BEST MANAGEMENT PRACTICES: MARINE PRODUCTS PROCESSING

GUIDE FOR BEST MANAGEMENT PRACTICES OF RAW PRODUCT, WATER AND EFFLUENTS FOR MARINE PRODUCTS PROCESSING PLANTS IN NEW BRUNSWICK

COASTAL ZONES RESEARCH INSTITUTE INC.
- Fisheries and Marine Products Division -

BEST MANAGEMENT PRACTICES: MARINE PRODUCTS PROCESSING

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1.0 Context

This guide was developed to address marine products processing activities that are found in New Brunswick. This industrial activity constitutes a very important component of the provincial economy. In 2002, the 133 seafood plants having a processing permit issued by the provincial department of Agriculture, Fisheries and Aquaculture processed slightly more than 103,000 metric tons of marine products and the exports have reached a value of nearly 900 millions dollars. Most of these plants are located in rural areas, where they provide work to thousands of local residents. The size and mode of operation of these processing plants varies considerably. Some plants are seasonal while others operate all year long. Some plants process large volumes of marine products, others process more modest volumes. Some plants process more than one marine species whereas others orient their activities towards a sole species.

The processing of marine products requires large volumes of potable water, an increasingly limited resource whose cost could increase in the future. The use of large volumes of water, in addition to causing a significant loss of raw product, has as a direct consequence the generation of large volumes of effluents. These effluents can be particularly rich in residual organic matter (fats, protein). Furthermore, their characteristics can be quite variable from one plant to the other, because they are closely linked to the different types of production. The discharge of these effluents, in harbours and bays, remains a constant source of concern in terms of environmental impact and public health. Their high organic matter content frequently contributes to the pollution of coastal waters near marine products processing plants. This pollution is characterised by a significant multiplication of algae. The presence of algae in excessive quantities can lead to an extreme reduction of the oxygen level in the water, sufficient to create a “dead zone” where marine organisms cannot survive. This type of organic pollution generates increasingly strong reaction from the public, and also constitutes a factor limiting the use of coastal areas for other purposes, including economic development, recreation and tourism.

Consequently, some environmental standards according to which processing plants are authorised to operate, are on the verge of being tightened. Almost certainly, seafood processors will soon have to adopt best management practices (BMP) aimed at better controlling the quantity of water used as well as that of effluents generated in-plant, and/or to equip themselves with technologies to treat effluents that are adapted to both their needs and their budget.

It should be noted that the present guide is exclusively centred on the implementation of best management practices for the raw product, water and effluents of processing plants, and that it will not deal with technologies for the treatment of effluents. The implementation of such best management industrial practices effectively represents a logical approach for any processor interested in obtaining a tool that is both simple and relatively inexpensive, aimed at reducing the impact caused by the discharge of the effluents of his plant in the environment, and to conform to current regulations. The implementation of these BMP guidelines might even be sufficient to allow the processing plant to meet the existing environmental standards without the need for further investments in technologies to treat effluents, not to mention the operating costs linked to them. Moreover, the implementation of such practices often leads to an increase in the yield in the plant, which represents another quite appreciable financial incentive for any processor.

Undertaking such an exercise may however be intimidating, at first glance, for any marine products processing plant. This is why the proposed approach is based upon a step by step procedure that all processors have learned to master during recent years, that is the Hazard Analysis Critical Control Point (HACCP) system. At the same time, it is extremely important that the implementation of best management practices of the raw product, water and effluents in the plant is in complete conformance with the standards of the HACCP and of any other quality management program (QMP) already in place.

Reading this guide will help you to discover the benefits that your seafood processing plant can gain, in terms of both environmental and economic performance, by the adoption of BMP for the raw product, water and effluents.

2.0 Organic pollution

Marine products processing involves many steps and the use of large volumes of potable water. During the various steps required for such processing, mechanical action as well as water act vigorously on the raw product, thus forming an effluent containing raw product particles in a wide range of sizes. These particles, called total solids (TS), are classified according to their size and their solubility as total suspended solids (TSS) or total dissolved solids (TDS) (Figure 1). The solid particles are made up mainly of biodegradable organic matter (proteins and their multiple derivatives; fats, oils and greases; etc).

photo: Bertin Gauvin

This organic matter usually breaks down rather quickly once it reaches the marine environment. "Aerobic" bacteria are the principal living organisms responsible for its degradation (biodegradation). As their name implies, these bacteria need air, and more precisely oxygen, to be able to carry out the degradation of organic matter efficiently. This is why such aerobic biodegradation is characterised by the uptake of a large amount of oxygen dissolved in water, which is normally measured in terms of biochemical oxygen demand (BOD) or chemical oxygen demand (COD).

However, problems can occur when the quantity of organic matter discharged is too large and/or if its dispersion is limited in coastal waters. The assimilative capacity of the marine environment is then overwhelmed, which brings about significant changes. In addition to the reduction of oxygen dissolved in water [$O_2\downarrow$], the biodegradation of this organic matter can provoke considerable changes in the chemistry of the receiving waters: increase in the ammonia concentration [$NH_3\uparrow$], overload of nitrogen (N) and phosphorus (P) based nutrients, pH variation, increased turbidity of the water, etc.

Phosphorus (P) and nitrogen (N) are two chemical elements essential for the growth of algae and are normally present at limited concentrations in the environment. An increased availability of phosphorus and nitrogen stimulates the growth of algae. An overabundance of algae can have a significant negative effect on the marine environment because algae consume oxygen during the night instead of producing it and they also produce carbon dioxide (CO_2). In turn, these algae die and decompose, in the same manner as the organic matter discharged from a processing plant, thus becoming a permanent source of nutrients for subsequent generations of algae, which become even more abundant. These cyclic algal blooms thus contribute to a considerable increase in the quantity of organic matter present.

photo: Bertin Gauvin

As we have seen, the decomposition of organic matter by aerobic bacteria requires substantial quantities of oxygen. The biodegradation of excessive quantities of organic matter can thus lead to the consumption of all the dissolved oxygen needed for the survival of most marine life, and can hinder the action of the aerobic bacteria. The decomposition of organic matter is then slowed down and it accumulates as sediments. The low oxygen levels create conditions under which another type of bacteria, known as "anaerobic", eventually replace those that need oxygen to ensure the biodegradation of the organic matter. The decomposition becomes anaerobic and noxious foul-smelling gases, such as hydrogen sulphide (H_2S) and methane (CH_4), are then produced. All these

Figure 1: Types of solids

Total Solids
(fixed and volatile)
Solids retrieved after evaporation and subsequent drying of the sample between 103 and 105°C

Total Suspended Solids (TSS)
(solids retained by a filter of 2.0 micrometers [or smaller] nominal pore size under specific conditions)

Total Dissolved Solids (TDS)
(solids that pass through a filter of 2.0 micrometers [or smaller] nominal pore size under specific conditions)

Note : 1 micrometer is equivalent to one thousandth of a millimeter or to approximately 0.00004 inch changes can contribute to the disappearance of the marine organisms normally found at the bottom.

The accumulation of organic matter also creates conditions that contribute to the rapid growth of the bacterial flora as well as the multiplication of pathogenic bacteria, such as *Escherichia coli* (*E. coli*), that constitute a danger to public health. The presence of pathogenic bacteria at too elevated concentrations can also lead to the closure of coastal zones to activities such as swimming as well as recreational harvesting and commercial production of molluscs.

photo: Bertin Gauvin

This type of organic pollution is known under the scientific name of eutrophication, a word that means "well/highly nourished", and that indicates the presence of excessive quantities of nutrients. This phenomenon is currently considered as one of the most significant environmental problems that threatens the quality and health of coastal ecosystems throughout the world. There is no doubt that the marine products processing industry will be called upon to assume a significant role in order to minimise the problem.

3.0 How to measure organic pollution

In order to estimate the degree of organic pollution, it is necessary at first to analyse the composition of the effluents generated by your processing plant. These analyses will provide you with the physical and chemical (i.e. physicochemical) characteristics of your effluents. The following approach describes the essential steps to be carried out in order to measure this pollution. It should be noted that the abbreviations presented in the text will be used in subsequent calculations.

Step 1. **Measurement of the volume of effluents generated**
Measure the total volume of effluents (TVEf) generated by the process per unit of time (litres/minute, litres/ hour, m^3/work period, m^3/day, etc.). These measurements will make it possible thereafter to calculate the volume of effluents generated by the processing of one kilogram of raw product (expressed in L/kg r.p.) or by the production of one kilogram of finished product (expressed in L/kg f.p.).

Step 2. **Physicochemical characterisation of the generated effluents**
The procedure used to collect and preserve a sample is very important, because the results of the analyses are entirely dependant on the quality of that sample. Two sampling methods are currently used in processing plants.

The first one consists of rapidly collecting (within a few seconds) a single sample (grab sample) at a given time and at a specific point in the plant (Figure 2). The sample is labelled and rapidly placed in a refrigerator if it can be brought on the same day to a nearby laboratory. It may become necessary that such a sample be frozen if it must be shipped to a distant laboratory or if you want to accumulate a certain number of samples before you bring them to a nearby laboratory.

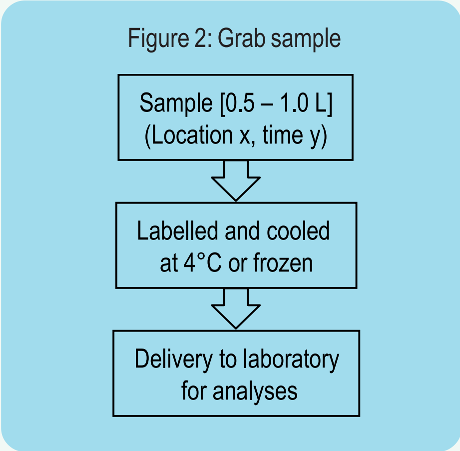


Figure 2: Grab sample

However, the physicochemical composition of the effluents generated by marine products processing is well known to be quite variable. This is why the creation of a representative sample, composed of several single samples (composite sample) is recommended in order that the physicochemical characteristics obtained take this variability into account (Figure 3). A series of grab samples of one (1) litre is collected during the normal production period at a predetermined location (a spot on the processing line, at the discharge point of the general effluent, etc.) of the plant. Each grab sample is collected rapidly (within a few seconds) and at a regular time interval. Because the physicochemical characteristics of effluents are very unstable, it is important to refrigerate the grab samples until the composite sample can be created. The creation of a composite sample consists of combining together in a large container, all the grab samples of constant volume (1 litre) that have been collected at regular time intervals (example: every 15 minutes) during a production period that should not exceed 2 hours. It is important to thoroughly mix the whole before collecting a 1 litre sample from this combination of several grab samples. This one litre sample, composed from several grab samples, is identified and placed in a cooler, before being sent rapidly to a laboratory for analyses purposes (it might be necessary that such a sample be frozen in order to be sent to a laboratory distant from your plant). If you wish to analyse the effluents produced over production periods exceeding 2 hours, it is preferable to create successive composite samples instead of a single cumulative composite sample.

Several analyses must be carried out to obtain the major physicochemical characteristics of an effluent discharged by a marine products processing plant. A description of some important terms follows:

Ammonia (NH_3) : This is a measure (in mg/L) representing the quantity of ammonia contained in an unfiltered sample of effluents, and resulting from the bacterial decomposition of proteins.

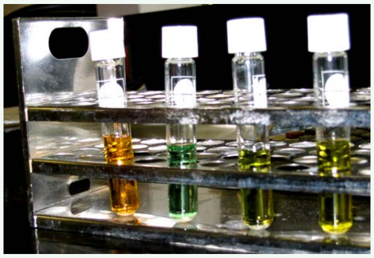
Fats, oils and greases (FOG) : This is a measure (in mg/L) representing the quantity of fatty matter (fats, oils and greases) contained in an unfiltered sample of effluents.

Organic matter : Organic matter is a generic term which includes all the various biodegradable compounds (fats, proteins, sugars, etc.) coming from animal and plant tissues.

pH : This is a measure of the acidity or the alkalinity of a sample. The pH varies along a scale of 1 (highly acidic) to 14 (highly alkaline), with 7 as a neutral point.

Total Biochemical Oxygen Demand ($BOD_{5\ Total}$) and Soluble Biochemical Oxygen Demand ($BOD_{5\ Soluble}$) : These are measures (in mg/L) that indicate the quantity of oxygen necessary for the degradation of the organic matter contained in an unfiltered ($BOD_{5\ Total}$) or filtered ($BOD_{5\ Soluble}$) sample of effluents by aerobic bacteria maintained under defined conditions during a 5 day period.

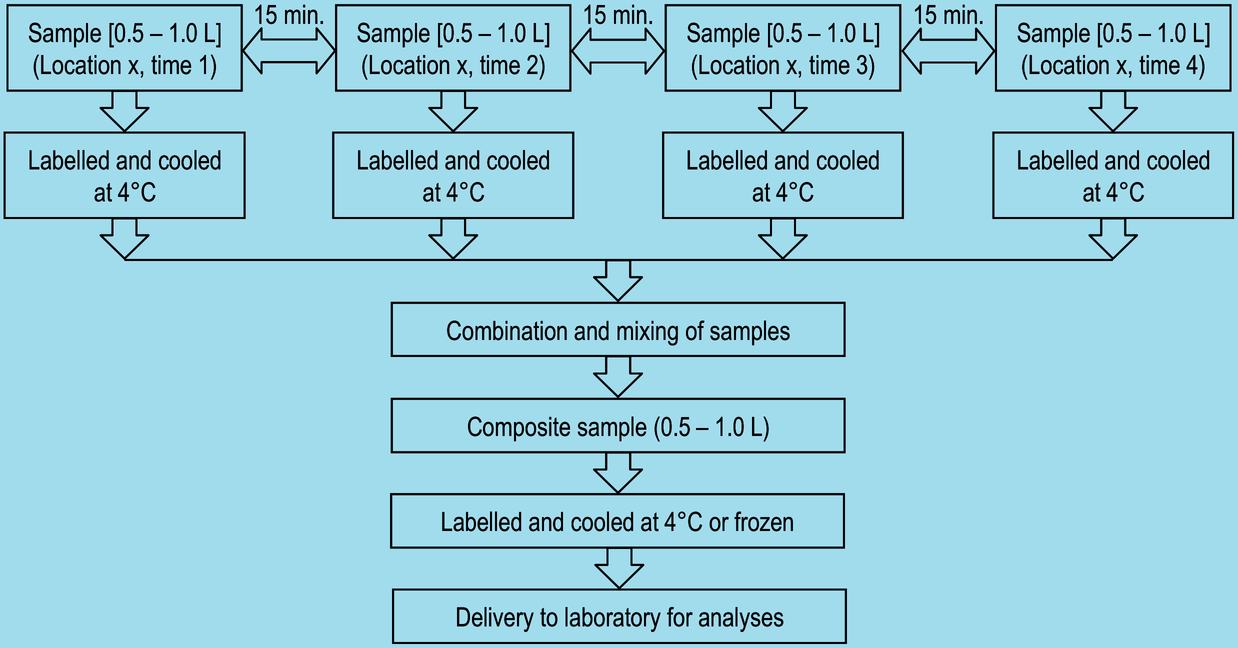
Total Chemical Oxygen Demand (COD_{Total}) and Soluble Chemical Oxygen Demand ($COD_{Soluble}$) : These are measures (in mg/L) that indicate the quantity of oxygen necessary for the degradation of the organic matter contained in an unfiltered (COD_{Total}) or filtered ($COD_{Soluble}$) sample of effluents, by a chemical product reacting under defined conditions. The determination of the COD is faster than the determination of the BOD (the results can be obtained a few hours after the laboratory receives the sample). It is therefore used more often to estimate the level of organic contamination of effluents. There is a correlation between COD and BOD; typically the COD value will be somewhat higher than BOD, for a given sample.



