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ENVIRONMENTAL ASSESSMENT AND MANAGEMENT OF THE FISH PROCESSING INDUSTRY

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Preface

The main objectives of this study are to present technical information and costs related to waste management in the seafood processing industry. Although there is a lack of published data on environmental management in the fish processing industry in developing countries, the focus is on seafood processors in developing countries drawing upon developed countries' experiences as relevant.

Recovery and utilization of seafood wastes, both from wastewater and solid wastes, can be good policy for protecting the environment and for the seafood processing industry. Various options, such as production of fish meal, fish silage, and mince are explored. Fish silage, for example, is generally suggested as an option for waste utilization in small operations, whereas production of fish meal is more suitable for large plants.

The study will serve as a background document to the First Consultation on the Fish Processing Industry, Gdansk, Poland, June, 1987. This is the third in a series of environmental research studies on the food processing industry prepared by UNIDO, Studies and Research Division. Previous studies covered (a) vegetable oils and fats, and (b) all of agro-industries.

Contents

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Glossary of terms

Amino acids	The nitrogenous organic compounds that serve as the structural units of proteins.
Astaxanthin	A violet crystalline pigment found in combination with protein in the shells of crustaceans ($C_{40}H_{52}O_4$).
BOD_5	The amount of oxygen, expressed as milligrams per liter of water, consumed over a five day period in stabilizing organic material in water of a predetermined temperature and pH.
Bloodwater	The substance oozing out of pits or bins in which fish waste solids and trash fish are accumulated.
Brine	Water containing large amounts of salt.
Carotenoid	Any of several red or yellow pigments related to the red or orange compound carotene ($C_{40}H_{56}$).
Chitin	A polysaccharide (carbohydrates that decompose into more than three simple sugars) that forms part of the hard outer covering of insects, crustaceans and some other invertebrates.
Chitosan	A substance derived from chitin by boiling the chitin in a strong alkaline solution.
Dissolved Air Flotation (DAF)	A wastewater treatment method in which tiny air bubbles are used to remove suspended solids.
Evisceration	The process of removing the inner organs of the body, particularly organs of the thorax and abdomen such as the intestines, heart, lung, liver and kidneys.
Fish meal	Whole fish and/or waste parts which have been cooked, dried and ground.
Fish Protein Concentrate (FPC)	Fish meal which has been ground to a flour-like consistency and which has been manufactured under hygienic conditions appropriate to food for human consumption.
Fish silage	A liquified form of whole fish or fish wastes produced by grinding the fish and then keeping it under acid conditions until the cells and tissues have been broken down.
Flocculate	To collect in bunches; in wastewater treatment it refers to the process of precipitating suspended solids out of the wastewater stream.

Flume	A chute or trough for carrying water.
Mantle	A membranous flap in the body wall of a mollusk.
Minced fish	Fish flesh that has been separated from inedible portions and rendered into small pulverized particles or into a powdered form.
Offal	That part of the fish that remains after the fillets have been removed.
Retort	In the context of food processing, to autoclav, i.e. to heat in air-tight chambers with pressurized steam, or other means which do not entail boiling, to temperatures above 100°C.
Sludge	In wastewater treatment, the solids and/or microorganisms that are precipitated out of wastewater.
Stickwater	Water which has been in close contact with fish, usually as as result of precooking or pressing operations, and consequently contains large amounts of organic material.

Introduction

This study presents technical information on waste management in the seafood processing industry. Information is provided on characteristics of wastewater and solid wastes, on recycling options, and on treatment and disposal methods. To the limited extent that data are available, costs of wastewater treatment and economic parameters for recycling options are included. Throughout the report, the focus is on information relevant to seafood processors in developing countries.

Chapter 1 of the report points out that two characteristics of the vast majority of seafood processors - their small sizes and remote locations - severely limit both the wastewater treatment and the recycling options which can be considered feasible. Although most wastewater treatment systems are too expensive for small processors, the disposal of untreated wastewater does not generally cause serious environmental problems. Seafood wastes are not toxic. Except for clam and oyster shells, the wastes are highly biodegradable and can serve as food for local marine and bird life. Further, the wastewaters are usually discharged into water bodies which are able to assimilate the wastes.

Chapter 2 offers an explanation of the parameters used in assessing the potential of wastewater to degrade the waters into which it is discharged. This chapter also describes typical plant operations and wastewater characteristics for selected types of seafood processors. Figures showing the basic steps in seafood processing, once again for selected processors, are to be found in chapter 3. The processing stages which result in solid wastes are clearly marked. Chapter 3 also includes descriptions of the characteristics of solid wastes for major seafood processing categories.

Chapter 4 contains the discussion of the major solid waste recycling options. Seafood wastes are of interest, and are potentially very valuable, due primarily to their high protein content. In addition to the protein, seafood wastes contain a range of nutrients, and the shells - from crabs, shrimp, clams, and oysters - a variety of chemicals. Recycling options include the manufacture of food products designed for human consumption, the production of animal feed additives, fertilizers, and a number of specialized chemicals. The traditional solution to recycling seafood wastes is the production of fish meal, an animal feed additive. This solution is not recommended for small processors for two reasons: the resulting meals are generally of poor quality, and the production process results in effluents with extremely high concentrations of pollutants. Of the other recycling options, the one most generally suggested for small processors is the production of fish silage, also an animal feed additive. The recycling option that offers the most promise for waste reduction is the production of minced fish-based foods.

Brief explanations of the basic wastewater treatment methods appropriate to seafood processors, as well as a table showing effluent limitations suggested by the World Bank and the United States Environmental Protection Agency for major seafood processing categories, are presented in chapter 5. Biological treatment methods - except for ponds, lagoons, and extended aeration - can only be used by processors which have a constant, continual effluent flow. Anaerobic systems cannot be used where salt water forms part of the wastewater stream. Chapter 5 also includes a discussion of wastewater recycling options. These options are, in general, still at the experimental stage.

Chapter 6 provides limited information on production costs, selling prices, and profitability for the major products which can be manufactured from seafood processing wastes. The only two products for which detailed production cost data are available in the literature are crab meal, an animal feed supplement, and chitosan, a chemical used in treatment of wastewater. What information is available on wastewater treatment costs is given in chapter 7. Unfortunately no cost data based on actual experience in wastewater treatment are available. Instead, formulas and tables which can be used to estimate costs are provided.

Health and safety problems in seafood processing plants are briefly reviewed in chapter 8. The most common health problems are dermatological. In canning plants, high noise levels, excessive heat, and humidity can cause problems. In all processing plants the highest levels of sanitation must be maintained in order to protect the quality of the products. Study conclusions are recommendations are to be found in chapter 9.

The study outlined above will serve as a background document to the Consultation on the Fisheries Industry, Gdansk, Poland, 1987. This is the third in a series of environmental research studies prepared by UNIDO's Studies and Research Division for the food products industries. Two previous studies of agro-industries were completed in 1976.

1. GENERAL ENVIRONMENTAL CHARACTERIZATION OF THE FISH AND SHELLFISH PROCESSING INDUSTRY

Worldwide the seafood processing industry generates an enormous amount of waste. This waste has a tremendous potential to help solve the problems of hunger and poor nourishment which face most of the developing world. Under present conditions this potential cannot be realized. The potential cannot be realized due to market structure and economics. The technology to convert the tremendous amounts of waste available into human food is available. However, even the simpler technologies which can convert these wastes to animal food are largely impracticable. They are impractical as a consequence of two characteristics of the vast majority of seafood processing plants: their small sizes and their remote locations. The end result is that a very large proportion of the waste produced at seafood processing plants is dumped. Although this is a tragedy from the point of view of world hunger problems, from an environmental viewpoint the dumping of these wastes does not usually cause difficulties of major consequence. The dumping of seafood wastes is not usually a serious environmental problem because the wastes are not toxic, are highly biodegradable, and are generally dumped into water bodies which have an adequate capacity for assimilating them.

In 1950 the total world harvest of fish and shellfish was about 20 million metric tons.[1/] Between 1950 and 1975 the world harvest of fish and shellfish more than tripled. In the mid to late seventies the world harvest stabilized at some 70 million tons.[2/3/] In at least some parts of the developing world the rate of increase in fish harvests was even greater than the worldwide average. In Thailand for example, the fish harvest increased ninefold between 1960 and 1972.[4/] In the ASEAN region as a whole the fish harvest increased almost sixfold between 1950 and 1975.[5/]

The rapid increases in harvest sizes have led to some concern that world fishery resources could be endangered. Although there is no concensus among scientists, it is perhaps the majority view that a completely laissez-faire

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1/ United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guidelines, VIII. Fish Processing Industry, Bangkok, 1982, p. 1.

2/ Ibid., p. 1.

3/ Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, p. 281.

4/ United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guidelines, VIII. Fish Processing Industry, Bangkok, 1982, p. 1.

5/ Ibid., p. 1.

approach can lead to "overfishing". Overfishing of a species can be said to have occurred when the size of the catches and/or the size of the individual fish caught ar so small as to be uneconomical.

Fish populations worldwide are under stress not only from intensified fishing operations. They are also under stress due to the multiple demands made on the water resource for power generation, irrigation, and waste disposal. The habitat of fish is affected, almost always negatively, by the presence of waste discharges and by the changes in flow brought about by irrigation projects and power generation plants. The negative impacts on their habitat result in reduced ability of the fish to reproduce and survive. The reduced ability of the fish to survive compounds the dangers of increased global harvesting activity. Under the combined pressures of overfishing and impaired habitat, some fish species may be driven beyond their ability to sustain populations. The fish most likely to be driven to extinction are the most economically valuable ones. Consequently, the viability of a country's seafood industry may depend on national and international efforts to protect the fishery resource from undesirable harvesting and waste disposal practices.

There are unfortunately no figures available on how much of the 70 million or more tons of fish harvested annually is wasted. That the amount wasted is very large, however, can be deduced from several facts. In the first place a certain percentage of the fish caught is actually by-catch, or trash fish. That is, in the process of fishing for the desirable fish species, varying amounts of fish are captured that cannot be, or are not, processed into food for humans. The ratio of desired to trash fish varies widely depending both on the fishing techniques used and the species sought. Just to give one example, in Indonesia the ratio of shrimp to trash fish ranges from about 1:5 during the peak of the shrimp season to as low as 1:20 during the off season.[6/] Most by-catch is not landed but rather is simply dumped at sea.

A second source of wastage is spoilage. This problem is particularly acute in developing countries. Since fish spoil easily, it is necessary to keep them iced if the weather is warm. Since much of the developing world lies in the tropics and since many of the fishing boats in these countries have little or no refrigeration equipment, fish spoil between the time they are caught and the time they can be delivered to processing plants. Spoilage also occurs after the fish arrive at processing plants. Processing plants in developing countries suffer from limited refrigeration capacities. If a catch is particularly large it can easily exceed the plant's capacity to either process or store the fish quickly enough to prevent spoilage.

The last source of the large amount of waste generated in the seafood processing industry is the processing itself. Wastage rates during processing vary tremendously depending on techniques and species. The rates run from almost zero in the case of a large integrated tuna processing plant to almost 90 percent of the weight of the catch in the case of clams. Crabs and shrimp

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[6/] Kompiang, I. Putu, "Utilization of Trash Fish and Fish Wastes in Indonesia (as Animal Feeds)", in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, p. 131.

have wastage rates running up to around 85 percent. The processing of marine finfish sustains wastage rates of 55-75 percent.[7] While there are no worldwide figures, it has been estimated that some two thirds of the fish landed in the United Kingdom is not processed into food for humans.[8] In a developed country like the United Kingdom, a high proportion of this "waste" is actually processed into fish meal, a product used primarily as an additive in animal feeds. In the developing world, due both to the higher spoilage rates, and to the inability to process wastes into fish meal, the real wastage rate, i.e. the proportion of the catch that must simply be dumped, is certainly much higher.

The wastes generated by the seafood processing industry can be divided into two main categories, wastes from shellfish and wastes from finfish, particularly marine finfish. It is the wastes from marine finfish that have the potential to alleviate problems of human malnutrition. This is because the wastes have nearly as much protein as the part processed into food. On a dry basis, fish contain 60-90 percent protein. This protein is particularly valuable because the amino acids present are very similar to the amino acids in mammalian flesh. All the amino acids essential to human nutrition are present.

In the short term, the only process that offers a viable means to increase the percentage of the fish that can be turned into human food is the use of meat-bone separators. Essentially, in this process various mechanical devices are used to squeeze or tear off scraps of meat that ordinary processing leaves attached to bones or shells. However, even with these devices, large amounts of waste remain, from trash fish and from bones, heads, viscera and other fish parts not fit for human consumption. Production of fish meal is the traditional way in which an attempt is made to capture the protein and other nutrients available in this waste.

Fish meal consists of whole fish and waste parts of fish which have been cooked, dried and ground. In developed countries fish meal is produced in large plants which can afford sophisticated equipment. In developing countries, and in many cases in developed countries as well, most seafood processing plants are too small and too far removed from one another to support a large, sophisticated fish meal processing plant. As a result, if attempts are made to produce fish meal, it is often of poor quality. In order to solve this problem, it has been suggested that small, remote seafood processors manufacture fish silage instead of fish meal. Fish silage is made from the same ingredients as fish meal and used for the same purpose, i.e. as an ingredient in animal feeds. Instead of being cooked, dried and ground, the materials are simply chopped and mixed with water. Acids are added and the

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7/ Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-283.

8/ Keay, J. N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", In Advances in Fish Science and Technology, Aberdeen, UK, 1980, p. 275.

mixture allowed to sit until the fish solids have dissolved. No sophisticated equipment is needed and a batch of fish silage can be made virtually with any amount of waste that is available, whenever desired. Silage stores well even in warm climates and has consequently been considered an ideal solution to seafood waste utilization in developing countries.

Both fish silage and fish meal are used primarily in the feeding of non-ruminants. Fish silage in particular has been found to be useful in the feeding of swine. If a seafood processor is located in the vicinity of a swine production industry, the seafood processor, the swine producers, and even the country in which this lucky conjunction occurs may profit. St. Helena, a small island in the middle of the Atlantic, has reaped the benefits of having a seafood processor close to hog rearing operations. Prior to the production of fish silage by the seafood processors St. Helena's pig rearing industry was importing fish meal. Fish silage generally sells for about one fifth the price of fish meal.[9/] Thus, with the production of fish silage the pig rearing industry benefitted by having a cheaper source of food. The seafood processor benefitted by not having to pay to treat or dump its wastes, and St. Helena as a whole benefitted by being able to reduce its foreign payments.

In spite of the promise of fish silage, in practice it is far from providing a panacea to the waste disposal problems of small, remote seafood processors. Fish silage is bulky and heavy to transport. In a study done for seafood processors in Akutan, Alaska, it was estimated that fish silage could only be economically transported a distance of about 400 kilometers. Within that distance there was no market for the silage.[10/] While conditions in Alaska are atypical in many respects, the problem of distance to markets, or simple lack of markets, faces seafood processors the world over.

The cases of St. Helena and Akutan encapsulate the basic realities of seafood waste utilization. On the one hand they demonstrate that it is possible to utilize these wastes, even in developing countries, and even when the processors are small and located in seemingly remote areas. On the other hand, they show that, in industrial nations as well as in developing nations, the solutions to the waste disposal problems of small, remote seafood processors depend on local circumstances. Solutions must fit the conditions imposed by geography and climate, and by available industries and markets. There are no general solutions to the problem of waste utilization in the seafood processing industry. Rather there are a variety of possibilities which, with imagination and knowledge of local circumstances, can be exploited to benefit all concerned.

The same two characteristics, small size and remote location, which preclude a general solution to waste utilization, also have significant repercussions on waste treatment and disposal. Most seafood processors are

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[9/] United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, Washington, 1984. EPA 910/9-83-114, p. 7.

[10/] Ibid., p. 7.

not only small, they are also seasonal operations. Many plants operate only a few weeks or a few months of the year. Such plants simply cannot afford most conventional waste treatment systems. Even such a simple treatment procedure as the screening of wastewater prior to its discharge can prove to be impractical.

In 1980 seafood processors operating in five towns in Alaska requested that they be allowed to discharge wastewaters without screening. Their grounds were that "the costs of screening are wholly out of proportion to the effluent reduction benefits achieved".[11/] The processors pointed out that screening involved much more than buying, installing, and operating the screens. In the vicinity of the seafood plants there were no sites where the screened out solids could be disposed of in landfills. Thus the solids would have to be barged to sea. This solution entailed considerable costs: costs for enlarging docks, costs for buying barges, costs for fuel for towing the barges, and costs to buy boats to tow the barges. The processors then went on to point out that the large expenditures required would, in effect, achieve nothing. The solids would end up in the receiving water in any case, just as they would if no screening were undertaken.

These problems of the Alaskan seafood processors, far from being unique, are common to remote seafood processors everywhere. A small seafood processor is not in a position to operate its own landfill disposal site even if land is available. Very few seafood processors are so fortunate as to be located close enough to a municipal landfill to be able to afford to truck wastes to it. Even if there is a nearby municipal landfill it almost certainly will not be geared to the needs of seafood processors. Seafood wastes, when disposed of on land, spoil extremely quickly. If they are not covered within a few hours they become sources of obnoxious odors and attract vermin, insects, and other pests. Few of the small towns near which seafood processors tend to be located are in a financial position to cover wastes frequently enough to avoid these problems.

The "hidden" costs of screening uncovered by the Alaskan processors, i.e. the costs of barging where neither recycling nor land disposal of wastes are feasible, will also be common to other seafood processors. Even processors located in the tropics, which might think they have little in common with Alaskan woes, will generally face the same obstacles. The Alaskan processors faced costs for dock enlargement because the existing docks were "minimal". That is, the docks were only wide enough to accomodate the needs for landing the catches. This can be the case anywhere. More important, during the height of the season, precisely when they would be most needed to tow wastes, all available boats were occupied in bringing in the catch. Even if a fishing boat were willing to undertake the task of towing wastes, it might not have sufficient power. This problem is extremely likely to face seafood processors in developing countries. In developing countries the boats used for fishing are even smaller and less powerful than Alaskan fishing boats. The most critical problem with barging of wastes, however, is the fuel required. Fuel

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11/ United States Federal Register, Vol. 45, No. 154, Thursday, 7 August 1980, pp. 52411-52416.

is at a premium in Alaska. Fuel is similarly frequently at a premium in remote locations in developing countries. It is not only expensive but also, during the fishing season, what fuel is available is needed for the fishing boats. To use fuel for the transportation of wastes must be considered an unjustified extravagance in all but unusual circumstances.

As mentioned in the foregoing discussion, most seafood processors are too small to be able to take advantage of the traditional solution to seafood wastes, the production of fish meal. Many processors are too remote to take advantage of the potential of fish silage. Due to the remoteness of many plants, the nature of seafood wastes, and the expenses involved, neither land disposal nor barging out to sea is likely to offer a practical solution to waste disposal. Thus most small processors must simply discharge their wastes, often with no treatment, into the nearest water body. Fortunately the very characteristic of seafood wastes, their biodegradability, which makes them poor candidates for landfills, makes them easy to dispose of in water bodies. Unless conditions are unfavorable, grinding and a properly designed outfall are sufficient to prevent serious environmental problems.

Most seafood processors are located along the coast. In many coastal areas even relatively large amounts of seafood waste can be discharged without having serious negative impacts on the water into which they are dumped. The three most important factors in determining whether or not a discharge will negatively affect a water body are the degree of dilution, the rate of dispersion, and the nature of the water body itself.

As long as the amount of wastewater is relatively small in relation to the volume of water into which it is discharged, dilution alone will mitigate negative impacts. However, in areas where the movement of water is slow, as is frequently the case in bays and as also occurs at the mouths of some rivers, any solids suspended in the wastewater stream will settle out. If particles of solids settle out in a restricted region, bottom dwelling species can be smothered and breeding and spawning areas destroyed. As a consequence a facility located adjacent to waters with little or no flushing action may find that harmful accumulations of wastes are being built up although the discharge volumes would cause no problem at sites more favorably located.

Water bodies with strong tides or currents can usually assimilate large amounts of seafood wastes. Problems may however occur at any low points in the ocean bed. Solids suspended in the wastewater stream will be carried by the tides or currents away from the discharge point. However, where the current or the flushing action of the tides subsides, particles will settle out. Since particles will tend to accumulate at low points, ocean-floor depressions can suffer the same negative impacts mentioned for areas with slow moving waters.

The condition or characteristics of the water body in which wastes are dumped must also be considered. As a general rule, water bodies which contain high levels of dissolved oxygen and low levels of nutrients are better able to absorb wastes than other water bodies. However, in coastal areas there is a major exception to this rule. The exception is where the receiving waters are flushing tidal marshes. In these circumstances, the nutrient load entering the water from the marshes is frequently so heavy that the wastes from a seafood processor have no noticeable effect on water quality. In a study done on the east coast of the United States, for instance, it was estimated that the waste contributed by a small seafood processor was the equivalent of the load contributed by a 300 square meter section of the marsh.[12]

As implied in the above discussion, as long as seafood processing wastes do not settle out and smother the bottom dwelling organisms, their potential for creating environmental problems is negligible. The main reason for this is that, with the exception of shells, most of the wastes serve as food for a variety of fish species and birds. That is, unlike most municipal wastes, seafood processors' wastes do not first have to be broken down by bacteria, then utilized by plants or protozoa, and then gradually worked up through successive links in the food chain. Seafood processing wastes can, to a large extent, be eaten directly by the fish and birds indigenous to a region. The significance of this can be seen in the fact that at almost every fish processing plant discharge point the waters are teeming with fish.

The abundance of fish in the vicinities of seafood processor discharges has led some investigators to maintain that, far from being an environmental problem, seafood processing discharges are actually good for the environment. This idea has been termed "bioenhancement". Although scientists agree that seafood wastes can cause increases in fish populations, they are not in agreement that these increases are beneficial. In the first place the species that most clearly benefit from the discharges are the so-called scavenger species. These species tend to be tolerant of polluted conditions. Secondly, increases in the population of a given species can lead to increases in diseases among fish. It is the opinion of the U.S. Environmental Protection Agency that at the present time knowledge about "bioenhancement" is insufficient.[13] As a consequence, the abundance of certain fish species should not be used as a sign that waste discharges are not having detrimental environmental impacts.

Bioenhancement does serve to emphasize an important aspect of the evaluation of impacts of seafood processing wastes. Seafood processing wastes cannot be simply equated to municipal wastes. Although one uses the same parameters to analyze the nature of seafood wastes as are used for municipal and other wastes, one should not be misled by this apparent similarity. The implications of a seafood processor's wastewater having a certain character according to the standard parameters may be significantly different from the implications of municipal wastewater with a similar character. The true

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[12] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Assessment of Seafood Processing and Packing Plant Discharges and Their Impacts on Georgia's Estuaries, Rockville, MD, 1982, NOAA-82073007, p. 23.

[13] United States Environmental Protection Agency, Section 74 Seafood Processing Study, Executive Summary, EPA, Washington, D.C., 1980, 440/1-80/020, p. 6.

impact of a wastewater stream can only be determined by investigations of the condition of the water body into which the wastewater stream has been discharged.

The condition of a water body into which wastes have been discharged is generally studied by looking to see what species are present and what their relative frequency and abundance is. Very often specific bottom dwelling organisms, referred to as indicator organisms, are used for this purpose. In a healthy water body, for example, an indicator organism may constitute only 7 percent of the population. When the same water body becomes polluted the indicator organism may constitute 90 percent of the bottom dwelling population.[14] Thus, when the species found in the vicinity of a discharge are either different from, or are found in different relative frequencies than in places more removed from the discharge point, it is likely that a wastewater discharge is having a negative environmental impact.

