Environmental Protection Agency Technology Transfer Program

Upgrading Seafood Processing Facilities To Reduce Pollution

Waste Treatment Systems

Industry Seminars For Pollution Control

New Orleans, La.
March 5 & 6, 1974

Seattle, Wash.
April 2 & 3, 1974

ENVIRONMENTAL ASSOCIATES, INC.
Consulting Scientists and Engineers
Corvallis, Oregon

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ABSTRACT

These documents were designed by Environmental Associates, Inc. of Corvallis, Oregon to supplement formal presentations at various Technology Transfer Seminars presented by the U.S. Environmental Protection Agency in each region of the country where fish and/or shellfish processing is a significant industry. This report covers all major subcategories of seafood processed in the United States. The bulk of the material appearing herein was developed by Environmental Associates, Inc. under separate contract with the E.P.A. (Contract Number 68-01-1526).

The wastewater streams and solid wastes generated in the processing of fish and seafood are thoroughly characterized. Then the various wastewater treatment and solid waste disposal alternatives applicable to the subject industries are discussed and the costs of each recommended alternative (capital and operating/maintenance) reviewed for "typical" processing operations. The numbers presented in this report are averages of values developed within a limited time framework; they should not be used as the sole bases for design or cost estimation for specific facilities. The influences of site specificity and other local conditions dictate that each design situation be considered separately. Furthermore, mention of trade names does not constitute endorsement.

Included at the back of this document are four papers which were included in the first of the series of seminars. These

discuss: 1) applications of dissolved air flotation in the fish industry; 2) screening and dissolved air flotation of shrimp processing wastewaters; 3) characterization and treatment of fish meal and crab processing wastes in Canada; and 4) waste treatment technology in Canada.

In a separate document, the various methods of wastewater recycle and reuse, process modification, new product development and other in-plant changes designed to minimize the environmental impact of the seafood industry are comprehensively discussed.

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1. INTRODUCTION

1.1. Need for Wastewater Treatment

Concern about the discharge of industrial wastewaters into the navigable waters of the United States was expressed in the Federal Water Pollution Control Act Amendments of 1972 (the "Act"). The Act requires the Environmental Protection Agency to establish effluent limitations on point sources of discharge. Many substances are discharged into receiving waters in sufficient quantities to lower the water quality to the point that beneficial uses are impaired. Substances which are potential pollutants include solids (floating, suspended, settleable, and dissolved), organic matter, nutrients, heat, toxic materials, acids and bases.

Floating solids, including foam, grease, scum, and fish viscera are unsightly and interfere with natural aquatic functions such as oxygen transfer and light penetration. Settleable solids adversely affect light penetration, and after settling form anaerobic sludge beds from which emanate methane and hydrogen sulfide. The anaerobic environment on the bottoms of streams and bays prevents hatching of non-bouyant eggs of aquatic animals. Turbidity and limited light penetration hinder the growth of aquatic vegetation. If the receiving waters are to be used for domestic water supplies, treatment becomes more difficult if large amounts of suspended solids are present.

Organic matter decomposes when present in the marine environment, thus depleting the amount of oxygen in the water. More desirable species of fish and aquatic life, such as trout and bass, will be replaced by scrap fish, such as carp and others having lower oxygen requirements, when the dissolved oxygen levels fall below 5 mg/l.

Nutrients (particularly phosphorus and nitrogen), when present in the marine environment under the proper conditions, stimulate algae growth. Fish living within the algae bloom will often have off-flavors. When the algae die, their decomposition exerts an oxygen demand which can cause fish kills, unpleasant odors, and unsightliness. Reaeration of oxygen-depleted waters by natural means such as stream ripples and waves is limited.

Changes in temperature may adversely affect aquatic organisms and the dissolved oxygen content of the water. Many fish have narrow temperature tolerance ranges. If the temperatures vary from the optimum, fish cannot carry out many important functions such as reproduction. Water will not hold as much dissolved oxygen at lower as it will at higher temperatures. Increased temperatures also accelerate algae growth, thus compounding the dissolved oxygen problem.

Toxic chemicals are common in some industrial effluent streams, but are not prevalent in seafood processing wastes. Toxic substances discharged to receiving waters can be harmful to plant, animal, and human life.

Acids and bases present in the effluent can adversely influence biological activity in the receiving waters. Most living organisms can live only near the neutral pH of seven. Even slight deviations from this value can drastically influence the organisms living in the waters. Seafood processing wastes typically have pH's within the six to eight range.

Wastewater treatment of some form is needed to avoid the impairment of water quality. Treatment, when discharging to a municipal system, usually does not need to be as complete as when the wastewaters flow directly to the receiving waters. Requirements of local, state, and federal agencies will dictate the required degree of treatment.

1.2 Industry Categorization

Important factors in the design of a cost effective waste treatment system are: the characteristics of the waste load, the contaminants to be removed and the level of removal required, the scale of the operation, and, very importantly, local factors such as climate, land availability, solids disposal sites, and by-product recovery facilities. For a specific problem certain variables may be identified such as the required level of removal of certain contaminants and possibly the scale of the operation. Factors such as local conditions and specifics of the plant site will have to be determined for each case.

Characterization of the waste load is one of the most important factors and can be an expensive and time consuming step in the design procedure. It is expensive because field personnel are required to take measurements and collect wastewater samples for subsequent laboratory analysis. It can be time consuming if the nature of the operation is seasonal or intermittent, requiring long delays before or during an appropriate sampling period.

When reviewing an entire industry, one way to maximize efficiency is to categorize the industry such that the waste loads are relatively uniform within each category, and then to conduct a sampling program to characterize the effluent within each group. Once these data are obtained, the designer has background information for most cases and needs only to verify that his plant is typical. The background data will suffice in many cases to determine the most cost effective system. A few samples should be collected to verify the assumptions made.

Several factors should be considered in a categorization study. Some of the more important to the seafood industry are: geographic location, manufacturing processes and subprocesses, form and quality of finished product, species and condition of the raw product, production capabilities, waste loads, number of plants engaged in the activity and ages of facilities and the seasonality of operation.

Recent studies of the wastes from the U.S. seafood industry (Environmental Associates, 1973 and 1974) resulted in the following categorization scheme. The industry was first divided into three main groups: 1) fish reduction; 2) finfish; and 3) shellfish.

The finfish and shellfish groups were further subdivided by commodity and type of preservation method: canning, curing, fresh pack, or freezing. To determine which segments of the industry were more significant from the standpoint of the magnitude of pollution abatement efforts required, a matrix analysis was performed to help focus the study on the more important areas. Field investigation work was then concentrated in these areas, the data analyzed and the subcategorization shown in Tables 1 and 2 developed. The subcategories are listed in approximate order of importance in terms of the waste loads produced per day from a typical plant.

Table 1. Fish reduction and finfish subcategories.

Fish meal production without solubles plant
Fish meal production with solubles plant
Alaska salmon canning
Northwest salmon canning
Tuna canning
Herring filleting
Herring pickling
Sardine canning
Jack mackerel canning
Mechanized bottom fish, groundfish, or miscellaneous finfish
Conventional bottom fish, groundfish, or miscellaneous finfish
Alaska bottom fish (halibut)
Alaska fresh/frozen salmon
West Coast fresh/frozen salmon
Catfish

Table 2. Shellfish subcategories.

Alaska shrimp
West Coast or New England shrimp
Gulf shrimp
Alaska crab
Mechanized blue crab
West Coast crab
Mechanically shucked surf clams
Conventional shucked surf clams
Conventional blue crab
Steamed/canned oysters
Hand shucked oysters
Alaska scallops
Non-Alaska scallops
Abalone or sea urchin
Lobster

1.3 Waste Categorization

Waste from seafood processing plants typically can be grouped into four categories:

a) "Contaminated fish processing waters" are defined as waters which have been in contact with the raw or finished product, and offal. These waters include flume water, plant wastewater, clean-up water and water used in the machines that do the actual processing. It is these waste streams which contribute the largest part of the waste load.

b) "Uncontaminated fish processing waters" are defined as wastewaters which have not been in contact with the fish. These waters include can cooling water.

c) "Storm water" is water which reaches drains used solely for carrying storm and/or drainage water off the premises.

d) "Sanitary wastes" are waters which originate from toilets and other domestic wastewater facilities within the plant.

1.4 Industry Wastewater Characterization Summary

During the studies conducted by Environmental Associates, Inc. (1973 and 1974), initial evaluations of the industrial segments resulted in sampling programs whose sizes were based on the relative importance of the respective categories. The greater the waste loads from the plants and the larger the industrial category, the greater was the number of samples taken. Because of the large variations in waste loads that occur, large number of samples frequently must be taken to properly define the wastewater.

The parameters of major pollutional significance to the canned and preserved fish and seafood processing industry are: 5-day (20°C) biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, settleable solids, oil and grease, organic nitrogen, ammonia nitrogen, raw product input rate, and food/product recovery, and flow. Of these BOD, suspended solids, grease and oil, flow, and production are considered to be the most significant variables.

All wastewater samples taken should be flow-proportioned composites of the total plant effluent. This method of sampling has been found to reduce variability in the data and produce more representative samples than would otherwise be obtained by other sampling methods.

Results from wastewater sample analyses conducted by a laboratory are usually expressed as concentrations, normally milligrams per liter (mg/l). For design purposes, data are best left in this form. However, for the purpose of characterization, variations in daily flow and daily production need to be considered by converting mg/l to pounds of waste produced per ton of product (usually raw product) processed. The following formula will convert mg/l to lbs/ton:

$$(\text{mg/l})\ (8.34)\ (\text{MGD}) \div (\text{tons/day}) = \text{lbs/ton}$$

where MGD is an abbreviation for million gallons per day.

Figures 1 and 2 show the relative waste loads for the finfish and shellfish categories. Figures 3 and 4 depict the relative amounts of waste produced per day for the two major categories. The listings on these four figures are generally in order of decreasing impact on the receiving waters (season lengths as well as waste loads being considered).

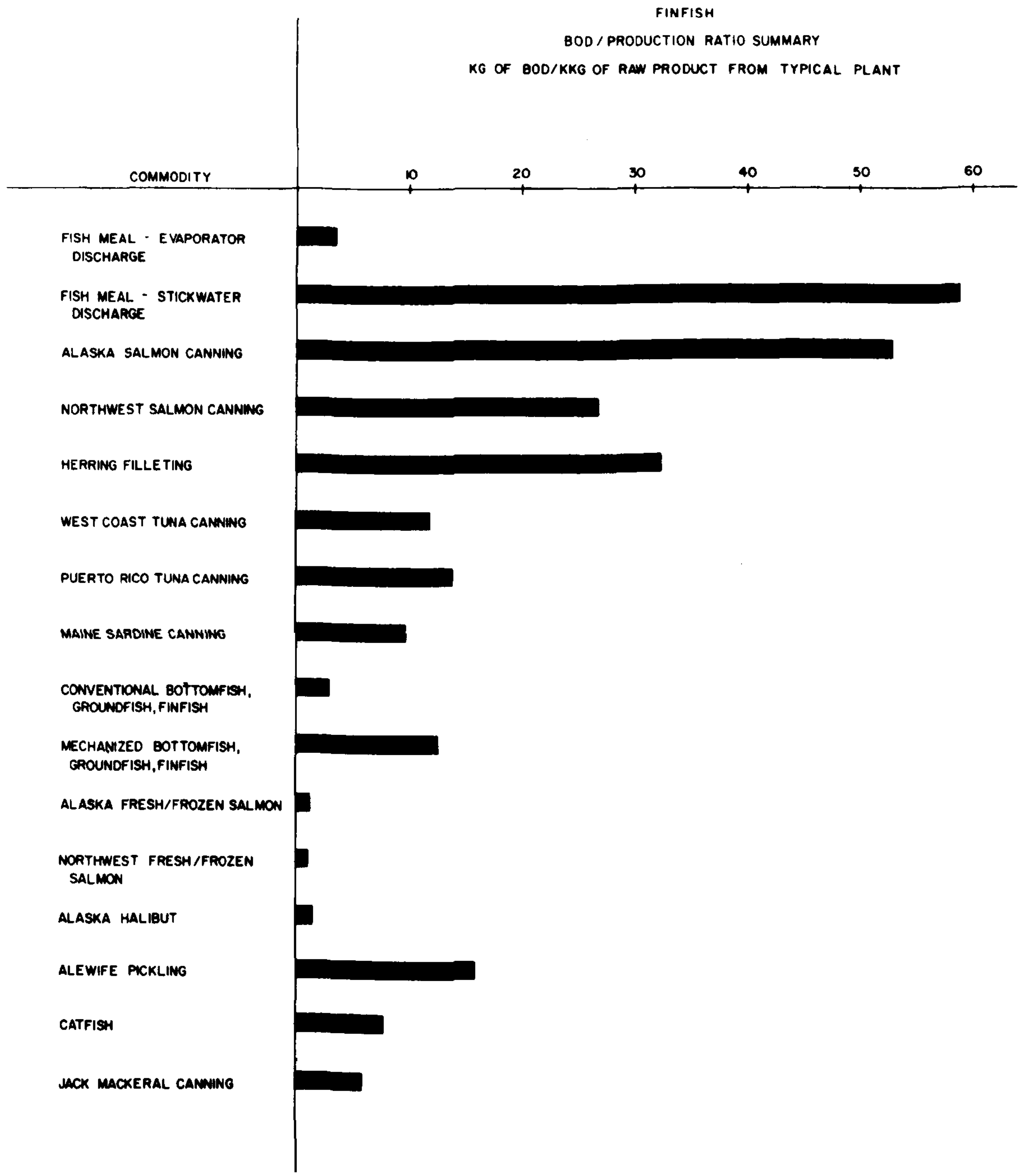


Figure 1. Relative waste loadings for the finfish catagory.

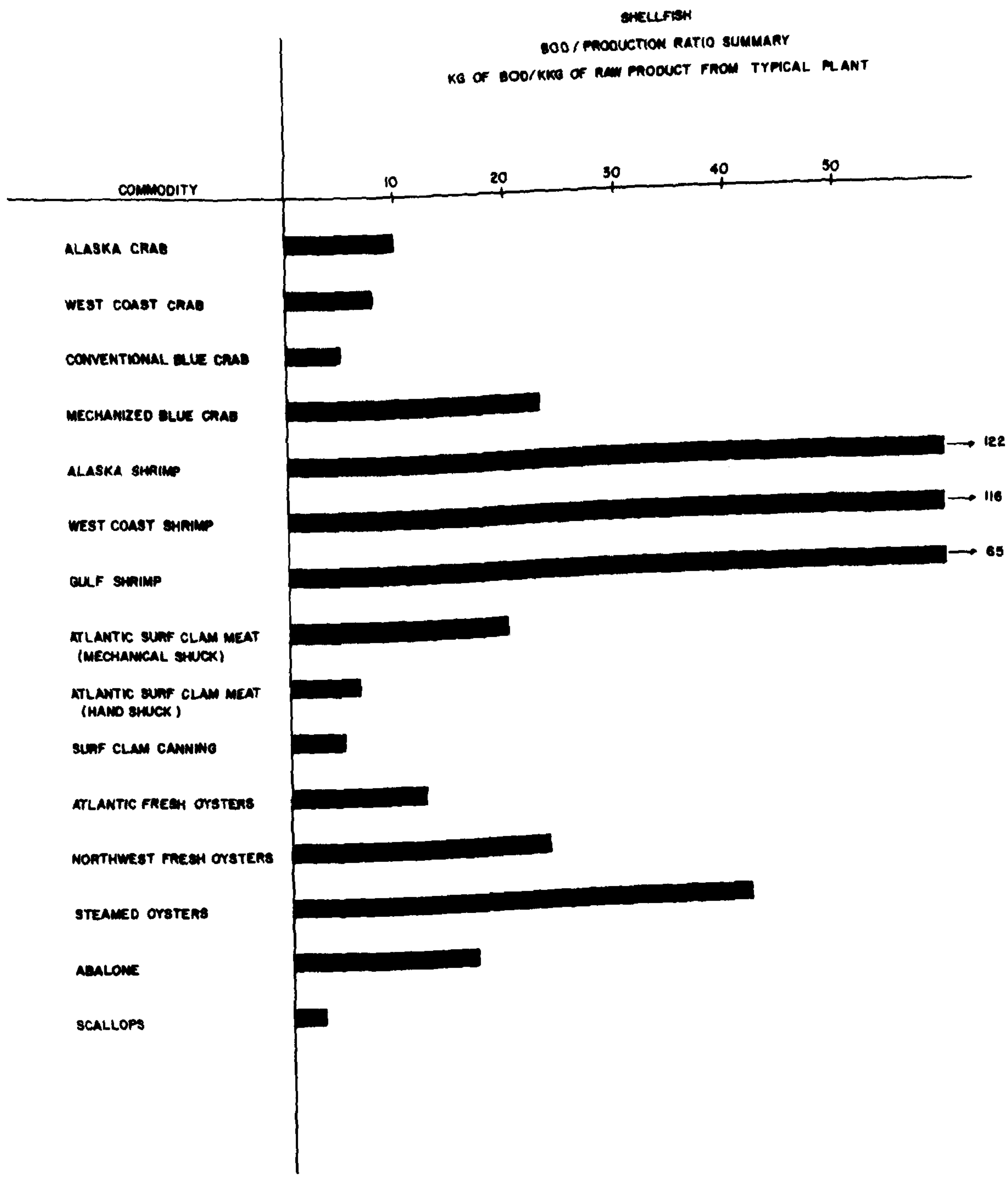


Figure 2. Relative waste loadings for the shellfish catagory.

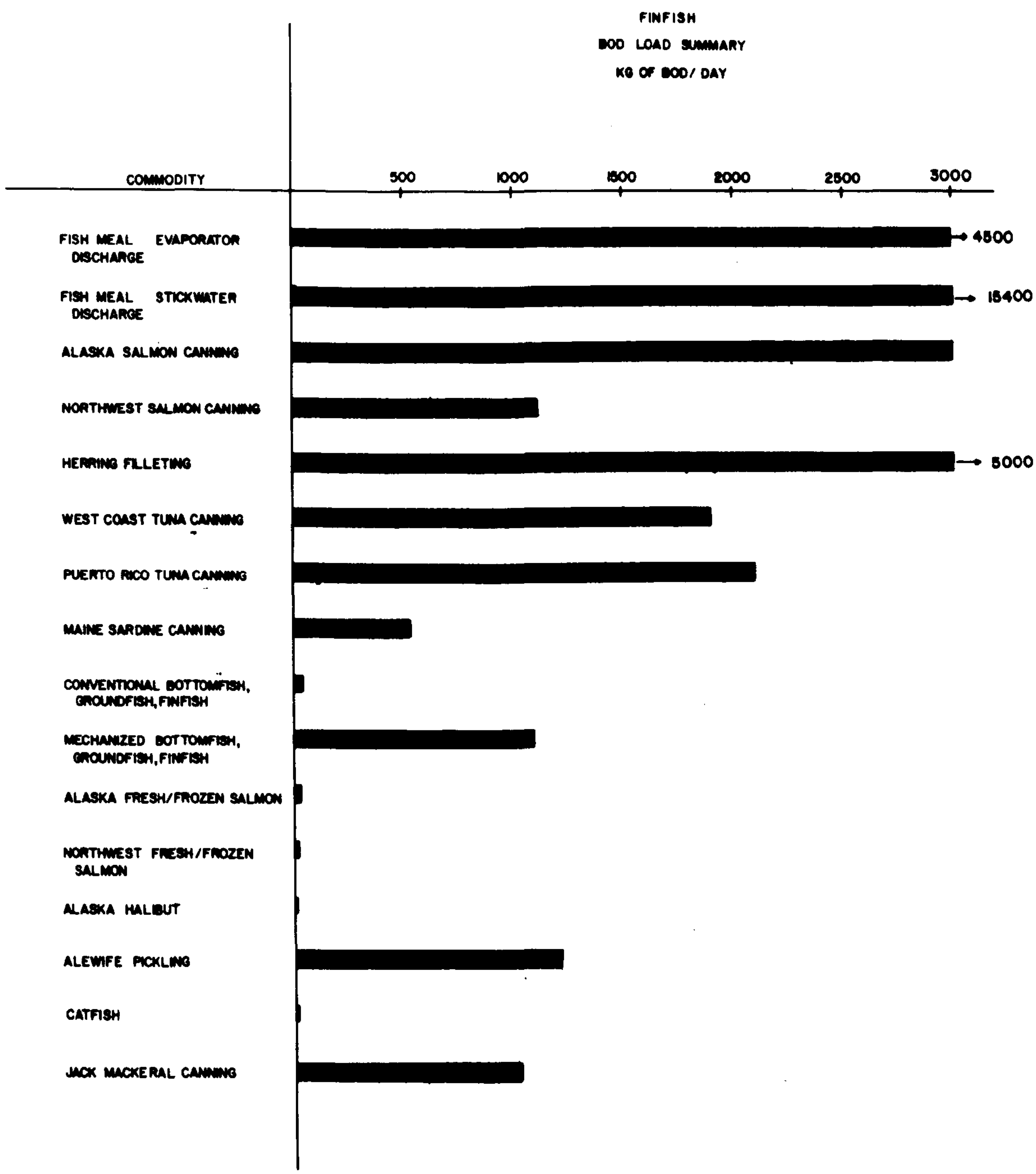


Figure 3. Relative amounts of waste produced per production day for the finfish cataqory.

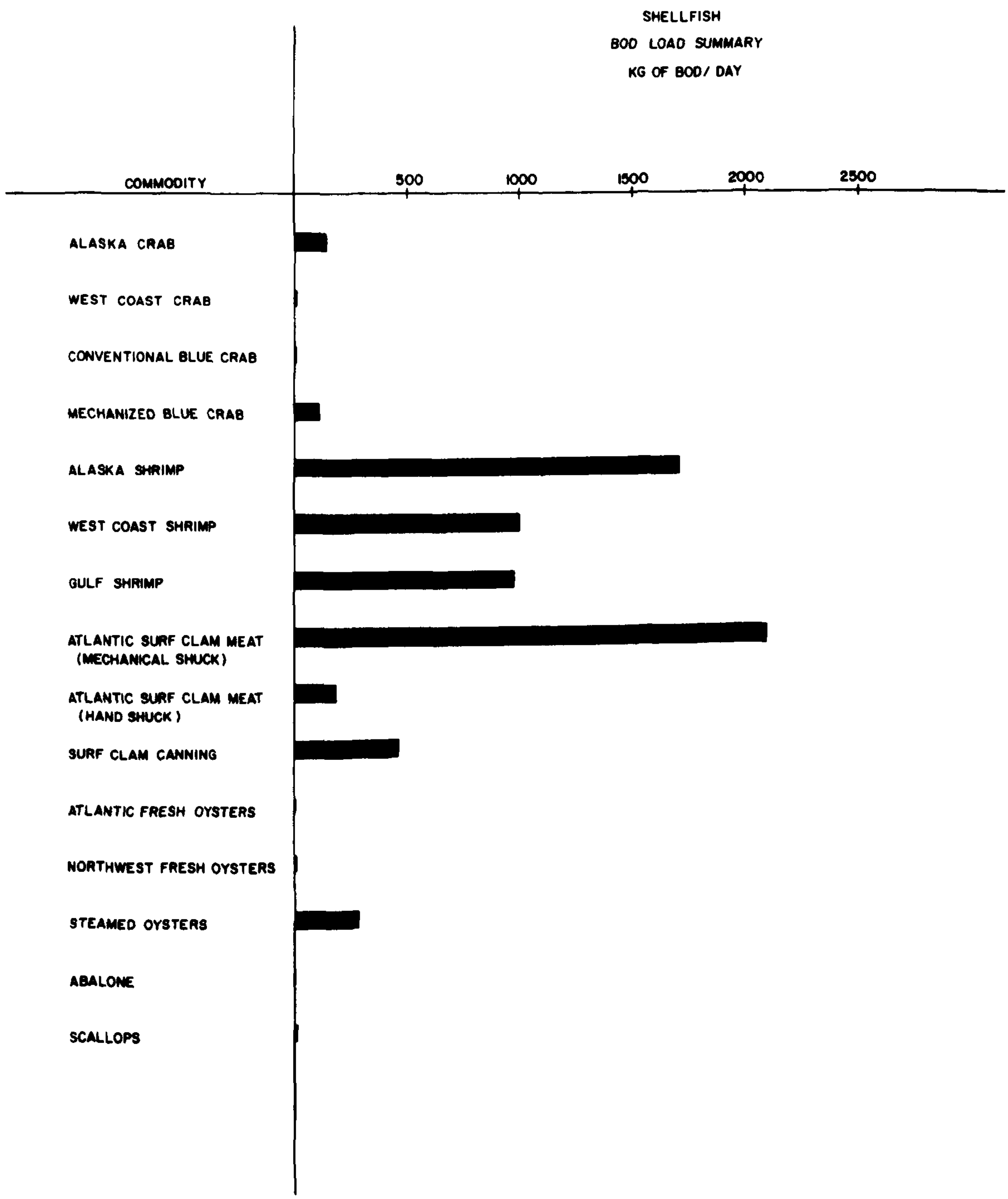


Figure 4. Relative amounts of waste produced per production day for the shellfish catagory.

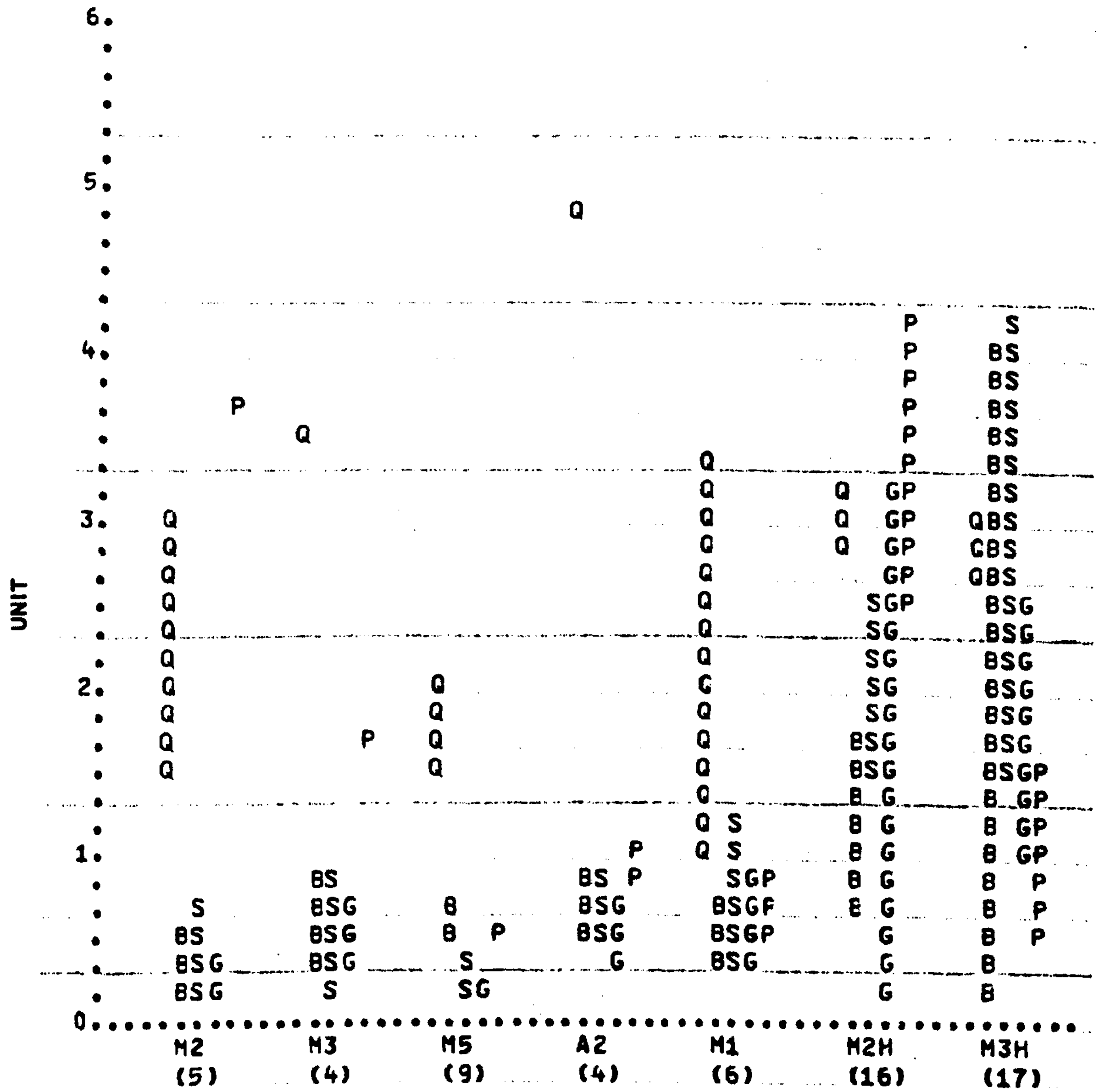
In the following sections, the wastewater characteristics of each of the major subcategories (as defined on Tables 1 and 2) are presented. These data were generated (largely) during the recent studies by Environmental Associates (1973 and 1974). Accordingly, for each subcategory there appears a discussion of the sampling program involved and the conclusions reached as a result of data analysis.

1.4.1 Industrial Fish Meal Process

Regardless of the species being rendered, five general types of wastewaters are discharged from a wet reduction process: evaporator, drop-leg water, bailwater, washwater, and stickwater. Most large plants employ solubles recovery systems and discharge only evaporator water. Some medium-size plants evaporate the stickwater, but discharge the bailwater, and the smaller, older plants often discharge both stickwater and bailwater. Five of the plants sampled were menhaden reduction plants located on the Atlantic or Gulf Coast and three were anchovy reduction plants located in California.

Figure 5 shows a normalized (to production) summary plot of the wastewater characteristics taken from all the fish meal reduction processes with solubles plants. Five parameters: flow, BOD, suspended solids, grease and oil, and production, are shown for each plant sampled. The vertical scale is in dimensionless units with the scaling factor shown at the bottom of the figure. The average value of the parameter is at the center of the vertical spread with the height of the spread representing one standard deviation above

Figure 5. FISH MEAL PROCESS PLCT (WITH SOLUBLES PLANT)



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 10000 L/KKG
B	5 DAY BOD	1 UNIT = 5 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 2 KG/KKG
G	GREASE & OIL	1 UNIT = 2 KG/KKG
P	PRODUCTION	1 UNIT = 20 TON/HR

and below the mean. A plant code is shown at the bottom of each group, where "M" stands for menhaden, and "A" stands for anchovy. The number in parentheses under the plant code is the number of samples taken from each plant.

The first four plants (M2, M3, M5, and A2) discharged only evaporator water, while the remaining three plants (M1, M2H, and M3H) discharged bailwater instead of evaporating it. It can be seen that the waste load was generally lower from the plants not discharging bailwater. Plants M2 and M3 provided good examples of the reduction in waste loads that can be achieved by evaporating the bailwater. The codes M2H and M3H represent historical data collected when both plants discharged or barged bailwater, while the codes M2 and M3 represent recent data when both plants were treating and evaporating the bailwater. Table 3 shows the average waste loads both before and after bailwater treatment and evaporation and the percent reductions obtained.

Table 3. Waste load reduction using bailwater evaporation.

	Parameter (kg/kkg)		
	Suspended solids	BOD	Grease and oil
Plant M2 - Before	4.1	5.9	3.0
- After	0.88	1.7	0.53
- % Reduction	78	71	82
Plant M3 - Before	5.6	10.1	3.5
- After	1.2	3.6	1.0
- % Reduction	78	64	71

Figure 6 shows a summary of the waste loads from two plants discharging both stickwater and bailwater. The waste loads are about 20 to 40 times greater than those from plants utilizing evaporators.

Table 4 summarizes the average waste loads from plants with three types of discharges: solubles plant only, solubles plant plus bailwater, and stickwater plus bailwater.

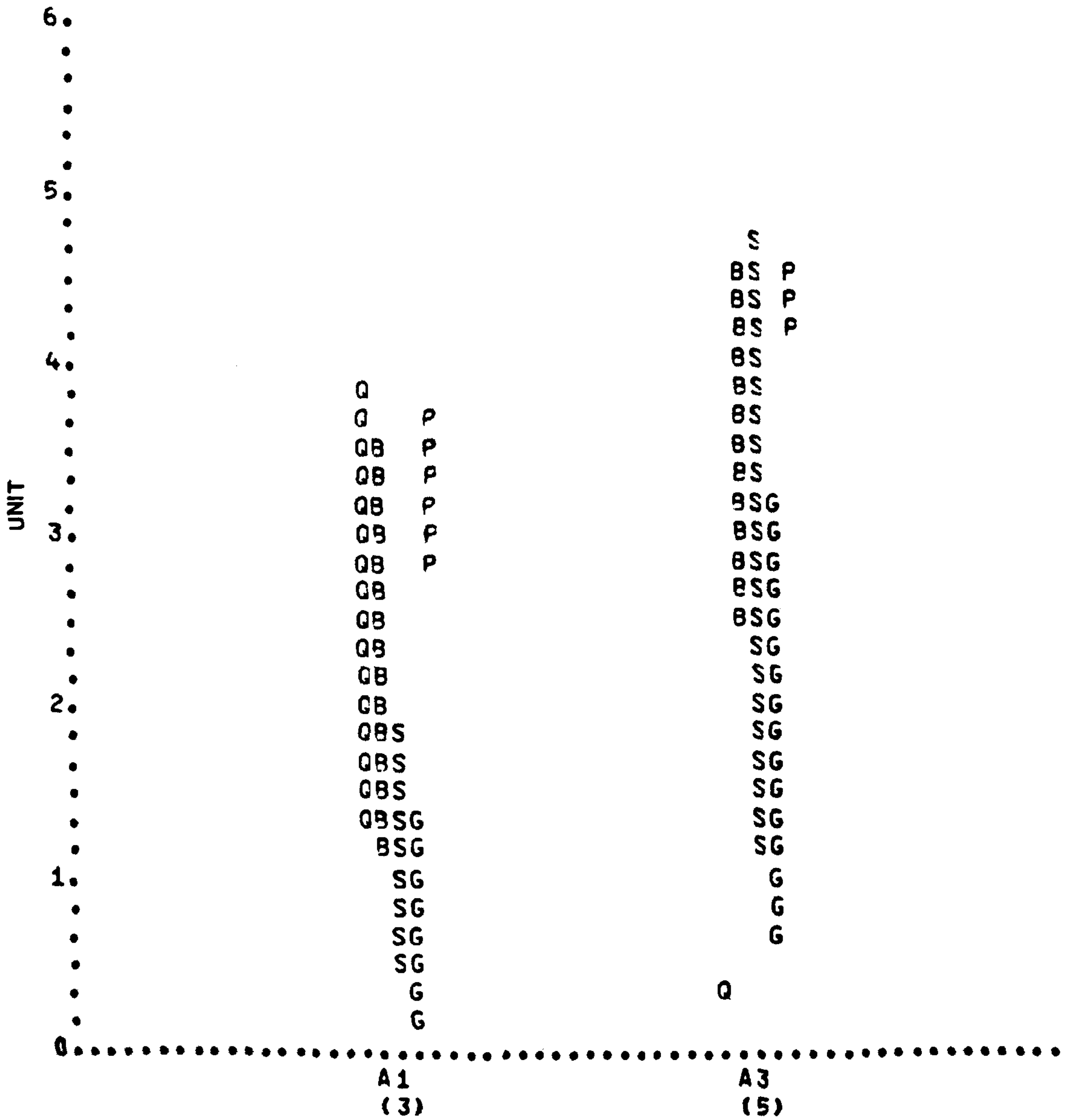
Table 4. Summary of average waste loads from fish meal production.

Parameter (kg/kkg)	Solubles plant	Solubles plant and bailwater	Stickwater & bailwater
Suspended solids	1.0	3.8	41
5 day BOD	2.9	6.1	59
Grease and oil	0.74	2.5	25

The fish meal production industry was segmented into two subcategories: those with a discharge equivalent to that from a solubles plant only, and those without a solubles plant. The exemplary plants treat, recycle, and evaporate the bailwater and washwater. The older, smaller plants typically have no existing solubles plant facilities to expand or modify to treat the stickwater or bailwater; therefore, these were placed into a separate subcategory.

Statistics from plants sampled in these two categories are shown in Tables 5 and 6. The tables show the estimated means, standard deviations, and ranges for each of several parameters.

Figure 6. FISH MEAL PROCESS PLOT (WITHOUT SOLUBLES PLANT)



SYMBOL	PARAMETER	SCALING FACTCR
Q	FLCW	1 UNIT = 5000 L/KKG
B	5 DAY BOD	1 UNIT = 20 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 20 KG/KKG
G	GREASE & OIL	1 UNIT = 20 KG/KKG
P	PRODUCTION	1 UNIT = 2 TON/HR

Table 5. FISH MEAL PROCESS SUMMARY
(DISCHARGE FROM)
(SOLUBLES PLANT ONLY).

