could also be used as a source of raw material for marine oils, enzymes, proteins and other valuable products.

A further increase in fish processing wastes is expected with the identification of aquaculture as a means to decreasing sea catches.

Olafsen *et al.* reviewed in the 2013 market the availability and consumption of marine residual raw materials from the Norwegian fish processing industry. The 260,000 tons which was not recovered was generated offshore dues to the lack of suitable technology for the fishing boats (Aas *et al.* 2014). The 600,000 tons recovered was split into the following group of products:

- Protein concentrate (fresh re-use of salmon raw material): 26%.
- Oil: 24%.
- Human consumption: Tran (omega 3), extracts: 2%.
- Human consumption – seafood products: 10%.
- Energy: 7%.
- Fish meal: 11%.
- Fur-bearing animal food: 20%.

Table 13. Recovered raw materials from the marine fish processing industry in Norway 2013

Year	Tons/year		
	Fish and shellfish raw material	Residual raw material	Recovered for use
2013	3,070,000	867,000	600,000 (69%)*

* 260,000 tons/year from white fish processed offshore was not re-used.

Source: Olafsen et al.

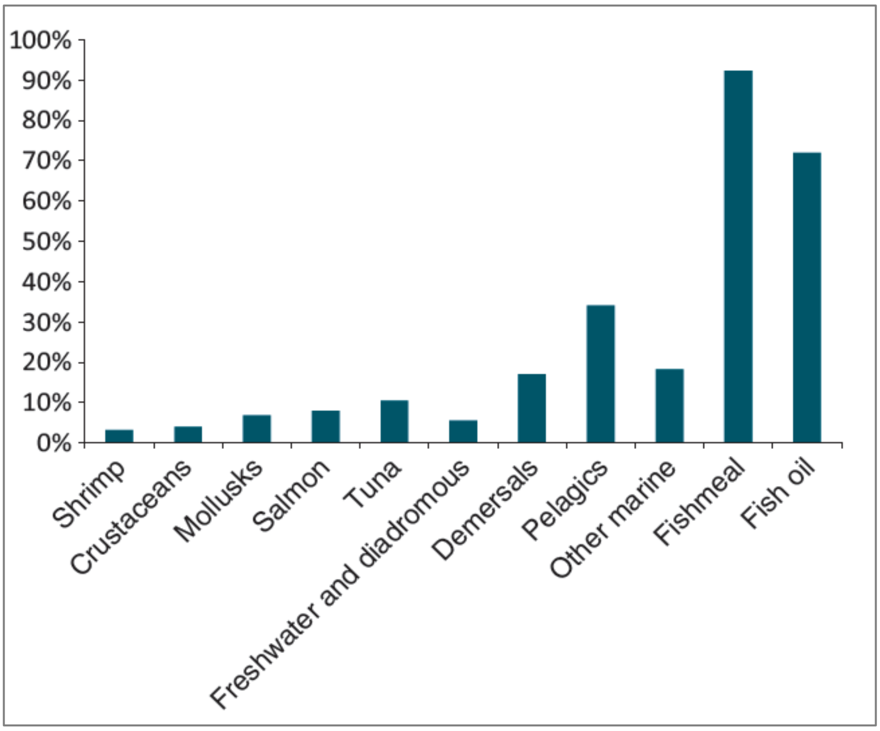
Olafsen *et al.* showed that in 2013 from the:

- White fish industry: 45,000 tons to Feed products & 25,000 tons to Human consumption: seafood, Tran & extracts.
- Pelagic fish: 65,000 tons to Feed products & 3,000 tons to Human consumption: seafood, Tran & extracts.
- Aquaculture industry: 140,000 tons to Feed products & 10,000 tons to Human consumption: seafood, Tran & extracts & 20,000 tons to biogas production.

The feed marked is the largest: 49% was for fish feed; 25% for fur animals, 21% for household animals and 5% for pets. In principle, the products are interesting due to the protein and fat content. There is a growing interest for this market, and R&D in the Norwegian Fishery sector is focusing on developing new products and markets for the industry.

The driving force in the growing market of the fish waste is the rise of the fish waste prices. In addition, the significant change in approach to the fish waste is observed. According to World Bank's estimation, the changes in real price will be very essential (World Bank 2014). The prognosis is that the prices especially of fish meal and fish oil will increase in the next years (Figure 11). Such situation can constitute a stimulating factor in the increasing of the fish waste prices. The higher prices, the more profitable separation of waste in fish processing industry.

Figure 11. Projected change in real prices between 2010 and 2013 by commodities



Source: World Bank 2014.

According to Norges sjømatråd AS the prices for fish waste allocated to fodder production increased from 1.54 NOK per kg in 2012 to 1.84 NOK in 2013. From the other site, the price referred by Norway Pelagic from Norway for high quality of fish waste allocated for human consumption products reached even 5.0 NOK per kg of fish waste. Fish waste for human products needs special handling. It require avoidance the use of any chemicals during waste separation. Waste should be chilled immediately on place and the transportation should be carried out in proper conditions. It can generate additional cost but at the end, it is cost-effective.

In certain cases there is the change of the name noticeable: instead of "fish waste" the "fish by-products" appear. Such a tendency allowed for a change in the perception of the meaning the fish waste, likewise it became possible to alter in classification of fish waste.

In the Nordic countries we have seen developments related to sieving technologies; Salsnes Filter and FiltreX integrated with solutions of conveyor belts, 3X Technoloy (Icelandic company) and Dantech (Danish) together with Flygt (Swedish), which have been described in Chapter 4.5.

3.5 Energy consumption and savings

Fish processing facilities need energy to produce hot water, steam and electricity for process and cleaning applications. Electricity is used for electrical equipment, air conditioning, cooling, freezing, and ice production. Energy consumption can be divided into two parts. Approximately 80% energy consumption depends on production and 20% is constant and independent of production. General recommendations to obtain energy efficiency are through reduced heat loss, improved cooling efficiency, and heat recovery, where heat pumps is an alternative along with hydropower and other renewable energy such as wind/wave or solar energy.

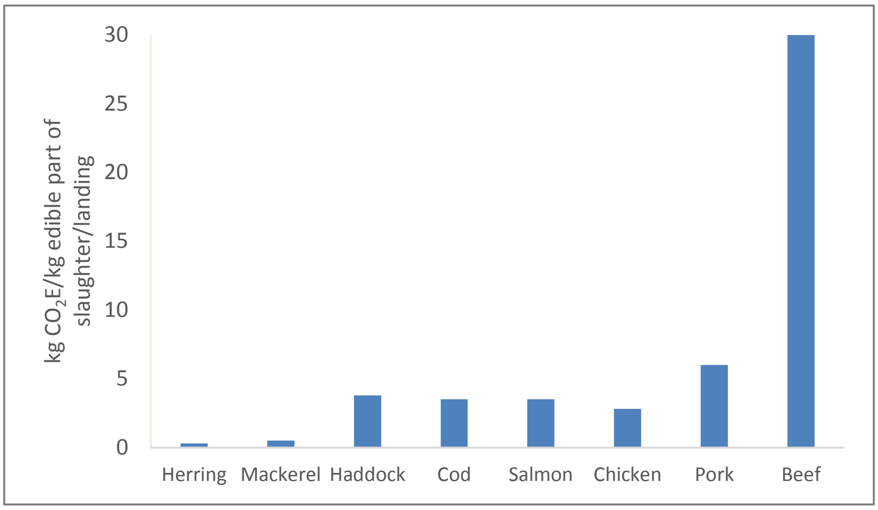
The energy consumption is as for water consumption highly related to the price of energy as of water. High prices of electricity can inspire development and implementation of emerging technology. The level of achieved potential savings, in case of application novel technology will be different in terms of electricity price.

3.6 Air emission

3.6.1 Carbon footprint

The seafood is competitive compared with meat produced in agriculture (Figure 12). Despite extremely low emissions of greenhouse gases there is still potential for improvement. For fisheries, this lies especially in better fuel efficiency and more climate-friendly cooling systems on board vessels, while for salmon production it is about optimisation of feeding and feed production.

Figure 12. Emissions of greenhouse gases from fisheries and aquaculture compared with meat from agriculture



Source: Benjaminsen, 2013.

The level of greenhouse gases emissions depends of the availability of renewable energy in particular countries. Taking into consideration sources of renewable energy in the Nordic countries, this is mostly located above the average indicated in the EU. Today, the need to develop more environmentally-friendly technologies to replace technologies and energy systems emitting high amount of CO_2 is a factor which is widening the system of energy policy, making it more dynamic. Energy policy and innovation policy are combined in different ways. In some of the Nordic countries such as Finland and Denmark, this may even lead to integration of science and innovation policy and energy policy. Contradictory, in Norway, where hydropower is easily available, the drivers for innovation are less visible.

3.6.2 Odor

Odor is often the most significant form of air pollution in fish processing. Major sources include storage sites for processing waste, cooking by-products during fish drying processes, and odor emitted during filling and emptying of bulk tanks and silos. Fish quality may deteriorate under the anaerobic conditions found in onboard storage on fishing processing facilities. This deterioration causes the formation of odorous compounds such as ammonia, mercaptans, and hydrogen sulphide gas.

The largest odor source in the fish by-products segment is the fishmeal driers. Odorous gases from reduction cookers consist primarily of hydrogen sulphide (H_2S) and trimethylamine [$(CH_3)_3N$], but are emitted from this stage in appreciably smaller volumes than from fishmeal driers. The canning processes also release some odors. Fish cannery and fish by-product processing odors can be controlled by means of afterburners, chlorinator– scrubbers, or condensers.

3.6.3 Other air emissions

Particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), organic acids, acrolein, acetaldehyde, formaldehyde, and nitrogen oxides have been identified as pollutants associated with smokehouses.

3.7 Other emissions

Noise and vibration exposure may result from proximity to noisy machinery (e.g. compressors, automatic packing machinery, condensers, ventilation units, and pressurized air).

3.8 Reduction of the emissions – industry example

3.8.1 Smoking

The source of smoke is wood or sawdust or coconut husk, depending on the particular flavor required. The fish that is salted and partially dried is used for smoking. Smoking can be cold, hot or liquid (liquid smoke, generated smoke, or a combination of liquid smoke and generated smoke). If the temperature is below 35 °C, it is cold and which is 70 to 80 °C it is hot. Exhaust Gases – particulate emissions of are generally not a serious problem in the fish-processing sector. The primary process source is the fish smoking process, which is relevant if the gas from this process is not treated effectively in the cleaning process. The recommended control techniques for particulate emissions during fish smoking include the following:

- consider use of integrated smoking units with incineration and heat recovery
- clean the kiln exhaust using filters, incinerators, and / or wet scrubbers

- ensure that smoke from the fish processing process is emitted from a stack of sufficient height
- transfer air emissions to the boiler house for use as the supply air for the combustion process. This method requires that the boiler house be located parallel to the emission sources and that the capacity (supply air volume) matches the need for combustion process air.

Methods in the field of emission control were utilized, such as new catalytic afterburners for cleaning emissions, the reduction of exhaust air and the use of smoke condensates (liquid smoke, Ls). Liquid smoke is a liquid form of smoke as a food additive. Smoke produced from the heated wood raw material (wood chips and sawdust) are high in moisture. Smoke condensate is simple smoke cooled and condensed to a liquid. Smoking in liquid smoke is a process of treating fish by exposing it to smoke which is regenerated by atomizing smoke condensate in a smoking chamber under the time and temperature conditions similar to those for hot or cold smoking. This proven and cost-effective smoking process distinguishes itself above all through the fact that the harmful substances contained in the smoke have already been filtered out during production of the smoke condensate. Liquid smoke chambers work as a closed system. As no emissions result during the smoking phase, they are regarded as particularly environmentally friendly.

Smoking without tar and ash reduces the level of soiling in the smoking installations, in turn reducing the use of smoke resin cleaners by up to 70%. At the same time, water requirements for cleaning work are reduced by up to 50%. The wastewater volume is smaller and less contaminated with harmful substances. Cleaning of the smoke generator is unnecessary. This smoking method has not any environmental emissions during food production. This process is made without any fire, smoke and dust. The advantages at a glance:

- Emission-free smoking without expensive approvals procedures.
- No high-cost reheating.
- No high-cost emissions measurement.
- Reduction in wastewater.
- No disposal of tar residue and ash.