In sum, the amount of waste generated by the seafood processing industry is very large. Most seafood processors are too small and too remote to take advantage of standard recycling technologies. Furthermore even simple wastewater treatment systems are often impractical. Since neither land disposal nor barging out to sea is likely to be cost effective, most of the waste is simply returned, untreated, to the sea adjacent to the plant. Fortunately this can usually be done without serious negative environmental consequences. The most serious environmental impacts of water disposal of untreated wastes are likely to be aesthetic. If solids are not ground sufficiently prior to discharge, they float, smell, and are visually objectionable. In contrast, land disposal can create serious problems. If seafood wastes are not covered quickly and adequately they attract and act as breeding grounds for vermin and insects. Land disposal can thus easily create a human health hazard.

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[14] Ibid., p. 34.

2. CRITICAL WASTEWATER PARAMETERS AND CHARACTERISTICS IN SEAFOOD PROCESSING

2.1 Critical wastewater parameters in seafood processing

A great deal of water is used in the processing of both finfish and shellfish. Water is used to store fish upon arrival at a processing plant; to move the fish from place to place within the plant; to transport waste materials such as fins, shells, heads, and bones away from working areas; to clean the fish; in cooking and canning operations; and to clean equipment, working surfaces, and floors. Most of this water, which contains various materials that have entered the water stream, becomes wastewater. In most of the developing world, and in many cases in developed countries as well, this wastewater is discharged with little or no treatment into nearby water bodies. The materials which have become mixed with the water are considered pollutants because they usually have negative effects on the water bodies into which the wastewater is discharged. The negative impact, actually the potential of a wastewater stream to have a negative impact, is assessed by measuring certain parameters of the wastewater stream. The parameters of primary concern in the case of seafood processing are the amount of wastewater, its biological oxygen demand (synonymous with biochemical oxygen demand), the suspended solids it contains, and the amounts of oils and grease present. Occasionally bacteria (particularly coliform), temperature and nitrogen require attention. The significance of each of these parameters is discussed in the paragraphs which follow.

2.1.1 Volume

The volume of wastewater is a matter of concern under three conditions: 1) when it is large relative to the volume of the water body into which it is discharged; 2) when the volume of wastewater influences the amount of pollutants present in the wastewater stream; 3) when wastewater treatment becomes necessary.

If the body of water into which the wastewater is discharged (referred to as the receiving water) is small in relation to the wastewater stream, the wastewater stream can significantly alter basic receiving water characteristics. The most frequent example of this is the discharge of salt water into fresh water systems, or the reverse. This is not presently a widespread problem in the seafood processing industry. However, with the growth of inland fish farming the possibility for this kind of disturbance in receiving waters must be kept in mind.

In the seafood processing industry the volume of water used is directly correlated to the pollutant levels of the wastewater. That is, the more water used in processing, the more materials enter the wastewater stream. This is a direct result of the highly soluble nature of the raw materials, i.e. the fish. Whenever fish or fish parts are in contact with water, substances such as blood, oil, and proteins are taken up into the water stream. Thus a processing plant which, for example, uses water to transport fish or fish parts from one part of the plant to another will have higher pollutant levels in its wastewater stream than a comparable plant which uses dry handling techniques for transportation. This fact is significant whenever it is desirable to reduce pollutant levels in receiving waters. If wastewater treatment needs to be instituted, the correlation between volume and pollutant load can be of considerable importance.

If wastewater needs to be treated, the higher the volume of flow the higher the costs. Wastewater treatment systems are designed to handle specific volumes of water, and even in the case of such simple systems as grinding and screening, higher volumes mean higher costs. Both initial capital investment and ongoing operating costs increase with increasing volume. Since in the fish processing industry, increased volumes are also associated with increased pollutant loads, a decrease in wastewater volume has a two-fold effect. When wastewater volumes are lowered, the design capacity of the treatment system can be reduced. Simultaneously, the pollutant load that the treatment system will have to cope with will automatically decrease. This means that in the seafood processing industry a plant which reduces the amount of water it uses may be able to realize water treatment savings in two ways. The design capacity of the treatment system can be reduced and it may well be possible to use a less sophisticated type of treatment system. Since the amount of pollutants in the wastewater stream will be reduced, it may even be possible to achieve desired receiving water quality with no treatment system at all.

2.1.2 Biological oxygen demand

The materials which enter the water stream in a seafood processing plant are almost exclusively organic. Organic materials in a water body are normally decomposed or stabilized by a variety of microorganisms which live in the water body. The microorganisms utilize the organic materials to grow and reproduce. In doing this they use oxygen and give off carbon dioxide. The more organic material present in a water body, the faster the microorganisms grow and reproduce, and the faster they use up the available oxygen.

The amount of oxygen that is available in a water body depends on a number of factors. Green plants in the water release oxygen during their growth cycle. Oxygen from the air can enter the water when conditions are turbulent, as when a stream runs over a fall. The colder the water is the more oxygen it can hold dissolved within it. The oxygen that a water body contains does not only serve the microorganisms that decompose organic materials. This oxygen is also needed by the tiny organisms which feed on the microorganisms, and by all the animals further up the food chain including whatever fish species are present. If, due to the introduction of additional organic materials, the microorganisms start to use up oxygen faster than it is being introduced into the water body, the levels of available oxygen start to fall. When the oxygen levels fall fish and other aquatic organisms are stressed. If levels fall far enough the fish start to die. It is for this reason that organic materials in wastewater streams are considered pollutants. They can lead, through the increased activity of microorganisms, to the oxygen in a water body becoming depleted. Without oxygen, fish and other desirable organisms die. Figure 2.1 shows this process in schematic form.

As shown in figure 2.1, when an organic load is introduced into a water body oxygen levels start to fall. Microorganisms on the other hand begin to increase. Initially this increase is followed by an increase in protozoa and fish, the life forms which feed on the microorganisms. However, as oxygen levels continue to fall the numbers of fish and protozoa fall. When oxygen is depleted only microorganisms that can live without oxygen survive. These microorganisms, facultative bacteria, can live both in the presence and in the absence of oxygen. When oxygen is not available in a free form the facultative bacteria strip off oxygen that is present in association with nitrogen or sulfur. As the oxygen is stripped off hydrogen sulfide and nitrogen gases are released. It is the release of these gases that results in the undesirable odors associated with badly polluted water bodies. Under these conditions, where the oxygen supply has been depleted and noxious gases are being released, the water body is considered septic, as indicated in figure 2.1. As also shown in figure 2.1, if no additional organic load is introduced, the water body will, in time, recover. Once the organic materials have been sufficiently decomposed so that the activity level of microorganisms falls, oxygen levels rise. When oxygen levels rise high enough protozoa and fish return.

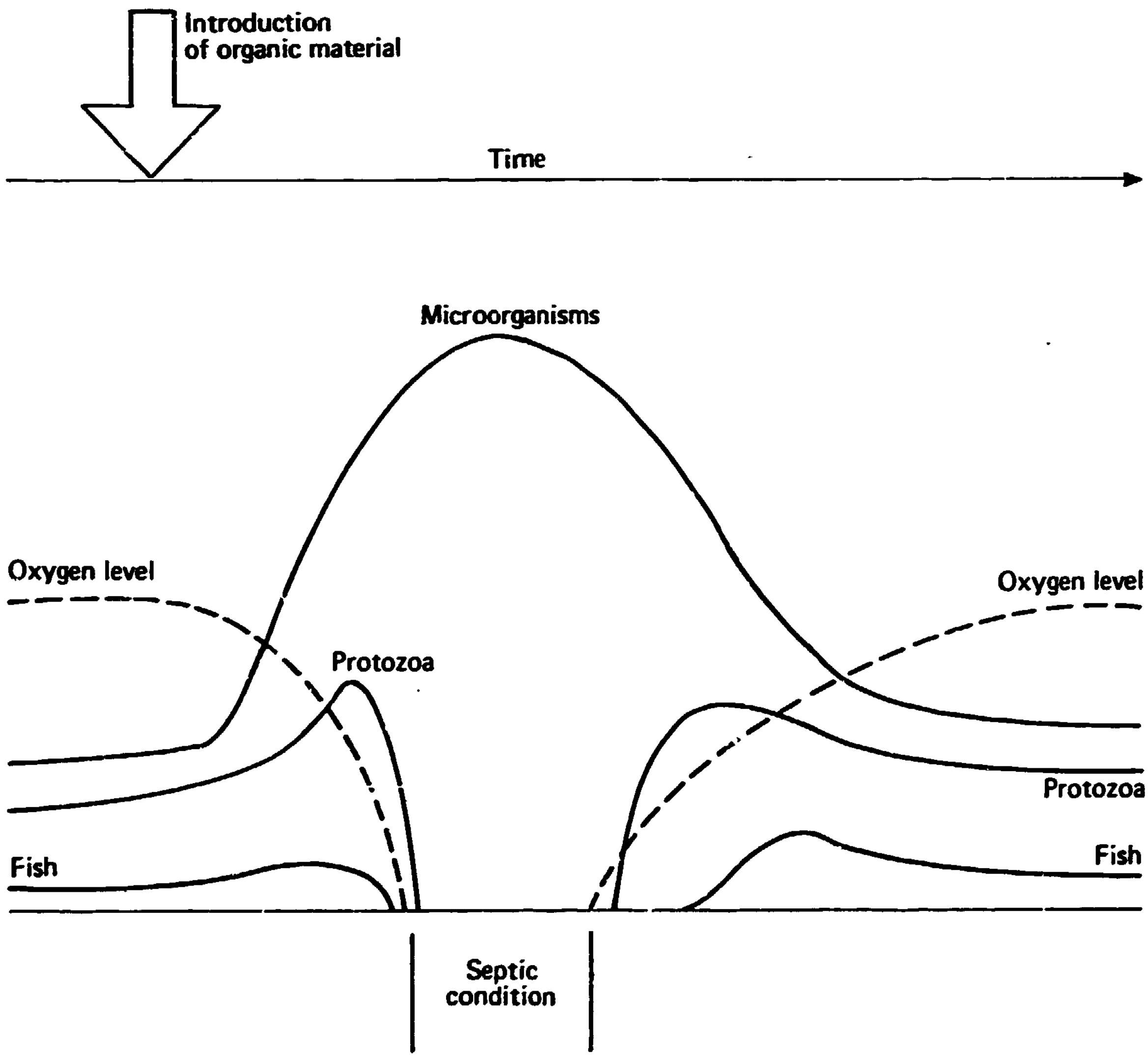
As discussed above, the introduction of an organic load into a water body can lead to stress on, or even death of, desirable aquatic species. If the load is large enough the water body can become septic. In this context, how large an organic load is is a question of the amount of oxygen that will be needed in order to decompose or stabilize the organic material. For this reason attempts are made to determine how much oxygen is required to decompose the organic matter in a wastewater stream. The amount of oxygen required is referred to as the wastewater's oxygen demand. In order to completely stabilize an organic load in water, the wastewater would have to be kept at 20°C for over 100 days. For test purposes it is impracticable to wait this long to find out how much oxygen is required. As a consequence the most commonly used test is run for five days. The amount of oxygen used by the organic load over this period is called the five day biochemical oxygen demand, BOD_5. The results of a BOD_5 test are expressed as milligrams of dissolved oxygen consumed per liter of wastewater. In order to be able to compare the relative strengths of wastewaters, variables such as the temperature and pH of the water during the BOD_5 test have been standardized.

2.1.3 Suspended solids

Suspended solids are all those particles in a wastewater stream that can be removed by standard filtration procedures. Suspended solids may float to the surface, remain suspended in the water, or eventually settle out to the bottom. Suspended solids which float to the surface can form a blanket of scum. These blankets are objectionable on aesthetic grounds. In addition a scum blanket reduces the amount of oxygen that can enter the water from the air. Surface scum also reduces the amount of light which can penetrate the water. This reduction in sunlight hinders the photosynthetic process and the growth of green plants, further reducing the amount of oxygen available in a water body. Finally, if a scum blanket is thick enough it provides a breeding ground for flies and other insects, thus constituting a public health hazard.

Suspended solids which remain suspended (their specific gravity being nearly the same as water) are objectionable primarily because they reduce the distance that sunlight can penetrate into the water. As with surface scum, this has a negative effect on plant life. Those suspended solids which are heavier than water will eventually settle out. They settle primarily where

Figure 2.1. Assimilation of organic materials in water



Source: Naomi Peña, UNIDO consultant.

water movement is slow. If the accumulation of such solids in a given area is thick enough, fish breeding areas can be destroyed and bottom dwelling organisms smothered. These bottom dwelling organisms are important both in the process of breaking down organic materials and as links in the food chain. If bottom dwelling organisms are destroyed, the result is generally a deterioration in the abundance and diversity of species at higher levels in the food chain. If the amount of organic solids which settles in a given area is great enough, it can also lead to a depletion of oxygen, and the resulting emission of unpleasant gases.

2.1.4 Oils and grease

The processing of some fish species generates large quantities of oil. If this oil is not recovered, its discharge into receiving waters can cause a variety of problems. Since oils and greases generally float they are objectionable on aesthetic grounds. Even a very thin film of oil can be seen quite easily. Grease, both alone and in conjunction with suspended solids, can form a surface scum. Films of oil and grease patches can harm birds which come into contact with them. Recreational beaches which lie in the path of oil or grease discharges can be rendered unfit for use. Similarly, shoreline property, particularly residential property, loses both amenity and use values when contaminated with oil or grease residues.

2.1.5 Bacteria

Bacteria are normally of concern only if wastewater is discharged into waters from which shellfish are harvested. The consumption of shellfish which have been contaminated with bacteria, particularly bacteria of the kinds found in the human intestinal system, can cause a number of intestinal and viral infections.[15] In a study done in the United States, the wastewater from conventional fish, crab, clam and oyster processors was tested for the presence of coliform, the bacteria typical of the human digestive tract. In all cases the number of coliform present in the wastewater exceeded the limits considered safe for discharges into shellfish harvesting waters.[16] This finding was particularly disturbing because in all cases the plants had taken precautions to prevent human wastes from entering the processing wastewater stream. In addition all the plants disinfected their wastewater. Coliform counts exceeded safe limits in spite of this disinfection and in spite of the fact that relatively large amounts of chlorine were being used. Any seafood processor which is discharging wastewater into shellfish harvesting waters should be alerted to this problem.

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[15] World Health Organization, Coordinated Mediterranean Pollution Monitoring and Research Programme, First Report on Coastal Quality Monitoring of Recreational and Shellfish Areas (Med VII), Copenhagen, 1978, p. 5.

[16] United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157.

2.1.6 Temperature

Temperature is important because aquatic species are sensitive to temperature, and because of the relation between temperature and oxygen levels. Fish species can only survive within specific temperature ranges, some preferring cooler water and others warmer water. Temperature also affects the activity level of microorganisms. As mentioned in the discussion of biological oxygen demand (see section 2.1.2) the amount of dissolved oxygen that a water body can hold depends on its temperature. The colder the water the more oxygen it can hold. For this reason, water from the various cooking processes, particularly those used for sterilization in connection with canning, should be cooled if the receiving water body is not sufficiently large to absorb these wastewaters without a significant change in temperature. In general the temperature of the receiving water should not be elevated by more than about 3°C.[17/]

2.1.7 Nitrogen

Discharges of nitrogen are of concern because they are a nutrient for plants. If an excess of nitrogen is available plants grow and reproduce faster than is desirable. An overabundance of nutrients leads to undesirable masses of plants growing in a water body, often referred to as algal blooms. Algal blooms are undesirable both on aesthetic grounds and because they can contribute to oxygen depletion in a water body. When the algae die they fall to the bottom where they must be decomposed like other organic materials. As discussed in section 2.1.2, if algae growth is excessive, the decomposition process uses up oxygen that is needed for survival of fish and other aquatic organisms.

2.1.8 Combined effects

Each of the parameters discussed above has an impact, usually negative, on the waters into which a discharge is made. It is generally not possible to say a priori which impacts a receiving body can absorb without creating pollution problems. That is, it is not possible to know exactly how much wastewater at a given temperature can be assimilated without causing damage to fish or other organisms. Similarly one does not know how high a biochemical oxygen demand, what concentration of suspended solids, or how much nitrogen can be discharged, alone, or in combination, without cause for concern. Particularly in the case of seafood processing wastes discharged into ocean waters, it is unwise to base wastewater management decisions only on analyses of the characteristics of the wastewater. Conditions in the receiving water should also be investigated.

Deterioration in the quality of receiving waters manifests itself in the partial or total destruction of many types of organisms. Stress- or pollutant-tolerant organisms become more prevalent, and species diversity

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17/ Katsuyama, Allen M., ed., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979, p. 13.

diminishes. The system as a whole often becomes less capable of self-regulation and individual species fluctuate widely in relative abundance. These wide fluctuations result in economic costs to seafood processors. Variations in harvest sizes and species caught render planning, processing, and marketing difficult. Of greater significance however is the fact that the economically valuable species are generally the most sensitive to the presence of contaminants. Substantial reductions in receiving water quality due to suspended solids, reduced oxygen levels, changes in temperature, or the destruction of bottom dwelling organisms can quickly lead to reduced reproduction and maturation of such prized species as shrimp, salmon and trout.

2.2 Wastewater characteristics of principal types of seafood processors

Fish processing plants can be divided into four categories. These categories are differentiated by the types of fish handled. The four categories, together with lists of the main fish species handled in each category, are given below.

Marine finfish

Tuna
Sardines
Cod
Ocean perch (redfish)
Herring
Mackerel
Giant johnfish
Giant grouper
Menhaden

Marine shellfish

Crabs
Shrimp
Clams
Oysters
Lobster

Freshwater fish

Catfish
Salmon
Perch
Smelt
Trout

Fish meal

Waste parts from marine finfish
By-catch fish

Some plants are set up so that they can operate as either marine finfish or marine shellfish processors.

Simplified, the seafood processing operation consists of five operations: pre-processing, precooking, separation of edible meat, inspection, and packaging. Pre-processing may consist of washing of dredged crabs, thawing of frozen fish, or beheading of shrimp. Precooking or blanching is practiced to facilitate the removal of skin, bones, shells, gills or other inedible parts. The separation of the meat from the inedibie parts is accomplished by butchering in the case of finfish and by shucking in the case of shellfish. This separation can be done manually, mechanically, or by some combination of manual and mechanical steps. After the edible meat has been separated out it is subject to an inspection process. Remaining inedible or undesirable parts are removed and meat in an unacceptable condition discarded. Unless the product is destined for the fresh fish market, packaging will involve freezing, canning and/or pasteurization. More detailed descriptions of the operations involved in the principal types of seafood processing plants, together with information on wastewater characteristics, are given in the following paragraphs.

2.2.1 Marine finfish

Plant operation, sources and characteristics of wastewater

Upon arrival at a processing plant marine finfish are placed in holding bins where they are packed with ice to prevent deterioration. In some cases evisceration - the removal of the intestines and other inner organs - has been done on the boats. If not, or if it is necessary to remove the scales, these will constitute the first procedures undertaken at the plant. In most cases the fish will be transported from the bins to the tables where the first processing operations take place by means of flumes - chutes through which a stream of water flows. If the fish are not to be sold fresh they may be precooked or blanched. In any case, whether it is directly from the holding bins or after an intervening step or two, the fish will be transported by flume to the filleting tables. Here fillets are cut from both sides of the fish. All parts of the fish other than the fillets are called offal and are waste products as far as the marine finfish processor is concerned. The offal, which constitutes some 70 percent of the weight of the fish, is washed off the working tables and into flumes.[18/] The flumes carry the offal into receiving bins from where it will either be discarded or recovered for fish meal or fish silage. The fillets themselves, except for those species which do not need to have their skins removed, are transported by flumes to skinning machines. From the skinning machines the fillets are flumed onward to inspection tables. Here remaining bones or defective meat are removed. If the fillets are to be sold fresh they are then dipped into a brine or phosphate solution. If they are to be frozen they may either be frozen as individual fillets or in large blocks.

[18/] United Nations Economic and Social Commisison for Asia and the Pacific, Industrial Pollution Control Guidelines, VIII. Fish Processing Industry, Bangkok, 1982, p. 3.

Large amounts of water are used in a typical marine finfish processing plant. Some 50-65 percent of the water used is accounted for by the various flumes. Washing of the fish, including the washing necessary to remove the innards and skins, and to separate the fillets from the bones, accounts for some 15-25 percent of water usage.[19] Estimates of the amount of water that a typical fish processor uses per ton of final product vary tremendously. Water usage seems to depend more on the amount of water available than on the amount of water needed for any particular operation.[20] Although the figure for wastewater given in table 2.1 is 5,240 liters per ton of product for a conventional marine finfish plant, some plants use as much as 204,000 liters per ton of product.[21]

Table 2.1. Marine finfish plant, wastewater characteristics

Parameter	Conventional plant	Mechanized plant
Wastewater	5,240 L/MT	13,500 L/MT
BOD_5	3.32 kg/MT	11.9 kg/MT
SS	1.42 kg/MT	8.92 kg/MT
Oils and grease	0.348 kg/MT	2.48 kg/MT

L = liter
MT = metric ton
kg = kilogram

BOD_5 = five day biochemical oxygen demand
SS = suspended solids

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

Both salt and fresh water are used in marine finfish processing. Salt water is usually used in the flumes running from the holding bins to the tables where evisceration and filleting operations are carried out. Salt water is also used in the flumes used to carry offal from the work tables to the receiving bins. Fresh water is used to transport the fillets to the skinning machines, in the skinning machines, and in cooking operations. A list of the various sources of wastewater in a finfish processing plant is given below. Immediately following the list is a table presenting wastewater characteristics for a typical marine finfish plant. All characteristics in this and succeeding tables are given per ton of product.

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[19] Ibid., p. 9.

[20] Ibid., p. 7.

[21] Ibid., p. 9.

Marine finfish plant, sources of wastewater

(a) Holding bins for receiving fish
(b) Flumes
(c) Washing of fish, including removal of scales
(d) Precooking
(e) Skinning machines
(f) Washdown at evisceration, filleting and inspection stations
(g) Brine or phosphate dip
(h) Cooking and canning
(i) General clean up including washing of floors

Tuna, plant operation, sources and characteristics of wastewater

In contrast to the majority of seafood operations, tuna plants tend to be large and in operation year round. As a consequence they are in a position to afford sophisticated equipment, both for processing and for wastewater treatment. Almost all of the waste products in a tuna operation, in direct contrast to other seafood plants, are recovered and turned into by-products. Meat that is unsuitable for human consumption is made into pet food. Parts that are unsuitable for either of these uses are recovered in fish meal and oil production operations. Thus a large tuna processor is, in effect, a marine finfish and fish meal plant combined.

Tuna are normally frozen aboard the fishing boats and thawed after arrival at the processing plant. They are butchered, precooked, cooled and cleaned prior to being canned. Wastewater in a tuna plant comes both from the primary operations leading up to the canning of tuna meat for human consumption and pet food, and from the secondary operations involved in the processing of wastes into fish meal, oil and fish solubles. Sources of wastewater from both primary and secondary operations are listed below. Tuna plants normally recover the water from the precooking operation. This water is then used for the production of fish solubles. In addition, the water in which waste parts have been accumulated and transported is recovered. It too is utilized in the production of fish solubles. The recovery of these two wastewater streams vastly reduces the organic load of wastewater discharges from integrated tuna/fish meal plants. Table 2.2 shows wastewater characteristics from a tuna processing plant. A general description of the processes involved in the recovery of wastes for the production of fish meal, fish oil and fish solubles can be found in section 2.2.4.

