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Characterization and Treatment of Fish Processing Plant Effluents in Canada

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CHARACTERIZATION AND TREATMENT OF FISH PROCESSING PLANT EFFLUENTS IN CANADA

by

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ABSTRACT

The Environmental Protection Service of Environment Canada is currently developing guidelines for the control of effluents from fish processing plants. In order that these guidelines be based on proven technology, it was necessary to collect data on waste characterization and treatability. Environment Canada has funded a number of studies to collect this information and the results from five of these studies are summarized in this report.

RESUME

Le Service de la protection de l'environnement d'Environnement Canada élabore actuellement des directives de contrôle concernant les effluents des usines de traitement de poisson. Pour que ces directives soient basées sur une technologie éprouvée, il a fallu recueillir des données sur la manière de déterminer les déchets et la possibilité de les traiter. Environnement Canada a subventionné un certain nombre d'études à ces fins, et les résultats de cinq de ces études sont résumés dans le présent rapport.

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CHARACTERIZATION AND TREATMENT OF FISH PROCESSING PLANT EFFLUENTS IN CANADA

by

M.J. Riddle and K. Shikaze*

SECTION I

INTRODUCTION

Canada's position as a major fish processing nation can be judged from the 1970 Fisheries Statistics. During that year, approximately 1.5 million metric tons of fish (live weight) were landed in Canada with a landed value in excess of $200 million. Canada exported some 380,000 metric tons of processed fish with a value of $247.4 million. This makes Canada the second largest fish exporting country in the world behind Japan.

Table 1 below summarizes the landings in volume and value for 1970 for both Atlantic and Pacific Regions as well as freshwater fish. It should be noted that the Atlantic region processes 85% of the fish catch by volume, however this only represents 65% of the total landed value and 70% of the total marketed value of all fish landed in Canada.

Table 1. Volume and Value of Seawater and Freshwater Fish Caught in Canada (1970 Annual Statistics Review of Canadian Fisheries)

	Landings (lbs x 10^6)	Landed Value ($ x 10^6)	Marketed Value ($ x 10^6)
Atlantic	2375.1	131.6	290.0
Pacific	238.5	60.2	110.0
Sea Fisheries Total	2613.6	191.9	400.0
Freshwater Fisheries	120.0	15.6	22.0
Canada Total	2733.6	207.5	422.0

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Table 2 below summarizes the volumes and landed value of the 10 major fish species landed in Canada. It should be noted from table 2 that the herring catch represents approximately 40% of the total volume landed but the landed value of herring represents approximately 16% of the total landed value of the 10 major fish species. In comparison salmon landings account for approximately 6% of the total volume landed with a landed value of approximately 25%. During the 1971-72 fishing seasons the herring catch declined markedly and as a result the use of herring for fish meal production has been discouraged.

Table 2. Volume and Landed Value of Ten Major Species (1970 Annual Statistics Review of Canadian Fisheries)

No.	Species	Volume Landed (lbs x 10^3)	Landed Value ($ x 10^3)
1	Herring	1,064,400	13,539
2	Cod	494,836	23,180
3	Small Flatfish	311,180	15,486
4	Redfish	243,855	8,056
5	Salmon	159,490	48,030
6	Haddock	49,477	5,296
7	Lobster	36,584	29,661
8	Mackerel	34,613	1,253
9	Halibut	32,981	12,179
10	Turbot	26,097	1,092
Canada - Total of 10 Major Species		2,733,600	207,500

In 1970 the Canadian fishing industry supported a commercial fleet of 39,350 boats with a value of $267 million. The industry employs some 53,000 fishermen of which 41,700 work in the Atlantic provinces of Nova Scotia, New Brunswick, Prince Edward Island, Quebec and Newfoundland.

Table 3, below, summarizes the number of fish processing plants and persons employed in these plants by province for 1969. It should be noted from this table that, although there are some 450 processing plants in Canada, the number of persons employed in these plants is approximately 19,000, giving an average of approximately 30 persons per processing plant. Plant processing capacity ranges in size from 60 million pounds of raw fish processed per year to approximately 100,000 lbs. of raw fish processed a year. The largest plants employ in excess of 300 persons where as the smallest operations are usually run by a single family.

Across Canada the industry provides necessary employment for a large number of small communities. These communities, most of which are scattered along both coastlines are dependent to a significant degree, if not wholly, on the fishing industry for their livelihood. The industry also plays a significant role in the lives of both Indian and Eskimo native peoples both as a source of food and a means of commercial livelihood.

Table 3. Number of Fish Processing Plants and Persons Employed in these Plants by Province
(1969 Dominion Bureau of Statistics, "Fish Products Industry")

Province	Number of Fish Processing Plants	Number of Persons Employed
Nova Scotia	136	5,177
New Brunswick	92	3,219
Prince Edward Island	23	597
Quebec	46	1,414
Newfoundland	71	5,104
Ontario & Prairie Provinces	35	923
British Columbia	57	2,725
Canada - Total	460	19,159

Current methods of processing fish require the use of considerable quantities of water for: cleaning the fish, transporting the waste material, plant clean-up, and use in deodorizers. The discharge of this waste water directly into adjacent lakes and rivers solved the disposal problem of the fish processors for many years. In recent years the expansion and consolidation of the fish processing industry and the improvement of the by-product recovery techniques has made it economical to remove the large solid material from the waste water by screening. The screenings were processed and the resulting fishmeal was sold as animal feed, but the remaining waste waters still have been discharged to receiving waters.

As a result of the discharge of this waste water, and the inefficient operation of offal screening devices, serious pollution problems have occurred around fish processing plants. This has been aggravated by the congregation of a number of plants around harbour areas. These plants then discharge their waste material into the harbour which is not subjected to the tidal flushing action required to sufficiently dilute these waste and thus prevent pollution problems.

The fishing industry relying on a renewable resource is often affected by pollution. However, it is difficult for the Canadian fishing industry to lay the blame at other industrial polluters when it is also contributing to this pollution. It therefore seems reasonable to expect the fishing industry to take an exemplary position with respect to water pollution control. However, one of the major problems has been the lack of information on waste characteristics and type of treatment that could be effectively employed. In order to aid the industry in its fight against water pollution, the Canada Department of the Environment has undertaken a number of studies to characterize and to determine the treatability of the effluents from various processing plants. These studies will be discussed in this paper. Firstly, however, it is necessary to outline the major processing techniques employed in this industry as well as to review the literature to obtain an indication of the present level of knowledge in the characterization and treatment of these wastes.

SECTION II

PROCESS DESCRIPTIONS

The processes which characterize the fish processing industry in Canada can be divided into the following five major groups:

Groundfish processing
Herring processing
Salmon processing
Shellfish processing
Fishmeal processing

Each group has a unique production process and consequently unique effluent characteristics. Variations in processing procedures are found from plant to plant, but the major features of each type of production are quite consistent and are discussed below.

2.1 Groundfish Processing:

Cod, halibut, ocean perch (redfish), sole and flounder are the species of fish referred to as groundfish. With the exception of halibut the remaining species are processed in somewhat the same manner.

2.1.1 Cod, Redfish, Sole and Flounder:

The fish are either stored whole in the ship or are eviserated prior to storage, the viscera and blood being washed overboard. At the wharf, unloading is usually accomplished by pitching the fish into a basket that has been lowered into the hold. The fish are then weighed, washed and iced in tote boxes. In some larger plants, mechanized unloading methods are used to minimize manual handling.

Most groundfish require no pretreatment prior to filleting, but the scales must be removed from redfish before they can be filleted. The descaling of redfish is accomplished in a revolving cylindrical screen which removes the scales by the abrasive action of the fish rubbing against themselves.

In small plants, the fish are processed by hand. The fillets are cut on a wooden board next to a sink, washed and immediately iced in boxes for distribution.

Most plants processing fillets use mechanized equipment. First, the fish are washed in large wash tanks or by water sprays in large rotating tumblers. Next the fish pass to filleting machines or hand filleting tables. Filleting machines only operate on certain fish sizes and shapes, but considerably reduce labor costs and increase yields, over hand-filleting. The skin is removed from fillet by hand or machine. The solid wastes from filleting and skinning operations are usually rendered for pet food or animal meal. Figure 1 outlines a typical groundfish filleting operation.

The skinned fillets are transported by conveyor belt through a washing tank and, in some cases, a brining tank. After inspection the fillets are packed into containers by hand or frozen and then packed. Steaks are produced from the eviscerated fish by cuts made at right angles to the backbone. These steaks are marketed frozen or fresh. Fillets are marketed frozen (fresh or breaded), chilled or fresh.

2.1.2 Halibut:

After being landed on the vessel, the halibut are dressed by removing the viscera and cutting away the gills. The halibut are then packed in ice in the hold. Halibut are ordinarily processed in relatively small plants. The fishermen usually behead the fish before sale to the processor.

If the fish are not processed immediately, they are re-iced in the fish plant. The majority of halibut are filleted and marketed frozen, however, some are frozen whole or sold fresh.

Prior to whole freezing, a continuous belt washer sprays the fish. The fish are frozen with a glaze protection at approximately -20°F.

Halibut are cut in fletches (boneless and skinless pieces produced from fresh fish). This process divides the halibut into four or more trimmed meaty protions weighing from 5 to 20 pounds. The fletches are frozen and either glazed or packaged in moisture proof wrapping. Other forms of fresh or frozen halibut include packaged fillets, steaks, and breaded fillets.

2.2 Pelagic and Estuarial:

The most important pelagic and estuarial species are salmon and herring.

2.2.1 Salmon:

The five main species of salmon are spring, sockeye, coho, pink and chum. The major portion of the catch (approximately 80%) is canned.

Spring, coho, and some sockeye salmon are caught using a trolling technique whereas the remaining species of salmon are netted. Troll caught salmon are gutted at sea and subsequently stored in ice. Following unloading a small portion are usually sold fresh while the balance is frozen and glazed for sale in this form or as steaks cut from the frozen fish.