4. Case studies

4.1 Pelagic fish industry

4.1.1 Case study 1- P/F Pelagos, Faroe Islands

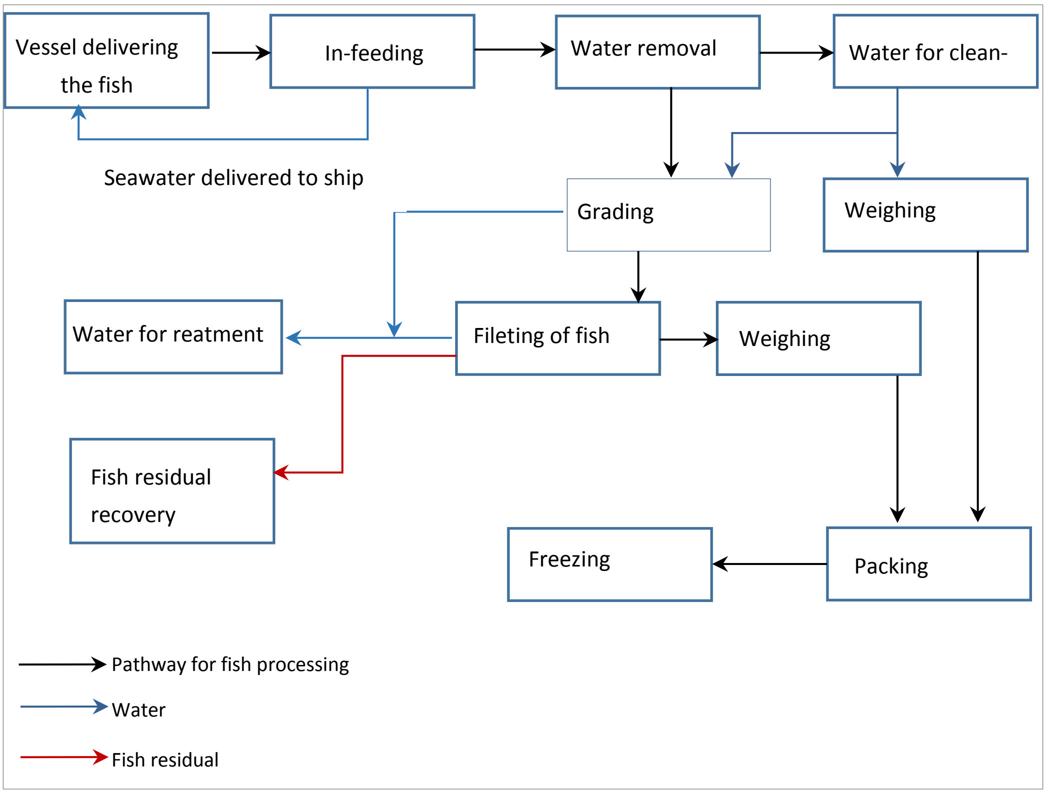
Description of the plant

The fish processing plant of Pelagos, which was located at Fuglafjørdur on the Faroe Islands, was completely new. It was opened in August 2014 and visited a month later. Fillet production had yet not started, but the whole fish processing system was in place. Figure 14 shows the delivery of at Pelagos. Fresh fish is brought to the plant in RSW water (Refrigerated Sea Water) from the fishing ground. The water was returned back to the boat after the fish had been processed. The fish processing system had been delivered by Skaginn (see details in Section 4.5.) from Iceland. The capacity of the plant has in phase 1 a freezing capacity of 600 metric tons/d, but is ready to be increased to 1,000 metric tons/d. The plant is the closest neighbour to a fish fodder factory; Havsbrun. Fresh waste is delivered daily during production. The product can be sorted in 12 different size categories, where each of the 12 categories can be sent to round fish freezing. The Skaginn production system are reporting the following benefit:

- Automatic system from feeding to palletizing (vision).
- Minimum need for workers, except for removal of bad products, feeding to the freezer and maintaining the system.
- Maximum product quality due to: careful handling of the fish in all steps, fast freezing, freezing under minimal pressure.
- Minimum spill.
- Ergonometric build-up.
- Fully automised weighing and sorting system based on vision.
- Compact system compared to the high capacity (small footprint).
- The system can operate without stop in long periods when needed.

The schematic of the process in Pelagos is shown in Figure 13.

Figure 13. Schema of production system in Pelagos



BAT measures in place

Several water savings, waste minimisation and contamination reduction measures have been implemented in Pelagos. Figure 14 shows how focus has been on receiving high quality raw materials, on minimising the storage time of the raw materials when delivered and on avoiding bringing water from the delivering boat into the food processing plant. Fish and ice-water are immediately after landing of the boat pumped into the intake tank of the plant where the water is returned back to the boat and the fish is fed into the plant by transport conveyors. The water in the tanks of the boat is brought back to the field where the water is changed with clean water from the field.

Figure 14. The delivery of fish from the fish fleet included delivering by the harbor outside the plant. The fish and RSW (Refrigerated Sea Water) was pumped into the intake, where the water was separated and returned to the boat

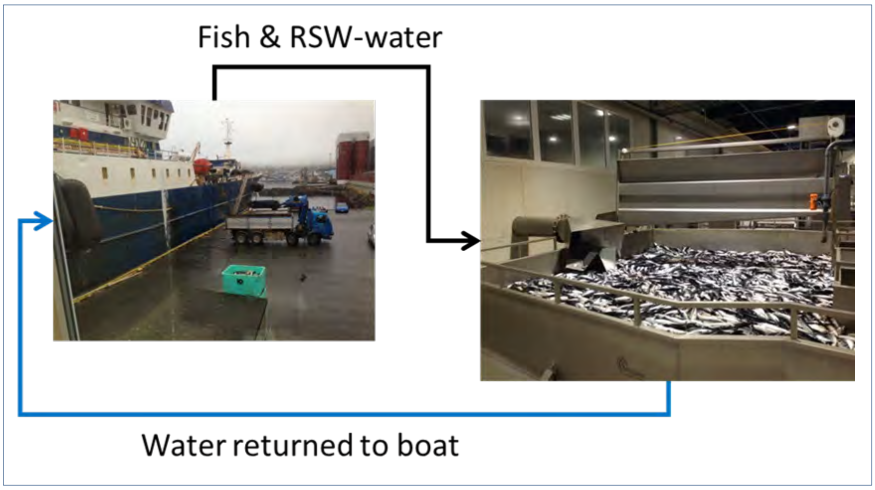


Figure 15 shows the processing of residues and oil from Pelagos into fish fodder production in Havsbrun's process plant. All fish residues and oil recovered by Pelagos is delivered to Havsbrun for processing into fish fish meal and fish flour which is used for fish fodder. Pelagos is located beside Havsbrun, a fishmeal and fish flour processing plant. As shown in Figure 15, underneath the transport conveyors for whole fish, a 400 µm sieve was placed to collect any residuals. The wastewater collected underneath the transport conveyors was transported to the wastewater treatment plant, a flotation unit (DAF) where oil and fat was recovered and delivered to Havsbrun for re-use.

Figure 15. The waste is collected at the site. 400 µm sieves followed by 100 µm sieves are used underneath the transport conveyors. The water underneath is collected and treated in a flotation unit (DAF = Dissolves Air Flotation). The residual is delivered to Havsbrun for processing into fish fodder

Figure 16 shows the careful cleaning, sorting and transport of the fish through the plant. The high content of fish protein in the fish feed is a trademark for Havsbrun, and Pelagos get well paid for the fish protein. Figure 17 shows a few pictures illustrating the operation during operation of the plant. The filleting process had not started when the plant was visited.

Figure 16. Careful sorting of the fish automatically and without damaging the fish is important for minimizing waste and producing a high quality product

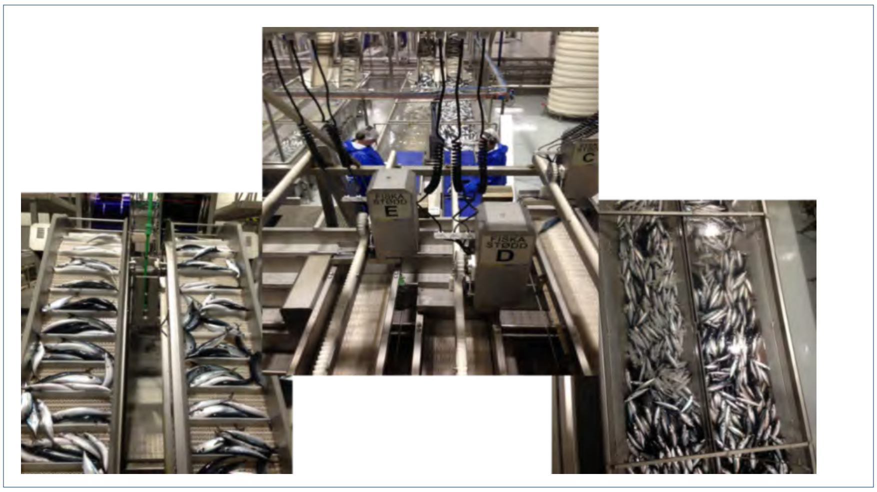
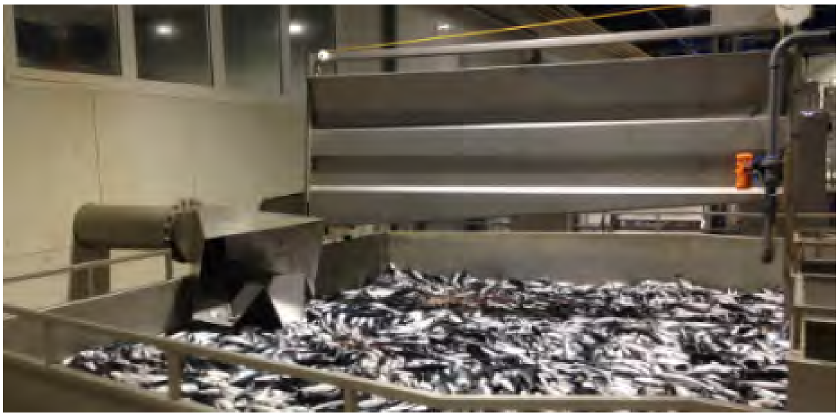
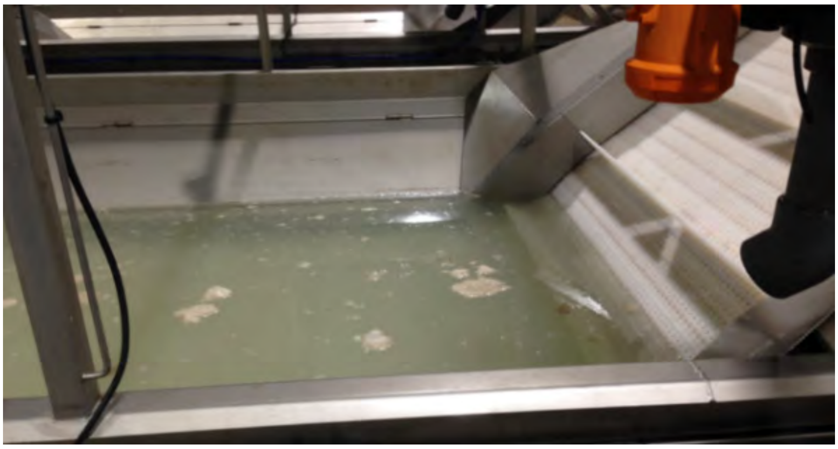


Figure 17. Some pictures from the process plant during operation

a) The boat with the catch has the fish in RSW water. After loading, the water is returned to the boat.



b) The fish including pumping water is pumped into the intake tank.



c) The waste is collected by the source, and the water is collected underneath the sieves and sent for further treatment.

Environmental regulations

Minimization/optimizing water use: Generally, the authorities has not established any requirement on this. Water is not a scarce resource at the Faroe Islands. The factory is pumping in seawater from the fjord, which is filtered and UV treated before used in the production. The expected water usage is ~40 tons/h for the whole-fish production (freezing the fish) and 40 tons/h from the filleting department.