Tuna processing plant, sources of wastewater

Primary operations

(a) Thawing
(b) Precooking
(c) Cooling
(d) Butchering
(e) Cleaning and sorting
(f) Canning
(g) Retorting (steam heating at over 100°C)

Secondary operations

(a) Odor control apparatus
(b) Evaporation procedures

Table 2.2. Tuna processing plant, wastewater characteristics

Parameter	Range	Typical value
Wastewater	5,590 - 45,100 L/MT	22,300 L/MT
BOD_5	6.8 - 20 kg/MT	15 kg/MT
SS	3.8 - 17 kg/MT	11 kg/MT
Oils and grease	1.7 - 13 kg/MT	5.6 kg/MT
Organic nitrogen	0.75 - 3 kg/MT	- - -
Ammonia nitrogen	0.052 - 0.42 kg/MT	- - -

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

Sardines, plant operation, sources and characteristics of wastewater

Sardines are transferred by water either to storage tanks or directly to the packing tables. The head and tails are usually removed by hand. They are then packed in cans and precooked to remove undesirable oils. Oils or sauces are then added to the cans. The cans are sealed, retorted, cooled, and washed. Wastewater comes from the unloading operation, from holding tanks if these are used, and from packing, cooking, cooling and washing of the cans. Table 2.3 below gives wastewater characteristics from a sardine plant.

Table 2.3. Sardine processing plant, wastewater characteristics

Parameter	Typical value
Wastewater	8,690 L/MT
BOD_5	9.22 kg/MT
SS	5.41 kg/MT
Oils and grease	1.74 kg/MT

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

2.2.2 Marine shellfish

No general description of a marine shellfish processing plant can be given as the operations involved depend on the species being handled. In the following paragraphs, process descriptions and wastewater characteristics are given for typical crab, shrimp and clam operations.

Blue crabs

Blue crabs are brought to the processing plant live. They are unloaded onto trolleys for immediate steam cooking at 121°C for 10-20 minutes. The cooked crabs are stored overnight in a cooling locker and then the main claws are removed. The meat from the body of the crab is normally picked by hand. Sometimes the bodies and smaller claws are run through a mechanical picker to separate the meat from the shell. The main claws are hand picked. The meat is packed either into plastic bags or into cans. If it is canned, the cans are pasteurized. Wastewater comes from the containers in which the crabs are brought to the plant, from the cooking and cooling operations, from the stations where the meat is picked from the claws and bodies, and from canning and retorting. Table 2.4 below gives typical values for wastewater parameters.

Table 2.4. Blue crab plant, wastewater characteristics

Parameter	Range, conventional plant	Range, mechanized plant
Wastewater flow	1,060 - 1,310 L/MT	29,000 - 44,600 L/MT
BOD_5	4.8 - 5.5 kg/MT	22 - 23 kg/MT
SS	0.70 - 0.78 kg/MT	12 kg/MT
Oils and grease	0.21 - 0.3 kg/MT	4.3 - 6.9 kg/MT
Organic nitrogen	0.80 - 1.0 kg/MT	2.7 - 4.4 kg/MT
Ammonia nitrogen	0.06 kg/MT	0.16 - 0.24 kg/MT

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

Dungeness, Tanner and King crabs

With crabs such as Dungeness, Tanner and King, the first step in processing is usually butchering. The legs and shoulders are removed from the main body of the crab which is either flumed or transported dry to a disposal pit. The legs and shoulders are transported in a flume to a continuous cooker. After cooking the legs and shoulders are either cooled and hand picked or sent in a flume to shaking tables where the meat is separated from the shell. This is usually accomplished by pounding. The meat is inspected and sorted and then dipped into a brine solution. It may be sold fresh, frozen, or canned. Wastewater comes from the butchering operation, the cooker, from coolers, flumes, from the tables where the meat is separated from the shell, from the inspection station, and from general plant clean-up operations. Wastewater characteristics for a Dungeness crab plant are shown in table 2.5.

Table 2.5. Dungeness crab plant, wastewater characteristics

Parameter	Range
Wastewater	14,800 - 38,000 L/MT
BOD_5	6.6 - 15 kg/MT
SS	2.1 - 4.4 kg/MT
Organic nitrogen	1.4 - 2.8 kg/MT
Ammonia nitrogen	0.075 - 0.18 kg/MT

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

Shrimp

Shrimp are brought to the processing plant in ice. Upon arrival they are de-iced, separated from debris and weighed. The shrimp are usually blanched. Shells are removed either mechanically or by hand. The exact steps used in preparation of shrimp vary from place to place as well as with the final form in which the shrimp are to be sold. In addition to being sold either frozen or canned, shrimp may be sold either breaded or unbreaded. Wastewater flows come from washing and blanching operations, from peeling, inspection and sorting, and from deveining and retorting where these operations are undertaken. If shrimp are mechanically peeled, the peeling machines are the largest source of wastewater in a shrimp processing plant, accounting for some 45-55 percent of all water used.[22]

[22] The World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 91.

Table 2.6. Shrimp plant, wastewater characteristics

Parameter	Frozen	Canned	Breaded
Wastewater flow	73,400 L/MT	60,000 L/MT	116,000 L/MT
BOD_5	130 kg/MT	120 kg/MT	84 kg/MT
SS	210 kg/MT	54 kg/MT	93 kg/MT
Oils and grease	17 kg/MT	42 kg/MT	- - -

Note: In this table loadings are given per ton of raw shrimp delivered to the plant, not per ton of finished product as in the other tables.

Source: The World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 92.

Clams

Upon arrival at a processing plant clams are first washed. They are then shucked and the meat is washed. The bellies are removed and the meat is given a second wash. The meat is then sorted and minced and given a final wash after the mincing. This final wash is necessary to remove sand that becomes embedded in the meat during the harvesting (accomplished by dredging). After the final wash the minced clam meat is drained and packaged. Clam meat is sold fresh or frozen or cooked and canned. If the clam meat is canned it is retorted. Wastewater is generated by the shucking, by each of the washes, and at the debellying station. If the clams are canned, wastewater also comes from the retorting process. Table 2.7 provides typical wastewater values.

Table 2.7. Clam processing plant, wastewater characteristics

Parameter	Conventional plant	Mechanized plant
Wastewater flow	4,570 L/MT	19,500 L/MT
BOD_5	5.14 kg/MT	18.7 kg/MT
SS	10.2 kg/MT	6.35 kg/MT
Oils and grease	0.145 kg/MT	0.461 kg/MT

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume I: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

2.2.3 Freshwater fish

In general the processing of freshwater fish follows the same pattern as the processing of marine finfish. Two of the more important species are salmon and catfish. Brief descriptions of processing operations along with wastewater chaiacteristics are given in the paragraphs which follow.

Salmon

When salmon arrive at a processing plant they are first sorted into the various species. If the salmon is not to be processed immediately it is iced or put into chilled brine. If the salmon have not been butchered at sea, butchering is the first step in processing. If they have been butchered at sea only the head has to be removed at the plant. During seasons when the salmon catch is particularly good and plant capacity is exceeded, some of the salmon are frozen without being butchered. After butchering salmon are sometimes given a pre-rinse to reduce the amount of slime adhering to the carcasses. The eviscerated fish are then moved to a wash tank. Here remaining blood, tissues lining the body cavity, sea lice, and organ particles are removed. This washing operation, along with the pre-rinse if practiced, accounts for some 90 percent of the total wastewater flow from a salmon processor.[23/] After being washed the salmon meat is cut and packed into cans. The cans are retorted and cooled. As with tuna processors, salmon plants are often set up to process meat unsuitable for humans into pet food. In addition to the pre-rinse and washing operations, sources of wastewater are as follows: mechanisms used to transfer fish from the boats to the plant, holding bins, the packing of the meat into cans, and the retorting, cooling and washing of the cans.

Table 2.8. Salmon plant, wastewater characteristics

Parameter	Conventional Plant	Mechanized Plant
Wastewater flow	3,750 - 5,400 L/MT	18,500 - 19,800 L/MT
BOD_5	2.0 - 3.4 kg/MT	45.5 - 50.8 kg/MT
TSS	0.8 - 2.0 kg/MT	20.3 - 24.5 kg/MT
Oils and grease	0.15 - 7.8 kg/MT	5.2 - 6.5 kg/MT

Sources: Middlebrooks, E. Joe, Industrial Pollution Control, Volume I: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227. The World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 89.

23/ Ibid., p. 88.

Catfish

Catfish are generally brought to a processing plant alive. They are electrically stunned and the head and dorsal fins removed. After this they are eviscerated, skinned and given a final cleaning to remove any remaining skin, fins or blood. The fish are then weighed and sorted by size. The larger fish are cut into steaks or fillets. Smaller fish are packaged whole. Catfish are sold either fresh or frozen. Wastewaters come from the tanks used to hold the catfish when they arrive at the plant, from the stations where they are eviscerated, skinned and cleaned, and from the packaging operations.

Table 2.9. Catfish plant, wastewater characteristics

Parameter	Range
Wastewater flow	15,800 - 31,500 L/MT
BOD_5	5.5 - 9.2 kg/MT
TSS	6.8 - 12.0 kg/MT
Oils and grease	3.8 - 5.6 kg/MT
Organic nitrogen	0.51 - 0.75 kg/MT
Ammonia nitrogen	0.0045 - 0.045 kg/MT

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

2.2.4 Fish meal processing plants

Fish meal is made from the solid wastes generated in the processing of marine finfish. It can also be made from whole fish harvested for the purpose of rendering into meal. If the wastewater at a finfish plant is screened prior to discharge, the solids from this screening process can also be used by the fish meal plant. The by-catch (trash fish caught during normal fishing operations) can also be utilized. The waste solids, screenings, and/or whole fish are stored as they are, i.e. without drying, in bins or pits. As this material accumulates, the weight of the material causes a viscous substance to ooze from the pits or bins. This substance is referred to as bloodwater. In developing countries where fish meal plants tend to be small, relatively unsophisticated operations, this bloodwater may often be wasted. Bloodwater contains extremely high levels of BOD_5 and suspended solids. The average BOD_5 of blood water is 128,900 milligrams per liter. The average suspended solids load is 15,230 milligrams per liter (mg/l).[24] As a consequence of these extremely high values, there is a substantial risk that the wastewater discharges from a fish meal plant not practicing recovery of bloodwater will have serious negative impacts on the receiving waters. In developed countries the fish meal plants tend to be large and well equipped. In these larger plants either the bloodwater is recovered or plant operation precludes bloodwater from being generated. If bloodwater is recovered it is introduced into the continuous cooker, the first step in manufacturing fish meal.

In the production of fish meal the trash fish, waste from marine finfish plants and bloodwater are first put into a continuous cooker. After being cooked the entire mass is transferred to a screw press. This press separates the solid part of the cooked material from the liquid. The solid part is called the press cake. This press cake is dried, ground, and bagged as fish meal. In order to facilitate drying, the press cake is often first milled. Drying is done in forced-draft, gas fired dryers. After drying, the press cake is again milled and then blown to cool it. A schematic drawing of the fish meal production process is given in figure 2.2. The drying of the press cake results in highly objectionable odors. As a consequence many plants have installed salt water scrubbers to reduce these odors. The scrubbers are one of the two sources of wastewater from fish meal processing plants which recover their bloodwater.

The liquid that is generated by the screw press is called press liquid. It consists of oil and water mixed with both dissolved and suspended solids. This press liquid is first screened to remove the solids. These solids are combined with the press cake during the drying process (see figure 2.2). The remaining liquid contains dissolved fish protein, ash, fats and oil. It is pumped to storage tanks, heated, and then goes to a centrifuge where the oil is separated out. This oil is generally washed prior to being sold. The liquid that remains after the oil has been separated out is called stickwater. In general stickwater is any water that has been in close contact with fish and has drawn large amounts of organic compounds into itself. This is most frequently the result of a cooking operation. As with bloodwater, in developing countries this stickwater is most frequently discarded. And as with bloodwater, this stickwater has high levels of BOD_5 and suspended solids. The average BOD_5 of stickwater is 115,990 mg/l. Its average suspended solids load is 9,310 mg/l.[25] The fact that fish meal plants in developing countries tend to discharge both their bloodwater and their stickwater has been cited as one of the reasons for encouraging the production of fish silage rather than fish meal in these countries.[26] In developed countries, or where fish meal plants are larger and can afford sophisticated equipment, the stickwater is recovered. It is heated and then evaporated in

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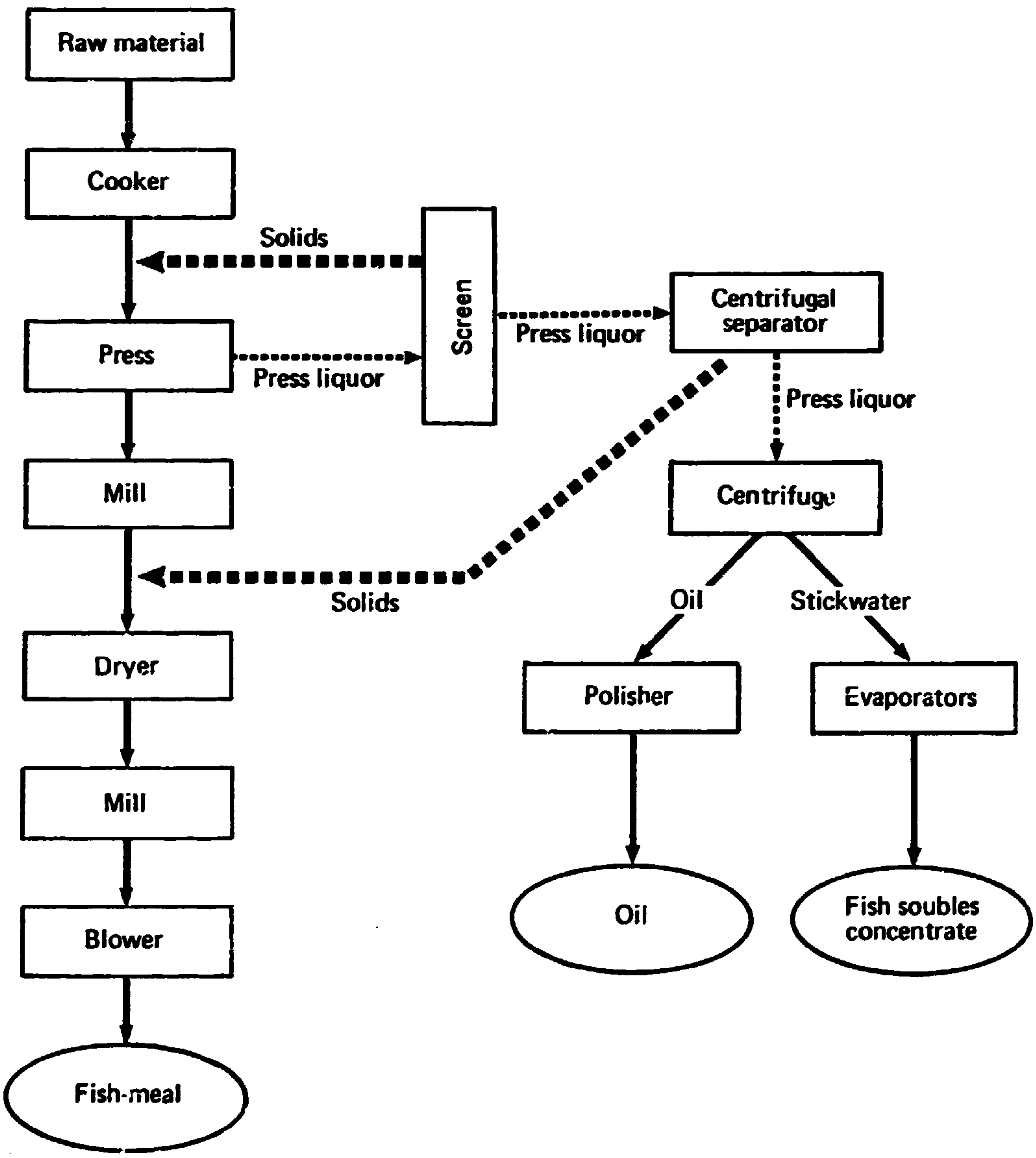
[24] United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guidelines, VIII. Fish Processing Industry, Bangkok, 1982, p. 10.

[25] Ibid., p. 10.

[26] Ibid., p. 7.

Figure 2.2. Fish meal processing ' the wet method



Source: Naomi Peña, UNIDO consultant.

triple effect evaporators. The resulting concentrate is either sold separately as fish solubles concentrate or it is combined with the press cake to improve the press cake's nutritional value. The triple effect evaporators are the second source of wastewater from a fish meal plant that practices recovery of bloodwater and stickwater. Wastewater sources from fish meal plants can be summarized as follows:

Plants practicing recovery of bloodwater and stickwater	Plants not practicing recovery of bloodwater and stickwater
Scrubbers	Storage bins (bloodwater)
Evaporators	Pump-out of bins
	Scrubbers
	Centrifuges (stickwater)
	General clean-up

Table 2.10 gives wastewater characteristics for a fish meal plant which practices recovery of bloodwater and stickwater.

Table 2.10. Fish meal plant which practices bloodwater and stickwater recovery, wastewater characteristics

Parameter	Value
Wastewater flow	35,000 L/MT
BOD_5	2.96 kg/MT
SS	0.92 kg/MT
Oils and grease	0.56 kg/MT

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume I: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

3. SOURCES AND CHARACTERISTICS OF SOLID WASTES

Seafood processing wastes fall into two main classes, those from finfish and those from shellfish. Finfish wastes contain high concentrations of proteins. These are especially valuable from the point of view of human nutrition because they contain a full range of amino acids. Shellfish wastes contain relatively less protein, and the protein which is present does not contain the full range of amino acids necessary for good nutrition. One of the main materials of interest in shellfish wastes is chitin. Chitin serves as a binder in the shells and is primarily of interest as the raw material out of which chitosan is produced. Chitosan can best be described as a gum. Its primary use is as a flocculant in wastewater treatment systems. In spite of the differences in their composition, which are described in more detail in sections 3.1 and 3.2, both finfish and shellfish wastes are difficult to dispose of on land. The difficulty is a result of their high water content and the rapidity with which they spoil. The high water content, ranging from 60-90 percent of their weight, makes transportation uneconomical except for very short distances.[27/] When the wastes spoil they give off foul odors and rapidly attract insects and vermin. Crab wastes, for example, spoil within five hours in warm climates.[28/] Rain accelerates the spoilage rate. Even when wastes are covered, gases produced by their decomposition can crack the soil and allow odors to spread. These difficulties with land disposal are sufficiently troublesome so that where dumping into a water body is not acceptable, utilization options should be explored.

There are three major sources of solid wastes in the seafood processing industry: spoilage, by-catch, and wastes generated during processing. Spoilage rates are particularly high in developing countries where boats and processing plants may lack adequate refrigeration equipmen In addition many developing countries lie in the tropics or sub-tropics wher warm climates accelerate spoilage. Little can be done to reduce this source of waste other than increasing access to refrigeration equipment. Wastes from both by-catch and processing, on the other hand, can potentially be converted into either food for humans or animal feeds. In particular, the possibility of converting by-catch fish into minces, from which a number of products can be manufactured, holds promise as an economically attractive way to utilize a major source of waste in the seafood processing industry.

By-catch waste has attracted attention in part because of the sheer volume of material available. It has been estimated that several million tons of by-catch, primarily from tropical and sub-tropical waters, result from shrimp

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[27/] Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-327.

[28/] Brooks, Clayton, "A Historical Perspective", Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982. Report No. UM-SG-MAP-81-03, pp. 6-10.

harvesting operations alone.[29] Table 3.1 below presents estimated annual by-catch from shrimp harvesting operations in selected regions.

Table 3.1. Estimated shrimp-related by-catch, selected regions

Region	Estimated tonnage
South Atlantic	37,000
Gulf of Mexico	562,000
Gulf of California	160,000
Guyana Coastal Waters	80,000
Indonesia (Java Sea and Arafuru Sea)	227,000

Sources: United States Food and Agriculture Organization, Strategy for Shrimp By-Catch Utilization, Rome, 1982, FIIU/C745, pp. 1-2. Kompiang, I. Putu, "Utilization of Trash Fish and Fish Wastes in Indonesia (as Animal Feeds), in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, pp. 131-137.

The characteristics of shrimp-related by-catch vary from region to region. From the point of view of mince production the primary characteristics of interest are size of fish, proportion of fish of commercially valuable species, proportion of fatty fish, whether or not toxic varieties are present, and whether species diversity is low or high. In the Gulf of Mexico and in Guyanan coastal waters, for instance, a good proportion of the by-catch consists of fish of commercial size and species. By-catches with these characteristics lend themselves to being sorted. The commercial species can be retrieved and manufactured into frozen minced fish blocks. In the Gulf of California, on the other hand, by-catches consist of very small fish, very few of which belong to commercially valuable species. However, species diversity is low, with 74 percent of the fish belonging to one of eight species, and very few fatty fish are present.[30] Both fatty fish and a wide variety of species cause problems in the manufacture of minces. The fact that Gulf of California by-catches are free from these two problems has encouraged investigators to try to solve the problems posed by the one negative characteristic - small size. Efforts of this sort, attempts to adapt

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[29] United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216, p. 4.

[30] Ibid., p. 4.

mince technologies to the specific characteristics of by-catches in the developing world, are underway in Mexico, Guyana, India, Thailand and Indonesia.

The last source of solid waste in the seafood processing industry is the preparation of fish for sale. During processing edible as well as inedible materials are discarded. Scales, tails and fins, viscera, heads, bones and shells, as well as considerable amounts of flesh which remain attached to the bones and shells contribute to the solid waste. Except in the case of large tuna and salmon processing plants, where wastes from preparation of human food are used in producing pet foods and fish meal, the proportion of the raw fish which ends up as waste is high. Table 3.2 below gives the percent fish which ends up as waste for major seafood categories.

Table 3.2. Solid waste as percent of raw weight

Finfish - marine and freshwater	55-75
Crabs	50-60
Shrimp	65-85
Clams and oysters	82-90

Source: Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-283.

Further details of the sources of waste during processing are given in sections 3.1 and 3.2. These sections also provide diagrams showing typical processing operations for major seafood categories. The diagrams are designed to show at a glance which individual steps contribute to the solid waste load.

3.1 Solid wastes from finfish processing

Figure 3.1 illustrates a typical finfish processing operation. As can be seen, the first sources of solid waste are the preparatory steps: precooking, evisceration, and the removal of scales where this is necessary. In come cses fish are eviscerated and/or beheaded at sea rather than at the processing plant. This is generally done, for example, with halibut. After the preparatory steps, if any, the fish are moved to the filleting tables. Here fillets are removed from both sides of the fish. What is left over - bones, head and tail, and considerable amounts of flesh which remain attached to the bones - is referred to as offal and is ordinarily discarded. If a mincing operation is undertaken, somewhere between a quarter and a half of the flesh remaining attached to the bones can be recovered.[31] The other two steps which, in a typical finfish processing plant, generate solid waste are the removal of the skins and final inspection. During inspection remaining bits of undesirable materials, such as bones, viscera, or connective tissues, are removed and flesh which is spoiled or damaged eliminated.