Total Nitrogen or Total Kjeldahl Nitrogen (TKN) and Total Soluble Nitrogen or Total Soluble Kjeldahl Nitrogen ($TKN_{Soluble}$) : These are measures (in mg/L) that represent the quantity of nitrogen (chemical symbol N) contained in an unfiltered (TKN) or a filtered ($TKN_{Soluble}$) sample of effluents. This nitrogen comes from the organic matter which is part of the total solids (TS) present in the effluent of a marine products processing plant.

Total Phosphorus (P_{Total}) and Soluble Phosphorus ($P_{Soluble}$) : These are measures (in mg/L) that represent the quantity of phosphorus contained in an unfiltered (P_{Total}) or filtered ($P_{Soluble}$) sample of effluents. The phosphorus can originate from the decomposition of organic solids, food additives authorised for the process, and cleaning products.

Figure 3-Composite sample



Total dissolved solids (TDS) : This is a measure (in mg/L) of the solids of very small size present in a sample of effluents that pass through a standard glass fibre filter during the filtration.

Total suspended solids (TSS) : This is a measure (in mg/L) of the solids present in a sample of effluents and retained by a standard glass fibre filter during the filtration.

Total solids (TS) : This is a measure (in mg/L) of all the TSS and TDS present in a sample of effluents.

Step 3. **Estimation of the quantity of pollutants produced**
Estimate the quantity of TSS for an hour or a day of production by means of the following formulae :

$$TSS_{(Kg/hr)} = [TSS_{(mg/L)} \times TVEf_{(L/hr)}]/1{,}000{,}000$$

or

$$TSS_{(Kg/day)} = [TSS_{(mg/L)} \times TVEf_{(L/day)}]/1{,}000{,}000$$

These same formulae will also enable you to estimate the quantity of TKN, FOG, P, and NH_3 discharged, as well as the BOD (COD) required, by hour or by day of production. You could also estimate these quantities, by doing the appropriate calculations, for your entire processing season.

4.0 Environmental Regulations

Environment Canada manages two national laws related to pollution prevention: the *Canadian Environmental Protection Act (1999);* and the pollution prevention provisions of the *Fisheries Act*. There are currently no Environment Canada regulations that are specifically related to the discharge of effluents from marine products processing plants. Applicable legislative measures are in fact found in the "pollution prevention" section of the *Fisheries Act,* more precisely in article 36(3). In 1975, Environment Canada published a document entitled "Fish processing operations liquid effluent guidelines" (Regulations, codes and protocols - Report EPS, 1-WP-75-1 from the Water Pollution Control Directorate). These guidelines for the disposal of the effluents of marine products processing plants do not however constitute legal requirements. They are rather guidelines that aim at alleviating some of the common problems linked to the discharge of these types of effluents, by reducing the incidence of these problems to a level that reflects the use of good industrial practices by the processing plant.

At the provincial level, all marine products processing plants that discharge their effluents into a receiving water body are required to file an application to obtain a "Water Quality Approval to Operate" in order to be able to be operational according to the *Clean Environment Act*. This approval, issued by the N.B. Department of Environment and Local Government, contains some general conditions derived from the "Fish processing operations liquid effluent guidelines" published by Environment Canada, as well as some requirements associated with the classification of each plant by this provincial department (Table 1).

It is already foreseeable, in view of the increasing deterioration of the quality of our coastal waters, that the existing regulations will be strengthened to counter this important environmental problem. It is essential that all processors have a good understanding of the problem generated by the discharge of effluents as well as of the approach to follow to minimise it, so that their industry can contribute to the establishment and to the respect of these future standards, and in a general manner, to the improvement of the health of the environment.

5.0 General Approach

Nowadays, each entrepreneur active in the field of marine products processing should know the relative significance of his plant as a source of pollution, and which preventative measures he can put in place to minimise the environmental impacts. Several studies have demonstrated that it is possible to reduce the discharge of polluting substances in a plant considerably, simply by establishing best management practices (BMP) for the raw product, water and effluents. These relatively simple and inexpensive measures consist of a series of procedures which make it possible to :

- Reduce the volume of potable water used
- Reduce the volume of effluents discharged
- Reduce the contact between raw product (especially the residues) and water
- Increase the yield and thus reduce the quantity of raw product that ends up in the effluents as TSS and TDS
- Optimise the use of food additives and cleaning/disinfecting products

5.1 Setting up a team

The development and the implementation of a BMP policy do not require great investments in equipment. The application of this policy can include minor changes in the techniques by which water is used, as well as during the handling of raw material and disposal of residues and effluents. In fact, it requires primarily a firm commitment on behalf of management, the co-operation of all concerned employees, and a receptivity to changes in some work habits.

Table 1. Classification and related requirements pursuant to the allocation of a Water Quality Approval to Operate to a marine products processing plant by the New Brunswick Department of Environment and Local Government.

Class	Volume of efluents (m^3/day)	Biochemical oxygen demand (tonnes/year)	Total suspended solids (tonnes/year)	Minimum required screen size	Other requirements
1A	> 20,000	> 2,000	> 2,000	25 mesh (0.71 mm)	- Log book - Alarm system in pump pit - 3 mm (1/8 inch) screen prior to final discharge - Outfall of effluent pipe below water level at low tide
1B	10,001 - 20,000	401 - 2,000	401 - 2,000	25 mesh (0.71 mm)	- Same as above
2	1,001 - 10,000	41 - 400	41 - 400	25 mesh (0.71 mm)	- Same as above
3	101 - 1,000	1 - 40	1 - 40	3 mm (1/8 inch) or 25 mesh (0.71 mm) at the discretion of the Department	- Outfall of effluent pipe below water level at low tide - Other requirements at the discretion of the Department
4	< 100	0 - 1	0 - 1	3 mm (1/8 inch)	- Outfall of effluent pipe below water level at low tide - Other requirements at the discretion of the Department

1. It should be noted that more advanced treatment may be required by the Department if the discharge of the treated effluents leads to a deterioration of the quality of the receiving water body.
2. As of August 2002, classes 1, 2, and 3 are subjected to a condition requiring sampling and the analysis of the effluents of each species processed (3 samples of each during the course of the peak of the season).

To do this, it is first necessary to create a work team which will be responsible for the development and implementation of the BMP project. This team must include :

- an administrator, who will promote and facilitate, on behalf of plant management, the acceptance of the measures for the implementation of the BMP policy planned by the work team;
- an internal (production and/or maintenance manager) or external professional, who will co-ordinate the execution of the actions planned by the work team based upon the decisions taken, and who will ensure follow-up based on the results and the evaluations obtained;
- assistants, who will carry out the actions planned by the work team, in order to establish the BMP policy and to ensure that it is put into practice by the plant workers.

5.2 Drawing up a plan of action

The team is responsible for the development of an action plan in order to implement a BMP policy adapted to its plant. This action plan will have to take the characteristics of each production process into account. The team will establish the objectives, define the steps of the task and fix the time limits for its implementation. The general approach for the development of BMP described in this guide can be extremely useful to you throughout this process.

5.3 Development of detailed production diagrams

A good knowledge of all the characteristics of each production process used in a plant is absolutely essential to any effective planning and implementation of BMP for raw product, water and effluents. A substantial amount of information can be summarised and presented in the form of detailed production diagrams, such as those presented in appendix B. These diagrams illustrate the main steps for processing various marine products, while providing information on the relative volume and nature (fresh or salt) of the various water streams, as well as the relative concentrations of dissolved and suspended organic matter found in the various effluents produced. It then becomes easier to identify and to put in order of priority the locations on the production line where the implementation of BMP will be most beneficial.

5.4 Development of inputs/outputs budgets

The development of a BMP policy adapted to the plant requires a good knowledge of the quantities of products used and generated during each production process. For that, it is necessary to prepare tables that will be used to compile data in order to allow the establishment of an inputs/outputs budget for a given period of production. A period of one hour of production has been used in the following tables, as an example, for the purposes of presenting the approach.

5.4.1 Determining the quantity of water and products used (inputs)

Enter in Table 2 all the steps of the production process as well as the list of the products used in each one of these steps. Start by determining the quantity of raw product processed. Measure the volume of potable water (VPW) used for each step of the production process ($VPW_{step\ 1}$ … $VPW_{step\ N}$) (in litres/hour) and identify their use (transport of the raw product or the residues, cooking, cooling, etc.). Calculate the total volume of potable water (TVPW) used for the entire process. Calculate the percentage of flow attributable to each water stream, relative to the total flow. Measure also the volume of potable water necessary for the cleanup and enter it in the table. Determine the quantity of food additives (chemical products) used. All these measurements must be done during a period of normal processing and on several occasions, in order to estimate the quantities correctly. This is meticulous but essential work to be done in the course of planning aimed at reducing the volumes of water used and effluents generated.

5.4.2 Determining the quantity of products and residues generated (outputs)

Enter in Table 3 all the steps of the production process and establish a detailed inventory of the finished products, by-products, as well as solid and semi-solid residues generated at each one of these steps. Determine the quantity of each type of finished product and by-product generated. Note the type and physical state of each residue as soon as it is separated from the raw product, if it is in contact or not with water, and the relative duration (short or prolonged) of this contact. It is important to underscore that one of the main objectives to attain here is to isolate the residues before their contact with water, in order to limit their disintegration and their dissolution in the effluent. The choice of isolation and handling techniques mainly depends on the physical state and quantity of residues.

Measure the volume of effluents (VEf) generated at each step of the production process ($VEf_{step\ 1}$ … $VEf_{step\ N}$) and the total volume of effluents (TVEf) generated for the whole process. Calculate the percentage of flow attributable to each water stream, relative to the total flow. These measurements must be done during a period of normal processing and on several occasions, in order to obtain a representative estimate.

5.4.3 Physicochemical characteristics of effluents generated

The analyses required to carry out a complete physicochemical characterisation of the effluents generated have been described previously. Table 4 gathers the analyses deemed essential in order to determine the composition of the various effluents generated in the course of a marine products production process. It should be noted that BOD determination is not considered as an analysis that is absolutely essential to perform this exercise, because it is an analysis the results of which are only available after a minimum delay of 5 days, whereas the results of most of the others can be available in less than 24 hours. The determination of COD is recommended instead, in order to make this procedure more rapid. In addition to being more rapid, the determination of COD is more reliable because it is less vulnerable to the multiple variations that can affect the analytical conditions or that can occur during the procedures. If you estimate that the determination of the BOD or other characteristics is necessary

Table 2. Inventory of the products used during one (1) hour by the production process.

Processing steps	Products used (inputs)						
	Raw product (kg/hr)	Potable water			Chemical products (kg/hr)		
		Use	VPW (L/hr)	% of total	Salt	Phosphates	Others (nitrogen compounds, etc)
1st step							
2nd step							
- / / -							
Nth step							
Total/hour			TVPW				
Cleaning							

This evaluation does not encompass the water and products used for domestic and sanitary (kitchen, toilets, showers, etc.) purposes because these effluents are normally rejected in the municipal effluent.

Table 3. Inventory of the products generated during one (1) hour by the production process.

Processing steps	Generated products (outputs)							
	Finished products (kg/hr)	By-products (kg/hr)	Residues				Effluents (VEf)	
			Type and physical state	Contact with water	(kg/hr)	% of total	(L/hr)	% of total
1^{st} step								
2^{nd} step								
- / / -								
N^{th} step								
Total/hour								
Cleaning								
Main effluent							TVEf	

for your planning, simply add that information to the table.

These data (Tables 2, 3 and 4) will enable you :

- to calculate the volume of potable water used, the volume of effluents, as well as the quantities of pollutants generated by the processing of one kilogram of raw product (kg TSS/kg r.p., kg TKN/kg r.p., etc.) or by the production of one kilogram of finished product (kg TSS/kg f.p., kg TKN/kg f.p., etc).
- to identify the steps of the process that generate an excessive quantity of effluents and organic pollutants (TSS, TKN, etc.)
- to identify the critical points in the process in terms of organic pollution produced, that depend on the critical management points (CMP).

5.5 Identification of critical management points (CMP)

You are now able to complete your global understanding of the environmental impact of each step of your production process and to gather essential information for the development of a plan of action. Use a table comparable to Table 5 with the goal of gathering and analysing the critical points of organic pollution that have been identified. The problems identified could be related to the:

1) quality of the raw product
2) management of the potable water and effluents
3) management of residues
4) use of chemical products

As for the seriousness of the problem, the use of a relative scale, such as the one presented below, will allow its practical classification for developing your action plan. Not all factors considered may fit the definition described for a specific level of concern. If one or more of the factors considered fits best in the next higher level, the general priority of the problem should be advanced to the next higher level in the interests of adopting a precautionary approach.

Relative scale :

1. **negligible problem** (the quality of the raw product is good, volumes of water and effluents are low, the quantities of solid residues as well as of total suspended solids (TSS) and total dissolved solids (TDS) are low, and the use of chemical products is absent or low)

Table 4. Initial compilation of the physicochemical characteristics of various effluents.

Processing step	VEf	TSS		COD_{total}		$COD_{soluble}$		TKN		P		FOG	
	L/hr	mg/L	kg/hr	mg/L	kg/hr	mg/L	kg/hr	mg/L	kg/hr	mg/L	kg/hr	mg/L	kg/hr
1^{st} step													
2^{nd} step													
- / / -													
N^{th} step													
Total/hour													
Cleaning													
Main effluent													

2. **moderate problem** (the quality of the raw product is average, volumes of water and effluents are average, the quantities of solid residues as well as of total suspended solids (TSS) and total dissolved solids (TDS) are average, and the use of chemical products is moderate)

3. **significant problem (critical management point - CMP)** (the quality of the raw product is less than satisfactory, volumes of water and effluents are high, the quantities of solid residues as well as of total suspended solids (TSS) and total dissolved solids (TDS) are high, and the use of chemical products is excessive)

The approach described in the following sections will make it possible to identify the problems (critical points) and to determine the level of seriousness of each one of those, whereas the information in Section 5.6 will help you find the sources or probable causes of the problems, as well as the corrective measures to apply. Depending on the seriousness of the problem and the objectives targeted, you can establish a priority for the preventive measures to be carried out.