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	33.4	28.2	6.04	107
PROCESS TIME HR/DAY	22.1	2.21	19.0	24.0
FLOW L/SEC	243	156	64.6	645
(GAL/MIN)	3840	2470	1020	10200
FLOW RATIO L/KKG	30800	13900	12100	65200
(GAL/TON)	7390	3320	2910	15600
SETT. SOLIDS ML/L	4.61	--	--	--
RATIO L/KKG	142	--	--	--
SCR. SOLIDS MG/L	--	--	--	--
RATIO KG/KKG	--	--	--	--
SUSP. SOLIDS MG/L	28.0	11.4	12.1	55.3
RATIO KG/KKG	0.864	0.351	0.372	1.72
5 DAY BOD MG/L	90.2	23.6	52.7	145
RATIO KG/KKG	2.78	0.728	1.62	4.[illegible]6
COD MG/L	198	77.5	67.6	386
RATIO KG/KKG	6.09	2.39	2.70	11.3
GREASE & OIL MG/L	22.5	10.1	8.87	47.5
RATIO KG/KKG	0.694	0.311	0.273	1.46
ORGANIC-N MG/L	4.87	3.07	1.33	12.3
RATIO KG/KKG	0.150	0.095	0.041	0.395
AMMONIA-N MG/L	2.76	2.36	0.489	8.36
RATIO KG/KKG	0.085	0.073	0.015	0.276
PH	6.07	1.40	4.33	7.75
TEMP DEG C	35.8	14.8	14.1	47.0

PLANTS M2 , M3 , M5 , A2

Table 6. FISH MEAL PROCESS SUMMARY (WITHOUT SOLUBLES PLANT).

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	7.60	1.46	5.15	10.3
PROCESS TIME HR/DAY	15.7	11.8	7.33	24.0
FLOW L/SEC	13.1	12.9	1.87	46.3
(GAL/MIN)	208	204	29.6	743
FLOW RATIO L/KKG	7390	7800	931	27700
(GAL/TON)	1770	1870	223	6640
SETT. SOLIDS ML/L	29.4	37.4	2.66	124
RATIO L/KKG	217	276	19.7	918
SCR. SOLIDS MG/L	62.1	--	--	--
RATIO KG/KKG	0.459	--	--	--
SUSP. SOLIDS MG/L	5530	3400	1550	14300
RATIO KG/KKG	40.8	25.1	11.4	106
5 DAY BOD MG/L	7940	2330	4330	13400
RATIO KG/KKG	58.6	17.2	32.0	98.3
COD MG/L	15300	6370	6420	30900
RATIO KG/KKG	113	47.1	47.5	228
GREASE & OIL MG/L	3380	2390	793	9620
RATIO KG/KKG	25.0	17.7	5.86	71.1
ORGANIC-N MG/L	703	8.68	687	721
RATIO KG/KKG	5.20	0.064	5.07	5.32
AMMONIA-N MG/L	30.0	6.76	18.9	45.2
RATIO KG/KKG	0.221	0.050	0.140	0.334
PH	6.80	0.026	6.78	6.82
TEMP DEG C	32.3	15.5	21.3	43.3

PLANTS A1 , A3

A basic assumption was that the bailwater, washwater, and stickwater processed by the solubles plant during a given period resulted from the volume of fish processed just previous to the solubles plant operation period under consideration. The amount of fish processed was then equally distributed over the solubles plant operational period which followed, allowing the waste loads to be properly related to the production levels. As a result, the wastewater summary tables show long processing times and relatively low production rates, and it must be remembered that these are in terms of solubles plant operation and not fish pressing and drying time. For cases where bailwater was being discharged, the flow rate was determined by averaging over the period of solubles plant operation so that the two waste loads could be added properly.

Table 7 shows the wastewater balance summary for plants with only evaporator and air scrubber discharges (M3, A2) and Table 8 shows the wastewater balance for plants with evaporator and bailwater discharges (M2H, M3H). It can be seen that the largest flows (by far) were from the evaporator. Bailwater flows are relatively small but contain substantial waste loads. Air scrubbers can contribute relatively large flows containing about the same concentrations of wastes as the evaporator flows.

While most of the total plant BOD load was contributed by the evaporator process, very little suspended solids or grease and oil were added at that point. It was determined that the evaporator (sea water) intake contributed an average of only 8% of the BOD, but 52% of the suspended solids and 78% of the grease and oil (Environmental Associates, Inc. 1974).

Table 7. Fish meal production with solubles plant material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) evaporator	80 - 85%	60 - 85%	60 - 90%
b) air scrubber	15 - 20%	15 - 40%	10 - 40%
Total effluent average M3, A2	51,000 l/kkg	3.7 kg/kkg	1.6 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Products	
a) oil	6 - 8%
b) meal	20 - 21%
By-products	
a) solubles	15%
Wastes	
a) water	56 - 59%

Average Production Rate, 540 kkg/day (600 tons/day)

Table 8. Fish meal production with bailwater material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) evaporator	>99%	17 - 48%	12 - 36%
b) bailwater	<1%	52 - 83%	64 - 88%
Total effluent average M2H, M3H	29,300 l/kkg	8 kg/kkg	5 kg/kkg

Average Production Rate, 450 kkg/day (495 tons/day)

Table 9 shows the wastewater balance summary for a fish meal plant with no solubles plant discharging stickwater and bailwater. The largest and strongest flow was the stickwater, which is the liquid remaining after the oil is recovered from the press liquor. The waste load from the stickwater is one of the strongest in the entire seafood industry, being very high in BOD, suspended solids, and grease and oil. The bailwater also contributed a relatively high flow and load.

1.4.2 Salmon Canning Process

Since the salmon canning process is essentially the same from plant to plant, the only two factors prompting further subcategorization are geographic location and plant size.

The salmon canning industry was subcategorized into Alaska and Northwest regions because of the much greater costs and treatment problems encountered in Alaska. Furthermore, due to the large size range of the industry in both areas, the Alaska industry was divided into three sizes and the Northwest industry into two sizes for the purpose of costing control and treatment technologies. There is no obvious distinct grouping of plant sizes; however, the following divisions were established to develop criteria which would adequately cover the range:

Alaska salmon canning--large: greater than 80,000 cases annually;

Alaska salmon canning--medium: between 40,000 and 80,000 cases annually;

Table 9. Fish meal production without solubles plant material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) stickwater	45%	93%	94%
b) bailwater	39%	7%	6%
c) washdown	1%	<1%	<1%
d) air scrubber	15%	<1%	<1%
Total effluent average A3	1870 l/kkg	71 kg/kkg	59 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Products	
a) meal	28%
b) oil	8%
Wastes	
a) stickwater	35%
b) water vapor	29%

Average Production Rate, 187 kkg/day (207 tons/day)

Alaska salmon canning--small: less than 40,000 cases annually;

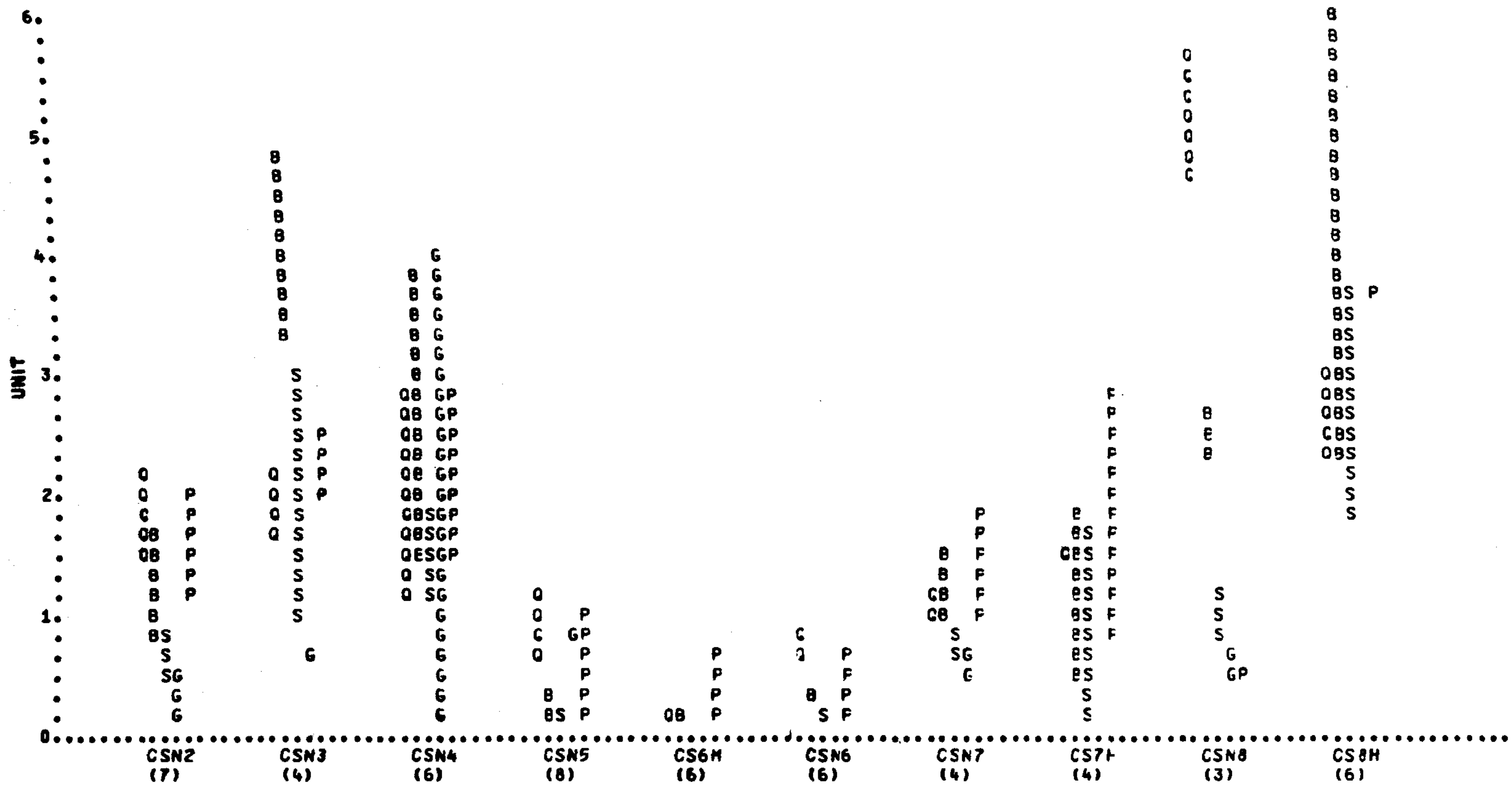
Northwest salmon canning--large: greater than 20,000 cases annually; and

Northwest salmon canning--small: less than 20,000 cases annually.

Figure 7 summarizes the wastewater characteristics of three salmon canning plants in Alaska (CSN2, CSN3, CSN4) and four plants in the Northwest (CSN5, CSN6, CSN7, and CSN8). Codes CS7H and CS8H represent historical data from the same plants as CSN7 and CSN8, respectively. Two of the Alaskan plants sampled, CSN2 and CSN4, are in the "small" range (less than 40,000), and one, CSN3, is in the "medium" range (40,000-80,000 cases). All of the plants sampled in the Northwest are in the large range (over 20,000 cases).

It was noted that, in general, the waste loads from the plants in Alaska were greater than those in the Northwest. The main reason for this is that one Northwest plant (CSN5) did all butchering by hand and two other Northwest plants (CSN6 and CSN7) practiced a high percentage of manual butchering during the sampling period, using the iron chink only when large quantities of fish arrived. The three salmon plants in Alaska used the iron chink routinely, and also ground their solids before discharge, which increased the waste load. The waste load at CSN3 appears to have been higher than average; however, this may have been due to the fact that samples were taken from a sump where solids accumulated over the sampling period. The historical information from plant CS8H was obtained

Figure 7. SALMON CANNING PROCESS FLOW.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 10000 L/KKG
B	5 DAY BOD	1 UNIT = 20 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 20 KG/KKG
G	GREASE AND OIL	1 UNIT = 10 KG/KKG
P	PRODUCTION	1 UNIT = 2 TON/HR

during a high production period when the iron chink was being used extensively. The data collected during 1973 appear to be lower and may be due to plant modifications accomplished in the meantime.

Table 10 summarizes statistics of the waste loads from all the plants sampled which used the iron chink exclusively (CSN2, CSN3, CSN4, CSN8). The flow ratio was not included for CSN8 as it was not considered to be typical. These data provided the base which was used as the typical raw waste load from salmon canning processes in both Alaska and the Northwest.

The canning operations in the Northwest, which include hand butchering, were included with the fresh/frozen salmon subcategory, since the unit operations are similar except for the canning operation, which does not increase the load by a significant amount.

For Alaskan salmon plants, located in isolated places, intake water is obtained from nearby surface water streams. For plants located in towns, the intake water is supplied usually from the municipal systems. The water used in the canneries is chlorinated either by the plant itself, or by the municipal treatment plant. City water is generally used by northwest plants for all phases of the operation.

Table 11 shows the wastewater balance for a salmon canning operation (CSN6) using an iron chink butchering machine. It can be seen that this machine contributes a significant portion of the flow and a very great portion of the BOD and suspended solids load. The main reason that the BOD loads for the northwest plants were quite variable and generally lower than the Alaskan plants was because the iron chink was used only on a portion of the total fish processed.

Table 10. MECHANICALLY BUTCHERED SALMON
PROCESS SUMMARY

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	4.09	2.45	1.18	10.4
PROCESS TIME HR/DAY	7.13	4.22	--	8.25
FLOW L/SEC	19.0	11.6	5.42	48.9
(GAL/MIN)	302	184	85.8	775
FLOW RATIO L/KKG	19200	11200	5800	47800
(GAL/TON)	4610	2670	1390	11500
SETT. SOLIDS ML/L	26.5	17.8	6.66	72.7
RATIO L/KKG	510	342	128	1400
SCR. SOLIDS MG/L	1700	1440	462	4680
RATIO KG/KKG	32.6	21.9	8.18	89.8
SUSP. SOLIDS MG/L	1330	639	489	2930
RATIO KG/KKG	25.5	12.3	9.41	56.3
5 DAY BOD MG/L	2710	1230	1060	5750
RATIO KG/KKG	52.1	23.6	20.4	111
COD MG/L	5150	2130	2180	10400
RATIO KG/KKG	99.2	41.1	42.0	200
GREASE & OIL MG/L	417	325	85.3	1270
RATIO KG/KKG	8.03	6.26	1.64	24.5
ORGANIC-N MG/L	446	267	130	1130
RATIO KG/KKG	8.59	5.13	2.49	21.9
AMMONIA-N MG/L	10.3	4.75	3.96	22.1
RATIO KG/KKG	0.198	0.091	0.076	0.426
PH	6.71	0.172	6.51	6.38
TEMP DEG C	13.9	1.85	11.9	15.6

PLANTS CSN2, CSN3, CSN4, CSN8

Table 11. Salmon canning process material balance (iron chink).

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) thaw tank	30%	6%	6%
b) iron chink	39%	73%	74%
c) sliming table	17%	8%	7%
d) fish cutter	2%	3%	3%
e) can washer and clincher	8%	3%	7%
f) washcown	4%	7%	3%
Total effluent average CSN6	6400 l/kkg	57.7 kg/kkg	118 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	60 - 62%
By-product	
a) roe	4 - 6%
b) milt	2 - 3%
c) oil	1%
d) heads	12 - 14%

Average Production Rate, 37 kkg/day (41 tons/day)

Table 12 shows the wastewater material balance for an operation employing exclusively manual butchering (CSN5, CS6N). It can be seen that the total loads were much lower for the hand butchering operation than for the mechanical butchering line. The hand butchering operation for the canning process is identical to the fresh/frozen butchering operation, hence the load for the manual canning operation is similar to that from the fresh/frozen operation except for the wastes from the fish cutting and can filling operation, which increase the load about 45 percent. Plant CSN2 used a hand packing operation rather than a mechanical filler; therefore, their wastes were lower.

1.4.3 Salmon Fresh/Frozen Process

Since the fresh/frozen salmon process is essentially the same throughout the industry, geographic location and size were considered to be the only major factors affecting subcategorization.

It was decided that the fresh/frozen salmon industry be subcategorized into "Alaska" and "West Coast" regions because of the greater costs and more serious treatment problems encountered in Alaska. The size range of the industry is significant in both regions; however neither is as great as the range for salmon canning.

Information on the size range of the industry in terms of annual production is limited. Table 13 summarizes data obtained from a study conducted by the Municipality of Metropolitan Seattle (Peterson, 1970) involving Northwest fresh/frozen salmon plants.

Table 12. Salmon canning process material balance (hand butchered).

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) butchering line	20%	24%	17%
b) fish cutter	20%	16%	17%
c) can filler	5%	21%	30%
d) can washer	22%	5%	5%
e) washdown	33%	34%	30%
Total effluent Average CSN5, CS6M	5400 l/kkg	3.4 kg/kkg	2.0 kg/kkg

Average Production Rate, 4.8 kkg/day (5.3 tons/day)

Table 13. Annual production of Northwest fresh/frozen salmon.

Plant Number	Raw Product Processed Annually (kkg)	(tons)
1	360	400
2	680	750
3	725	800
4	1815	2000
5	2720	3000
6	4535	5000

Table 14 estimates the daily peak production rates for Alaskan fresh/frozen salmon plants. Based on these figures and observations made during the plant investigations, the dividing line between large and small Alaskan and Northwest fresh/frozen salmon plants was placed at 2370 kkg (2500 tons) of raw product processed annually.

Table 14. Daily peak production rates of Alaska fresh/frozen salmon plants (Phillips, 1974).

Size	Daily Peak Production Rate (kkg)	(tons)
Large	80-110	90-120
Medium	45-70	50-75
Small	27-45	30-50

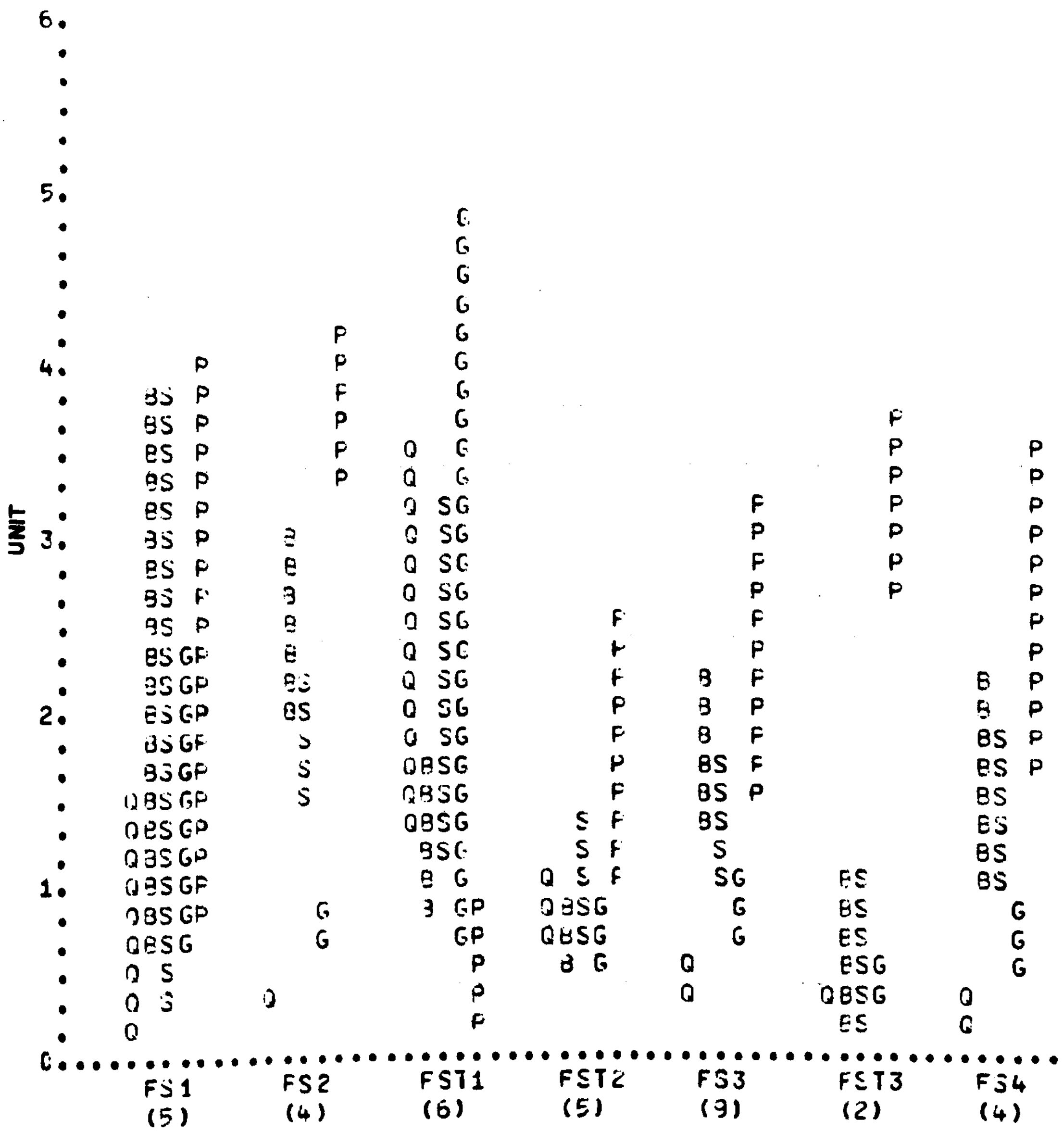
Figure 8 is a summary plot of the wastewater characteristics of four fresh/frozen salmon operations in Alaska (FS1, FS2, FST1, FST2) and three operations in the Northwest (FS3, FS4, FST3). The code FS represents processes which butcher round salmon, while the code FST represents the processing of troll-dressed salmon, which have been eviscerated at sea. The four processes in Alaska (FS1, FST1, FS2, FST2) fall into the "large" range, while the three Northwest processes (FS3, FST3, FS4) are in the "small" range.

It can be can be seen that the waste loads from the troll-dressed processes were lower than those from the round processes and that the waste loads from the Alaskan plants seem to have been slightly higher than those from the Northwest plants. The waste loads from all these operations, however, were relatively low, with BOD's less than 3 kg/kkg.

Since the unit operations, where most of the waste is generated, are similar for either the hand butchered fresh/frozen process or the hand butchered canning process, they were included in one subcategory; the average waste loads from the round fresh/frozen processes (FS1, FS2, FS3, FS4) and from the hand butcher canning process (CSN5, CS6M) were to characterize both segments of the industry.

It would not be efficient to further subdivide the industry into "round," "troll-dressed" and hand butchered canning processes with the corresponding regulations and enforcement efforts required. The slight advantage enjoyed by those plants processing mostly troll-dressed fish was considered to be of little importance, since the waste loads from any of these processes are relatively

Figure 8. FRESH/FROZEN SALMON PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 10000 L/KKG
B	5 DAY BOD	1 UNIT = 1 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 0.5 KG/KKG
G	GREASE & OIL	1 UNIT = 0.2 KG/KKG
P	PRODUCTION	1 UNIT = 1 TON/HR

low. Table 15 summarizes processes sampled. These data were used to determine the typical raw waste loadings from fresh/frozen salmon or hand butchered salmon canning processes in both Alaska and the West Coast

Table 16 shows that the primary source of wastewater from the fresh/frozen salmon process is the wash tank operation, in which the eviscerated fish are cleansed of adhering blood, mesentaries, sea lice, and visceral particles. Also, depending upon the condition of the fish, a preliminary rinse of the round fish prior to butchering may also be implemented. This primary rinse is employed to reduce the amount of slime adhering to the fish to facilitate handling. The wash tank or wash tank plus pre-rinse contributes about 90 percent of the total effluent flow. The butchering table is essentially a dry operation except for short hose-downs of the area at the discretion of the crew. Some plants use small hoses attached to cleaning spoons and others use a small constant flow on the table.

The production rates vary considerably, due to raw product availability. The rates observed at the round fish operations averaged about 16 kkg/day (18 tons/day). Round fish processing predominates in both Alaska and the Northwest; however, large volumes of pre-dressed fish are handled on occasion as can be seen from the production rates for plant FST3.

The recovery of eggs and milt represent about five and three percent of the round salmon weight, respectively. Other by-product recovery, such as the grinding and bagging of heads and viscera, is done only occasionally in Alaska and for the

Table 15. HAND BUTCHERED SALMON
PROCESS SUMMARY

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	2.13	1.09	0.733	4.38
PROCESS TIME HR/DAY	6.34	1.80	3.67	8.98
FLOW L/SEC	2.15	1.09	0.754	4.99
(GAL/MIN)	34.1	17.2	11.9	77.5
FLOW RATIO L/KKG	5040	3100	1410	13000
(GAL/TON)	1210	743	338	3120
SETT. SOLIDS ML/L	1.02	1.19	0.109	4.38
RATIO L/KKG	5.15	5.99	0.547	20.5
SCR. SOLIDS MG/L	193	155	37.5	600
RATIO KG/KKG	0.971	0.782	0.189	3.32
SUSP. SOLIDS MG/L	236	185	47.6	722
RATIO KG/KKG	1.19	0.933	0.240	3.64
5 DAY BOD MG/L	493	179	233	923
RATIO KG/KKG	2.48	0.900	1.17	4.55
COD MG/L	1070	601	332	2600
RATIO KG/KKG	5.38	3.03	1.67	13.1
GREASE & OIL MG/L	341	628	15.0	1770
RATIO KG/KKG	1.72	3.16	0.076	8.39
ORGANIC-N MG/L	80.9	40.0	29.0	181
RATIO KG/KKG	0.407	0.202	0.146	0.914
AMMONIA-N MG/L	2.12	0.794	0.979	4.34
RATIO KG/KKG	0.011	0.004	0.005	0.020
PH	6.73	0.318	6.25	7.33
TEMP DEG C	13.2	2.51	9.19	15.7

PLANTS CSN5, CS6M, FS1 , FS2 , FS3 , FS4

Table 16. Fresh/frozen round salmon process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) process water	88 - 96%	76 - 92%	74 - 97%
b) washdown	4 - 12%	4 - 24%	3 - 23%
Total effluent average FS1, FS2, FS3, FS4	3750 l/kkg	2 kg/kkg	0.8 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	
a) salmon	65 - 80%
b) eggs	5%
c) milt	3%
By-product	
a) heads	8%
b) viscera	5 - 7%
Waste	1 - 2%

Average Production Rate, 16.4 kg/day (18 tons/day) most part these solids are disposed of directly into the receiving water. The heads and viscera in the Northwest plants are usually collected for pet food or for reduction to fish meal.

1.4.4 Herring Filleting Process

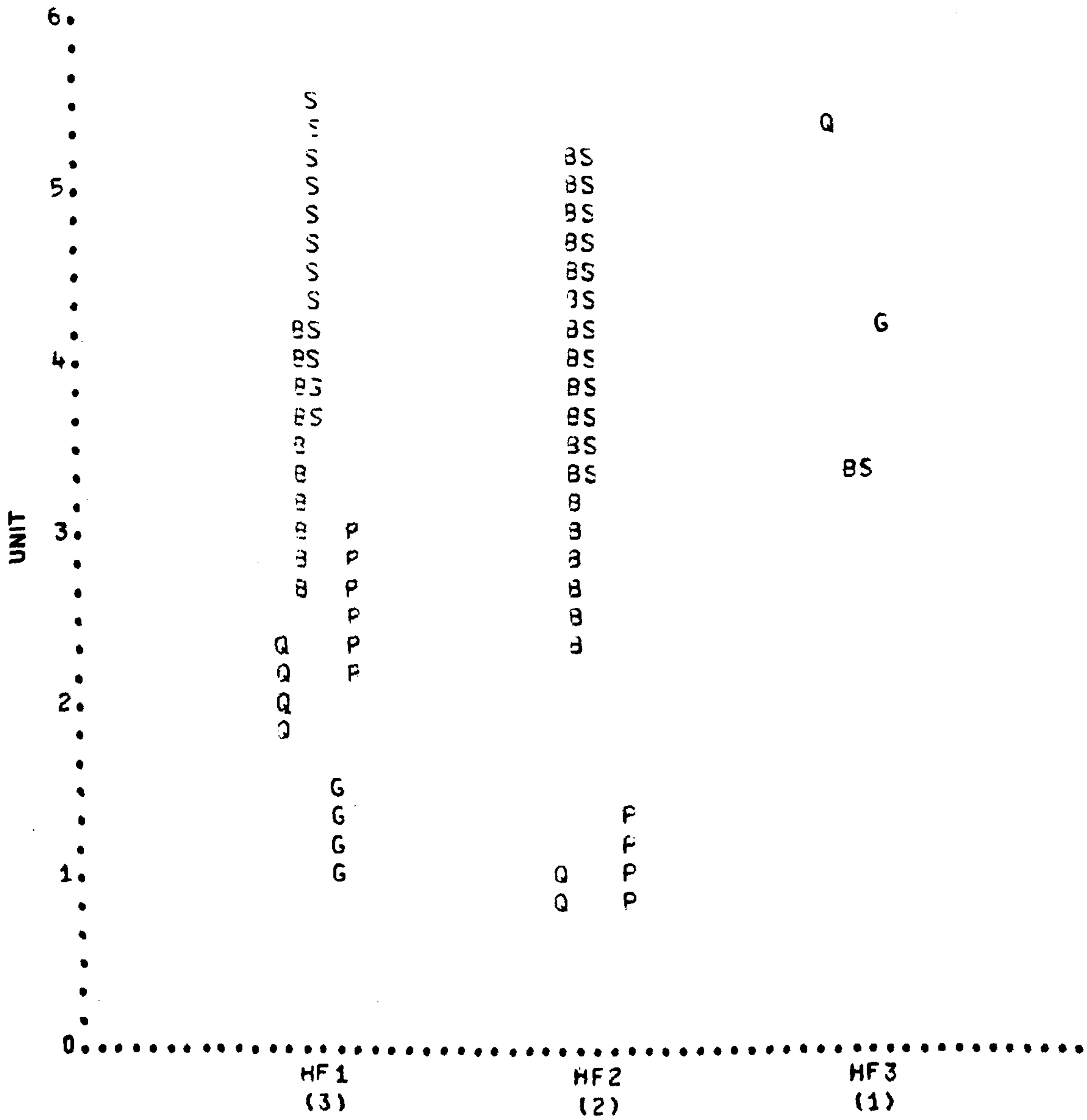
Since the herring filleting process is essentially the same from plant to plant and the number of plants is too small to separate the industry into size ranges, geographic location was considered to be the only factor requiring further attention in the subcategorization process.

Figure 9 summarizes the characteristics of three herring filleting plants. Plant HF1 is located in New England, plant HF2 in the Maritime region of Canada and plant HF3 in Southeastern Alaska. Information on plant HF2 was obtained from a study conducted by the Environmental Protection Service of Canada (Riddle and Shikaze, 1973).

It was noted that the waste characteristics for all the plants were similar. One difference was the relatively high flow ratio observed at the Alaska plant. This high ratio is not considered to be typical, since the investigation was conducted at the beginning of the season and few fish were being processed. At low processing rates, water use is more independent of production rate.

Table 17 summarizes statistics of the waste loads from all three plants excluding the high flow ratio from the Alaska plant. It was determined that the process is uniform enough to allow the industry to be characterized by an average of the data from the plants in different regions.

Figure 9. HERRING FILLETING PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 5000 L/KKG
B	5 DAY BOD	1 UNIT = 10 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 5 KG/KKG
G	GREASE & OIL	1 UNIT = 5 KG/KKG
P	PRODUCTION	1 UNIT = 5 TON/HR

Table 17. **HERRING FILLETING PROCESS SUMMARY.**

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	9.10	7.49	1.72	28.3
PROCESS TIME HR/DAY	7.33	5.23	--	8.00
FLOW L/SEC	19.7	19.7	2.74	71.1
(GAL/MIN)	312	311	43.4	1130
FLOW RATIO L/KKG	7360	5990	1420	23000
(GAL/TON)	1760	1430	341	5510
SETT. SOLIDS ML/L	13.7	11.7	2.46	44.3
RATIO L/KKG	101	85.7	18.1	326
SCR. SOLIDS MG/L	925	--	--	--
RATIO KG/KKG	6.81	--	--	--
SUSP. SOLIDS MG/L	2740	403	2040	3610
RATIO KG/KKG	20.2	2.96	15.0	26.5
5 DAY BOD MG/L	4690	297	4140	5300
RATIO KG/KKG	34.5	2.19	30.5	39.0
COD MG/L	8520	962	6790	10600
RATIO KG/KKG	62.7	7.07	49.9	77.5
GREASE & OIL MG/L	1840	1650	305	6160
RATIO KG/KKG	13.5	12.1	2.24	45.4
ORGANIC-N MG/L	487	364	106	1440
RATIO KG/KKG	3.59	2.68	0.779	10.5
AMMONIA-N MG/L	21.9	17.3	4.38	67.2
RATIO KG/KKG	0.161	0.127	0.032	0.494
PH	6.45	4.59	--	6.31
TEMP DEG C	15.8	12.6	--	21.7

PLANTS HF1 , HF2 , HF3

City water was used in both the New England and Alaskan plants monitored. Table 18 shows the sources of wastewater from a herring filleting process. The largest percentage of the total flow and waste load is produced by the filleting machines and the associated fluming. The flow from each filleting machine is only about 0.4 l/sec (6 gpm); however, the fluming of product to and from the machine is much higher. The bailwater, when a fish pump unloading operation is used, constitutes a relatively large flow and waste loading. This could be reduced by using a dry unloading system.

The New England plant is relatively large and was observed to process an average of 78 kkg/day (86 tons/day) of raw fish when they were available. Each filleting machine operated at about 1.4 kkg/hr (1.5 tons/hr).

Table 18 shows percentages of food and by-product recovery for this process. The food product averages 42 to 45 percent but varies with the season and the type of filleting machine used. During the spring spawning season roe and milt are collected in addition to the fillets. This increases the food recovery by about three to five percent. The rest of the solid waste is either sent to reduction plants or discharged with the wastewater.

1.4.5 Tuna Canning Process

Segregation of the tuna industry as a distinct subcategory of the seafood industry was done prior to sampling because of the homogeneity of the tuna processing methods, extensive by-product recovery, and the magnitude of production. This segregation was

Table 18. Herring filleting process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) process water	58%	70%	59%
b) bailwater	37%	27%	38%
c) washdown	5%	3%	3%
Total effluent average HF1	10,200 l/kkg	34 kg/kkg	23 kg/kkg

Product Material Balance Summary

End Product	% of Raw Product
Food products	42 - 45%
By-product	
a) heads, viscera (for reduction)	55 - 58%

Average Production Rate, 78 kkg/day (86 tons/day)

substantiated by the data and information obtained by the field crews and subsequent comparison to the other subcategories of the industry.

Although widely distributed, the tuna processors utilize a common technology for the production of canned tuna and various by-products. The waste characteristics of this common technology do show geographic variation which, although obvious internally, does not justify further subcategorization of the tuna industry. This variation is due to operational inconsistencies which could be corrected to minimize differences and thus justify a common waste treatment technology applicable to all plants.

Table 19 shows average flows and loadings of the combined effluent from all nine processors sampled. The amount of water used per unit product varied considerably. It was also noted that the waste loads in terms of screened solids, BOD and COD were relatively low compared to other seafood processing industries, due to good by-product recovery.

The processing of tuna as currently practiced requires a considerable volume of fresh water obtained from domestic sources and (usually) salt water pumped directly from the ocean or from saline wells. The saline water or domestic industrial water is used in direct contact with the tuna in only those stages prior to the precook operation; except saline water may also be used in the latter stages where contamination of the cooked fish would present a problem.

Table 20 lists the average flow from each unit operation. Total water use ranged from 246 cu m/day (0.064 mgd) to

Table 19. Tuna process summary (9 plants)

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range		
Flow Rate, cu m/day[1]	3060	3370	110	246	-	11,700
(mgd)	(0.808)	--	--	(0.065	-	3.1)
Flow Ratio, l/kkg[2]	18,290	9023	49	5570	-	33,000
(gal/ton)	(4386)	--	--	(1336	-	7914)
Settleable Solids, ml/l	2.1	1.8	86	0.2	-	5.9
Settleable Solids Ratio, l/kkg	29.0	15.5	53	6.9	-	50.1
Screened Solids[3], mg/l[4]	63.5	--	--	--	-	--
Screened Solids Ratio, kg/kkg	1.3	--	--	--	-	--
Suspended Solids, mg/l	670	763.7	109	357	-	1769
Suspended Solids Ratio, kg/kkg	10.1	4.5	45	3.8	-	17.3
5 day BOD, mg/l	939	692	73	421	-	2510
5 day BOD Ratio, kg/kkg	13.0	4.1	31	6.8	-	19.9
20 day BOD, mg/l	--	--	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	--	--	-	--
COD, mg/l	2210	939.9	42	1310	-	3940
COD Ratio, kg/kkg	35.0	15.3	57	14.1	-	63.8
Grease and Oil, mg/l	364	207	57	130	-	589
Grease and Oil Ratio, kg/kkg	5.78	3.40	58	3.20	-	13.18
Organic Nitrogen, mg/l	56.5	25.10	44	30	-	93.8
Organic Nitrogen Ratio, kg/kkg	1.22	0.049	40	0.75	-	2.17
Ammonia-N, mg/l	6.9	4.27	61	2.2	-	13.0
Ammonia-N Ratio, kg/kkg	0.119	0.072	60	0.02	-	0.23
pH[5]	6.7	0.408	6	6.2	-	7.2

1 day = 8 hrs
2 weight of raw product
3 dry weight
4 two samples
5 laboratory pH

nine plants

Table 20. Tuna process material balance

Wastewater Material Balance Summary

Average Flow*, 3,060-cu m/day (0.81 mgd)

Unit Operation	% of Average Flow	Range, %
a) thaw	65	35 - 75
b) butcher	10	5 - 15
c) pack shaper	2	1.5 - 2.5
d) can washer	2	1 - 3
e) retort	13	6 - 19
f) washdown	7	5 - 10
g) miscellaneous	1	0 - 2

Product Material Balance Summary

Average Raw Product Input Rate, 167 kkg/day (184 tons/day)

Output	% of Raw Product	Range, %
Food product	45	40 - 50
By-products		
Viscera	12	10 - 15
Head, skin, fins, bone	33	30 - 40
Redmeat	9	8 - 10
Waste	1	0.1 - 1.5

* Including clean-up water

11,700 cu m/day (3.13 mgd) with an average of 3060 cu m/day (0.808 mgd), where a day was defined as one 8-hour shift.