Net caught fish are usually taken close to the canneries and are often held for short periods in the boats without refrigeration. Canning operations are conducted for the most part employing standard cannery equipment in a conventional manner. The principal exception is the use

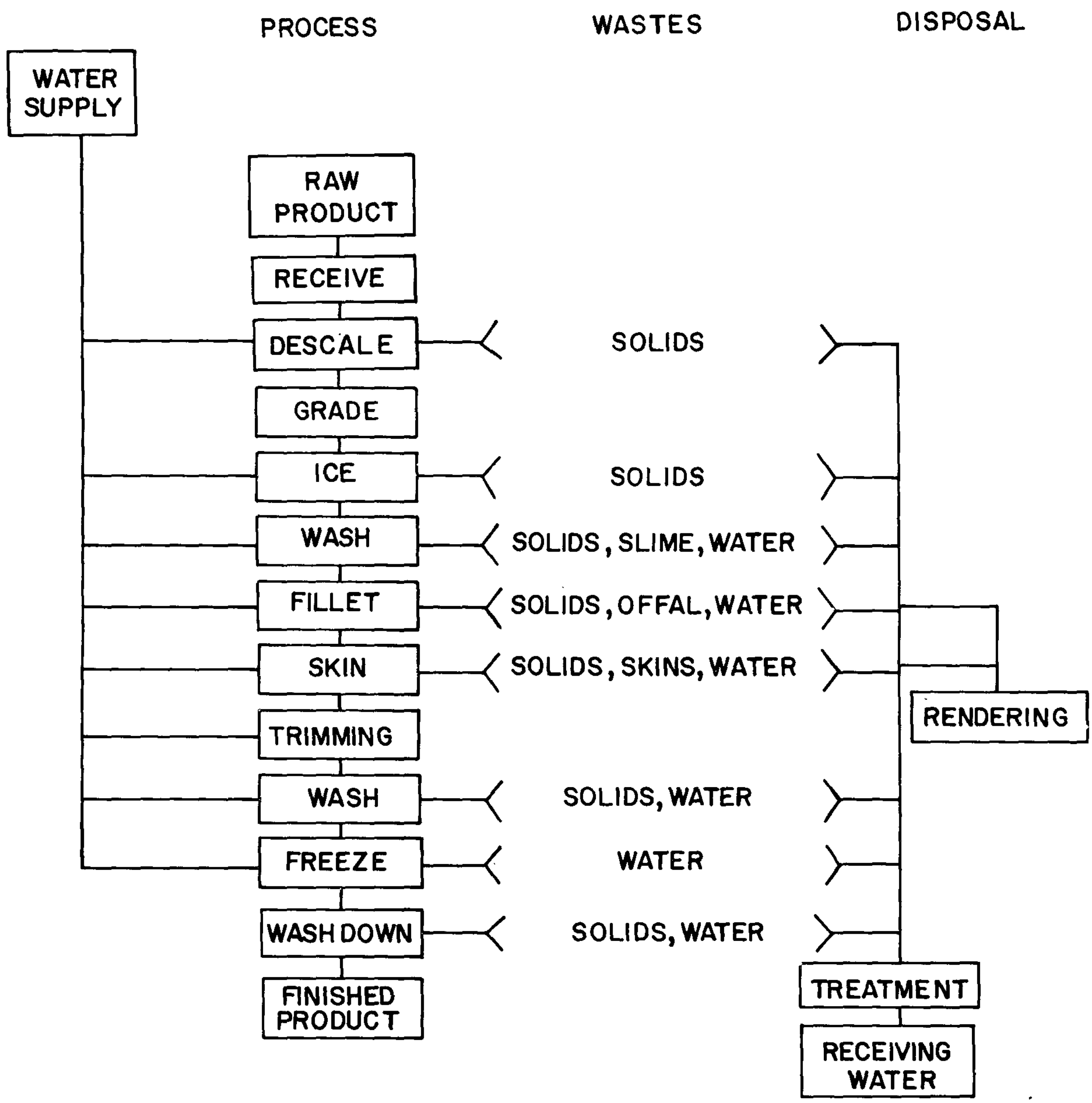

FIGURE 1. GROUNDFISH FILLETING

of the "iron chink". The iron chink performs several functions in one operation by mechanically removing heads, fins, and viscera. During all the steps a strong stream of water continuously washes the blood away. The remaining canning operations are somewhat standard, as shown in figure 2. The fish are washed, inspected and cut into can-length portions and the cans are filled mechanically. Finally, the cans are automatically sealed under vacuum and then retorted.

2.2.2 Herring Processing:

Herring is processed into a number of products, including fish oil, fish meal, herring fillets, marinated herring, and for the herring roe. This section describes only the operations which process herring for human consumption - herring filleting, marinated herring and herring roe.

2.2.2.1 Herring Filleting:

As with the groundfish processing plants herring are trucked to the plant and stored in holding bins, there being packed in ice. Herring are delivered to the plant round (head, tails, fins and viscera intact) and, in the filleting operation, have the heads, tails, fins and viscera removed by automatic machines. After filleting they are prepared for consumer marketing.

Wastes from herring filleting originate from the fluming of the round herring to the splitting machines, and from the water used in the machines themselves. Offal is removed prior to final discharge of the waste water for further processing in the fish meal operation.

2.2.2.2 Marinated Herring:

In the production of marinated herring, round herring is trucked to the processing plant and stored in iced or refrigerated bins. From the storage bins the herring are either flumed or conveyed to a hand or machine splitting operation where removal of head, tails, fins and viscera takes place. The resulting split fillets are then stored in barrels or vats in a solution of brine and acetic acid for a period of 5 to 9 days. After this period the solution is dumped and the fillets are introduced to a second solution of brine and acetic acid and stored at low temperature for a period of two weeks. While in this stored solution the fillets are called bismarcks. Following this two-week storage period the bismarcks are dumped, skinned, and repacked in barrels ready for distribution. The process is illustrated in Figure 3.

Wastes are produced during the splitting operation, clean-up, and acetic acid brine dumps. The offal is transported to fish meal plants for further processing.

With both the herring filleting and marinated herring processing, the waste is extremely colored, due mainly to the loss of blood during the splitting operation. The coloration does not dissipate readily upon discharge to the receiving waters.