5.5.1 Raw product quality management

Some critical points are linked to the storage conditions of the raw product. The implementation of BMP for raw product, water and effluents in processing plants therefore starts on board fishing vessels, from the moment the raw product arrives on board, and is pursued after receiving the raw product, because the biochemical degradation of marine products is very rapid when they are stored under conditions conducive to excessive bacterial multiplication. The action of these bacteria contributes greatly to weaken biological tissues, which results not only in a significant reduction of the yield and quality of the finished product, but also in the production of runoffs saturated with organic matter. These weakened marine products are then submitted to several washings and repeated handling in the plant, and a significant quantity of organic matter, in the form of total suspended solids (TSS) and total dissolved solids (TDS), thus ends up in the effluents of the processing plant.

The critical points for the management of the quality of the raw product that are associated with storage conditions are :

- air exposure
- storage temperature
- duration of storage
- physical conditions of storage (especially excessive stacking)
- application of sanitary procedures

5.5.2 Potable water and effluents management

The processing of marine products requires great volumes of potable water, an increasingly limited resource whose cost could increase in the future. The direct consequence of this huge consumption of water is the generation of large volumes of effluents.

The excessive use of water, and consequently the generation of large volumes of effluents linked to each step of the production process, constitutes an important critical point.

Based on the results of the inputs/outputs budget and on your own objectives, you can establish a grid to classify each water stream used (Table 2) and effluents generated (Table 3) at each step as a function of their volume.

Table 5. Organic pollution critical points compilation and analysis.

Processing steps	Problem identification	Significance of problem	Probables sources or causes	Preventive measures to apply	Priority of execution
1st step					
2nd step					
- / / -					
Nth step					
Cleaning					

Note that all of the definitions of volumes and quantities used below are examples for discussion purposes only. The project team should characterise and specifically define these terms in a similar manner, as appropriate for your individual plant and production system.

- Small volume: a volume that is less than 5% of the total volume of water used or effluent generated
- Medium volume: a volume that is greater than 5% and less than 10% of the total volume of water used or effluent generated
- High volume: a volume that is greater than 10% of the total volume of water used or effluent generated

Based on the results of your inputs/outputs budget and on the classification grid thus created, you can :

- identify problematic areas in terms of water consumption and generation of effluents
- complete columns 2 and 3 of Table 5
- establish the distribution and relative importance of the streams of potable water and effluents on your production diagram

5.5.3 Residues management

The marine products processing industry generates large quantities of solid and semi-solid residues that fluctuate between 65 and 85 % of the raw product. These residues constitute a major source of pollution, because a relatively significant quantity of them is eventually found in the effluents.

Critical points related to the management of residues depend on :

- the quantity of residues generated
- the physical state of the residues generated (solid, semi-solid, liquid)
- the quality (freshness) of the residues generated and their storage conditions
- the duration of contact between the residues and water
- the intensity of contact between the residues and water

Based on the results of your inputs/outputs budget (Tables 2 and 3) and on your own objectives, you can :

1) establish a classification grid of the residues generated (Table 3).

- Small quantity of residues : a quantity of residues that is less than 5% of the total quantity of residues generated
- Average quantity of residues : a quantity of residues that is greater than 5% and less than 20% of the total quantity of residues generated
- High quantity of residues : a quantity of residues that is greater then 20% of the total quantity of residues generated

2) establish a classification grid of the portion of raw product (based upon TSS) that is found in the effluent, which determines the degree of contamination by organic matter of the effluent (Table 4).

- Small quantity of organic matter : a quantity of organic matter that is less than 20 mg/L
- Average quantity of organic matter : a quantity of organic matter that is greater than 20 mg/L and less than 200 mg/L
- High quantity of organic matter : a quantity of organic matter that is greater than 200 mg/L

This exercise will enable you to :

- identify processing steps that are more problematic in terms of residue management
- complete columns 2 and 3 of Table 5
- enter the distribution as well as importance and relative loads of organic matter for the streams of residues on your production diagram

Note that all of the definitions of volumes and quantities used above are examples for discussion purposes only. The project team should characterise and specifically define these terms in a similar manner, as appropriate for your individual plant and production system.

5.5.4 Chemical products management

To ensure the quality and the food safety of the finished products, the industry uses a variety of chemicals (food additives, cleansers, disinfectants, etc.) that can also become an important source of organic

pollution. These may contain nutrients, such as phosphorus (P) and nitrogen (N), which are eventually found in the effluents, and that can contribute to the pollution and eutrophication process of coastal waters. Based on the information gathered in Table 2, you can pinpoint the critical points associated with the excessive use of chemical products. This information can be transcribed and described in more detail in Table 5. It is also helpful to make use of the production diagram by noting on it the relative use of the various chemical products at the time of the various steps in the production process.

5.6 Establishment of best management practices (BMP)

It is important to underscore that your work team should now be quite familiar with all the details linked to processing activities in the plant and should also have been able to identify the most urgent problems to solve. This basic knowledge constitutes a solid foundation that will be very useful in order to undertake the next step — implementation of the BMP in the processing plant. The main challenge to take up will be to encourage the employees and management to modify some habits, sometimes well entrenched, in their way of doing things. Therefore, it is very important that adequate resources have been allocated to the project and that all those involved (workers, technical and professional employees, leaders) adopt an attitude of co-operation and an open-mind in order to facilitate the implementation of the BMP.

The work that is left to do is considerable and may seem somewhat daunting. It is useful therefore to envision, at this stage, the multiple economic and social advantages that the seafood processing plant will be able to realise :

- Reduction of the water supply cost (↓ volume of water);
- Improvement in yield (optimal use of raw product) and quality of the finished products;
- Increased opportunity to develop valuable by-products and residues;
- Reduction in the cost of treatment of the effluent (↓ volume of effluent);
- Better control of the sources of pollution;
- Improvement of the corporate image, positive recognition by the community and concerned governmental authorities;
- Increased pride of employees working for a processing plant concerned about the consequences of its processing activities on the environment.

In order to facilitate the implementation of BMP for raw product, water and effluents in your processing plant, it has been divided into four distinct sections as follows :

1) management of the quality of the raw product
2) management of the potable water and effluents
3) management of the residues
4) management of the chemical products

In spite of some differences, it should be noted that some of the strategies to be implemented are complementary and thus they have the same objectives.

5.6.1 Best management practices for raw product quality

The critical management points (CMP) for the raw product can be controlled in a significant manner by working in concert with the fishers in order to promote the importance of the freshness of the catches that are landed. Subsequently, management measures can be adopted by the employees to ensure the maintenance of a constant quality of the product in the plant. Steps must be taken:

- to reduce the transit of the raw product on the deck of the boat and storage period at the processing plant;
- to reduce exposure to the air, in order to diminish the biochemical decomposition (oxidation, excessive bacterial multiplication, etc.) of the raw product;
- to apply the proper storage techniques in order to prevent physical pressure (crushing) on the raw product;
- to apply the proper icing techniques in order to maintain the temperature of the raw product at below 4°C;
- to use conservation agents (activated ice or spraying with citric acid based solutions, brine, etc.) if the period of storage of the raw product is relatively extended;
- to apply the proper sanitary maintenance procedures for all surfaces and containers coming in contact with the raw product

5.6.2 Best management practices for potable water and effluents

The BMP for the water and effluents generated in a marine products processing plant consist essentially of :

- reducing the use of potable water and consequently the volume of the main effluent produced;
- separating the streams containing little or no organic matter for their possible reuse or simply for their immediate discharge into the environment;
- separating the streams rich in organic matter (in order to reduce the volume of effluents to treat and increase the concentration of TSS) so that these streams can be directed toward appropriate treatment.

5.6.2.1 Potable water

The main objective targeted in the scope of the establishment of BMP for potable water in a processing plant is to **reduce its consumption** without affecting the quality and food safety of any finished product. It is thus important to respect the requirements and food safety standards imposed by your existing quality management program (QMP) or hazard analysis critical control point (HACCP) system. The logical consequence of this operation is a proportional reduction of the total volume of effluents generated.

To ensure the success of this objective, it needs to be worked out methodically. The work team must develop a customised plan that includes three phases.

Phase one (exploratory phase)

This first and crucial phase in the implementation of BMP for potable water is to understand how and why this potable water is used in the process, to quantify the volumes used (in litres or m^3), and to properly visualise the type and the volume of effluents that will thus be generated. Tables 2, 3 and 4, that you will have created, will contain the information necessary so that you can perform this analysis/ review. A critical analysis of these results, compiled in Table 5, will help you identify the water over-consumption that is most obvious.

Second phase

The objective of the second phase is to identify all unnecessary sources of potable water loss, in other words, all the quantities of water that are not used at the time of production (pure wastage). Create a sub-team that will be tasked to inspect meticulously all your installations (production and auxiliary zones) and to note, among others, the following problems :

- Potable water losses caused by leaks from pipes, hoses, taps and pieces of equipment;
- Automatic spraying maintained in operation on the production line during breaks and production shutdown periods, as well as in the sanitary zones;
- Pipes and taps from which water runs needlessly between periods of use.

The sub-team must submit a report outlining the work done and containing guidelines aimed at solving such problems permanently. The persons responsible for each sector (production supervisor, maintenance team supervisor, etc.) must be advised of the findings and decisions made, because they are the ones who will ensure that corrective actions will be taken. The work team will have to prepare a program of education and awareness for the employees as well as a long term follow up program.

Third phase

The objective of the third phase is to reduce the volume of potable water used during the essential steps of the production process. In order to realise this at once difficult and important phase of the project, it is recommended to complete Table 5 in consultation with the personnel who possess practical knowledge on the work methods and technologies used, while being guided by the general advice given below.

- identify the sources and/or probable causes of the problems detected in water management;
- list the preventive measures that can be applied to decrease the volume of water used;
- discuss among yourselves the feasibility and the cost of each proposed change;

- make sure that the measure envisaged will conform with your HACCP and QMP standards;
- identify the priority of execution of the proposed change.

At this stage, you will have without doubt noticed that some steps of your production process consume relatively more water than others. These steps are the ones on which you will have to concentrate your efforts. You will note that most of the advice presented below is aimed specifically at reducing the consumption of water at each step individually, but that some of these remain of more general application:

- install a system to measure the volume of water used (flow meters), particularly at processing steps and equipment that necessitate large quantities of water;
- perform a regular (daily) check-up of the volume of water used and record this information;
- install valves in order to allow you to better control the water flows;
- install nozzles that will enable you to reduce the volume and pressure of water in the spraying or automatic sprinkling (continuous and periodic) systems of your production lines;
- install solenoid valves to stop automatically the supply of water during periods of work stoppage.

Raw product cleaning

Depending on the physical state of the raw product to be cleaned and the residues (impurities) to remove:

- use a vacuum suction system;
- use brushes (manual, mechanical, rotating, etc.) with or without vacuum suction;
- use compressed air or aerosol (compressed air/water) hoses instead of water hoses;
- put nozzles on cleaning hoses in order to allow you to reduce water flow while increasing the water pressure;
- install valves that can easily be turned off on taps and at the end of hoses.

Transportation of raw product, removal of by-products and residues

Dry conveyors can be used to transport raw product on some production lines, with care to ensure that this conforms with the principles of your hazard analysis critical control point (HACCP) system. Use dry methods of transport for the removal of residues. Replace your flumes with dry conveyors. If the physical state and/or quantity of by-products and residues does not permit the installation of such a conveyor, collect them in watertight containers of appropriate size and transfer them as frequently as necessary to a cool or refrigerated area.

Cooling the raw product, the cooked products, the containers, etc.

It is recommended to use a re-circulation system equipped with cooling instead of a simple running water overflow (T ~ 7- 8°C), for keeping any raw product in water as well as for cooling cooked, sterilised or other products. If necessary, this system will be equipped with filters and/or devices that permit sterilisation (ozone, ultraviolet [UV] rays) of the water thus re-circulated. In order to maintain the cooling water at a temperature of approximately 7-8°C, it is recommended to use a heat exchanger rather than a cooler. The heat exchanger allows the recovery of heat, which can be used for other purposes on the production line or elsewhere in the plant, and thus leads to savings on energy expenses. It should be noted that the fresh water destined to cook products, for steam production, for cleaning, or for many other uses, can also be used as a cooling agent. The recycling of ice, after being used for the conservation of raw product, can also represent an alternative as a cooling agent, because it will permit the temperature of the water in the re-circulation system to be lowered to less than 7°C. Finally, it is recommended to install separate cooling systems for the raw product (before the critical control points) and for the cooked products (after the critical control points).

Cleaning and disinfecting the processing plant

Food products processing activities require very rigorous cleaning and disinfecting of all work surfaces (containers, conveyors, equipment, walls, floors, etc.) in order to guarantee the food safety of the finished product. The governmental agencies responsible for ensuring the implementation of the standards linked to food safety attribute a great importance to their respect in the food processing domain. They offer many awareness programs linked to the various aspects of sanitary maintenance of food processing plants and more particularly on what has to be done with the various chemical products used to facilitate that maintenance. It is however important to underscore that the cleaning procedures are particular to each plant and that the use of water remains essential to attain an acceptable level of food safety.

The cleaning of a marine products processing plant is one of the steps that consumes the most potable water. Water consumption at the time of cleaning can represent from 25 to 40% of the total volume of potable water used during the production process. It generally starts by rinsing equipment and walls with 5 cm (2 in) diameter hoses, in order to make the residues fall to the floor. These residues are then directed towards the floor drains (covered with a screen) using the same water spray. During this process, the residues accumulate on the screen while the water, greatly enriched with organic matter, flows down and joins the effluent. It is usually only at the very end of this step that the solids, which have undergone serious washing during that operation, are collected and disposed of. This cleaning step alone consumes approximately 70% of the total volume of potable water used during the cleaning and disinfecting (decontamination) of the plant. It is thus very important to re-evaluate your cleaning technique. It stands to reason that any dry cleaning measure will considerably reduce the volume of water required for cleaning.