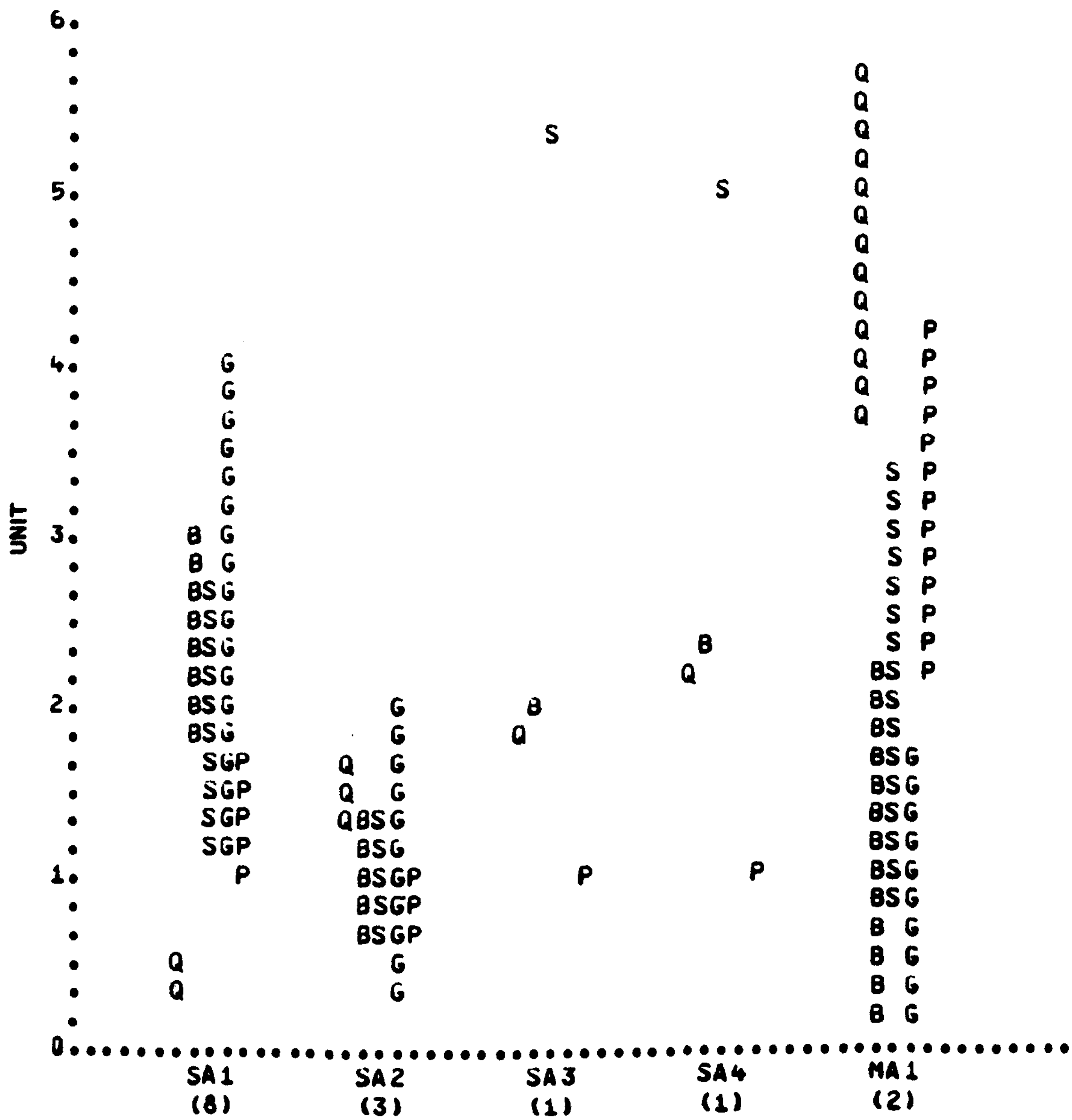
1.4.6 Sardine/Jack Mackerel Canning Process

The jack mackerel canning process in California is fundamentally the same as the sardine canning process observed in Maine. The wastes are also similar, as can be observed by studying the summary plot of the sardine and mackerel canning wastewater characteristics shown in Figure 10. The SA codes are the sardine plants discussed earlier in this section, and the MA1 code represents the jack mackerel plant. Plants SA1 and SA2 were investigated by Environmental Associates. Information on plants SA2, SA3, and SA4 were obtained from the Maine Sardine Council study (Atwell, 1973). The wide standard deviation for the mackerel plant is probably due to the fact that only two samples were taken. It was decided, therefore, that the jack mackerel canning process be included in the same subcategory as large sardine canning plants.

Relatively few sardine plants are still operating; however, their sizes range widely. Of the 17 active processing operations, five were considered to be large (over 55 thousand cases annually), eight were considered to be medium (30 to 55 thousand cases annually) (Reed, 1973). Ten of the 17 plants are located outside of population centers.

Plants SA1 and SA2 both used dry conveyors to move the fish from the holding bins to the packing lines. This decreased the flow and reduced the waste load (because it reduced the contact

Figure 10. **SARDINE/MACKEREL CANNING PROCESS PLOT.**



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 5000 L/KKG
B	5 DAY BOD	1 UNIT = 5 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 2 KG/KKG
G	GREASE & OIL	1 UNIT = 1 KG/KKG
P	PRODUCTION	1 UNIT = 5 TON/HR

time of the fish with the water). Table 21 compares flows and waste loads at plant SA2 before and after installation of the belt conveyor.

Table 21. Waste load reduction using dry conveyor (Plant SA2).

Parameter	Before	After	% Reduction
Flow ratio (l/kkg)	20,400	7590	63
Suspended solids (kg/kkg)	8.7	2.0	77
BOD (kg/kkg)	12.3	5.0	59

Tables 22 and 23 summarize waste load statistics for the plants.

Table 24 shows the wastewater material balance for a typical sardine canning plant. Each of the plants sampled used city water for in-plant processing. Available surface water (salt or brackish) was used to transport the fish from trucks or boats to brine storage tanks.

The flume to the packing tables was observed to contribute 18 to 62 percent of the water. Another large source of waste loading is the stickwater from the precooking operation. The flow is quite low; however, the BOD and suspended solid loadings are significant. A very great reduction in BOD, suspended solids, and grease and oil could be made by storing the stickwater from the precook operation and transporting it to a reduction plant for oil and solubles recovery.

Table 22. **SARDINE CANNING PROCESS SUMMARY** .

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	5.05	1.05	3.30	7.38
PROCESS TIME HR/DAY	6.78	1.42	5.34	8.30
FLOW L/SEC	9.10	4.16	3.52	19.4
(GAL/MIN)	144	66.0	55.8	308
FLOW RATIO L/KKG	7590	3670	2780	16600
(GAL/TON)	1820	880	667	4020
SETT. SOLIDS ML/L	1.48	1.48	0.204	5.35
RATIO L/KKG	11.2	11.2	1.55	40.7
SCR. SOLIDS MG/L	34.4	30.1	5.90	113
RATIO KG/KKG	0.261	0.229	0.045	0.361
SUSP. SOLIDS MG/L	883	581	227	2390
RATIO KG/KKG	6.70	4.41	1.73	18.1
5 DAY BOD MG/L	1280	433	639	2310
RATIO KG/KKG	9.74	3.28	4.85	17.5
COD MG/L	1650	1430	287	5400
RATIO KG/KKG	12.5	10.8	2.18	41.0
GREASE & OIL MG/L	250	219	42.7	825
RATIO KG/KKG	1.89	1.66	0.324	6.26
ORGANIC-N MG/L	103	86.9	18.6	331
RATIO KG/KKG	0.780	0.660	0.141	2.51
AMMONIA-N MG/L	3.77	3.11	0.706	11.3
RATIO KG/KKG	0.029	0.024	0.005	0.091
PH	6.35	5.19	--	6.40
TEMP DEG C	20.7	17.0	--	23.0

PLANTS SA1 , SA2 , SA3 , SA4

Table 23. MACKEREL CANNING PROCESS

PARAMETER	MEAN	STD DEV	MINIMUM	MAXIMUM
PRODUCTION TON/HR	15.7	4.81	12.3	19.1
PROCESS TIME HR/DAY	6.5	--	6.0	7.0
FLOW L/SEC	86.4	4.81	83.0	89.8
(GAL/MIN)	1370	76.4	1320	1430
FLOW RATIO L/KKG	23200	5160	19500	26800
(GAL/TON)	5560	1240	4680	6430
SETT. SOLIDS ML/L	2.08	--	--	--
RATIO L/KKG	48.2	--	--	--
SCR. SOLIDS MG/L	1690	--	--	--
RATIO KG/KKG	39.1	--	--	--
SUSP. SOLIDS MG/L	182	107	107	258
RATIO KG/KKG	4.23	2.48	2.48	5.98
5 DAY BOD MG/L	262	213	111	413
RATIO KG/KKG	6.08	4.95	2.58	9.58
COD MG/L	546	292	340	753
RATIO KG/KKG	12.7	6.76	7.88	17.4
GREASE & OIL MG/L	40.4	32.0	17.8	63.0
RATIO KG/KKG	0.938	0.741	0.414	1.46
ORGANIC-N MG/L	47.6	21.1	32.6	62.5
RATIO KG/KKG	1.10	0.490	0.756	1.45
AMMOMIA-N MG/L	2.82	2.22	1.25	4.39
RATIO KG/KKG	0.065	0.051	0.029	0.102
PH	6.84	--	--	--
TEMP DEG C	14.7	--	--	--

Table 24. Sardine canning process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) flume (boat to storage)	14 - 46%	12 - 28%	11 - 57%
b) flume (brine tank to table)	18 - 62%	14 - 22%	16 - 30%
c) pre-cook can dump	<1 - 4%	28 - 67%	14 - 51%
d) can wash	3 - 4%	16 - 23%	9 - 10%
e) retort	8 - 53%	1 - 2%	1 - 4%
f) washdown	1 - 10%	1 - 6%	1 - 12%
Total effluent average SA1, SA2, SA3, SA4	7600 l/kkg	10 kg/kkg	7 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	30 - 60%
By-products	
a) heads and tails (reduction or bait)	35 - 65%
b) scales	1 - 2%

Average Production Rate, 31 kkg/day (34 tons/day)

Table 24 also shows that the food product yield for the sardine canning process can vary from a low of 30 percent to a high of 60 percent. This wide range in yield is related to the size of fish being canned. Since the same size can is often utilized for various sizes of fish, more waste originates from the large fish, which have a higher percent of the head and tail removed.

The heads and tails that are removed are usually dry conveyed to trucks which transport the waste to reduction facilities. Some solid waste is also collected by lobster fishermen for bait. Scales, another by-product, are removed on the boats prior to storage, and are used for cosmetics, lacquers, and imitation pearls.

Product rates varied from a low of 26 kkg/day (29 tons/day) to a high of 35 kkg/day (39 tons/day) at the plants investigated.

Only end-of-pipe composite samples were taken of the jack mackerel canning process. Therefore, the flows from different unit operations could only be estimated. The jack mackerel and sardine canning unit operations are similar, with the main difference being that the mackerel is a larger ish and is cut into pieces before being packed into the can.

The brine tank overflow, which consists of sea water to which salt has been added to make a brine, is one of the major sources of waste flow. This source plus the smaller continuous flows emanating from the slicing machine and the automatic can filling machine constitute about 90 percent of the total flow for the process.

The variability of raw product caused intermittent operation of the jack mackerel canning process; however, it can be seen from the production rate on Table 23 that the plant had a large capacity. The production ranged from 72 kkg/day (80 tons/day) to 113 kkg/day (125 tons/day) during the period sampled.

Only about 40 percent of the mackerel is recovered as food product and this includes a portion of the viscera. The reason for this is that the removed head and tail portions are large and contain considerable flesh.

The large pieces of solid wastes are recovered using a screen and subsequently rendered with other fish processing scraps.

1.4.7 Bottom Fish, Groundfish, and Miscellaneous Finfish Processes

Although there are a variety of species and processing operations in the bottom fish, groundfish, and miscellaneous finfish processing industry only three factors affected subcategorization: geographic location, size, and degree of mechanization (therefore water use). The bottom fish, groundfish, and miscellaneous finfish industry was subcategorized into "Alaska" and "Non-Alaska" regions because of the greater costs and more significant treatment problems encountered in Alaska.

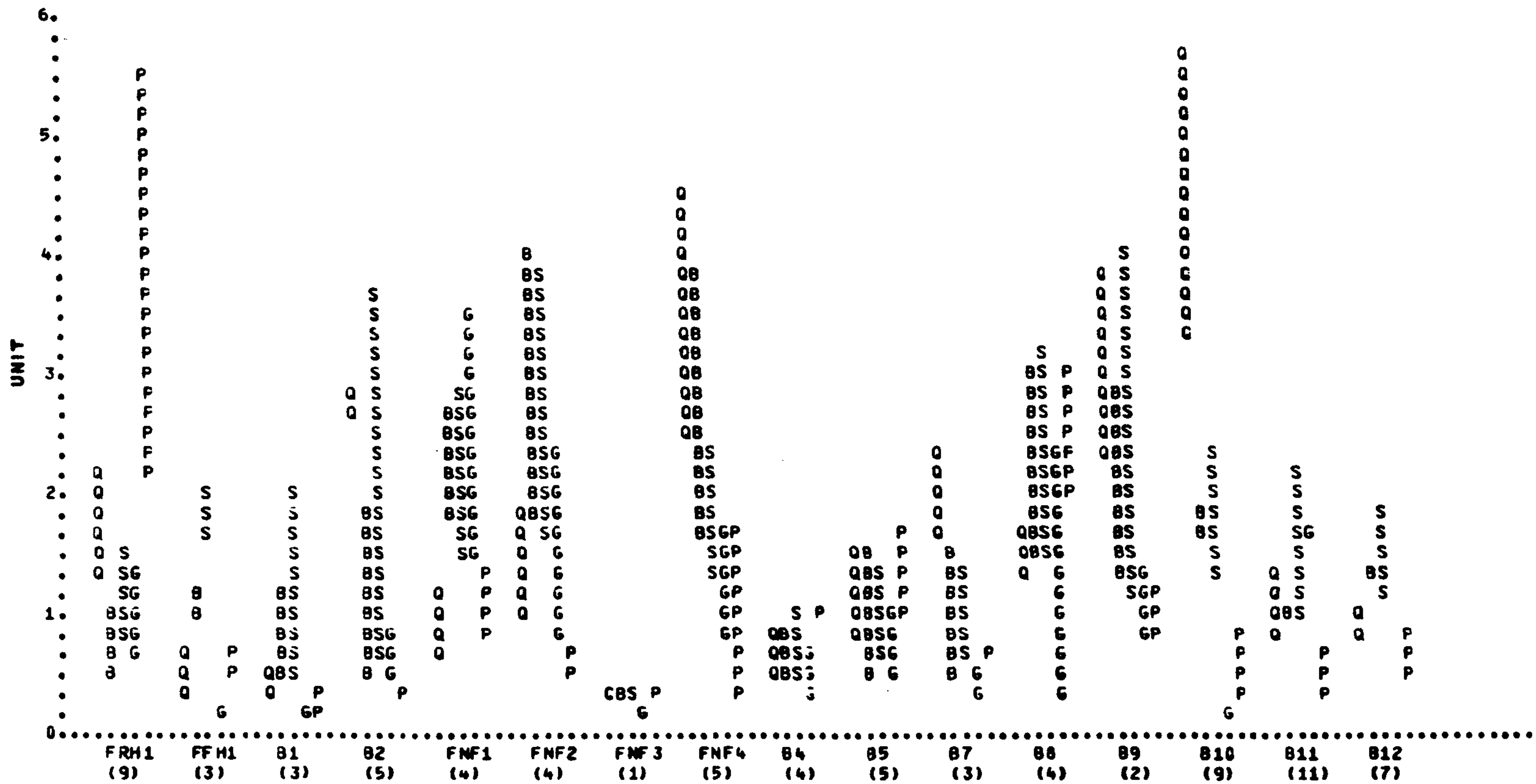
The halibut is the most significant bottom fish processed in Alaska. Two typical halibut processes were observed; whole freezing and fletching, but neither contributed a very high waste load.

With respect to Non-Alaska regions, the bottom fish industry was subcategorized into "conventional" and "mechanized" processes due to the increased water and waste loads associated with the latter.

A conventional process is defined as one where the unit operations are carried out essentially by hand, requiring a relatively low volume of water. A mechanized process is defined as one where many of the unit operations are mechanized and relatively large volumes of water are used. Figure 11 shows a summary plot of the wastewater characteristics or what are considered to be conventional processing operations with little or no mechanization. Figure 12 shows a summary plot for what are considered to be high-water-use mechanized processing operations. With respect to Figure 11, codes FRH1 and FFH1 refer to halibut processing operations in Alaska, codes B1, 2 refer to groundfish plants in New England, codes FNF1, 2, 3, 4 to finfish plants in the Middle Atlantic and Gulf regions, and codes B4, 5, 10, 11, and 12 refer to bottom fish plants in California. With respect to Figure 12, codes W1 and N2 refer to whiting plants in New England, CFC1 to a fish flesh plant in the Gulf, and B6 and B6H to a bottom fish plant in the Northwest. Code B6H represents historical data obtained for plant B6.

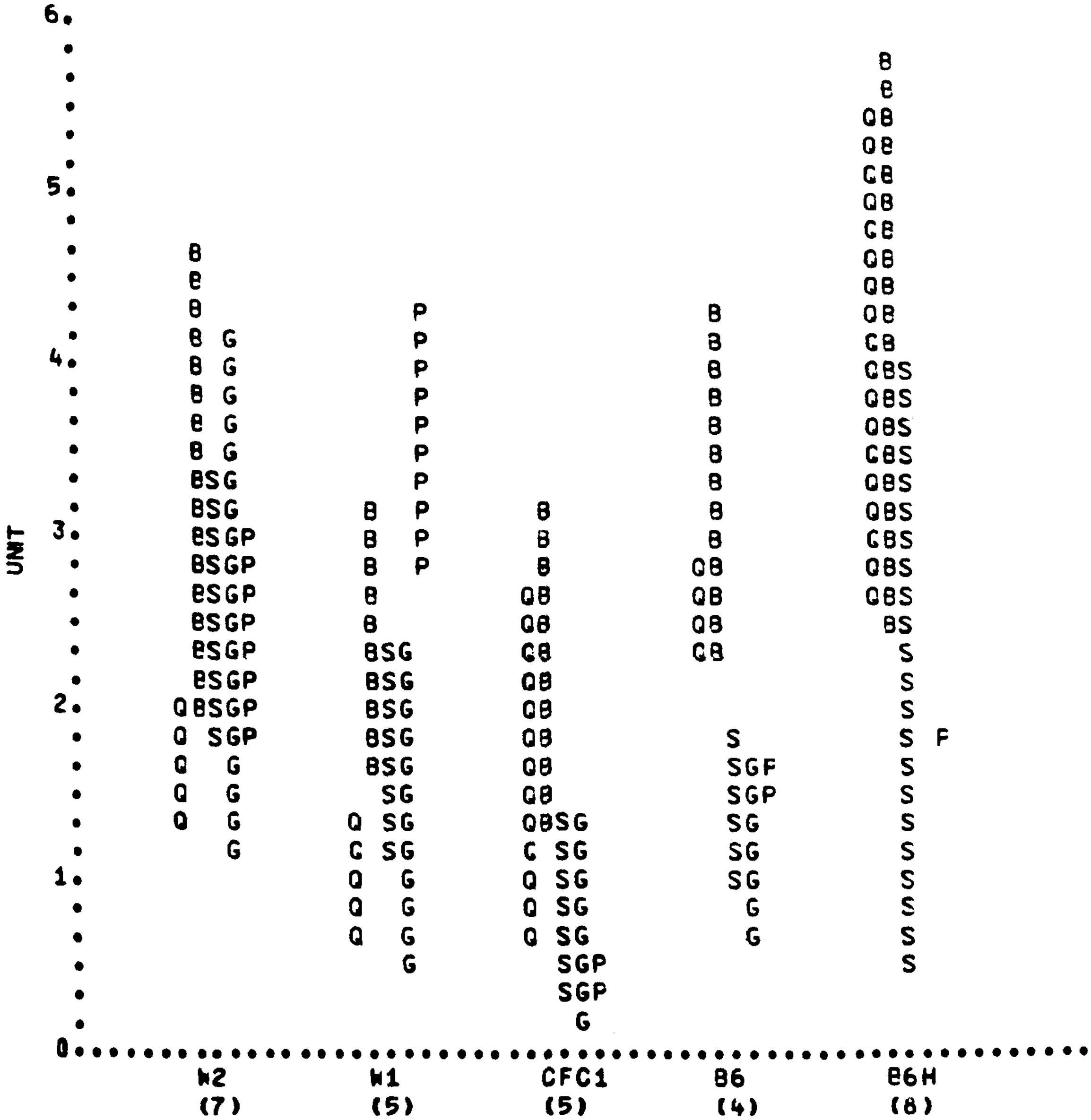
Plant sizes range widely for both the Non-Alaska conventional and mechanized portions of the industry, with the mechanized plants being larger on the average. Information on the annual production of bottom fish is limited. Based on studies conducted in the Northwest and observations made during this study, the

Figure 11. CONVENTIONAL BOTTOM FISH PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 5000 L/KKG
B	5 DAY BOD	1 UNIT = 2 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 1 KG/KKG
G	GREASE AND OIL	1 UNIT = 0.5 KG/KKG
P	PRODUCTION	1 UNIT = 2 TON/HR

Figure 12. MECHANICAL BOTTOM FISH PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 10000 L/KKG
B	5 DAY BOD	1 UNIT = 5 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 5 KG/KKG
G	GREASE & OIL	1 UNIT = 2 KG/KKG
P	PRODUCTION	1 UNIT = 2 TON/HR

following divisions were made to break the industry into approximately equal size ranges. The division between large and medium conventional plants was set at 3630 kkg (4000 tons) of raw product per year and the division between medium and small conventional plants was set at 1810 kkg (2000 tons). The division between large and small mechanized plants was set at 3630 kkg (4000 tons).

Table 25 segregates the plants investigated into the selected size ranges.

Table 25. Non-Alaska bottom fish size breakdown.

Size	Conventional	Mechanized
Large	FNF4, B8	W1, W2, B6
Medium	B5, B7, B9, FNF1, FNF2, B10, B11, B12	--
Small	B1, B2, B4, FNF3	CFC1

Although some variability is evident between the plants in the conventional and mechanized subcategories (especially within the flow ratio and production parameters), the following observations can be made. The waste loads, in terms of BOD, suspended solids, and grease and oil, were four to five times greater for the mechanized operations than the conventional operations. The highly variable flow ratios for the conventional operations were caused mainly by the different methods of washing the fish before processing. For example, the high flow ratio exhibited by plant B10 was attributable to the fact that a high velocity jet spray was used to wash the fish as they were conveyed to the processing lines. The flow ratio for plant FNF4 was also relatively higher and was caused by the use of a fish pump to unload the fish from the boats.

The plants represented by codes FRH1 and FFH1 are considered to be large halibut processing operations. The waste loads from the halibut processing operations are relatively low, being of the same order of magnitude as the Alaska fresh/frozen salmon process. Table 26 summarizes statistics of the waste loads from the Alaska halibut process.

Since the waste loads were relatively low and uniform for all the conventional bottom fish processes, it was reasonable to place them into one subcategory. Table 27 summarizes statistics of the waste parameters for the Non-Alaska conventional bottom fish plants. Plant FNF3 was not included in the average because a small number of fish were being handled in the round on the day the sample was taken and this was not considered typical.

The plants used to represent a mechanized bottom fish process were two New England whiting plants (W1, W2), a fish flesh plant on the Gulf (CFC1), and a bottom fish plant in the Northwest (B6 and B6H). Plant B6 was included in the mechanized subcategory because it used a mechanical scaler with high velocity water jets. Since this was the only scaler of this type observed, and it contributed a high percentage of the waste load, it could not be considered to be typical. Plant CFC1 was also included in the mechanized subcategory, because mechanical beheading and

Table 26. ALASKA BOTTOM FISH (HALIBUT) PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	4.39	4.60	0.560	16.4
PROCESS TIME HR/DAY	5.13	0.526	4.76	5.30
FLOW L/SEC	6.93	8.73	0.638	29.1
(GAL/MIN)	110	138	10.1	461
FLOW RATIO L/KKG	5480	4380	1080	17000
(GAL/TON)	1310	1050	259	4070
SETT. SOLIDS ML/L	4.74	5.97	0.435	19.3
RATIO L/KKG	26.0	32.7	2.38	109
SCR. SOLIDS MG/L	807	948	84.3	3250
RATIO KG/KKG	4.42	5.20	0.462	17.3
SUSP. SOLIDS MG/L	276	86.1	145	479
RATIO KG/KKG	1.51	0.472	0.795	2.52
5 DAY BOD MG/L	331	71.0	213	490
RATIO KG/KKG	1.81	0.389	1.17	2.59
COD MG/L	722	132	498	1010
RATIO KG/KKG	3.95	0.722	2.73	5.55
GREASE & OIL MG/L	53.8	55.4	7.08	198
RATIO KG/KKG	0.295	0.304	0.039	1.19
ORGANIC-N MG/L	57.2	26.1	22.2	122
RATIO KG/KKG	0.314	0.143	0.122	0.669
AMMONIA-N MG/L	3.41	2.45	0.783	9.31
RATIO KG/KKG	0.019	0.013	0.004	0.054
PH	6.59	0.502	6.24	6.35
TEMP DEG C	10.1	0.954	9.44	10.3

PLANTS FRH1, FFH1

Table 27. CONVENTIONAL BOTTOM FISH PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	1.77	1.17	0.453	4.30
PROCESS TIME HR/DAY	6.91	0.770	5.50	8.00
FLOW L/SEC	4.07	3.45	0.731	13.1
(GAL/MIN)	64.4	54.7	11.6	208
FLOW RATIO L/KKG	9210	6340	2240	25700
(GAL/TON)	2210	1520	536	6160
SETT. SOLIDS ML/L	10.2	24.0	0.275	58.5
RATIO L/KKG	94.1	221	2.53	539
SCR. SOLIDS MG/L	407	404	57.0	1470
RATIO KG/KKG	3.75	3.72	0.525	13.5
SUSP. SOLIDS MG/L	189	67.8	89.8	352
RATIO KG/KKG	1.74	0.625	0.827	3.24
5 DAY BOD MG/L	354	165	135	765
RATIO KG/KKG	3.26	1.52	1.24	7.05
COD MG/L	646	271	270	1310
RATIO KG/KKG	5.95	2.50	2.49	12.1
GREASE & OIL MG/L	54.7	40.1	12.2	159
RATIO KG/KKG	0.504	0.369	0.113	1.47
ORGANIC-N MG/L	49.6	24.1	18.1	110
RATIO KG/KKG	0.457	0.222	0.166	1.01
AMMONIA-N MG/L	3.20	1.75	1.03	7.35
RATIO KG/KKG	0.029	0.016	0.010	0.070
PH	6.62	0.491	5.82	7.26
TEMP DEG C	16.5	3.64	10.3	24.3

PLANTS B1 , B2 , B4 , B5 , B7 , B8 , B9 , B10 , B11 , B12 , FNF1, FNF2, FNF4 eviscerating machinery was used; however, the fish flesh process is relatively new and is not typical of the rest of the industry. The waste loads from the two whiting plants were considered to be the most representative of the mechanized segment of he industry and are summarized in Table 28.

Several conventional bottom fish processes exist, of which the filleting process is considered to be the most important. There are two main options within the filleting process; the use of skinners and/or scalers. Table 29 shows the wastewater balance for three operations (B2, B4, B8) which used skinners most of the time. The skinners are mechanical and can constitute a large percentage (13 to 64 percent) of the flow and load (6 to 36 percent of BOD), depending on the type used. The flow from the fillet tables is quite variable depending on water conservation practices. It is common practice for a small hose to be continuously running at each filleting position. Fish are sometimes rinsed before filleting or eviscerating and are usually dipped in a wash tank afterward to clean and preserve the flesh. The flows from either of these operations are relatively small; however, the BOD and suspended solids loads can be moderately high.

Table 30 presents the wastewater balance for three operations (B1, B6, B11) which commonly used a descaler. It can be seen that the descaler can contribute a substantial flow and waste load, depending on the type. The scalers which use high pressure water jets in a revolving drum can contribute a very high load. One plant, B6, at times used a scaler which increased the water flow and waste load by a factor of four. This scaler was so signi-

Table 28. MECHANICAL BOTTOM FISH
PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	5.91	1.69	3.28	9.33
PROCESS TIME HR/DAY	5.95	3.96	3.15	8.76
FLOW L/SEC	18.3	1.47	15.6	21.3
(GAL/MIN)	290	23.3	247	338
FLOW RATIO L/KKG	13600	4720	6600	24800
(GAL/TON)	3250	1130	1580	5950
SETT. SOLIDS ML/L	6.67	0.081	6.51	6.83
RATIO L/KKG	90.4	1.10	88.3	92.5
SCR. SOLIDS MG/L	820	16.7	788	853
RATIO KG/KKG	11.1	0.226	10.7	11.5
SUSP. SOLIDS MG/L	808	228	453	1340
RATIO KG/KKG	11.0	3.08	6.13	18.1
5 DAY BOD MG/L	1060	268	634	1680
RATIO KG/KKG	14.4	3.63	8.59	22.7
COD MG/L	2110	807	954	4070
RATIO KG/KKG	28.6	10.9	12.9	55.1
GREASE & OIL MG/L	302	140	115	652
RATIO KG/KKG	4.10	1.90	1.56	8.84
ORGANIC-N MG/L	86.9	17.9	57.0	127
RATIO KG/KKG	1.18	0.243	0.773	1.72
AMMONIA-N MG/L	3.91	1.59	1.69	7.79
RATIO KG/KKG	0.053	0.021	0.023	0.106
PH	7.32	0.550	6.93	7.71
TEMP DEG C	19.6	--	--	19.5

PLANTS W1 , W2

Table 29. Conventional bottom fish process material balance (with skinner).

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) skinner	13 - 64%	6 - 36%	5 - 39%
b) fillet table	22 - 83%	43 - 76%	39 - 80%
c) pre-rinse or dip tank	1 - 13%	7 - 26%	5 - 34%
d) washdown	3 - 21%	4 - 20%	7 - 21%
Total effluent average B2, B4, B8	8000 l/kkg	2.8 kg/kkg	1.8 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	20 - 40%
By-products	
a) carcass (reduction, animal food)	55 - 75%

Average Production Rate, 16.5 kkg/day (18 tons/day)

Table 30. Conventional bottom fish process material balance (with descaler).

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) descaler	42 - 66%	56 - 61%	26 - 70%
b) fillet table	21 - 36%	16 - 30%	12 - 19%
c) pre-wash or dip tank	3 - 10%	4 - 8%	4 - 8%
d) washdown	7 - 18%	6 - 19%	7 - 18%
Total effluent average B1, B10, B11	10,000 l/kkg	2.5 kg/kkg	1.6 kg/kkg

ficant and contributed such a high waste load that it was not considered to be a conventional operation. On the average, however, the waste loads were about the same whether or not skinners or scalers were used. Flow ratios and waste loads varied significantly between plants, caused partly by different processing methods and partly by different degrees of water conservation; however, the average flows and loads from all the plants were relatively low, compared to other seafood processes.

The two whiting plants sampled (W1, W2) were considered to be typical mechanized operations where the fish were beheaded, descaled, and partially eviscerated by mechanical methods and relatively large water flows were used. The finfish process in the Gulf (CFC1) was processing croaker for fish flesh and was highly mechanized. The Northwest plant (B6) used conventional processing except for the large scaler, which produced a high waste flow.

Table 31 itemizes the wastewater sources for a typical whiting process. The process water included water from the largest source of wastewater. The largest portion of the process water was attributed to the fluming of fish from the storage bins to the processing line using a high pressure hose and elevator. The replacement of the hose by a dry conveyor system such as used in the sardine plants would reduce the waste flow and load significantly. The visceral flume contributed about 20 percent of the waste load and could be replaced by a dry conveyor system.

Table 32 shows the wastewater balance for a whole halibut freezing operation. The first unit operation is the grading and

Table 31. Whiting freezing process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) process water	70 - 75%	74 - 77%	74 - 78%
b) washdown	3 - 8%	2 - 5%	2 - 6%
c) visceral flume	22%	21%	20%
Total effluent average W1, W2	13,500 l/kkg	14 kg/kkg	11 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food Products	50%
By-product a) heads, scales, viscera (to reduction plant)	48%
Waste	≃ 2%

Average Production Rate, 35 kkg/day (38 tons/day)

Table 32. Halibut freezing process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) head cutter/grader	3%	11%	10%
b) washer	79%	72%	62%
c) washdown	18%	17%	28%
Total effluent average FRH1	8600 l/kkg	1.5 kg/kkg	1.2 kg/kkg

Product Material Balance Summary

End products	% of Raw Product
Food products	90%
By-products	
a) heads	10%
Wastes	minimal

Average Production Rate, 33 kkg/day (36 tons/day)

head cutting operation, which produces a minimal waste load comprising about three percent of the total flow and a somewhat larger percentage of the BOD and suspended solids loads. One plant observed used no water for this operation. The washing operation is handled in two different manners, and they produce substantially different waste flows. In one system, a continuous spray washer was used, as well as spray hoses for the gut cavity. For this, the flow and waste loads were rather large, comprising about 80 percent of the total flow and 70 percent of the BOD. The other method involves washing the fish in shallow tanks with brushes. This produces a much lower flow, but higher waste concentrations such that the waste load is similar to the other method. For both processes observed, the washdown was similar, producing about 20 percent of the total flow and waste load. The waste flows from a halibut fletching process are minimal (Table 33) with the washdown around the trim table constituting about 80 percent of the total BOD load.

The production rates at halibut processing plants can be quite high. The average production for the monitored whole freezing operation was 33 kkg/day (36 tons/day), while the average production for the fletching operation was 5.6 kkg/day (6.2 tons/day).

Solid waste from the freezing operation is minimal since the only non-food products are the heads and carcasses which are often used for bait. There is no visceral waste since the fish are eviscerated at sea. Solid waste from the fletching operation is about 40 percent, which consists of the carcasses and heads which may be used for bait or disposed to the receiving waters.

Table 33. Halibut fletching process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) trim table	48%	19%	16%
b) trim area washdown	46%	80%	83%
c) butchering area washdown	6%	1%	1%
Total effluent average FFH1	2400 l/kkg	2.1 kg/kkg	1.8 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	
a) fletches	51%
b) tip, trim, bellies	9%
By-products	
a) heads	10%
Wastes	
a) carcasses	30%

Average Production Rate, 5.6 kkg/day (6.2 tons/day)

1.4.8 Herring Pickling Process

The marinated or pickled herring process is typified by large flows and waste loads and is highly seasonal. It was considered to be less important than the fresh/frozen or canned herring industry because relatively few pickling operations exist in the United States. Very few sea herring are pickled; a moderate volume of alewife or river herring are pickled.