While most finfish operations follow the series of steps shown in figure 3.1, a few variations or exceptions should be noted. The most obvious exceptions are large, integrated tuna or salmon operations. Here virtually all solid wastes generated in the preparation of human food are recovered for use either in the manufacture of pet foods or as inputs into fish meal. An integrated tuna or salmon operation generates, in effect, no solid waste. With fish such as sardines, where the product is canned, the packing of the fish into the cans creates a solid waste stream. Once sardines are packed they are given an initial cook to remove undesirable oils. These oils, plus residues of whatever oils or sauces are used to replace the cooked-out oils, can also be considered a "solid-waste". Finally, in some cases, an initial sorting of fish occurs prior to removal of the fish from the holding tank. Where this is done, as is almost always the case with catfish, the holding tanks themselves are a source of solid waste.

The most important aspects of finfish wastes, from the point of view of both disposal and recycling, are the water content, the fats, the proteins and the minerals present. The water content is primarily a problem where land disposal of wastes is contemplated. The fats pose problems both for disposal, whether in water or on land, and for many recycling options. The fats present in fish are predominantly long chain, polyunsaturated fatty acids. These fats are desirable from the point of view of nutrition but they tend to oxidize rapidly. It is this rapid oxidation, creating spoilage, that causes problems in land disposal. If fat levels are high, as they are in many species, including menhaden, anchovies and sardines, disposal of wastes in water can lead to the formation of films or grease patches. High fat contents are also undesirable in minces, fish silages and fish meals intended for human consumption.

The desirable substances in finfish wastes are the proteins, vitamins, minerals and trace elements present. The protein content of fish wastes is almost as high as the protein content of the portion used for food. With the exception of tuna, which contains 25 percent protein, a typical fish fillet contains 16-20 percent protein. Fish wastes contain 10-15 percent protein. When the water has been removed, i.e. on a dry basis, fish contain 30-65 percent protein, 6-10 percent protein-nitrogen, 4 percent phosphate (P_2O_5) and 1 percent potash (K_2O). A wide variety of other minerals and trace elements is also present. The protein in fish wastes accounts for the interest in recycling these wastes for use as food for humans and feed for animals. The nitrogen-phosphate-potash combination is the basis for use of

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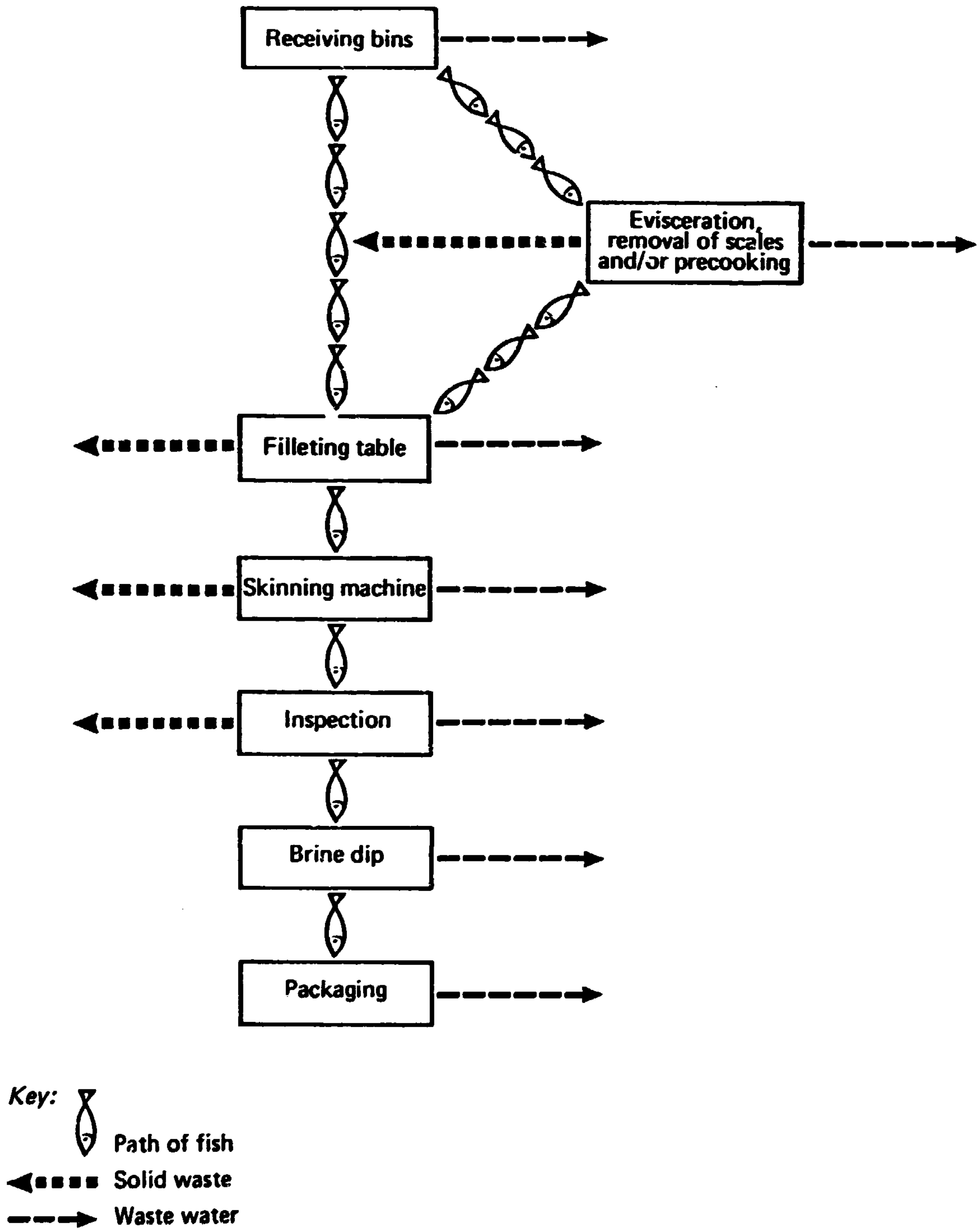
[31] Green, John H. and Joseph F. Mattick, "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, pp. 229-251.

Figure 3.1. Schematic of groundfish processing



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

fish wastes as fertilizer. Dry fish wastes are equivalent to a 8:4:1 (N:P:K) fertilizer. Raw fish wastes are equivalent to a 2:1:0 fertilizer.[32]

3.2 Solid wastes from shellfish processing

The bulk of the waste generated by shellfish processing consists of the shells themselves. It is this preponderance of shells in the wastes which accounts for the relatively lower percent of protein content of shellfish as compared to finfish wastes. Since meals from fish wastes are valued according to the percent of protein present, meals from shellfish wastes do not command prices as high as those received for finfish-based meals. This, along with the extremely rapid decomposition rates, the difficulties in dewatering, and the fact that shellfish processors are if anything even smaller than finfish processors, explains why shellfish wastes are even less frequently rendered into meal than finfish wastes.

Shellfish wastes fall into two major categories, wastes from crustaceans such as crabs and shrimp, and wastes from mollusks such as oysters and clams. The exoskeletons of crustacea contain 25-45 percent protein, 15-24 percent chitin and 40-50 percent calcium carbonate.[33] It is the chitin content of these wastes that has generated considerable interest in recycling possibilities. The use of chitin-derived chitosan in wastewater treatment has received the most attention, but chitosan's potential uses include many others. to make moisture-proof films and coatings, for sizing paper and textiles, as an additive in oil well drilling mixtures, as a thickening agent, and in pharmaceuticals. At present the chitin content of crustacean shells is exploited only in Japan where it is used extensively in treatment of wastewater, polluted waters and sludges. However, work on extraction and application of chitosan continues and crustacean wastes may prove to be a valuable resource for other countries as well.

3.2.1 Crustacean wastes

Typical plant operations for blue crabs are shown in figure 3.2. As can be seen blue crabs are cooked immediately upon arrival at the plant. The meat is then cooled and removed from the shells. The removal of the meat, called picking in the case of crabs, is the only step in blue crab processing in which solid wastes are generated. The solid waste consists of legs, claws, shells and the attached meat. In the case of other crab species, such as Dungeness, Tanner, and King, the process is similar except that the crabs are butchered prior to being cooked. The butchering results in viscera and gills being contributed to the waste stream. Tanner, Dungeness and King crabs are also subject to an inspection after picking where unacceptable meat is discarded. If the crab meat is canned, solid wastes, bits of meat, enter the waste stream at the canning stage.

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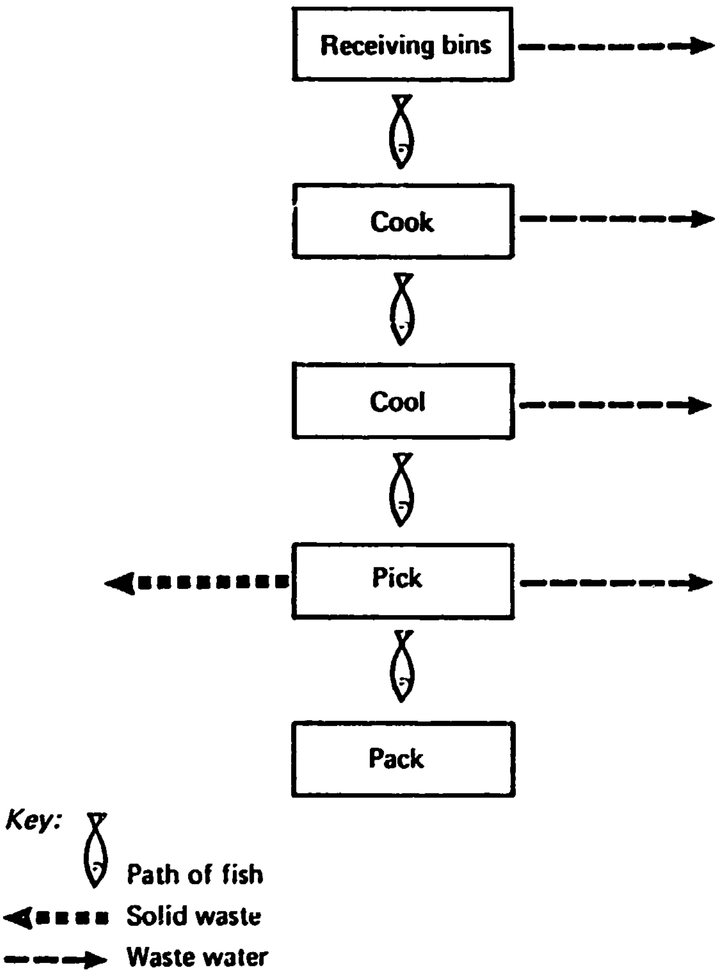
[32] Swanson, G. R.. E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-327.

[33] Ibid., pp. 281-327.

Figure 3.2. Blue crab processing schematic



<u>Source</u>: Adapted from Middlebrooks, E. Joe, <u>Industrial Pollution Control, Volume 1: Agro-Industries</u>, John Wiley and Sons, New York, 1979.

Figure 3.3 presents a general picture of the sequence of steps in a shrimp processing plant. Details vary considerably depending on location, on whether the shrimp is to be frozen or canned, and on whether or not the shrimp is breaded. As can be seen from figure 3.3, solid waste is generated at a large number of points in the process. In the first step the waste consists of trash fish and debris netted along with the shrimp. At the next step - peeling - heads and tails are removed along with the shell. Further pieces of shell are removed in the next series of steps; washing, the separator, shaking and blowing. Blanching may or may not result in pieces of meat entering the waste stream. The final steps - inspection, sizing and grading, and packing - contribute pieces of meat to the waste stream. If the shrimp are frozen rather than canned the packing does not contribute to the solid waste stream. In some cases, in addition to the steps shown in figure 3.3, the shrimp are deveined. If so, deveining generates solid waste. Finally, if the shrimp are breaded, residue from the breading process, i.e. unused batter or batter ingredients, add to the solid waste.

Table 3.3 summarizes the contents of shrimp and crab wastes. These wastes consist of exoskeletons (shells), meat remaining on shells, heads, tails, and other inedible parts.

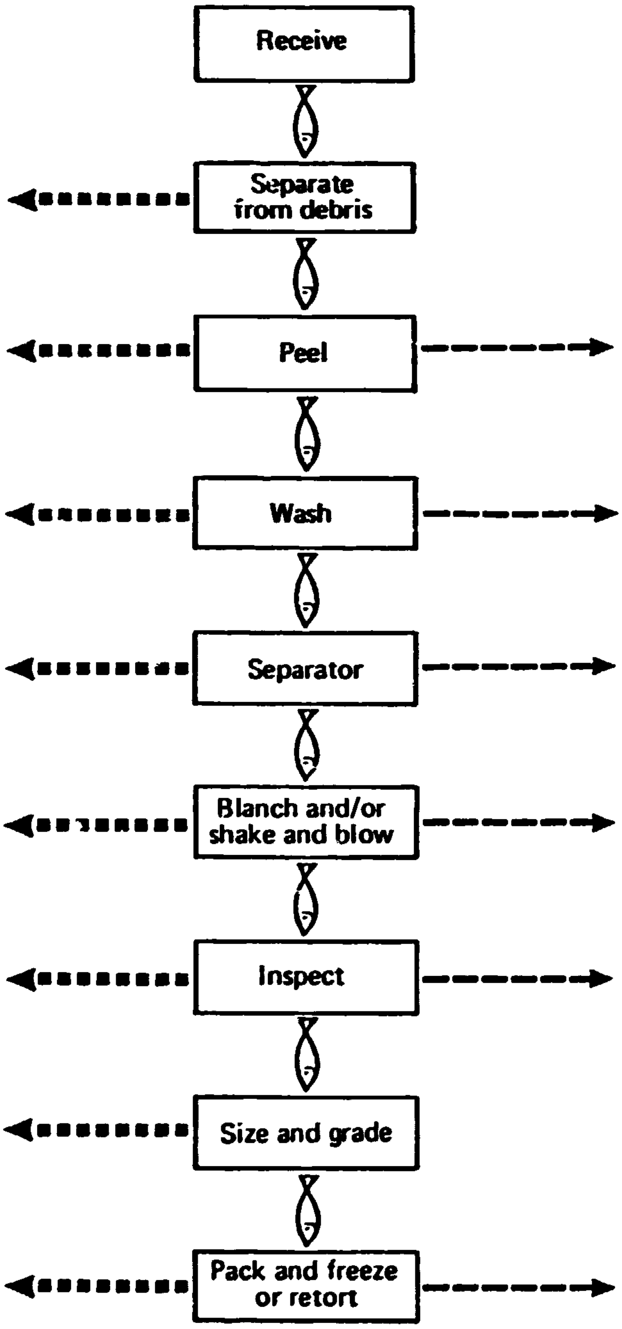
Table 3.3. Shrimp and crab wastes, dry basis (percentage)

	Crab	Shrimp
Protein	11 - 42	11 - 42
Chitin	9 - 42	9 - 42
Calcium carbonate	36 - 58	36 - 58
Nitrogen[a/]	4.4 - 7.3	5.4 - 7.9
Phosphorous[a/]	0.6 - 1.8	2.1 - 2.9
Potassium[a/]	0.4 - 1.3	1.6
Sulfur	0.5	0.3
Magnesium	0.9	0.8

[a/] The fertilizer equivalent of the nitrogen-phosphorous-potassium combination present in the waste is 6:4:1 (N:P:K).

Source: Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-327.

Figure 3.3. Shrimp processing schematic



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

In addition to the substances listed in table 3.3, shrimp wastes contain significant amounts of carotenoid pigments and cholesterol. Carotenoid pigments are red or yellow pigments related to the compound carotene ($C_{40}H_{56}$). These pigments are of interest because, when used as part of the feed, they can enhance the flesh color of pond raised salmon, trout, shrimp and prawns, as well as the color of a variety of species raised as pets. Good color is important because fish with good color command higher prices. Carotenoid pigments are also found in significant concentrations in red crab and crawfish wastes.

The carotenoid pigments present in shrimp wastes will gain importance as increasing proportions of the world harvest of salmon, trout and shrimp come from aquaculture operations rather than from fishing of oceans or rivers. As of 1975 it was estimated that 80 percent of the world's aquaculture harvest came from the Indo-Pacific region. At that time the harvest from aquaculture was believed to be some six million tons, with the People's Republic of China being the lead producer.[34]

Shrimp culture operations are of particular interest in many developing countries. In addition to the considerable shrimp raising industries in Southeast Asia, a number of Latin American countries are becoming active in the field. For these, and other countries which may be interested in shrimp raising operations, the value of shrimp wastes should be particularly noted. In addition to the carotenoid pigments, shrimp wastes are valuable for shrimp culture because of the cholesterol present and because the wastes act as stimulants for feeding. Cholesterol has been shown to be necessary for some shrimp to molt. Although the specific substances have not been identified, it is known that feeds which do not include shrimp wastes often fail to stimulate feeding behavior in pond raised shrimp. The inclusion of shrimp wastes in shrimp feeds stimulates feeding, accelerates growth rates and results in larger shrimp.

3.3.2 Mollusk wastes

Clam processing is shown in figure 3.4. The primary wastes in clam processing are the shell and the belly. The belly constitutes 7-10 percent of the weight of the clam. Since the shell can constitute up to 90 percent of the weight of the clam, the solid waste in clam processing is many times the weight and volume of the product. In addition to the shell and belly, sand and grit are discharged during processing. Although only three washing steps are shown in figure 3.4, clam processing can include several more washes in an attempt to eliminate all the sand and grit. This sand and grit becomes embedded in the clams when they are dredged, and often becomes embedded in the flesh itself.

Both clam and oyster wastes are primarily of interest due to the calcium carbonate present in the shells. Oyster shells represent 75 percent of the total weight of the oyster, and clam shells usually constitute some

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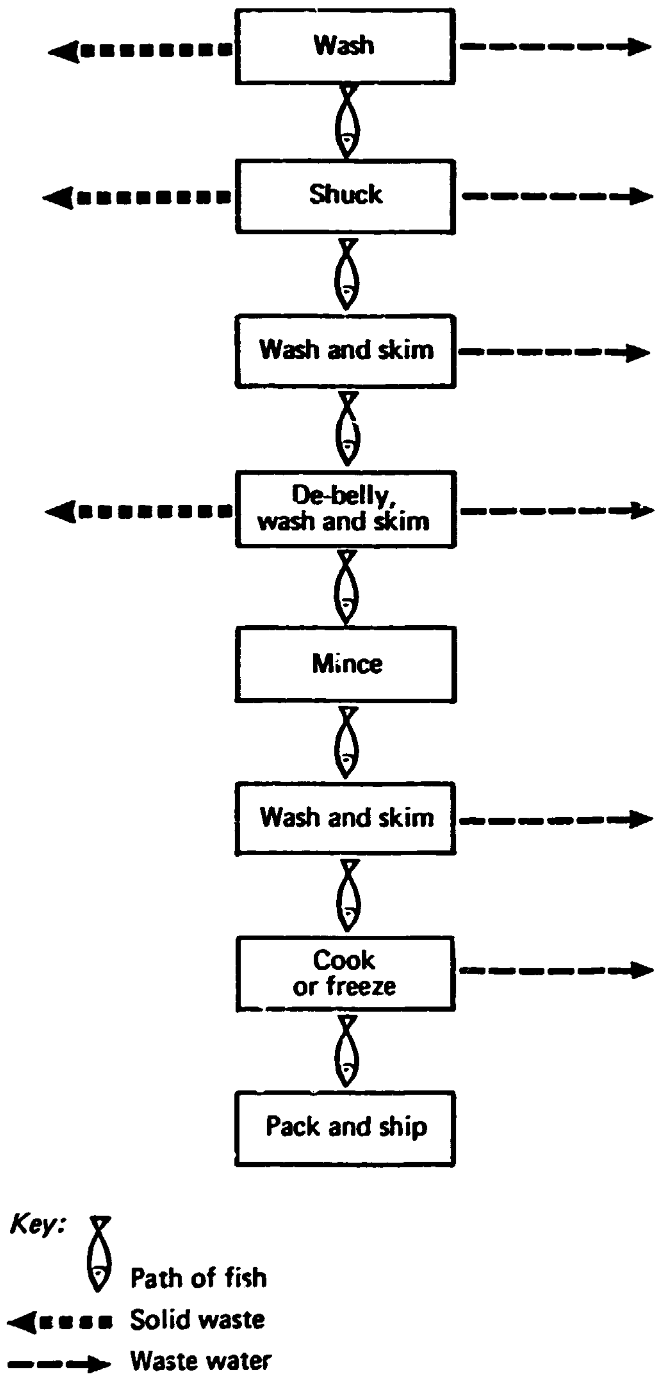
[34] Meyers, Samuel P., "Utilization of Shrimp Processing Wastes in Diets for Fish and Crustacea", Florida Sea Grant College, Report No. 40, 1981, pp. 261-274.

Figure 3.4. Clam processing schematic



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

65-80 percent of the clam's weight.[35] Calcium carbonate is the substance from which lime is obtained. Consequently clam and oyster shells can be used in most applications where lime is desired: for soil conditioning, the neutralization of acid wastes, and in the manufacture of cement. The calcium carbonate is also of interest in poultry feeds where it is used for its calcium content. The only other substance of interest in these wastes is laminarinase, an enzyme found in clam wastes which can be used to split polysaccharides.

Unlike other seafood processing wastes, clam and oyster shells can create problems due to their extreme durability. This durability can be taken advantage of in applications such as the use of mollusk shells for landfill or as a roadbed material. If, however, these shells are dumped in one location, over a number of years piles of considerable size will build up. If these piles accumulate in navigible waters they can block channels and create hazards for ships.

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[35] Ibid., p. 290 and Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979, p. 218.

4. SOLID WASTE REDUCTION: BY-PRODUCT AND RECYCLING POSSIBILITIES

Wastes from seafood processing are inherently valuable. They can be used to produce a wide range of products which may be considered to fall into four general categories: food for human consumption, feeds for animals, fertilizers or soil conditioners, and chemicals. A few specialty uses such as pearl essence, a decorative material, or isinglass, which is used to filter wine, fall outside of these categories, but such uses are not of major significance. The limitations on waste recycling are primarily of an economic nature, although in some cases existing technologies may be too sophisticated for practical application. The only product which has a well established market, a proven technology, and can use virtually all wastes is fish meal. Unfortunately the production of fish meal is impractical for most seafood processors. To be economical a fish meal processing plant must have a capacity of approximately ten tons per day.[16] Very few seafood processors are large enough, or located in sufficient proximity to other processors to support a facility of this size. Consequently most seafood processors will have to turn to other options if they want to recycle wastes. In most cases the viability of these other options is determined by market conditions. While the products are useful, there may be no local markets for them and shipping costs generally prohibit taking advantage of more distant markets. Alternatively, local markets may exist but competition from other, lower cost products which can fulfill the same purpose may render recycling financially unattractive. The remainder of this chapter discusses the major products in each of the four categories listed above. Emphasis is on applications which are of particular interest to developing countries. Table 4.1 lists the most common recycling options classified by the type of waste from which they are made, rather than according to the major "end product" categories.

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[16] Carter, P. M., et.al., Recent Developments in the Utilization of Meat and Fish Wastes in the Tropics, Tropical Development and Research Institute, London, p. 3.