Here are some suggestions :

1. Start cleaning by the recovery and continuous disposal of solid and semi-solid residues, using dry cleaning procedures. It is important that each employee makes sure that residues do not accumulate on the work surfaces or on the floor around him.
2. Manually clean the conveyors, work surfaces, equipment, etc., by scraping them with brushes and brooms with stiff bristles, squeegees or with the help of suction brushes. Then, sweep the floor in order to pick up the accumulated solid residues, shovel it into appropriate containers and dispose of this material.
3. To remove residues from hard to reach areas (corners, spaces under the equipment, conveyors, etc.), use flexible hoses with vacuum, compressed air or aerosol spray (compressed air/water). If none of these techniques are effective, then use a hose with a water spray.
4. Make sure that all cleaning hoses are equipped with nozzles that can easily be opened or closed, that can reduce the water flow and that permit water pressure to be increased between 25 to 30 bars.
5. After having collected all the solids, wash the surfaces to be cleaned with cold water, because the use of hot water can facilitate protein adhesion on the equipment, conveyors, etc., and thus make cleaning more difficult. Spraying must be done with a spray that has a low volume/pressure ratio, because the objective of this operation is to wet the surfaces and to facilitate the elimination of the organic matter. Brush (scrub) surfaces that are very encrusted with solid matter.
6. Do your cleaning with detergent, then apply disinfectants by fine sprays, preferably on clean surfaces, and finally, rinse them well with water. Follow these steps while observing the instructions established by your quality management program (QMP) or by any hazard analysis critical control point (HACCP) system. It is important:
   a) not to exceed the quantities of detergent suggested;
   b) to use the detergent most appropriate for the circumstances and alternate between types (alkaline, neutral, acidic) of detergents to take full advantage of their specific properties;
   c) to test new types of detergents - some are more effective and less harmful to the environment;
   d) to use hot water for the preparation of the detergent solution, because the cleaning power of the solution at 50-60°C is twice as powerful as at 5°C;
   e) not to mix various detergents together in order to reduce the possibility that their cleaning power can be neutralised or to provoke the generation of toxic vapours.
7. The rinsing with detergents and disinfectants must be made with a low volume/high pressure spray, because the objective of this operation is to rinse the largest surface possible while using the smallest quantity of water possible. A flat-spray nozzle held at an approximate 60° angle and producing a pressure of 25 to 30 bars will provide the most effective rinsing.

After all these changes, it is useful to estimate the result of your efforts. Use the model of Table 2 to create another table that could be entitled "Inventory of the products used in one (1) hour during the production process, after implementation of BMP for water". Measure once again the water flows used at each step and record the results in the table. Calculate the total volume used for the entire process as well as the percentage of discharge that represents the flow of each stream in relation to the total flow. The comparison of initial and final water volume measurements will allow you to evaluate the magnitude of the results brought about by the changes. You can calculate the percentage of water reduction at each step and for the total volume, for an hour of production, by using the following formula:

$$\% \text{ water reduction} = [(V_i - V_f) / V_i] \times 100$$

V_i: initial volume (L/hr)
V_f: final volume (L/hr)

Some processing plants have been able to attain 50% reduction of the potable water volume used simply by applying conservation techniques based upon such BMP.

The procedures and modifications that have been proposed for these three phases will not only allow considerable reduction in the volume of water used, but will also reduce the volume of effluents and the disintegration and dissolution of the organic matter in the effluent, and will thereby result in an automatic lowering of the quantity of TS (TSS, TDS), proteins, TKN, P, FOG, as well as of COD and BOD.

5.6.2.2 Effluents

The main objective in managing effluents is to reduce their impact on the environment by reducing the volume of water used and the quantity of organic matter lost. Integrated management of effluents includes the:

1. Physicochemical characterisation of the effluents;
2. Segregation (separation) of the effluents according to their load of organic matter;
3. Re-use of water that is still low in organics;
4. Exploitation of nutrient-rich effluents for value-added products;
5. Primary treatment of the effluents to recover the suspended organic matter (Dissolved Air Flotation [DAF], etc.);
6. Secondary treatment of the effluents to eliminate the dissolved organic matter (bio-filtration, etc.);
7. Sterilisation of the treated effluents (chlorination, ozonation, UV treatment, etc.) to permit their recycling;
8. Recycling of treated and sterilised effluents.

Only the first three items will be discussed because the presentation of information linked to the treatment and exploitation of effluents would extend beyond the purpose of the present exercise, which aims to identify and to promote the implementation of BMP for raw product, water and effluents. However, it is important to fully understand that the implementation of BMP constitutes an indispensable basis that will greatly facilitate the implementation of any other subsequent step in the treatment and use of the effluents and residues.

1) Second physicochemical characterisation of the effluents generated

The implementation of BMP for the effluents must be done after having completed the implementation of best management practices related to: a) the quality of the raw product, b) the potable water, c) the residues and, d) the chemical products. Each one of these steps will contribute to a reduction in the organic load of the effluents. It is thus important to perform again the physicochemical characterisation of each stream of effluent generated in order to allow you to better orient your efforts at that level.

Use exactly the same approach that you have already used at the time of the initial characterisation of your effluents. Based on Table 4, create another table that could be entitled "Compilation of the physicochemical characteristics of various effluents – second characterisation". Collect again composite samples at each step of the production, in order to analyse them and compile the results obtained in this new table. Measure again the flow of effluents generated at each one of the steps and also record them in the table.

The comparison of these two tables will enable you to better evaluate the results of your efforts. You can also calculate the percentage of reduction of the effluent and that of the reduction of organic matter at each step during an hour of production, by using the two following formulae:

$$\% \text{ effluent red.} = [(V_i - V_s) / V_i] \times 100$$

$$\% \text{ red. TSS} = [(Qty_i - Qty_s) / Qty_i] \times 100$$

red. : reduction
V_i : initial volume (L/hr)
V_s : secondary volume (L/hr)
Qty_i : initial quantity of TSS (kg /hr)
Qty_s : secondary quantity of TSS (kg /hr)

The second formula can also be used to calculate the reduction in TKN, P, COD, BOD, etc. These data can also be used as basic information to undertake the next step, which consists essentially of managing the effluents produced by segregating them.

2) Segregation (separation) of effluents

The "segregation" of effluents is a technical term that identifies a method to manage the effluents produced in a plant. It is here that the analyses done to determine the physicochemical composition of each stream of effluents take on special importance. It is effectively from this information that you have obtained on the organic matter load of each stream that you will be able to decide which streams you should combine or keep separate in order to direct them for another usage in-plant or for immediate treatment. Based on data from the table that you have entitled "Compilation of the physicochemical characteristics of various effluents – second characterisation" and those from the classification grid of the fraction of organic matter dissolved in the effluent, described in section 5.5.3, you can now decide the path of each stream. Here are some examples:

- All the streams containing a small quantity of organic matter (e.g. TSS $\leq$ 20 mg/L) can be merged either with the main stream of effluents for their direct discharge in the environment, or to a secondary stream in order to be reused. The reuse of effluents will enable conservation of potable water as well as reduction of the volume of effluents to be discharged or treated.
- All the streams containing an average quantity of organic matter (e.g. TSS $\leq$ 200 mg/L) can be merged either with the main stream of effluents for their direct discharge in the environment, or a secondary stream that can be directed towards an appropriate secondary treatment. This approach will reduce the volume of effluents directed towards primary treatment.
- All the streams containing a high quantity of organic matter (e.g. TSS > 200 mg/L) must be merged with a stream which is directed towards an appropriate primary treatment (and a secondary treatment if necessary). This treatment will help to reduce organic pollution considerably.
- The streams containing products with value-added potential can be directed towards the appropriate treatment (evaporation, reverse osmosis, ultra-filtration, etc.) that will allow a more economical recovery of well defined product(s) and possibly an increase in income for the processing plant. This recovery will also help to reduce organic pollution.

It is important to underscore that each seafood processing plant must use all the means available to it so that it can reduce the volume of effluents to be treated. There is a very important principle to keep in mind in regard to the treatment of effluents, whatever technique you plan to use. The greater the volume of effluents, the more expensive the treatment will be. **Reduction thus translates into savings.**

3) Re-use of water

The reuse of water that has had limited contact with raw product and is low in organic matter is a good method to conserve potable water. However, it is important to realise that potable water, once used in the process, automatically becomes a "wastewater" (or effluent) by definition, no matter how clean it is. One cannot re-use such wastewater for operations requiring strictly potable water. Nevertheless, it is possible to re-use effluents that contain little or no organic matter (cooling water if it cannot be re-circulated) for cleaning of the raw product, the equipment, the containers, for pre-cleaning the floor, etc.. It is the critical control point (CCP) identified by your hazard analysis critical control point (HACCP) system for this production line that must be used to limit the nature of the reutilization of the wastewater.

5.6.3 Best management practices for residues

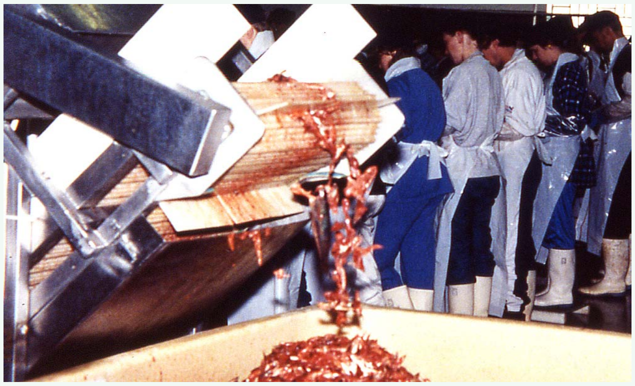
The main objective of the management of residues is to slow down their physical and biochemical degradation. This will increase the possibility of their recovery for value-added products and reduce their disintegration and their dissolution in the effluent. The maintenance of the quality of residues depends on several factors, but the most important ones are the period of exposure to water, to air and to room temperature. In order to ensure the conservation of residues and by-products, it is necessary to:

- Adopt internal regulations that compel employees to consider residues as a raw product to be exploited and not as a waste to be discarded;
- Develop and apply techniques to isolate, to recover and to quickly remove the residues by means of dry methods;
- Develop and apply techniques to handle, to preserve and to store the residues, before they are shipped to plants specialised in the reuse of residues or to composting sites;
- Actively seek to enhance to the maximum your residues by identifying the best market or outlet that will enable you to make the best profit.

The achievement of this step might require some adjustments to the way of thinking and the work practices of employees and some modifications on the production line. However, it will enable reduction of raw product loss at the source and in a very significant manner will reduce the load of organic matter in the effluents, which means a direct reduction in the costs of final treatment of the effluents. The isolation, recovery and immediate removal of the residues by means of dry methods is one of the most important challenges of the marine products processing industry. Because residues bathing in water are a major cause for the presence of organic matter in the effluent, the implementation of means of dry handling will have a major impact on all aspects affecting the management of organic pollution. Experiments at the industrial scale have demonstrated that substantial cost savings can be realised in the treatment of effluents for each dollar invested in the recovery of residues before their contact/dilution with water.

The residues include components of the raw product in the liquid, semi-solid and solid state, which cannot be used to make primary products but which may still have use for secondary by-products. The majority of the liquid and semi-solid residues comes from cleaning the raw product. Examples include the residues resulting from 1) the dismemberment (break-up) of crab and lobster, 2) the cutting and evisceration of fish, 3) the opening of molluscs, etc.. These residues are most likely to be dissolved in water and to clog up the mesh of the screen that is found at the outfall of the main effluent pipe. Make sure to avoid as much as possible the use of water to isolate, recover and remove residues along the processing line. Here are some alternative techniques recommended to replace cleaning hoses or water sprinklers:

- Use hoses, pipes, brushes (manual, mechanical, rotary) with vacuum suction, connected directly to an appropriate container;
- Use a compressed air jet to remove and sweep (displace) the residues into appropriate containers;
- Remove the residues manually, with the help of brushes (manual, mechanical, rotary) or any other suitable tool and deposit them in appropriate containers;
- The dry cleaned product can be rinsed, if necessary, with the help of an aerosol jet or a water jet equipped with a nozzle that permits reduction of the flow and increasing the pressure, as well as being easy to turn off.



Collect the residues (especially the liquid and semi-solid residues such as the viscera, the immature gonads, the skins, etc.) in watertight containers of an appropriate size. It is preferable to install a dry conveyor to collect and remove the solid residues present in large volume (heads and carcasses of fishes, carapaces of crustaceans, shells of molluscs, etc). An alternative consists of installing watertight containers of an appropriate size that will be transferred as frequently as necessary to a cool or refrigerated location. The dry conveyors and containers that collect the residues must be installed directly under the processing line, in a way that the employees can easily slide residues into them without spilling them on the floor. Empty the containers of residues as often as you can to a cool or refrigerated location.

It is important to store residues in the same manner as raw product and not as a waste, before their shipment to specialised recovery plants. Depending on the use that will be made of them, some residues should be preserved by freezing, acidification or by the addition of chemical preservatives.

Even though this guide does not cover the enhancement of residues as an objective, it is very important to underscore that each seafood processing plant must use all the means enabling it to reduce the quantity of unusable wastes (putrefied wastes) and thus increase the potential value of these residues. This enhancement of residues is done primarily by composting as well as by the production of fishmeal and silage, but more recent innovations include the extraction of value-added products such as:

- chitin and its multiple derivatives (carapace of crustaceans)
- pigments (carapace of crustaceans, algae, etc.)
- enzymes (viscera and digestive system)
- gelatine (the skins and carcasses of fishes)
- omega-3 fatty acids (fish oil)
- flavours
- protamin (a functional protein found in the milt of herring)

5.6.4 Best management practices for chemical products

The use of chemical products in the marine products processing industry is unavoidable. They help to clean and to disinfect the plants, to preserve the quality of the raw product and the finished products, to increase the yield, etc.. However, some chemical products can be harmful to the environment (and sometimes to human health). The user of these products must thus follow the manufacturers instructions as well as the laws and regulations adopted by concerned governmental agencies. At the plant, the management of chemical products is controlled by your hazard analysis critical control point (HACCP) system and your quality management program (QMP). The use of the food additives is also regulated by the Canadian Food Inspection Agency (CFIA). The objective of this guide is primarily to draw your attention to reducing the use of phosphorus- and nitrogen-based chemical products, two chemical elements whose excessive presence in the environment contribute to the process of eutrophication of coastal waters. It is thus recommended to:

- take into consideration the chemical composition of these products, when they are being selected;
- choose environmentally friendly products;
- follow instructions for the use of these products;
- do not exceed the quantities suggested.

5.7 Establishment of verification measures

After having implemented best management practices in your plant, you might perhaps want once again to evaluate their global effect. For this, you can quantify the products generated per hour of production (according to the procedure described at section 5.4.2) and perform the physicochemical characterisation of the main effluent. A table similar to Table 6 could allow you to register the initial and final data and also serve to set in place a continuous program of verification.