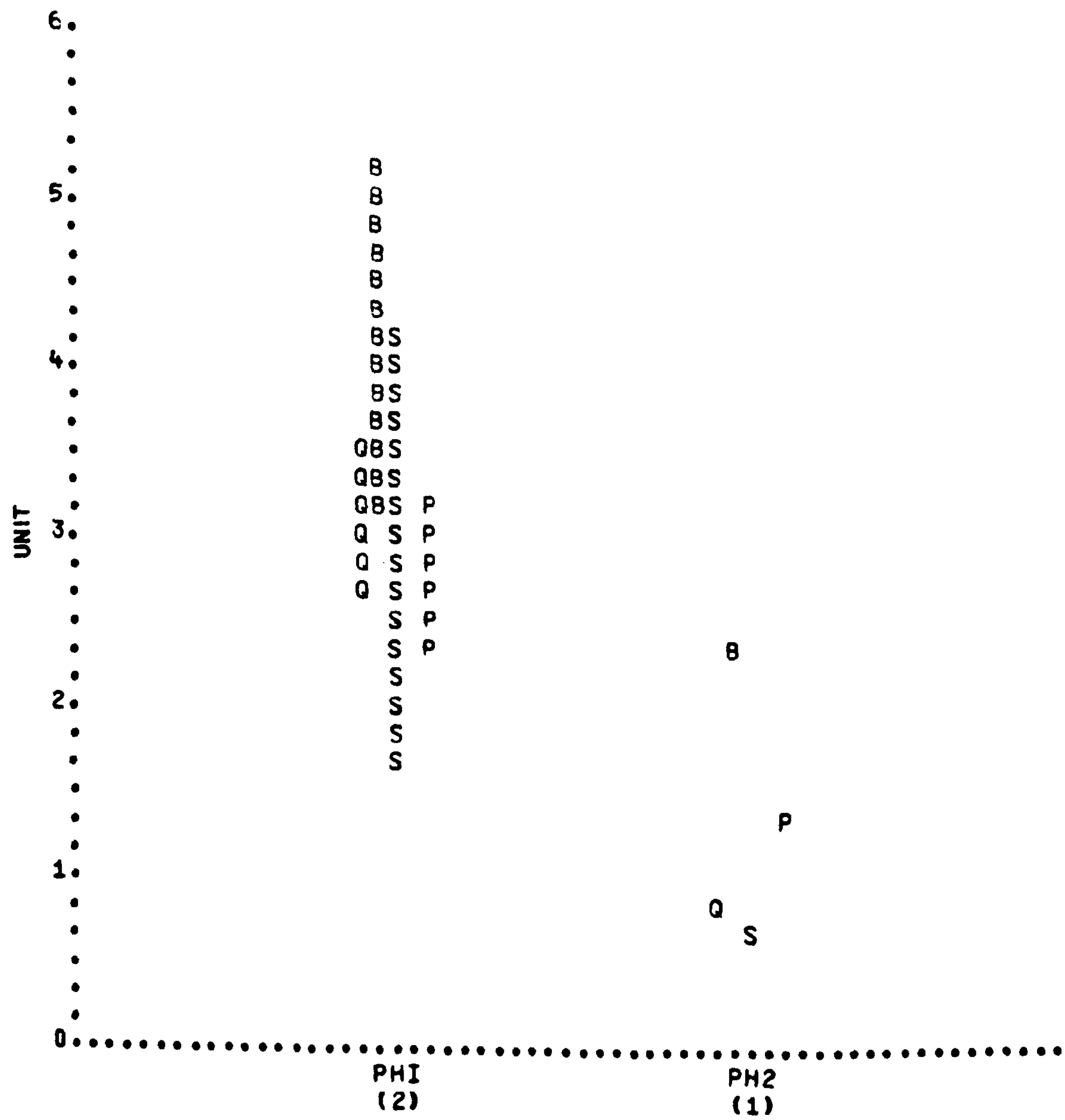
Since the alewife pickling season is in the spring, it was not possible for Environmental Associates to investigate any active operations in the recent studies. A limited amount of historical data on Chesapeake Bay plants were obtained, providing the equivalent of three composite samples (Clifford and Associates, 1973).

The alewife pickling industry is located in the Middle Atlantic region and is not considered large enough to divide into size ranges. Therefore, it was decided that all of the alewife pickling industry be included in one subcategory.

Figure 13 and Table 34 summarize the characteristics of the two alewife pickling plants sampled. These data were used as the typical raw waste loads for this segment of the seafood industry.

Both of the plants sampled received their water from wells. The heavy waste loads came from the scalers, cutting tables, and curing vats (Table 35). The curing vat wastewater comprised only two percent of the total flow; however, it made up 42 percent of the mean BOD and 21 percent of the mean suspended solids. The waste loads are relatively high from this type of process and

Figure 13. **ALEWIFE PICKLING PROCESS PLOT.**



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 5000 L/KKG
B	5 DAY BOD	1 UNIT = 5 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 2 KG/KKG
G	GREASE & OIL	1 UNIT = 0.001 KG/KKG
P	PRODUCTION	1 UNIT = 2 TON/HR

Table 34. **ALEWIFE PICKLING PROCESS SUMMARY.**

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	4.14	2.08	1.46	9.37
PROCESS TIME HR/DAY	7.88	0.530	7.50	8.25
FLOW L/SEC	12.3	13.2	1.52	46.6
(GAL/MIN)	195	209	24.0	739
FLOW RATIO L/KKG	9960	7780	2030	30400
(GAL/TON)	2390	1860	486	7280
SETT. SOLIDS ML/L	--	--	--	--
RATIO L/KKG	--	--	--	--
SCR. SOLIDS MG/L	--	--	--	--
RATIO KG/KKG	--	--	--	--
SUSP. SOLIDS MG/L	372	317	66.4	1210
RATIO KG/KKG	3.71	3.16	0.662	12.0
5 DAY BOD MG/L	1630	646	720	3210
RATIO KG/KKG	16.3	6.43	7.17	31.9
COD MG/L	1890	1330	445	5350
RATIO KG/KKG	18.8	13.2	4.44	53.3
GREASE & OIL MG/L	--	--	--	--
RATIO KG/KKG	--	--	--	--
ORGANIC-N MG/L	--	--	--	--
RATIO KG/KKG	--	--	--	--
AMMONIA-N MG/L	--	--	--	--
RATIO KG/KKG	--	--	--	--
PH	5.62	0.671	5.00	6.23
TEMP DEG C	17.8	--	--	17.8

PLANTS PH1 , PH2

Table 35. Pickled herring process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) scaler	53%	27%	45%
b) cutting table	45%	29%	31%
c) curing vat	2%	42%	21%
d) brine vat	1%	2%	2%
Total effluent average PH1	15,500 l/kkg	21 kg/kkg	6 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	42 - 45%
By-products	
a) scales	2 - 3%
b) heads	10 - 12%
c) viscera and fins	32 - 35%
Wastes	5 - 10%

Average Production Rate, 42 kkg/day (46 tons/day)

may be troublesome to treat because of the high salt content. All wastewater was discharged to the waters of Chesapeake Bay. One plant used settling basins prior to discharge.

The production rates were relatively high at these alewife pickling plants with an average of 36 kkg/day (40 tons/day) being observed. The product recovery did not vary appreciably between the two plants and averaged about 42 to 45 percent. Both plants collected their solid wastes for reduction.

1.4.9 Catfish Processes

Subcategorization for the catfish processing industry was relatively straightforward, largely due to the fact that the industry is in relative infancy and is much more homogeneous than most of the other seafood processing industries.

As is the case with nearly all fish and shellfish processors, the catfish processors do not enjoy a constant supply of raw product. Raw material availability is seasonal and a function of such factors as the water temperatures in the immediate area, rainfall frequency and intensity (affecting harvesting), development of certain off-flavors (due to algae), and priority in work scheduling on the farm. Recently, as the processing industry has become more organized, the producers have been enticed to harvest (although on a limited scale) through the summer months. Some processors, furthermore, have entered the production business, thereby assuring themselves more complete control over raw product supply.

Another consideration in subcategorization was condition of raw product on delivery to the processing plant. In the catfish industry, the farm-raised catfish are delivered either alive in aerated tank trucks or packed on ice or "dry." The wastewaters from the live haul are, of course, much greater in volume than those from iced transportation and are contaminated mainly with feces, regurgitated material, and pond benthos. The ice, on the other hand, where used in packing the fish for transport, is usually bloody and contains significant amounts of slime. Although the two types of wastes differ in character and concentration, it was felt that these differences were not sufficient to warrant separate subcategories.

A third consideration in subcategorization was the variety of species being processed. Although the most common variety currently processed is the channel catfish, others are handled by the plants in lesser amounts. The results of the analyses of the samples gathered during the plant monitoring phase of this study indicated that no significant difference in the nature of the waters from the processing of various species existed (Table 36).

Plant location and age were also considered. The catfish industry is located in the central and southern states in areas of similar climatic conditions (conducive to the raising of farm catfish) in flat to moderate rolling terrain. In general, the soils present no severe construction problems. High water tables, in certain localities, present problems. Many of the plants are located in rural areas on sufficient acreage to permit installation of adequate treatment systems. Those with inadequate land in their

Table 36. Catfish Process Summary (5 plants).

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range
Flow Rate[3], cu m/day[1]	116	74	64.6	79 - 170
(mgd)	(0.031)	(0.020)	(64.6)	(0.021 - 0.045)
Flow Ratio, l/kkg[2]	22,586	7747	34.3	13,710 - 31,491
(gal/ton)	(5416)	(1860)	(34.3)	(3288 - 7552)
Settleable Solids, ml/l	8.0	10.0	125	0.45 - 24.7
Settleable Solids Ratio, l/kkg	201	263	131	7.1 - 651.4
Screened Solids[4], mg/l	125	--	--	124 - 126
Screened Solids Ratio, kg/kkg	3.2	--	--	2.5 - 3.9
Suspended Solids, mg/l	399	233	55.9	332 - 509
Suspended Solids Ratio, kg/kkg	9.0	2.1	23.3	7.5 - 11.5
5 day BOD, mg/l	350	244	69.9	244 - 408
5 day BOD Ratio, kg/kkg	7.9	1.2	15.8	5.5 - 9.2
20 day BOD[4], mg/l	494	--	--	344 - 1101
20 day BOD Ratio, kg/kkg	11.2	--	--	7.2 - 15.1
COD, mg/l	695	512	73.6	456 - 780
COD Ratio, kg/kkg	15.7	3.4	21.8	10.3 - 17.6
Grease and Oil, mg/l	200	107	53.5	168 - 246
Grease and Oil Ratio, kg/kkg	4.53	0.83	18.3	3.79 - 5.55
Organic Nitrogen, mg/l	27	16.5	61.0	23 - 33
Organic Nitrogen Ratio, kg/kkg	0.62	0.08	12.9	0.51 - 0.75
Ammonia-N, mg/l	0.98	0.81	82.7	0.20 - 2.00
Ammonia-N Ratio, kg/kkg	0.022	0.016	74.0	0.0045 - 0.0451
pH	6.3	--	--	5.8 - 7.0

1 day = 8 hrs
2 weight of raw product
3 excluding the salt water processing plant
4 based on data from two plants

possession currently either: 1) have access to other land (at a price); or 2) are reasonably well suited for incorporation into a nearby municipal system. As mentioned previously, age of plant is not a significant factor in this industry.

For all the above reasons, the United States catfish processing industry was placed into a single subcategory.

The samples on which this study is based were taken at five processing plants during April, May and June of 1973. Those months are some of the poorer production months in the industry. Because the peak production season does not come until late summer and fall, mostly small fish were being processed and the additional amount of time required to process smaller fish held the production volume down. The major complication was the severe flooding throughout much of the Mississippi Delta, which hindered or prevented harvesting of the fish, along with other normal industry operations.

Depending on the location of the particular plant, a well or city water system supplied the raw water and a city sewer system or local stream was called upon to receive the final effluent. Table 37 itemizes the flow sources. The three main flows formed the effluent and its constituent waste loads. The flow from the live holding tank area produced the largest volume of water (59 percent) and contained the least waste. Conversely, the cleanup flows contributed a relatively small volume of water (7.5 percent), but contained the highest waste concentrations. The processing flows were the third factor and they contributed a medium volume of water with a medium-to-heavy waste concentration.

Table 37. Catfish process material balance.

Wastewater Material Balance Summary

Average Flow*, 109 cu m/day (0.027 mgd)[1]

	Unit Operation	% of Average Flow	Range, %
a)	live holding tanks	59.2	54.7 - 63.7
b)	butchering (be-heading, eviscerating)	-	-
c)	skinning	4.1	7.3 - 2.1
d)	cleaning	13.8	18.3 - 9.1
e)	packing (incl. sorting)	3	4.7 - 1.5
f)	clean-up	7.5	9 - 5.1
g)	washdown flows	13.2	15.7 - 9.2

Product Material Balance Summary

Average Raw Product Input Rate, 4.25 kkg/day (4.69 tons/day)

Output	% of Raw Product	Range, %
Food Product	63	-
By Product	27	0 - 32
Waste	10	5 - 37

*Including clean-up water

[1]Based on figures from 3 plants

Water reuse was limited to the holding tank and was not a universal practice. Plant 4 retained water in holding tanks for a week or more with an overflow of roughly 0.2 l/sec (3 gpm) from each tank, and as a partial consequence, had the lowest total daily flow of all the plants. Plant 2 had to drain each holding tank completely each time fish were removed from it because of the tank and plant design. Plant 2 had the highest total water usage with over three times the flow of Plant 4, and used almost exactly twice as much water per unit of product. The other plants reused holding tank water in varying degrees.

Holding tank flows ran into the tanks from stationary faucets and when the tanks were full the flow drained through stand-pipe drains. Clean-up flows came almost exclusively from hoses, but processing flows were quite diverse in origin. Processing flows came from skinning machines, washers, chill tanks, the packing area, and eviscerating tables and included water used to flume solids out of the processing area.

The by-product solids were removed from the processing area in two ways. They were "dry-captured" in baskets or tubs and removed by that means or flumed to a screening and collection point. All of the plants sampled used the same type of skinning machine, which was designed to operate with a small flow of water. The skins were washed out of the machine; there is no way to effect dry capture of the skins, short of redesigning the equipment.

While the holding tank flow waste load was mainly made up of feces, slime, and regurgitated organic matter, the processing and clean-up waste loads were made up of blood, fats, small chunks of skin and viscera, and other body fluids or components. A high waste load came from the tanks where the fish were washed, and from the chill tanks. There was no way to "dry-capture" this waste which was composed of blood, fats, and some particulate organic materials.

1.4.10 Alaska Crab Process

Subcategorization for the Alaskan crab industry was relatively complicated. In the course of the field work it became evident that, although differences in the processes existed, the variations in wastewater flow and content noted were not significant when compared to the normal plant-to-plant and day-to-day variations within each of the process groups (canning, freezing, and sections).

The king, Dungeness and tanner crab processing industry in Alaska were however, separated from the rest of the United States for several reasons. These reasons were all based on the assumption that a subcategory should be designated whenever differences between plants would seriously affect the development of:

1. treatment design configurations;
2. designation of expected effluent levels after treatment; and/or
3. estimation of costs of treatment.

A very important item in the Alaskan crab processing industry is the plant location. In this region of the country, perhaps more than in any other, site specificity must be an over-riding concern in the development of waste management, treatment, and disposal alternatives. Most, if not all, of the king, tanner and Dungeness crab processing plants in Alaska are located south of Bristol Bay in terrain which can most aptly be described as "vertical." Virtually every plant is built on piling because of the lack of suitable real estate. Although most Alaskan crab processing plants are isolated individual facilities located remotely from population centers, a few concentrations of processing plants in populous areas exist. The most notable one is in the city of Kodiak, Alaska, where 14 processing plants are located either on pilings, on barges, or in reconditioned (floating or grounded) ships along the Kodiak waterfront.

The fact remains, however, that the general location of the Alaskan processors in an area of limited accessibility and of inflated costs (the Army Corps of Engineers Construction Price Index lists Kodiak, as 2.5, based on a national average of 1.0) justifies the designation of a separate subcategory for these processors.

For the above reasons the Alaskan Dungeness, king and tanner crab processing industries were placed into a single subcategory.

Each of the plants sampled in Kodiak, Alaska used city water for processing and water volumes and flow rates were easily obtained from water meter readings. Plants outside of Kodiak used mostly salt water in processing except for the cooking operation which used local runoff waters.

The average total wastewater flow and the itemization per unit operation are listed in Table 38 for the section process, and in Table 39 for the combined frozen and canned meat processes without use of the grinder. This could be done since the grinders only operated on an intermittent basis, as the solids in the butcher area accumulated to a certain point.

The water used in the sections process (Table 38) was about 75 percent of that used in the frozen and canned meat process. Most of the water came from the washing and cooling of the sections (60 percent) and contributed a moderate amount of waste. The butcher and cooking operations contributed low flows and low-strength wastes. Most of the water in the frozen and canned meat process (Table 39) came from the meat extraction and cooling operations (57 percent) and contributed a moderate-strength waste. The butcher and cook flows were high-strength but low in volume. The pack, freeze and retort operations contributed a low-strength waste which was about 25 percent of the total volume.

Tab les 40 and 41 show the water flow breakdown for the sections and combined frozen and canned meat processed when the grinder was operating to dispose of the carapaces, viscera and gills from the butcher area. It can be seen that the water flow increased about 50 percent for the sections process and 25 percent for the frozen and canned meat processes. A typical grinder used 170-225 l/min (45-60 gal/min). Most plants processing sections used only one grinder while almost all frozen and canned meat operations used two.

Table 38. Material balance - Alaska tanner and king crab sections process and Alaska Dungeness crab whole cooks (without waste grinding).

Wastewater Material Balance Summary

Average Flow,* 240 cu m/day (0.058 mgd)

Unit Operation	% of Average Flow	Range,%
a) butcher	5	2 - 8
b) precook and cook	15	10 - 20
c) wash and cool	60	50 - 70
d) sort, freeze, pack	10	5 - 15
e) clean-up	10	5 - 15

Product Material Balance Summary

Average Raw Product Input Rate, 13.09 kkg/day (14.40 tons/day)

Output	% of Raw Product	Range, %
Food product	64	57 - 69
By-product	34	20 - 40
Waste	2	1 - 15

* Including clean-up water used during eight hours of processing.

Table 39. Material balance - Alaska tanner crab frozen and canned meat process (without waste grinding).

Wastewater Material Balance Summary

Average Flow,* 352 cu m/day (0.092 mgd)

Unit Operation	% of Average Flow	Range, %
a) butcher	2	1 - 3
b) precook and cook	5	2 - 7
c) cool	20	15 - 30
d) meat extraction	37	30 - 40
e) sort, pack, freeze	11	8 - 20
f) retort**	15	-- - --
g) clean-up	10	5 - 15

Product Material Balance Summary

Average Raw Product Input Rate, 12.3 kkg/day (13.5 tons/day)

Output	% of Raw Product	Range, %
Food product	14	10 - 20
By-product	84	70 - 89
Waste	2	1 - 15

* Including clean-up water used during 8 hours of processing at the plants using fresh water.

** Canning operation only.

Table 40. Material balance - Alaska tanner and king crab sections process (with waste grinding).

Wastewater Material Balance Summary

Average Flow*; 360 cu m/day (0.086 mgd)

Unit Operation	% of Average Flow	Range, %
a) butcher and grinding	26	15 - 40
b) precook and cook	19	15 - 25
c) wash and cool	36	20 - 50
d) sort, pack, freeze	9	5 - 12
e) clean-up	10	15 - 20

Product Material Balance Summary

Average Raw Product Input Rate, 13.1 kkg/day (14.4 tons/day)

Output	% of Raw Product	Range, %
Food product	64	57 - 69
By-product	21	15 - 30
Waste	15	10 - 30

* Including clean-up water during eight hours of processing

Table 41. Material balance - Alaska tanner crab frozen and canned meat process (with waste grinding).

Wastewater Material Balance Summary

Average Flow* 439 cu m/day (0.116 mgd)

Unit Operation	% of Average Flow	Range, %
a) butcher and grinding	30	25 - 45
b) precook and cook	3	1 - 5
c) cool	6	2 - 9
d) meat extraction	34	30 - 40
e) sort, pack, freeze	7	5 - 10
f) retort**	10	5 - 15
g) clean-up	10	8 - 15

Product Material Balance Summary

Average Raw Product Input Rate, 8.4 kkg/day (9.25 tons/day)

Output	% of raw procuct	Range, %
Food product	14	10 - 20
By-product	66	50 - 75
Waste	20	10 - 30

* Including clean-up water during 8 hours of processing.
** Canning operation only.

Table 42 lists the combined averages obtained for the total Alaska crab industry with grinders. The operation of the grinder required an increase in water use of about 66 percent and the waste loads were increased by a factor of about 5 on a unit product basis. Tables 43 and 44 show the combined section and the combined freezing and canning process respectively; it can be seen that the freezing and canning processes used more water and had higher waste loads than the section processes. The reason for this is that much more solid waste is generated in the freezing and canning process and there is typically one grinder in the butcher area and one grinder in the meat separation area while in the section process, there is just one grinder in the butcher area.

1.4.11 West Coast Crab Process

Subcategorization for the Oregon, Washington, and California tanner and Dungeness crab processing industry was developed following much of the reasoning outlined in the discussion of the Alaskan crab industry.

The major differences between the two regions' processing industries were geographical, with one exception: the use of the brine tank in the "lower 48," whereas, it was not generally used in Alaska.

The geographical reasons alluded o above, of course, included considerations of climate, topography, relative isolation of the processing plants, land availability, soil conditions,

Table 42. Alaska crab process summary (8 plants) with grinding

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range
Flow Rate, cu m/day[1]	366	103	28	156 - 507
(mgd)	(0.096)	(0.027)	(28)	(0.041 - 0.134)
Flow Ratio, l/kkg[2]	40,340	21,040	52	17,600 - 85,500
(gal/ton)	(9670)	(5060)	(52)	(4220 - 20,500)
Settleable Solids, ml/l	15.6	16.9	103	1.4 - 43.7
Settleable Solids Ratio, l/kkg	412	613	148	46.1 - 1820
Screened Solids, mg/l	16,500	20,770	125	807 - 29,400
Screened Solids Ratio, kg/kkg	580	372	64	28 - 1220
Suspended Solids, mg/l	1030	1140	110	201 - 1630
Suspended Solids Ratio, kg/kkg	38	20	53	20 - 67
5 day BOD, mg/l	1480	1656	112	627 - 2520
5 day BOD Ratio, kg/kkg	51	20	39	22 - 89
20 day BOD, mg/l[3]	2160	1470	68	763 - 4390
20 day BOD Ratio, kg/kkg	101	133	131	31 - 230
COD, mg/l	2440	1225	50	954 - 4540
COD Ratio, kg/kkg	84	32	38	34 - 142
Grease and Oil, mg/l	345	241	70	79 - 754
Grease and Oil Ratio, kg/kkg	13	11	85	4 - 31
Organic Nitrogen, mg/l	217	101	47	92 - 350
Organic Nitrogen Ratio, kg/kkg	7.6	3.4	44	3 - 13
Ammonia-N, mg/l	5.7	2.7	47	2.1 - 8.7
Ammonia-N Ratio, kg/kkg	0.22	0.09	43	0.09 - 0.35
pH[4]	7.5	0.38	5	7.1 - 7.9

1 day = 8 hrs
2 weight of raw product
3 based on seven observations
4 based on five observations

Table 43. Alaska crab section process summary with grinding (4 plants)

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range
Flow Rate, cu m/day[1]	330	124	37	156 - 439
(mgd)	(0.088)	(0.033)	(37)	(0.041 - 0.116)
Flow Ratio, l/kkg[2]	29,000	12,260	42	17,600 - 43,400
(gal/ton)	(6970)	(2940)	(42)	(4220 - 10.400)
Settleable Solids, ml/l	16	17	107	1.4 - 37.7
Settleable Solids Ratio, l/kkg	245	342	139	46 - 754
Screened Solids, mg/l	13,900	12,070	87	807 - 27,000
Screened Solids Ratio, kg/kkg	307	198	65	28 - 474
Suspended Solids, mg/l	904	597	66	201 - 1600
Suspended Solids Ratio, kg/kkg	22	12	55	7 - 32
5 day BOD, mg/l	1525	1930	126	627 - 2520
5 day BOD Ratio, kg/kkg	36	10.5	29	22 - 44
20 day BOD, mg/l[3]	1590	1327	83	781 - 3130
20 day BOD Ratio, kg/kkg	42	19	45	31 - 63
COD, mg/l	2620	1560	60	954 - 4540
COD Ratio, kg/kkg	64	22.3	35	34 - 80
Grease and Oil, mg/l	304	152	50	79 - 400
Grease and Oil Ratio, kg/kkg	8	5.5	69	3 - 15
Organic Nitrogen, mg/l	205	115	56	92 - 350
Organic Nitrogen Ratio, kg/kkg	5	1.6	33	3.3 - 6.0
Ammonia-N, mg/l	5.8	3.1	54	2.5 - 8.7
Ammonia-N Ratio, kg/kkg	0.18	0.19	105	0.09 - 0.30
pH[4]	7.3	--	--	7.1 - 7.5

1 day = 8 hrs
2 weight of raw product
3 based on three observations
4 based on two observations

Table 44. Alaska Crab Frozen & Canned Meat Process Summary without grinding (4 plants)

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range
Flow Rate, cu m/day[1]	400	69.1	17	322 - 507
(mgd)	(0.106)	(0.018)	(17)	(0.085 - 0.134)
Flow Ratio, l/kkg[2]	51,700	56,600	110	32,800 - 85,500
(gal/ton)	(12,400)	(13,580)	(110)	(7870 - 20,500)
Settleable Solids, ml/l	15.3	19.2	125	1.8 - 43.7
Settleable Solids Ratio, l/kkg	580	829	143	78 - 1820
Screened Solids, mg/l	19,180	10,600	56	9000 - 29,400
Screened Solids Ratio, kg/kkg	853	289	34	517 - 1220
Suspended Solids, mg/l	1158	424	37	661 - 1630
Suspended Solids Ratio, kg/kkg	54	11.4	21	45 - 67
5 day BOD, mg/l	1434	630	44	656 - 2160
5 day BOD Ratio, kg/kkg	66	1.7	3	54 - 89
20 day BOD, mg/l[3]	2590	1602	62	1280 - 4390
20 day BOD Ratio, kg/kkg	144	75	52	60 - 230
COD, mg/l	2262	983	43	1140 - 3450
COD Ratio, kg/kkg	104	26.5	25	86 - 142
Grease and Oil, mg/l	387	329	85	86 - 754
Grease and Oil Ratio, kg/kkg	18	13.7	77	4 - 31
Organic Nitrogen, mg/l	230	99	43	97 - 320
Organic Nitrogen Ratio, kg/kkg	10	3.3	33	8 - 13
Ammonia-N, mg/l	5.6	2.8	50	2.1 - 8.7
Ammonia-N Ratio, kg/kkg	0.26	0.08	31	0.2 - 0.35
pH	7.6	0.81	0.11	7.3 - 7.9

1 day = 8 hrs
2 weight of raw product
3 based on three observations

and availability of unlimited water. All of these aspects then, together with the significant difference in wastewater characteristics (chloride) between the two regions, prompted designation of different subcategories for the Alaskan industry versus the Oregon, Washington, and California tanner and Dungeness crab processing industry, for the purpose of designing and estimating the cost of treatment systems and for developing recommended effluent standards and guidelines.

Table 45 lists the average waste loads without fluming for all three plants sampled. These values were influenced by both whole cook and meat picking processes; however, the meat picking process was by far the largest operation. The time-averaged waste load characteristics of a typical plant would be similar to that generated by the meat picking process alone.

All of the plant sampled follow the same general processing steps except for two unit operations. The first variation was in the bleed-rinse step. After the crab were butchered the pieces were either conveyed via belt below a water spray or packed into large steel baskets and submerged in circulating rinse water. In either case a continuous wastewater flow resulted. There was no appreciable difference in the characteristics of the waste streams from each method. The second variation in processing was the cooling method employed following cooking. Some plants employ a spray cool and others submerge a steel basket containing the crabs in circulating rinse water. The waste characteristics were unaffected by the cooling method.

Table 46 itemizes the flow from each unit operation as a percentage of the total flow without fluming. The total average

Table 45. West Coast Dungeness crab process summary without shell fluming (3 plants).

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range
Flow Rate[3], cu m/day[1]	55	--	--	-- - --
(mgd)	(0.014)	(--)	(--)	(-- - --)
Flow Ratio[4], l/kkg[2]	19100	3870	20	15,000 - 21300
(gal/ton)	(4580)	(670)	(15)	(3560 - 5110)
Settleable Solids, ml/l	84	12	14	70 - 92
Settleable Solids Ratio, l/kkg	1604	447	28	1470 - 1960
Screened Solids, mg/l	--	--	--	-- - --
Screened Solids Ratio, kg/kkg	--	--	--	-- - --
Suspended Solids, mg/l	146	26	18	122 - 177
Suspended Solids Ratio, kg/kkg	2.7	0.5	20	2.6 - 2.9
5 day BOD, mg/l	412	143	35	319 - 505
5 day BOD Ratio, kg/kkg	8.0	5.1	2.2	6.6 - 10.6
20 day BOD, mg/l	--	--	--	-- - --
20 day BOD Ratio, kg/kkg	--	--	--	-- - --
COD, mg/l	609	122	20	516 - 740
COD Ratio, kg/kkg	11.3	1.6	14	11.0 - 12.0
Grease and Oil, mg/l	--	--	--	-- - --
Grease and Oil Ratio, kg/kkg	--	--	--	-- - --
Organic Nitrogen, mg/l	86	12	14	68 - 95
Organic Nitrogen Ratio, kg/kkg	1.61	0.35	22	1.41 - 1.99
Ammonia-N, mg/l	5.6	1.9	33	4.0 - 7.0
Ammonia-N Ratio, kg/kkg	0.10	0.04	45	0.075 - 0.14
pH	7.4	0.5	7	7.3 - 7.7

1 day = 8 hrs
2 weight of raw product
3 two values
4 five values

Table 46. Oregon Dungeness crab whole and fresh-frozen meat process (without fluming wastes)

Wastewater Material Balance Summary

Average Flow*: 120 cu m/day (0.032 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	butcher (clean-up)	8	4 - 11
b)	bleed rinse	25	12 - 30
c)	cook	3	2 - 4
d)	cool	30	26 - 33
e)	pick (clean-up)	7	5 - 8
f)	brine and rinse	27	18 - 34

Product Material Balance Summary

Average Raw Product Input Rate, 6.3 kkg/day (7.0 tons/day)

Output	% of Raw Product	Range, %
Food product	22	17 - 27
By-product	63	50 - 66
Waste	15	7 - 23

* Including clean-up water

flow observed for the three processes was about 120 cu m/day (0.032 mgd). The only water from the butcher area was washdown and contributed a relatively low flow and waste load. The cooking flow was low in volume but high in strength. The flow from the bleeding area was moderate and contributed relatively little waste. The cooling water contributed a large flow but very little waste. The major source of waste came from the brining operation which produced a high salt load.

The use of fluming to remove solids from the butchering and meat picking area increased the water flow by about 70 percent and produced a moderately high waste load.

1.4.12. Blue Crab Processes

It was obvious that the blue crab industry had to be broken down into two subcategories. The first encompassed the conventional (hand picking) blue crab processing plant, and the second included those blue crab processing plants employing the Harris claw picking machine (or equivalent) for the removal of meat from claws or from body sections or both.

The condition of the raw product on delivery to the processing plant was of considerable concern in the blue crab processing industry, especially with respect to dredged crab. Because of the greater number of injured crab and large amount of silt and mud carried into the plant it was felt that the process wastewater from crabs harvested by dredging during the winter months may have a higher waste load than that of crabs harvested during other periods of the year.

The manufacturing processes and subprocesses were important factors affecting subcategorization, as discussed above. The utilization of the claw picking machine either for claws or for bodies, or both, introduced significantly greater quantities of wastewater, BOD, grease, etc., into the waste stream and at the same time changed the character of the waste stream through the addition of large quantities of sodium chloride. Sodium chloride at the levels found in these blue crab processing plants is inhibitory to many biological treatment systems. Its toxic effect is increased by the fact that the machines are operated on the average less than two days per week, meaning that waste streams fluctuate from very low salinity to extremely high salinity from day to day throughout the processing season. Indeed, the treatability problems involving high strength brines (together with other factors) prompted the designation of a separate subcategory for blue crab processors employing claw picking machines.

All conventional plants sampled used domestic water supplies. Table 47 itemizes the flow from each unit operation as a percent of the total. The majority of the flow (50 percent) was cooling water from continuous ice making operations, but contributed negligible organic waste loads. The washdown was an intermittent source which contributed an average of 23 percent of the total flow, but also contributed only a small waste load. The cooker flow averaged 17 percent and contributed the greatest load to the wastewater streams. Table 48 contains the process summary for the conventional process.

The mechanized process produced considerably more wastewater than the conventional processes. Table 49 itemizes the

Table 47. Conventional Blue crab process material balance

Wastewater Material Balance Summary

Average Flow*, 2.52 cu m/day (0.00066 mgd)

Unit Operation	% of Average Flow	Range, %
a) washdown	23	17 - 26
b) cook	17	13 - 21
c) ice	60	-- - --

Product Material Balance Summary

Average Raw Product Input Rate, 2.59 kkg/day (2.85 tons/day)

Output	% of Raw Product	Range, %
Food product	14	9 - 16
By-product	80	79 - 86
Waste	5	-- - --

* Including clean-up water

Table 48. Conventional blue crab process summary (2 plants).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	2.52	2.40 - 2.66
(mgd)	(0.00067)	(0.0006 - 0.0007)
Flow Ratio, l/kkg[2]	1190	1060 - 1315
(gal/ton)	(285)	(255 - 315)
Settleable Solids, ml/l	4.6	3.3 - 5.8
Settleable Solids Ratio, l/kkg	5.2	4.4 - 6.2
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	667	596 - 739
Suspended Solids Ratio, kg/kkg	1.2	0.7 - 1.5
5 day BOD, mg/l	4410	3630 - 5180
5 day BOD Ratio, kg/kkg	5.2	4.8 - 5.5
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	6420	5480 - 7360
COD Ratio, kg/kkg	7.5	7.2 - 7.8
Grease and Oil, mg/l	216	204 - 228
Grease and Oil Ratio, kg/kkg	0.34	0.22 - 0.39
Organic Nitrogen, mg/l	790	611 - 969
Organic Nitrogen Ratio, kg/kkg	0.94	0.80 - 1.03
Ammonia-N, mg/l	53.3	47.6 - 59
Ammonia-N Ratio, kg/kkg	0.065	0.063 - 0.068
pH[3]	7.6	7.2 - 8.0

1 day = 8 hrs
2 weight of raw product
3 laboratory pH

Table 49. Mechanized Blue crab process material balance

Wastewater Material Balance Summary

Average Flow*, 178 cu m/day (0.047 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	machine picking	90.5	-- - --
b)	brine tank	0.5	-- - --
c)	wash down	7.7	-- - --
d)	cook	0.2	-- - --
e)	ice making	1.1	-- - --

Product Material Balance Summary

Average Raw Product Input Rate, 4.8 kkg/day(5.3 tons/day)

Output	% of Raw Product	Range, %
Food Product	14	9 - 16
By-product	80	79 - 86
Waste	5	-- - --

* Including clean-up water

flow from each operation. The cooking water, which had a high organic concentration, was diluted considerably by the water from the mechanical picker. The mechanical operation also produced brine wastes from the flotation tanks and from the subsequent meat washing. The brine tanks averaged about 1040 liters (275 gal.) and were dumped once per shift. The concentrations of sodium chloride were very high, being about 100,000 to 200,000 mg/l (as chloride).

The proportions of the raw product going into food products, by-products and waste are listed on Tables 47 and 49 and were about the same for both types of processes. About 14 percent of the crab is utilized for food (Soderquist, et al., 1970). Up to 80 percent could be dry-captured for by-products, which would leave about 5 percent entering the wastewater flow.

The maximum mechanized production rate is about 1.8 kkg/hr (2 tons/hr) on a raw product basis and the maximum conventional rate is about 500 kg/hr (1100 lbs/hr). The average production rates are about 2/3 the maximum for both processes. During a day's operation the processing is continuous; however, the length of the shift and the number of days the plants operate are intermittent, due to fluctuations in the raw product supply.

Table 50 presents the combined mechanized plant wastewater averages. The concentrations of all the parameters were much higher for the conventional than the mechanized processes. For example, the average BOD concentration from the conventional plants was 4410 mg/l, but only 650 mg/l from the mechanized plants. However, this was due to the much greater water use

Table 30. Mechanized blue crab process summary (2 plants).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	178	76 - 279
(mgd)	(0.047)	(0.020 - 0.073)
Flow Ratio, l/kkg[2]	36,900	29,000 - 44,900
(gal/ton)	(8860)	(6960 - 10760)
Settleable Solids, ml/l	2.5	2.4 - 2.6
Settleable Solids Ratio, l/kkg	92	77 - 107
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	331	398 - 496
Suspended Solids Ratio, kg/kkg	11.7	11.5 - 22.3
5 day BOD, mg/l	650	496 - 796
5 day BOD Ratio, kg/kkg	22.7	22.3 - 23.0
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	1040	644 - 1450
COD Ratio, kg/kkg	34	29 - 42
Grease and Oil, mg/l	150	147 - 154
Grease and Oil Ratio, kg/kkg	5.6	4.3 - 6.9
Organic Nitrogen, mg/l	107	61 - 153
Organic Nitrogen Ratio, kg/kkg	3.6	2.7 - 4.4
Ammonia-N, mg/l	5.8	3.5 - 8.3
Ammonia-N Ratio, kg/kkg	0.2	0.16 - 0.24
pH[3]	7.0	6.8 - 7.2

1 day = 8 hrs
2 weight of raw product
3 laboratory pH

in the mechanized process, which diluted the waste. The volume of water used per unit of raw product was about 30 times greater in the mechanized than the conventional process. The waste loads per unit of raw product were, therefore, much lower for the conventional process. For example, the average BOD ratio from the conventional process was 5.2 kg/kkg, compared to 22.7 kg/kkg from the mechanized process.

1.4.13. Alaskan Shrimp Process

The reasoning followed in the development of the Alaskan shrimp subcategory paralleled in many respects the reasoning followed in the designation of the Alaskan crab subcategory. As is the case with the crab industry, the Alaskan shrimp industry is characterized by large processing plants operating heavily during the peak processing months of the year and only intermittently during the remainder of the year. Raw material availability, as with crab, is very much a function of weather.

Indications are that the condition of raw product on delivery to the processing plant is a significant factor in determining the character of the wastewater streams emanating from the process. Unlike crab, shrimp are delivered to the plant on ice and the age of the individual animals in a load will vary from one day to one week. The degree of natural decomposition (or degradation) varies correspondingly. As a general rule, the older the mean age of the animals in a load, the greater will be the total pollutant content of the processing waste stream.