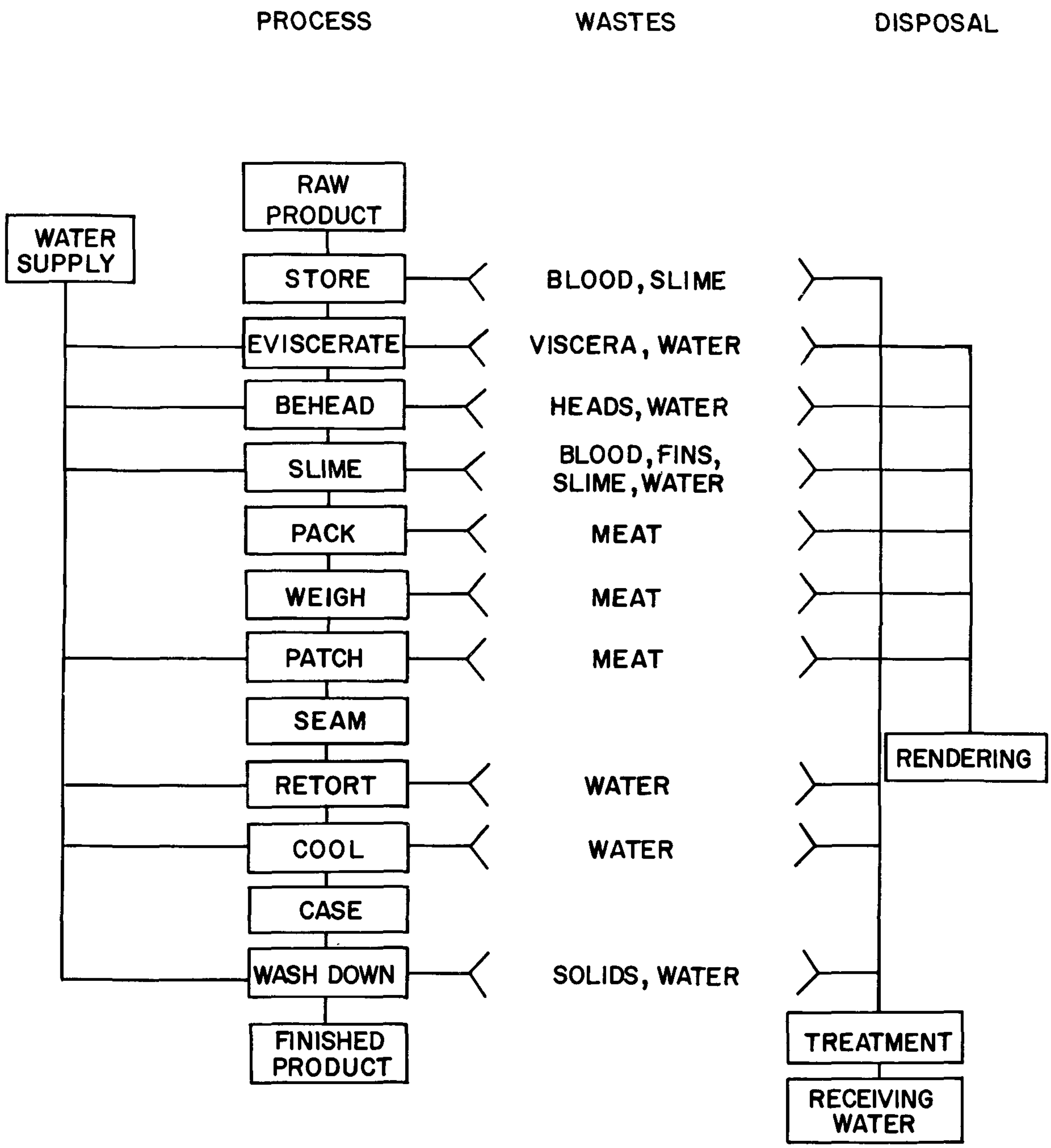

Figure 2. Salmon Canning

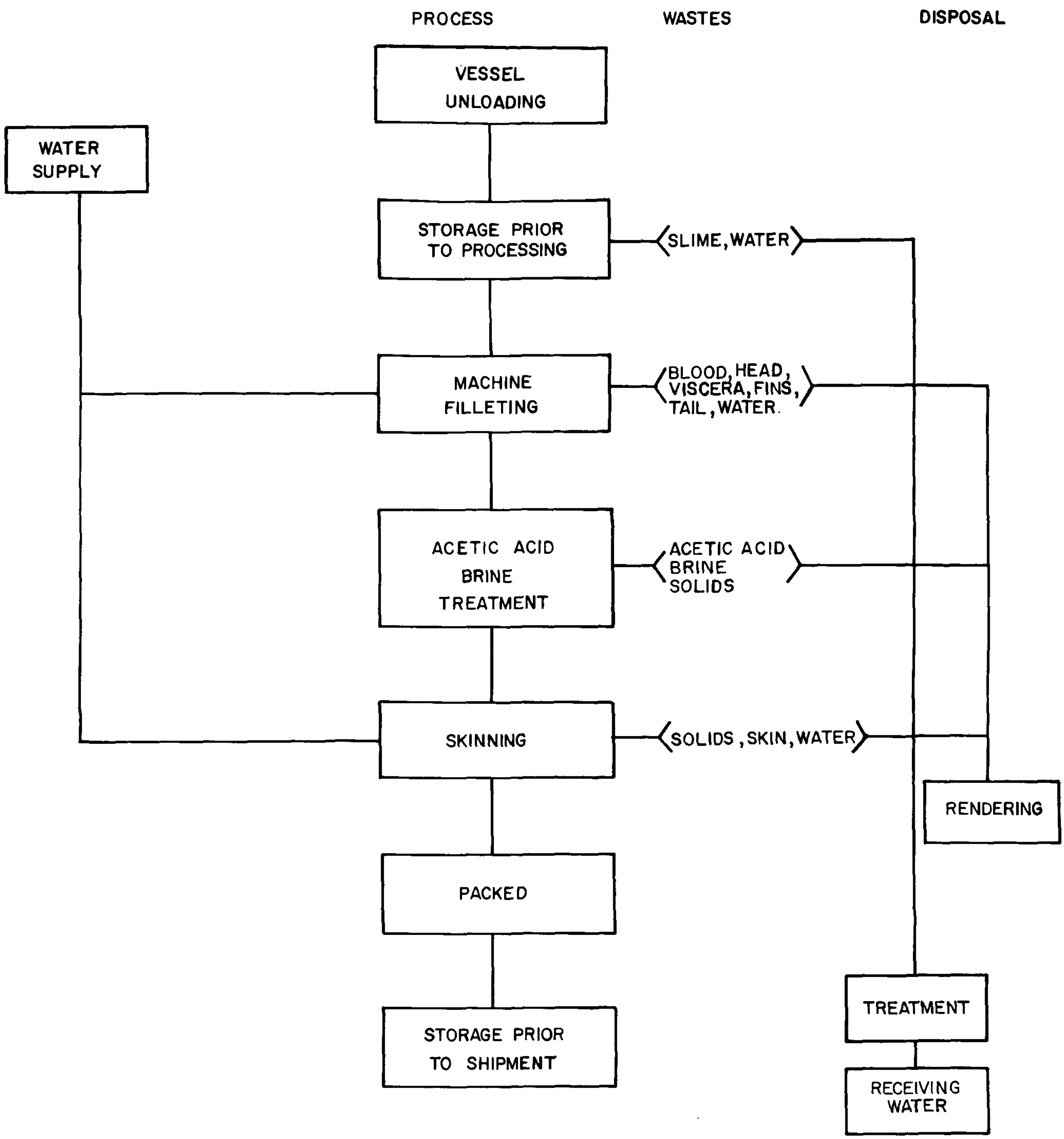

Figure 3. Process Flow Diagram
Marinated Herring Plant

2.2.2.3 Herring Roe:

There has recently been a marked increase in the herring roe industry. The herring are brined prior to process for removal of the roe. The roe are salted, packaged and refrigerated prior to shipment. Following roe removal the remaining herring flesh is sent for reduction to fish meal or to pet food production.

2.3 Shellfish Processing:

Lobster is the major species of shellfish caught and processed in Canada. Lobster are caught in large traps and must be kept alive until processed. Approximately 65 percent of the lobsters are marketed in their shells either alive or cooked. The remaining 35 percent are cooked and shucked.

Lobsters are steam cooked in retorts for 20 to 30 minutes and are water cooled after cooking to facilitate handling. If the lobsters are to be butchered their backs are removed and the remaining viscera are washed free. The cooking, cooling and washing waters contain considerable quantities of solids and organic pollutants.

Small numbers of cooked lobsters and meat are frozen for later marketing. Low storage temperatures and quick turnovers are necessary for the maintenance of high quality. Little lobster meat is canned because of the rapid degradation of texture and flavour quality of the canned product.

2.4 Fish Meal Production:

In the processing of most species of fish for food purposes from 30 to 80 percent of the raw material is waste. Efforts are made by most plants to recover all edible portions, and the recent introduction of deboning machines promises greater utilization in the future. Still, much of the fish poses a disposal problem and one practice has been to produce a protein concentrate for poultry feed. Oil may also be recovered from oily species.

The waste material, termed offal, is normally conveyed wet or dry to the fish meal plant and stored in pits until enough is accumulated to warrant operation. Solids recovered by screening of off-loading and processing water are also sent to the fish meal plant. During storage some liquid is drained or pressed from the offal. This stream called bloodwater, is not large in volume but is very strong in terms of organic content. Some plants attempt to recover this, but most discharge the stream with the plant effluent.

The general flow for fish meal production is shown in Figure 4. The offal is hashed by machine if large pieces are present, and then cooked in direct or indirect continuous steam cookers for up to 10 minutes. Non-oily offal may be added directly to driers, while oily species are pressed to expel most of the water and oil prior to entering the drier.

In the latter case the press liquor undergoes a fine solids separation using vibrating screens or decanting centrifuge followed by oil separation in nozzle centrifuges. The oil is further clarified in polishing

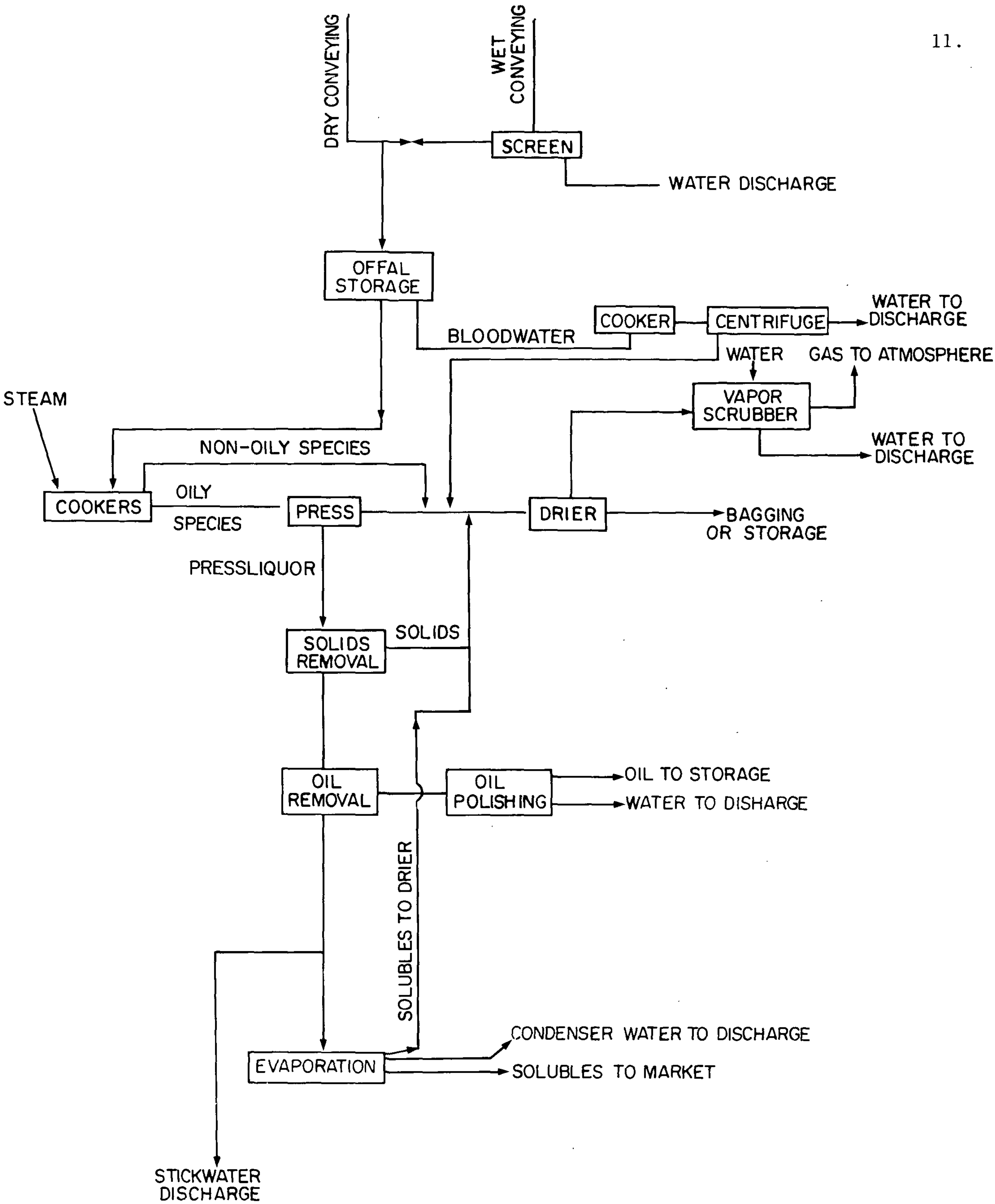

Figure 4. Flow Diagram for Fish Meal Production

centrifuges before sale as either an edible oil or animal oil. The aqueous phase may still contain up to five or six percent organic solids and is termed stickwater. At one time this was discarded, but now many plants employ multiple effect evaporators to concentrate these solids. The resultant product is termed condensed fish solubles and contains from 30 to 50 percent solids. It is marketed as a poultry or animal feed, a specialty fertilizer, or is recycled back to the driers for incorporation in the meal. The condenser water used in the evaporators does pick up volatile solids and gases, the extent depending on the degree of freshness of the offal and the manner of operation of the evaporators.

The fish meal driers are usually rotary kilns, with heat being supplied by direct flame heating of the air, or by indirect heating using steam. The solids are dried to between 5 to 10 percent moisture content, ground to pass 10 mesh screens and sold in either 100 lb. bags or in bulk. The steam and odors generated during the drying of the meal can be very obnoxious and most plants employ some sort of direct water scrubbing to these vapours prior to release. Large volumes of water are employed for this, and the scrubber effluents will contain a significant quantity of organic material.

Many fish processing plants in Canada combine a number of the above-mentioned operations. For instance, many plants on the West Coast have the capability of processing both groundfish and salmon. These operations might also be linked to a fish meal plant. The resulting wastes from the fish processing plant are usually flumed together and discharged as one effluent, after removal of the offal.