Table 6. Compilation of continuous measures of verification of the performance of the BMP

Used / generated products	**Initial mesures** (before BMP)	**Final measures** (after BMP)	**% of reduction/ increase**	**Verification measures 1** (date)	**Verification measures 2** (date)	**Verification measures 3** (date)
Quantity of raw product (kg/hr)						
Potable water volume (L/hr)						
Quantity of finished product (kg/hr)						
Quantity of by-products (kg/hr)						
Quantity of residues (kg/hr)						
Volume of effluents (L/hr)						
TSS (mg/L)						
TKN (mg/L)						
FOG (mg/L)						
P (mg/L)						
BOD (mg/L)						
COD (mg/L)						

By comparing initial and final results, you should notice a:

- Reduction in total volume of potable water (TVPW) used, in % = $[(TVPW_{Initial} – TVPW_{Final}) / TVPW_{Initial}] \times 100$
- Reduction in total volume of effluent (TVEf), in % = $[(TVEf_{Initial} – TVEf_{Final}) / TVEf_{Initial}] \times 100$
- Increase in the quantity (Qty) of finished products, in % = $[(Qty_{Final} – Qty_{Initial}) / Qty_{Initial}] \times 100$
- Increase in the quantity (Qty) of residues/by-products, in % = $[(Qty_{Final} – Qty_{Initial}) / Qty_{Initial}] \times 100$
- Reduction of the quantity (Qty) of organic matter in effluent, in % = $[(Qty_{Initial} – Qty_{Final}) / Qty_{Initial}] \times 100$

(where Qty can be the value in TSS, TKN, FOG, P, BOD, COD, etc.)

Refer to the calculation method at section 3, step 3 of the guide

Qualitative improvements, both in primary products and residues, are more subjective but should still form a part of the verification process as they have the potential to yield immediate improvements in the economic "bottom line" for the plant.

It is strongly recommended to set-up routine check-ups of the BMP performance, from two to three times per processing season. The stability of the verification measurements, in relation to final measurements, will confirm the proper operation of your BMP. The opposite can demonstrate a lack of control and/or a lack of continuity in the application of your BMP.

After having implemented these BMP for raw product, water and effluents in your plant, it is possible that the load of organic matter in your general effluent now satisfies the current environmental standards. The data and information that you have registered in Table 6 can also be used as tools to make predictions linked to future marine products processing activity needs. If you want, you can estimate the volume of water that will be used, the quantity of products that will be generated, as well as the volume of effluents and quantities of pollutants that will be discharged by the processing of a kilogram or a metric ton of raw product. This type of calculation will enable you to better plan your needs in potable water, food additives, detergents and disinfectants, as well as chemical products necessary for the treatment of your effluents. It will also facilitate comparisons between the various types of production that you do at your plant, in terms of their respective environmental impact. These data could also be used to allow you to compare the economic and environmental performance of your plant with those of other marine products processing plants in your region or elsewhere in the world.

As examples:

a) You can calculate the total volume of effluents (TVEf) in litres (L) that will be produced for each kilogram (kg) of raw product (r.p.) [or finished product (f.p.)] using the following formula:

$$\text{TVEf (L/kg r.p.)} = \frac{\text{TVEf (L/hr)}}{\text{Qty r.p. (kg/hr)}}$$

A useful bit of information is that 1 litre of effluents/kg of r.p. = 1 m^3 of effluents/metric ton of r.p.

b) You can calculate the quantity of total suspended solids (TSS) in grams (g) that will be produced for each kilogram (kg) of raw product (r.p.) using the following formula:

$$\text{TSS (g/kg r.p.)} = \frac{\text{TSS (mg/L)} \times \text{TVEf (L/hr)}}{\text{Qty r.p. (kg/hr)} \times 1000}$$

A useful bit of information is that 1 gram of TSS/kg of r.p. = 1 kg of TSS/metric ton of r.p.

5.8 Establishment of periodic/continuing education program

One of the last responsibilities of the work team will consist of establishing a periodic/continuing education program for the employees, which will ensure their receptivity to, and the continuity of application of, the BMP programme. To do this, the work team must:

1. Undertake an awareness campaign for the employees, focused on the problems created by the waste of potable water and organic pollution originating from processing activities.
2. Clearly demonstrate the favourable impact from BMP implementation in your processing plant on the neighbouring environment (your customers as well as consumers will be sensitive to this environmental consideration by your processing plant). Do not hesitate to promote these results.
3. Underscore clearly the contribution of each one of the employees for each beneficial improvement made, in order to recognise their efforts and to encourage them to pursue their good work, and thus favour their adoption of new work habits.
4. Establish internal regulations governing the changes made in order to promote their implementation and obtain the desired results.
5. Describe and make well known to the personnel the proposed changes in their individual work tasks; organise a training course dealing with their new work tasks, in order to facilitate learning.
6. Establish a control system for each critical point of the production process. Assign people who will have as a responsibility to locate and signal problems. Make known the necessary and available measures to solve a problem (repair of equipment, etc.) or to prevent it (continuing training, etc.).
7. Ensure appropriate training for new employees.

6.0 Benefits

Communities are increasingly concerned about the health of their environment and specific environmental issues, including the discharge from marine products processing plants, hold their attention. The challenge, for the seafood processing plants located in the Atlantic region, is to reduce the organic pollution generated by their processing activities, while remaining competitive in the domestic and foreign markets. Such a constraint requires a relatively simple approach, that can be easily implemented by the staff of the plant, and results in a minimum expenditure for equipment and external expertise. It is precisely this type of approach, both logical and inexpensive, that has been presented in this BMP guide.

This guide, focused on best management practices of raw product, water and effluents, contains basic information necessary so that a processing plant, regardless of its size, can undertake a program to reduce the organic pollution generated by its marine products processing activities. The measures presented are applicable to all types of productions that are found in the plants of the Atlantic region and the most common of these are illustrated in this guide by means of production diagrams.

The main benefit of this guide is to allow the personnel of the plant to maximise their contribution during the implementation of the organic pollution reduction program and to thus minimise the needs for external expertise. If external expertise becomes necessary, the guide will nevertheless allow the persons in charge at the plant to better understand and follow the various stages of work carried out by this external expertise. It will also facilitate the follow-up process that you will have to implement in your plant, in order to ensure that measures taken are respected and that the reduction program always functions properly.

Another obvious benefit, particularly interesting for any processing plant, is linked to an increase in yield, tied to a better management of the raw product. An improved management of the quality of the raw product, from the fishing vessel and right through the production line in the plant, will inevitably translate into an increase in yield, as will a reduction in the duration of contact between water and the raw product. In a context where marine resources are more and more limited and expensive, you will thus be able “to do more with less”. A

better management of residues, in itself, opens doors to enhanced value for them and to a potential in terms of value-added products.

However, the benefits linked to the implementation of the present guide go beyond the advantages associated with the implementation of an organic pollution reduction program and to the financial gains resulting from an improved yield of raw product in the plant. The inputs/outputs budget that you have developed constitutes an important source of information that will allow you to increase the performance of your seafood processing plant, by identifying sources of waste or operations whose functioning can be optimised. This strategic information, derived from your own processing plant, also constitutes basic knowledge that will be very useful if you plan to make significant modifications to your industrial processes.

It has also been demonstrated that the adoption of best management practices for your raw product, water and effluents constitutes the critical preliminary step to any additional technological approach (dissolved air flotation, decanter, membranes, etc.) aimed at allowing your processing plant to respect environmental standards.

Thus here is a flexible and affordable tool to facilitate your task at the time of the implementation of your organic pollution reduction program, and that could perhaps even constitute the first step towards an ISO 14000 certification for your seafood processing plant.

7.0 References and other useful sources of information

Part of the information and advice given in this guide comes from some of the following bibliographic sources. The procedure described for the implementation of these best management practices for raw product, water and effluents originates from the Fisheries and Marine Products Division of the Coastal Zones Research Institute, and was inspired by the hazard analysis critical control point (HACCP) system.

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Several reports from the "Fraser River Action Plan", with some of them listed below, are related to BMP of raw product, water and effluents of the marine products processing industry. They are all available free of charge on the web at the following URL address : *http://www.rem.sfu.ca/FRAP/PDF_list*

AGRA Earth & Environmental Limited and Hydromantis Inc., 1995. Fraser River Action Plan – Study of Water Conservation as a Means to Improve Wastewater Treatment and Reduce Treatment Costs. Report DOE FRAP 1996-22, Environment Canada, 149 pages. [On line] *http://www.rem.sfu.ca/FRAP/9622.pdf*

NovaTec Consultants Inc., 1994. Fraser River Action Plan - Guide for Best Management Practices for Process Water Management at Fish Processing Plants in British Columbia. Report DOE FRAP 1994-20, Environment Canada Industrial Programs Section Environmental Protection, x + 117 pages. [On line] *http://www.rem.sfu.ca/FRAP/9420.pdf*

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A list of 130 documents dealing with the effluents of marine products processing plants and published during the period 1970-2001 is available at the following URL address : *http://osulibrary.orst.edu/guin/seafood/wastetext.htm*

A version of the main federal and provincial applicable laws is available on the web at the following sites :

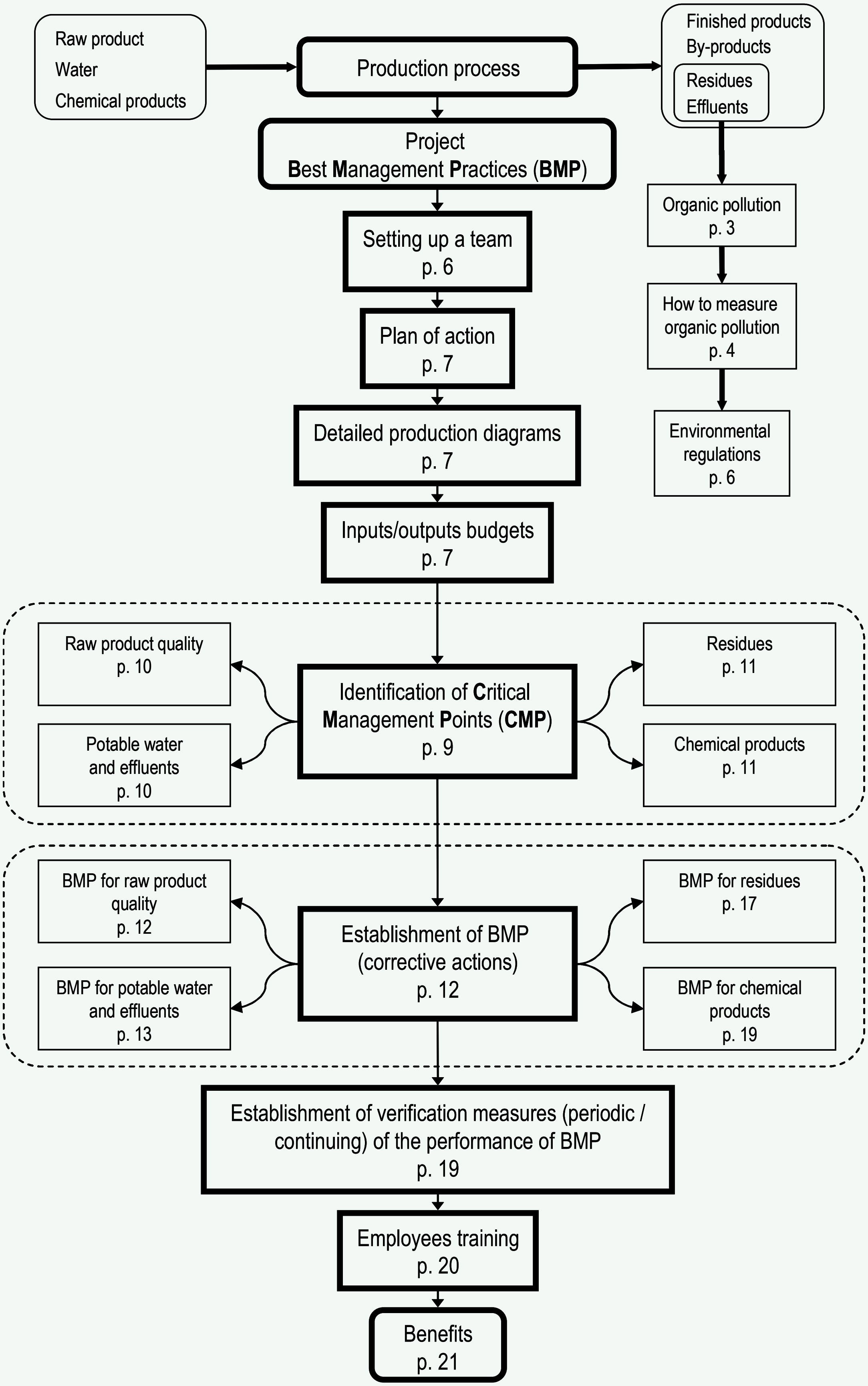
Federal laws

- Canadian Environmental Protection Act : *http://laws.justice.gc.ca/en/C-15.31/text.html*
- Fisheries Act : *http://laws.justice.gc.ca/en/F-14/59176.html*

Provincial laws (New Brunswick)

- Clean Environment Act : *http://www.gnb.ca/acts/acts/c-06.htm*
- Clean Water Act : *http://www.gnb.ca/acts/acts/c-06-1.htm*
- Fish Processing Act : *http://www.gnb.ca/acts/acts/f-18-01.htm*

APPENDIX A – DIAGRAM OF THE MAIN STEPS IN THE GUIDE



APPENDIX B – PRODUCTION DIAGRAMS

Crab (cooked and frozen)

Shrimp (cooked and frozen)

Lobster (cooked and canned)

Lobster (raw tails)

Molluscs

Herring (marinated - barrel)

Herring (marinated - bottled)

Herring (roe)