In addition to age in terms of numbers of elapsed days since harvest, the biological age of the shrimp appears to be an important factor in determining wastewater characteristics. Although Phase I of this study was of insufficient duration to determine the exact effect of maturity on wastewater characteristics, previous investigation by the National Marine Fisheries Service Technology Laboratory in Kodiak and by the National Marine Fisheries Service, Seattle Laboratory indicate that a significant difference in total waste loading exists between early spring and late summer (Collins, 1973). Early indications are that as the shrimp mature and become larger, the organic levels in the waste streams decrease. The difference in organic load from processing of mature versus immature shrimp has been indicated to be as much as 50 percent.

The variable "manufacturing process and subprocesses" applies to the Alaskan shrimp processing industry. Two main types of peelers are used, Laitram Model A and Laitram Model PCA (with steam precook). Furthermore, those shrimp to be canned are subjected to a subsequent blanching step which is not a part of the process for shrimp which are to be frozen. While these variables are significant in the Alaskan shrimp processing industry, their importance falls short of dictating that a separate subcategory be established for Model A versus Model PCA peeled shrimp. The differences between the two systems are mainly matters of degree rather than of character.

"Location of plant" is a very important item in the Alaskan shrimp processing industry and in large part justified designation of a separate subcategory. The arguments appropriate for this decision are the same arguments presented earlier for Alaskan crab and need not be reiterated in their entirety here. It is sufficient to mention that those variables tied to the location of the plant such as climatic conditions, terrain, and soil types are unique to the Alaskan region and severely constrain the number of available waste management alternatives which can be considered in the development of proposed waste management alternatives.

Either seawater or fresh water is used for some steps in processing, depending on plant location with regard to water availability and quality. Seawater is commonly used in the remote areas where good quality water is available. Those plants located in high density processing areas generally use fresh city water. One plant in the Kodiak area uses a salt water well. The plants using seawater normally use more water than fresh water plants because the city fresh water is metered.

Table 51 lists the percentages of water used in the unit operations of a typical shrimp plant (either sea or fresh water). Trash fish removal and shrimp storage are small contributors to the total plant flow, but add a moderate waste load. Peelers are the biggest water user in the plant and the largest waste load source. Washers and separators contribute 15 percent of the water and a moderate amount of the waste load. Meat fluming and clean-up make up 25 percent of the water usage and add a low to moderate load to the waste stream. Blanchers and retort water (where applicable) are insignificant both in volume and total waste contribution.

Table 51. Alaska shrimp frozen and canned process

Wastewater Material Balance Summary

Average Flow* 1340 cu m/day (0.356 mgd)

Unit Operation	% of Average Flow	Range, %
a) fish picking and ageing	4	0 - 5
b) peelers	45	40 - 50
c) washers and separators	15	10 - 30
d) blanchers	2	1 - 5
e) meat flume	19	10 - 20
f) retort and cool**	5	3 - 8
g) clean-up	10	5 - 15

Product Material Balance Summary

Average Raw Product Input Rate, 13.9 kkg/day (15.3 tons/day)

Output	% of Raw Product	Range, %
Food product	15	13 - 18
By-product	65	50 - 80
Waste	20	15 - 40

* Including clean-up water during ieght hours processing
** Included in canning process only

Table 52 summarizes the data from the Model PCA peeler plant using seawater and the data from the Model A peeler plant using fresh water. The water flow per unit product was about twice as high in the seawater plant. The BOD, COD, and screened solids load per unit product were 20 to 50 percent greater at the PCA peeler plant while the settleable solids (l/kkg) were four times those of the Model A plant. The increased load from the seawater plant was attributable to the additional fluming used at this point.

1.4.14. <u>West and Gulf Coast Shrimp</u>

Subcategorization for the shrimp industry was relatively complicated.

In the course of the field work it became evident that, although differences in the processes existed, the variations in wastewater flow and content were not significant when compared to the normal plant-to-plant and day-to-day variations within each of the processes. The major difference between larger Gulf shrimp, South Atlantic and smaller West Coast, New England varieties are geographical and species diversity.

Manufacturing processes and subprocesses, form and quality of finished product, and nature of operation showed variation between the canning processes and breading processes. Analysis of the sample data indicates that the West Coast canning process, the Gulf Coast canning processes and the breaded shrimp processes were each dissimilar enough so they should be considered separately.

Table 52. Alaska frozen shrimp process summary* (plants S1 & K2).

Parameter	Mean	Range
Flow Rate,[1] cu m/day[2]	1173	770 - 1582
(mgd)	(0.31)	(0.204 - 0.418)
Flow Ratio,[3] l/kkg	73,370	58,300 - 111,100
(gal/ton)	(17,600)	(14,300 - 26,400)
Settleable Solids, ml/l	4.8	0.23 - 10.8
Settleable Solids Ratio, l/kkg	546	14.8 - 1240
Screened Solids,[4] mg/l	8898	1030 - 20,850
Screened Solids Ratio, kg/kkg	861	246 - 1530
Suspended Solids, mg/l	1727	1090 - 2740
Suspended Solids Ratio, kg/kkg	207	80 - 415
5 day BOD, mg/l	1150	410 - 2930
5 day BOD Ratio, kg/kkg	122	30 - 220
20 day BOD, mg/l	2330	1160 - 3950
20 day BOD Ratio, kg/kkg	171	85 - 290
COD, mg/l	2595	1090 - 6340
COD Ratio, kg/kkg	274	115 - 465
Grease and Oil, mg/l	180	33 - 750
Grease and Oil Ratio, kg/kkg	17	5 - 55
Organic Nitrogen, mg/l	150	16 - 297
Organic Nitrogen Ratio, kg/kkg	10.9	1.2 - 21.8
Ammonia-N, mg/l	6.8	4.8 - 10.2
Ammonia-N Ratio, kg/kkg	0.50	0.35 - 0.75
pH[5]	7.7	7.4 - 8.5

1 flow from plant S1 neglected
2 day = 8 hrs--process water and clean up water
3 weight of raw product
4 wet weight
5 field pH

* Clean up water is included in this table.

Perhaps the major point upon which to base a decision to declare separate waste treatment facilities by region within the contiguous United States is "location of plant." Certainly climatic conditions, terrain, soil type, height of the water table, etc., are significant considerations in the development of recommended treatment designs, their cost, and the effluent levels which can be reasonably expected from those designs. Differences in these variables do exist between the northern and southern states. The southern states have a special problem regarding high water tables, limited land availability suitable for lagoons and similar waste treatment facilities, and limited dispersion in nearby bayous.

Table 53 itemizes the water use by operation for a typical Gulf or lower East Coast canning process. Well water was used in two of the three plants sampled for de-icing, peeling and cooling of retorted cans. All other process waters (for belt washers, etc.) were municipal. The COD and suspended solids concentration in the well water averaged approximately 55 mg/l eauh.

The plants in metropolitan areas discharged their wastewaters into sewage systems, whereas the other plants merely pumped their waste to local receiving waters. The total flow rates averaged about 790 cu m/day (0.20 mgd) and were similar for all the unit processes. The largest flows were from the peelers, which also caused the largest flow variations. Some days flows were reduced on peelers. This was due to the shrimp being too fresh (caught the night before) which made peeling more difficult.

Table 53. Canned Gulf shrimp material balance.

Wastewater Material Balance Summary

Average Flow*, 788 cu m/day (0.208 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	peelers (Model A)	58.1	42.1 - 73.0
b)	washers	8.8	8.0 - 9.9
c)	separators	6.9	5.1 - 9.2
d)	blancher	1.6	.006 - 2.5
e)	de-icing	4.2	.005 - 7.4
f)	cooling & retort	12.1	8.0 - 19.5
g)	washdown	8.3	6.9 - 9.6

Product Material Balance Summary

Average Raw Product Input Rate, 23.9 kkg/day (26.4 tons/day)

Output	% of Raw Product	Range, %
Food Product	20	15 - 25
By Product	65	58 - 71
Waste	15	13 - 18

*Including clean-up water

Flow was decreased so the shrimp would pass over the rollers at a slower rate, thereby being cleaned more thoroughly. These peelers usually averaged 170 to 225 l/min (45 to 60 gpm) per peeler, but on days when a slow peel was desired, the flow was sometimes lowered to 55 to 75 l/min (15 to 20 gpm).

Table 54 itemizes the water use by unit operation for a typical West Coast shrimp process. The two plants studied were located either over water or partially over water, with liquid wastes being discharged directly into adjacent waterways. The average plant flow was 472 cu m/day (0.125 mgd). The largest percentage of this flow (61 percent) was attributed to the mechanical peelers. Water used in these plants for production was all city water. Due to the use of a large number of peelers the flow from Plant #2 (five peelers) was twice as large as that from Plant #1 (two peelers). Plant #2 used PCA peelers, which blanch the shrimp prior to peeling; Plant #1 used the Model A peeler, which may be followed by blanching. Plant #2 recycled approximately 10 percent of the total water flow. The water from the separators and washers was used to flume the incoming shrimp to the peelers.

Table 53 itemizes the water use in each operation of a typical breaded shrimp process. The two plants sampled utilized both well and city water. The average flow was about 650 cu m/day (0.173 mgd). The Johnson (P.D.I. - peel, devein, inspect) peelers averaged 31 percent of Plant #2's flow; this varied with the number of machines operating. The Seafood Automatic peelers averaged 12.8 percent of Plant #1's flow for comparable production.

Table 54. West Coast--Shrimp Canning

Wastewater Material Balance Summary

Average Flow*, 472 cu m/day (0.125 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	de-icing tanks	5.8	3.7 - 7.8
b)	peelers (PCA & Model A)	61.5	57.1 - 77.5
c)	washer & separator	11.9	10.1 - 12.8
d)	blancher	1.6	1.2 - 2.1
e)	grading line	1.7	1.5 - 1.8
f)	can washer	3.5	0.002 - 6.3
g)	retort & cooling	5.2	3.6 - 6.8
h)	washdown	8.8	4.2 - 9.5

Product Material Balance Summary

Average Raw Product Input Rate, 9.0 kkg/day (9.9 tons/day)

Output	% of Raw Product	Range, %
Food Product	15	12 - 18
By Product	70	65 - 75
Waste	15	12 - 17

*Including clean-up water

However, the waste concentrations were very close between the two makes of machines, even though three times as many Johnson peelers were in operation as Seafood Automatic peelers. This would seem to indicate that the Seafood Automatic peelers generated a higher waste load. Washdowns comprised one of the largest single daily flows originating from these plants, averaging 50 percent of the total. It appeared that this flow could be reduced significantly with proper water management.

Table 53 shows that the product portion which could be used for by-products was about 65 percent; however, not all plants had an available rendering plant. Many plants hauled their solid wastes to the local dump. All three plants sampled employed some form of screening to remove their large solids. Two forms of screening were used: vibratory and tangential. One of the plants sampled used a tangential screen which has a piston drive solids compressor installed. This ram squeezed the shells (eliminating 50 percent of retained water), and bagged them into 25 to 30 lb plastic bags, which were then transported to the city dump.

West Coast shrimp (Table 54) are not beheaded at sea; the only preprocessing done is to remove most of the debris and trash fish from the catch. The debris and miscellaneous fish comprise between 3 and 8 percent of the raw weight of the freshly caught shrimp. The average raw product input was about 9.0 kkg/day (10 tons/day) with the average shift length being 9 hours. The percent of raw product utilized for food was less than obtained from the Gulf and lower East Coast canned and breaded shrimp and averaged about 15 percent (Table 54). The shrimp product, when it arrived at the plants, had seldom been held more than three days. The older shrimp were processed first, and from qualitative observations there seemed to be a definite correlation between shrimp age and amount of waste produced. A difference in waste strength was anticipated because of the strong enzymatic action (degradation) of shrimp as a function of time. However, due to the plants processing different ages of shrimp on the same days, the effect of age on wastewater strength could not be determined for the data. The solid wastes which could be utilized for by-product totaled about 70 percent of the input. These were captured either by vibrating screens or trommel screens. In many cases the wastes were transported by truck to a rendering plant, where they were dried and added to fertilizers or used as supplements to various feeds low in calcium.

Since the breaded and fresh frozen shrimp were beheaded at sea, the yield was substantially greater in this industry. The range of the yield (Table 55) was 75 to 85 percent, depending on type of breading, method of peeling, size of shrimp, etc. The raw product was generally in very good condition on arrival; if caught locally it was kept iced and in coolers until processed. Frozen shrimp are sometimes stored, if space is available, until all the fresh shrimp are processed. Most of the imported shrimp at the time of this study came from India, Saudi Arabia, Mexico, and Ecuador. On some days at Plant #1, over 50 percent of the shrimp processed were of foreign origin. The actual working day ranged from a low of seven hours to a high of eleven hours. Average raw product processed totaled 6.3 kkg/day (7.0 tons/day).

Table 55. Breaded Gulf shrimp material balance.

Wastewater Material Balance Summary

Average Flow*, 653 cu m/day (0.173 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	hand peeling	4.8	2.8 - 6.8
b)	thawing or de-icing	4.5	1.7 - 6.7
c)	breading area	2.0	1.4 - 2.6
d)	washdown	51.1	28.9 - 73.3
e)	automatic peelers	37.6	33.7 - 54.8

Product Material Balance Summary

Average Raw Product Input Rate, 6.3 kkg/day (7.0 tons/day)

Output	% of Raw Product	Range, %
Food Product	80	75 - 85
By Product	15	10 - 20
Waste	5	3 - 6

* Including clean-up water

Table 56 lists the average flows and loadings from all three of the Gulf Coast canning processes sampled. It can be seen that the water flow per unit product was relatively uniform with a mean of about 47,000 l/kkg and a coefficient of variation of 21 percent. The COD loads were also uniform with a mean of 109 kg/kkg and a coefficient of variation of 18 percent. BOD was available only from Plant #1 and averaged 46 kg/kkg.

Table 57 summarizes the wastewater characteristics from the two West Coast processors sampled. The PCA peeler process had a higher flow but lower waste load than the Model A peeler. The West Coast Model A process had about the same flow per unit product as the Gulf Coast Model A process; however, the West Coast process waste loadings were higher than the Gulf Coast levels. This may have been due to the condition and size of shrimp, which are smaller on the West than the Gulf Coast and are harder to peel.

Table 58 summarizes the wastewater characteristics from the two breaded shrimp processors sampled. The wastewater flows and the loadings per unit of raw product were very similar for the two processes and quite similar to the Gulf nd lower East Coast canned processes.

1.4.15. Clam Processes

Although there is a variety of clam processing operations, the only factors which are considered to affect subcategorization are the degree of mechanization and plant size.

Table 56. Gulf shrimp canning process summary (4 plants)

Parameter	Mean	Standard Deviation	Coefficient of Variation (% of mean)	Range
Flow Rate, cu m/day[1]	788	927	12	695 - 905
(mgd)	(0.208)	(0.0245)	12	(0.184 - 0.239)
Flow Ratio, l/kkg[2]	46,900	9800	21	33,000 - 57,000
(gal/ton)	(11,000)	(2350)	21	(7900 - 14,000)
Settleable Solids, ml/l	13.9	5.3	38	5.4 - 31
Settleable Solids Ratio, l/kkg	520	470	90	184 - 978
Screened Solids, mg/l	--	--	--	-- - --
Screened Solids Ratio, kg/kkg	--	--	--	-- - --
Suspended Solids, mg/l	802	459	57	483 - 1100
Suspended Solids Ratio, kg/kkg	37.7	15.2	40	15.9 - 50.1
5 day BOD, mg/l[3]	1081	216	20	1008 - 1432
5 day BOD Ratio, kg/kkg	46	--	--	43 - 61
20 day BOD, mg/l	--	--	--	-- - --
20 day BOD Ratio, kg/kkg	--	--	--	-- - --
COD, mg/l	2296	653	28	1975 - 2658
COD Ratio, kg/kkg	109	20	18	86 - 122
Grease and Oil, mg/l	258	169	66	148 - 759
Grease and Oil Ratio, kg/kkg	11.0	9.8	88	5.4 - 36.4
Organic Nitrogen, mg/l	196	62	32	39 - 290
Organic Nitrogen Ratio, kg/kkg	7.6	7.7	102	1.9 - 13.4
Ammonia-N, mg/l	12	5.4	46	7 - 14
Ammonia-N Ratio, kg/kkg	0.51	0.12	24	0.22 - 0.47
pH[4]	6.7	--	--	6.5 - 7.0

1 day = 8 hrs
2 weight of raw product
3 based on one plant
4 laboratory pH

Table 57. West Coast canned shrimp process summary (2 plants).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	472	342 - 602
(mgd)	(0.124)	(0.0905- 0.159)
Flow Ratio, l/kkg[2]	60,000	47,000 - 73,000
(gal/ton)	(14,000)	(11,000 - 18,000)
Settleable Solids, ml/l	75.8	33.4 - 117.8
Settleable Solids Ratio, l/kkg	4000	2000 - 7070
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	968	652 - 1284
Suspended Solids Ratio, kg/kkg	54	48 - 61
5 day BOD, mg/l	2112	1310 - 2915
5 day BOD Ratio, kg/kkg	116	96 - 137
20 day BOD, mg/l	2530	1900 - 3100
20 day BOD Ratio, kg/kkg	152	114 - 186
COD, mg/l	3582	2233 - 4932
COD Ratio, kg/kkg	197	163 - 232
Grease and Oil, mg/l	716	605 - 827
Grease and Oil Ratio, kg/kkg	42	39 - 44
Organic Nitrogen, mg/l	215	164 - 266
Organic Nitrogen Ratio, kg/kkg	12.2	12.0 - 12.5
Ammonia-N, mg/l	6.9	4.4 - 9.5
Ammonia-N Ratio, kg/kkg	0.38	0.32 - 0.45
pH[3]	7.5	7.3 - 7.6

1 day = 8 hrs
2 weight of raw product
3 field pH

Table 58. Breaded shrimp process summary (2 plants)

Parameter	Mean	Range
Flow Rate, cu m/day[1]	653	656 - 742
(mgd)	(0.173)	(0.149 - 0.196)
Flow Ratio, l/kkg[2]	115	106,000 - 124,000
(gal/ton)	(28,000)	(26,000 - 30,000)
Settleable Solids, ml/l	15.0	13.7 - 16.4
Settleable Solids Ratio, l/kkg	490	461 - 519
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	790	720 - 861
Suspended Solids Ratio, kg/kkg	92	76 - 107
5 day BOD, mg/l	732	700 - 762
5 day BOD Ratio, kg/kkg	84	81.3 - 87
20 day BOD, mg/l	849	648 - 1133
20 day BOD Ratio, kg/kkg	105	60 - 140
COD, mg/l	1209	1109 - 1309
COD Ratio, kg/kkg	138	138 - 139
Grease and Oil, mg/l	--	-- - --
Grease and Oil Ratio, kg/kkg	--	-- - --
Organic Nitrogen, mg/l	50	43 - 57
Organic Nitrogen Ratio, kg/kkg	5.8	5.4 - 6.1
Ammonia-N, mg/l	1.0	0.7 - 1.3
Ammonia-N Ratio, kg/kkg	0.11	0.09 - 0.14
pH[3]	7.81	-- - --

1 day = 8 hrs
2 weight of raw product
3 field pH

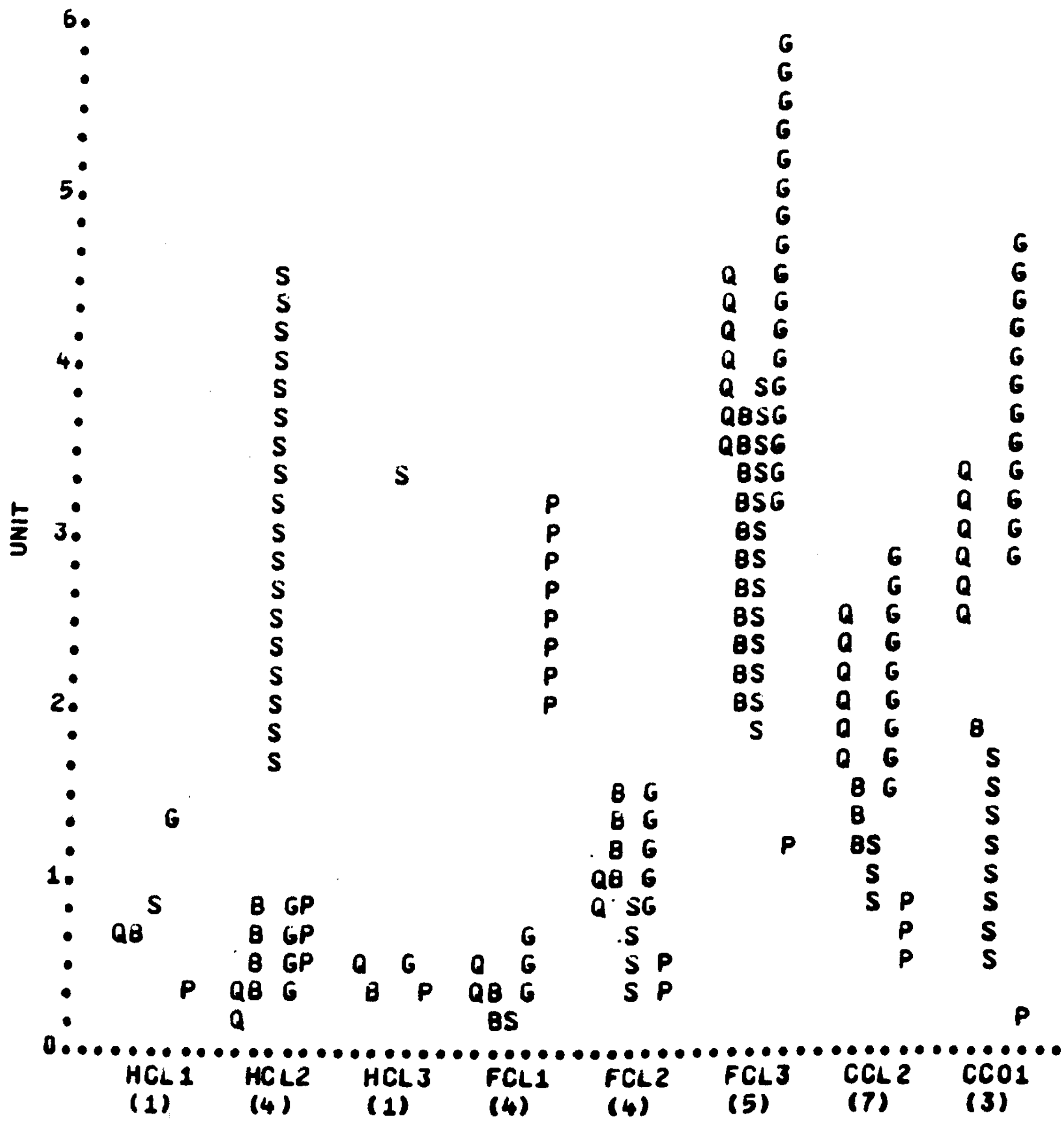
A conventional clam process is defined as one where the unit operations are performed essentially by hand and with a relatively low water flow. A mechanized clam process is defined as one where most of the unit operations are mechanized and where, consequently, water flow is relatively high. Figure 14 summarizes the wastewater characteristics for both the conventional and mechanized clam processes. Plant represented by codes HCL1, 2 and 3 are conventional hand-shucking operations, while plants FCL1, 2, 3 and CC12 are mechanized operations. Code CC01 represents a conch canning process, which is conducted in conjunction with a clam canning operation. It can be seen that the conventional hand-shucking operations contribute much lower wastewater flows and organic loadings than the mechanized operations.

The data from the three conventional plants are relatively uniform; however, a greater range in the data from the mechanized plant is evident. The plant with code FCL1 shucked but did not debelly the clams, resulting in lower waste loads. The plant with code FCL3 was a highly mechanized plant with very high water use due to considerable washing of the product. Plant FCL3 also steam cooked the clams to facilitate shucking and condensed the clam juice, leading to higher waste loads from the evaporator condensate.

All the conventional clam operations were included in one subcategory; all the mechanized clam operations were included in another subcategory for the above reasons.

Table 59 summarizes the waste characteristics from the onventional clam plants. The large standard deviation of suspended solids was caused by the highly variable nature of the sand

Figure 14. CONVENTIONAL OR MECHANIZED CLAM PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 10000 L/KKG
B	5 DAY BOD	1 UNIT = 10 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 5 KG/KKG
G	GREASE $ OIL	1 UNIT = 0.2 KG/KKG
P	PRODUCTION	1 UNIT = 10 TON/HR

Table 59. CONVENTIONAL CLAM PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	4.08	1.63	2.28	8.58
PROCESS TIME HR/DAY	4.60	2.01	2.30	6.00
FLOW L/SEC	5.37	2.08	2.41	10.4
(GAL/MIN)	85.1	32.9	38.2	165
FLOW RATIO L/KKG	5110	2620	1770	11700
(GAL/TON)	1230	627	423	2810
SETT. SOLIDS ML/L	0.49	4.55	1.54	18.3
RATIO L/KKG	33.2	23.3	7.88	93.3
SCR. SOLIDS MG/L	730	402	233	1750
RATIO KG/KKG	3.73	2.06	1.19	8.37
SUSP. SOLIDS MG/L	2340	1300	740	5640
RATIO KG/KKG	11.9	6.63	3.78	28.3
5 DAY BOD MG/L	1040	299	574	1740
RATIO KG/KKG	5.31	1.53	2.94	8.37
COD MG/L	1640	519	849	2860
RATIO KG/KKG	8.36	2.65	4.34	14.6
GREASE & OIL MG/L	31.9	19.7	8.90	82.5
RATIO KG/KKG	0.163	0.101	0.045	0.422
ORGANIC-N MG/L	167	47.8	92.7	278
RATIO KG/KKG	0.854	0.244	0.474	1.42
AMMONIA-N MG/L	4.98	2.21	1.98	10.5
RATIO KG/KKG	0.025	0.011	0.010	0.053
PH	6.99	0.068	6.91	7.04
TEMP DEG C	19.1	13.5	--	19.5

PLANTS HCL1, HCL2, HCL3

content in the effluent, especially during washdown. There is little information available on the size range of hand-shucked surf clam operations; however, investigations of the plants sampled indicated that a large plant would be one which processed more than 5000 tons of clams annually.

Table 60 summarizes the waste parameters from the mechanized clam plants. Plant FCL1 was not included, since it was a hybrid operation and did not include the debellying operation.

The water for the clam plants was from fresh water wells or municipal water supplies. Table 61 shows the wastewater balance for a typical clam canning operation and indicates that most of the flow and waste load is due to the washing operations. Typically, large amounts of water are used to wash the product at different stages in the process. One plant (FCL3) used a total of five drum washers, although two were more common. The washdown flow was also considerable at some plants and ranged from 22 percent to 45 percent at the plants observed.

The wastewaters are commonly discharged to receiving waters; however, some plants discharged to municipal systems and one plant located a few miles inland was using a spray irrigation disposal system. Some plants use grit chambers to remove sand and shell particles and one plant (FCL3) passed their effluent through a tangential screen before discharge.

The production rates at the plants monitored were variable and depended to a large degree on the combination of unit operations employed. The plant which shucked but did not debelly (FCL1), handled a large volume of clams, averaging 147 kkg/day (162 tons/day)

Table 60. MECHANICAL CLAM PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	7.68	3.79	2.76	17.2
PROCESS TIME HR/DAY	7.11	0.379	6.74	7.30
FLOW L/SEC	55.6	58.9	6.97	209
(GAL/MIN)	881	934	110	3310
FLOW RATIO L/KKG	23500	15300	6130	63300
(GAL/TON)	5640	3680	1470	15200
SETT. SOLIDS ML/L	3.72	2.90	0.758	11.3
RATIO L/KKG	87.4	68.2	17.8	266
SCR. SOLIDS MG/L	251	246	36.1	896
RATIO KG/KKG	5.91	5.78	0.849	21.1
SUSP. SOLIDS MG/L	315	255	60.8	985
RATIO KG/KKG	7.41	6.00	1.43	23.2
5 DAY BOD MG/L	765	395	262	1760
RATIO KG/KKG	18.0	9.30	6.15	41.5
COD MG/L	1250	947	268	3730
RATIO KG/KKG	29.5	22.3	6.30	87.3
GREASE & OIL MG/L	22.4	14.6	5.88	60.2
RATIO KG/KKG	0.528	0.343	0.138	1.42
ORGANIC-N MG/L	101	45.1	40.0	213
RATIO KG/KKG	2.38	1.06	0.941	5.01
AMMONIA-N MG/L	3.76	2.35	1.04	9.32
RATIO KG/KKG	0.089	0.055	0.024	0.231
PH	6.73	0.549	6.10	7.06
TEMP DEG C	25.4	9.86	17.4	36.4

PLANTS FCL2, FCL3, CCL2

Table 61. Surf clam canning process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) iron man	<1%	<1%	<1%
b) first washer	35%	31%	52%
c) first skimming table	<1%	<1%	<1%
d) second washer	16%	24%	25%
e) second skimming table	15%	32%	15%
f) washdown	33%	13%	8%
Total effluent average CCL2	21,000 l/kkg	13 kg/kkg	5.2 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	10 - 15%
By-products	
a) shell	75 - 80%
Wastes	
a) belly	7 - 10%

Average Production Rate, 38 kkg/day (41 tons/day)

The ratio between the weight of clams in the shell to clams before debellying is about four to one. The average production at plants whih shucked and debellied the clams was about 50 kkg/day (55 tons/day). The final food product without the bellies is about 10 to 15 percent of the weight in the shell. The clam bellies are sometimes used for bait or animal food but are often discharged to the receiving waters or ground up and discharged to the municipal sewer system. Clam shells are generally used for fill or road beds, but are sometimes barged back to the clam beds. The food product recovery for conchs is about 30 percent, which is much higher than for clams. The conch shells are sold for souvenirs or used for fill or road beds.

Three conventional hand shucking clam processes were monitored by the Environmental Associates, Inc. during September, 1973, in the mid-Atlantic region. The plants operate all year on an intermittent basis. The conventional plants are generally smaller than the mechanized plants.

It can be seen from Tables 59 and 60 that the flows and loads are much lower, except for suspended solids, from the hand-shucking operation than from the mechanized operations. The suspended solids parameter is hard to sample accurately, especially during washdowns, since the concentration of fine sand fluctuates greatly at the beginning of the period.

The hand shucked clam plants are usually located in rural communities or areas and obtain water from domestic supplies or fresh water wells. Table 62 shows that most of the waste flow and loads come from the washing operations after shucking and debellying.

The production rates at the three plants sampled averaged bout 20 kkg/day (22 tons/day) which was about half the rate of the mechanized plants and ranged from 7 kkg/day (8 tons/day) to 33 kkg/day (36 tons/day). The yield of food product from the hand shucked plants was similar to the mechanized plants. The final product is shipped to other plants for further processing into canned clams or chowder.

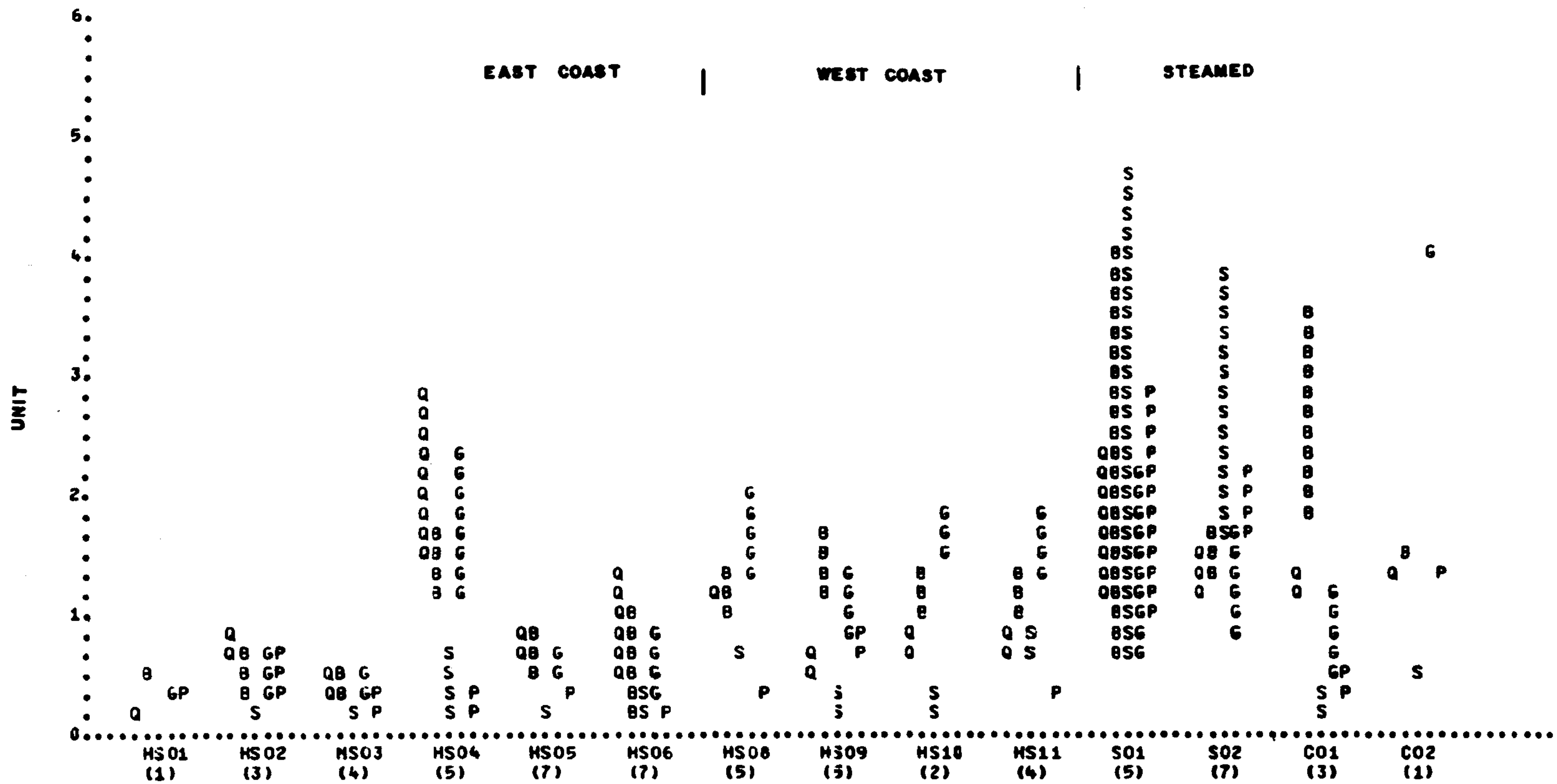
Table 62. Hand shucked clam process material balance.

Wastewater Material Balance Summary			
Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) first and second washers	83-92	65-97	10-96
b) washdown	8-17	3-34	4-89
Total effluent average	5100 l/kkg	5.3 kg/kkg	12 kg/kkg
Average production rate:	20 kkg/day (22 tons/day)		

1.4.16. Oyster Processes

The only factors which were considered to affect subcategorization within the oyster industry were degree of mechanization and plant size. Figure 15 is a summary plot of the wastewater statistics for all the oyster processes sampled. Plants represented by codes HS01 and HS06 were East Coast hand-shucked oyster operations; plants represented by codes HS08 through HS11 were West Coast hand-shucked oyster operations; codes S01 and S02

Figure 15. FRESH/FROZEN, STEAMED, OR CANNED OYSTER PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 50000 L/KKG
B	5 DAY BOD	1 UNIT = 20 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 50 KG/KKG
G	GREASE AND OIL	1 UNIT = 1 KG/KKG
P	PRODUCTION	1 UNIT = 0.5 TON/HR

represent steamed oyster processes; code C01 represents a West Coast canned oyster operation; and C02, a West Coast canned oyster stew operation. It should be noted that the production is listed in terms of the oyster meat after shucking. The reason for this is that the measurement of final product in this case is much more accurate, due to variable amounts of loose or empty shells coming into the qlant.

It was noted that the waste loads from the steamed and canned oyster processes were higher than those from the hand-shucked operations. Therefore, it was decided that the oyster industry be subcategorized into conventional hand-shucked oyster processes and the more mechanized steamed or canned oyster processes.

Table 63 summarizes statistics from the steamed and canned oyster plants sampled.

It appears that the waste loads from the West Coast hand-shucked oyster processes were a little higher than those from the East Coast processes. It was not considered necessary to further divide the hand-shucked oyster subcategory, however, since the total waste loads per day is quite small. The average Pacific Coast oyster plant only produces about 30 kg of BOD/day, which is very low when compared to other seafood commodities. Table 64 shows summary statistics from the Pacific hand-shucked oyster plants sampled.