Collecting and maximizing reuse of waste: The authorities require that BAT is applied, and collection and maximizing reuse of waste is a key factor. Trimmings from filleting of fish is collected as by-product in two stages, on sieves located directly under the filleting machines (400 µm), and in the treatment plant for wastewater (200 µm). Residual waste, oil and fat are collected in the flotation unit. No flocculant is applied since all the waste are to be re-used. Low temperature water is applied to ensure high quality of the finished product.

Other types of waste are sorted and the possibility for re-use is available for paper, cardboard, plastic, iron and metal.

No mass balance figures are available for the plant at the Faroe Islands since data for the first year of reporting is yet not available. In 2014, the production of the plant was < 75,000 tons per day of raw product.

Minimizing emissions to the recipient: The requirement for water treatment before emission to the recipient is to apply a sieve < 1 mm mesh and a fat removal unit with a min hydraulic retention time (HRT) of 15 min and a maximum surface loading of 10 $m^3/m^2/h$ (m/h). The flotation unit at Pelagos had a volume of 28 m^3. Table 14 summarizes the discharge requirements for treated wastewater from the plant.

The factory's discharge pipe is located 50 m from the waterside at 20 m depth. The requirement is minimum 1 m below sea surface at the lowest tide. The recipient is an open cove without any threshold with maximum depth of 25–30 m, which is feeding into a fjord with tidal current.

Table 14. Discharge requirement for wastewater from Pelagos

Compound	Requirement
Total Suspended Solids, TSS	300 g/ton fresh fish
Fat and oil	100 mg/l
COD	1.5 kg/ton fresh fish
Mineral oil	10 mg/l
pH	6–9

The factory has no specific requirements related to emission to air. Heat is recovered from the freezing system. The general Danish requirements for noise and odor is valid, and the factory has to carry out a risk assessment with regard to emissions of ammonia from the freezer.

The factory has a new and modern plate freezing system with minimum opening for raw materials. The freezing storage is located in blasted mountain tunnels in the neighborhood. The factory is recycling waste heat for its own heating system. The freezing capacity is presently 1 200 tons/d, but can be increased to 2,000 tons/d.

4.1.2 Case study 2 – Norway Pelagic AS, Måløy

Description of the plant

Norway Pelagic AS was established in 2007, through a merger of several smaller companies. In 2010, Norway Pelagic also acquired two more plants in Måløy. In July 2013, Norway Pelagic became a wholly owned subsidiary of Austevoll Seafood. Norway Pelagic has several pelagic fish processing plants located along the Norwegian coastline. The number of plants has been reduced, and the remaining plants have become larger and more automated. The plant at Måløy is located alongside a fish oil and fish flour plant.

The plant at Måløy prepared in 2012 an application for changes to the existing permit. The application included processing of:

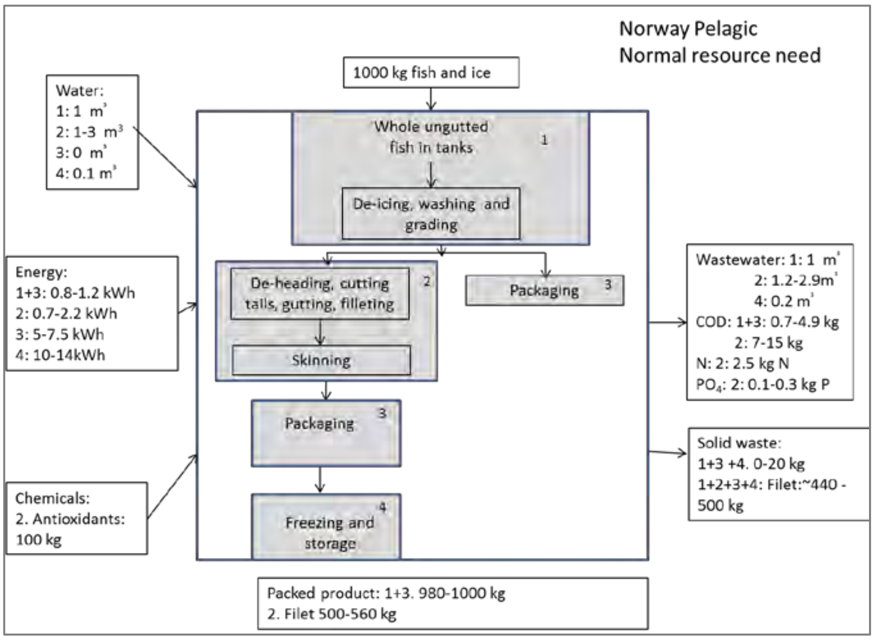
- 50,000 tons/year of pelagic fish for production of round packed fish.
- 50,000 tons/year of herring or mackerel for fillet production.

The following products were included in the plans:

- 50,000 tons/year of round packed pelagic fish.
- 25,000 tons/year of filet products from the filet production.
- 25,000 tons/year of by-products:
  a) Fish & animal feed.
  b) Production to human products.
- 250 tons/year of vacuum packed products.

The plant at Måløy is preparing round-packed fish and filets, and is recovering all by-products of the fish. Figure 18 shows the normal input and output figures from a plant like Norway Pelagic.

Figure 18. Normal input and output of the type of fish processing plant at Måløy



BAT measures in place

Norway Pelagic at Måløy has installed Cleaner Technology system delivered by DanTech (Danish Technology and ITT Flygt Norway (the Flygt concern is Swedish), see more details in Section 4.5. The objective of the selected system has been to collect the waste where it is produced to ensure that cleaner by-products are produced and to meet the requirements for BAT. Focus in the plant at Måløy is:

- Being close to the raw materials (receiving fresh fish) and to have a steady and good supply of fish.
- Being located as the close neighbour to a fish feed and fish oil processing plant to be able to deliver fresh and high quality by-products from the fish processing, and thus get a good price for the by-products, and to allow for production of human products.
- Implementation of a modern, automated technology for fish processing. The motive of selecting technology has been:
  a) Collecting the fish waste and oil as close as possible to where it is produced and re-cover as much as possible as fast as possible to keep the quality.
  b) Avoid using chemicals which can deteriorate the fish by-products.

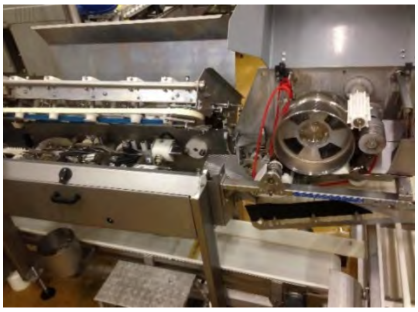
c) Keep the plant clean & tidy according to safe food quality standards and minimize the amount of water needed for cleaning in the plant.

- Motivation and training of personnel to follow the standards of the plant.
- Be involved in R&D to improve the price for the by-products from the waste. Develop the marked for more valuable by-products, including products for human consumption.

The plant has been designed with the aim of collecting waste where it is produced and limit the amount of water needed to be treated. The design includes needing 1.5 m^3 water per ton fish processed. The water is holding <4 °C through the plant to limit the need for antioxidants to control the quality of the product and the waste. To recover fish proteins, fat and oil, no chemicals are used in the flotation unit. Figure 19shows the place where the fish is delivered. It is delivered in icy water. Figure 20 and 21 shows pictures from the equipment. During the visit, the plant had been cleaned the day before and no production took place.

Figure 19. Fish is delivered by boat or trucks. The fish is kept in icy water and the water is after having processed the fish in the plant returned to the boat or truck. The recipient of treated wastewater is into the fjord which is seen behind the fish delivery station

Figure 20. Pictures taken in the plant (Norway Pelagic AS, Måløy)



The plant has 8 filleting and 8 skinning machines and sorts the fish into two fractions.

1000 µm sieve is used through the plant to separate waste from production from water and treat the most contaminated fractions.

700 µm sieve is used to treat the less contaminated fraction.

Filtrasep/Fitracon collects the 1000 µm treated water.

Figure 21. A DAF unit is used to remove fat and oil from the water; here the fat is seen on the surface of the flotation unit

Environmental regulations

Minimization/optimizing water use: Generally, the authorities has not established any requirement on this. Water is not a scarce resource in Norway. For the factory the driving force for minimizing the amount of water used is the cost for wastewater treatment. The factory is pumping in seawater from the fjord, which is filtered and UV treated before used in the production. Around 35 m^3/h of freshwater is used and 5 m^3/h of seawater. Filleting requires most of the water.

Collecting and maximizing reuse of waste: The authorities require that BAT is applied, and collection and maximizing reuse of waste is a key factor. Trimmings from filleting of fish is collected as by-product in two stages, on sieves located directly under the filleting machines (1000 µm), and in the treatment plant for wastewater (700 µm). Residual waste, oil and fat is collected in the flotation unit where no flocculant is applied to ensure that all the waste can be re-used. The driving force for the factory is the increased value of the recovered waste. Higher quality waste can be used for human consumption and a higher price will be obtained.

Minimizing emissions to the recipient: All process wastewater from production, cleaning, unloading of fish etc. should be collected in a sedimentation tank and pass through a fat removing unit before discharged. The fat removal unit should have a min. hydraulic retention time (HRT) of 15 min and a maximum surface loading of 10 $m^3/m^2/h$ (m/h). A flotation unit has been installed at Norway Pelagic, Måløy. The plant is required to perform four series of measurements per year including controlling and reporting the amount of water discharged and the concentration of fat, organic matter (TOC, COD or BOD) and solids. No requirements are made for reporting the amount of other nutrients, such as N and P. No specific concentration requirements have been established in the discharge permit.

Actual monitoring data of discharges for 2014 is summarized in Table 15. Calculation of amount per weight fish processed is based on total amount of raw fish processed. The difference between discharge of COD, TSS, Fat, Tot-P and Tot-N is higher when fillet production is taking place, and especially with herring. The high fat content of herring and the variation in fat depending on the time of the year of the catch is very large. The measured values and water volume is for the total production of which only 1/3 of the fish is used for fillet production. The treated water is discharged into Måløybassenget/Ulvesundet.

Table 15. Actual yearly discharge to sea, based on measurements out of the Norway Pelagic's treatment plant (2014) at Måløy

Finished product		**Energy**	**Water****					
Filet herring	**Round packet ***	**Total energy MWh**	**COD**	**Tot-N**	**Tot-P**	**Fat**	**TSS**	**Flow**
tons/year					**Tons**			**(m^3)**
15,156	40,000	10,119	22.8			250.4	45.5	48744**
% of raw materials					**mg/l – average per day**			
50	100		6708–9930	191–234	41.5–57.5	1383–2900	1894–3990	
Ton/ton fish proc.		*kWh/ton finished product*	kg/ ton fish processed					*m^3/ton raw material (to filet)*
0.5	1	206	~ 0.3	~0.1	~0.03	3.3	0.6	1.5

*herring, mackerel, saithe.

**only for fillet production.

Raw materials: Filet herring 30 312 tons/year, Round packed product* 40,000 tons/year.

Discharge monitoring and process improvements for the future.

The monitoring and control system from the effluent treatment and internally in the plant is not sufficiently good. Samples are required taken four times per year. There is no requirements for when and how samples are to be taken. The majority of solids (TSS), organic material (COD and BOD), nutrients (Tot-N and Tot-P) and fat is produced and discharged during fillet production. In the Måløy plant filleting takes place 50–60 days per year. The highest amount of fat is present in the plant when filleting of herring is in place, and the fat variation during the herring catch is also large. Samples are sent to an accredited lab and when the analyses is received, it is most of the time impossible to understand the results. The analytical method for fat is questioned. In several cases, the laboratory is finding more fat coming out of the plant than coming in, in spite of the fact that the flotation unit is performing well, and large amounts of fat have been removed, see Figure 20. More reliable sampling procedures and monitoring methods, also applicable for daily use in the factory would help improving performance. The lack of good and reliable methods for sampling and monitoring performance of the treatment plants is also limiting the possibilities for studying and looking into improved technology solutions. Norway pelagic has different types of flotation unit in different plants, but sampling to find the best suitable technology has not given any valuable information due to the problems associated with sampling and monitoring.