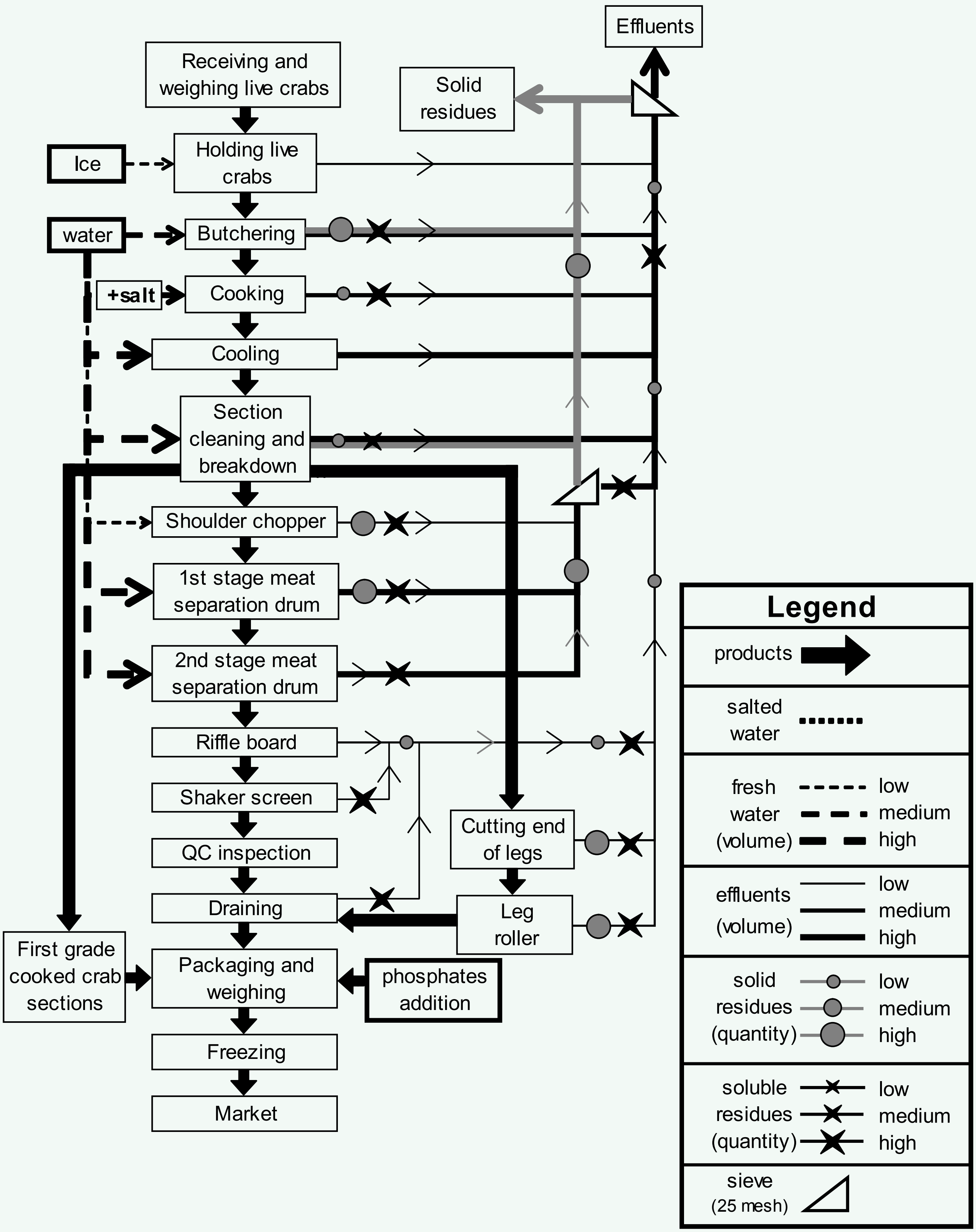
Herring (smoked)

Groundfish (fresh and frozen)

Groundfish (salted)

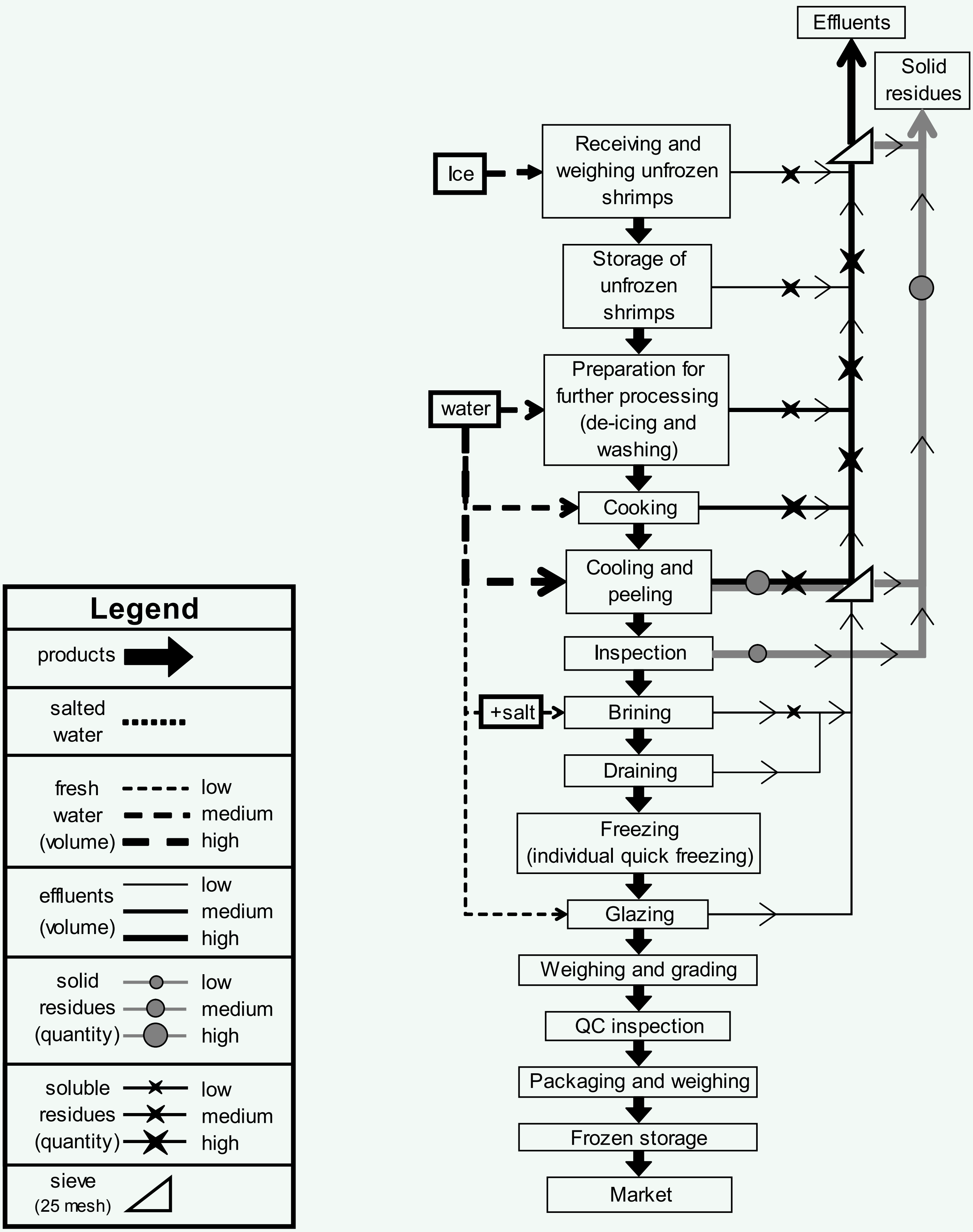
Crab (cooked and frozen)

Solid and liquid residues distribution



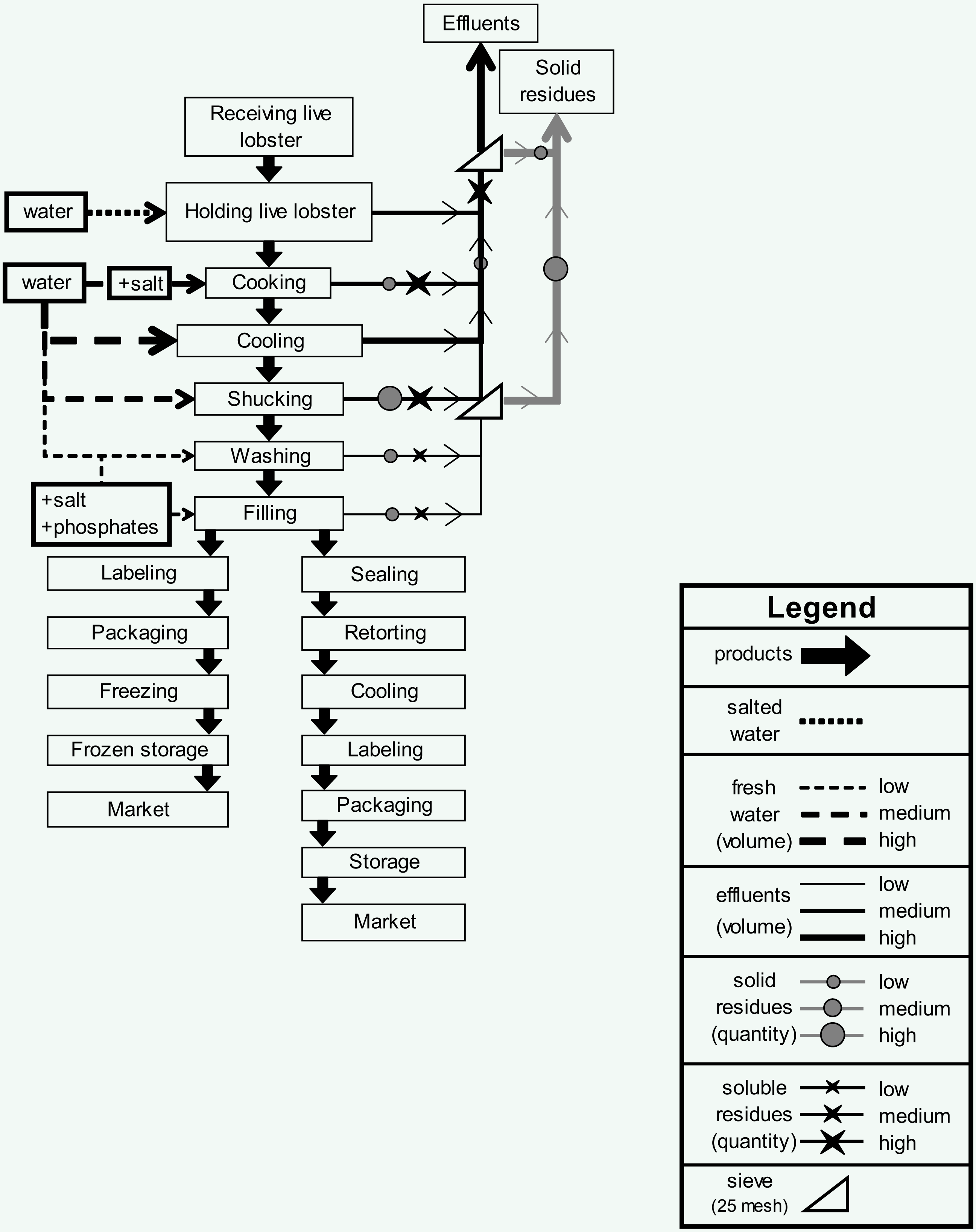
Shrimp (cooked and frozen)

Solid and liquid residues distribution



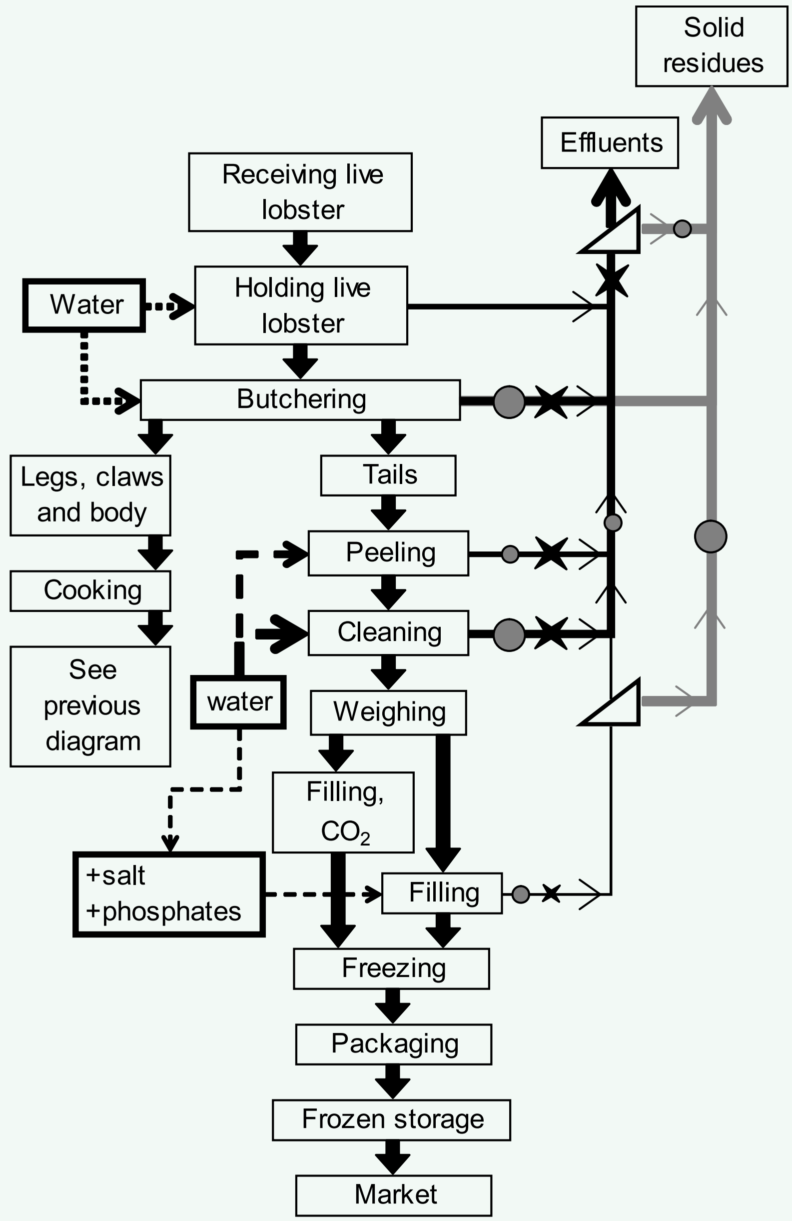
Lobster (cooked and canned)

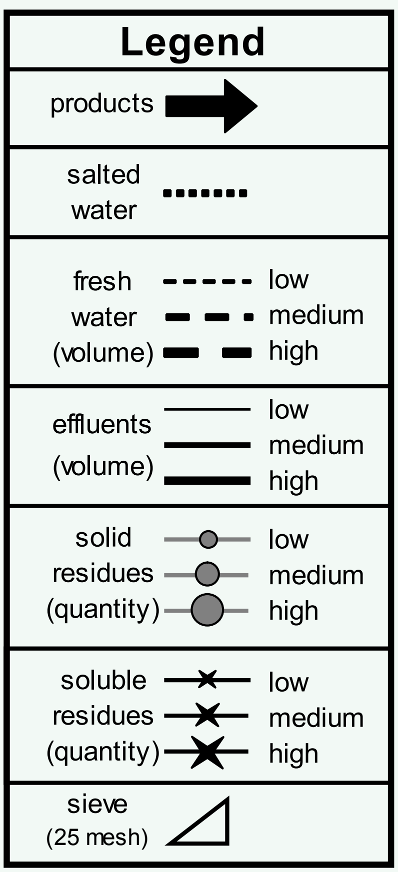
Solid and liquid residues distribution



Lobster (raw tails)