Since the size range of the hand-shucked oyster industry is quite large, it was divided into three size groups for the purpose of determining treatment costs of a typical plant. Based on investigations made in the field the large and medium size

Table 63. STEAMED OR CANNED OYSTER PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	0.679	0.349	0.234	1.36
PROCESS TIME HR/DAY	7.12	1.15	5.50	8.19
FLOW L/SEC	10.7	5.46	3.75	24.3
(GAL/MIN)	170	86.5	59.4	388
FLOW RATIO L/KKG	70200	10300	52200	92400
(GAL/TON)	16800	2460	12500	22100
SETT. SOLIDS ML/L	6.85	3.72	2.22	16.3
RATIO L/KKG	481	261	156	1150
SCR. SOLIDS MG/L	1450	1060	158	5720
RATIO KG/KKG	101	116	11.1	401
SUSP. SOLIDS MG/L	1110	952	198	3610
RATIO KG/KKG	78.1	66.0	13.9	254
5 DAY BOD MG/L	565	170	303	964
RATIO KG/KKG	39.7	12.0	21.3	67.7
COD MG/L	1040	137	799	1330
RATIO KG/KKG	73.1	9.59	56.1	93.3
GREASE & OIL MG/L	27.0	20.6	5.70	81.1
RATIO KG/KKG	1.90	1.45	0.400	5.59
ORGANIC-N MG/L	72.3	17.6	43.9	112
RATIO KG/KKG	5.08	1.23	3.08	7.39
AMMONIA-N MG/L	3.36	1.05	1.79	5.35
RATIO KG/KKG	0.238	0.073	0.126	0.410
PH	6.94	0.150	6.78	7.07
TEMP DEG C	15.0	5.75	10.00	20.1

PLANTS S01 , S02 , C01 , C02

Table 64. HAND SHUCKED OYSTERS
PROCESS SUMMARY

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	0.178	0.146	0.034	0.561
PROCESS TIME HR/DAY	7.06	1.56	4.75	8.00
FLOW L/SEC	1.70	1.05	0.473	4.40
(GAL/MIN)	26.9	16.6	7.50	69.3
FLOW RATIO L/KKG	40600	11600	22500	67600
(GAL/TON)	9730	2780	5400	16200
SETT. SOLIDS ML/L	2.57	1.35	0.865	5.39
RATIO L/KKG	104	54.9	35.1	243
SCR. SOLIDS MG/L	302	195	79.9	808
RATIO KG/KKG	12.3	7.93	3.25	32.3
SUSP. SOLIDS MG/L	634	315	226	1430
RATIO KG/KKG	25.7	12.8	9.17	57.3
5 DAY BOD MG/L	616	78.2	477	783
RATIO KG/KKG	25.0	3.18	19.4	31.3
COD MG/L	1210	162	921	1550
RATIO KG/KKG	49.0	6.57	37.4	63.1
GREASE & OIL MG/L	36.6	6.96	24.9	52.0
RATIO KG/KKG	1.49	0.283	1.01	2.11
ORGANIC-N MG/L	154	63.2	65.5	309
RATIO KG/KKG	6.24	2.57	2.66	12.5
AMMONIA-N MG/L	2.61	0.565	1.68	3.38
RATIO KG/KKG	0.106	0.023	0.068	0.158
PH	6.82	0.155	6.66	7.00
TEMP DEG C	7.99	4.01	1.97	10.00

PLANTS HS05, HS09, HS10, HS11

ranges were divided at 300 tons of finished product per year, and the medium and small ranges at 150 tons of finished product per year.

Table 65 shows the wastewater balance for a typical steamed oyster process. It was noted that a large portion of the flow and load is caused by the washdown at these plants. The largest flow comes from the culler and shocker which is used to clean and partially open the shell before steam cooking; however, the BOD load is relatively small.

Table 66 shows the wastewater balance for typical East and West Coast hand-shucked oyster processes. It can be seen that the two sources of water are the blow tanks and the washdowns. The blow tanks, which are used to wash and add water to the product, are the major sources of wastewater and BOD loads. The washdowns can be a major source of suspended solids from the fine pieces of sand which are on or in the oyster shells.

In general, the wastewater loads were higher at the West Coast plants than the East Coast plants. The reason for this appears to be the difference in the type of oysters processed and the flows used. The West Coast plants typically use more water than the East Coast plants in washing the product. One plant on the East Coast (HS05) breaded the oysters after shucking. This operation was found to contribute about 50 percent of the BOD load at that plant; however, the overall load was about average, due to water conservation (see Table 67).

Table 65. Steamed oyster process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) belt washer	11%	10%	63%
b) shocker	43%	9%	26%
c) shucker	15%	11%	1%
d) blow tanks	7%	6%	<1%
e) washdown	23%	64%	10%
Total effluent average SO2	66.500 l/kkg	30 kg/kkg	137 kg/kkg

Average Production Rate, 6.8 kkg/day (7.5 tons/day) (production for the oyster processes is measured in terms of final product).

Table 66. Hand shucked oyster process material balance.

Wastewater Material Balance Summary--East Coast

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) blow tank	71 - 94%	81 - 94%	11 - 58%
b) washdown	6 - 29%	6 - 19%	42 - 89%
Total effluent average	37,000 l/kkg	14 kg/kkg	11 kg/kkg

Wastewater Material Balance Summary--West Coast

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. solids
a) blow tank	45 - 68%	83 - 95%	24 - 75%
b) washdown	32 - 55%	5 - 17%	25 - 76%
Total effluent average	41,000 l/kkg	25 kg/kkg	26 kg/kkg

Table 67. Breaded oyster process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) blow tank	71%	38%	8%
b) breading	9%	50%	8%
c) washdown	20%	12%	84%
Total effluent average HSO5	37,00 l/kkg	14 kg/kkg	11 kg/kkg

1.4.17. Sea Urchin Roe/Abalone Process

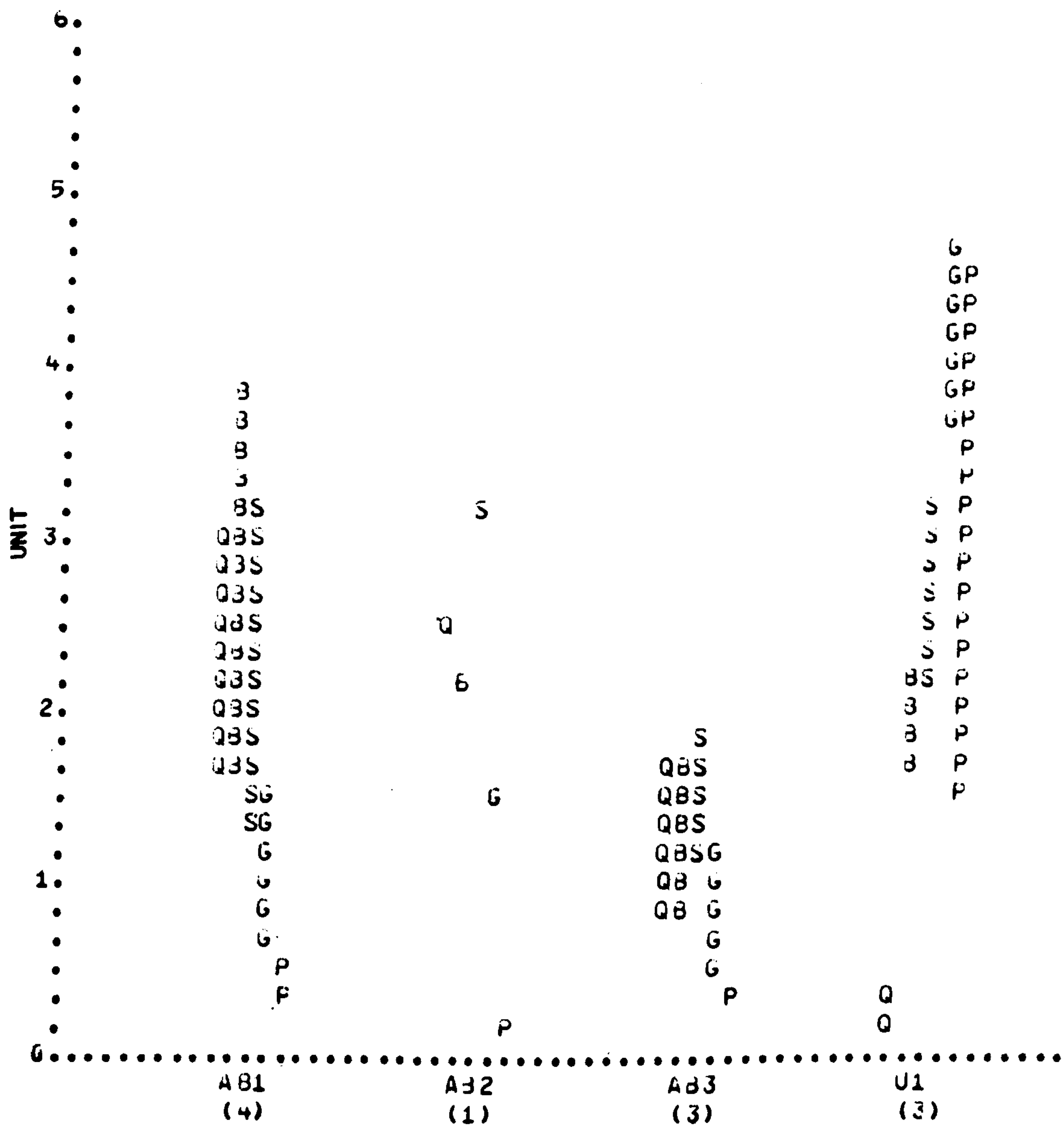
The sea urchin roe process and the abalone process, although different, have similar waste loads per unit of production, as shown in Figure 16. Since both the sea urchin and abalone are relatively small industries and are located in the same areas, it was determined that the processes be combined into one subcategory. The summary statistics for the four abalone and sea urchin processes sampled are shown in Table 68 and were used as the typical raw waste loads from these two industries.

Table 69 shows that the primary source of wastewater in the abalone process is from the processing area and consists of various small flows used to keep the area clean. These small flows may be either continuous or intermittent at the discretion of the plant personnel. The flat surfaces of the processing table and the slicing machines are periodically cleansed to facilitate handling as well as to rinse away accumulated wastes.

Washwater that is used to cleanse the foot muscle prior to trimming was handled differently in each of the three plants sampled. The largest plant, AB1, utilized recirculated washwater which was dumped twice a day. Plant AB2 used a system which recirculated the washwater during a single wash cycle and then discharged it, and plant AB3 used a continuous flow of water through the washing mechanism during each wash cycle.

The production rates of abalone plants are quite low, with an average of 0.183 kkg/day (0.202 tons/day). The input also varies considerably due to fluctuations in raw product availability.

Figure 16. ABALONE/SEA URCHIN PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 20000 L/KKG
B	5 DAY BOD	1 UNIT = 10 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 5 KG/KKG
G	GREASE & OIL	1 UNIT = 1 KG/KKG
P	PRODUCTION	1 UNIT = 0.2 TON/HR

Table 68. **ABALONE/SEA URCHIN PROCESS SUMMARY**.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	0.196	0.267	0.015	0.363
PROCESS TIME HR/DAY	4.77	3.35	2.20	9.33
FLOW L/SEC	0.537	0.075	0.405	0.698
(GAL/MIN)	8.50	1.19	6.41	11.1
FLOW RATIO L/KKG	31900	21600	7910	88100
(GAL/TON)	7650	5180	1900	21100
SETT. SOLIDS ML/L	6.49	3.48	2.14	15.3
RATIO L/KKG	207	111	68.3	489
SCR. SOLIDS MG/L	134	110	25.6	423
RATIO KG/KKG	4.29	3.51	0.817	13.5
SUSP. SOLIDS MG/L	379	115	263	648
RATIO KG/KKG	12.1	3.66	6.48	20.7
5 DAY BOD MG/L	632	200	328	1100
RATIO KG/KKG	20.2	6.39	10.5	35.2
COD MG/L	1170	411	567	2150
RATIO KG/KKG	37.4	13.1	18.1	68.7
GREASE & OIL MG/L	59.9	46.9	11.4	188
RATIO KG/KKG	1.91	1.56	0.365	6.01
ORGANIC-N MG/L	77.0	38.9	27.0	175
RATIO KG/KKG	2.46	1.24	0.861	5.59
AMMONIA-N MG/L	3.43	1.84	1.13	8.09
RATIO KG/KKG	0.109	0.059	0.036	0.258
PH	6.66	0.865	5.38	7.19
TEMP DEG C	18.1	11.0	--	20.6

PLANTS AB1 , AB2 , AB3 , U1

Table 69. Fresh/frozen abalone process material balance.

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) process water	49%	50%	39%
b) wash tank	26%	20%	42%
c) washdown	25%	30%	19%
Total effluent average AB1	47,100 l/kkg	27 kg/kkg	11 kg/kkg

Product Material Balance Summary

End Product	% of Raw Product
Food Products	
a) steaks	38 - 42%
b) trimmings (patties, canned)	34 - 36%
By-products	
a) shell	10 - 12%
Wastes	
a) viscera	10 - 12%

Average Production Rate, 0.34 kkg/day (0.38 tons/day)

Table 69 shows the breakdown of raw product into food product, by-product, and waste. The recovery of food product varies with species and whether the abalone are packed whole or prepared as steaks. The average recovery of sliced steaks is approximately 38 to 42 percent. Good quality trimmings are retained along with low quality steaks for the production of abalone patties. The weight of trimmings is usually around the same as the net weight of the steaks recovered.

The abalone shells are retained for sale to curio shops and to producers of jewelry and gift items. These shells constitute the only by-product recovery at present. The viscera are collected as solid waste and turned over to the municipalities for disposal.

One relatively large sea urchin plant in Southern California was sampled during October of 1973. All process water, excluding washdown, was fresh, unchlorinated sea water trucked to the plant as needed. The use of sea water is an integral part in the processing of sea urchin roe as fresh water cannot be substituted if the processor is to still retain the desired product form. Clean-up and other non-process waters are obtained from domestic sources.

Table 70 shows the wastewater material balance. It can be seen that the sea urchin process consists of two main unit operations. Immediately after removal from the shell, the roe is placed in tanks of sea water to avoid dessication prior to brining. These tanks and the wash tanks, into which roe is subsequently placed for further cleansing, constitute the "wash tank"

Table 70. Sea urchin roe process material balance

Wastewater Material Balance Summary

Unit Operation	% of Total Flow	% of Total BOD	% of Total Susp. Solids
a) wash tanks	76%	90%	87%
b) brine tanks	24%	10%	13%
Total effluent average Ul	4270 l/kkg	19.4 kg/kkg	13.6 kg/kkg

Product Material Balance Summary

End Products	% of Raw Product
Food products	8 - 10%
Wastes	
a) shell and viscera	90 - 92%

Average Production Rate, 5 kkg/day (5.6 tons/day) unit operation. The wash tank flow is intermittent, since it is changed about every 10 to 30 minutes. The "brine tank" unit operation also produces an intermittent flow, being dumped four times per day. The contribution of the washdown or clean-up is unknown, as it was not sampled; however, it was not considered to be very significant.

The average production rate observed was 5 kkg/day (5.6 tons/day), but was quite variable. This is due to problems inherent in a new industry, such as meeting stringent product quality requirements and experimentation to arrive at the most efficient method of production. The usual shift length was around 8 to 12 hours since the raw product, when available, arrived in large quantities.

Table 70 shows that the major portion of the sea urchin is lost as waste with only about eight percent recovered as finished product. At present, the egg skein or roe is used in its entirety and is the only marketable product. In addition, around 20 percent of the sea urchin roe is discarded because of underdevelopment or discoloration. Prior to washing down the butchering area, the waste solids are collected and retained for disposal to the municipal system.

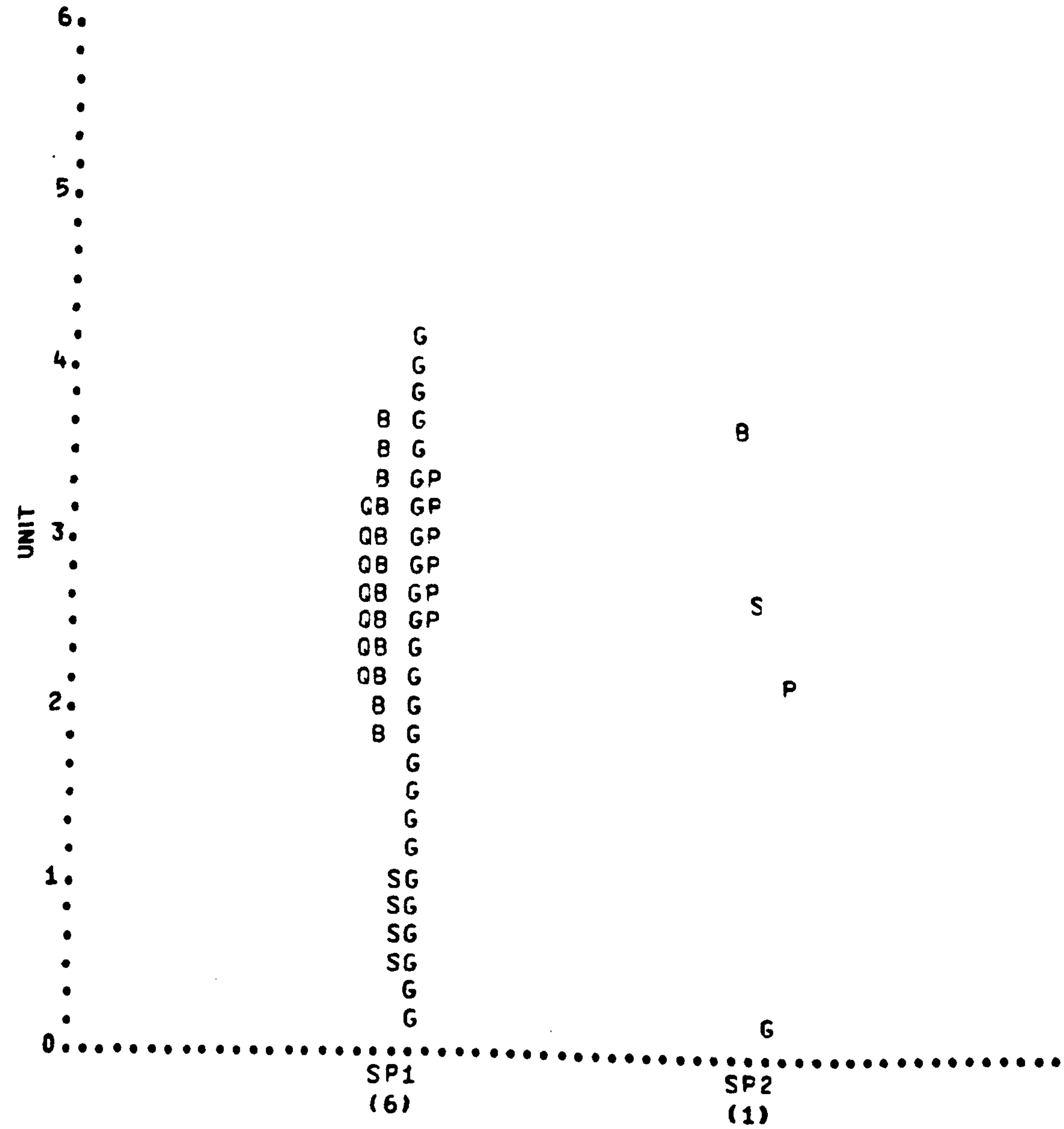
1.4.18. Scallop Process

The only factor which was considered to influence subcategorization of the scallop industry (excluding calico scallops) was geographic location, since the processing operations are essentially the same. It was determined that the processing operations in Alaska be separated from those outside of Alaska because of greater costs. Figure 17 shows a summary plot of the wastewater characteristics of two scallop processes in Alaska. It was noted that the flows and waste loads were minimal. Table 71 shows the average values of the wastewater parameters for the two plants. There are no data for non-Alaska operations, since the two Alaska plants were the only ones sampled. Other plants were observed in the Middle Atlantic region using essentially the same process; therefore, it should be a good assumption that the waste loads would be similar.

Both plants sampled used chlorinated municipal water sources, derived from reservoirs and deep wells. The only wastewater produced was in the washing operation; however, each plant sampled had a different method. Plant SP1 used a two-stage continuous flow washing system in which a large volume of fresh water was used. Plant SP2 used a non-flowing brine tank which was dumped approximately every eight hours. The effluent was discharged to the receiving water at one plant and to the municipal sewer system at the other plant.

Production rates for the two plants were similar, averaging about 9 kkg/day (10 tons/day) of finished product. Production rates for the scallops were recorded in terms of finished product since they are shelled and eviscerated at sea. The yield is nearly 100 percent since the only wastes produced are small scallop pieces not suitable for freezing, solid waste removed during inspection, and small amounts of dissolved organic matter.

Figure 17. ALASKAN SCALLOP PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTCR
Q	FLOW	1 UNIT = 5000 L/KKG
B	5 DAY BOD	1 UNIT = 1 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 0.5 KG/KKG
G	GREASE & OIL	1 UNIT = 0.1 KG/KKG
P	PRODUCTION	1 UNIT = 0.5 TON/HR

Table 71. ALASKAN SCALLOP PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	1.27	0.302	0.776	1.35
PROCESS TIME HR/DAY	8.63	4.05	5.77	11.5
FLOW L/SEC	2.55	3.48	0.202	11.3
(GAL/MIN)	40.4	55.2	3.20	178
FLOW RATIO L/KKG	6990	9410	509	30600
(GAL/TON)	1680	2260	136	7330
SETT. SOLIDS ML/L	0.903	0.910	0.123	3.28
RATIO L/KKG	6.31	6.36	0.862	22.3
SCR. SOLIDS MG/L	874	--	--	--
RATIO KG/KKG	6.11	--	--	--
SUSP. SOLIDS MG/L	122	98.8	23.5	381
RATIO KG/KKG	0.851	0.691	0.164	2.56
5 DAY BOD MG/L	453	90.7	301	655
RATIO KG/KKG	3.17	0.635	2.10	4.58
COD MG/L	587	57.2	482	707
RATIO KG/KKG	4.10	0.400	3.37	4.94
GREASE & OIL MG/L	15.5	20.1	1.34	66.2
RATIO KG/KKG	0.108	0.141	0.009	0.463
ORGANIC-N MG/L	97.1	18.7	65.5	139
RATIO KG/KKG	0.679	0.131	0.456	0.370
AMMONIA-N MG/L	4.50	1.09	2.74	6.39
RATIO KG/KKG	0.032	0.008	0.019	0.349
PH	6.58	0.397	6.30	6.86
TEMP DEG C	8.33	3.93	5.56	11.1

PLANTS SP1 , SP2

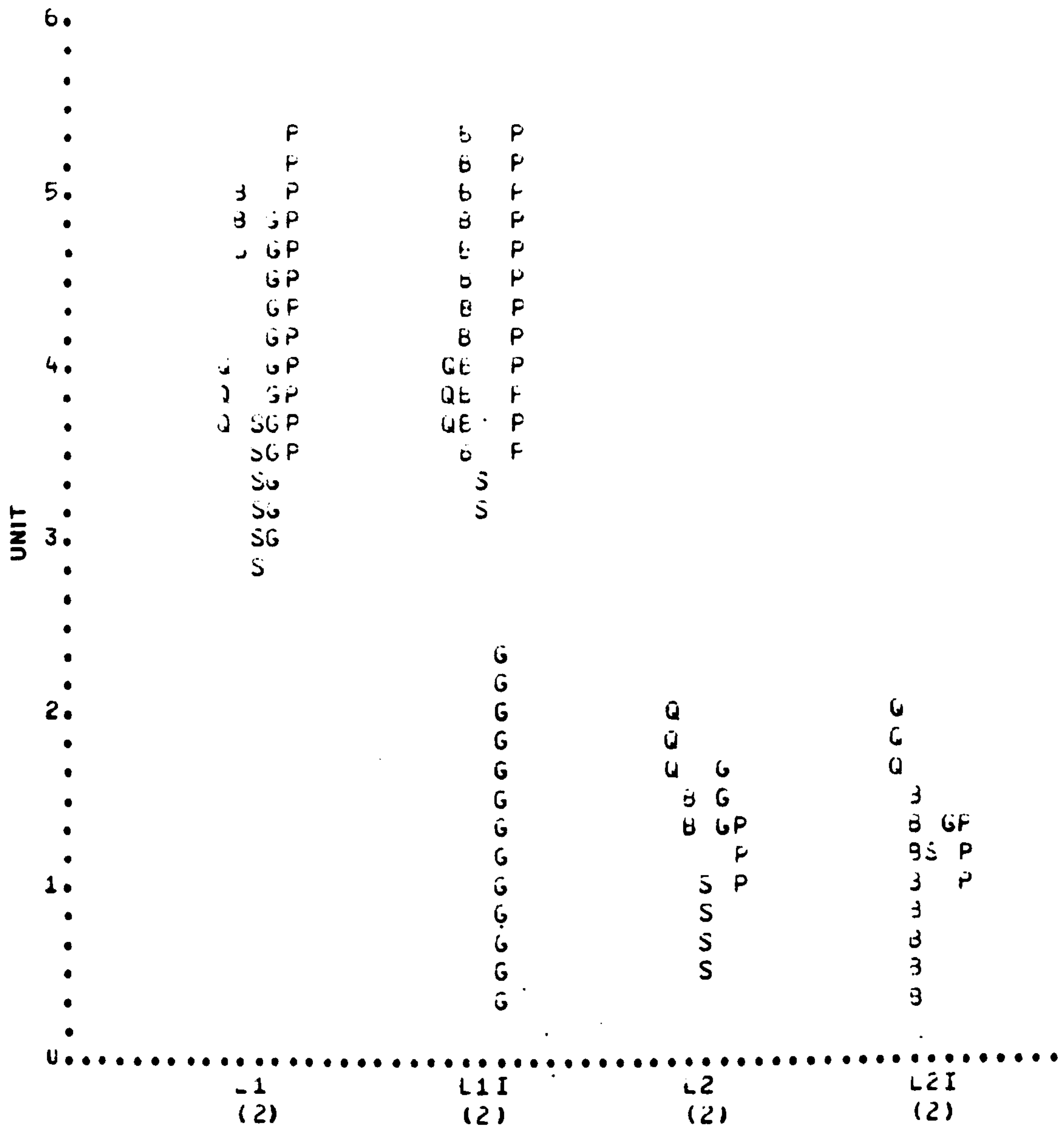
1.4.19. Lobster Process

The American lobster industry essentially involves holding and shipping operations. The holding operation contributes little or no waste load, as can be seen from Figure 18 which shows the intake and discharge from holding tanks at two plants. Codes L1I and L2I represent the characteristics of the intake water at plants L1 and L2, respectively; while codes L1 and L2 represent the discharge from the holding tanks at these two plants. It can be seen that the discharge was essentially the same as the intake with the exception of the grease and oil levels (plant L1). This indicates that there was little or no waste discharge from the holding tanks and that this aspect of the lobster industry should not be included as a subcategory of the seafood processing industry for the purpose of setting effluent limitations. For American lobster plants that boil the product for the fresh market, it was determined that they be included with the spiny lobster process as a subcategory.

Figure 19 summarizes the characteristics of the wastewater from two spiny lobster plants sampled in the Southern California area. It was noted that the flow and loads were relatively low per unit of production. Table 72 summarizes the characteristics from the two spiny lobster plants sampled. These values were used as the typical raw waste loads from cooked lobster processes.

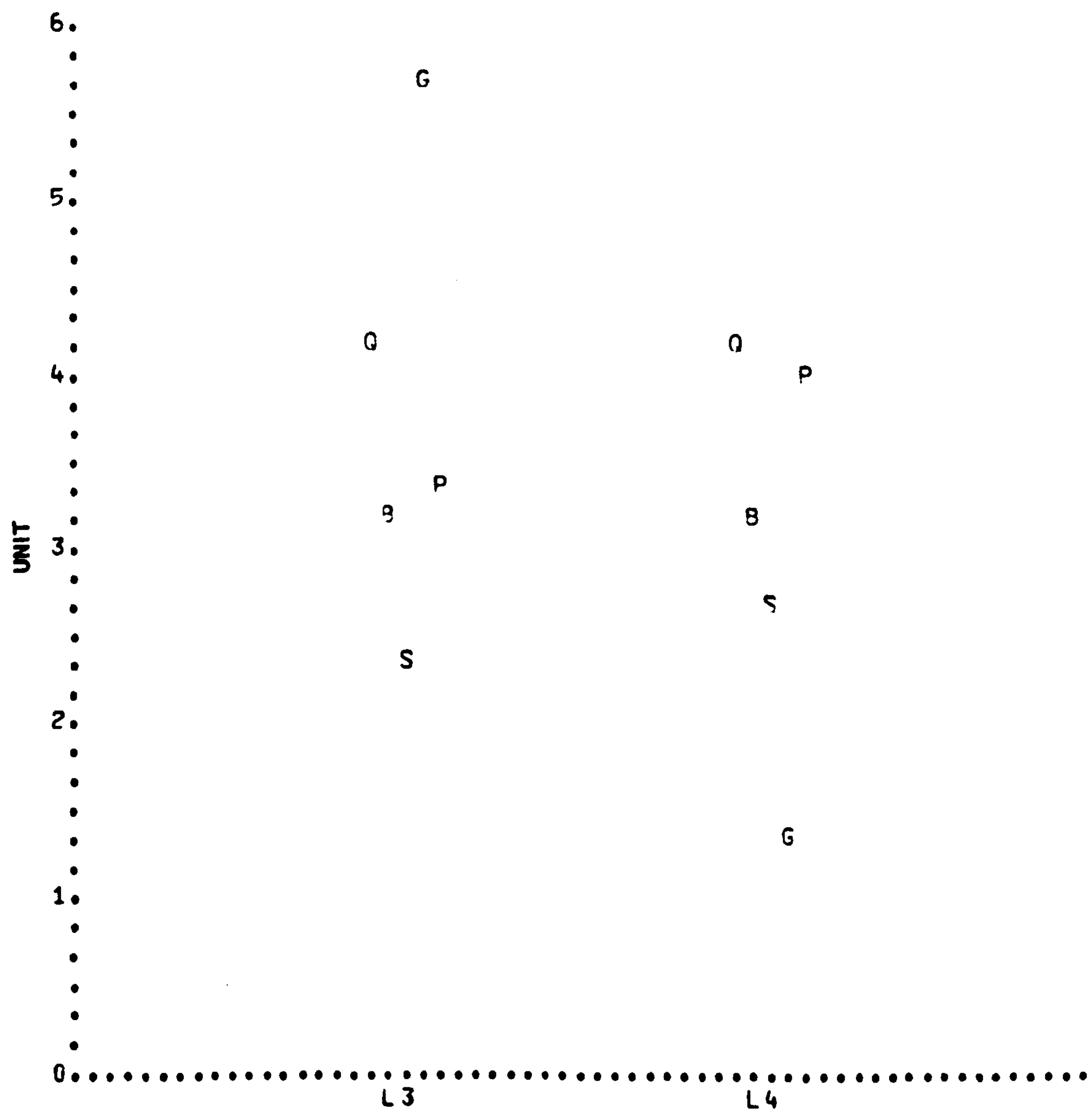
The American lobster requires considerable volumes of sea water to sustain life in the holding tanks. These waters are pumped from the local estuary or harbor to live holding tanks which are stacked in tiers such that the overflow from the

Figure 18. AMERICAN LOBSTER PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 50000 L/KKG
B	5 DAY BOD	1 UNIT = 0.2 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 0.5 KG/KKG
G	GREASE & OIL	1 UNIT = 2 KG/KKG
P	PRODUCTION	1 UNIT = 0.1 TON/HR

Figure 19. SPINY LOBSTER PROCESS PLOT.



SYMBOL	PARAMETER	SCALING FACTOR
Q	FLOW	1 UNIT = 500 L/KKG
B	5 DAY BOD	1 UNIT = 1 KG/KKG
S	SUSPENDED SOLIDS	1 UNIT = 0.5 KG/KKG
G	GREASE & OIL	1 UNIT = 0.050 KG/KKG
P	PRODUCTION	1 UNIT = 0.1 TON/HR

Table 72. SPINY LOBSTER PROCESS SUMMARY.

PARAMETER	MEAN	STD DEV	5% MIN	95% MAX
PRODUCTION TON/HR	0.367	0.047	0.263	0.467
PROCESS TIME HR/DAY	0.400	0.141	0.300	0.500
FLOW L/SEC	0.193	0.025	0.149	0.246
(GAL/MIN)	3.06	0.393	2.36	3.90
FLOW RATIO L/KKG	2090	--	--	--
(GAL/TON)	500	--	--	--
SETT. SOLIDS ML/L	--	--	--	--
RATIO L/KKG	--	--	--	--
SCR. SOLIDS MG/L	--	--	--	--
RATIO KG/KKG	--	--	--	--
SUSP. SOLIDS MG/L	590	56.6	467	706
RATIO KG/KKG	1.23	0.116	1.02	1.46
5 DAY BOD MG/L	1550	--	--	--
RATIO KG/KKG	3.23	--	--	--
COD MG/L	2390	184	2050	2770
RATIO KG/KKG	4.99	0.383	4.28	5.78
GREASE & OIL MG/L	83.0	72.1	14.4	272
RATIO KG/KKG	0.173	0.150	0.030	0.568
ORGANIC-N MG/L	273	22.6	231	320
RATIO KG/KKG	0.569	0.047	0.483	0.668
AMMONIA-N MG/L	6.87	3.32	4.06	16.3
RATIO KG/KKG	0.019	0.007	0.009	0.035
PH	7.10	0.283	6.90	7.30
TEMP DEG C	--	--	--	--

PLANTS L3 , L4

top tank flows into the next lower tank. When the water leaves the last set of tanks, it is discharged directly back to the receiving water.

The higher COD loadings can be attributed to the saline nature of the process waters. The average discharge BOD loading was 0.6 kg/kkg; however, by comparing the discharge with intake, the BOD loadings added by the holding tanks averaged only 0.1 kg/kkg.

Each of the spiny lobster operations sampled used city water for processing. The main source of wastewater from the spiny lobster process is the cooking water which is high in sodium chloride and dissolved organics.

Most parameters corresponded very closely between the two plants except for grease and oil. This was due to sampling problems caused by the high concentrations of grease and oil which rise to the top of the cooking containers, making it difficult to obtain an accurate composite sample. The wastewaters from the two plants sampled were discharged to municipal treatment facilities.

The production rate at the two American lobster plants sampled averaged about 2.0 kkg/day (2.2 tons/day). There is essentially no solid waste produced, since the animals are usually sold alive to restaurants and retail outlets. Some plants feed the lobsters, which increases the waste loads slightly.

The production rates at the two spiny lobster plants sampled averaged only about 135 kg/day (300 lbs/day), which was considered to be lower than normal due to the lack of product during the sampling period. The percent of solid waste depends on whether tails or whole lobsters are being cooked. When only the tails are processed, the cephalothorax is removed prior to cooking, which makes up about 20 percent of the raw product.

2. WASTE TREATMENT TECHNOLOGY

2.1 Introduction

Little of the technology currently available to the seafood processing industry has been demonstrated at the operational level. Most processors have little if any significant wastewater treatment at the plant. As a result, most technologies which might be found applicable in the future are presently unproven. The methods currently available and thought to be most applicable to the seafood industry are discussed below. The relative costs, efficiency and practicality of each method vary significantly with each subcategory of the industry and location of the plant site. The applicability of waste treatment technology to individual sites is contingent on land availability, operational continuity, plant age, water source and other factors such as climate and product which determine the most cost-effective technology.

2.2 Physical-Chemical Treatment of Wastewater

Physical methods of wastewater treatment include the technologies to remove coarser wastes such as shell, viscera, carcasses, etc., from the wastewater stream. The most common method used to effect this type of removal is screening. Chemical oxidation is an example of the use of chemicals only to remove pollutants. Air flotation and the various methods of sludge treatment are examples of physical-chemical treatment.

2.2.1. Screening

Screening is practiced in varying degrees throughout the U.S. fish and shellfish industry for both marketable solids recovery and to prevent solids from entering receiving waters or municipal sewers. Nearly all fish processors produce large volumes of solids. Fish and shellfish solids have commercial value as by-products only if they can be collected prior to significant decomposition, economically transported to subsequent processing locations, and marketed. The importance of capturing the solids in dry form to help retard spoilage and minimize handling expense has been recognized by many processors. Solids should be separated from the process water as soon as possible to minimize leaching. A study (Riddle and Shikazi, 1973) of freshwater perch and smelt processing showed that a two-hour contact period between offal and transport water increased the COD concentration by 170 percent, while BOD and suspended solids increased about 50 percent.

Screens may be classified as follows:

a. revolving drums (inclined, horizontal and vertical axes);

b. vibrating, shaking and oscillating screens (linear or circular motion);

c. tangential screens (pressure or gravity fed);

d. inclined troughs;

e. bar screens;

f. drilled plates;

g. gratings;

h. belt screens; and

i. basket screens.

Wire mesh screens are specified in terms of the number of openings per inch ("mesh"). The specification of mesh or mesh equivalents for screens often is ambiguous. At least two standard series are used to define mesh size in terms of openings and wire diameter--U.S. sieve and Tyler screen scale sieve. The 200 mesh Tyler screen has been accepted by the U.S. Bureau of Standards. Table 73 lists the equivalent sizes of U.S. series screens for each Tyler screen. The larger the sieve number, the finer the screen. Ordinary window screen is about (Tyler) #14 mesh (14 openings per inch)

Rectangular holes or slits are correlated to mesh size either by geometry or performance data. Mesh equivalents specified by performance can result in different values for the same screen, depending on the nature of the screen feed. For example, a tangential screen with a 0.076 cm (0.030 in) opening may be said to be equivalent to a 40 mesh screen. This is because the slant of the screen and the nature of the waste may cause the screen to retain particles larger than 0.417 mm diameter.

Revolving drum screens consist of a covered cylindrical frame with open ends. The screening surface covering the frame is either a perforated sheet or woven mesh. Of the three basic revolving drums, the simplest is the trommel screen with the drum axis slightly inclined. Wastewater is fed into the raised end of the rotating drum. The captured solids migrate to the lower end, while the liquid passes through the screening surface. A catch basin is located below the screen.

Table 73. Comparison of Tyler and U.S. sieve series (Perry, 1950).