4.1.3 Challenges in the pelagic industry

The pelagic fish processing industry experiences a relatively low profitability, large seasonal variations and production of large volumes over short seasons (Utne, 2010). The demand for herring has increased significantly and has resulted in growth in the Norwegian herring industry. Since 2012, the price of Norwegian Spring Spawning herring (NVG-sild) has increased significantly compared with the North Sea herring (Nordsjøsild), see

Figure 22. Development of price and catch of North Sea herring (Nordsjøsild) and Spring Spawning herring (NVG-sild) from 2010–2014 in an increasing market situation

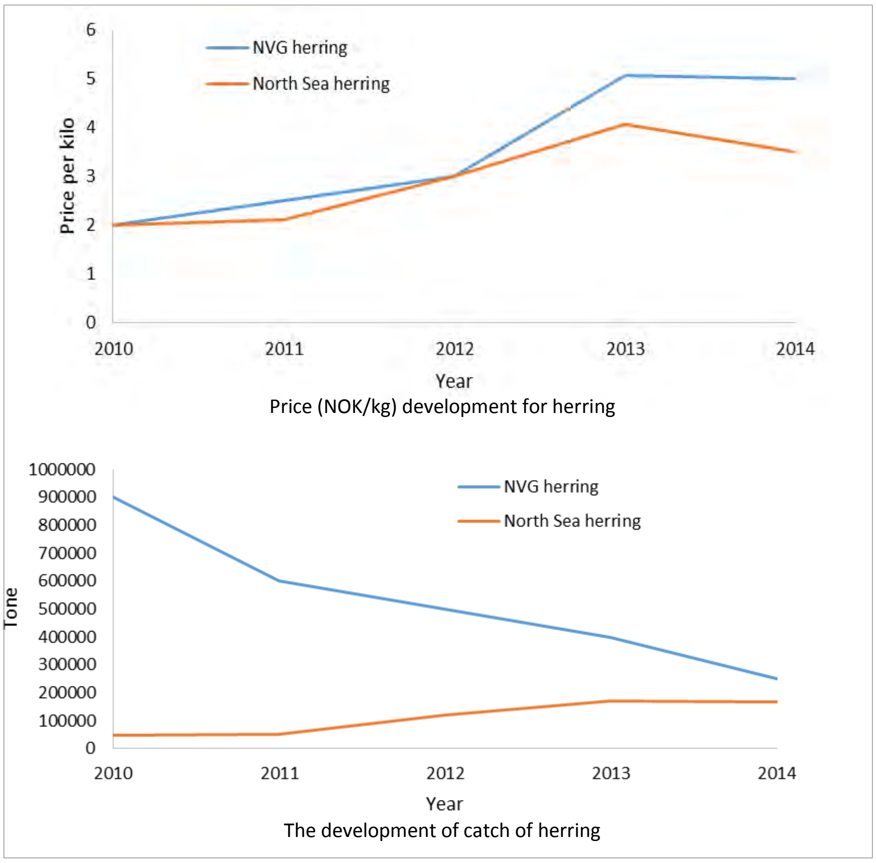


Figure 22. The high first hand price for NVG-herring has created challenges in the markets and has reduced the margins of earning for the onshore fish processing industry, with the result that pelagic fish producers in many countries have initiated development of alternative products, including consumption products based on pelagic fish.

Increased focus on the re-use of residual materials

The driver for improved profitability in the industry has increased the interest for re-use of residual materials from the fish processing industry. The pelagic fish production has reached the furthest with respect to recovery, but can still improve by producing more valuable products than today.

Marine by-products are still considered a huge unexploited potential for increased value in the pelagic industry. By-products from Nordic fisheries, included fish farming consist of viscera (liver, roe, stomachs, etc.), heads, backbones, cuts and rejected fish from processing. The by-products are generated when the fish is gutted, headed and further processed – either on-board fishing vessels or in processing plants onshore.

The Norwegian fisheries produced about 870,000 tons of by-products in 2013, which is around 30% of all the fish caught and cultured in Norway. Today most of the by-products are used as raw materials for feed production; such as fishmeal and silage. About 195,000 tons are still dumped into the sea, mainly from the fishing fleet. The total benefit from by-products represents between 2.0 and 2.5 bill. NOK. If the industry succeeds to utilize more of the by-products as food for humans and as ingredients in food, health foods, nutraceuticals, cosmetics etc., the added value can be multiplied. In 2012 an added value of 2.3 bill NOK from marine by-products was achieved, whereof only 11% was from human consumption products (Olafsen *et al.*, 2013). Onshore ~45% of the by-products were recovered, while only 14% of the by-products from the fleet was recovered, mainly by producing fishmeal. Iceland is in the lead on residual by-products and ~32% of the total sale is from residual materials (Grønnevet and Sigurdsson, 2011). The income from the cod industry at Iceland has increased in spite of reduced volumes of caught fish due to the development in the market for by-products.

Research has been initiated to improve the re-use of by-products from the white fish catch of the fish fleet. Iceland has been rather advanced for re-using by-products by the fish fleet (Halldorsson, 2011), especially related to fish heads from the white fish (Kjerstad, *et al.*, 2014). R&D collaboration between technology suppliers and the fish fleet has been important. The export of dried fish heads from the white fish was 9159 tons and the price was ~32 NOK/kg in 2012 (Hagstofan, Statistics Iceland 2014). The volume of freshly frozen fish tongues was in 2013 ~320 tons with a price of 60 NOK/kg. The export of frozen cod cheeks was in 2011 ~82 tons with a price of 50 NOK/kg.

Norway has today eight larger vessels in the fish fleet producing consumption products, and the fleet is moving towards the same trend as Iceland, but still has a work to do, to reach the results of Iceland with respect to implementing technologies and developing the market for the by-products from the fish fleet.

Recipient treated water

Most of the fish processing industry receives fish from the fish fleet and is therefore located close to the open sea in areas with protected harbours. Figure 23 illustrates such an area.

Figure 23. Typical recipients from the larger fish processing industries in the Nordic countries is to the sea in areas with high current and high degree of dilution

Cleaner production and regulations of the pelagic fish processing industry

The best available technique (BAT) regulation in the pelagic fish processing industry is focusing on the largest plants, producing > 75 tons/day of finished products. The holistic BAT approach includes:

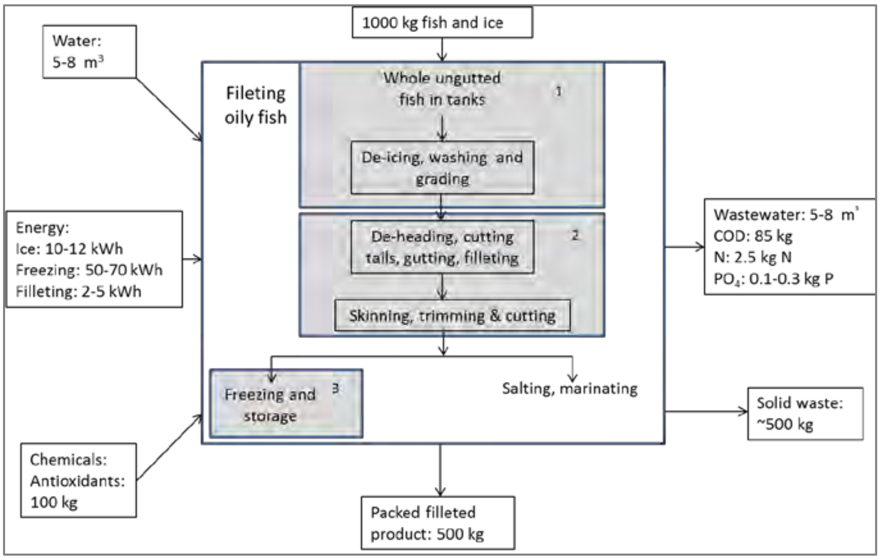
- Resources utilization: Fish, water, energy, chemicals, recovering waste: Maximizing utilization of the resource.
- Waste production; Minimizing amount of waste.
- Wastewater (quality and volumes); Minimizing discharge of pollutants (kg/kg raw fish).
- Noise, energy and odour: Minimizing emissions to air.

For the fileting of fat fish, Figure 24 shows the inputs and outputs from the industry (UNEP, 2009). The Figures are similar to Ghaly *et al.* (2013) and BREF (2006). From a BAT perspective, the possibilities of reducing water, energy and chemical need as well as maximizing the recovery from waste is a good approach. With the high demand for fish proteins for food in the fish industry and animal production, the industry can increase the margins by recovering materials and selling it. For filleting oily fish, the normal production includes:

For processing 25,000 tons/year of herring (oily fish) to fillet:

- Water consumption: 125–200,000 m^3/year; or 5–8 m^3/ton fish processed.
- COD discharge: 2200 tons; 85 kg/ton fish processed.
- Tot-N discharge: 62.5 tons; 2.5 kg N/ton fish processed.
- PO_4-P discharge: 2.5–7.5 tons; 0.1–0.3 kg P/ton fish processed.
- Energy:
  a) Filleting; 50–125 tons; 2–5 kWh/ton fish processed.
  b) Freezing; 1,250–1,750 tons; 50–70 kWh/ton fish processed.
- Chemicals: Antioxidants: 2,500 tons; 100 kg/ton fish processes.
- Solid waste: 50% of processing amount.

Figure 24. Normal inputs and outputs from the filleting of oily fish (herring)



Source: UNEP, 1998.

Table 16. Total water consumption and COD outlet before introduction of BAT in the filleting of herring

Production country	Water consumption m^3/t raw fish	COD loads kg/t raw fish
Iceland	4–8	
Norway	4–10	
Sweden	4–6	Approx. 50
Denmark	3.3	95
Awareness of water consumption	1.55	15–30

BREF (2006) are presenting some examples of how implementing BREF can improve the environmental situation in the white fish industry, see examples in Table 17 and * Lower numbers have been reported by Norway Pelagic, but it is impossible to differentiate between fillet production and whole fish production due to the low number of measuring data from the industry Table 18.

Table 17. Impact of introducing BAT in the white fish and herring industry, BREF (2006; Planmiljø (2009)

Thawing of fish & shellfish		
Fish type	**BAT details**	**Water consumption**
White fish, shrimps and prawn	Thawing in containers with warm water (30–35 ^{o}C). Air bubbled in at the bottom	1.8–2.2. m³/t raw fish
Mackerel	Recirculating of thawing water. Stirring by air.	$\leq$ 2 m³/t raw fish

Case study results after introduction of various BAT		
Production type	**Water consumption**	**COD load**
Herring production in Denmark	1.3–3.1 m³/t raw fish	10–24 kg/t raw fish

Discharge data; BAT introduced (filleting of herring): Dry transport of fat, viscera, skin and fillets with mesh conveyors			
Parameter	**Wet transport (kg/t raw herring)**	**Dry transport (kg/t raw herring)**	**% reduction**
Total N	1.4	0.99*	30
Total P	0.17	0.12*	29
COD	26.3	15*	43
Dry material	17.8	10.9*	39
Oil/fat	7.3	3.5	52

* Lower numbers have been reported by Norway Pelagic, but it is impossible to differentiate between fillet production and whole fish production due to the low number of measuring data from the industry

Table 18. Possible reductions for single processes in the herring, mackerel and white fish processing industry

Process	BAT introduced	Possible reduction (%)	
		Water	COD
Herring filleting			
Washing and sorting	Improved/reduced nozzles	50–65	
Head cutting, removal of viscera & tail	Dry removal and dry transport of viscera	4–6	40–50
Filleting, removal & transport of frames and belly strips	Improved/reduced nozzles & introduction of dry belts. Dry transport of frames & belly strips	50	30–50
	Improved/reduced nozzles & introduction of fine mesh belt conveyors, collection of frames & belly strips at site of production	50	30–50
Skinning	Skinning incl. dry transport or using fine mesh belt conveyors for transport of skin and fat	50	30–50
Mackerel			
Sorting	Replace nozzles with smaller nozzles	50	
Thawing	Replace running water by thawing in vessels with recirculation and air stirring	60	
Skinning	Filtrate and reuse water from washing of fish and neutralizing in acid bath		30–50
Whitefish			
Thawing	Thawing in warm water in containers. Circulation by air bubbled in at the bottom	60	
Head cutting	Tilt the slides for transport of heads to eliminate water usage	100	
Filleting	Improved/reduced nozzles, and dispensing intermittently	90	
Waste	Dry collection by filter conveyor Dry collection by vacuum suction		30–50 30–50

4.2 Salmon processing industry

4.2.1 Case study 3 – Nordlaks Produkter AS

The production and processing operations in Nordlaks are divided into two different daughter entities, both located in Stokmarknes, Norway:

- Nordlaks Oppdrett AS is responsible for the fish farming operations in Nordlaks. This entity runs the production of Atlantic salmon and Rainbow trout in the regions of Lofoten, Vesteraalen and in the south of the county Troms.