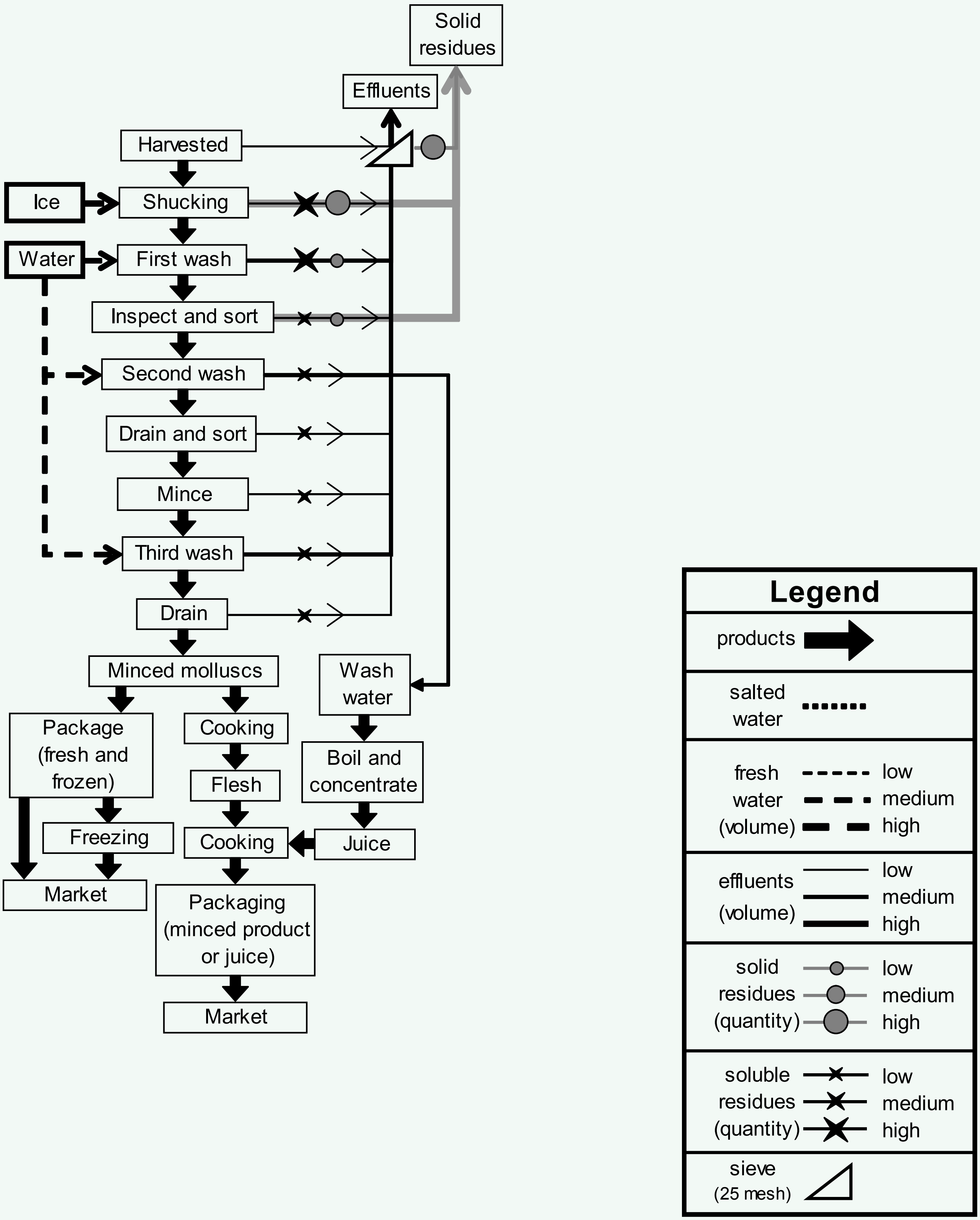
Solid and liquid residues distribution





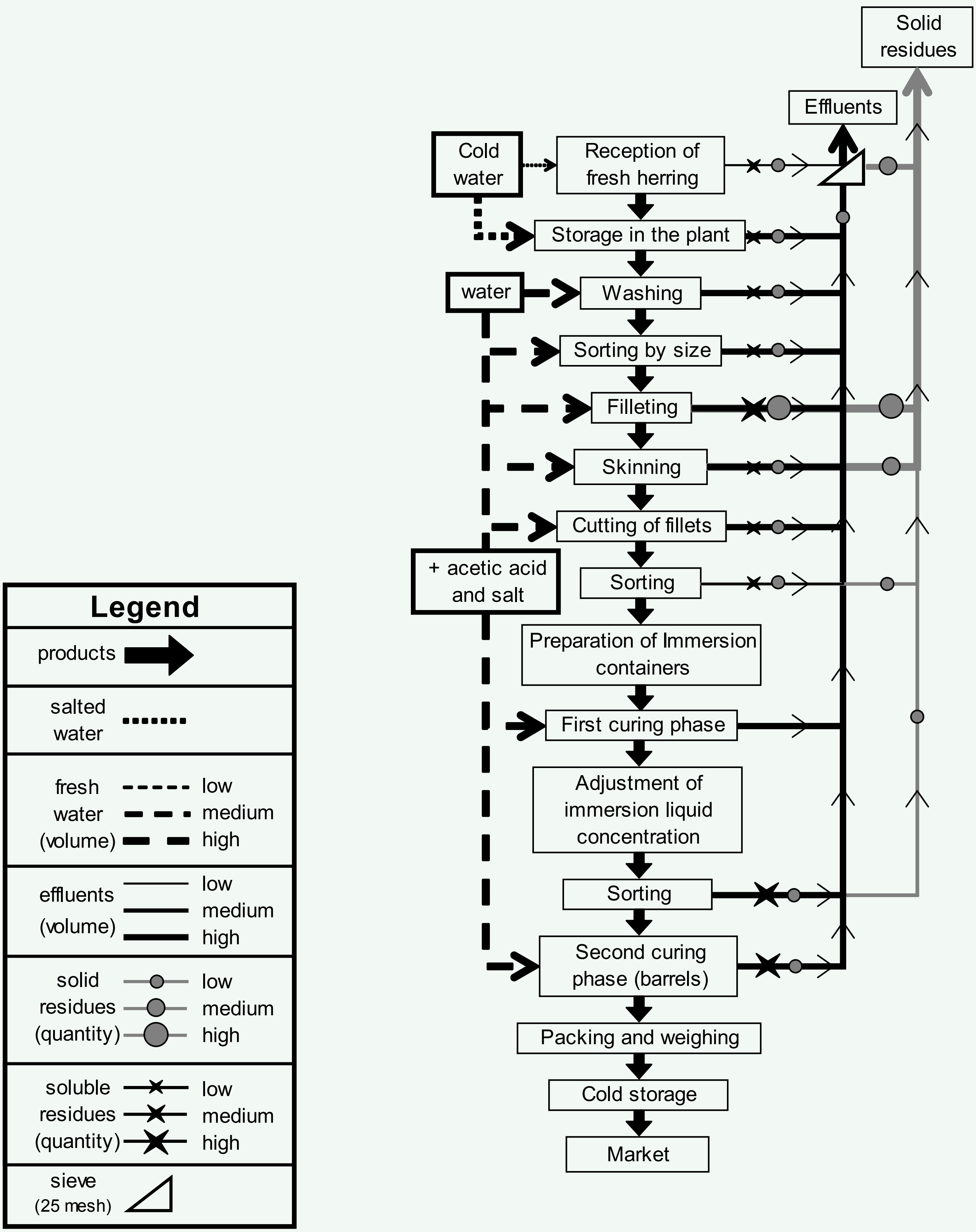
Molluscs

Solid and liquid residues distribution



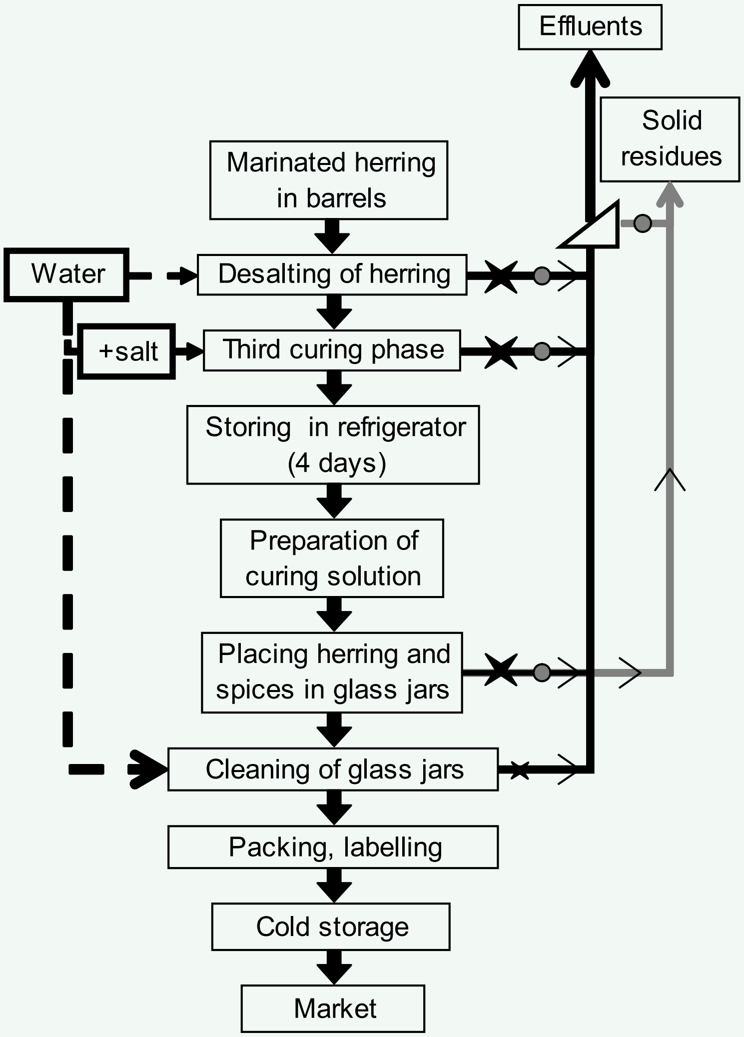
Herring (marinated - barrel)

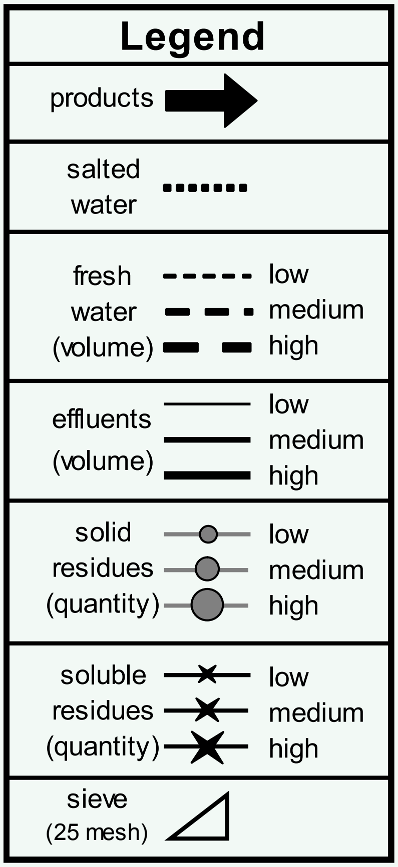
Solid and liquid residues distribution



Herring (marinated - bottled)

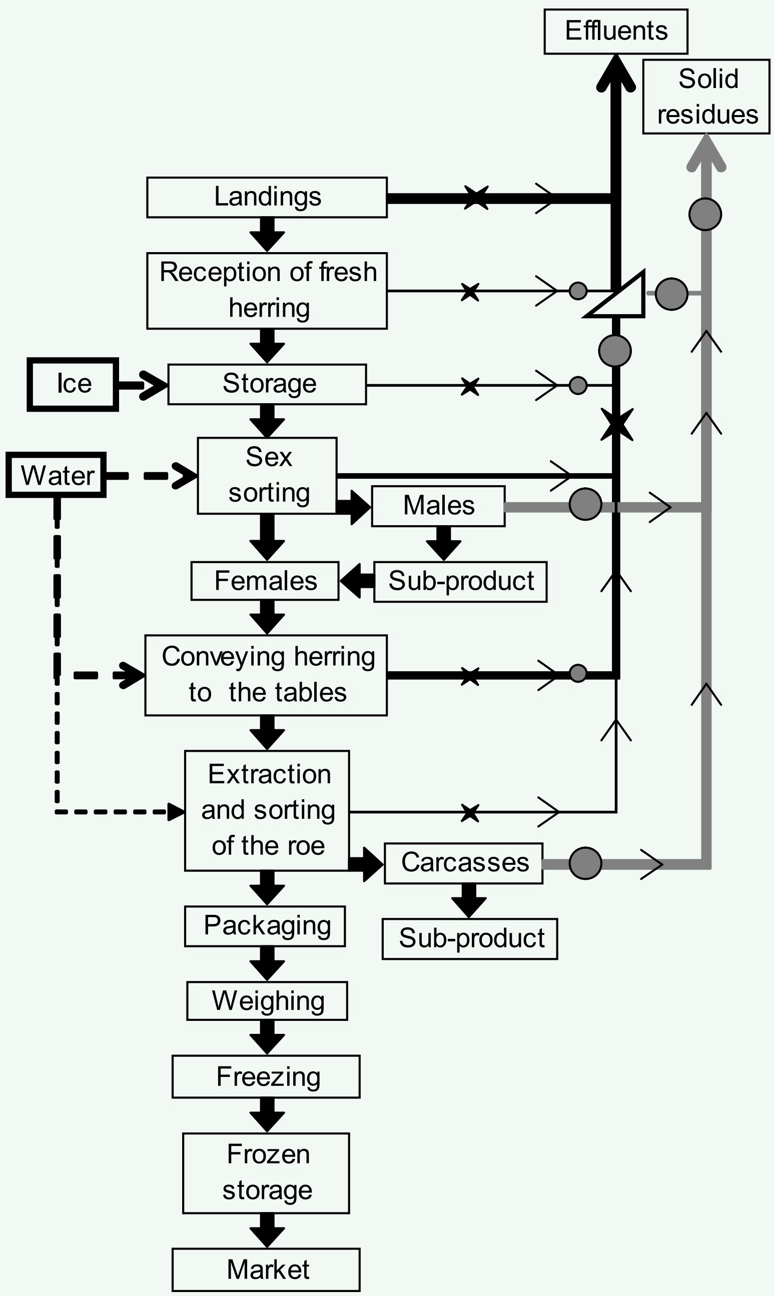
Solid and liquid residues distribution

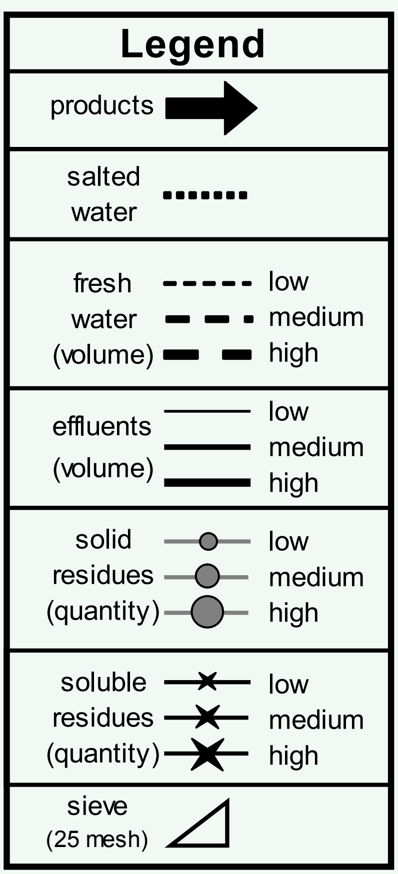




Herring (roe)