SECTION III

LITERATURE REVIEW

3.1 Characterization Studies:

Fish processing wastes vary considerably in pollutional strength. This variation is due in part to:

1. Species of fish being processed
2. The age of fish being processed
3. The processing techniques
4. Plant size
5. Water usage

The characterization of wastes from various types of fish plants has been the subject of a number of studies. Table 4 summarizes the characteristics of effluents from fish processing plants as reported in 8 different studies and reports. It should be noted that the BOD_5 values are all in the same order of magnitude, however, greater fluctuations occur in the suspended and total solids values. These fluctuations are due to those factors listed above.

Table 4. Characteristics of Effluents from Fish Processing Plants as Reported in the Literature

Author (Fish Processed)	BOD_5 (mg/1)	Suspended Solids (mg/1)	Total Solids (mg/1)
Washington State Pollution Control Commission (1969) (Species of fish not specified)	2700-3400	2200-3020	2198-21,820
Limprich (1966) (Herring, Red Perch, Fish Meal)	2658	--	--
Soderquist et al (1970) (Bottom fish processing)	192-1726	300	--
Matusky et al (1956) (Wastewater)	1000	425	--
Chun et al (1968) (Tuna fish processing)	895	1091	17,900
Soderquist et al (1970)			
Salmon processing	397-3082	40-1824	88-3422
Sardine packing	100-2200	100-2100	--
Stanley Associates (1972)			
Halibut	64-150	66-110	--
Sole	160-195	34-85	--
Salmon	390-1900	665-760	--
Shaffner (1970)			
Ocean Perch	390-540	330-1395	--

Table 5 summarizes the characteristics of effluents from fish meal plants as reported in the literature. The major effluents of concern are bloodwater and stickwater, which although very high in BOD_5 and suspended solids are relatively small in volume. This compares to deodorizer water which has a low value of BOD_5 and suspended solids but large volumes of this effluent are produced in fish meal production. The total effluent characteristics as shown in table 5 indicate the result of diluting the high strength low volume wastes, such as bloodwater and stickwater, with the low strength high volume wastes, such as deodorizer water. The results given in table 5 for the different effluents are all of the same order of magnitude. Variations in the results for the total effluents are due to differences in the relative volumes of each type of waste discharged by the fish meal plant. For instance, some plants recover all stickwater while other plants discharge it with their plant effluents.

3.2 Treatability Studies:

The difficulties in the treatment of wastes from fish processing plants are attributable to high flows, medium to high BOD_5 and suspended solids and high grease and protein levels. The short and variable processing season, high peak loadings and rapid biodegradability of the wastes also cause treatment problems.

3.2.1 Physical Treatment:

With the possible exception of the work by F.G. Claggett of the Fisheries Research Board of Canada, which will be discussed later, little work on the physical or biological treatability of fish processing wastes has been undertaken.

A study by the New Brunswick Water Authority (1970) indicated the effectiveness of screening wastes from groundfish processing plants. Using both 10 and 40 mesh screens BOD_5 removals up to 60 percent were reported, however, the median removal value was 33 percent for both screens. Further, the 40 mesh screen provided approximately 25 percent removal of BOD_5 for deodorizer water and for the total effluent from fish meal plants.

Shaffner (1970) concluded that passing the wastewater from groundfish plants over 20 mesh screens would remove approximately 20 percent of the BOD_5 and 16 percent of the suspended solids.

Flotation has been examined as another method of suspended solids removal from fish processing plant effluents. Davis and McKinney (1970) used chemical flocculation and flotation to remove oil and solids from herring pumpwater. It was reported that the organic matter was concentrated from 0.4 percent to a 1.0 percent sludge by pressurized air flotation of a recycled portion of the clarified effluent. Davis and McKinney concluded that, while flotation could recover at least half of the solids remaining in screened pumpwater, it was uneconomic because of its complex operation and the creation of a sludge handling problem.

Table 5. Characteristics of Effluents from Fish Meal Plants as Reported in the Literature

	BOD_5 (mg/l)	Suspended Solids (mg/l)
Matusky *et al* (1956)		
Stickwater	110,000	125,000
Deodorizer water	800	2,000
Canadian Plant and Process Eng. (1970)		
Stickwater	25,000-72,000	6,500-47,000
Bloodwater	55,000-90,000	40,000-55,000
Total Effluent	18,000-42,500	8,638-23,910
Shaffner (1970)		
Stickwater	34,000	13,270-53,880
Deodorizer water	490	390
Total Effluent	4,400	4,300
Delaney (1971)		
Deodorizer water	47	--
Total Effluent	3,180	1,020
Shawinigan Eng. Co. Ltd, (1968)		
Stickwater	38,000	68,010
Total Effluent	257	33,500
Stanley Associates (1972)		
Stickwater	69,000-83,000	10,000-15,000

3.2.2 Biological Treatment:

Soderquist et al (1970) reported that the carbon:nitrogen ratio of fish processing wastewater indicated that biological treatment should be successful. The biochemical oxidation rate was found to be similar to sewage, however, nitrification began sooner and was more significant. Soderquist et al (1970) further reported that a number of authors had found that oil and grease interfered with the oxygen transfer in an activated sludge system. In Soderquist's opinion pretreatment to remove high solids, grease and oil content is a necessity if biological treatment is to be successful.

Matusky et al (1965) stated that fish solids and oil digested readily and the resultant sludge dewatered easily. The digester loading rates varied from 0.1 to 0.36 pounds volatile solids per cubic foot per day.

A review of the literature indicates the current knowledge and process technology involved in the characterization and treatment of wastes from various types of fish plants. It is obvious that if the Canadian fish processing industry is to adequately respond to the need for pollution control better effluent characterization and treatability data must be made available to this industry. Thus the Department of Environment has embarked on a number of projects to collect this data.

SECTION IV

ENVIRONMENT CANADA STUDIES

The studies undertaken by Environment Canada are as shown in table 6. The majority of these studies were carried out during the summer of 1971 or 1972. The exception is study #5, the characterization and treatability of the wastes from a groundfish and salmon processing plant, this study is still continuing and should be complete by mid-1974. The results from these studies will be presented in two parts, the first part being the characterization results and the second part the results of the treatability studies.

4.1 Characterization Studies:

4.1.1 Groundfish:

The groundfish operations involve the processing of halibut, cod, redfish, sole and flounder. Two basic types of processing are used:

a) dry line operations which use a system of conveyors to move the raw product and mechanically operated filleting tables. In the majority of cases offal is removed from the filleting area by fluming.

b) wet line operations characterized by the use of water to flume the raw product and the offal.

In general dry line operations are used in the larger operations whereas the smaller plants rely on wet transport of raw product and offal. In the majority of cases fish are washed in tanks or spray conveyors immediately prior to processing.

Table 6. Summary of Studies of Fish Processing Effluents Undertaken by Environment Canada

Location of Study	Type of Effluent Study	Types of Fish Processed	Processing Techniques	Date of Study
1. Wheatley, Ontario	Treatability and Characterization	Perch & Smelt (Freshwater fish) Fish Meal Production	Filleting	Summer, 1971
2. Lower mainland of British Columbia	Characterization	Groundfish & Herring	Filleting	Summer, 1971
3. Northeast New Brunswick	Characterization	Herring	Marinated and Filleting	Summer, 1971
		Groundfish	Filleting	
		Shellfish, Shrimp Fish Meal production		
4. Maritime Region	Characterization	Groundfish Fish Meal production	Filleting	Summer, 1972
5. Lower mainland of British Columbia	Characteriation and Treatability	Groundfish	Filleting	Continuing
		All species of Salmon	Canning	

4.1.1.1 Dry Line Processing:

Tables 7 to 10 give the BOD_5, suspended solids and ether soluble oil loadings in the effluent from the processing of halibut, grey cod, ling cod, sole and redfish. The results are given in both concentrations, means and ranges, and in pounds of parameter per 1000 pounds of raw product, again in both means and ranges.

Examination of tables 7 to 10 indicates the wide variability in effluent BOD_5 and suspended solids loadings. This variability in loadings not only existed in effluents from the processing of different species in one plant but also in the effluents from processing of the same species in plants of differing size. Table 11 below summarizes the BOD_5 effluent loadings for the processing of sole, grey cod and ling cod - the species processed in the three different sized plants studied (study #2).

Table 7. Summary of BOD_5 Loadings from Groundfish Processing Plants Study #2

Plant Size	Sole	Grey Cod	Ling Cod
Lbs of Raw Product/Day	Lbs BOD_5/1000 Lbs Raw Fish		
6,000	1.4	8.1	6.3
10,000	2.7	2.2	4.1
15,000	0.7	0.9	6.0
Average	1.6	3.7	5.5

Table 12 summarizes the total effluent values for the dry line processing of groundfish. The results indicate the range of BOD_5 loadings for this type of groundfish processing varied from 1.3 pounds of BOD_5 to 7.9 pounds of BOD_5 per 1000 pounds of raw product.

Further examination of table 12 indicates the variability of suspended solids loading of 0.98 to 2.4 pounds per 1000 pounds of raw product and of 0.13 to 1.0 pounds per 1000 pounds of raw product for ether soluble oil (study #2 and #3).

The variability of the effluent in terms of BOD_5, suspended solids and ether soluble oil loadings is considerable due to differences in water usage, age of fish processed, amount of fish processed as well as the processing techniques. A review of tables 7 to 12 indicates that there is no relationship between effluent loadings and plant size.