Tyler Standard Sieve Series				U.S.Series approximate equivalent no.
Opening (in)	Opening (mm)	Tyler mesh	Diameter of wire (in)	
0.312	7.925	2-1/2	0.088	
0.263	6.680	3	0.070	
0.221	5.613	3-1/2	0.065	
0.185	4.699	4	0.065	4
0.156	3.962	5	0.044	5
0.131	3.327	6	0.036	6
0.110	2.794	7	0.0328	7
0.093	2.362	8	0.032	8
0.073	1.981	9	0.033	10
0.065	1.651	10	0.035	12
0.055	1.397	12	0.028	14
0.046	1.168	14	0.025	16
0.0390	0.991	16	0.0235	18
0.0328	0.833	20	0.0172	20
0.0276	0.701	24	0.141	25
0.0232	0.589	28	0.0125	30
0.0195	0.495	32	0.118	35
0.0164	0.417	35	0.0122	40
0.0138	0.351	42	0.0100	45
0.0116	0.295	48	0.0092	50
0.0097	0.246	60	0.0070	60
0.0082	0.208	65	0.0072	70
0.0069	0.175	80	0.0056	80
0.0058	0.147	100	0.0042	100
0.0049	0.124	115	0.0038	120
0.0041	0.104	150	0.0026	140
0.0035	0.089	170	0.0024	170
0.0029	0.074	200	0.0021	200
0.0024	0.061	250	0.0016	230
0.0021	0.053	270	0.0016	270
0.0017	0.043	325	0.0014	325
0.0015	0.038	400	0.0010	

The horizontal drum screen usually has the invent immersed in the wastewater being held in the catch basin. The solids are retained by ribs on the inside of the drum and conveyed upward until deposited by gravity into a centerline conveyor. Backwash sprays are generally used to clean the screen. A typical horizontal drum is shown in Figure 20. Claggett and Wong (1969) tested this type of rotary screen on salmon canning wastewater and bailwater from herring boats. The results are listed in Table 74.

Table 74. Northern Sewage Screen test results (34 mesh).

Waste stream	Percentage reduction of total solids
Salmon canning	57%
Herring bailwater	48%

Inclined and horizontal drum screens have been used successfully in whiting processing operations, herring filleting processes, and fish reduction plants.

At least one commercial screen available employs a drum rapidly rotating (about 200 rpm) about a vertical axis. The wastewater is sprayed through one portion of the cylinder from the inside. A backwash is provided in another portion of the cycle to clear the openings. Woven fabric up to 400-mesh has been used satisfactorily. This unit is called a "concentrator" (see Figure 21) because not all of the impinging wastewater passes through. About 70 to 80 percent of the wastewater is treated effectively, which necessitates further treatment of the concentrate. The efficiencies of this, and other systems, in treating shellfish

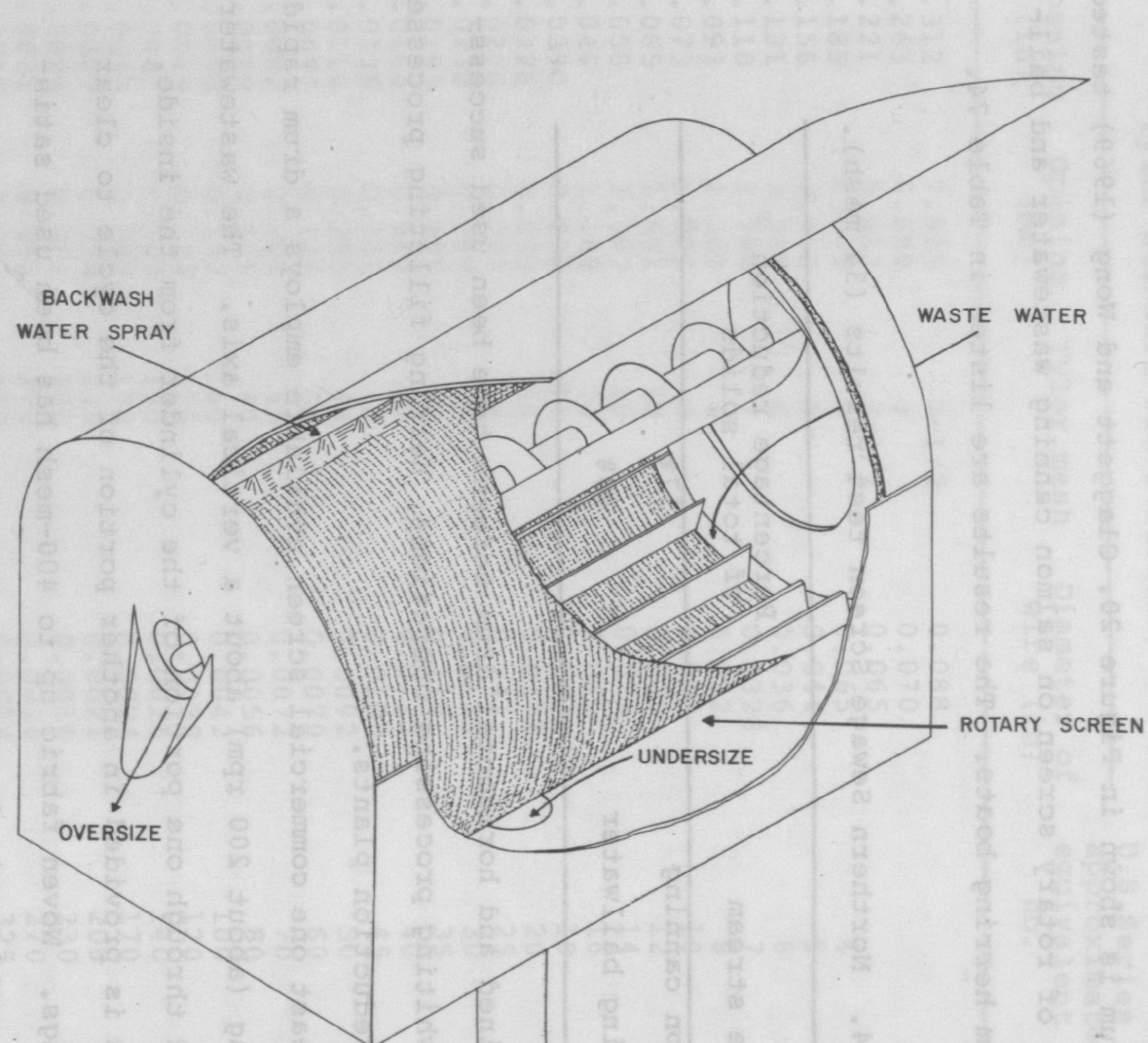


Figure 20. Typical drum rotary screen.

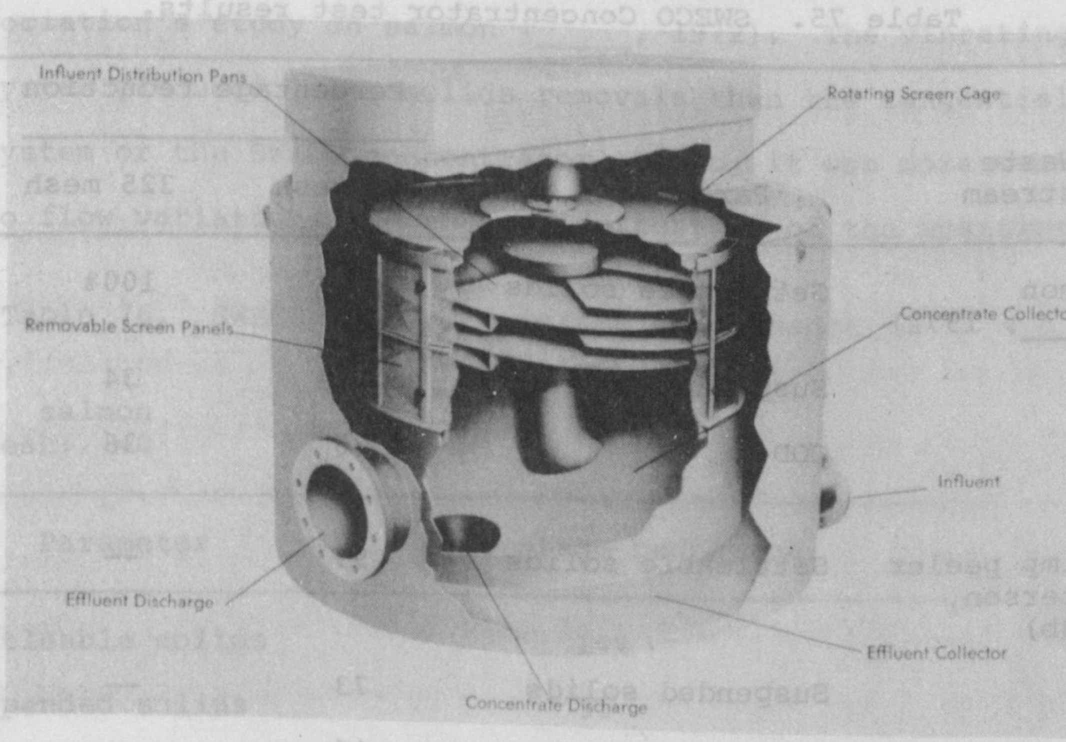


Figure 21. SWECO centrifugal wastewater concentrator

and seafood wastes have been investigated on a pilot scale in the Washington State salmon industry (_____, 1972) and Alaskan crab and shrimp industries (Peterson, 1973b). The results of these studies are shown in Table 75.

Table 75. SWECO Concentrator test results.

Waste stream	Parameter	Percentage reduction	
		165 mesh	325 mesh
Salmon (_____, 1972)	Settleable solids	--	100%
	Suspended solids	53%	34
	COD	36	36
Shrimp peeler (Peterson, 1973b)	Settleable solids	99	--
	Suspended solids	73	--
	COD	46	--

Case history five further discusses the application of the SWECO centrifugal wastewater concentrator.

Vibratory screens are more commonly used in the seafood industry in plant processing operations rather than wastewater treatment. The screen housing is supported on springs which are forced to vibrate by an eccentric. Retained solids are driven in a spiral motion on the flat screen surface and discharged at the periphery. Other vibratory-type screens impart a linear motion to retained particles by eccentrics. With vibratory screens, blinding is frequently a problem when seafood wastewaters are being handled. Salmon waste is probably the most difficult to screen because of its fibrous nature and high scale content. Crab butchering waste, also quite stringy, is somewhat less difficult to screen. Table 76 lists the results of the National Canners Association's study on salmon (_____, 1972). The vibrating screen system produced lower solids removals than the tangential screen system or the SWECO concentrator. Also, it was more sensitive to flow variations and the solids content of the wastewater.

Table 76. SWECO vibratory screen performance (_____, 1972).

Species: salmon
Screen mesh: 40

Parameter	Percentage reduction
Settleable solids	14%
Suspended solids	31
COD	30

Tangential screens are finding increasing acceptance because of their inherent simplicity, reliability and effectiveness. They consist of a series of parallel, triangular or wedgeshaped bars oriented perpendicularly to the direction of flow. The screen surface usually is inclined from 45 to 60 degrees. Solids move down the face and fall off the bottom as the liquid passes through the openings ("Coanda effect"). No moving parts or drive mechanisms are required for the operation. The feed to the screen face is via a weir or a pressurized nozzle system impinging the wastewater tangentially on the screen face at the top. The gravity-fed units are limited to about 50 to 60 mesh (equivalent) in treating seafood wastes. Pressure-fed screens can be operated with mesh equivalents of up to 200 mesh. Shrimp waste presents significant blinding problems to tangential screens in a narrow mesh range. Shrimp peeler waste is much more readily handled on tangential screens with equivalent mesh sizes of 35 to 40 than 20 mesh.

Tangential screens have met with considerable acceptance in the fish and shellfish industry. They appear to represent the most advanced waste treatment concept that is currently being voluntarily adopted by broad segments of the industry. One reason for this wide acceptance has been the thorough testing history of the unit. Data are available (although much is proprietary) on the tangential screening of wastewaters emanating from plants processing a variety of species. A summary of some recent work appears in Table 77.

Coarse pre-screening is often desirable to prevent harmful objects from entering the waste treatment system. Floor drains are normally covered with a coarse grate or drilled plate with holes approximately 0.6 cm (0.25 in) in diameter. A coarse grate and a magnet are desirable to prevent oversize or unwanted objects such as polystyrene cups, beverage cans, rubber gloves, tools, nuts and bolts, or broken machine parts from entering the treatment system. Such objects can cause serious damage to pumps and may foul the screening system.

Table 77. Tangential screen performance.

Waste stream	Parameter	Percentage Reduction 30 mesh	40 mesh	40 mesh	100 mesh*	150 mesh*
Sardines (Atwell, *et al.*, 1972)	Suspended solids	26%	--	--	--	--
	BOD	9	--	--	--	--
Salmon (______, 1972)	Settleable solids	--	--	--	35%	86%
	Suspended solids	--	--	--	15	36
	COD	--	--	--	13	25
Shrimp (Peterson, 1973b)	Settleable solids	88	--	93	83	--
	Suspended solids	46	--	43	58	--
	COD	21	--	18	23	--
Salmon (Peterson, 1973b)	Settleable solids	50	--	--	--	--
	Suspended solids	56	--	--	--	--
	COD	55	--	--	--	--
King crab (Peterson, 1973b)	Settleable solids	83	--	--	--	--
	Suspended solids	62	--	--	--	--
	COD	51	--	--	--	--
Salmon (Claggett, 1971)	Total solids	--	56	--	--	--
Herring (Claggett, 1969)	Total solids	--	48	--	--	--
Shrimp (Environmental Associates, 1974)	Suspended solids	25	--	--	--	--
	COD	16	--	--	--	--

*Pressure fed

Some seafood processors utilize a perforated inclined trough to separate large solids from the wastewater. The wastewater is fed into the lower end and conveyed up the trough by a screw conveyor. The liquid escapes through the holes while the solids are discharged to a holding area. Inclined conveyors and mesh belts are commonly used throughout the fish and shellfish industry to transport and separate liquids from solid wastes.

A typical screening arrangement using a tangential screen is shown in Figure 22. Various other screening devices may be substituted in the arrangement. A sump is useful in dampening brief periods of high flow that may overload the screen. It also helps mitigate the wastewater solids loads where batch processes cause fluctuations. Some form of agitator may be required to keep the suspended solids in the sump suspended. Ideally, the sump should contain a one-half hour storage capacity to permit repairs to downstream components. The pump used is an important consideration. Centrifugal trash pumps, of the open impeller type, are commonly used. This type of pump tends to pulverize solids as they pass through. During an experiment on shrimp wastes the level of the settleable solids dramatically increased when the wastewater was passed through a centrifugal pump (Peterson, 1973b). Positive displacement or progressing cavity non-clog pumps are recommended.

Screens should be installed with the thought that auxiliary screen cleaning devices may be required later. Blinding is a problem that depends, to some extent, on the type of screen employed, but to a greater extent on the nature of the waste

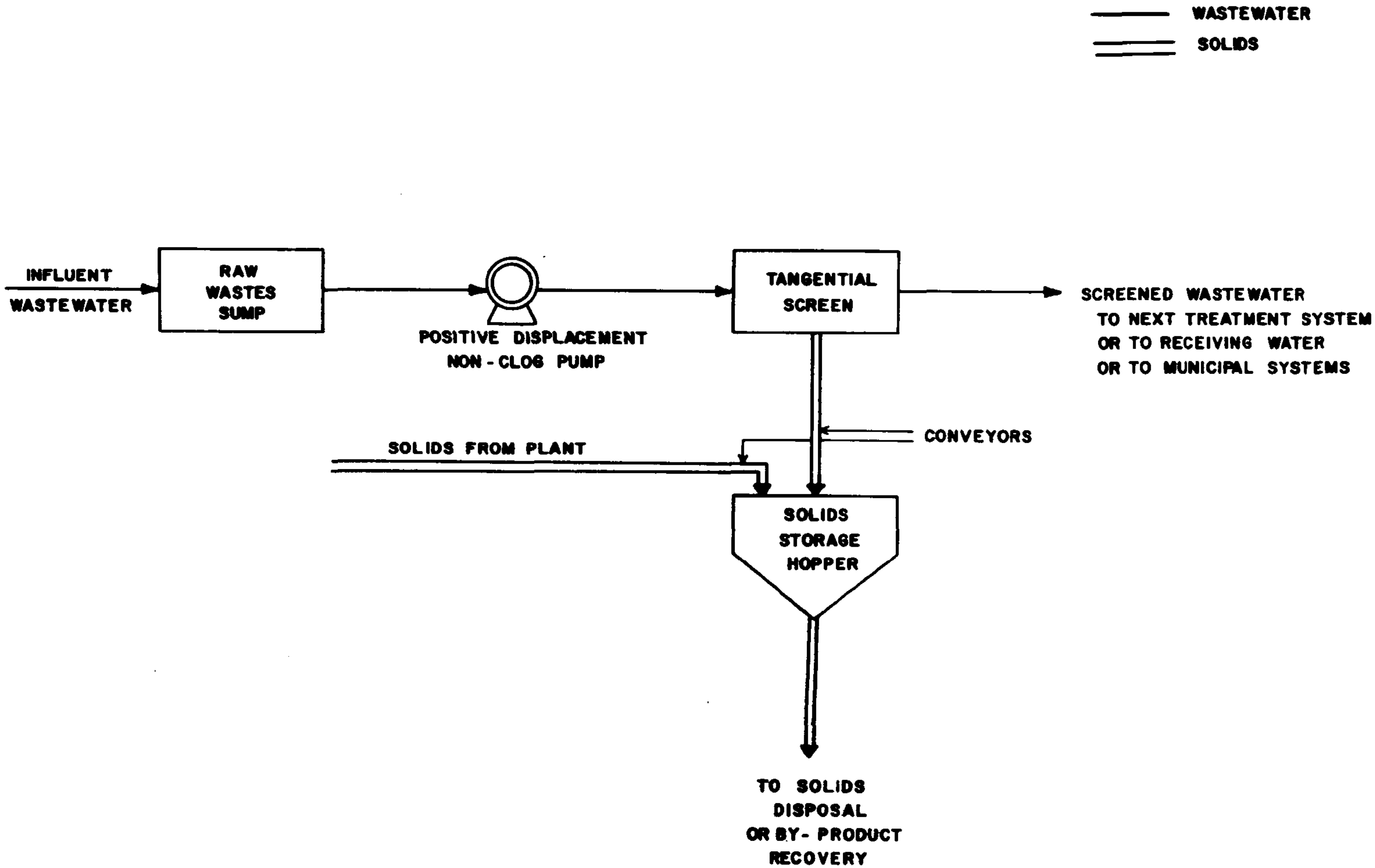


Figure 22. Typical tangential screening system (Environmental Associates, Inc.).

stream. Salmon waste is particularly difficult to screen. One processor has installed mechanical brushes over his tangential screen, which reduces plugging by sweeping the face of the screen (see Plate 1).

Many of the screen types mentioned above produce solids containing considerable excess water. In most cases, this water will have to be removed either mechanically or during storage by draining. A convenient place to locate a screen assembly is above the storage hopper so that the solids discharge directly to the hopper. However, hoppers do not permit good drainage of most stored solids. If mechanical dewatering is necessary, it may be easier to locate the screen assembly on the ground and convey dewatered solids to the hopper.

Processing wastewaters from operations in seafoods plants are highly variable with respect to suspended solids concentrations and the sizes of particulates. On-site testing is required for optimum selection in all cases.

Some thought should be given to installing more than one screen to treat different streams within the process plant. Some types of screens are superior for specific wastewaters and there may be economy in using expensive or sophisticated screens only on the hard-to-treat portions of the waste flows. Microscreens (with screen openings as small as 0.010 mm) to effect solids removal from salmon wastewaters in Canada have been tried. They were found to be inferior to tangential screens for that application. Microscreens and microstrainers have not, however, been applied in the United States.

Plate 1. Brush-cleaned screen at salmon cannery (courtesy New England Fish Company).

Screens of most types are insensitive to discontinuous operation and flow fluctuations, and require little maintenance. The presence of salt water necessitates the use of stainless steel elements. Oil and grease accumulation can be reduced by spraying the elements with a fluorocarbon coating.

Screens of proper design are a reliable and highly efficient means of seafood waste treatment, often providing the equivalent of "primary treatment." The cost of additional solids treatment, approaching 95 percent solids removal by means of progressively finer screens in series, must, in final design, be balanced against the cost of treatment by other methods, including chemical coagulation and sedimentation. Screened solids have the advantage of seldom requiring additional dewatering before transport (greater than 10 percent solids) to a reduction plant or other ultimate disposal site.

Figure 23 depicts cost curves for installing screens, together with operation and maintenance costs.

2.2.2. Air Flotation

Air flotation with appropriate chemical addition is a physical-chemical treatment technology capable of removing heavy concentrations of solids, greases, oils, and dissolved organics in the form of a floating sludge. Flotation cells utilize the buoyancy of released air bubbles rising through the wastewater to lift materials in suspension to the surface. These materials include substantial dissolved organics and chemical precipitates, under controlled conditions. Floated, agglomerated sludges are

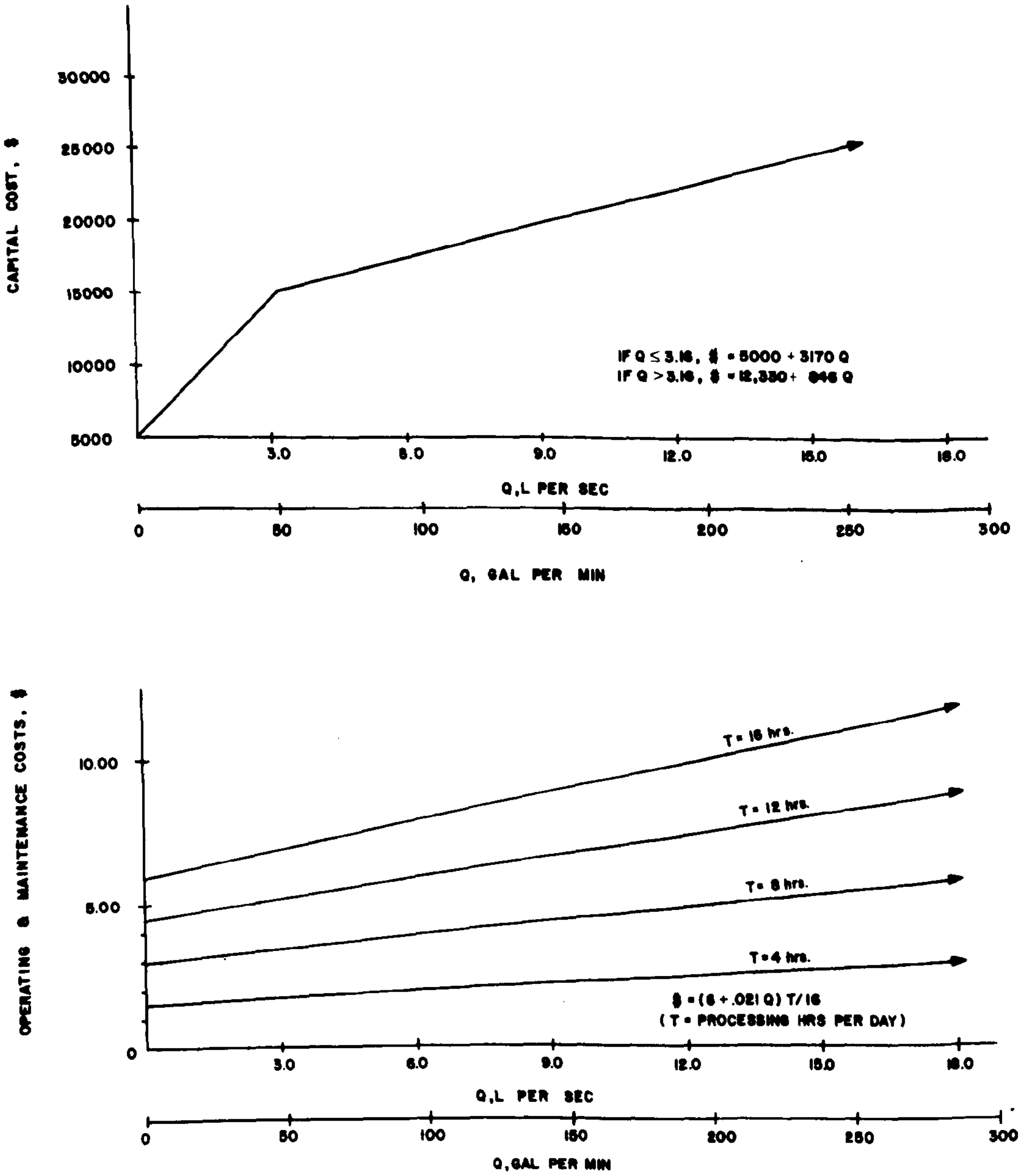


Figure 23. Cost curves for tangential screen installation and maintenance (Environmental Associates, Inc., 1974).

skimmed from the surface, collected and dewatered. Adjustment of pH to near the isoelectric point can effect appreciable removals of dissolved protein from fish processing wastewaters (proteins are least soluble at their isoelectric point; for fish proteins these range from pH 4.5 to 5.0). The main differences between flotation cells are the shape of the cell, the manner in which the air is mixed with the water, and the amount of water pressurized.

Because the flotation process brings partially reduced organic and chemical compounds into contact with oxygen in the air bubbles, satisfaction of immediate oxygen demand is a benefit of this process.

Present flotation equipment consists of three types of systems for wastewater treatment: 1) vacuum flotation, 2) dispersed air flotation, and 3) dissolved air flotation.

2.2.2.1. Vacuum flotation

In this system, the waste is first aerated, either directly in an aeration tank or by permitting air to enter on the suction side of a pump. Aeration periods are brief, some as short as 30 seconds, and require only about 185 to 370 cc/l (0.025 to 0.05 cu ft per gallon) of air (Nemerow, 1971). A partial vacuum of about 0.6 atm (9 inches of mercury) is applied, which releases some air as minute bubbles. The bubbles and attached solids rise to the surface to form a scum blanket which is removed by a skimming mechanism. A disadvantage is the expensive airtight structure needed to maintain the vacuum. Any leakage from the atmosphere adversely affects performance. No known vacuum flotation units are in use in the seafood industry.

2.2.2.2. <u>Dispersed air flotation</u>

Air bubbles are generated in this process by the mechanical shear of propellers, through diffusers, or by homogenization of gas and liquid streams. The provision of aeration tanks in this process, for flotation of grease and other solids, usually is ineffective. Heavy solids that settle to the bottom are collected at a central sludge sump for removal. The floating material is removed to a scum trough from which it is pumped. Some success has been obtained on scum-forming wastes (Metcalf and Eddy, 1972). Figure 24 depicts a typical dispersed air flotation unit.

Table 78 lists removal efficiencies of a dispersed air flotation unit treating tuna wastes. The conclusion of the study was that the unit was ineffective without chemical additions. While removal efficiencies for this process are not as high as those for the dissolved air flotation unit, the price is considerably less. A unit large enough to accommodate a 20.4 l/sec (450 gpm) flow costs approximately $18,000.

2.2.2.3. <u>Dissolved air flotation</u>

In this process, the untreated wastewater or a recycled stream is pressurized to 3.0 to 4.4 atm (30 to 50 psi) in the presence of air and then released into the flotation tank. The recycle stream is held in the pressure unit for about one minute before being mixed with the unpressurized main stream just prior to entering the flotation tank. Figure 25 contains a schematic diagram of a typical dissolved air flotation system. Figure 26 shows a typical dissolved air flotation unit.

The Hydrocleaner Aeration/Flotation Cycle

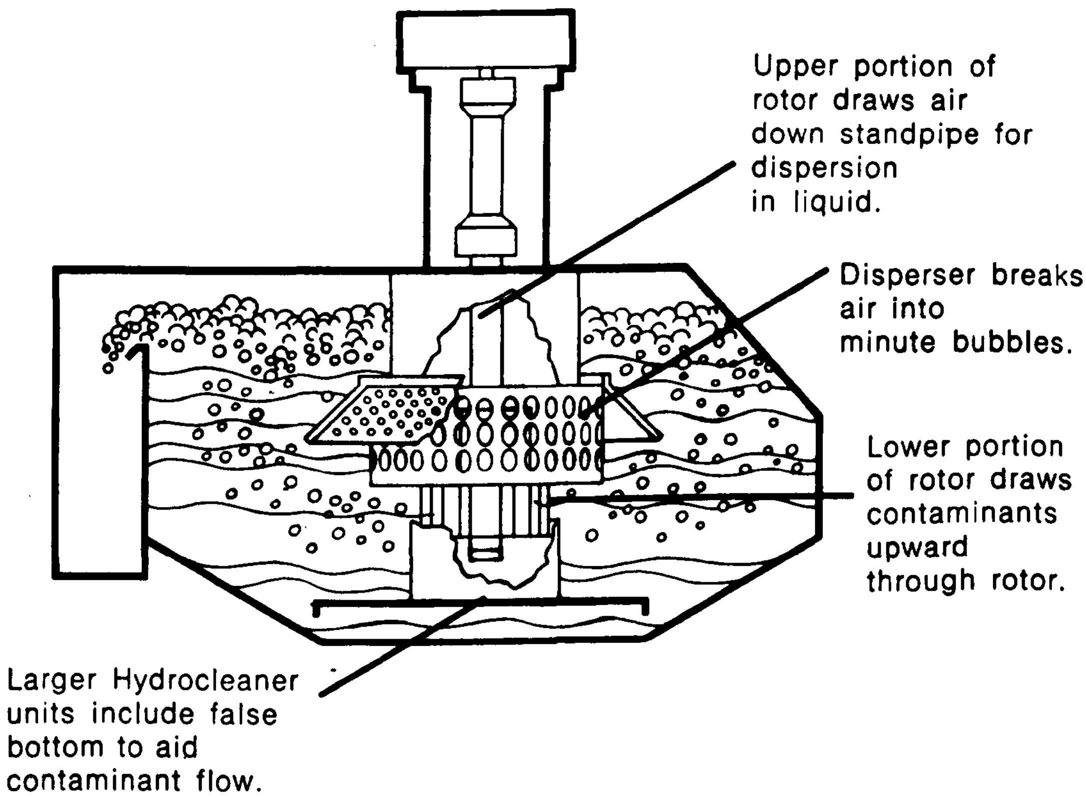


Figure 24. WEMCO dispersed air flotation unit.

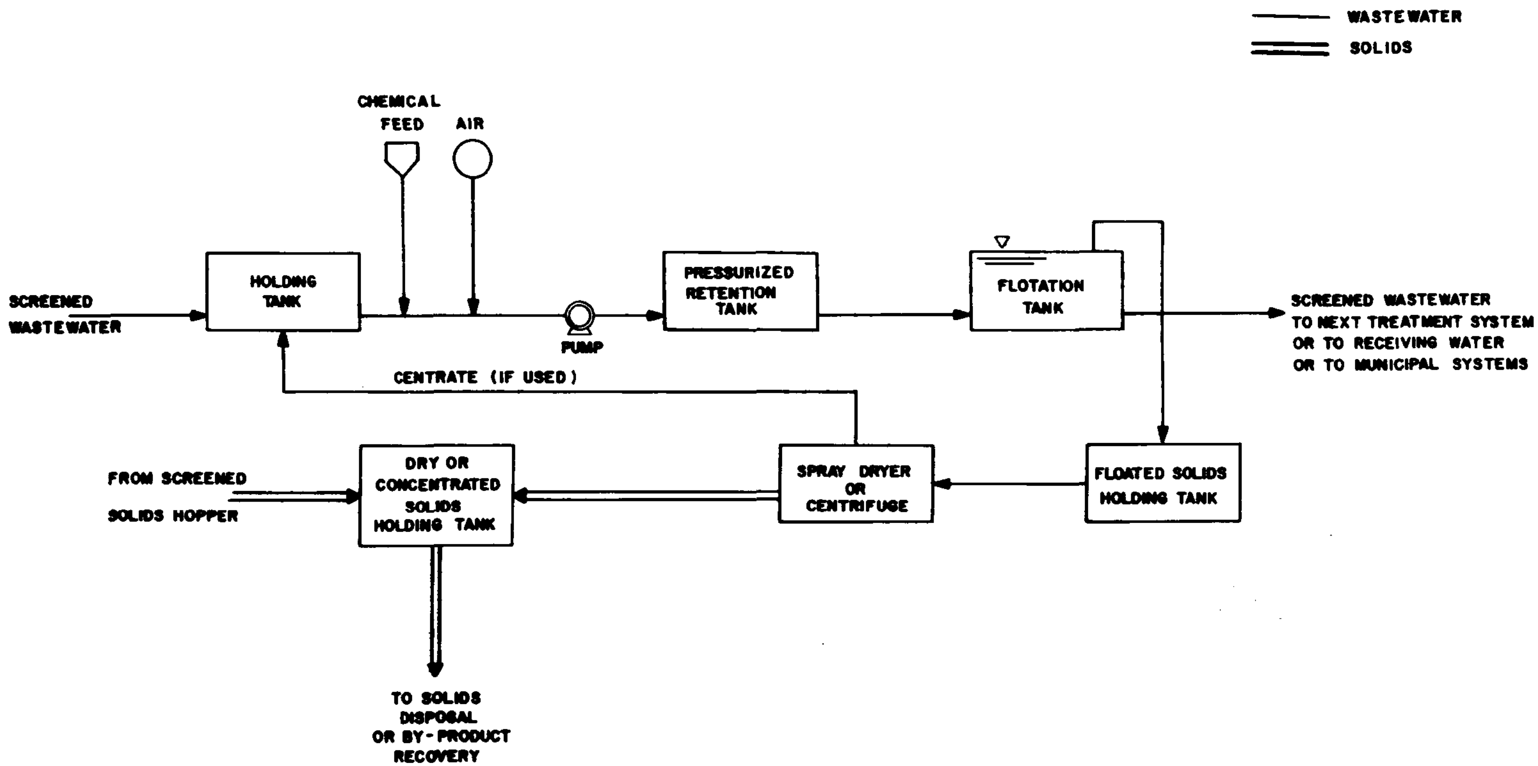


Figure 25. Typical dissolved air flotation system (Environmental Associates, Inc.).

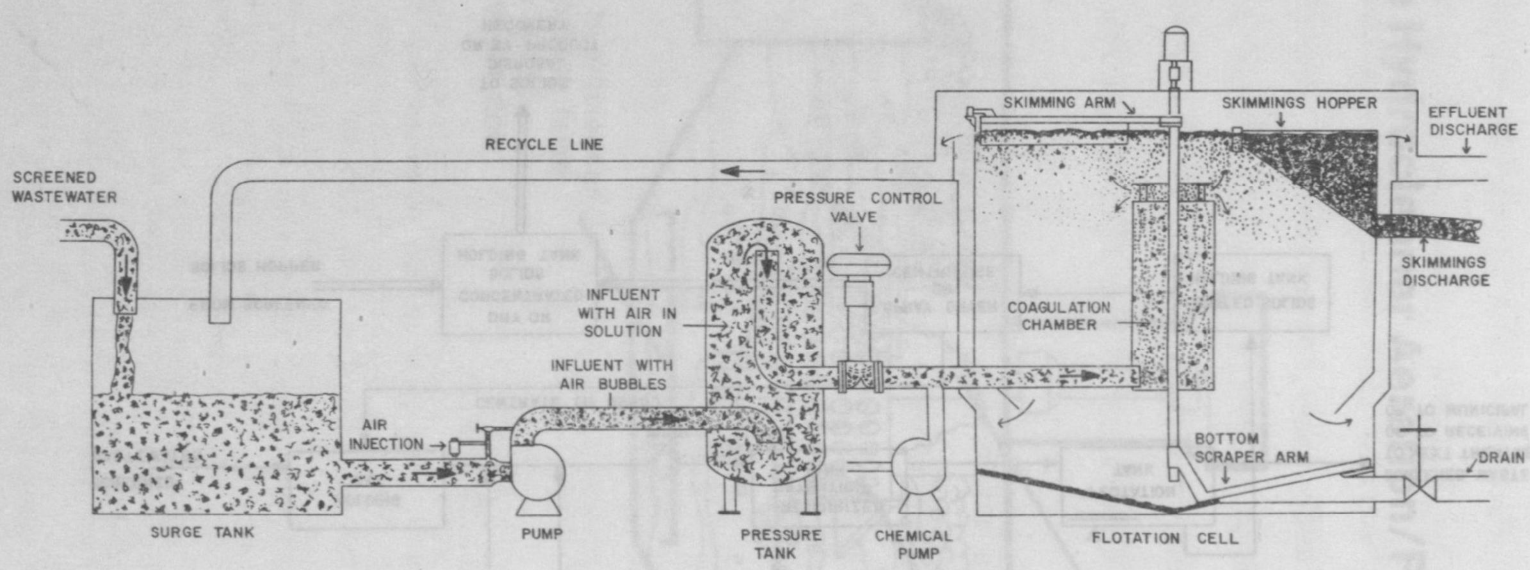


Figure 26. Carborundum Corporation dissolved air flotation system.

Table 78. Removal efficiencies for the dispersed air flotation unit (_____. 1973).

Agency: Jacobs Engineering Company
Unit: Dispersed Air Flotation--WEMCO hydrocleaner
Operation: 5-10 minute retention time, pilot study
Species: Tuna

Additive	Parameter	Influent (mg/l)	Reduction (%)
Tretolite chemical 7-16 mg/l	BOD_5	4400	47
	G&O	273	68
	SS	882	30
	(averages of 5 runs)		
Drew 410 3-14 mg/l	BOD_5	211	47
	G&O	54	50
	SS	254	30
	(averages of 8 runs)		

The flotation system of choice depends on the characteristics of the waste and the necessary removal efficiencies. Although Mayo (1966) found recycle pressurization gave best results for industrial waste and required less power, the design of flotation units should proceed from pilot plant studies of the actual wastes involved.