Table 4.1. Commonly reported uses for solid wastes

FINFISH	
Whole fish or any part of fish	Fish Protein Concentrate (FPC) Fish meal Fish silage Fish pellets or flakes Bait Fertilizer
Flesh and/or organs	Mince Pet foods Mink feed Insulin Isinglass (used as filter to clarify wine)
Oil	Vitamins Margarine or cooking oil Paints or protective coverings Mushroom culture
Skin	Glue
Scales	Pearl essence Flocculant
SHRIMP AND C S	Flavorings Shrimp or crab meal Fertilizers Fish pellets or flakes Carotenoid pigments
CLAMS AND OYSTERS	Lime (soil conditioning, concrete, or neutralization of acid wastes) Roadbed or landfill material Poultry and hog feeds Oyster bed maintenance Bait Chitosan (used for wastewater treatment) Laminarinase (enzyme used to split polysaccharides)

Sources: Green, John H. and Joseph F. Mattick. "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, pp. 229-251. Hood, L. F. and R. R. Zall, "Recovery, Utilization and Treatment of Seafood Processing Wastes", Advances in Fish Science and Technology, Department of Food Science, Cornell University, Ithaca, New York, 1980, pp. 355-361. Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979. Meyers, Samuel P., "Utilization of Shrimp Processing Wastes In Diets for Fish and Crustacea", Florida Sea Grant College, Report No. 40, 1981, pp. 261-274. Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conv , Van Nostrand Reinhold Company, New York, 1980, pp. 281-322. United S Environmental Protection Agency, Environmental Assessment of Alternative Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83-115.

4.1 Food for human consumption

The utilization of seafood wastes for food for human consumption is the most valuable of the recycling options. It is the most valuable because the price, per kilogram of waste converted, which food products can command is higher than the price which animal feeds or fertilizers can command. It is also the most valuable option in terms of meeting developing world problems of malnutrition and undernourishment. The two recycling-for-food options which have the potential for absorbing large portions of waste are minces and fish protein concentrate. These, along with some minor waste utilization options, are discussed in the following three subsections.

4.1.1 Minces

The most promising method for waste utilization in the seafood processing industry is the manufacture of minces and mince-based products. Minced fish is fish flesh that has been separated from the inedible portions of the fish. Although the technology involved in making mince is still in need of improvement, and although there is a need for further development of end products, minces must be considered the foremost recycling option for the developing world for a number of reasons.

(a) No other recycling option holds as great a potential for being able to command high enough prices to make it worthwhile for fishermen to land by-catches in good condition. The possibility of being able to use, for human food, the vast resource which by-catches represent, is almost enough in itself to put mince at the top of the list of options which should be considered by developing countries.

(b) Minces are already being produced and sold both in the west and, primarily in Japan, in the east. Thus there is a proven market for minces and mince products.

(c) Improvements in mince technology and mince product development are being actively pursued in the developed world. This is extremely important since it means that the developing world can take advantage of the research capabilities of the United States, Europe and Japan. Although most of the work in the developed world focuses on flesh obtained from commercial species rather than on by-catch utilization, some of the research results should prove valuable to developing country efforts.

(d) It is too soon to say what the minimum economic plant size for mince production will be. However the possibility of utilizing by-catch means that many processors which might not otherwise be able to take advantage of any recycling option, may find it possible to recover a sizeable portion of their wastes.

Mince is usually produced by physically screening the flesh from the non-flesh components. Mincing has traditionally been used either on whole fish which have had their heads and guts removed or on the flesh remaining attached to bones after the filleting operation. In the past equipment used in meat and fruit processing was adapted and used in the seafood processing industry. Recently machines especially designed for fish flesh separation have become available. In these machines a belt moves against a perforated drum or cylinder. Two cylinders, one of which rotates, or a screw feed and cylinder can also be used. The flesh is in effect scraped or torn from the bones and forced through the perforations. Depending on speed, pressure, and hole sizes, the resulting mince can range from a powdery consistency to a coarse mince consisting of small flesh particles.

Chemical and biochemical means for separating the flesh are also under development. Of particular interest for the developing world are techniques which can be applied to fish which have not been eviscerated. Such techniques are of interest because, in many cases, by-catch fish are so small that evisceration by hand is difficult. In Norway mince has been prepared from sardines which have not been eviscerated. The sardines are cut into pieces of 1-2 centimeters and mixed with an equal weight of water. They are then washed with acetic or propionic acid. This breaks down the skin, viscera, membranes, and other tissues which contain fats. These substances can then be removed by decanting the mixture. The flesh can then be removed from the bones by spraying with pressurized water. Finally the water is removed from the flesh by pressing it through a filter. The yield from this process compares favorably with yields from traditional mechanical methods.[17/]

The main difficulty in mince production is achievement of a mince of good quality and desirable characteristics. The precise characteristics desired in a mince depend on the end product or products for which it will be used. In general terms the characteristics of interest are appearance, including color, texture, the ease with which the mince forms gels, its ability to combine with water, how it reacts when heated, and the extent to which the fats and proteins have decomposed. Problems in manufacturing a mince of the desired qualities are traceable to preprocessing, processing, and storage. A brief discussion of some of these problems is presented in the next five paragraphs. Further information on sources of problems is given in table 4.2.

[17/] United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216, p. 13.

Table 4.2. Sources of problems in production of mince

1. Raw materials	Improper storage prior to processing increases bacterial counts. Elevated bacterial levels, aggravated by the dispersal of the bacteria throughout the mince during processing, increases the risk of spoilage occuring. Many of the species used for mince contain high levels of parasites. Most of the parasites in marine fish are not harmful. They are, however, aesthetically unacceptable. Species which contain trimethylamine oxide (TMAO) - cod, hake, haddock, pollock and croaker - cannot be used in nitrate-cured products.
2. Bones	Fragments of sufficient size to be visible or cause internal injury render the mince unacceptable. Bone particles of small size can lead to gritty textures and taste sensations.
3. Proteins	Almost all species are vulnerable to protein breakdown due to the mixing of enzymes from the gut into the flesh. Such mixing and breakdown is most prevalent if fish from which the guts have not been removed are minced. However, if even small amounts of gut materials become incorporated into the mince extensive protein degradation can occur. Protein degradation results in a product which is tough and has a grainy consistency. It also results in a decreased ability of the mince to form gels and to bind water. The species which contain trimethylamine oxide are subject to protein degradation during frozen storage.
4. Fats	The polyunsaturated fats present in fish of almost all species predisposes minces to problems of spoilage and poor flavors. The mincing process disperses enzymes active in the decomposition of fats, increases the amount of surface area exposed to air, and spreads fat-degradation catalysts found in the blood throughout the mince. All of these accelerate the process of fat decomposition.
5. Color	The mincing process often results in a product of darker color than the raw material. In many countries a light color is preferred and is necessary for marketing success.

Source: United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome 1981, FIIU/T216.

The most pervasive problem stemming from preprocessing conditions is spoilage. Unfortunately spoilage problems are more of an obstacle in the developing world than elsewhere. Spoilage is caused both by the decomposition of the polyunsaturated fats characteristic of all fish and by bacterial contamination. In the developed countries most mince is produced from commercially valuable species which tend to have relatively low levels of fats thereby minimizing problems of fat deterioration. In the developing world mince technology is primarily of interest as a means of utilizing by-catch species. Many by-catch species have very high fat levels and at present there are no really satisfactory solutions to the problems presented for mince production by high initial fat levels.

Spoilage due to bacterial contamination is also more of a problem in the developing world than in developed countries. Prevention of bacterial spoilage depends on keeping the fish cold prior to processing. As mentioned earlier, much of the developing world lies in warm climatic zones and refrigeration equipment is often lacking or inadequate. This problem is fortunately at least in principle soluble. Given sufficient economic justification refrigeration equipment can be purchased and electricity generated.

Bacterial spoilage and high initial fat levels are the primary problems attributable to the preprocessing stage. Aside from such preprocessing or initial conditions of the fish, the processing technologies have the greatest impact on final mince characteristics. The processing technologies can be divided into those employed prior to separation of the flesh, the technology used to achieve the separation, and the post separation technologies. It has been discovered that pre-separation procedures have if anything a greater impact on final mince quality than the separation technology itself. As a consequence machines are being developed to control and improve handling of the fish prior to mincing. Examples include machines to cut out the spinal cord and belly membranes and machines to feed the fish into the separator so that the skin is kept away from the screen through which the flesh is pressed. Such devices help eliminate the contaminants which are responsible for decomposition of both proteins and fats.

As far as the separation procedure itself is concerned, the sizes of the perforations, the amount of pressure with which the flesh is pressed against the screen, and the speed with which the fish are moved across the screen are the principal determinants of mince characteristics. Smaller holes and slower speeds result in minces of finer textures. Faster speeds which create greater shear rates can lead to a reduction in the mince's ability to bind water and to an increase in the mince's "rubberiness". While these qualitites are ordinarily undesirable, in some applications like the manufacture of kamaboko, a Japanese fish sausage, the rubberiness is required in order to give the final product its desired elasticity. In mechanical separation all equipment that comes in contact with the fish must be made of stainless steel or non-metallic materials. Otherwise the mince is subject to ferric ion contamination which greatly accelerates fat decomposition.

Post separation technologies include a wide variety of techniques and additives which have been tried to prevent or rectify problems caused by preprocessing characteristics and separation technologies. Information on some of these is presented in table 4.3. In general, the technologies focus on improving color and on rectifying or preventing problems caused by the decomposition of fats and proteins. The usefulness of particular procedures depends on the species being processed and on the final products into which the mince will be made.

Problems in the storage of minces are due to the fact that both proteins and fats continue to decompose. Most minces are frozen and some fish species are particularly susceptible to protein decomposition when frozen. For the developing world both canning and drying should be considered as alternatives to frozen storage. Canning is an effective way to reduce fat deterioration. Any other oxygen impermeable packaging will accomplish the same goal, as will glazing of the mince. The most common form of drying mince is with salt. The salt can be incorporated and dispersed through the mince during the separation stage. Minces which contain 20 percent salt and whose moisture content has been reduced to 15 percent are safe from microbial spoilage. Antioxidants and/or air and moisture-proof packaging are however still necessary to inhibit deterioration of fats.

Minces can be used to manufacture a wide variety of products. Some of the most important of these are listed in table 4.4. Many of the products listed in table 4.4 are marketed in different forms in different countries. Thus, there are fish balls designed for the Scandanavian market and fish balls of the types eaten in southeast Asia. Further, many of the products can be made either from whole fillets or from minced materials. It is generally believed that products made from whole fillets are preferred to those made from mince. Experiments have shown that this is not always the case. "Prawn" or "scampi" made from finfish mince and then flavored with shellfish extracts cannot be distinguished from the real thing even by experts. Further, although adults, for example, prefer fish fingers made from fillets, children actually prefer fish fingers made from mince.[38/]

[38/] Keay, J. N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278.

Table 4.3. Techniques for improving mince characteristics

1. Washing	Once the flesh has been separated from the bone it is often washed. This removes inorganic salts, water-soluble proteins, pigments, visceral contaminants, and bacteria. In some cases it also helps remove fats. Washing improves the texture of products made from fine minces but has little effect on coarse minces or on minces made from high quality raw materials. Since washing can also have undesirable effects it should only be undertaken if necessary. Undesirable effects include losses of proteins, vitamins and minerals. It is also difficult to control the final water content of washed minces.
2. Additives	Shrimp, soy and some cereal products as well as a wide range of chemical antioxidants can be added to inhibit decomposition of fats. Soy protein and polyphosphates can be used to improve the ability of minces to combine with water. A wide variety of substances that preserve foods at low temperatures are utilized to reduce protein deterioration. Proteases, enzymes active in the breakdown of proteins, can be used to reduce toughness.
3. Acid and alkaline treatments	Alkaline treatment in the presence of certain salts stabilizes proteins during freezing. Alkaline treatment is also used to increase the ability of minces to form gels and combine with water. Alkaline washes can improve color. Acid washes are used to facilitate the removal of blood, skin and visceral pigments.
4. Reformation	The object of reforming is to try to recreate the texture of whole fillets, including their flakiness. Small amounts of soluble alginates are incorporated into the mince. The mixture is then spread in layers of the desired thickness. The layers are gelled by adding calcium ions. They are then washed to remove excess calcium salt, stacked, cut and frozen.
5. Packaging	Poor color can be masked by incorporating minces into products such as meat sausages or smoked foods where a dark color is expected.

Sources: United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216. Keay, J. N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278.

Table 4.4. Primary mince products

1. Fish fingers or sticks
2. Fish cakes or burgers
3. Fish balls
4. "Prawns" and "Scampi"
5. Smoked fish
6. Extender in meat sausages
7. Surimi[a]
8. Kamaboko

[a] Surimi is a semi-processed intermediate product. It has been used for centuries in Japan to make a wide range of products, including kamaboko. In the past it was made almost exclusively from Alaskan pollock. Recently attempts to make it from other fish have met with success.

Sources: Keay, J. N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278. United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216.

4.1.2 Fish protein concentrate B (FPC B)

Fish protein concentrates are basically fish meals of a flour-like consistency which are manufactured under strict hygenic standards and are designed for consumption by people. They are classified as either type A or type B. Type A concentrates are light colored, bland and odorless. In order to achieve these characteristics most of the fat content of the fish must be eliminated. In the U.S. the maximum fat content of a concentrate designed for human consumption is 0.5 percent. Since it is presently very expensive to reduce fats levels this far, concentrate of type A is rarely manufactured. Type B concentrates have higher fat contents and, consequently, stronger tastes and odors. A fat content of up to 10 percent is acceptable in type B concentrates.

Since fish protein concentrates are manufactured essentially in the same manner as fish meal, as a means of waste utilization they are subject to the same major drawback as fish meal production. In order to be economical a production plant must be fairly large and large quantities of fish must be available virtually on a year round basis. Moreover since the product is designed for human consumption only fresh fish or fresh offal can be used. The equipment must be made of stainless steel or other materials that can be easily cleaned and sterilized so that the hygenic standards required in food plants can be met. These considerations would eliminate fish protein concentrate as a waste utilization option worthy of serious attention were it not for several counterbalances.

Like mince, fish protein concentrate can be made from by-catch fish. Once again this means that locations which otherwise would not be in a position to support solid waste reduction measures might find a recycling plant attractive. While fish protein concentrate would not command as high a price as mince, a plant manufacturing concentrate might be able to pay fishermen adequately well for them to land by-catches. In 1980, fish protein concentrate B (FPC B) which was 70-75 percent protein sold for $US 900 a ton.[39/] This makes FPC B one of the cheapest sources of animal protein available for human consumption. This price, the opportunity to take advantage of by-catches plus fish protein concentrate's potential for alleviating problems associated with malnutrition, particularly in children, are the powerful arguments in favor of giving fish protein concentrate a hearing.

The nutritional credentials of fish protein concentrate B are impressive. The protein in FPC B is rated higher or equal to the protein in milk or meat. FPC B is particularly rich in lysine and methionine which are the two amino acids most commonly found in only limited quantities in vegetable proteins. The high lysine content makes FPC B particularly valuable as a supplement in diets based on wheat since these diets are deficient in lysine. FPC B is also useful as a supplement to corn-based diets due to the presence of substantial amounts of niacin and vitamin B_{12}. Vitamin B_{12} is virtually absent from corn and the niacin that is present in corn can only be metabolized to a very limited extent. In addition to these nutrients, FPC B is rich in calcium, phosphorus and iron. Magnesium is also present.

The value of FPC B as a dietary supplement has been proven. It is particularly useful in treating children suffering from malnutrition. Swellings are rapidly reduced, hemoglobin levels increase and weight gain is accelerated. In one study for instance, children who received one teaspoon of FPC B six times a week for three months gained almost two and a half times as much weight as the children who did not receive the FPC B.[40/]

FPC B would no doubt be extensively produced and used as a dietary supplement or food additive were it not for some serious shortcomings. The main difficulties are that many people find the texture unpleasant, it is not soluble in water, and sometimes the "fishy" taste is too strong. FPC B itself is not at all "chewy" and it is often found to impart a feeling of grittiness. Since it is insoluble in water it is difficult to incorporate FPC B in many foods and dishes. In spite of these difficulties, limited testing indicates that FPC B can be accepted by the peoples of many developing nations. A summary of the acceptability of FPC B in selected developing nations is shown in table 4.5. The countries in which tests were carried out were ones in which dried fish products played an important role in the diet. It was felt that such countries would most easily adapt to FPC B, since dried fish is in many respects similar to FPC B.

39/ United Nations Food and Agriculture Organization, Report on the Marketing Study of Fish Protein Concentrate (FPC B), Rome, 1980, FAO TF/INT 268 (FH), p. 5.

40/ Ibid., p. 5.

Table 4.5. Acceptance of Fish Protein Concentrate B in selected developing countries

Country	Good acceptance	Rejection	Results inconclusive
Latin America			
Barbados	x		
Brazil			x
Dominican Republic			x
Haiti	x		
Jamaica	x		
Trinidad	x		
Africa			
Egypt		x	
Ghana	x		
Liberia	x		
Malawi			x
Mali	x		
Niger		x	
Senegal	x		
Southern Sudan	x		
Zaire	x		
Asia			
India	x		
Indonesia		x	
Pakistan		x	
Philippines	x		
Sri Lanka	x		
Thailand	x		

Source: United Nations Food and Agriculture Organization, Report on the Marketing Study of Fish Protein Concentrate (FPC) B, Rome, 1980, FAO TF/INT 268 (FH).

It is unlikely that FPC B will become a commercial product on any significant scale in the near future. In order for commercialization to be successful a breakthrough either in product development or in the character of FPC B itself, i.e. in the production technology, will be necessary. However, for any country that is seriously committed to using its by-catch resource to alleviate problems of malnutrition, and is willing to market FPC B through, for example, school nutrition programs, FPC B represents a viable, worthwhile means of reducing waste.

4.1.3 Use of underutilized parts

To a limited extent solid waste can be reduced by making efforts to recover parts ordinarily discarded. Both with finfish and with shellfish the percent of the flesh recovered depends on the efficiency of the workers or, where the operations are mechanized, the machines. Good filleting and picking practices alone can significantly reduce the amount of solid waste. In the case of clams additional meat can be recovered by boiling whole shells or large shell pieces. The mantle is released from the shell after two minutes of boiling, and the adductor muscles can be removed by minor scraping after being cooked in a pressure cooker at 15 psi for 12 minutes at 121°C.[41] Similarly the mantles of scallops are usually discarded although they can be removed fairly easily. This recovered meat can be most easily used in products such as chowders. Finally, in some cases markets exist for fish eggs (roe), livers, and the male reproductive organs (milt). Recovery of such parts can contribute to plant income as well as help reduce waste.

4.2 Feed for animals

Seafood processing wastes are, with a few important exceptions, used as ingredients in animal feeds because they are a relatively inexpensive source of animal proteins. The exceptions are the use of oyster and clam shells in poultry feeds and the use of shrimp wastes for the carotenoid pigments. The most well established product which serves as an ingredient in animal feeds is fish meal. Fish meal is made either from whole fish caught especially for rendering into meal, primarily menhaden, or from waste fish parts, primarily wastes from tuna and salmon processing plants. In order to produce a fish meal of high quality in an economic manner it is necessary to use expensive equipment. This means that a sizable capital investment is required and the plant must be large and operate throughout the year to be profitable. Since most seafood processors in developing countries are not in a position to meet these conditions, when they attempt to produce fish meal it is generally of a low and uneven quality. As a consequence it is generally suggested that seafood processors in developing countries produce fish silage instead of fish meal. Fish silage represents a more viable way for developing countries to produce an animal feed from fish wastes. Since it is, in effect, a substitute for fish meal, the two are discussed together in the following subsection. The use of fish wastes in fish feeds and for bait is discussed subsequently.

4.2.1 Fish silage and fish meal

When produced in the small cottage industries typical of the developing world, fish meal is made by steaming or boiling the waste fish and then pressing them. These operations are basically analogous to the operations performed in a large fish meal plant. The primary difference emerges in the drying procedures. The small operators do not have drying equipment.

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[41] Hood, L. F. and R. R. Zall, "Recovery, Utilization and Treatment of Seafood Processing Wastes", Advances in Fish Science and Technology, Department of Food Science, Cornell University, Ithaca, New York, 1980, p. 358.

Therefore after being pressed the cakes of fish material are left to dry in the sun. During wet seasons or when humidity is high the cakes do not dry properly and their moisture content remains high. The high moisture content leads to the growth of molds and to spoilage.

Table 4.6 shows the content of fish meals made at plants of the type found in developed countries. In contrast to the values shown, samples taken in Indonesia from small cottage industries rarely had moisture contents under 13 percent. In some cases moisture content was as high as 17 percent. In addition protein content was rarely over 50 percent.[42] The low protein content is undesirable since it is primarily for the protein content that fish meals are used in animal feeds.

Table 4.6. Fish meal content, standard fish meal plant

Protein	55-70%	Generally 60-65%
Fats	5-10%	8% Preferred
Water	6-10%	8% Preferred
Ash	12-33%	15-20% Preferred
Fiber	less than 1%	

Source: Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-237.

Fish silage is basically fish wastes that are liquified rather than dried. Properly prepared fish silage will keep without spoiling for at least three months even at warm temperatures (30°C). It may remain in good condition for as long as two years. In preparing fish silage the waste fish or fish parts are minced and mixed with water. The mixture is then either fermented by adding a carbohydrate such as molasses or the solids are liquified through the use of organic acids. The liquification process takes from five to ten days, occurring more quickly at higher temperatures. The only capital investment needed is for the containers in which the silage is prepared and stored. These containers must be acid resistant. Silage can be produced in batches as small as 50 kilograms or in amounts as large as a ton or more a day. If large amounts are to be processed, mincing and mixing devices will also be required. Concrete tanks treated with bitumen can be used to store large quantities of silage.

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[42] Kompiang, I. Putu, "Utilizaton of Trash Fish and Fish Wastes in Indonesia (as Animal Feeds)", in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, pp. 131-137.

The acids usually used to make silage are sulfuric, formic or propionic. They can be used either alone or in combination. Most investigators report that formic acid produces the best product. However, investigators in Indonesia found that poultry did better on fermented silage than on silage prepared with acids. In addition they found that it was necessary to use equal amounts of propionic and formic acid in order to prevent growth of molds and spoilage. In Indonesia the acids were used at the rate of 3 percent (by weight).[43] Although satisfactory results have been reported using as little as 2.2 percent acid, the U.S. Environmental Protection Agency recommends using acid at the rate of 3.5 percent.[44][45]

A fair amount of work has been done testing the use of silage in animal feeding regimes. In practice silage is most often used for feeding hogs. At least in experiments silage has also given good results when used in limited amounts in poultry feeding (up to 8 percent of the dry matter of the diet), as part of the nitrogen supplement given to sheep (up to 10 percent of the supplement), as a partial replacement of the milk proteins given to young calves, and in trout and salmon feeds. Silage can only be used in limited amounts primarily because of its fat content. If silage is given in too large amounts growth rates decline and the animals' flesh can acquire unpleasant tastes. In the case of swine, for example, the diet should not contain more that 1 percent fats of fish origin. Thus if the silage contains 40 percent fats, as it may if made from very oily fish species, the silage could only be used for 2.5 percent of the dry matter of the diet ($.025 \times .40 = .01$).[46] If the 1 percent ceiling on fats is observed, silage can be used for up to 15 percent of the dry matter of hog feeds with good results. In one test hogs fed silage actually showed better weight gains than the hogs receiving fish meal. Further, food conversion efficiences (kilograms consumed per kilogram of weight gained) improved with increasing percents of silage in the diet.[47]

The fact that fish silage can be used in poultry and swine diets is more significant than may be apparent from the relatively low percentages discussed in the previous paragraph. One of the main problems in raising poultry and hogs in developing countries is the low nutritional value of many of the locally available feedstuffs. Often fish meal and/or soybean meal must be imported to supply sufficient protein. As a good source of protein, fish

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[43] Ibid., p. 134.

[44] Austreng, E., "Fish Silage and Its Use", Il Pesce (Italy), Vol. 1, No. 4, December 1984, p. 29.

[45] United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114, p. 40.