4.1.1.2 Wet Line Processing:

Table 13 summarizes the total effluent loadings for the wet line processing of groundfish from studies #3 and #4. The BOD_5 effluent loadings

Table 8. Effluent From Dry Line Processing of Halibut and Redfish - Study #2

Plant Size (Lbs raw fish/day)	BOD_5 Conc. (mg/l) Range ($\bar{x}$)	BOD_5 Lbs/1000 lbs raw fish Range ($\bar{x}$)	S.S. Conc. (mg/l) Range ($\bar{x}$)	S.S. Lbs/1000 lbs raw fish Range ($\bar{x}$)	Ether Soluble Oil Conc. (mg/l) Range ($\bar{x}$)	Ether Soluble Oil Lbs/1000 lbs. raw fish Range ($\bar{x}$)
Species: Halibut						
10,000	145-420 (282)	1.3-4.0 (2.6)	95-245 (170)	0.8-2.4 (1.6)	--	--
15,000	-- (204)	-- (4.0)	-- (352)	-- (7.2)	--	--
Species: Redfish						
15,000	40-114 (77)	0.4-1.1 (0.7)	14.4-101.3 (48.9)	0.1-3.5 (1.3)	12.9-35.0 (23.9)	0.12-0.35 (0.2)

($\bar{x}$)=mean

Table 9. Effluent from Dry Line Processing of Grey Cod - Study #2

Plant Size (Lbs raw fish/day)	BOD_5		S.S.		Ether Soluble Oil	
	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish
	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)
Species: Grey Cod						
6,000	120-1775 (607)	0.7-39.1 (8.1)	196-694 (259)	0.6-6.0 (2.5)	9.0-227.7 (61.6)	0.04-5.0 (1.7)
10,000	53-1547 (435)	0.3-7.5 (2.2)	75-1006 (293)	0.4-4.8 (1.5)	0.4-55.2 (16.7)	0.01-0.64 (0.2)
15,000	27-117 (74)	0.4-1.5 (0.9)	20.5-90.0 (44.1)	0.3-0.6 (0.5)		

($\bar{x}$)=mean

Table 10. Effluent from Dry Line Processing of Ling Cod - Study #2

Plant Size (Lbs raw fish/day)	BOD_5		S.S.		Ether Soluble Oil	
	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish
Species: Ling Cod	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range (x)	Range (x)
6,000	471-1050 (500.1)	2.2-12.7 (6.3)	173.6-517 (248.3)	1.6-5.1 (3.5)	-- (45.7)	-- (0.3)
10,000	30-1102 (468)	0.22-7.4 (4.1)	28-564 (237)	0.21-5.5 (2.2)	-- (320)	-- (0.37)
15,000	54-546 (300)	1.1-11.0 (6.0)	41.6-121.1 (95.5)	0.8-2.3 (1.8)		

$(\bar{x})$=mean

Table 11. Effluent from Dry Line Processing of Sole - Study #2

Plant Size (Lbs raw fish/day)	BOD_5 Conc. (mg/l) Range $(\bar{x})$	BOD_5 Lbs/1000 lbs raw fish Range $(\bar{x})$	S.S. Conc. (mg/l) Range $(\bar{x})$	S.S. Lbs/1000 lbs raw fish Range $(\bar{x})$	Ether Soluble Oil Conc. (mg/l) Range $(\bar{x})$	Ether Soluble Oil Lbs/1000 lbs raw fish Range $(\bar{x})$
Species: Sole						
6,000	96-540 (213.8)	0.3-4.8 (1.4)	92.1-269.8 (124.8)	0.2-1.9 (0.8)	37.6-290.6 (109.4)	0.2-2.3 (1.3)
10,000	200-990 (515)	1.5-7.6 (2.7)	118-908 (332)	0.69-3.2 (1.4)	3.0-526.4 (215)	0.01-4.1 (1.6)
15,000	45-130 (81.8)	0.4-1.1 (0.7)	32.6-173.8 (70.5)	0.04-1.5 (0.6)	0.3-43.6 (10.9)	0.02-0.4 (0.1)

$(\bar{x})$=mean

Table 12. Total Effluent from Dry Line Groundfish Processing

Study Number	Plant Size (Lbs raw fish/day)	BOD_5 Conc. (mg/l) Range ($\bar{x}$)	BOD_5 Lbs/1000 lbs raw fish Range ($\bar{x}$)	S.S. Conc. (mg/l) Range ($\bar{x}$)	S.S. Lbs/1000 lbs raw fish Range ($\bar{x}$)	Ether Soluble Oil Conc. (mg/l) Range ($\bar{x}$)	Ether Soluble Oil Lbs/1000 lbs raw fish Range ($\bar{x}$)
2	6,000	96-1775 (451.5)	0.3-39.1 (5.7)	92.1-1006.4 (226.5)	0.2-6.2 (2.4)	2.4-260.6 (56.8)	0.03-5.0 (1.0)
	10,000	30-1547 (411.0)	0.22-7.6 (2.7)	6.8-1006 (254)	0.1-5.5 (1.6)	0.4-526.4 (93.3)	0.01-4.1 (0.75)
	15,000	27-546 (101.9)	0.4-11.0 (1.3)	14.4-173.8 (64.5)	0.04-3.5 (0.98)	0.33-43.6 (14.6)	0.02-0.4 (0.13)
3	Unknown Plant Size	100-1140 (455)	-- (5.0)	30-232 (135)	-- (1.0)	0-500 (100)	-- (1.0)
4	300,000	178-389 (279)	3.80-15.57 (7.9)	140-576 (290)	2.42-23.06 (22.5)		

($\bar{x}$)=mean

Table 13. Total Effluent from Wet Line Groundfish Processing

Study Number	Plant Size (Lbs raw fish/day)	BOD_5 Conc. (mg/l) Range $(\bar{x})$	BOD_5 Lbs/1000 lbs raw fish Range $(\bar{x})$	S.S. Conc. (mg/l) Range $(\bar{x})$	S.S. Lbs/1000 lbs raw fish Range $(\bar{x})$	Ether Soluble Oil Conc. (mg/l) Range $(\bar{x})$	Ether Soluble Oil Lbs/1000 lbs raw fish Range $(\bar{x})$
3	Unknown Plant Size	602-1205 (1136)	-- (15.0)	148-965 (489)	-- (7.0)	200-1500 (900)	-- (13)
4	250,000	146-648 (295)	-- (18.0)	220-1300 (513)	-- (34.0)		
	180,000	270-750 (520)	-- (20.2)	30-470 (160)	-- (7.1)		
	120,000	300-1005 (584)	-- (18.8)	160-1550 (424)	-- (12.0)		

$(\bar{x})$=mean

vary from 15.0 to 20.2 pounds per 1000 pounds of raw product whereas the suspended solids loadings vary from a low of 7.0 pounds to a high of 34.0 pounds per 1000 pounds of raw product. As with dry line processing these effluent loadings vary widely.

Comparison between the effluent loadings from dry and wet line processing of groundfish (tables 12 and 13) indicates that wet line processing produces an effluent in excess of three times the dry line effluent loadings. These increased loadings are due to:

a) increased BOD_5, suspended solids and oil concentrations in the wet line effluents.

b) water consumption figures (table 14) indicate that wet line processing requires 2 to 3 times the water required for dry line processing.

This variation in the effluent loadings from dry and wet line groundfish processing supports the theory that the longer water is in contact with fish solids the higher the BOD_5, suspended solids and oil concentrations in the effluent. In wet line processing, water is in contact with the fish for considerably longer periods than in dry line processing. Study #1, carried out on freshwater fish processing, also supports this theory.

A major step toward reducing the pollution from groundfish processing plants would be the widescale adoption of dry transporting techniques as opposed to the presently more commonly used fluming methods characteristic of wet line processing.

4.1.2 Pelagic and Estuarial:

4.1.2.1. Salmon:

Spring, coho and some chum and pink salmon are usually glazed and sold whole, while the majority of the remaining salmon catch is canned. The wastes from the canning operation include butchering water, viscera, wash water, retort water and cooling water.

Table 15 shows the values of total effluent from salmon canning and glazing operations as determined from study #2. The results indicate that BOD_5 loadings of about 25 pounds per 1000 pounds of raw fish can be expected form salmon canning using either iron chink or hand processing techniques. The suspended solids in the effluent will vary from about 15 to 25 pounds per 1000 lbs of raw fish.

Water use figures from study #2 indicate that salmon canning requires between 0.9 to 8 gallons per pound of salmon canned. The processing of spring salmon (glazing and storage) requires approximately 1.5 gallons per pound of product.

Frequently, water used in the unloading of salmon at the plant dock is discharged direct to the harbour. Following unloading, the ships holds are washed, this wash water also enters the harbour directly. Table 15 gives the effluent load associated with the hydraulic pumping

Table 14. Water Consumption in Groundfish Processing

Study Number	Plant Size	Process	Water Consumption (fresh and salt) Gals./1000 lbs fish filleted
Study #2	6,000 lbs raw fish/day	Groundfish - dry line	2040
	10,000 lbs raw fish/day	Groundfish - dry line	1630
	15,000 lbs raw fish/day	Groundfish - dry line	3780
Study #3	Unknown Plant Size	Groundfish - dry line	1500
		Groundfish - wet line	4600
Study #4	300,000 lbs raw fish/day	Groundfish - dry line	16,700
	270,000 lbs raw fish/day	Groundfish - wet line	32,900
	180,000 lbs raw fish/day	Groundfish - wet line	18,500
	40,000 lbs raw fish/day	Groundfish - wet line	10,000

Table 15. Summary of Total Effluent Results from Salmon Processing

Study	Processing and Plant Capacity	BOD_5	S.S.	Ether Soluble Oil
		(Lbs of parameter/1000 lbs of raw fish)		
Study 2	Spring Salmon (Glazing)	1.83	1.2	0.2
	Hand Processing (Canning)	29.1	16.8	3.8
	30,000 lbs. raw fish per day			
	Iron Chink 70,000 lbs. raw fish per day	27.3	22.6	7.4
	Salmon Unloading (Hydraulic pumping)			
	Pink	2.8	0.81	
	Sockeye	1.54	0.49	
	Coho	1.13	0.26	

method of unloading salmon. Table 15 indicates that the wastes from the unloading operations vary somewhat but should be considered as part of the plants effluent and should, therefore, be treated in the plants effluent treatment systems.

4.1.2.2 Herring:

There has recently been a marked increase in the volume of herring being processed for human consumption because of the general decline in the total herring catch and restrictions on the use of herring for fish meal.

The major waste sources associated with the variety of herring processing techniques include pumpout water, brine used in roe recovery processing, acetic acid-brine dumps used in the marinating process, and water used during the filleting processes. The majority of wastes are screened prior to discharge, however pumpwater used in the unloading process is usually discharged direct to the harbour.

Table 16 gives the effluent characteristics for food herring production as reported from studies 3 and 5. The total plant effluent from marinated herring does not include the acetic acid-brine dumps. The results shown indicate the high strength of the effluents generated by food herring production. The high BOD_5 and suspended solids in the pumpout water indicates clearly the necessity of treating these wastes in the plants effluent treatment system rather than allowing direct discharge to the harbour.

4.1.3 Shellfish:

4.1.3.1 Lobsters:

Lobsters are processed solely in the Atlantic region. The main waste source occurs from the butchering operations with its associated wash water. The effluent loadings vary from 20 to 30 pounds of BOD_5 per 1000 pounds of raw product with a suspended solids loading of from 4 to 7 pounds per 1000 pounds of raw product. Water usage averages about 2500 Imp. Gallons per 1000 pounds of raw product.