- Nordlaks Produkter AS operates one of Norway's largest and most updated factories for harvesting salmon. It is located together with the Nordlaks headquarter in Stokmarknes. The processing factory produces different standard trimmings of fillets and portions – both fresh and frozen. The products are frozen, both conventionally and with the unique fresh freezing method TRUFRESH®. Custom packing is also part of our business.

The products delivered by Nordlaks Produkter includes:

- Fresh salmon and trout, gutted/head on.
- IceBerg™, superior and pre-rigor whole frozen salmon and trout, gutted/head on.
- Salmon fillets, fresh or frozen.
- Frozen salmon portions, skin- and boneless, IQF-frozen.
- Salmon or trout products packed according to customer specification.
- Salmon products for private labels.

Figure 25. Nordlaks Production and Nordlaks headquarter in Stockmarknes, Norway. The fish farm cages where receiving fresh fish are stored prior to slaughtering is seen in the front

Foto: Øyvind Stavnes, Stockmarknes, Norway.

Nordlaks Produkter is processing fish from the fish farm industry. The discharge permit of 2013 included the following production:

- 60,000 tons/year of salmon and other cultured fish is slaughtered and packed.
- 10,000 tons/year of salmon and other cultured fish is filleted.
- 3,000 tons/year of salmon oil production.

Production philosophy
The quality of the product is to be known: Every batch of fish delivered to Nordlaks Production slaughter has to be accepted for slaughtering. This means there needs to be a CV following the fish:

- This needs to include information whether the fish has been debugged from lice or not, and if it has been debugged, the CV must contain:
  a) Information about the type of debugging agent used.
  b) From the type of agent, the veterinary evaluates the waiting period needed to ensure there are no residuals left.
  c) Analytical information of the fish. The Norwegian Food Safety Authority takes weekly samples of fish muscles and livers for analyses of priority pollutants, PCP, Dioxins etc. This information is registered in NIFES database, which makes a yearly report based on information from all aquaculture plants.

Waste: Nordlaks has a philosophy that they use all and throw nothing. All residues are collected:

- Backbones and belly strips from the fillet department is packed and frozen for human consumption.
- The residual residues are used to produce oil an silage Category 3.
  a) The oil is sold for human consumption and for fodder ingredient.
  b) The silage is sold as raw material for protein concentrate and flour production (Fodder ingredient).
- The residual fraction which ends in the drainage of the factory is collected by Rotasieve (coarse filter) and fine filters (sieve band filter). This is delivered as silage Category 2:

a) The supplier use the oil for technical use.

b) The protein fraction can be used for biogas production.

Discharge permit

Process wastewater includes cleaning water, blood water, slaughtering water, transport water or water in direct contact with the raw fish, the product or waste, or which has been added contaminated components from other sources. Silage water is also included.

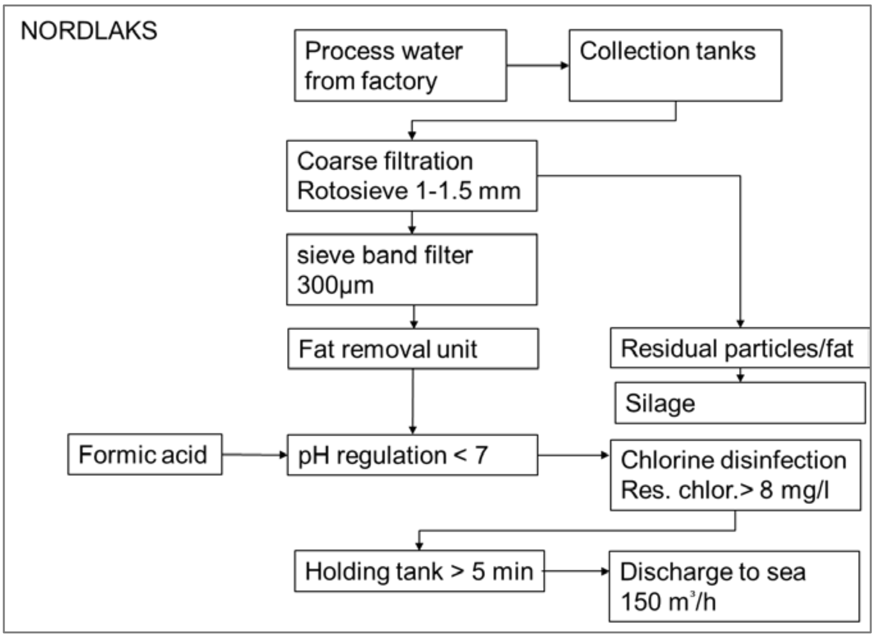
Process wastewater should be collected and routed through a sieve with a mesh of <500 µm before discharges. The sieve should be self-cleaning. Further treatment includes a fat removal in a unit with >15 minutes contact time and a surface loading of <10 m/h. The fat removal unit should be placed downstream the sieve. If alternative fat removal units are used, maximum fat content in treated water should be <100 mg/l.

Sampling of treated water should be done minimum 4 times per year, during the time when the highest production takes place, using flow proportional samples averaging over three days.

Wastewater treatment

Figure 26 shows the schematics of wastewater treatment from Nordlaks Produkter.

Figure 26. The wastewater treatment of process water of Nordlaks



Production figures and water consumption form 2012 were as follows:

- Slaughtering and processing whole fish: 53,929 tons.
- Further processing of cultured fish: 2,854 tons.
- Water consumption: 118,197 m^3 (0.46 m^3/ton fish processed).

All waste from the processing of fish is re-used for fish feed or oil for human consumption.

Analyses from treated water sampled in January 2015 is listed in Table 19.

Table 19. Analyses performed on treated wastewater from the process plant in January 2015

Parameter	Unit	Value
Fat in water	mg/l	47
Suspended solids	mg/l	660
COD	mg/l	2,300
Tot-N	mg/l	84
pH		6.6

4.2.2 Challenges in the salmon processing industry

A recent report from Nofima (Ytrestøyl *et. al.,* 2014) shows that the average Norwegian salmon diet in 1990 contained 65% fish meal and 24% fish oil and that it had come down to 19% and 11% respectively in 2013. The use of these two marine raw materials in feed production has been reduced and replaced by agricultural commodities such as soy, sunflower, wheat, corn, beans, peas, and rape seed oil. This substitution is mainly done because of heavy constraints on availability and high prices of fishmeal and fish oil. Fishmeal and other raw materials of animal origin have a more complete amino acid profile compared to protein of vegetable origin and have generally a higher protein concentration (Marine Harvest, 2014).

Feed and feeding strategies aim at growing a healthy fish fast at the lowest possible cost. In the last two decades, there has been a global trend of growing awareness about the economic, social and environmental aspects of optimal use of fishery by-products, and of the importance of reducing discards.

Nowadays, more and more waste is used in feed markets, and a growing percentage of fishmeal is being obtained from trimmings and other residues from the preparation of fish fillets. The more effective separation of fish waste over the particular salmon processing steps, can give the opportunity to utilize the fish waste for the salmon fodder production. In certain case very important is the location of the fish processing plants. The location near the facility that produces feed allows quick transport and provides the excellent quality of fish waste.

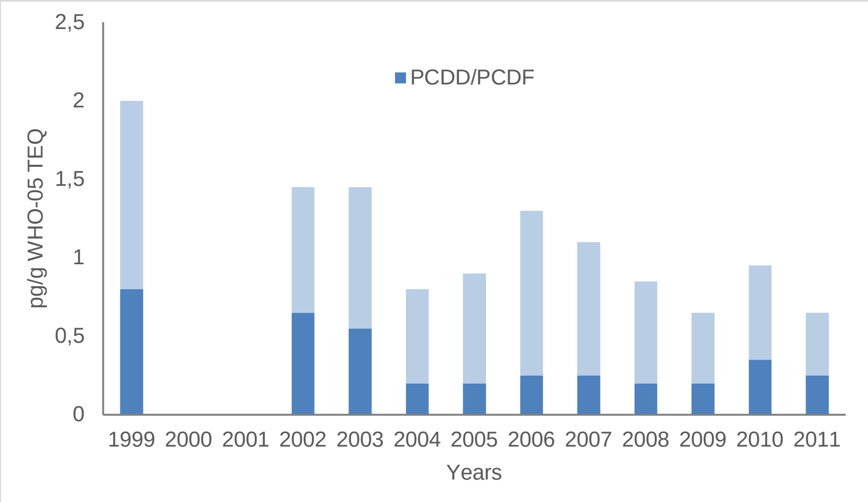
Considerable R&D is undertaken in several areas and the most important developments have been seen in the feed sector. In this industry, the majority of producers are small and have not the capital to undertake and supervise major R&D activities. This is expected to change as consolidation of the industry continues.

The location of salmon processing plants is important in terms of wastewater treatment and the wastewater discharging. In certain areas, the more strict requirements can be established. Especially in regards to nutritious substances removal (total N and total P). Strict permits for wastewater discharge may result in the needs to invest in modern wastewater treatment plants with enhanced nutrient removal. Otherwise, the wastewater should be discharged to the municipal wastewater treatment plant.

Environmental pollutants such as dioxins and PCBs, heavy metals, and organochlorine pesticides are a global threat to food safety. In particular, the aquatic biota can bioaccumulate many of these contaminants potentially making seafood of concern for chronic exposure to humans. Nøstbakken *et al.* (2015) investigated the conditions in Norwegian aquaculture industry, and from his article, we have taken some information. The global aquaculture production has grown substantially during the last decades. Farmed fish are an increasingly important source of seafood, accounting for almost fifty percent of the world seafood intake in 2010. As the world population is continuously growing, the demand for fish products is expected to increase in the coming decades. The output from capture fisheries has reached a plateau. Accordingly, if seafood is to remain a part of the diet in the future, it needs to be derived from aquaculture. Crustaceans and freshwater fish dominate in terms of production volume, but Atlantic salmon (*Salmo salar*) is one of the leading intensively farmed marine species with a 10 year mean increase of 11.2% in tonnage, and 23.6% in value during the first decade of the new millennia. Due to its content of important nutrients such as marine omega-3 fatty acids, proteins and vitamins, Atlantic salmon represents a valuable part of a healthy diet. However, concern regarding the presence of contaminants in seafood has arisen during the last decades. In order to evaluate the risk to consumers, there is a continuous need for data on contaminant levels such as mercury in fish as highlighted by the European Food Safety Authority (EFSA, 2012).

The EU has initiated extensive food surveillance program in Europe in order to control the presence of pharmaceutical residues and contaminants in the products of animal origin. The measures to monitor such substances are specified in the EU council directive 96/23. By using data collected over several years in these EU-initiated food surveillance program, it is possible to evaluate a large sample material of Norwegian farmed salmon, for the presence and mass fraction of a range of selected contaminants. This study has evaluated the presence of dioxins, PCBs, pesticides and heavy metals in fillets of Norwegian farmed Atlantic salmon in the period between 1999 and 2011. By examining these results in view of tolerable weekly intakes (TWI), we aimed to estimate safe consumption limits for humans, as well as trends in contaminant levels in Norwegian farmed Atlantic salmon in the period between 1999 and 2011, see example of result of PCB in Figure 26 In this study (Nøstbakken *et al.* 2015), contaminants were examined in more than 2,300 samples, and since most samples were pooled, the total number of fish analysed exceeds 10,000 individual Norwegian farmed salmon. The fish were sampled over a period of 13 years from all regions with aquaculture activity, thereby providing a representative overview of the contaminant levels in Norwegian farmed salmon over the last decade.

Figure 27. Measured concentrations of heavy metals, dioxins and PCB in aquaculture fish from 1999–2011. As concentrations measured in 2004–2011



Source: Nøstbakken et al, 2014.