[46] Machin, D. H., R. H. Young, and K. Crean, "The Use of Formic Acid Prepared Fish Silage Made from Shrimp By-Catch in the Diets of Fattening Pigs", Tropical Animal Production, Vol. 7, 1982, pp. 120-126.

[47] Ibid., pp. 123 and 125.

silage can replace such products. Thus the conversion of waste or trash fish into silage can provide an opportunity to substitute local for imported goods. Countries which may be trying to increase hog or poultry production should be particularly alert to the possibilities presented by this option. If advantage is to be taken of fish silage two factors should be kept in mind. Since silage is heavy and bulky transportation costs are high. Poultry and hog rearing operations should thus be encouraged to locate in close proximity to seafood plants. Second, if by-catch fish are to be used attention must be given to their oil content. If oil content is high, an antioxidant should be added to the silage to inhibit decomposition of fats. Animals receiving feeds in which fats have decomposed can develop symptoms indicative of toxicosis.

4.2.2 Fish wastes as fish food

Seafood processing wastes can be used as food for fish either in the form of bait or in the form of meals or pellets in aquaculture operations. The use of wastes for bait is perhaps the oldest of all methods for profitable disposal of processing wastes. It can only be utilized, however, where there are lobster or crab fisheries or where sportsmen can make use of the wastes. As with many options, an attendant problem is the preservation of the wastes so that they do not have to be used immediately. One solution to this latter problem is perhaps worthy of mention.

Clam bellies can be used to produce a bait which can be stored for at least five months. The bait can be used in lobster and crab traps and has an advantage over most conventional baits. With most conventional baits the first animal to enter the trap eats up the bait. The clam belly bait is prepared in such a way that it continues to attract animals after the first victims have been caught. The bellies are treated immediately after the clams are shucked with either formic acid or sodium chloride. This prevents them from spoiling. They can then be stored in sealed glass jars for at least five months. Prior to use as bait the bellies are mixed with a gelling agent and canned. Before being placed in the trap a hole is punched in the can so that the contents ooze slowly out. Although not a major contributor to solving waste disposal problems, such a recycling option may be of interest in selected locations.

Of more significance is the use of fish wastes in aquaculture. Aquaculture is an expanding industry worldwide, both developed and developing countries securing increasing percentages of their fish harvests from this source. Significant aquaculture industries exist in both Asia and the Americas. Aquaulture operations are in need of low cost, high quality proteins. Fish diets generally consist of at least 40 percent protein and costs for feeds can amount to 50 percent or more of the costs of running an aquaculture operation. Thus, as a relatively inexpensive source of protein, fish wastes can make a significant contribution to lowering aquaculture operating costs. Although wastes from finfish can be used to supply this protein, wastes from shellfish are of particular interest as either supplements to or substitutes for finfish pellets or meals. Shrimp meal for example can be used for up to 35 percent of the diets of pond raised shrimp and prawn.

Shellfish wastes are of particular interest for two reasons. Shellfish wastes are not as valuable as finfish wastes in either mammalian or poultry feeds. Consequently their market price is much lower. In 1982 for example, crab meal sold for $US 110 per ton while finfish meals sold for $US 478 per ton.[48] Secondly as part of the diet for trout, salmon, and shrimp shellfish wastes provide carotenoid pigments, particularly the pigment astaxanthin. Although synthetic astaxanthin is available it is thought that the naturally occuring astaxanthin found in crustaceans is more readily absorbed by fish. To the extent this is true, shrimp and some crab wastes can offer a product of unique value to the aquaculture industry.

Although regular shrimp meals contain carotenoid pigments, the levels of these pigments vary tremendously depending on the manner in which the meals are prepared. Drying techniques in particular seem to play an important role. As a consequence of the wide variations - ranging from 2 micrograms per gram to 153 micrograms per gram in one study - in amounts of carotenoid pigments in meals, and as a consequence of the importance of these pigments, investigators have looked for ways to extract and concentrate the pigments.[49] Two such methods are described briefly in the next paragraph.

In order to extract the carotenoid pigments, shrimp or crab wastes are ground and heated. Enzymes which function to breakdown proteins are added. When this process is completed soybean oil is added at a 1:1 ratio. The mixture is agitated and heated to 80-90°C for thirty mintues. It is then cooled and put into a centrifuge in order to separate out the oil. The pigment is contained in the oil. Alternatively, the wastes can be ground and treated with acids, in effect creating a silage. The silage is stirred and heated to 40-45°C for one to four hours. Soybean oil is then added, the pigment is absorbed into the oil and the oil again separated out. It has been estimated that in order to be commercially viable the extraction process must result in 60 milligrams of astaxanthin per 100 grams of oil.

4.3 Fertilizers

In the past fish wastes were used extensively as fertilizers. Today they have largely been replaced by petrochemical fertilizers.[50] However, for countries which have seafood processing industries and which are presently importing fertilizer, the use of fish wastes may offer an opportunity for substituting a local for an imported good. Since wastes from finfish have a

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[48] United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114, pp. 36 and 39.

[49] Meyers, Samuel P., "Utilization of Shrimp Processing Wastes in Diets for Fish and Crustacea", Florida Sea Grant College, Report No. 40, 1981, pp. 261-274.

[50] Green, John H. and Joseph F. Mattick, "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, p. 243.

higher value when used for animal feeds, most of the present interest in using seafood wastes for fertilizers focuses on shellfish wastes, crab and shrimp wastes in particular.

The primary difficulty with the use of crab and shrimp wastes as fertilizers is that unless they are processed they must be applied and preferably worked into the soil immediately. For most purposes this means that these wastes can only be used either before planting or after the harvest. Consequently, unless the shrimp and crab harvesting seasons coincide with pre or post planting seasons, this is not a viable option. Where the seasons do coincide the use of crab and shrimp wastes can be economically attractive for farmers. In Oregon in the United States, for example, a group of farmers has established a cooperative to collect and distribute unprocessed shellfish wastes. The wastes are given to the farmers at no cost and the shrimp harvesting season coincides with the time of year when the farmers need fertilizers.[51/]

Crab and shrimp wastes can also be dried and ground prior to being used as fertilizer. The dried and ground products have the advantage that they can be stored for long periods of time and can be easily transported over considerable distances. It is generally assumed that the difficulties of collecting and drying crab or shrimp wastes, along with the costs of operating a processing plant and the limited market for the products rule out this alternative. At least one operator in the coastal United States has found otherwise. He is successfully operating a crab meal production plant which has an annual production of about 800 tons. Further information on costs and revenues of a crab meal production plant are given in chapter six.

4.4 Chemicals: chitin

While a number of chemicals can be derived from seafood processing wastes, the only ones that have the potential for making a significant contribution to waste reduction are those derived from chitin. The chitin derivative which has received the most attention is chitosan. At present chitosan is primarily of interest as a flocculant which can be used in wastewater treatment. In order to obtain chitosan, chitin must be separated from the protein and minerals which, together with the chitin, are the substances from which the exoskeletons of crustacea are composed. As a consequence a number of other products are produced simultaneously with the chitosan: protein, calcium chloride and sodium acetate. The fact that protein is recovered along with the chitosan is, of course, of special interest.

At present processes for the commercial production of chitosan require substantial investments and highly trained technicians. There is little experience with the production processes outside of Japan where chitosan is used both in the treatment of polluted water and in sludge recovery. The

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[51/] Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, p. 299.

literature indicates that it is possible to remove either the proteins or the minerals from the wastes as a first step. If the proteins are to be removed first the wastes are washed with dilute caustic soda (sodium hydroxide) and the proteins precipitated out of the solution. The remaining wastes are then treated with an acid to remove the minerals. Once the minerals have been removed, the remaining material, which is essentially chitin, is treated again with caustic soda to remove the acetyl group (CH_3CO). This results in the chitosan product. A diagram of this process is shown in figure 4.1.

The single commercial producer of chitosan in the United States has found that it takes five to six kilograms of dry crab or shrimp wastes to produce a kilogram of chitin. For each kilogram of chitin produced, a kilogram of protein is also recovered. A kilogram of chitin yields 0.8 kilograms of chitosan.[52] Of considerable interest is the fact that a pilot plant has succeeded in producing high quality chitosan from dried, coarse-ground crabshell meal. Since the dried meal can be shipped considerable distances, if the process proves effective on a commercial scale it will mean that central recycling plants could be built. Shrimp and crab wastes from many processors could then be amassed in sufficient quantities to justify the capital expenses necessary for chitosan recovery.

Chitosan has been tested for effectiveness. Tests compared chitosan to ten commercially available synthetic flocculants commonly used in wastewater treatment. It was found that chitosan was at least as effective if not superior to the synthetic flocculants.[53] Petro-chemical based flocculants sell for $US 3.30 - $US 4.40 per kilogram. It is possible to produce chitosan to sell in this price range. Chitosan has the additional advantages that, unlike synthetic flocculants, it is non-toxic and is biodegradable. In order to compete with the synthetic flocculants it may be necessary to market chitosan in a ready-to-use form. To do this it should be put into a solution. For direct use in wastewater treatment the solution should be at a strength of 1 percent chitosan.

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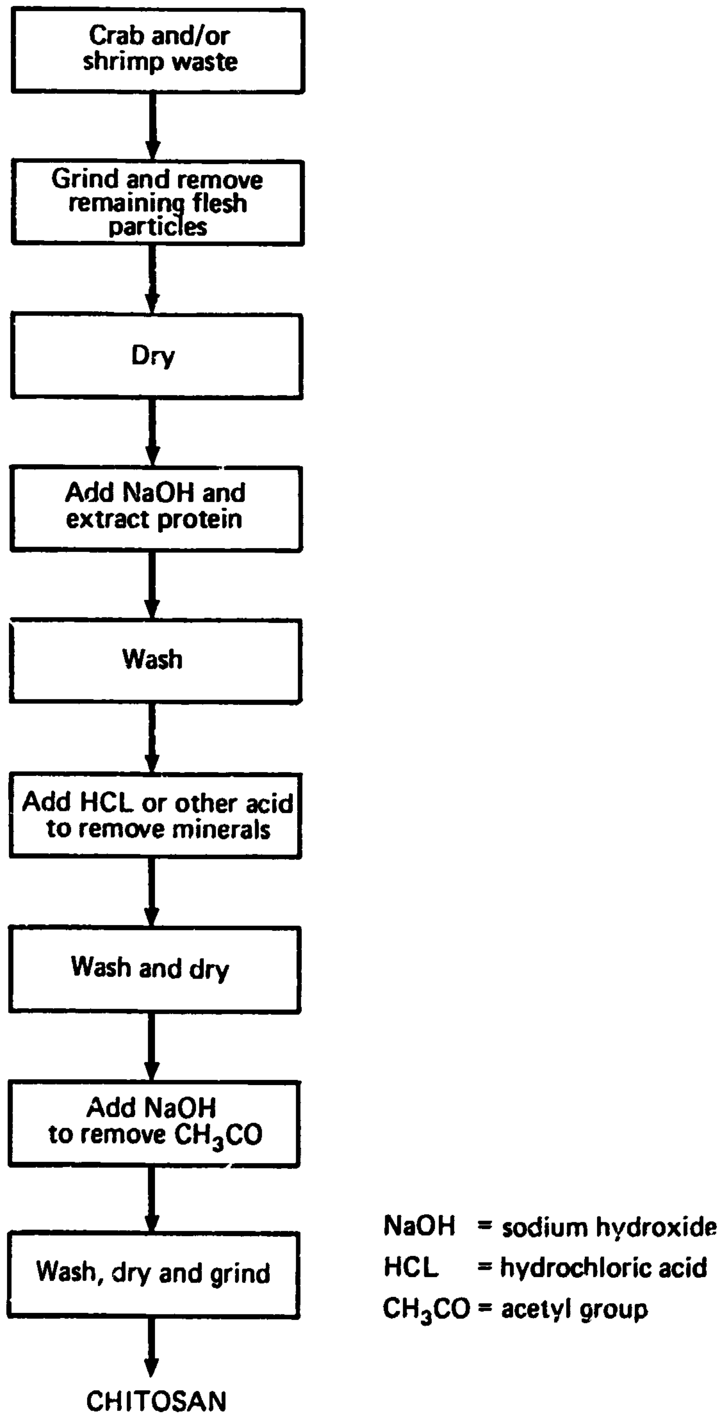
[52] Cantor, Dr. Sydney, "Chitin-Chitosan Production", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 74-83.

[53] Bough, Wayne A., et al, "Utilization of Chitosan for Recovery of Coagulated By-products from Food Processing Wastes and Treatment Systems" in Proceedings of the Sixth National Symposium on Food Processing Wastes, 9-11 April 1975, Madison, WI, EPA-600/2-76-224, p. 31.

Figure 4.1. Schematic of chitosan production process



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

5. WASTEWATER TREATMENT PROCESSES AND BY-PRODUCTS

5.1 Wastewater treatment processes

In most cases wastewater treatment is neither practical nor necessary for seafood processors. Most processors, particularly in developing countries, are small, remote, seasonal operations. They are located in coastal areas where they can discharge directly into waters whose assimilative capacities are adequate to prevent serious negative environmental impacts. In those cases where it has been determined that wastewater discharges are having negative impacts on receiving waters, attempts should be made to reduce water usage. Only if receiving waters continue to exhibit undesirable characteristics after reduction of water usage should wastewater treatment as such be undertaken. In addition to expenses incurred in the treatment process, costs will be incurred in disposing of resulting solids or sludges. The problems and costs of disposing of these solids and sludges may outweigh benefits achieved through wastewater treatment.

A determination of the conditions of receiving waters should include a visual inspection, an analysis of water quality, and an analysis of marine organisms. The visual inspection should determine whether oil or grease films can be seen and ascertain whether floating debris is present. Water quality analysis should include tests to determine dissolved oxygen levels, as well as concentrations of nitrogen, phosphorus and ammonia. Ammonia is released when protein decomposes. If it is present in high concentrations it is an indication that seafood wastes are accumulating. If present in sufficient quantities ammonia can be hazardous to marine life. Phosphorus, like nitrogen, is a nutrient for plants. If too great quantities of phosphorus or nitrogen are available plant growth becomes excessive. The analysis of marine organisms should focus on the relative size and distribution of microscopic protozoa, rotifer, crustacean and benthic populations. Finally, if wastewaters are being discharged into shellfish harvesting waters samples should be taken to determine coliform counts.

If an investigation of the type outlined in the previous paragraph indicates undesirable receiving water conditions, attempts should be made to reduce water usage. Studies in Canada showed that biochemical oxygen demand and suspended solids can be reduced by 50 percent simply by using dry handling techniques rather than flumes to transport whole fish, fillets and offal around the plant.[54/] A reduction of this magnitude should result in significant improvements in receiving water quality. Dry handling techniques for transporting fish include conveyor belts, pneumatic ducts, tote bins and front-end loaders. In addition to the elimination of flumes, water use can be reduced by using hoses with spring-loaded nozzles which shut off automatically when released. Such hoses should be used at evisceration and filleting tables and in general clean-up operations. Water can also be saved by cleaning floors with shovels prior to washing them down. Where fish are packed in ice

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54/ United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII. Fish Processing Industry, Bangkok, 1982, p. 14.

prior to processing, the ice should be separated by physical barriers from the fish. This prevents organic materials from being absorbed into the melted ice thereby reducing the organic load of the wastewater. Finally, where fish are frozen prior to processing they can be thawed with air, or thawing water can be recirculated.

If water reduction measures do not result in satisfactory receiving water conditions, wastewater treatment can be initiated. The simplest form of treatment is grinding. Grinding is the only treatment technology which does not create a solid waste disposal problem. Grinding aids in the assimilation of seafood processing wastes by facilitating dispersal of solids. When solids are dispersed over a larger area the chances of creating septic conditions or smothering bottom dwelling organisms are reduced. Grinding also accelerates decomposition rates. This may or may not be advantageous. If oxygen levels are depressed for shorter periods of time and recover faster, fish and other organisms are under stress for shorter periods and/or can return to an area more quickly. On the other hand, the accelerated rates may mean that oxygen levels fall low enough to result in fish kills.

If grinding in conjuction with a well placed outfall proves inadequate, more sophisticated treatment methods must be employed. The wastewater treatment methods applicable to seafood processors are screening, biological systems, and dissolved air flotation. Dissolved air flotation is discussed last because, although it is in principle a form of primary treatment, it is the most expensive and difficult of the treatment technologies generally used by seafood processors. All of these technologies - screening, biological systems, and dissolved air flotation - create solid wastes and sludges. Few seafood processors can take advantage of existing landfill operations to dispose of their solid wastes and the costs of operating a private landfill are generally prohibitive. Seafood sludges are difficult to dispose of on land because they are notoriously difficult to dewater. The result is that both solids and sludges must often be barged out to sea.

In American Samoa sludges from seafood processors were originally disposed of on land. The water did not percolate into the ground satisfactorily and evaporation was minimal. As a result the disposal sites became breeding grounds for disease carriers and sources of obnoxious odors. The dikes which should have contained the wastes failed, discharging the sludges into adjacent bays. In addition, drinking water sources were in danger of contamination. As a consequence the processors were forced to apply for permission to barge the sludges out to sea.[55/] In view of histories of this type, serious attention must be given to the costs of disposal of the solid wastes and sludges generated prior to embarking on wastewater treatment systems. Even if land disposal is planned, costs and consequences of barging to sea should be reviewed in case land disposal fails to operate satisfactorily.

[55/] United States Federal Register, Vol. 45, No. 166, Monday, August 25, 1980, pp. 56374-56376.

5.1.1 Screens

For most small seafood processors screening will be the most affordable and appropriate wastewater treatment technology, if grinding is inadequate. Screens used in food processing industries are of four types: static, vibrating, rotating, and tangential. There is no general agreement as to which type of screen produces the best results. Some processors have good experiences with static screens, whereas others find it necessary to move to more sophisticated types. The criteria that should be considered in choosing among the four types of screens are as follows: the initial cost of the screen, operating and maintenance costs, the hydraulic capacity of the screen, the hydraulic head which it requires, the speed with which the screen binds or clogs, the percentage of solids captured by the screen, the moisture content of screenings, and the amount of space taken up by the screen. Maximum benefits are obtained from all types of screens when opportunities for proteins and other waste materials to dissolve are minimized. The longer fish solids are in contact with water, the more materials dissolve. As a consequence screens should be located as close as possible to the point where waste materials enter the water stream. Agitation of wastes in water also facilitates the breakdown and dissolving of solids. If pumps, valves or pipes are used in conveyance of the wastewater stream, they should be designed to minimize agitation.

Simple static screens are the type of screen most frequently used by seafood processors. Generally, 20 mesh screens (screens with 20 openings per linear inch) are recommended. The primary limitations of these screens are that they can handle only relatively low flows, and in some cases have been found to bind or clog within as little as ten to thirty minutes. Consequently it is often necessary to devise a method for clearing the screen. Backwashing is the most common method although brushes or scrapers can also be used.

A study of small seafood processors on the eastern coast of the United States showed that static screens, if used in conjunction with good housekeeping practices, were sufficient for crab, clam, and oyster processors to meet the effluent limitation guidelines for suspended solids suggested by the World Bank. Blue crab processors were unable to meet the somewhat stricter limitations (2.2 kilograms per metric ton of crabs processed) set forth by the United States Environmental Protection Agency (U.S.E.P.A.). Finfish processors using only static screens were unable to meet either World Bank or U.S.E.P.A. limitations.[58/] Table 5.1 summarizes effluent limitations proposed by the U.S.E.P.A. and the World Bank.

[58/] United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157.

Table 5.1. Effluent limitations[a/]

	BOD_5		TSS		Oil and grease	
	U.S.[b/]	W.B.	U.S.	W.B.	U.S.	W.B.
Tuna	20.0	2.2	8.3	2.2	2.1	0.27
Salmon	2.7	11.0	2.6	2.8	0.31	2.8
Other finfish	1.2	4.7	3.1-3.6	4.0	1.0-4.3	0.85
Crabs	0.3-10	3.6	2.2-19	3.3	0.6-1.8	1.1
Shrimp	63-155	52.0	110-320	22.0	36-126	4.6
Clams and oysters	none	41.0	24-59	41.0	0.6-2.4	0.62

Note: All U.S.E.P.A. limitations shown are for conventional plants only. U.S.E.P.A. limitations for mechanized plants and for plants engaged in canning operations are considerably higher.

U.S. = United States Environmental Protection Agency

W.B. = The World Bank

[a/] Maximum amount to be discharged in any single day. All figures are kilograms per metric ton of raw material processed.

[b/] BOD_5 limitations from the U.S.E.P.A. are for new sources only. There are no U.S.E.P.A. limitations on BOD_5 for existing plants.

Sources: United States Environmental Protection Agency, "Effluent Guidelines and Standards, Canned and Preserved Seafood Processing Point Source Category", 40 CFR Ch. 1 (7-1-85 Edition), Washington D.C., 1985, pp. 115-180. World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 93.

Vibrating and rotating screens are able to process larger volumes of wastewater than simple static screens. They are more complicated than static screens but do not clog as easily. Vibrating screens may be either circular or rectangular. In rectangular vibrating screens the solids are discharged at the lower end of the screen. With circular vibrating screens the screened out particles may be discharged either to the center or to the periphery. Rotating screens take the form of a drum. They can be designed so that the flow goes from the inside of the drum, through the screen, and then to the outside, or the reverse. If the flow is from the inside to the outside, the solids collected inside the drum are removed by augers or collected in a trough. If the flow is from the outside to the inside the solids remain on the outside and are removed by a scraper. The literature does not report the effectiveness of either vibrating or rotating screens in the seafood industry. This suggests that these screens are rarely used by seafood processors, particularly by small processors.

Tangential screens are the last type of screen used in food processing industries. These screens are used by seafood processors and their effectiveness has been studied. Removal rates of from 40-75 percent for suspended solids are reported.[57] Figure 5.1 provides a picture of a tangential screen. In this type of screen thin layers of the wastewater stream are in effect sliced off by the blades that make up the surface of the screen. The solids remain on the surface and are discharged at the screen's lower end. Typically tangential screens are made of 304 stainless steel. They are 1.83 meters high and have openings of 0.7 to 1.0 millimeters. Use of such tangential screens, together with well designed outfalls, has proved adequate to meet discharge requirements in many cases.[58]

5.1.2 Biological treatment systems

Biological treatment systems are essentially attempts to duplicate nature's process. In natural water bodies the organic load of a wastewater stream is stabilized by bacteria which consume the organic materials. The object of a biological treatment system is to create an artificial environment in which bacteria or other microorganisms can do the same thing. Once a portion of the organic load has been stabilized in the artificial environment, the wastewater is discharged into a natural water body. Biological systems can be set up to operate under either aerobic (in the presence of oxygen) or anaerobic (in the absence of oxygen) conditions. The basic processes can be indicated as follows:

Aerobic treatment process:

Organic matter + bacteria + O_2 + nutrients = more bacteria + CO_2 + H_2O

Anaerobic treatment process:

Organic matter + bacteria + nutrients = more bacteria + CO_2 + CH_4
(CH_4 = methane)

In general anaerobic processes cannot be used by seafood processors. The bacteria normally used in anaerobic systems cannot live in salt water. However, the sludges resulting from aerobic treatment are notoriously difficult to dewater. Thus careful thought must be given to sludge disposal prior to embarking on design of an aerobic treatment system.