4.1.3.2 Crab:

Crab are processed on both the Atlantic and Pacific coasts, the largest volume being on the Pacific coast. As in lobster processing, the largest waste loads originate in the butchering area. BOD_5 effluent loadings vary from 20 to 60 pounds per 1000 pounds of raw product, with a suspended solids effluent load of between 10 and 30 pounds per 1000 pounds of raw product. Water consumption averages about 6,500 Imp. gallons per 1000 pounds of raw product.

The data given for both the lobster and crab effluent loadings was obtained from study #3.

Table 16. Effluent Characteristics from Food Herring Processing

Study No.	Processing	BOD$_5$ Conc. (mg/l) Range ($\bar{x}$)	BOD$_5$ Lbs/1000 lbs raw fish Range ($\bar{x}$)	S.S. Conc. (mg/l) Range ($\bar{x}$)	S.S. Lbs/1000 lbs raw fish Range ($\bar{x}$)	Ether Soluble Oil Conc. (mg/l) Range ($\bar{x}$)	Ether Soluble Oil Lbs/1000 lbs raw fish Range ($\bar{x}$)
3	Herring Filleting Total Plant Effluent	3200-5800 (3859)	-- (22)	1150-5310 (3011)	-- (21)	200-3000 (1200)	-- (10)
	Marinated Herring Total Plant Effluent	6900-14,000 (8880)	-- (215)	1508-4600 (3410)	-- (85)	800-5000 (2500)	-- (83)
	Pumpout Water (Herring Pumps)	-- (33,500)	-- (--)	-- (7955)	-- (--)	-- (500)	-- (--)

Study No.	Processing	COD (mg/l)	Total Solids (mg/l)	Setteable Solids (mg/l)	Soluble Solids (mg/l)
5	Total Plant Effluent	6258	6986	1476	5530

($\bar{x}$)=mean

4.1.4 Freshwater Fish Processing:

There is in Canada a sizeable freshwater fish processing industry. Study #1 was carried out at a plant which processes approximately 30 million pounds of perch and smelt per year. This plant fillets perch whereas smelts are eviserated. The combined effluent loadings from this plant are given in table 17. The sampling of the individual perch and smelt effluents as well as the combined effluent indicated the dampening effect of mixing the two component flows as the combined effluent is stronger, but less variable on a day to day basis, than its individual component parts.

During the study, water use in the plant was examined and found to be relatively constant at about 295,000 Imp. gallons per day, irrespective of the volume of fish processed. This is shown diagramatically on figure 5. A number of other studies also indicated that the rate of water usage was relatively constant regardless of the quantity of fish being processed.

Table 17. Combined Perch and Smelt Wastewater Characteristics (Study#1)

	BOD_5		S.S.	
	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish
Mean	3044	4.5	1397	2.3
Standard Deviation	±1413	±2.0	±724	±1.3
Coefficient of Variation	46.3%	45.4%	51.8%	58.7%
Number of Samples	40	29	40	29

4.1.5 Fish Meal Production:

The processing of fish meal can lead to the discharge of high strength wastes. A review of table 18 indicates the advisability of limiting the direct discharge of bloodwater and stickwater to receiving waters. Many plants do in fact recover both their bloodwater and stickwater, producing fish meal, condensed solubles and oil from these waste products. Such recovery practices should be encouraged in those plants which presently discharge their waste direct to the receiving water.

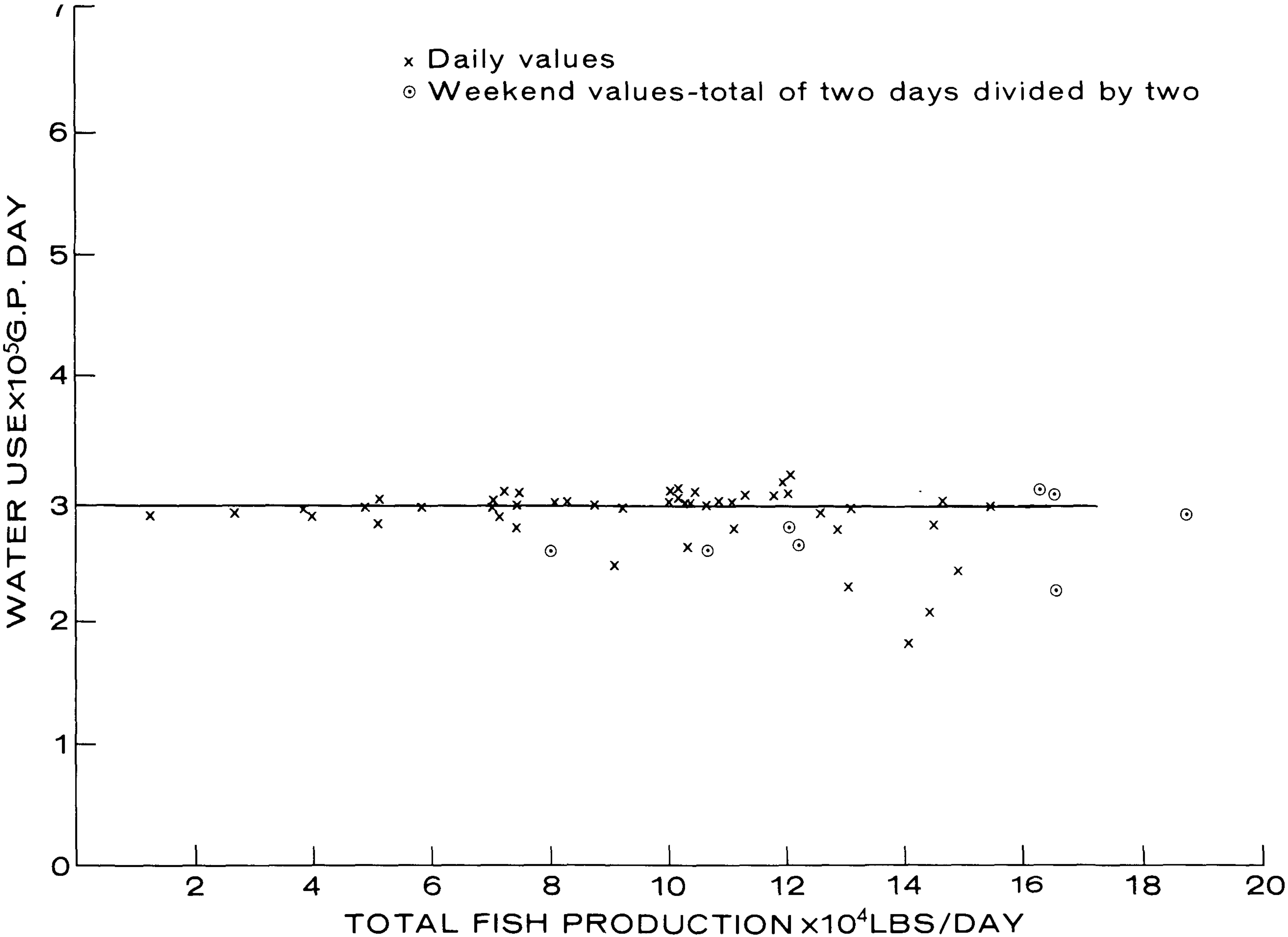

Figure 5. Water Use Against Total Fish Processed Per Day

Table 18. Average Effluent Characteristics from Fishmeal Processing

Waste Stream	BOD_5 (mg/l)	SS (mg/l)	Ether Soluble Oil (mg/l)
Non-Oily Bloodwater	120,000	--	3,000
Oily Bloodwater	80,000	15,000	--
Deodorizer Water	20	100	--
Condenser Water	10	80	--
Stickwater			
Groundfish	120,000	10,000	300
Herring	70,000	30,000	5,000
Perch and Smelt	160,000	66,000	1,200
Pumpout Water	34,000	8,000	500

Many of the studies reported previously indicate that the results obtained from BOD_5, suspended solids and oil analyses varied widely. This is due to:

1. Inherent sampling and analysis problems.
2. Variable characteristics of the fish such as age, sex, and season of the year.
3. Variations in the catch handling and storage techniques employed by the fishermen as well as the time required to transport the fish to the plant.
4. Variations of off-loading, storage and processing techniques employed by the plants.

Reliable results from fish plant effluents studies can only be obtained from a thorough sampling program. In most cases such a sampling program can only be carried out on the total effluent.

4.2 Treatability Studies:

4.2.1 Physical Treatment:

4.2.1.1 Screening:

In the course of pilot plant studies on the treatment of fish processing wastes, the Vancouver Laboratory of the Fisheries Research Board of Canada (Study #5) established that tangential screens equivalent to 40 mesh screens could successfully screen salmon canning wastewater and herring pumpout water. A diagram of such a screen is shown in figure 6. A design flow-rate of 50 IGPM per foot of cross-section could be maintained with periodic high pressure spraying of the screen surface to prevent clogging.

In a subsequent demonstration unit designed by the Fisheries Research Board staff, two 6 foot 45 degree tangential screens were used in parallel to handle a flow of 650 IGPM of salmon canning wastewater. The screen sizes were equivalent to 18 and 25 mesh respectively and subsequent visual examination revealed that the 25 mesh screen was subject to less plugging. With the addition of high pressure sprays working on a time clock of 10 seconds on every three minutes, the screens have operated satisfactorily and effectively on water from salmon canning, groundfish filleting, salmon unloading, herring unloading and herring roe recovery. These screens are preceded in line by a 4 mesh rotary screen, and typical recovery rates are given in table 19.

Table 19. Solids Removal by Tangential Screens (Study #5)

Wastewater Source	Flow Rate (Gals/ft. of cross section)	Insoluble Solids Removal %	Dry Solids Recovery (lb/hour)
Salmon Canning	56	43	280
Groundfish	66	10	24
Herring pump water plus process water	28	50	1500

During study #1 the effect on smelt and perch processing effluents of 20 mesh tangential screens, similar to that shown on figure 6, was examined. The percent suspended solids removals are shown in table 20.

Further tests of 25 mesh tangential screens are to be carried out on groundfish filleting effluents and pumpout water. These tests should be complete by August 1973.