A decrease of the levels in these contaminants has been seen over the years, the amount of Norwegian farmed salmon that can safely be consumed in terms of the TWI (Total weekly intake) has increased from 370 g per week in 1999, to more than 1.3 kg per week in 2011. It should be noted, however, that the contributions of dioxins and dl-PCBs from other food sources are not included in these calculations. The authors concluded that the levels of contaminants have been reduced along with the change in intake of food of the fish to increasing levels of vegetable feed used by the industry.

4.3 Canning industry

In fish canning industry a significant amount of water is used throughout all steps, including cleaning, cooking, cooling, sanitization and floor washing. Fish canning wastewaters are known to contain organic contaminants in soluble, colloidal and particulate form (Chowdhury *et al.,* 2010). The biodegradable organic matter is mainly in the form of proteins and lipids. The valorization of residuals and wastewaters and from the fish canning industry is of great concern, not only because of the high quantities generated, but also economic and environmental benefits may result from a proper treatment approach of the waste generated while reducing costs related to wastewater discharge. A limiting factor for reuse and recycling treated fish canning wastewater into an industrial plant and for other uses is the high salt content, which persists even after conventional treatment.

4.3.1 Case study 4 – Orkla Foods

Description of the company

Orkla Foods Sweden was established January 1st 2014 after a merge between Abba Seafood, Procordia and Grødinge. The company was established in 1838 in Bergen (Norway), but moved to Stockholm (Sweden) in 1850. It was registered as ABBA in 1906 and has since 1995 been a partner in Norwegian Orkla ASA. Procordia AB (former Abba Seafood AB) is the backbone of the fish processing factory who has a factory at Hagabeg. The final products are:

- caviar
- canned herring products
- anchovies
- numerous different canned products.

The raw materials covers fresh, spicy, salted and marinated herring, whitefish, sour-salted, frozen and peeled shrimps, crab, tuna fish, mackerel etc.

The environmental discharge permit allows for a processing <18,000 tons of marine commodities. In 2013 the production listed in Table 20 took place.

Table 20. Production in Orkla Foods in 2013

Commodities	Tons	Barrels
Herring	4,047	53,499
Roe	2,823	26,448
Anchovies	2,091	16,066
Whitefish	1,060	
Mackerel	6,381	
Others (lobster, salmon, crabs, shrimps)	13.7	

Environmental aspects

Possible environmental challenges includes:

- Discharge of treated wastewater to the sea.
- Formation of sludge and waste.
- Emissions to air from the plants.
- Consumption of chemicals.
- Consumption of packing materials.

The localization and recipients:

- Hagaberg; Cleaned wastewater is routed in a 3,000 m long discharge pipe (200 mm) to 28 m depth by Dødholmarna south east of Smøgen (West coast of Sweden).
- Bergrummet; Process water is treated mechanically in a three chamber well and is pumped into a equalization tank before discharged through a discharge pipe south of Dövik (15 th June–15 th August). The rest of the time, the water is routed to the local wastewater treatment plant.

- Kryddaranläggningen (Spice department); The process water is passing a sieve with 1 mm mesh before discharged close to the harbour.
- Sanitary sewage is routed to the municipal wastewater treatment plant.

The regulations
The treatment plant (since 30. August 2007):

- Sieving, fat removal, aeration and chemical precipitation in a flotation unit before discharge to sea. Max flowrate through the flotation unit: 50 m^3/h.

The treated water quality (Monthly average).
Hagaberg's treatment plant:

- <700 kg TOC/day
- <1.6 kg tot-P/day
- <56 tot-N/day.

Discharge from Kryddningen (Yearly):

- <4 ton TOC
- <0.2 ton tot-P
- <1 ton Tot-N.

Conditions in the permit includes:

- Investigating the possibilities for optimizing the reduction of organic matter, nitrogen and phosphorus as well as optimizing the oxygen addition to the aeration basin, the discharge of the water and the monitoring and control of the treatment.
- The company shall investigate the composition of effluent wastewater from a health- and environmental standpoint. The following parameters should be included: BOD, COD, TOC, phosphorus and nitrogen (kg/d) as well as chlorides, pH and SS. The discharge amounts shall relate to the production conditions.

- Challenges related to the routing of water to the municipalities pipe system needs to addressed, including, organic matter, corrosive properties, risks for odor problems, equalization over the day, hydrocarbon loading etc.
- Based on recipient investigations, the optimal location of the discharge pipe needs to be found, unless a permanent routing to municipal sewage system is facilitated.

Additionally: energy optimization, noise, odor and chemicals are regulated.

4.3.2 Challenges in the canning industry

Canning processing industry is working very often in cycles in terms of different canned fish species. It can have the strong effects on ecosystem and makes the difficulties arising from wastes, pollution, and sanitation problems.

As in other fish processing plants very essential is the location. Taking into consideration extremely high concentrated of wastewater contamination (mainly: high value of COD, N, P, fat and high concentration of brine) the one of the most important challenges in canning industry is the proper level of the wastewater treatment. In case that the final recipient is very sensitive, the level of nutritious substances removal must be very high. This high level of phosphorus and nitrogen removal can guarantee only advanced biological treatment plant. The population of bacteria present in activated sludge may be characterized in high sensitivity on the brine concentration. The brine should be separate in source to avoid the mixing with the rest of wastewater stream, and it should be treated in dedicate special installation. Another, often used solution is the gradually delivering wastewater with brine into the activated sludge chamber.

4.4 Emerging techniques

4.4.1 Costs and needs

Reducing labor costs

The use of fully automated fine mesh belt conveyors has been important in the Nordic fish processing industry for several reasons, one of which is to reduce the need for labor.

Water consumption
Incentives for reducing the water consumption is varying between the Nordic countries. For the fish processing industries in Norway and the Faroe Islands, the cost of water is very low. In Denmark, it is rather high and the industry has focused more on this than the Norway and the Faroe Islands.

Wastewater treatment
The costs of wastewater treatment is related to the investment costs and operational costs, and in all Nordic countries as in any European countries, by reducing the amount of water needing treatment, great savings can be made, for energy, for the size of plant etc.

Improving the treatment from primary to secondary to tertiary also increases the costs significantly, both with respect to investments and with respect to operation (energy, chemical and labor costs).

Energy
The costs of energy also varies considerable between the Nordic countries. Norway has rather low cost and Sweden rather high. The CO_2 footprint of the Norwegian energy is also lower than for other Nordic countries.

Recovered by-products
Protein, oil and fat has become a valuable source of income for many fish processing plants, and we see numerous examples of BAT plants having no waste from the fish processing. This is another reason for introducing better processing systems. In the discussion of the 3X Technology, we have given a cost example illustrating this driver to improve the processing system.

Sampling and monitoring
This is an area requiring improvement, especially if new wastewater treatment technologies is to be integrated in the process. The sampling and monitoring procedure required by the authorities in the pelagic fish processing industry in Norway is premature and not useful for improving the future environmental control of the industry.

4.4.2 Improving fish processing equipment

The FPE (Fish Processing Equipment) industry plays an important part in the fish food value chain. The FPE in a processing line determines the physical properties of the end product, the possible outcome of the production process in terms of shape, portion size, shelf life and in addition the possible utilization of rest raw materials and co-streams from the production process (Vázquez-Rowe *et al.,* 2013). While running as a part of a production cycle, the FPE consumes resources such as energy, water, oil, and cleaning agents to operate. The environmental load generated by the resource needed and waste generated by running the FPE for each product produced are added to the total environmental burden and resource need for production of the end product. When developing and designing new FPE, a focus on designing for environment and using sustainability as a driver for innovation becomes important to target the EU milestones for 2020 (Bar, 2015).

Better and tougher environmental requirements on fish processing equipment from governmental agencies, as well as long term commitment between producer and end customers may be an effective way of sparking green innovation initiatives. With the ever-increasing focus on the environment, the industry must eventually adapt to these changes as they materialise in the form of governmental regulations and consumer demands. When environmental requirements are not regarded as important, other design requirements will be prioritized.

Recycling of water is one of the priorities of the European Commission which has strict requirements for the State of the EEA which will be managed with economic tools, such as taxes, duties, financial and contractual licenses. The principle is that the user pays for the use and pollution. Environmental costs are inclusive as the cost of recycling the water for production.

Some examples seen from the Nordic industry is presented here.

Example: 3 X Technology, Iceland (cooling and thawing of fish)

As an example of responsible approach to special needs of fish processing industry in respect of environmental can serve the solution proposed by 3X Technology (http://3xtec.is). 3X Technology´s most important product is the RoteX machine, used mainly as an equipment for cooling and thawing of fish. The machine is water intensive and customers have urged 3X Technology's to find a solution for recycling processing water, as use of water is becoming more expensive, as well as the intensive environmental concern for disposal of wastewater. To solve this problem, the company has developed a prototype of filtration equipment, FiltreX, since a suitable solution to meet these needs was not found on the market. The device was tested in Kampi shrimp-factory in Isafjordur and H.G. fish-factory in Hnifsdalur in 2013. The equipment functioned efficient for filtering effluent water from these plants, and a significant amount of protein was captured before the water was discharged into the sea. In addition, in the concentration of solids particles in filtrated processing wastewater was decreased. The comparison of capital cost and estimated income (due to proteins recovery and their sales) shows that the payback over time is quite fast. Figure 28, Figure 29 and Figure 30 illustrates the equipment tested.

Figure 28. FiltreX filtration device

Source: Þórðarson et al., 2013.

Figure 29. FiltreX – shrimp processing water filtration in Kampa

Source: Þórðarson et al., 2013.

Figure 30. FiltreX – fish processing water filtration in H.G.

Source: Þórðarson et al., 2013.

Waste is collected from three sites in the plant: From shell presser, shell separation and blowers.
Table 21 and

Table 22 illustrates performance dataused for the calculations and calculated investments and profit from capturing protein in the system. An uncertainty is related to the few measuring data for protein. Establishing more reliable sampling procedures and analytical methods would definitively benefit the industry and the vendors of emerging technology.

Table 21. Performance of FiltreX equipment (Þórðarson et al., 2013) – shrimps processing

Site in the plant	TSS (mg/l)	COD (mg/l)	Protein, AE3 (%)	Water need (l/h)	Sample No.
Shell presser	9,800	4,500			1a
Shell presser & 400 µm filtering	6,570	5,600	3.6	1,320	1b
Shell separation	5,200	3,100		1,800	2a
Shell separation & 400 µm filtering	2,460	2,300	3.7		2b
From blowers	330	240			3a
From blowers & 400 µm filtering	190	240	6.3	59,400	3b
Water after 100 µm filtration	1,680	4,700	6.4		3e
Total				62,520	

Table 22. Investments and payback (profit) for capture of protein using FiltreX equipment (Þórðarson et al., 2013) – shrimps processing

Capture of protein		Filtration (400 µm)	
Hours per day	10		
Value of protein (kr)	197,500	Value of protein (kr)	33
Sales price of protein (kr/year)	10 111,013	Sales price protein (kr/year)	3,828,000
Variable cost (kr/kg)	15	Variable cost (kr/kg)	2
Variable cost (kr/year)	-767,925	Variable cost (kr/year)	232,000
Income (kr/year)	9,343,088	Income (kr/year)	3,596,000
Investment (kr)	-15,000,000	Investment (kr)	-10,000,000
Income	9,343,088	Income	3,596,000
	9,343,088		3,596,000
	9,343,088		3,596,000
	9,343,088		3,596,000
	9,343,088		3,596,000
	9,343,088		3,596,000
Profit (%)	58	Profit (%)	28

Example: DanTech, Danish collaborating with a Norwgian/Swedish partner (Fine mesh filter belt conveyor)

DanTech http://www.d-tech.dk has delivered the system to Norway pelagic as presented in Chapter 4.4. The company has developed the following products for the fish processing industry:

- The Dantech Roesep© System is a modular processing system for recovery of loose roe products such as herring, sardines, pollack and salmon. By intercepting, the valuable roe before it ends up in the waste stream the system is able to guide the loose roe via a chute to a pump where we can begin the recovery process. Through a series of processes, the system gently recovers loose roe and separates the wastewater and waste products from the good quality roe thus enabling recovery of a valuable by-product.
- The Dantech FitraCon© system filters all the wastewater which has been used in the process to not only recover any roe that has been lost but clean the waste water before discharging to the drain.
- FiltraSep© is the rotating separator ensures recovery and usage of raw materials and by-products otherwise lost in the wastewater. Apart from the possibility of additional revenue, the system prevents the wastewater from being polluted unnecessarily by residues and waste from the production. It is also an effective system for grading and separation of raw materials. If the FiltraSep® is placed on top of the FiltraCon® a significant reduction in solids, blood particles, and

other elements binding to solids is achieved is available in three different models.