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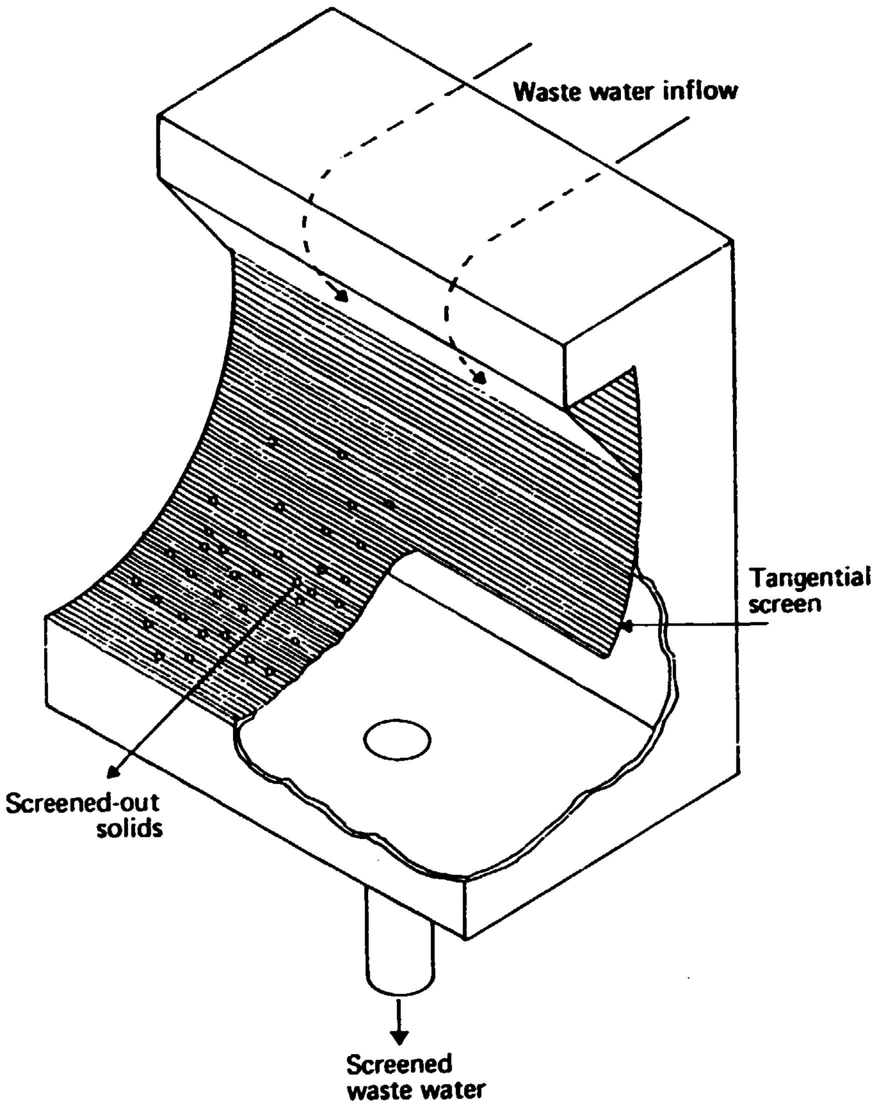
[57] United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII. Fish Processing Industry, Bangkok, 1982, p. 16.

[58] Ibid., p. 14.

Figure 5.1. Tangential screen



Sources: Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979. United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII, Fish Processing Industry, Bangkok, 1982.

Aerobic treatment can take a variety of forms: ponds or lagoons, activated sludge, biological filters or disks, and trickling filters are the most common. Brief descriptions of the more complicated systems are given in table 5.2. However, with the exception of ponds or lagoons - and their artificial equivalent, extended aeration - none of the aerobic treatment systems is suited to small seafood processors. In all aerobic treatment systems other than ponds or lagoons, a colony of bacteria or other microorganisms must be established and maintained. To do this, constant wastewater flow levels must be maintained. Small seafood processors do not generally have a constant wastewater flow, and many have no flow at all during part of the year. Consequently these systems are impractical for small processors. Outside of Japan, complicated biological treatment systems are not generally used even by large processors.

Table 5.2. Aerobic treatment systems

Activated Sludge	First suspended solids are allowed to settle out (primary treatment). Wastewater is then aerated together with microorganisms. Following aeration the wastewater goes to another tank or basin (the clarifier) where microorganisms and debris settle out. Some of the microorganisms are returned to the aeration tank. The remainder are removed for disposal.
Biological Filter	Prior to going to the aeration tank wastewaters are passed through a filter on which microorganisms are encouraged to grow. As in activated sludge, microorganisms from the clarifier are returned to the aeration tank. The clarifier is also the source for the filter microorganisms.
Biological Disks	In place of a standard aeration tank, aeration is accomplished by rotating disks. The disks are mounted on a horizontal shaft. Half of the disks are submerged in the wastewater. As the disks rotate, the wastewater is aerated. Microorganisms grow both on the disks and in the tank.
Trickling Filter	Wastewater is allowed to flow over beds of rocks. Oxygen is supplied by the air and the rocks provide a surface on which microorganisms can grow.

Source: Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979.

Ponds or lagoons are the simplest form of biological treatment. Since ponds and lagoons can accept intermittent inputs without any problem, they are the most appropriate biological treatment system for small seafood processors. Unfortunately the geology of many coastal areas is not suited for either ponds or lagoons. If the coastline is rocky the cost of creating a pond or lagoon is prohibitive. If the coast consists of wetlands, sandy or other highly permeable soils, and/or has a high water table, ponds or lagoons either cannot be created or, if they are created, will endanger drinking water supplies. However, in regions where land is available, relatively cheap, and soil conditions suitable, ponds or lagoons are good solutions to treatment of seafood processing wastes. If the pond or lagoon is not artificially aerated it should be one to two meters deep. BOD_5 loadings should be kept to 9-18 kilograms per 4,000 square meters and wastewaters should be retained for 60 or more days. If the pond is artificially aerated, the depth can be increased to 4 meters or more, but mixing is necessary. For mixing to be adequate, 8-16 horsepower per 3.8 million liters of water is required. In general 0.2 kilograms of sludge is produced for each kilogram of BOD_5 removed. This sludge accumulates and must eventually be removed.[59/]

In areas where ponds or lagoons cannot be established and where treatment beyond screening is necessary, extended aeration is probably the most suitable technology for small seafood processors. Extended aeration is essentially a system where a tank takes the place of the pond. Such systems can be bought ready made, in which case they are called package plants. In such a system wastewater is typically first screened and then pumped to a first tank, called a roughing tank. The wastewater is aerated for several hours and then discharged to a second tank. Aeration is continued and then solids are allowed to settle out. In tests on wastewaters from small seafood processors this type of system achieved 80-90 percent removal of BOD_5. The system was easy to maintain, only requiring cleaning of screens. At the time the study was done, 1973, the estimated cost for such a system was $US 7,000. This included the cost of equipment and installation.[60/]

5.1.3 Dissolved air flotation

Dissolved air flotation is a sophisticated wastewater treatment system used primarily by tuna and salmon processors. It is a form of primary treatment because, rather than trying to duplicate the natural process in which bacteria consume organic material, the process consists of a means of removing suspended solids from the wastewater stream. In ordinary primary treatment systems the initial removal of suspended solids is accomplished by allowing the suspended solids to settle out. This process is often aided by

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[59/] Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979, p. 161-162.

[60/] United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157, p. 29.

the addition of chemicals. The chemicals, called flocculants, bind the solids into large clumps, increasing their mass, with the result that a larger percentage of the suspended solids settle out, and do so more quickly. This system is not effective with seafood wastewaters because of the facility with which seafood solids dissolve.

In dissolved air flotation, rather than letting the suspended solids settle to the bottom, an attempt is made to bring them to the surface. The wastewater is first screened, as in normal primary treatment. It is then mixed with a flocculant and fed into the flotation tank. Some of the wastewater is pumped, along with air, into a pressurization tank. When the pressurized mixture of air and wastewater is released into the flotation cell, small air bubbles, 1-100 microns in diameter, form and rise to the surface. Due both to the action of the flocculants and to the fact that the air bubbles are negatively charged, suspended solids stick to the bubbles and are carried to the surface with them. Chemicals are generally added to the flotation cell both to control the overall acidity level and to foster the negative charge of the bubbles. A skimmer removes the suspended solids from the surface of the water.

If properly designed and operated, dissolved air systems can achieve good removals of suspended solids, BOD_5, and oils and grease. At one plant in California the mean removal rates were: suspended solids, 74.8 percent; BOD_5, 42.9 percent; oil and grease, 83.5 percent. However, at a nearby plant removal rates were much lower: suspended solids, 48.2 percent; BOD_5, 24.3 percent; oil and grease, 64.3 percent.[61/] The main difference was that the concentration of pollutants at the first plant was at least three times as great as at the second plant. The greater concentrations were a result of the fact that the first plant recycled the water used to thaw the tuna.

While the concentration of pollutants in the wastewater is a major factor in performance, it is by no means the only one. Good performance with dissolved air flotation systems depends on alert, trained operators, on maintenance of correct acidity levels in the wastewater, on proper use of coagulants and other chemicals, and on regulation of flow rates. To optimize coagulation of solids as well as to minimize solubility of proteins, the pH of the wastewater should be maintained as close as possible to 4.5-5.0. A plant in American Samoa which was able to maintain the pH in the flotation cell in the 4.2-6.5 range achieved suspended solid removal rates of 95 percent and oil and grease removal rates of 88 percent.[62/] As with the California plant which had a good removal record, concentrations of suspended solids and oil and grease in the wastewater prior to treatment were high.

[61/] Ertz, D. B., J. S. Atwell, and E. H. Forsht, "Dissolved Air Flotation Treatment of Seafood Processing Wastes - An Assessment", in Proceedings 8th National Symposium on Food Processing Wastes, Cincinnati, Ohio, 1977, EPA/600/2-77-184, p. 106-108.

[62/] Ibid., p. 111.

The major drawbacks of dissolved air flotation, aside from the difficulties of correct design and operations, are its cost and the disposal of the resulting sludge. In 1977 initial costs of dissolved air flotation systems were reported at $US 250,000 per plant. Operating costs ran as high as $US 1,000 per day. More than half of the operating cost was attributable to sludge disposal. Since oils and greases are removed along with the suspended solids, the resulting sludge has a high fat content. This high fat content makes it difficult to dewater the sludge. Dewatering with centrifuges has been tried with some success. The high fat content also makes the sludges unsuitable for animal feeds. In the meat and poultry processing industries, sludge from dissolved air flotation systems is often recovered for incorporation into salable products. It is not known whether recovery of sludge from dissolved air flotation systems will be possible in the seafood processing industry.

Dissolved air flotation is the most sophisticated wastewater treatment process used by seafood processors in the west. The Japanese, on the other hand, have experimented with other sophisticated treatment methods. Various activated sludge technologies are reported along with new designs of aeration tanks, and new coagulation methods. The coagulation systems are reported to have achieved BOD_5 removals of 99 percent.[63]

5.2 By-products

As in general in the seafood processing industry, wastewater is of interest primarily due to its high protein content. It was determined, for example, that the wastewater from processing of Alaskan pollock contained 30-60 percent as much protein as the finished product. That is, about half as much protein was lost as was made into food.[64] Although a number of methods for precipitating proteins from wastewaters are reported, only two products can, at present, be considered of commercial interest. The two commercial products, fish solubles and clam juice, are described below. Brief descriptions of some of the experimental products follow.

5.2.1 Fish solubles

The only truly established product recovered from seafood processing wastewater is fish solubles. Fish solubles are produced by fish meal processing plants. Fish solubles are in effect a concentrated stickwater from which the oil has been removed (see section 2.2.4). If the fish solubles are not returned to the fish meal in order to improve its quality, they are generally sold as a liquid fertilizer. Fish solubles containing 50 percent solids have been tested on both decorative houseplants and on vegetable

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[63] Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 53, No. 6, June 1981, p. 788.

[64] Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 55, No. 6, June 1983, p. 684.

crops. Decorative plants grew well, had a good, dark color with a glossy sheen, and aged more slowly than plants fertilized with inorganic fertilizers. Results on vegetables were also good. The fish solubles were tested on tomatoes, lettuce, radishes, peas, corn, and soybeans. Tomatoes, lettuce, radishes and peas were given from 15 to 30 milliliters of fish solubles per 3.8 liters of water. Soybeans were given up to 60 milliliters of soluble per 3.8 liters of water, and corn up to 90 milliliters. In general vegetables fertilized with fish solubles showed growth comparable to that of plants fertilized with inorganic products. Tomatoes were negatively affected if concentrations were too high but the corn crop was considered excellent and soybeans showed significantly improved yields.[65/]

5.2.2 Clam juice

The water from the final wash of minced clam meat can be converted into clam juice. The process is relatively simple, the only drawback being the limited market for the product. To produce the clam juice the wash water is put into a steam-jacketed kettle and boiled. This step is necessary in order to prevent the development of undesirable flavors. It also concentrates the liquid. The water is boiled for 10 to 60 minutes depending on the desired concentration of solids in the finished product. After boiling the juice is canned and retorted. Retorting is critical in obtaining a high quality product as it results in a sweeter flavor. Once retorted clam juice remains in good condition for at least six months at room temperature.

5.2.3 Protein extraction and related experimental processes

A number of chemicals have been tried in order to coagulate and precipitate the dissolved proteins from seafood processing wastewaters. Sulfuric acid (H_2SO_4), $FeCl_3$, and calcium chloride ($CaCl_2$), have all been found effective.[66/67/68/] It has also been reported that the maximum amount of protein and oil is recovered from bloodwater if the bloodwater is

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[65/] Aung, L. H., et.al., "Fish and Seafood Wastes as Nutrients for Agricultural Crop Fertilization", Florida Sea Grant College, Report No. 40, 1981, pp. 275-279.

[66/] Hang, Y. D., E. E. Woodams, and G. F. Parsons, "Isolation and Chemical Evaluation of Protein from Clam Wash Water", Journal of Food Science, Vol. 45, 1980, pp. 1040-1041.

[67/] Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 54, No. 6, p. 690.

[68/] Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 55, No. 6, p. 684.

heated to between 65°C and 80°C and the pH is adjusted to between 5.6 and 5.9.[69] In precipitating proteins from clam wash water sulfuric acid was used. Sufficient 10N H_2SO_4 was used to bring the pH down to 4.0. After a minute of stirring at 100 rpm, the mixture was stirred at 30 rpm for five minutes. It was then allowed to settle for one hour. The resulting precipitate was centrifuged and freeze dried. This method recovered approximately 40 percent of the protein present in the wash water. The product itself contained 67.9 percent protein, 1.22 percent fat, 0.32 percent fiber and 4.92 percent ash. Not all amino acids were present in sufficient quantities to meet the standard recommended by the Food and Agricultural Organization (FAO). Valine and Leucine concentrations were particularly low, representing only 80 percent of the recommended amounts.[70] Table 5.3 presents the FAO recommended amino acid profile for protein. Given the limitations of proteins obtained from clam wash water, this product would have to be combined with other products to provide good nutrition.

Table 5.3. Amino acid profile recommended by FAO (grams amino acid per 100 grams of protein)

Alanine	6.1
Arginine	5.2
Aspartic acid	7.7
Cystine	1.69
Glutamic acid	14.7
Glycine	2.2
Histidine	2.5
Isoleucine	4.0
Leucine	7.0
Lysine	5.4
Phenylalanine	3.05
Proline	10.7
Serine	7.7
Sulfur	3.5
Threonine	4.0
Tyrosine	3.05
Tryptophan	1.0
Valine	5.0

Source: Ooshiro, Zentaro, et.al., "Approaches to the Use of Plastein Reaction in Oily Fish", Memoirs Faculty of Fisheries, Kagoshima University Vol. 30, Japan, December 1982, pp. 369-382.

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[69] Ibid., p. 684.

[70] Hang, Y. D., E. E. Woodams, and G. F. Parsons, "Isolation and Chemical Evaluation of Protein from Clam Wash Water", Journal of Food Science, Vol. 45, 1980, pp. 1040-1041.

Other approaches under investigation for recovery or utilization of the protein available in seafood processing wastewater include the precipitation of plastein, a substance resembling protein, and the production of proteases, enzymes active in the digestion of protein. In the precipitation of plastein, proteins that have dissolved into the wastewater are recovered through the use of enzymes. Both the nutritional value of the plastein obtained and the extent to which the plastein is water soluble depend on the enzymes used. In one series of experiments, plasteins derived from the enzymes Molsin and Bioprase were tested. The plasteins contained 78-83 percent protein, and had amino acid profiles approaching the FAO standard. The Bioprase derived plastein had the better amino acid profile. Only Leucine and Tryptophan failed to meet the standard. Leucine was present in 83 percent of the recommended amount (5.8 grams per 100 grams of protein). There was no Tryptophan. Molsine derived plastein had only 60 percent of the recommended amount of Leucine. In addition only 90 percent of the recommended amounts of Isoleucine, Phenylalanine and Tyrosine were present. Tryptophan was again absent.[71/]

While the above described work has shown that it is possible to precipitate proteins and protein-like substances from seafood processing wastewaters, such precipitation does not result in commercially marketable products. In order to market either precipitated protein or plastein, the precipitate would have to be incorporated into as yet undefined products. An alternative approach, which yields a product that can be directly marketed, is the production of enzymes. Enzymes command high prices, and if the process involved proves feasible at industrial scales this approach could provide an attractive wastewater recycling option.

The basic theory behind enzyme production is that enzymes can be produced by fermenting seafood processing plant effluent. Small scale tests, performed in 4 liter capacity fermentation tanks, have given promising results. In the tests stickwater diluted with tapwater at a ratio of 2 percent stickwater to 98 percent tapwater was used. This was considered appropriate as the nutrients in the stickwater were similar to those present in normal seafood plant wastewaters. The best results were obtained when protein concentrations were equivalent to 4 milligrams of bovine serum albumin (BSA) per milliliter of wastewater. Yield was also greatest if the pH of the solution was adjusted to 7 prior to fermentation. However pH values from 5 to 8 also gave satisfactory yields. Although plain stickwater will produce enzymes, it was found that the addition of some carbohydrates greatly increased yields. If either glucose or mannose ($C_6H_{12}O_6$) were added at the rate of 1 percent (weight to volume), enzyme yields were tripled. Other carbohydrates tested were not effective in increasing yields. In the experiments various rates of agitation - from 300 rpm to 750 rpm - as well as various aeration rates were tried. If a process of this type is to be scaled up to commercial volumes, it is believed that careful attention will have to be given to aeration rates. Agitator speeds as well as levels of protein concentration will need to be optimized.[72/]

[71/] Ooshiro, Zentaro, et.al., "Approaches to the Use of Plastein Reaction in Oily Fish", Memoirs Faculty of Fisheries, Kagoshima University (Japan), Vol. 30, December 1982, pp. 369-382.

[72/] Wah-On, H. C., et al., "Protease Production by Fermentation of Fish Solubles from Salmon Canning Processes", Canadian Journal of Microbiology, Vol. 26, 1980, pp. 1049-10[illegible]6.

6. ECONOMICS OF BY-PRODUCT PRODUCTION AND SOLID WASTE RECYCLING

Available literature provides very few details of specific costs involved in manufacturing by-products from seafood processing wastes. What little information is available is from the United States. This cost information can therefore only be used as a general guide for developing countries interested in making initial estimates of feasibility. Actual costs for many of the items, particularly labor costs, costs of construction, and energy costs, will certainly be considerably different in most developing countries.

Table 6.1 shows selling prices for most of the significant products which can be manufactured from seafood processing wastes. Where available selling prices for previous as well as recent years are shown. The literature does not provide any cost or profitability data for the production of either mince or FPC B. In the United States it is generally held that the profitability of a fish meal plant depends on the sale of the fish oil.[73] Fish meal plants produce, in addition to the meal, both fish solubles and fish oil. However, the amount of oil produced depends greatly on the species of fish processed. For example, on the Atlantic coast of the United States, for every 50 tons of fish processed, one ton of fish meal, 0.7 tons of fish solubles, and 0.2 tons of oil are produced. In the Gulf of Mexico however, for every 50 tons of fish processed 1.10 tons of oil are produced. The amounts of fish meal and fish solubles are the same as on the Atlantic coast. The additional 0.9 tons of oil produced at Gulf of Mexico plants represent an additional income of $US 324 to $US 356 per fifty tons of fish processed. Looked at another way, if the sale of fish meal and fish solubles covers the costs of operating a fish meal plant, the Atlantic coast plants have a profitability of $US 72 to $US 79 per fifty tons processed while the Gulf coast plants have a profitability of $US 396 to $US 435 per fifty tons processed. However, the price history of fish meal shows fluctuations of over $US 250 per ton. Thus, if the sale of fish meal and fish solubles covers the costs of operation in average years, when the price of fish meal drops, only plants which produce relatively large amounts of oil will remain profitable. The next subsections provide cost information for the production of crab meal and chitosan.

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[73] Dressel, David, "Scrap Handling Practices Nationwide", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 26-30.

Table 6.1. Selling prices for products made from seafood wastes

Product	Selling Price (US dollars)	Year	Source
Mince (shellfish)	2.20-2.75/kg	1979-80	1
FPC B	900/ton	1980	2
Fish meal	527/ton	1973	3
	270/ton	1975	3
	380/ton	1980	4
	478/ton	1983	3
Fish oil	360/ton	1979-80	4
	396/ton	1983	3
Fish solubles	77/ton	1979-80	4
Crab meal	121/ton	1979-80	4
	110/ton	1983	3
Shrimp meal	71/ton	1979-80	4
Fish silage	100/ton	1983	3
Chitin	3.30/kg	1979-80	5
Protein from crustacean shells	0.77/kg	1977	6
Glucoseamine[a/]	22-33/kg	1979-80	7
Carotenoid pigment	88/kg	1979-80	7

[a/] Glucoseamine is an amino derivative which can be produced from chitin and is used in pharmaceuticals.

Sources:

1. Learson, Robert J., "A Look at the Options", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 109-112.

2. United Nations Food and Agriculture Organization, Report on the Marketing Study of Fish Protein Concentrate (FPC) B, Rome, 1980, FAO TF/INT 268 (FH).

3. United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114.

4. Drèssel, David, "Scrap Handling Practices Nationwide", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 26-30.

5. Fryer, Lee, "Protein Extraction", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 68-73.

6. Johnson, Edwin Lee and Quintin P. Peniston, "The Production of Chitin and Chitosan", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology Sea Grant Report No. MITSG 78-7, Cambridge, MA, 1978, pp. 80-87.

7. Cantor, Dr. Sydney, "Chitin-Chitosan Production", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 74-83.

6.1 Crab meal production

There is a general belief that due to costs of transportation and drying, and to the relatively low prices and limited market for crab meal, its manufacture is not profitable. However, there is reason to believe that the lack of profitability in most crab meal operations is due to use of inefficient plants with old, outdated equipment.[74] Both feasibility analysis of costs and revenues and the experience of a modern plant owner indicate that a crab meal plant producing between 800 and 1,300 tons per year can be profitable.

Table 6.2 shows the initial investment as of 1979-80 required for a crab meal plant capable of producing up to 1,800 tons of meal annually. No cost for land is included since land costs vary widely from region to region.

Table 6.2. Initial investment for 1,800 ton per year crab meal production plant

Equipment	
Dryer	$ 42,114
Feeding equipment	19,188
Mill	4,128
Air lock and vapor duct	9,025
Conveyors	9,600
Heat resistant material	2,300
Front end loader	9,500
	$ 95,855
Installation	$ 35,040
Building	24,000
Concrete slab	4,800
Total initial investment	$159,695

Source: Murray, Thomas, "Crab Meal Production: Costs and Returns", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 38-45.

[74] Learson, Robert, J., "A Look at the Options", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 109-112.