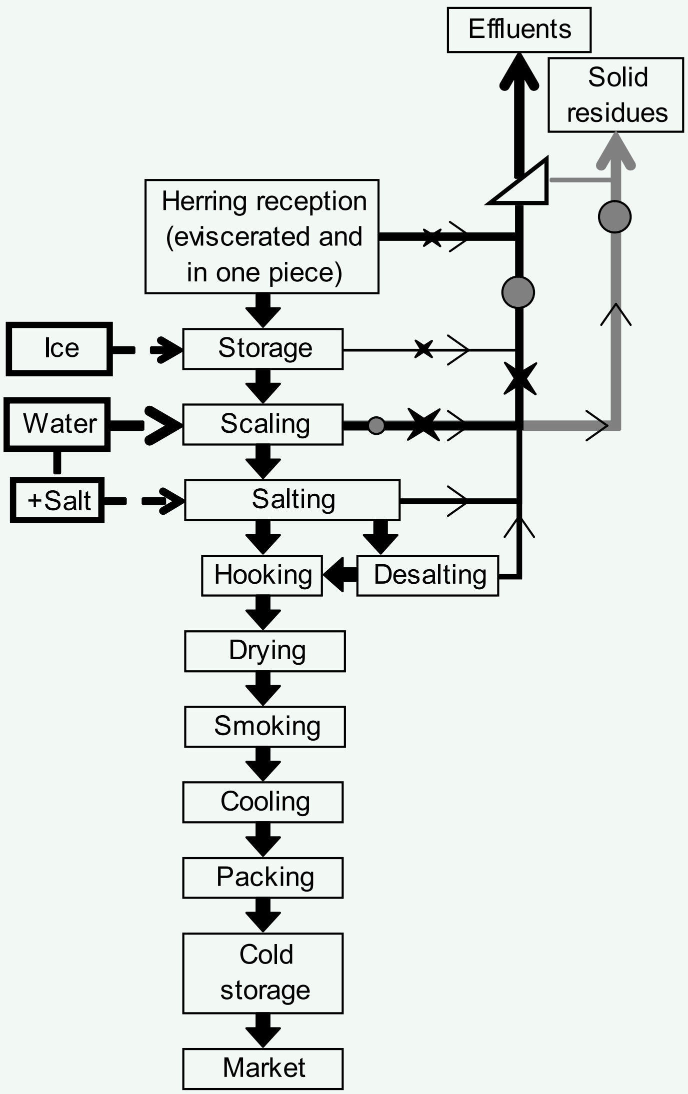
Solid and liquid residues distribution

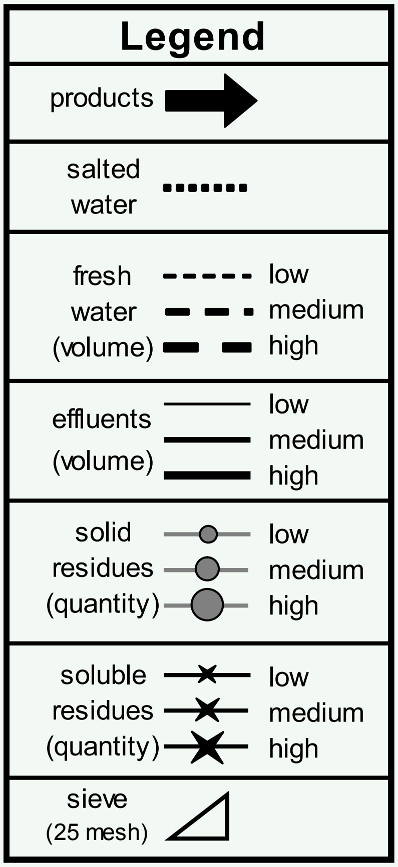




Herring (smoked)

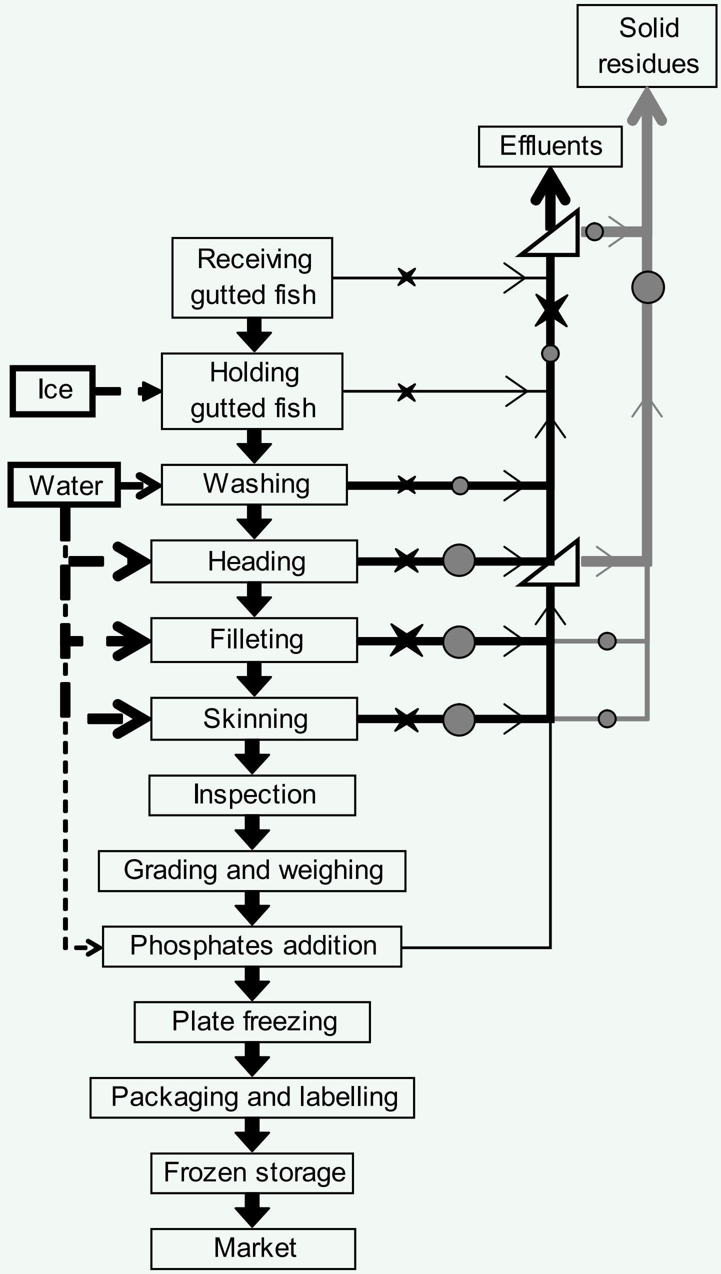
Solid and liquid residues distribution

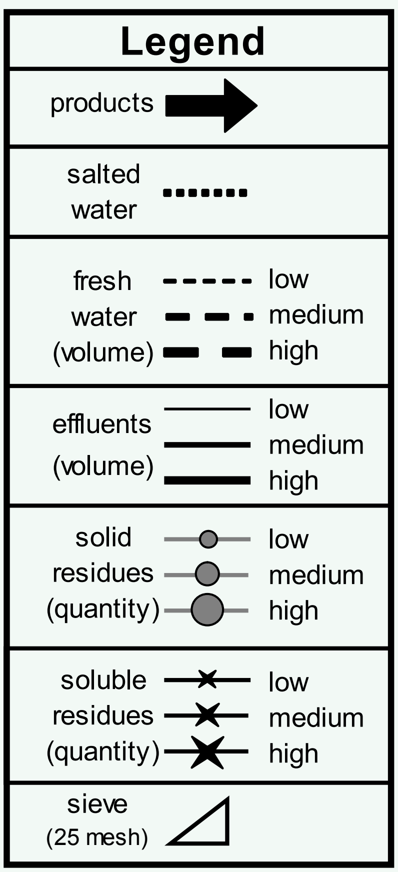




Groundfish (fresh and frozen)

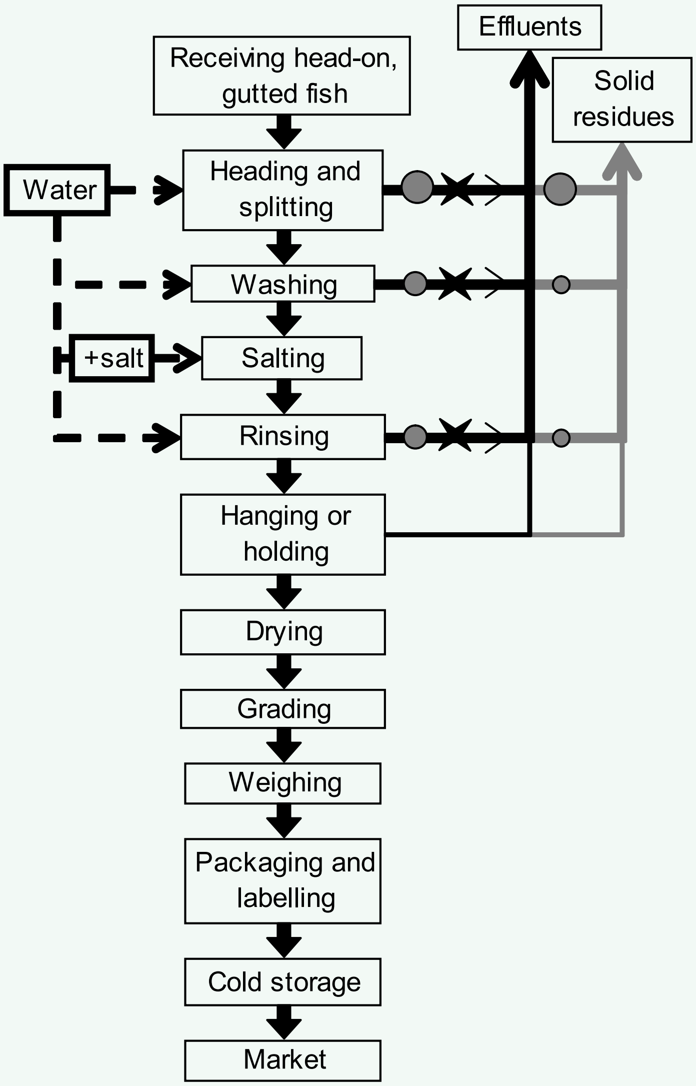
Solid and liquid residues distribution

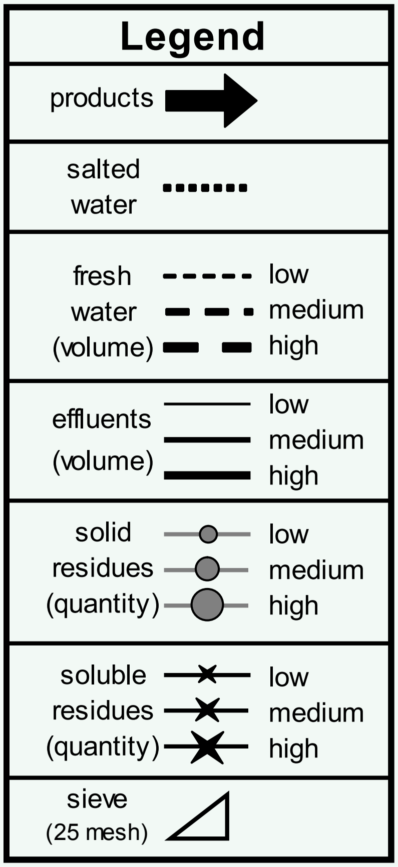




Groundfish (salted)

Solid and liquid residues distribution





APPENDIX C – ABBREVIATIONS

Abbreviations related to the physicochemical analyses	
BOD	Biochemical oxygen demand
$BOD_{5\ Soluble}$	Soluble biochemical oxygen demand (5 days)
$BOD_{5\ Total}$	Total biochemical oxygen demand (5 days)
CH_4	Methane
CO_2	Carbon dioxide
COD	Chemical oxygen demand
$COD_{Soluble}$	Soluble chemical oxygen demnd
COD_{Total}	Total chemical oxygen demand
FOG	Fats, oils and greases
H_2S	Hydrogen sulphide
N	Nitrogen
NH_3	Ammonia
O_2	Oxygen
P	Phosphorus
$P_{Soluble}$	Soluble phosphorus
P_{Total}	Total phosphorus
T	Temperature
TDS	Total dissolved solids
$TKN_{Soluble}$	Soluble total nitrogen or soluble total Kjeldahl nitrogen
TKN_{Total}	Total nitrogen or total Kjeldahl nitrogen
TS	Total solids
TSS	Total suspended solids

Abbreviations related to units of measure	
^0C	Degree Celcius (centigrade)
cm	Centimetre
in	Inch
hr	Hour
Kg	Kilogram
L	Litre
m^3	Cubic meter
mg	Milligram
min	Minutes
mm	Millimetre

General abbreviations	
BMP	Best management practices
CCP	Critical control point
CFIA	Canadian food inspection agency
CMP	Critical management point
DAF	Dissolved Air Flotation
E. coli	*Escherichia coli*
f.p.	Finished product
HACCP	Hazard Analysis Critical Control Point
QMP	Quality management program
$Qty_{Initial}$	Initial quantity
Qty_{Final}	Final quantity
$Qty_{Secondary}$	Secondary quantity
r.p.	Raw product
TVEf	Total volume of effluents
TVPW	Total volume of potable water
UV	Ultra violet
V_{Final}	Final volume
$V_{Initial}$	Initial volume
$V_{Secondary}$	Secondary volume
VEf	Volume of effluent
$VEf_{Step\ n}$	Volume of effluent at step "n"
VPW	Volume of potable water
$VPW_{Step\ n}$	Volume of potable water at step "n"

BEST MANAGEMENT PRACTICES: MARINE PRODUCTS PROCESSING

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