- FiltraFlo©. The wastewater is brought into the FiltraFlo® system a process of oxidation is initiated through millions of microbubbles created by precise and finely adjusted nozzles. The round hermetically closed tank provides centrifugal flotation, and brings sludge and pollution to the top. Here customized bendable scrapers remove the excess, and the cleaner, oxygenated water is pumped out from the bottom. The control unit ensures optimum usage of resources, perfect timing of volume and strength of the microbubbles, and ideal constant flow even when the production fluctuates in toughness or intensity.

Example: Skaginn, Icelandic company (Fully automated fine mesh filter belt conveyor)

Skaginn http://skaginn.com has delivered the system to Pelagos as presented in Chapter 4.4. The company has developed several emerging products, reducing energy and water need and allowing for recovery of high quality by products from the fish processing industry:

- QC weighing system: Skaginn/3X has introduced a high speed, gentle handling, quality controlled weighing system, supplementing typical weighing with Vision technique.
- Automatic Box freezer.
- Cleaning system.
- Super Chilling is forward thinking. A revolutionary technique developed by Icelandic pioneers of Skaginn.
- Pelagic processing system. Skaginn has designed and produced a new and improved pelagic processing system. This system can process all pelagic fish.

Salsnes filter, Norway; sieves for the industry

Salsnes Filter's patented filter technology for wastewater treatment and effluent treatment is leading the Norwegian market in municipal primary treatment. The filters are used also in the fish processing industry and fish farming as a fully-automated treatment technology to treat effluent, secure good quality of incoming water or to improve utilisation of raw materials. The sieves have a small footprint compared to traditional separation technology. Figure 31 shows an example.

Figure 31. Salsnes Filter delivers sieves in all mesh sizes from ~11 µm and larger

Source: www.salsnes-filter.com

4.4.3 Offshore by-products recovery

Research has been initiated to improve the re-use of by-products from the white fish catch of the fish fleet. A total of 260,000 tons/year of by-products from white fish processed offshore was not re-used in the Norwegian fish fleet due to lack of technology suitable for application in the fish fleet. This valuable waste not recovered. If the value of by-products are kept at the same level as of today, we expect new technology to be developed, making it possible to meet this need in a few years. FiltreX has also developed on-board vessel systems for recovering protein and automatic fish processing (http://3xtec.is).

4.4.4 Improved recovery in the fish processing industry

Among the different technologies that can be applied for the treatment of fish processing wastewater capability of membrane techniques highlights, aiming to produce dischargeable water, complying with the increasingly strict legislation on industrial pollution. Membrane separation technologies are potentially able to reduce the organic load of polluted effluents or process waters from fish industry, rendering a final filtrate whose discharge has a minimal impact on the environment (nutrients removal). In such case, the ceramic membrane can be use also for valuable by-product recovery from treated effluents (e.g. fish oil). Another possibility is to use the combination of flotation system and ceramic membrane treatment to enhance the fish oil recovery from fish processing wastewater. The idea is to avoid using the chemicals in flotation to receive not contaminated valuable by-product. Such material can by use even for human consumption products. Nowadays the companies from Nordic countries working intensively on developing new techniques and technologies that can be applicable in the fish processing industry.

Advanced flotation system

BIO-AQUA AS is a company from Denmark, which provides the integrated solution for wastewater treatment in fish processing industry. The company use the innovative system for advanced treatment of highly concentrated wastewater streams. The innovative is a Micro-DAF system where the microbubbles are formed by simple air only, no chemicals are used. Such solution can be very valuable in case when recovered material is used as a by-product. The contamination with chemicals often used to coagulation processes can cause of the deterioration of properties the removed material. With the demand of high quality of treated wastewater, a solution is a Micro-Ozone flotation. Ozone is used to coagulate the organic matter before flocculation and flotation. Figure 32 shows the Micro-DAT flotation system and the Nikuni pump.

Figure 32. The Micro-DAF flotation system and the Nikuni pump

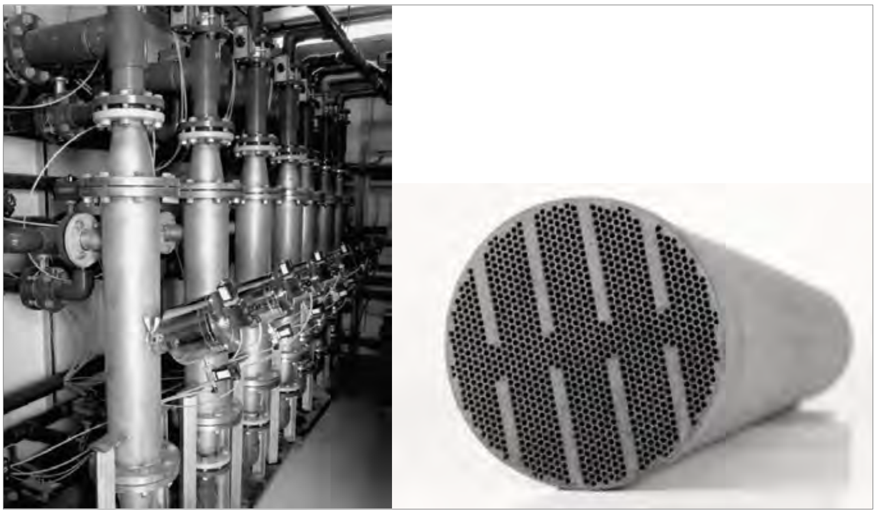
Source: www.bio-aqua.dk

Normex ADOXPOL™ is a Norwegian company, which develops the advanced wastewater treatment system with ozone oxidation and flotation technique for maximum water reuse. The solution is based on a combination of known methods such as filtration, flocculation and oxidation.

The key lies in the way these methods are combined, for best by-product recovery, all pollution must be treated as early as possible and if possible where it originates, in that way it is recovered at its best value. That will result in a cleaner wastewater with less soluble organic material. That means lower operational cost on the wastewater treatment system. The key factor in the system is the injection and mixing system and ozone oxidation.

Membrane separation
LiqTech International is also the company from Denmark. The company provides advanced filtration systems for water and wastewater treatment. The membrane substrates as well as the coatings are made from 100% silicon carbide (SiC). The application of SiC membranes are a compact and robust solution for among others wastewater re-use application. The SiC membranes are ideal in a scenario with known bio fouling potential, since the SiC membranes can be cleaned with any chemicals (pH 0–14), strong oxidizers (e.g. ozone) and have a high mechanical strength which enables high pressure back flush. SiC membrane separation technologies can be applied as a final step of wastewater treatment from fish processing industry. The SIC membrane can be use also for valuable by-product recovery from treated effluents. The ceramic filtration can be used for filtration the intake of the fresh water in recirculating aquaculture systems (RAS). Figure 33 shows the ceramic membrane systems from Liqtech.

Figure 33. SiC membrane filtration system



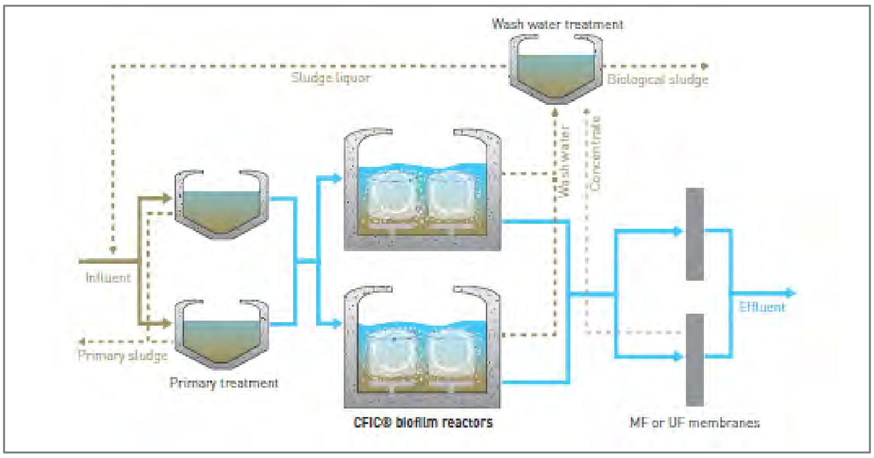
Source: www.liqtech.dk

Biological treatment technology: Biowater Technology

Biowater's proprietary CFIC® (Continuous Flow Intermittent Cleaning) technology offers industry-leading performance when compared with widely used Activated Sludge and MBBR solutions. The small footprint, combined with Biowater's approach to process design makes this far more versatile than existing solutions, making it very suitable for a wide range of wastewater treatment plants. CFIC® reactor contains highly packed biofilm carriers to a degree (typically 90–99% bulk volumetric fill) that little movement of the carriers occurs in the reactor during normal operation.

Microorganisms in the biofilm that attach on the surface of the carriers take up pollutants as food for growth. The CFIC ® process has continuous inflow to the bioreactor and intermittent cleaning, using influent wastewater, which removes excess biomass (sludge) from the biofilm carriers. Climate and temperature change affect treatment system performance. As wastewater temperatures drop in winter (Polar Bear weather), and during spring snow melt, bacterial activity decreases, thus treatment is impacted. Problems typically include mixed liquor washout conditions and a reduction in treatment capacity. Figure 34 shows a schematic of the CFIC system, which also has been delivered to the food processing industry.

Figure 34. Schematic of the Biowater technology process



Source: www. biowatertechnology.com

5. Conclusion

Best Available Techniques to ensure the minimum environmental impact without compromising the economic performance of the installation, have a strongly dynamic character, as they are highly affected by scientific and technical progress. One question arising from BAT implementation is which BAT should be chosen in any specific case. BATs are selected based on technical feasibility, environmental benefits and economic profitability. The concept of BAT does not prescribe which specific techniques should be used in order to reach the required environmental levels and does not account for local conditions in the preparation of the EU BREFs. The BREFs are describing the BAT associated emission and performance levels one can reach by using BAT.

The fish processing industry is experiencing a large variation in the availability of the raw materials to the industry and the market for their products. The industry is normally active in processing for a few months per year. This is the typical case for the pelagic and white fish industry. The aquaculture industry has increased the availability of fish to the market, but the lack of availability of fish proteins for feed to the fish has increased the demand for the by-products.

Focusing on cleaner technology principles and BAT is part of the common Nordic mindset and all the Nordic countries have had for many years an environmental licensing system building upon these principles. Therefore, the Nordic countries were well prepared when the EU approved the IPPC Directive in 1996.

BAT is intended to assist in identifying the techniques that are the best for the environment as a whole, and that are economically and technically available for Nordic industry. As there is more and more focus on the environmental impacts from industrial projects, it is of increasing importance to ensure that technologies and practices implemented achieve high level of environmental performance. Investors in Nordic countries try to find the appropriate balance between environmental performance and technical and economical availability.

However, regardless of the IED, in last past decades, the Nordic fish processing has been constantly modernized for improved efficiency, quality and environmental protection. All investments are designed to adapt the Nordic fishing sector to the available resources and environmental conditions. The aim is to minimise all possible sources of pollution from processing plants, as well as to ensure that the best available technology is used, with limit values set, especially for wastewater discharges.

The fish processing industry is implementing waste recovery and re-use as well as water saving solutions. Local conditions with non-vulnerable recipients to nutrients or organic loading has made the industry head for a level of water treatment technology which is not very sophisticated, but the increased market for more costly by-products might be moving the BAT solutions into another generation where we will see new technologies applied for recovering proteins and fat from the industry. In the future, we might also see that the market for nutrient recovery (phosphorus and nitrogen) also is becoming interesting.

Fish proteins are a valuable source and re-using the by-products will be economical beneficial in the future and is expected to move BAT for this industry into some interesting areas in the future.

It can be stresses, that an effective BAT implementation should be important tools for stimulating the development of a wide-ranging, cutting-edge market for water and energy-efficient technologies and products.