Table 6.3 shows annual costs and revenues if the plant is operating at a 1,200 tons per year level. The depreciation shown is for equipment only. Both the cost of the equipment itself and the cost of installation are depreciated over 15 years. Straight line depreciation is assumed, with zero value remaining at the end of the 15 years. In calculating the payments for borrowed money, i.e. the amount of principal and interest due, it was assumed that the entire amount needed for the initial investment, plus $US 4,000 to cover the taxes and insurance in the first year, would be borrowed. A seven year payback period and a 12 percent interest rate were used to calculate annual payments.

Table 6.3. Annual costs and revenues for a plant producing 1,200 tons of crab meal per year[a]

Fixed costs	
Depreciation	$ 8,726
Plant manager	17,000
Principal and interest	35,849
Insurance and taxes	4,000
Miscellaneous	1,500
Total fixed costs	$ 67,075
Variable costs	
Fuel	$ 27,600
Maintenance and repair	1,309
Electricity	2,848
Marketing	3,600
Office supplies	500
Telephone	500
Labor - salary and benefits	7,821
Total variable costs	$ 44,178
TOTAL ANNUAL COSTS	$111,253
ANNUAL REVENUES[b]	120,000
NET REVENUE	$ 8,747

[a] All prices shown are in 1979-80 dollars.

[b] Revenues are based on a selling price for the crab meal of $US 100 per ton. This selling price is in turn based on the assumption that the crab meal will be 31 percent protein. The higher the protein content, the higher the price the meal commands.

Source: Ibid.

As can be seen from table 6.3, the two largest items in the budget are for repayment of the loan and for fuel. As shown, both of these costs are almost certainly higher than they would be in actual practice. In the first place, it is unusual to borrow the entire sum needed for the initial investment. Annual costs can be lowered considerably by reducing the amount borrowed. In the second place, fuel costs are almost certainly overestimated. In calculating fuel costs it was estimated that the plant would be operating at 65 percent of capacity. At this level it was assumed that the dryer would consume 30 gallons of fuel per hour. The cost of fuel was set at $US 1.13 per gallon. However, a crab meal plant of this size actually operating at 65 percent of capacity experienced a fuel consumption rate of only 22 gallons per hour.[75] Thus the fuel costs shown in table 6.3 may be overestimated by some $US 7,000. This is extremely significant for profitability. As shown in table 6.3, net revenues for a plant producing 1,200 tons of crab meal annually is $US 8,747. Lowering fuel costs by some $US 7,000 would have the effect of almost doubling net revenue. The $US 8,747 net revenue shown represents a 5 percent return on investment. However, if net revenues are closer to $US 15,000, return on investment would be closer to 10 percent. A 10 percent return approaches the level necessary to consider an investment justifiable. This means that a more realistic estimate of fuel costs, particularly if coupled with borrowing less than 100 percent of the capital needed for the initial investment, would show a crab meal plant producing 1,200 tons annually as a profitable enterprise. That this is almost certainly the case is testified by the fact that an existing plant producing 800 tons annually is doing well.[76]

6.1.1 Chitosan production

Table 6.4 presents cost data for a plant designed to produce 450 tons of chitosan annually. Such a plant needs to produce 560 tons of chitin (see section 4.4), and will simultaneously produce 560 tons of protein. The authors of the data shown in table 6.4, Johnson and Peniston, assumed that chitin yield would represent 8.33 percent of the amount of waste processed. That is, in order to produce 560 tons of chitin, some 6,720 tons of waste would have to be processed. Since waste represents approximately half of the live weight of crabs, a plant of this size would have to have a 13,440 ton crab harvest as a source of supply. Since it was considered unlikely that any one location could provide tonnage of this magnitude, it was assumed that a portion of the waste would be shipped from other locations. The raw material cost shown as the first item in table 6.4 reflects costs involved in obtaining crab wastes from distant locations. In order to be shipped the wastes would first have to be dried. Total cost for drying and shipping was estimated at $US 0.55 per kilogram of chitosan produced. The raw material cost shown, $US 0.22, indicates that roughly 60 percent of the needed raw materials would be supplied locally at no cost. The other 40 percent would be obtained from more distant processors.

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[75] Conley, Weston, "Running a Crab Meal Plant", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 35-37.

[76] Ibid., p. 35.

Table 6.4. Production costs for chitosan (costs shown are per kilogram of chitosan produced)

Raw materials	$ 0.22
Chemicals	
HCl	0.38
NaOH	0.26
Labor	0.51
Steam	0.23
Water and electricity	0.11
Maintenance	0.04
Overhead	0.11
Amortization of investment	0.13
TOTAL	$ 1.99

Source: Johnson, Edwin Lee and Quintin P. Peniston, "The Production of Chitin and Chitosan", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology Sea Grant Report No. MITSG 78-7, Cambridge, MA, 1978, pp. 80-87.

The chemical costs shown in table 6.4 are based on a price of $US 55 per ton of 23 percent hydrochloric acid solution and $US 160 per ton of sodium hydroxide in a 50 percent solution. Labor costs are for fifteen men at $US 5 per hour, plus salaries for managers totalling $US 50,000 per year. It was assumed that heat would cost $US 4 per million BTU (British Thermal Unit). Maintenance was set at 5 percent of the cost of equipment, cost of equipment being $US 350,000. Overhead was estimated to amount to $US 50,000 annually. The total investment cost, $US 600,000, was amortized at 10 percent annually.

In order to calculate profitability Johnson and Peniston assumed that the chitosan could be sold for $US 4.40 per kilogram, and that the protein could sell for $US .77 per kilogram. Using these figures, the net income from a chitosan production plant in 1978 worked out as shown in table 6.5.

Table 6.5. Income and expenditure summary, chitosan production facility

Income		
Chitosan	- 450 tons at $4,400 per ton	$1,980,000
Protein	- 560 tons at $ 770 per ton	431,200
Total income		$2,411,200
Expenditures		
Manufacturing cost	- 450 tons at $1,990 per ton	$ 895,500
Costs related to sales	- 15 percent of sales	361,680
Total expenditure		$1,257,180
NET INCOME BEFORE TAXES		$1,154,020

Source: Johnson, Edwin Lee and Quintin P. Peniston, "The Production of Chitin and Chitosan", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology Sea Grant Report No. MITSG 78-7, Cambridge, MA, 1978, pp. 80-87.

Although the plant as envisioned by Johnson and Peniston required a 13,440 ton crab harvest and a $US 600,000 initial investment, practical experience indicates: 1) that to produce 450 tons of chitosan an even larger crab harvest would be required, and 2) that it is possible to produce chitosan profitably in much smaller, less expensive plants. Actual experience indicates that chitin yields amount to only 5-6 percent of waste, rather than the 8.33 percent envisioned by Johnson and Peniston.[77] Thus a plant producing 450 tons of chitosan annually would actually require a crab harvest of close to 20,000 tons. On the other hand, a company in the U.S. that has been involved in supplying technology for protein and chitin extraction believed that a profitable chitin/protein extraction plant could be built for $US 250,000 in 1980.[78]

[77] Fryer, Lee, "Protein Extraction", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 68-73.

[78] Ibid., p. 73.

7. COSTS OF WASTEWATER TREATMENT

No studies of actual costs encountered in treatment of seafood processing wastewater are reported in the literature. In 1975 Battelle Laboratory made estimates of what it would cost for small seafood processors to screen their wastewater. They estimated that small finfish plants would have initial capital costs of some $US 55,000 and annual operation and maintenance costs of $US 9,200. Small crab processors would have capital costs of $US 33,000 and annual costs of $US 8,200. The capital costs for small clam processors would be $US 22,500, and for small oyster processors $US 16,100. both clam and oyster processors would have operation and maintenance costs of $US 8,100 annually.[79] To estimate costs for other types of wastewater treatment and to relate costs more specifically to plant size and volume of wastewater flow, the United States Environmental Protection Agency provided formulas. The formulas are based on costs calculated in 1971 dollars. Consequently use of these formulas in 1987 in countries outside of the United States must be undertaken with extreme caution. The formulas are presented in tables 7.1 and 7.2. Table 7.1 gives formulas for plants with flows under 190 liters per minute; table 7.2 gives the corresponding formulas for plants having flows of over 190 liters per minute.

Table 7.1. Formulas for calculating wastewater treatment costs - plants with flows under 190 liters per minute

	Capital cost, 1971 $US	Operation & maintenance Costs per day, 1971 $US
Screening	5,000 + (760)F	(6 + .08F)A
Lagoon	[5,000 + (3,410)F]A	(7 + .12F)A
Extended	[22,000 + (7,880)F]A	(10 + .26F)A
Flotation	15,000 + (2,270)F + (7.9)S	(20 + .55F)A

F = wastewater flow in liters per minute
A = number of hours of operation per day divided by 16
S = dry weight of solids removed per day in kilograms

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 229.

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[79] United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157, pp. 3 and 39.

Table 7.2. Formulas for calculating wastewater treatment costs - plants with flows over 190 liters per minute

	Capital cost, 1971 $US	Operation & maintenance Costs per day, 1971 $US
Screening	12,330 + (200)F	(6 + .08F)A
Lagoon	[46,600 + (250)F]A	(7 + .12F)A
Extended aeration	[110,000 + (1,210)F)]A	(10 + .26F)A
Flotation	35,000 + (760)F + (7.9)S	(20 + .55F)A

Source: Ibid.

For finfish plants with wastewater flows on the order of 100 liters per minutes, table 7.3 provides an alternate estimate of wastewater treatment costs. These costs were estimated in 1975.

Table 7.3. Wastewater treatment costs for finfish plants having flows of approximately 100 liters per minute

	Capital cost (US dollars)	Operation & maintenance costs per day (US dollars)
Screening	12,000	4
Screening plus aerated lagoon	28,000	9
Screening plus flotation	46,000	17
Screening, flotation, and aerated lagoon	62,000	22
Screening, flotation and extended aeration	88,000	25

Source: United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII. Fish Processing Industry, Bangkok, 1982.

In addition to providing formulas to calculate the costs of wastewater treatment systems, the United States Environmental Protection Agency made estimates of the costs involved in reducing water flows. The costs represent initial investment required to replace flumes with dry handling systems such as tote bins or pneumatic conveyors, costs for high pressure hoses with spring-loaded nozzles or similar devices to reduce water used in washdown, and the costs to operate and maintain such equipment. Any savings that might accrue to processors from reduced water bills have not been factored in. Table 7.4 summarizes the estimates made by the United States Environmental Protection Agency in 1975 for implementing water reduction measures.

Table 7.4. Costs for water reduction systems

	Goal	Capital cost ($US)	O & M cost per day ($US)	Flow reduction achieved (percentage)	Plant size[a]
Conventional finfish	Reduce wash water	3,000	1	20	43
Mechanized finfish	Eliminate flumes	5,000	1	20	49
Mechanized clams	Reduce wash water	15,000	13	12	265
Oysters	Reduce wash water	15,000	14	14	8
Conventional salmon	Reduce wash water	16,000	77	10	35
Mechanized salmon	Reduce wash water	15,000	20	15	40
	Eliminate flumes	12,000	6	7	

[a] Plant size is given in tons of final product produced per day.

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 229.

The reduction of water used in washdown shown in table 7.4 for a conventional finfish plant is estimated to result in a 15 percent reduction of BOD_5 in the wastewater stream. The elimination of flumes in a mechanized finfish plant would lead to a 20 percent reduction of BOD_5. Significant reductions in wastewater BOD_5 would also be achieved in the case of oyster plants (a 30 percent reduction), and in conventional salmon plants (a 10 percent reduction). Only 7 percent reduction in BOD_5 is expected in the case of mechanized clam plants, and only 4 percent in the case of mechanized salmon plants.[10]

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[10] Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 229.

8. HEALTH AND SAFETY

The primary health problems in the seafood processing industry are dermatological. Skin infections, warts and various rashes may result from viruses and bacteria in the fish and from various chemicals used in preservation. In order to reduce the incidence of dermatological problems, as well as to protect the quality of the fish product, the highest sanitary standards should be maintained. Showering facilities should be provided, workers should be encouraged to wash before eating, and an eating area separated from work areas should be provided. In addition walls, floors, work areas and equipment should be washed with hot, pressurized water daily. Disinfectants should be used regularly.

Where canning and retorting operations are present, high temperatures and humidity levels, as well as excessive noise can also cause health problems. To reduce ill effects of high temperatures and humidity, cool drinking water and salt tablets should be available to workers. If high temperatures and/or humidity continue to cause problems, efforts should be made to improve ventilation systems. Noise levels above 90 decibels lead to increased accident rates. Workers should wear ear muffs when they have to work close to machinery creating noise at or above 90 decibels. If it is necessary to station workers close to such machinery for extended periods of time, they should be provided with a noise insulated room. Efforts should also be made to reduce noise levels. Noise levels can be reduced through good maintainance of mechanical equipment, the use of sound absorbent materials, nylon-coated cables, and proper adjustment of can conveyor systems.

Most accidents in the seafood processing industry are due to falls, cuts, and strains from lifting. In canning procedures accidents also may result from falling objects, burns from hot liquors and equipment, and from spills of acids and alkalis. The thorough, daily cleaning of floors required to maintain high sanitary standards will help reduce falls by eliminating grease and other slippery materials. In addition, floors should be covered with non-slip materials and be well drained. In order to reduce injuries from cuts, broken glass and tin scraps should be cleaned up promptly. To prevent injuries due to lifting, mechanical equipment should be provided wherever heavy loads must be moved. Table 8.1 summarizes additional procedures recommended by the World Bank to protect the health and safety of workers. Due to the need to maintain the highest sanitary standards, The World Bank also recommends that seafood processing facilities be subject to frequent government inspection.

Table 8.1. Health and safety maintenance procedures

1. Walls should be of ceramic material to allow for complete cleaning.

2. Mechanical equipment must have guards to protect workers from injury. Drums, pulleys and gears should be protected. In canning operations filling and closing machines should be totally enclosed except for intake and discharge openings.

3. All electrical installation and equipment should be in accordance with National Electrical Code standards. Electrical equipment should be grounded and checked regularly for defective insulation.

4. Steam pipes should be provided with thermal insulation.

5. Windows should be provided with screens to prevent insects from entering.

6. Elevated platforms, walkways, stairways and ramps should be provided with handrails, toeboards and non-slip surfaces.

7. Passage-ways for carts and workers must be adequate, and signs for exits and doorways easily visible.

8. Where boilers are used, workers responsible for clea[illegible] them should be provided with protective clothing, masks and footwear. [illegible]mergency eyewash and shower facilities should be available.

9. Where workers have to enter tanks or other enclo[illegible] areas they must be provided with self contained air respirators or w[illegible] respirator that receives air from the outside through a supply h[illegible] second worker should be stationed outside the tank or enclosed are[illegible] to watch to see that the worker inside is safe.

10. All workers should be given pre-employment and periodic medical examinations. To avoid tetanus, workers shoul[illegible] obtain immediate first aid after any cut.

11. Employees should be instructed in personal hygiene, sanitation, and safety practices. They should be given instruction in the proper use of all equipment including equipment for their personal protection, in safe lifting practices and in the location and handling of fire extinguishers.

Source: The World Bank, Office of Environmental Guidelines, Environmental Guidelines, Washington, D.C., 1984.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 For governments

In order to protect their seafood industries, governments should participate in international efforts to monitor fish populations and, where necessary, regulate fishing activity.

Governments should be alert to the limited number of situations which may require wastewater treatment. Processors located inland or along bays or similar geographic configurations where flushing action is poor should be monitored. Discharges from any large processors should also be monitored as should discharges into shellfish harvesting waters.

The most direct way for developing countries to reduce the volume of seafood wasted and to increase the amount of food produced is to increase refrigeration capacity. Increased refrigeration capacity on vessels and at processing sites would reduce spoilage of fish. Spoilage is responsible for a considerable amount of waste in developing countries.

Fish silage is of particular value in the raising of hogs and poultry. Countries which are trying to increase hog or poultry production should give serious attention to the feasibility of locating such enterprises in close proximity to seafood processors. In many cases hog and poultry production in developing countries is hampered by a scarcity of high quality proteins. Fish silage can supply this protein, but it is heavy and bulky and can only be economically transported over short distances.

Shrimp and some crab wastes are of particular interest as feeds for pond-raised trout, salmon and shrimp. Feeds containing shrimp and red crab wastes supply pigments necessary to give pond raised species the desired coloration. Shrimp feeds are also of value in shrimp rearing as a stimulant to feeding behavior. Any country which has, or is developing, an aquaculture industry should consider the feasibility of using shrimp and crab wastes. Such wastes can help reduce aquaculture production costs.

Countries where malnutrition is widespread, and where considerable volumes of waste are generated in one locality, may wish to consider the feasibility of producing fish protein concentrate.

Due to the need to maintain the highest sanitary standards, it is recommended that governments regularly inspect seafood processing facilities.

9.2 For industry

9.2.1 Recycling

The seafood industry generates a tremendous amount of waste. This waste is of interest primarily because of its potential to be exploited as a source of food. Seafood wastes have a high protein content. The protein contains all the amino acids necessary for good nutrition, and the wastes provide, additionally, a range of important vitamins and minerals.

By-catch - the undesired species caught in the process of harvesting the sought after species - represents a potentially very large source of food for developing countries. By-catch is, at present, usually dumped at sea. Work is underway to develop technologies capable of turning by-catch, particularly by-catch from shrimp harvesting operations, into minced fish. Products based on these minces are also being developed. It is hoped that these efforts will result in products of sufficient market strength to render the landing of by-catch profitable. If this occurs, the waste generated by the seafood processing industry will be substantially reduced.

In addition to waste from spoilage and by-catch, waste is generated during processing. Only 25-45 percent of a finfish ends up as a food product. The rest is waste. If this waste is recaptured rather than discharged in the wastewater stream, it can be utilized in a number of ways. The most appropriate uses will depend on local conditions and markets. Major uses for finfish wastes include: minces, fish meal, fertilizers, and fish silage. Under special circumstances the manufacture of glue, vitamins, cooking oils, or the use of wastes as bait may prove economically attractive. For the average small producer, the manufacture of fish silage or agreements with local farmers to supply fertilizer will be the most practical recycling options.

Shrimp and crab wastes can be made into a meal analogous to fish meal. Since shrimp and crab meals have less protein than finfish-based meals, they are less valuable as animal feed supplements. Where seasons coincide, shrimp and crab wastes can be used as fertilizer. The shells of shrimp, crabs and other crustacea are of interest as a source of chitosan. Chitosan can be used for wastewater treatment. Outside of Japan, however, chitosan must be considered a product which has yet to be proven in the market.

Where large amounts of oysters and/or clams are harvested, the shells can be expolited either for their lime content - to produce cement or as a soil conditioner - or can be used for landfill or roadbed material. Oyster and clam wastes can also be fed to hogs and poultry.

9.2.2 Wastewater treatment

The vast majority of seafood processing plants are small, seasonal operations, located in remote areas. Treatment of wastewater is usually neither economically viable nor necessary on environmental grounds. Seafood processing wastes are highly biodegradable and non-toxic. They are usually discharged into water bodies which have sufficient capacity to assimilate the wastes.

A determination that wastewater treatment is necessary should not be based solely on an analysis of the wastewater stream's characteristics. An investigation of actual conditions in the receiving water body should be undertaken. The investigation should include a visual inspection to determine whether oil, grease, or floating debris is present. Dissolved oxygen levels and concentrations of nitrogen, phosphorus and ammonia should be analysed. The investigation should include a study of the size and relative distribution of marine microorganisms and benthic populations.

Where an investigation of receiving water conditions indicates that discharges are having a negative impact on receiving water quality, and where simple grinding of solids and/or redesign of the outfall will not solve the problem, water reduction measures should be undertaken. Wastewater treatment should only be undertaken if water-use reduction measures prove insufficient to solve receiving water quality problems.

In cases where wastewater treatment is necessary, careful attention should be paid to the disposal of resulting solids and sludges. In many coastal locations geological factors - rocky terrain, sandy soils, wetlands, or high water tables - render the use of landfill for waste disposal impractical or undesirable. In addition, seafood wastes spoil extremely quickly. Even if landfill is feasible on geological grounds, unless great care is taken landfills accepting seafood wastes can become sources of obnoxious odors, and can attract insects and vermin, thus creating public health hazards. Seafood sludges are notoriously difficult to dewater. Attempts at land disposal of sludges have failed with the result that the sludges have had to be barged to sea with the attendant expenses.

The most appropriate wastewater treatment technology for small seafood processors is the use of screens. Good results with both static and tangential screens are reported by seafood processors. Ponds, lagoons, and extended aeration are the only biological treatment systems used by seafood processors outside of Japan. Where geological conditions permit, ponds and lagoons are good solutions to wastewater treatment for small processors. Dissolved air flotation is a treatment technology appropriate to large, sophisticated processors.

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SOMMAIRE

Cette étude constitue un document technique sur le traitement des rebuts dans l'industrie des fruits de mer. Elle se concentre sur les moyens d'utilisation des débris dans la production alimentaire et insiste particulièrement sur les méthodes de transformation des fruits de mer telle que pratiquée dans les pays en développement.

Le document fournit des données sur ce qui caractérise les eaux usées et les rebuts solides, le choix des recyclages possibles et les méthodes de traitement et d'évacuation. Il fait également mention du coût de traitement des eaux usées et des paramètres économiques relatifs aux options de recyclage.

Les débris de fruits de mer ont une valeur potentielle très élevée à cause de leur important contenu protéinique. Ils peuvent être utilisés dans la fabrication de produits alimentaires pour la consommation humaine, comme additifs dans la consommation animale et pour certaines spécialités chimiques. La production de poudre de poisson se faisant souvent dans de larges appareils n'est pas à conseiller pour de petites usines. Par contre, la production de hachis d'aliments à base de poisson et l'ensilage de poisson est recommandable.

La plupart des usines de traitement des produits de mer en pays en développement sont petites et situées loin des centres. Dans ces conditions, l'évacuation des eaux usées ne présente aucune danger pour l'environnement; les débris sont biodégradables et servent de nourriture à la faune marine et aux oiseaux. Quant aux eaux usées, elles sont habituellement écoulées dans des étendues d'eau qui peuvent en assimiler les détritus.

EXTRACTO

El estudio presenta información técnica sobre la gestión de desechos en la industria de elaboración de pesca y mariscos. El interés prioritario está en los procedimientos de aprovechamiento de desechos en otros productos alimenticios. Se de particular relieve a los datos relativos a los fabricantes de productos derivados de la pesca en los países en desarrollo.

Se suministran datos sobre las características de los desechos líquidos y sólidos, sobre las opciones de reciclado y sobre los métodos de tratamiento y eliminación de desechos. Se incluyen también los costos de tratamiento de los desechos líquidos y los parámetros económicos de las opciones de reciclado.

Los desechos de los productos pesqueros tienen un potencial muy valioso debido a su elevado contenido proteínico. Entre las opciones de reciclado cabe citar la fabricación de productos alimenticios para el consumo humano, aditivos para los piensos, aditivos, y algunos productos químicos especiales. Los grandes fabricantes suelen elaborar harina de pescado, pero esta práctica no se recomienda para las pequeñas instalaciones. Se recomienda en cambio la producción de alimentos y piensos de pescado desmenuzado.

La mayor parte de las fabricaciones de productos derivados de la pesca de los países en desarrollo disponen de instalaciones pequeñas ubicadas en lugares remotos. En estas circunstancias la evacuación de los residuos líquidos no elaborados no suele ocasionar problemas ambientales. Estos residuos son biodegradables y sirven de alimento para los peces y las aves. Los residuos líquidos suelen descargarse en recursos de aguas capaces de asimilar esos desechos.

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