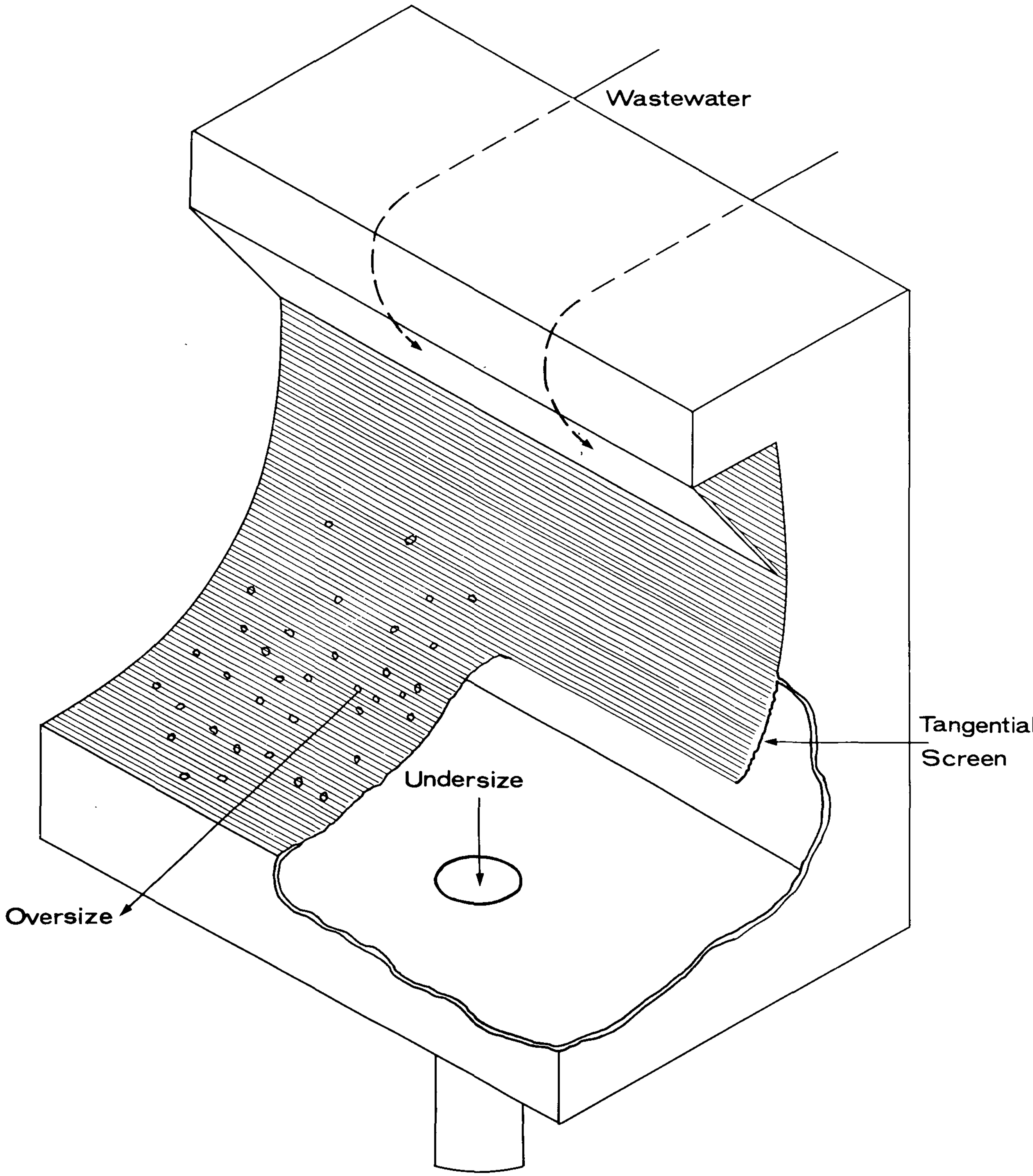

Figure 6. DSM Tangential Screen

Table 20. Suspended Solids Removal by Tangential Screens (Average and standard deviation of the S.S. Concentrations)

Wastewater Source	Before Screening (mg/1)	After Screening (mg/1)	Percent Removal
Smelt Processing			
Line 1	2362±380	1621±261	31.4
Line 2	3434±483	2473±332	28.0
Perch Processing	1107±191	825±156	25.5

4.2.1.2 Flotation for Protein and Oil Recovery:

Based on the pilot plant studies of the Fisheries Research Board of Canada, a demonstration protein and oil recovery system has been installed at a Steveston fish processing plant as a joint venture of the Fisheries Association of British Columbia, B.C. Packers, Ltd., and the Industrial Development Branch of the Fisheries Service, Department of the Environment. The unit was designed by Fisheries Research Board staff, and the operation of the unit has been monitored for two years. A flow diagram of the unit is shown in figure 7.

The unit consists basically of two 6-foot tangential screens of 18 and 25 mesh respectively, operating in parallel, followed by a dissolved air flotation cell. In this unit the screened water is pressurized to 45 psig, air is injected at 2 percent by volume, and retention time under pressure is supplied to allow the air to enter solution. As the pressure is released by passage through a throttling valve the water enters a baffled tank. The dissolved air is released under the reduced pressure in the form of minute bubbles which attach themselves to the solid or oil particles present. These rise rapidly to the surface and are skimmed off for recovery of protein and oil. The clarified liquid is withdrawn by stand-pipe from the bottom of the tank.

The use of chemical additives has been found necessary for proper clarification, for emulsion breaking, colloid destabilization, protein precipitation and flocculation. Two chemical combinations have been found to be effective for treating wastewater generated in fish processing. The one utilizes a caustic-alum combination and the incoming water is dosed with sodium hydroxide to raise the pH to about 9.2. Enough aluminum sulphate is then added to lower the pH to about 5.4 The other utilizes alum-polymer combination and enough aluminum sulphate is added to lower the pH to about 5.4 and an anionic polyelectrolyte is added to assist the proper flocculation. Both systems are equally effective but the latter has been favored slightly due to lower chemical costs, ease in solids recovery and lesser sensitivity to operating parameters. The clarification achieved

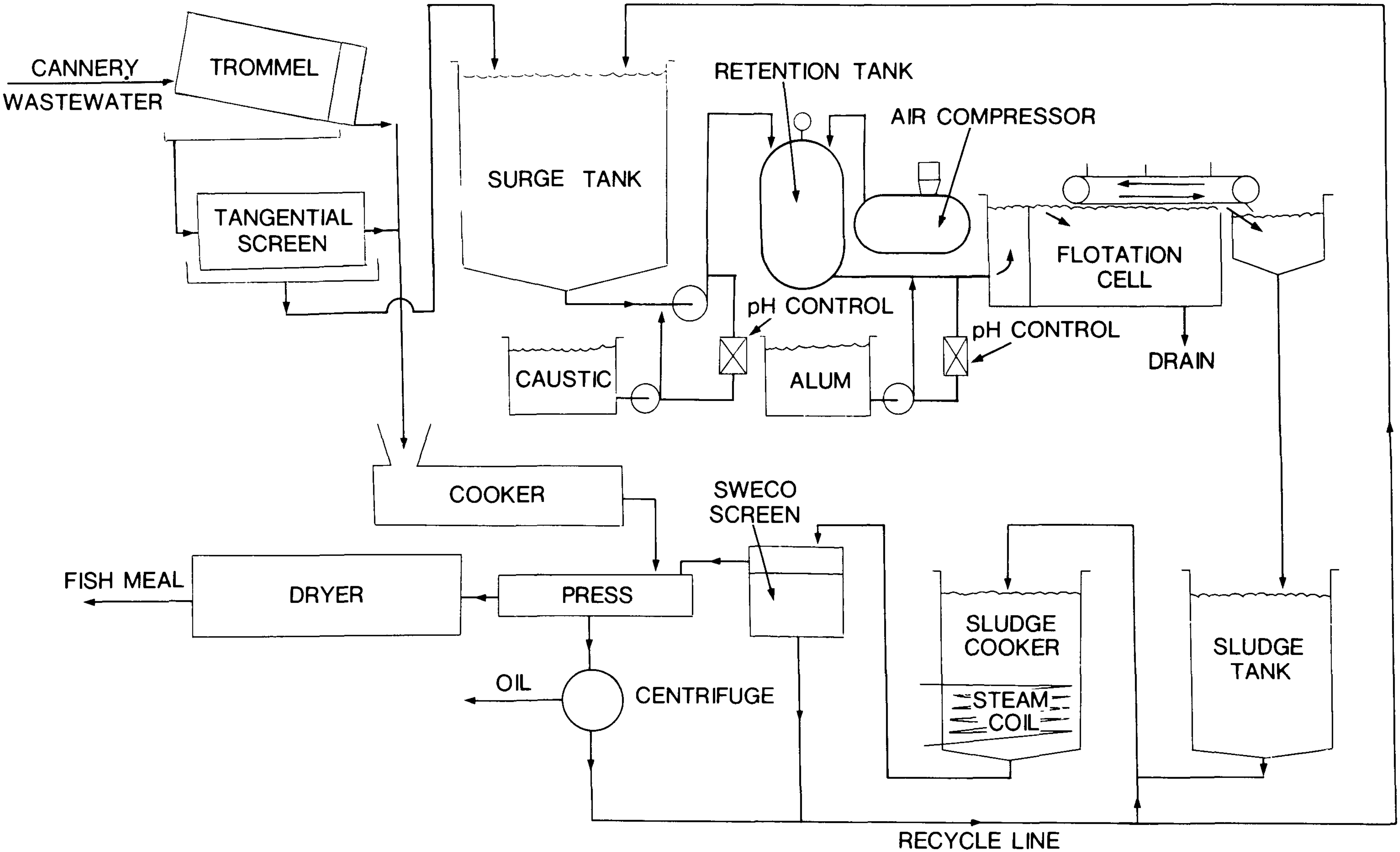

Figure 7 PROPOSED PLANT LAYOUT

is shown in table 21.

Table 21. Degree of Removal of Various Characteristics by Air Flotation (Study #5)

Water Source	Insoluble Solids	Soluble Solids	Protein	BOD_5	Oil
Salmon	92%	28%	61%	84%	90%
Herring	74%	44%	--	72%	85%
Groundfish	86%	14%	--	77%	--
Stickwater	95%	60%	--	--	95%

The solids which are skimmed from the flotation cell represent about 3 percent of the total flow treated. The solids content averages about 5 percent. Recovery is affected by raising the temperature of the stream to about 200 degrees F. to denature the protein followed by removal of the solids and oil by centrifuging. The solids are added to the driers for recovery as fishmeal. Analyses of the recovered solids is given in table 22.