Along with investments, the approach of governments and enterprises to manage processing activities has been changing as well. It must be emphasized that BATs do not only refer to the technology used at an installation, but also to the way the installation is designed, built, operated and maintained. Some BATs are a simple consequence of common sense and do not involve any investment. As a result, significant savings can be achieved thanks to higher productivity, reduced consumption of water and energy and the reduced wastewater pollution to treat.

To ensure that further improvement is taking place in this industry, it is necessary to improve the sampling and analytical procedures for treated water. Sampling and analyses of fat, COD and TSS is associated with large uncertainties in an industry where the water varies greatly from time to time dependent on the catch, the time of year and time of day of the sampling.

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Sammendrag

Nordisk Ministerråds BAT-gruppe (Best Available Technique) besluttet i 2014 å oppdatere Nordisk Ministerråds rapport fra 1997:580, BAT i fiskeindustrien, og utvide denne til å omfatte andre fiskeindustrier. I tillegg skulle prosjektrapporten benyttes som nordisk innspill til BREF-oppdateringen av mat, drikke og melk (FDM BREF).

BAT-gruppen er en undergruppe av arbeidsgruppen for bærekraftig forbruk og produksjon, HKP. BAT-gruppen arbeider med å fremme kunnskap om effektiv og bærekraftig produksjon som en forutsetning for et bærekraftig samfunn. Det nordiske samarbeidet rundt BAT har to formål: 1) Å utarbeide informasjon om BAT og renere teknologi i bransjer med mange nordiske, og spesielt små og mellomstore virksomheter, 2) Å sette et samnordisk fingeravtrykk på EUs arbeid med å utarbeide BREF-dokumenter. BAT er i denne sammenheng teknologier, som både bidrar til best mulig utnyttelse av ressursforbruket, til å produsere god matkvalitet og hindre utlipp som bidrar til å forringe vannkvalitet i lokale resipienter. En ytterligere forutsetning er at teknologiene som benyttes ikke fører til driftmessige og økonomiske uakseptable vilkår for produsentene. Målet er å bringe fram informasjon om gode løsninger som er benyttet, eller som er under utvikling.

HKP, BAT-arbeidsgruppes har bestått av:

- Danmark, Birgitte Holm Christensen, Miljøstyrelsen.
- Finland, Kaj Forsius, Finlands Miljöcentral SYKE.
- Island; Sigurður Ingason, Umhverfisstofnum.
- Færøyne, Lena Ziskason, Umhvørvisstovan.
- Norge, Egil Strøm, Statens naturoppsyn, Miljødirektoratet.
- Sverige, Annika Månsson/Maria Enroth, Naturvårdsverket.
- Åland, Susanne Särs, Ålands Miljö- och hälsoskyddsmyndighet.

Rapporten beskriver status mht. de teknikker som benyttes, deres utslipp og påvirkning på miljø og teknikker som kan betraktes som BAT. Informasjonen skal kunne benyttes av industrien, miljøkonsulenter og miljømyndigheter. Den vil bli benyttet som innspill fra de nordiske landene til EU prosessen under "Industrial Emissions Directive" (IED) i

forberedelsene av Rereansedokumentet om "Best Available Techniques" i matvare- drikke- og melkeindustrien (FDM BREF) knyttet til fiskeforedlingssektoren.

Markedet for fisk er økende og i følge "The Food and Agriculture Organization of the United Nations (FAO)," leverte fangstfiskeriene og akvakulturnæringen ca. 158 millioner tonn fisk og relaterte arter, hvorav ca. 136 millioner tonn til menneskeforbruk, i 2012, eller ca. 18,9 kg per person. Nordisk fiskeforedlingsindustri produsererte ca. 6,25 millioner tonn per år av fisk og fiskeriprodukter, og forbruket per person i de nordiske landene var mye høyere enn gjennomsnitlig forbruk på verdensbasis.

Havområdene som omgir de nordiske landene er rik på fiskressurser. Disse landene har alltid vært avhengig av naturressursene som næringsvei, og Nordisk fiskeforedlingsindustri har vært blant de ledende med å ta i bruk renere teknologi og miljøstyringssystemer de siste ti-årene. Industrien karakteriseres med et høyt forbruk av vann og høyt utslipp av organisk stoff. Nordisk fiskeforedlingsindustri spiller en vesentlig rolle internasjonalt, og å finne metoder eller systemer som kan begrense vannforbruket og forurensninger av vann er derfor meget viktig. Begrensningen i tilgang på marine ressurser og miljøkapasitet krever nye tilnærminger og implementering av nye teknlogiske prosesser for å redusere vannbehovet og utnytte avfall og verdifulle restprodukter fra industrien bedre.

Foredling av fisk innebærer anvendelse av teknikker som opprettholder kvaliteten og holdbarheten av produktene og bidrar til verdiskapning gjennom å skape behov for nye produkter fra industrien. Pelagisk fiskeforedling har nådd lengst med hensyn til gjenbruk av fiskeavfall, men har fortsatt fobedringspotensiale med hensyn på å produsere mer verdifulle produkter enn i dag. Marine bi-produkter er fortsatt sett på som et stort ikke utnyttet potensiale for økning av verdiskapningen i pelagisk fiskeindustri. Fiskeproteiner er verdifulle, og gjenbruk av biproduktene er lønnsomt og forventes å bevege BAT i denne industrien mot nye interessante områder i framtiden.

Fiskeforedlingsindustrien opplever stor variasjon i tilgangen til råstoff og markeder for sine produkter. Industrien er normalt aktiv med foredling bare noen få måneder i året. Dette er typisk for pelagisk- og hvitfiskindustri. Akvakulturindustrien har økt tilgjengeligheten for fisk på markedet, men begrensingen i tilgangen på fiskeproteiner som mat til fisken har økt behovet for bi-produkter fra fiskeforedlingsindustrien.

Fiskeforedlingsindustrien implementerer avfallsgjenvinning og gjenbruk samt reduksjon av vannforbruket. Lokale forhold, særlig mot Nord-Atlanterhavet som ikke er en spesielt følsom resipient for belastning av næringsstoffer og organisk stoff, har gjort at industrien ikke er ledende med hensyn til sofistikerte løsninger for vannrensing. Utviklingen av et marked for mer verdifulle restprodukter kan bevege industrien mot en ny generasjon av BAT løsninger der vi ser gjenvinning av god kvalitet av proteiner og fett fra industrien som kan leveres og i fremtiden kan vi muligens også oppleve at gjenvinning av næringsstoffer (nitrogen og fosfor) kan bli vanlig pga. et økende marked for å redusere utslipp og økende priser for næringsstoffene (spesielt fosfor).

Fokusering på renere teknologi og BAT er et nordisk tenkesett. Alle de nordiske landene har, fordi industriens utslippskrav i mange år har bygget på prinsippene om renere teknologi og BAT, lang erfaring med dette tenkesettet. De nordiske landene var godt forberedt da EU godkjente IPPC direktivet i 1996. Målsettingen med utslippskravene i Norden er å sikre at fiskeforedlingsindustriens produksjon foregår med teknologier og metoder som bidrar til optimal ressursutnyttelse og lavest mulig negativ påvirkning på miljø. Dette målet skal oppnås ved å formulere tillatelser og miljøkrav som er mest mulig enhetlige innen de ulike industrielle sektorer.

BAT for å sikre minimum negativt miljøpåvirkning uten å kompromittere økonomisk drift av installasjonen, er av dynamisk karakter, siden de er sterkt påvirket av teknisk/vitenskaplig og økonomisk fremgang. Et spørsmål som oppstår når BAT skal implementeres på en spesifikk installasjon er hvilken BAT som skal velges. BAT er selektivt basert på teknisk mulighet, miljømessige fordeler og økonomisk lønnsomhet. Konseptet om BAT beskriver ikke hvilke teknikker som skal benyttes for å oppnå nødvendige miljømål og det tas ikke hensyn til lokale forhold ved forberedelsene til EUs BREF. BREFs beskriver BAT resultatet knyttet til utslippet og ytelsen som kan oppnås med å benytte BAT.

BAT er tenkt benyttet for å identifisere teknikker som gir best helhetlig miljøresultat og som er økonomisk og teknisk oppnåelig for nordisk industri. Siden det er økende fokus på miljøeffekten av industrielle prosjekt, er det av økende viktighet å sikre at teknologiene og praksisen som implementeres bidrar til bedre miljøresultat. Investorer i nordiske land forsøker å finne riktig balanse mellom miljøeffektivitet og teknisk og økonomisk tilgjengelighet.

Uavhengig av IED, har nordisk fiskeforedlingsindustri det siste tiåret kontinuerlig modernisert for å forbedre effektivitet, kvalitet og miljøforhold. Investeringene er gjort for å tilpasse nordisk industi til tilgjengelige ressurser og miljøkrav. Målet er å minimere kildene til forurensing fra prosessanleggene og sikre at beste tilgjengelige teknikker benyttes med det verdisettet som er satt, spesielt for håndtering av avløpsvannet. Parallelt med investeringene, har også tilnærmingen fra myndigheter og bedrifter endret seg. Det er viktig å merke seg at BAT ikke bare referer til teknologier som benyttes ved installasjonen, men til hvordan den er utformet, bygget, driftet og vedlikeholdt. Noen BATer bygger på sunn fornuft og involverer ingen investeringer. Som et resultat av dette, kan man oppnå store besparelser takket være høyere produktivitet, redusert forbruk av vann og energi og redusert total mengde avløpsvann som må behandles.

For å sikre videre forbedring i industrien er det nødvendig å forbedre prøvetaking og analyseprosedyrene som skal benyttes. Prøvetaking av fett, COD og TSS involverer i dag store usikkerheter i en industri der vannmengde og kvalitet varierer fra tidspunkt til tidspunkt avhengig av fangsten som leveres samt tidspunktet på året og tidspunktet for prøvetaking.

Nordic Council of Ministers

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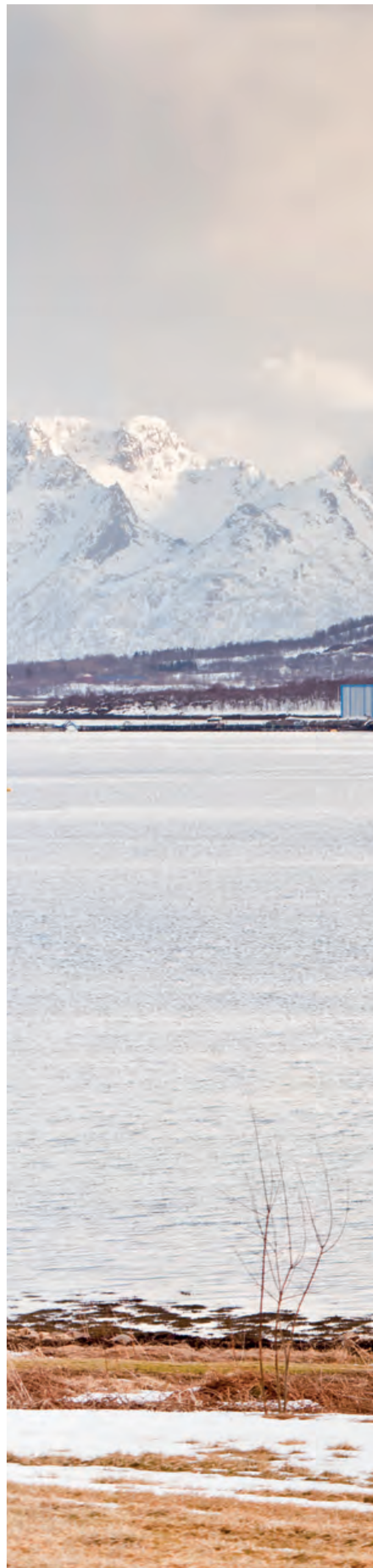
TemaNord 2015:566

BAT in fish processing industry

The Nordic Council of Ministers, the BAT Group under the Working Group for sustainable consumption and production, has requested the consultant to prepare a report on Best Available Techniques (BAT) in fish processing industry in the Nordic countries. The project describes the present status of the used techniques, their emissions and impacts on the environment and technologies that can be considered BAT. The provided information can be utilized by operators, environmental consultants and competent environmental authorities. The report will also be used as an input from the Nordic countries to the EU process under the Industrial Emissions Directive (IED) for preparation of the BAT Reference Document for Best Available Techniques in the Food, Drink and Milk Industries (FDM BREF) concerning the fish processing sector.



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