Table 22. Analysis of Solids Recovered by Air Flotation (Study #5)

Protein	65.0%
Oil	9.4%
Ash	12.6%
Moisture	10.1%

The effluent from a flotation cell has a biochemical oxygen demand (BOD_5) of 100 to 500 mg/l as opposed to screened wastewater which ranges from 200 to 3500 mg/l. The BOD_5 remaining is essentially soluble, is readily dispersed in the receiving water, and is easily assimilated by bacteria. In addition, this effluent is fully saturated with oxygen due to the use of dissolved air flotation.

Experiments in the demonstration unit indicated that better than 85% of the solids in stickwater can be recovered during air flotation by mixing 9 parts of clarified effluent with 1 part of stickwater prior to treatment (i.e. operating at 90 percent recycle). The resultant BOD_5 is still very high, averaging over 5000 mg/1, but this does offer a partial solution to the problem of handling salty stickwater. Yet to be established is the value of the recovered solids as an animal feed ingredient, and these experiments are planned for the near future.

Other chemical combinations are possible with the dissolved air flotation process. One currently under test in the Scandinavian countries involves the precipitation of protein by pH adjustment using sulphuric acid followed by reaction of the protein with a derivative for ligno-sulphonic acid, a pulp mill waste product.

The economics of dissolved air flotation treatment have not been fully established, but based on interim results obtained on salmon canning wastewater, the value of the recovered solids sold as fishmeal should offset the direct operating costs but not the capital investment.

4.2.2 Biological Treatment:

Several problems exist in attempting to design biological treatment systems for fish processing plants. Superimposed on the seasonal nature of the industry are discontinuous operating periods within the seasons. For example, many processing plants operate only one or two days a week in all except the busiest part of the fishing period. Such operations make almost any biological treatment system except lagoons impossible to use. This type of discontinuous flow would tend to upset the operation of all but the largest of joint municipal-industrial treatment plants.

Study #1 examined the treatability of combined perch and smelt wastewater using laboratory scale continuous flow biological reactors. By varying the detention time and sludge age in the continuous reactors, it was found that a sludge age in excess of 3 days is required for optimum removal of BOD_5, both filtered and unfiltered. Figure 8 summarizes the results for the continuous reactors, giving mean percent removals with standard deviations for each sludge age tested.

Examination of figure 8 indicate that increasing sludge age above 3 days with or without sludge recycle did not markedly effect the percent removal of filtered or unfiltered BOD_5. The removal of filtered BOD_5 was approximately 80 percent for each sludge age tested, whereas the removal dropped to approximately 45 percent for unfiltered BOD_5. Maximum BOD_5 removals could be achieved by either a short detention time reactor (7.5 hours) with sludge recycle and a 3 day sludge age or a larger detention time reactor (5 days) with no sludge recycle.

The Fisheries Research Board of Canada's Vancouver Laboratory (Study #5) have been experimenting with the use of a rotating biological contactor (RBC) pilot plant as a high rate biological treatment system for reducing the BOD_5 load after air flotation. This system involves passing wastewater through a compartmented trough in which styrofoam discs are slowly rotating. A biological growth develops on the disc and is

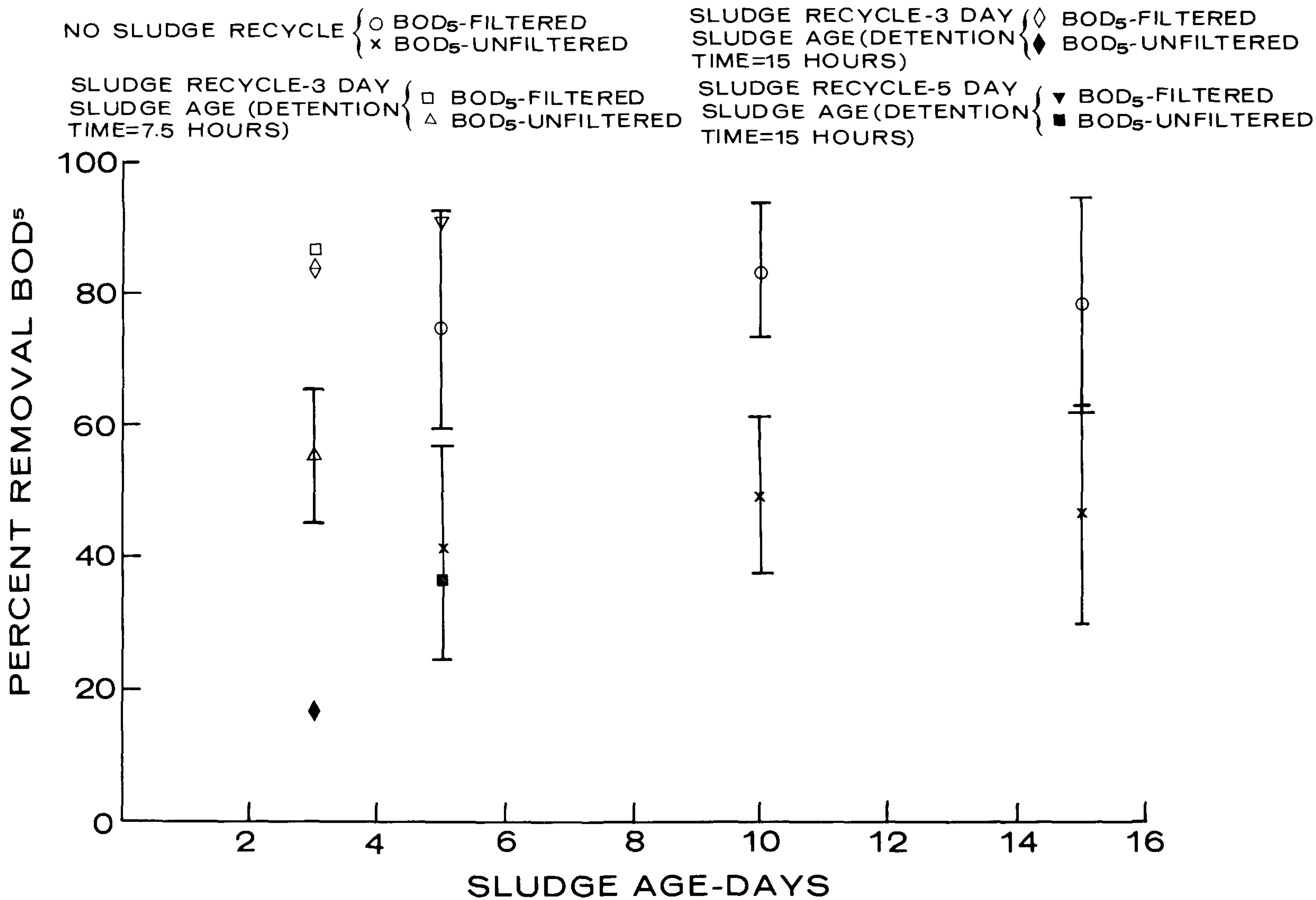

Figure 8. Continuous Reactor Studies-BOD5
(Combined Wastewater)

alternately exposed to the wastewater and air. Some of the biomass is constantly sloughed off the disc and is carried through the unit to a clarifier. Not only is the system stable to hydraulic surges, but continues to operate effectively under low flow or recycle conditions. Preliminary results indicate that, under normal conditions, a BOD_5 removal of 4.5 pounds per 1000 square feet of disc surface per day is easily attainable on a salmon canning plant effluent previously treated by air flotation, resulting in an effluent of about 50 mg/l of BOD_5.

In addition to previously mentioned advantages, the capital costs of this type of system is competitive with other high rate systems, whereas the operating costs are considerably lower.

4.2.3 Cost of Treatment Systems:

The capital costs associated with the installation of fine screening and air flotation can be estimated fairly readily from the data obtained in the installation of the demonstration unit at Steveston (Study #5). These are in the order of $2,500 and $10,000 per 100 Imp. gallons per minute respectively. Estimation of the cost of biological treatment by aerobic lagoons is more difficult because the largest portion of the total cost is in land aquisition. Roughly one acre of land per 100 Imp. gallons per minute is required if the water is from a groundfish plant or has been previously treated by screening and air flotation to about five acres per 100 Imp. gallons per minute for untreated wastes. Thus near metropolitan areas the cost could range from $40,000 to $200,000 per 100 Imp. gallons per minute to achieve proper secondary treatment, based on a price of $30,000 per acre. A further problem of lagoons would be the availability of suitable land in close proximity to many fish processing plants.

Table 23. Cost Estimate to Achieve Various BOD_5 Levels (100 IGPM of Flow)

Waste	BOD_5 Level (mg/l) 3000	500	100
Salmon	$2500	$12,500	$52,500
Herring	$2500	$12,500	$52,500
Groundfish	--	--	$12,500

SECTION V

CONCLUSION

The five studies undertaken by Environment Canada have provided the fish processing industry with characterization and treatability data on their effluents.

Although there is a good deal of variation in the effluent loadings determined for each type of effluent, characterization results are summarized in table 24.

Table 24. Summary of Characterization Data (Averages)

Fish Processed	BOD_5 Lbs/1000 lbs raw product	Suspended Solids Lbs/1000 lbs raw product
1. Groundfish Filleting		
a) Dry Line	4.5	1.5
b) Wet Line	18.0	15.0
2. Salmon Processing	28.2	19.7
3. Herring		
a) Filleting	22.0	21.0
b) Marinated	215.0	85.0
4. Shellfish		
a) Lobster	25.0	5.5
b) Crab	40.0	20.0
5. Freshwater Fish		
a) Combined Perch and Smelt	4.5	2.3

The major waste streams are associated with the processing of salmon, herring and shellfish. However, all major effluents associated with fish processing are of sufficient strength to require some type of treatment. In the majority of cases the removal of solids is adequate treatment to protect the receiving environment as this will prevent a build up of sludge around the effluent outfall with its consequent effect on dissolved oxygen. Following screening the effluent should be discharged through an outfall which allows sufficient tidal flushing action to dilute the remaining effluent and thus minimize pollution problems.

Bloodwater, stickwater and pumpout water are the effluents of highest strength associated with fishmeal production. Bloodwater and stickwater should be recovered and pumpwater should be fine screened prior to discharge to the receiving environment.

As stated previously fine screening will in most cases provide adequate effluent treatment provided this is coupled with a well designed outfall. In cases where the provision of this level of primary treatment produces an effluent which still creates pollution problems, then either flotation or biological treatment must be considered. In general most fish processing plants do not have easy access to land on which lagoons of adequate size can be built. This problem, coupled with the high cost of less land intensive methods of biological treatment, would lead to the use of flotation as an economical and practical method of secondary treatment. Further, flotation provides some economic return in the form of recovered sludge which can be recycled back to the fishmeal plant.

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