Air bubbles usually are negatively charged. Suspended particles or colloids may have a significant electrical charge providing either attraction or repulsion to the air bubbles. In treating industrial wastes with large quantities of emulsified grease or oil, it is usually beneficial to use alum, or lime, and an anionic polyelectrolyte to provide consistently good removals (Mayo, 1966).

Emulsified grease or oil normally cannot be removed without chemical coagulation (Kohler, 1969). The chemical coagulant should be provided in sufficient quantity to absorb completely the oil present whether free or emulsified. Good flotation properties are characterized by a tendency for the floc to float with no tendency to settle downward. Excessive coagulant additions result in a heavy floc which is only partially removed by air flotation. With oily wastewaters such as those found in the fish processing industry, minimum emulsification of oils should result if a recycle stream only, rather than the entire influent, were passed through the pressurization tank. This would insure that only the stream (having been previously treated) with the lower oil content would be subjected to the turbulence of the pressurization system. The increased removals achieved, of course, would be at the expense of a larger flotation unit than would be needed without recycle.

The water temperature determines the solubility of the air in the water under pressurization. With lower water temperatures, less recycle is necessary to dissolve the same quantity of air. The viscosity of the water, however, increases with a decrease in temperature, so that flotation units must be made larger to compensate for the lower bubble rise velocity at low temperatures. Mayo (1966) recommended that flotation units for industrial applications be sized on a flow basis for suspended solids concentrations less than 500 mg/l. Surface loadings should not exceed 81 l/sq m/min (2 gal/sq ft/min). The air-to-solids ratio is important, as well. Mayo (1966) recommended 0.02 kg of air per kg of solids to provide a safe margin for design.

Flotation is in extensive use for wastewater treatment among food processors. Mayo (1966) presented data showing high influent BOD and solids concentrations, each in the range of 2000 mg/l. Reductions reached 95 percent BOD removal and 99.7 percent solids removals, although most removals were five percent to 20 percent lower. The higher removals were attainable using appropriate chemical additions and, presumably, skilled operation. Dissolved air flotation was installed in one tuna plant sampled during the recent study conducted by Environmental Associates, Inc. Additional flotation units are planned by other processors. Demonstration-scale units have also been operated on shrimp, salmon, menhaden and crab wastewaters, with variable success (Atwell, et al., 1972; _____. 1971; Mauldin, 1973; Peterson, 1973). Table 79 summarizes the results of these tests.

It appears that flotation in many instances can provide treatment levels comparable to biological treatment (Jordan, 1973). Good operation and correct chemical addition are prerequisites for high treatment efficiency. Air flotation systems can also be operated at lower efficiencies to serve as "primary" treatment steps prior to a physical-chemical or biological polishing step, if that mode proves advantageous from the standpoint of cost-effectiveness.

Figures 27, 28 and 29 show the cost of installation and costs of operation and maintenance both with and without chemical additives for the dissolved air flotation unit.

Table 79. Dissolved air flotation performance--United States.

Waste stream	Additives	Parameter	Reduction
Sardines (Atwell, et al., 1972)	polymer, 2 mg/l alum, 200 mg/l	Suspended solids	95%
		BOD	64
		Oil & grease	80
Tuna (Jacobs Eng., 1972)	lime, pH 10.0-10.5	Suspended solids	66
	polymers: cationic, 0.05 mg/l anionic, 0.10 mg/l	BOD	65
		Oil & grease	66
Tuna (Jacobs Eng., 1972)	lime, 400 mg/l $FeCl_2$ 45 mg/l	Suspended solids	77
		BOD	22
		Oil & grease	81
Tuna (Environmental Associates, 1973)	$NaAlO_2$ 120 mg/l polymer	COD	37
		Suspended solids	56
	Alum polymer	COD	58
		Suspended solids	65
Shrimp (Peterson, 1973a)	alum, 200 mg/l polymer	Suspended solids	77
		COD	73
		Settleable solids	89
Menhaden bail water (Baker & Carlson, 1972)	acid, pH 5.0-5.3 alum polymer, anionic	Suspended solids*	87
		COD	80
		Oil & grease	100

*Nonstandard method

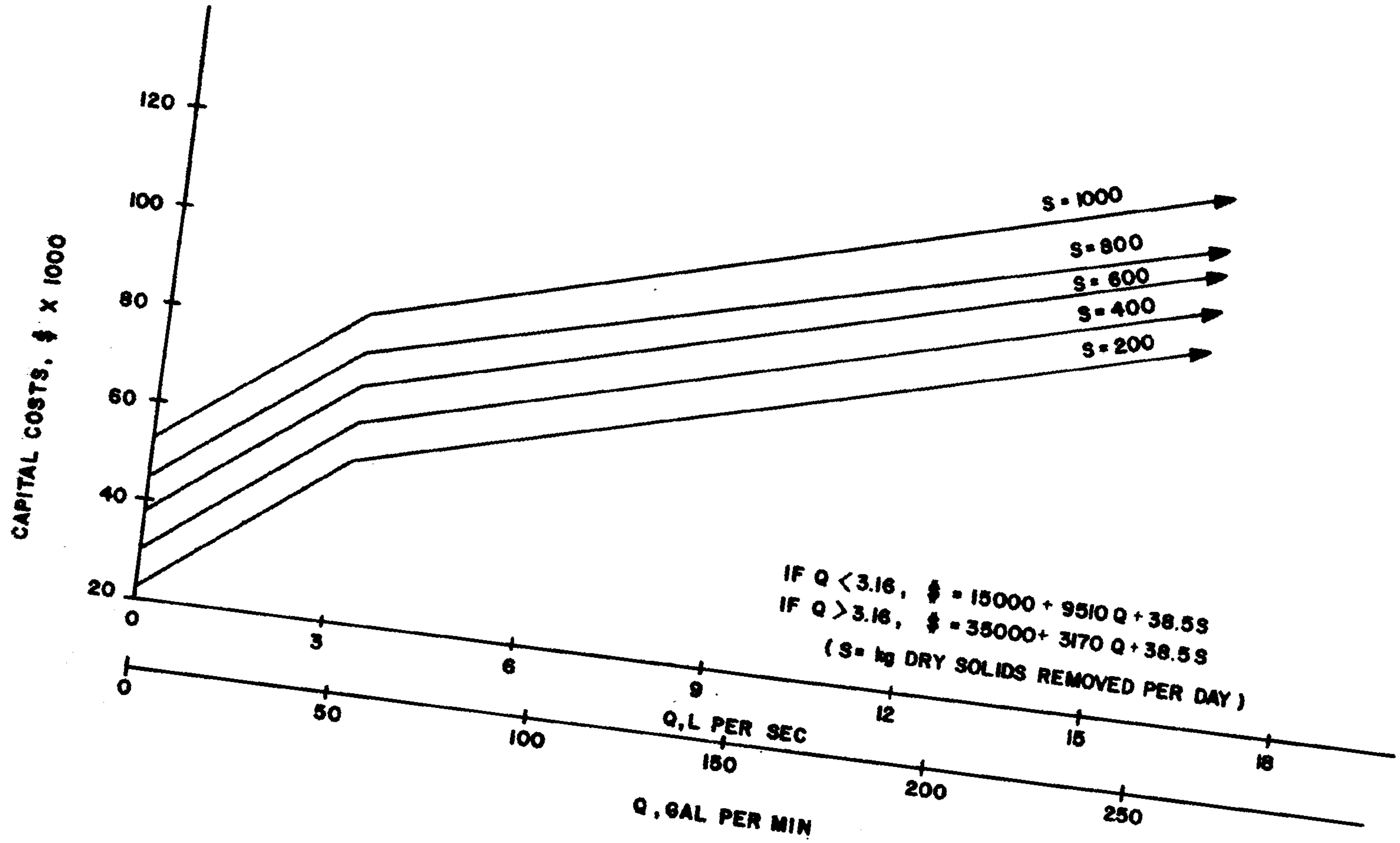


Figure 27. Installation costs of dissolved air flotation units (Environmental Associates, Inc., 1974).

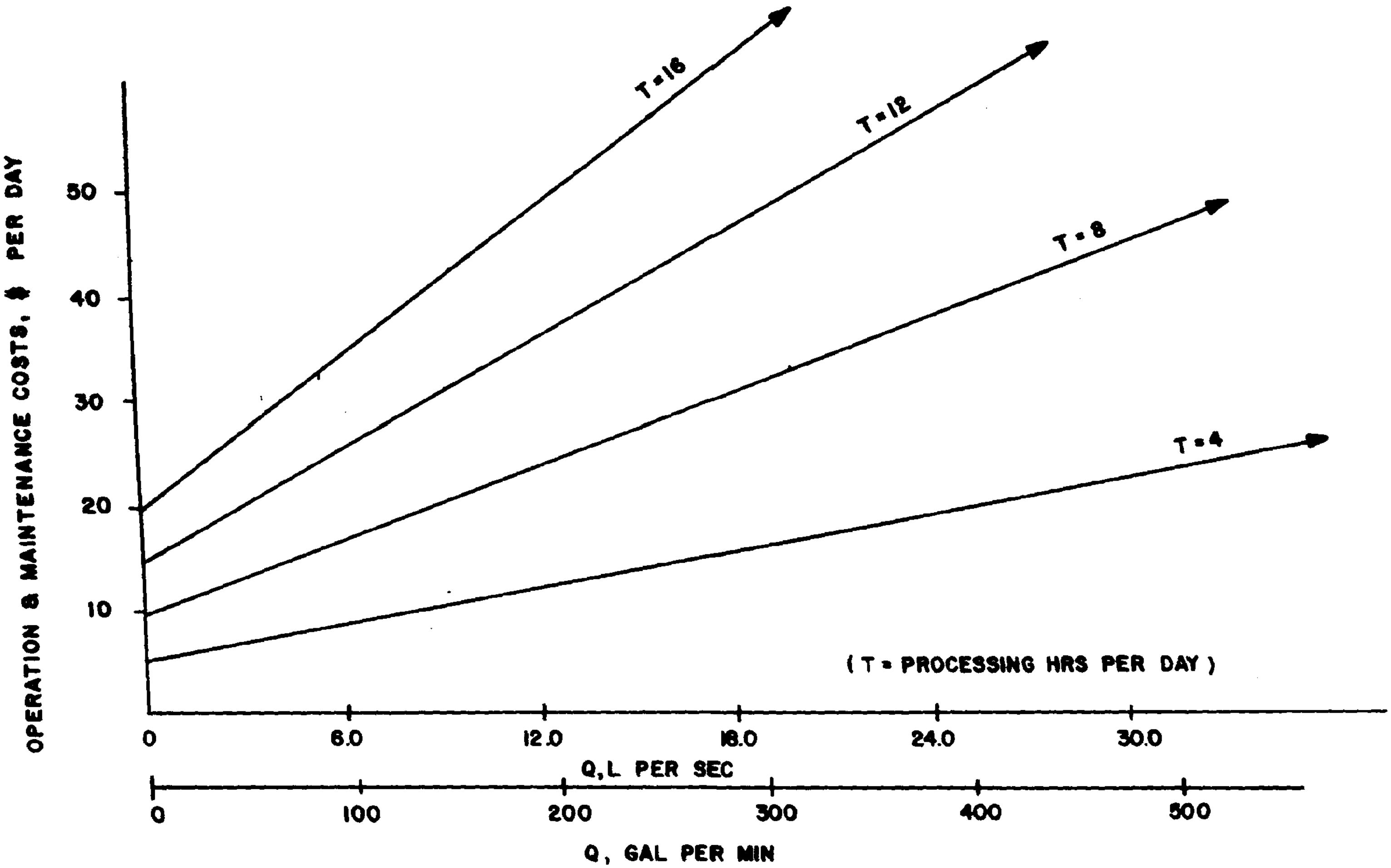


Figure 28. Operating and maintenance costs for dissolved air flotation unit operated with chemicals (Environmental Associates, Inc., 1974).

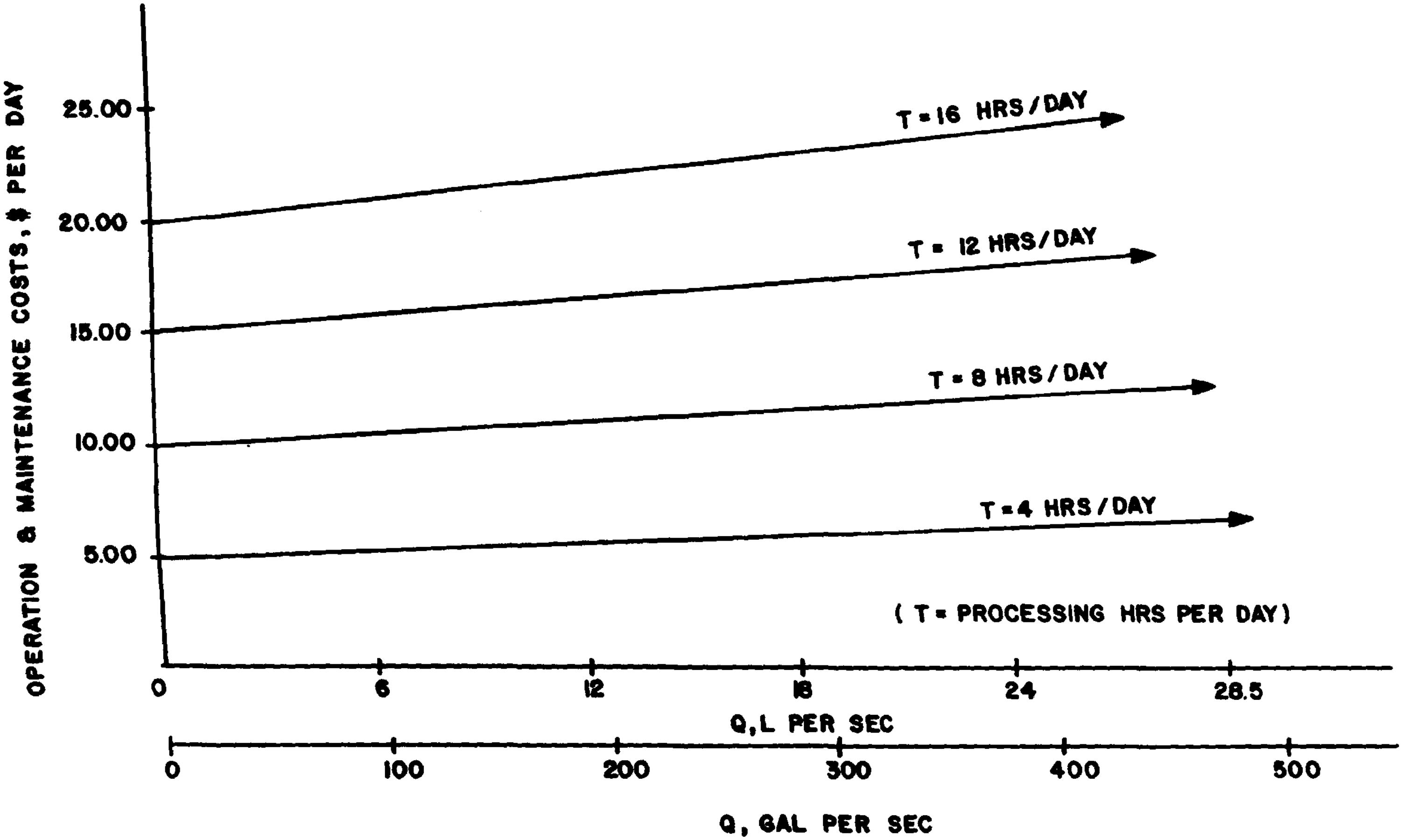


Figure 29. Operating and maintenance costs for a dissolved air flotation unit operated without chemicals (Environmental Associates, Inc., 1974).

2.2.3. Sedimentation and Clarification

Sedimentation is the separation of solids from a liquid by means of gravity. Ancillary functions of sedimentation units are grease flotation, flow equalization and (occasionally) BOD reduction. Often the first step in a multiple sedimentation process is the grit chamber which is a pretreatment basin for collecting heavy particles. The clarifier (Plate 2) commonly incorporates the use of chemicals to convert a large amount of the remaining particles into settleable solids, which are then removed.

The design of each unit is based primarily on 1) the vertical settling velocity of discrete particles to be removed, and 2) the horizontal flow velocity of the liquid stream. Detention times required in the settling basins range from a few minutes for heavy shell fragments to hours for low-density suspensions. The current absence of settling basins or clarifiers in the fish industries indicates the need for simple on-site settling rate studies to determine appropriate design parameters for liquid streams undergoing such treatment.

Removal of settled solids from sedimentation units is accomplished by drainoff, scraping, and/or suction-assisted scraping. Frequent removal is necessary to avoid putrefaction. Seafood processors using brines and seawater must consider the corrosive effect of salts on mechanism operation. Maintaining realibility in such cases may require parallel units even in small installations.

Sedimentation processes can be upset by such "shock loadings" as fluctuations in flow volume, concentration and,

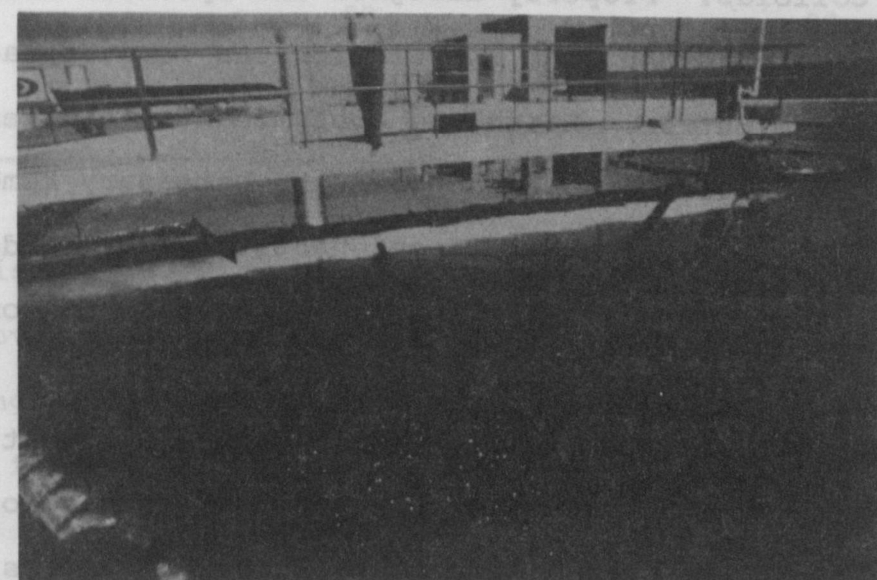


Plate 2. Surface view of a typical circular clarifier

occasionally, temperature. Aerated equalization tanks may provide needed capacity for equalizing and mixing wastewater flows. However, deposition of solids and waste degradation in the equalization tank may negate its usefulness.

Major disadvantages of sedimentation basins include areal requirements and structural costs as well as solids disposal problems. In addition, the settled solids normally require dewatering prior to ultimate disposal.

Chemical coagulants, such as alum and ferrous chloride, can be added to sedimentation processes to induce removal of suspended colloids. Properly designed and operated sedimentation units incorporating chemical coagulation can remove practically all particulate matter. Dissolved contaminants, however, will require further processing to achieve the necessary removals. The use of some coagulants in large quantities may render the resulting sludge unusable as a by-product because of contamination. Also, some flocculation agents are quite expensive.

Sedimentation tests run on a combined effluent from a fresh water perch and smelt plant produced an average of approximately 20 percent BOD and nine percent suspended solids removals after 60 minute detention (Riddle <u>et</u> <u>al</u>., 1972). The nature of most fish and shellfish wastewaters requires that chemical coagulants be added to sedimentation processes to induce removal of suspended colloids.

A partially successful gravity clarification system was developed using large quantities of a commercial coagulant called F-FLOK. In a test on salmon wastewater, reported by

Robbins (1973), the floc formed slowly, but sedimentation rates of four feet (1.2 meters) per hour were achieved. Table 80 summarizes the results of the test.

Table 80. Gravity clarification using F-FLOK coagulant.

Coagulant concentration (mg/l)	Total solids recovery (%)	Protein recovery (%)
5020	68	92
4710	60	80
2390	47	69

It is important to note that the gravity clarifiers described above, when operated with normal detention times, may release strong odors from rapid microbial action. This could also produce floating sludge.

2.2.4. Chemical Oxidation

This method uses chemicals to oxidize the organic matter present in the wastewater, thereby reducing the BOD load. Chlorine and ozone are the most common oxidants, although chlorine dioxide, potassium permanganate, and others are capable of oxidizing organic matter found in the process wastewater. This technology is not widely used because it lacks economic feasibility.

Chlorine could be generated electrolytically from salt-waters adjoining most processors of marine species, and utilized to oxidize the organic material and ammonia present (Metcalf and Eddy, 1972). Ozone could be generated on-site and pumped into deaerated wastewater. Deaeration is required to reduce the build-up of nitrogen and carbon dioxide in the recycle gas stream. The higher the COD, the higher the unit ozone reaction efficiency. Both oxidation systems offer the advantages of compact size. The operability of the technology with saline wastewaters, and the practicality of small units, have not been evaluated in the seafood processing industry (McNabney and Wynne, 1971).

The removal efficiency of chemical oxidation using chlorine on domestic wastes is 10 to 35 percent (_____, 1969). No known treatment facilities of this type have been used in the seafood industry.

2.2.5. Sludge Treatment

Sludges, floats, skimmings, and other slurries vary widely in dewaterability. Waste activated sludges and floated solids are particularly difficult to dewater. It is probable that most sludges produced in treating fish processing wastes would require conditioning before dewatering. Such conditioning may be accomplished by means of chemicals or heat treatment. Because of toxicity problems, anaerobic digestion to stabilize sludges before dewatering is not feasible at plants employing salt waters or brines. Aerobic digestion will produce a stabilized sludge, but not one which is easy to dewater. The amount and type of chemical treatment must be determined in light of the ultimate fate of the solid fraction. For example, lime may be deposited on the walls of solubles plant condensers. Alum has been shown to be toxic to chickens at 0.12 percent concentrations, and should be used with care in sludges intended for feed by-product recovery (_____, 1970).

A large variety of equipment is available for sludge dewatering and concentration, each unit with its particular advantages. These include vacuum filters, filter presses, gravity-belt dewaterers, spray dryers, incinerators, centrifuges, cyclone classifiers, dual-cell gravity concentrators, multi-roll presses, spiral gravity concentrators, and screw presses. Such equipment can concentrate sludges from 0.5 percent solids (5000 mg/l) to a semi-dry cake of 12 percent solids (120,000 mg/l) with final pressing to a dry cake of over 30 percent solids (300,000 mg/l). Units are generally sized to treat sludge flows no smaller than 38 l/min (10 gpm). Because maintenance requirements range from moderate to high, the provision of dual units is required for continuity and reliability.

Except in meal plants, solids dewatering and concentrating equipment is not presently employed in the fish industries. The wide variety now available implies that workable equipment exists which is suitable for moderately-sized installations [over 757 cu m/day (200,000 gpd)]. Sludge and float flows from smaller installations could probably not be utilized in dewatering equipment economically. This condition effectively favors the larger processors.

2.3. Biological Treatment of Wastewater

The term "biological treatment" encompasses the applications of living organisms to the reduction and/or removal of organic constituents and nutrients from wastewater. In practice, this is accomplished by the assimilation of dissolved and colloidal organic materials from the wastewater by the metabolic processes of microorganisms.

By far the largest and most important group of microorganisms utilized in biological treatment are the bacteria. To a lesser extent, molds, yeasts, protozoa, and rotifers are important in certain phases of the treatment processes. One additional group of organisms not generally considered with the microorganisms, but important nonetheless in wastewater treatment, are the algae, uni- and multicellular plants useful in some types of treatment systems. As with most living systems, microorganisms are very susceptible to environmental changes, especially abrupt, "shock" changes, so careful control must be maintained in biological treatment systems o assure the proper environment for effective microbial activity.

Microorganisms are classified by their specific environmental requirements. One division is based on the type of carbon source required by the organism. Those able to utilize inorganic carbon sources, specifically carbon dioxide, are termed autotrophic; those needing organic sources of carbon are termed heterotrophic.

Another classification is determined by the oxygen requirements of the organisms for growth. Those organisms which require the presence of free oxygen are called strict aerobes. Organisms requiring a complete absence of free oxygen are labeled strict anaerobes. Some organisms are capable of growth either with or without free oxygen, and these organisms are termed facultative.

The temperature range for growth is yet another factor by which organisms are classified. Psychrophiles grow best at low temperatures, but these organisms are of minimal importance in wastewater treatment. Mesophiles grow in the wide range of temperatures intermediate to the other groups. Thermophilic organisms grow at rather high temperatures not usually found in waste treatment systems, but some of the anaerobic bacteria useful in sludge digestion are of this type.

Other environmental parameters are bases for classifying the microorganisms; these include salt tolerance, sugar tolerance, osmotic pressure, etc. These categorizations are of limited importance, however, in the discussion of biological wastewater treatment.

In the actual treatment systems, many microorganisms are present, and the influent wastewater provides the nutrients and environment necessary for their growth. The organisms utilize the dissolved and colloidal organic materials, the levels of which are measured by the BOD test, for growth and reproduction, thereby creating new cells. These cellular organisms often clump together to form a slime or a mass, often called cultures, colonies, and biomass. The metabolic processes are efficient in removing constituents from the wastewater, and the organisms are usually fairly easy to remove from the water by sedimentation. Since the rate of BOD uptake from the water by the organisms depends mainly on the number of organisms, it is desirable to qaintain a fairly large number of organisms in contact with the raw waste to optimize the rate of BOD removal. This is done in many systems by recycling the settled organisms in the "sludge," thus, the origin of the term, "activated sludge." Treatment efficiency also depends heavily on the maintenance of the proper environment for microbial growth.

In biological treatment, the major considerations for BOD removal efficiency are the availability of oxygen to the organisms and residence time in the system. Aerobic organisms are much more versatile and resistant to slight environmental - changes than anaerobic organisms, and are much faster in metabolizing waste. They produce low-energy, relatively-inert end products (CO_2 and water), and are thus the most desirable organisms to utilize in treating wastewater. Anaerobic organisms are slower, are usually thermophilic, or upper mesophilic, and often produce reduced chemical compounds, many of which are highly-malodorous and undesirable. However, they do play a role in certain phases of wastewater treatment. The vast majority of biological treatment is carried out by aerobic organisms in bio-oxidative metabolic processes, which has led to the use of the term "biological oxidation" to describe aerobic microbial treatment.

One additional consideration in biological treatment, affecting mainly the treatment rate, is temperature. The metabolic processes of the microorganisms are affected directly by temperature. Generally, as temperature increases, the metabolic rate (and thus BOD removal rate) increases, and as temperature decreases, the metabolic rate decreases. Usually an upper limit temperature exists, above which the metabolic functions break down, but this temperature is rarely, if ever, reached in typical treatment systems. Low temperatures are quite a problem in some areas of the U.S., and near the freezing point of water, microbial metabolism drops off nearly to zero. This is a very important consideration in areas which experience cold weather during the year, and provisions must usually be made to combat this problem.

At the present, biological treatment is not practiced extensively in the U.S. seafoods industry. Sufficient nutrients are available in most seafood wastewaters, however, to indicate that such wastewaters are amenable to aerobic biological treatment. The salt found in nearly all wastewaters discourages the consideration of anaerobic processes. Salt is toxic to anaerobic bacteria and, although a certain tolerance to higher salt levels can be developed and carefully controlled (constant input systems), fluctuating loads continue to be inhibitory or toxic to these relatively unstable systems. Aerobic biological systems, although inhibited by "shock loadings" of salt, have been demonstrated feasible at full scale for the treatment of saline wastes of reasonably constant chloride levels. The effectiveness of many forms of biological oxidation however, remains to be demonstrated under the extreme variations common in the fish processing industry.

2.3.1. Activated Sludge

The activated sludge process, an aerobic system, is employed commonly in municipal wastewater treatment. It involves suspending a concentrated microbial mass in the wastewater in the presence of oxygen. Aeration (oxygenation) is accomplished by diffusion or mechanical agitation. Growth occurs naturally in the aerated organic wastes. The organisms floc or group together in highly active masses of living bacteria, food and higher life forms. Organic carbonaceous material is converted to carbon dioxide and water. Nitrogenous matter is concurrently oxidized to nitrate. The dissolved colloidal and suspended materials in the wastewater are converted by biological action to cell matter and then transported to the clarifier. A sludge pump removes the sediment and transports it to a sludge tank. The treated supernatant from the clarifier discharged as effluent, while the sludge is partially recirculated to maintain the high population of microorganisms in the aeration tank. This is schematically depicted in Figure 30.

By controlling the contact period and/or the concentration of recycled sludge, varying degrees of organic removal can be obtained. If a large organic load is present in the wastewater, higher sludge recycling rates, more air, and a longer contact time may be necessary to obtain adequate BOD removals. Maintenance of proper balance between these three critical criteria is necessary to obtain optimum efficiency from the system.

The conventional activated sludge process is capable of high levels of treatment when properly designed and skillfully

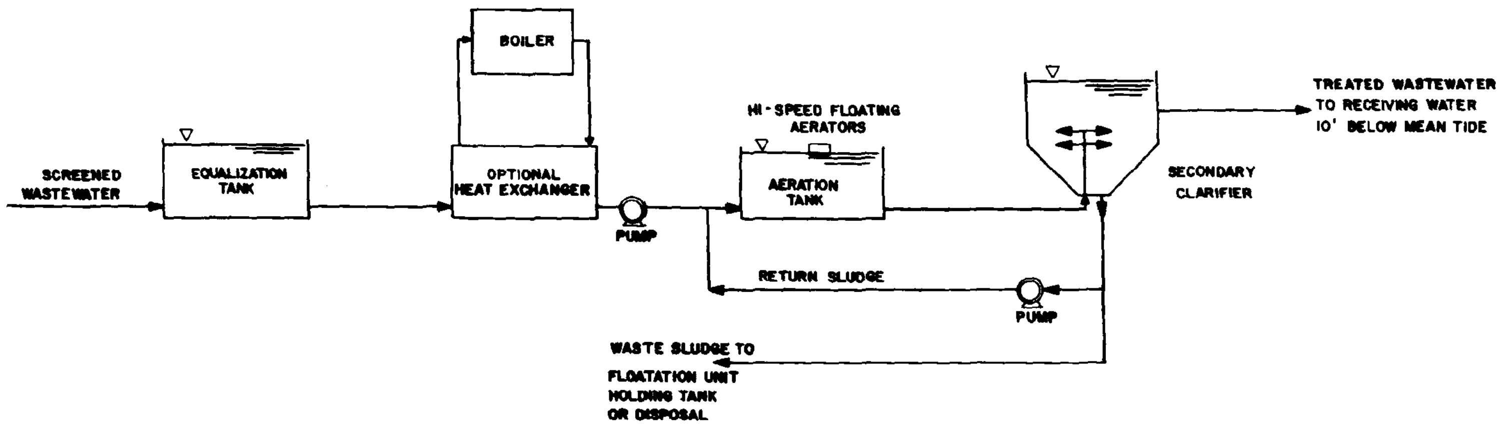


Figure 30. Typical activated sludge treatment system (Environmental Associates, Inc., 1973).

operated. Flow equalization, by means of an aerated tank, can minimize shock loadings and flow variations which are highly detrimental to treatment efficiency. Oily materials can have an adverse effect. A recent study (Environmental Associates, 1973) concluded that influent oil levels MLSS (petroleum based) should be limited to 0.10 kg/day/kg. Toxic metal, organic nondegradable matter, lack of nutrients required for biological oxidation, high temperatures, and high or low pH can also upset the activated sludge process.

The nature of the waste stream, complexity of the system, and the difficulties associated with dewatering waste activated sludge, indicate that for most application, the best actvated sludge system for the seafood industry would be the "extended aeration" modification. The extended aeration process is similar to the conventional activated sludge process, except that residence time in the aeration chamber is longer. The common detention time for extended aeration is one to three days, in contrast to the conventional six hours. This prolonged contact between the sludge and raw wastes provides ample time for the organic matter to be assimilated by the sludge and also for the organisms to metabolize the organics, allows for substantial removals of organic matter. In addition, the organisms undergo considerable endogenous respiration, which oxidizes much of the cellular biomass. During this phase of the growth curve (see Figure 31), metabolism plays a much more significant role than during the "logarithmic growth" phase, when cellular reproduction is dominant. Maintenance of significant endogenous respiration assures

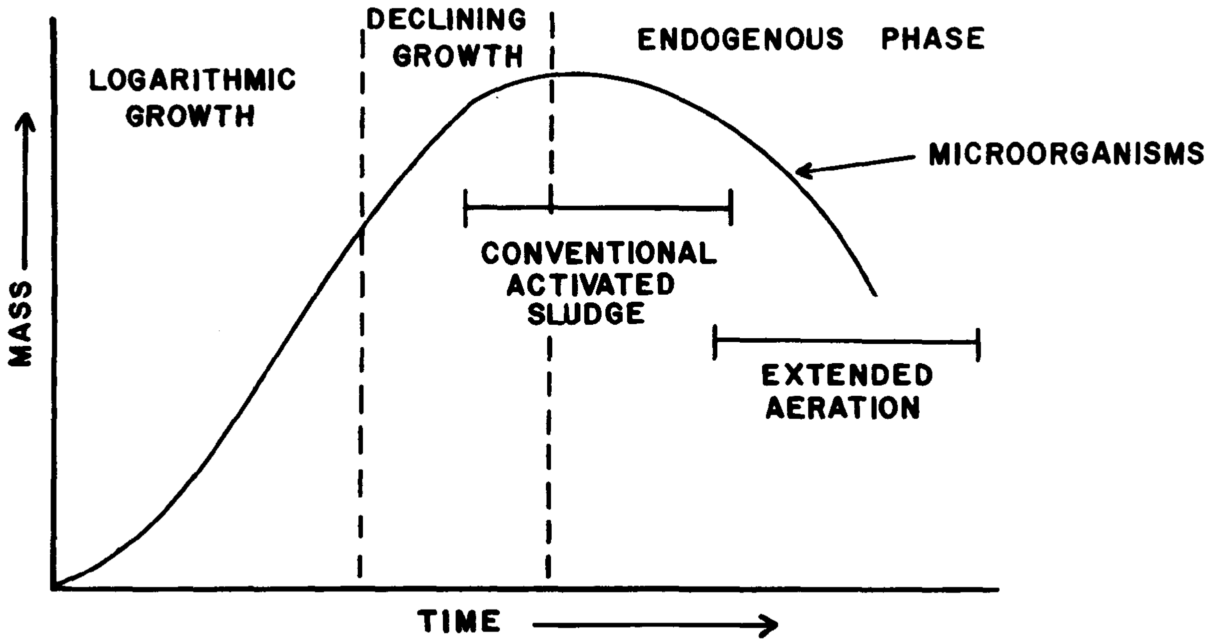


Figure 31. Phases of biological growth.

minimum accumulation of excess biomass. As a result, less sludge is produced and little is discharged from the system as waste activated sludge.

In extended aeration, as in the conventional activated sludge process, it is necessary to have a final sedimentation tank. The solids resulting from extended aeration are finely dispersed and settle slowly, requiring a long period of settling (hence larger sedimentation tanks). The system is relatively resistant to shock loadings, provided the clarifier has sufficient storage to prevent the loss of biomass during flow surges. Clarifiers can be built with additional storage area and adjustable overflow wiers to absorb flow surges. Extended aeration, like other activated sludge systems, requires a continuous flow of wastewater to nurture the microbial mass. The re-establishment of an active biomass in the aeration tank requires from several days to a few weeks if the unit is shut down or the processing plant ceases to operate for significant periods of time.

Both treatment units are available in all size ranges. It is unlikely that activated sludge will prove to be the most cost effective treatment where 1) processing is intermittent, or 2) plant flows are so large that alternative systems of suitable scale are available. The wide variation in quality of the small package extended aeration systems now available dictates careful selection of the equipment if the process is to approach the removals now achieved by well-operated municipal systems.

Figure 32 contains cost curves for initial capital costs of extended aeration systems. The curve was generated on the basis of flow (gpm) and daily processing time. Figure 32 also shows the operation and maintenance costs of extended aeration systems for various operating day lengths.

Depending on the efficiency of operation, extended aeration systems can typically achieve 80 to 90 percent reductions in BOD.

2.3.2. Rotating Biological Discs

The next biological treatment system to be discussed is the Rotating Biological Contactor (RBC), or Biodisc unit. This consists of light-weight plastic discs approximately 1.3 cm (0.5 in) thick and spaced 2.5 to 3.8 cm (1 to 1.5 in) on centers. The discs, to 3.4 m (11 ft) in diameter, are mounted on a horizontal shaft and partially submerged in a semicircular tank through which the wastewater flows. Clearance between the discs and tank wall is 1.3 to 1.9 cm (0.5 to 0.75 in). The discs rotate slowly, in the range of 5 to 10 rpm, passing the disc surface through the incoming wastewater. Liquid depth in the tank is kept below the center shaft of the discs. Reaeration is limited by the solubility of air in the wastewater and rate of shaft rotation.

Shortly after start-up, organisms begin to grow in attached colonies on the disc surfaces, and a typical growth layer is usually established within a week. Oxygen is supplied to the organisms during the period when the disc is rotating through the atmosphere above the flowing waste stream. Dense biological growth on the discs provide a high concentration of active organ-

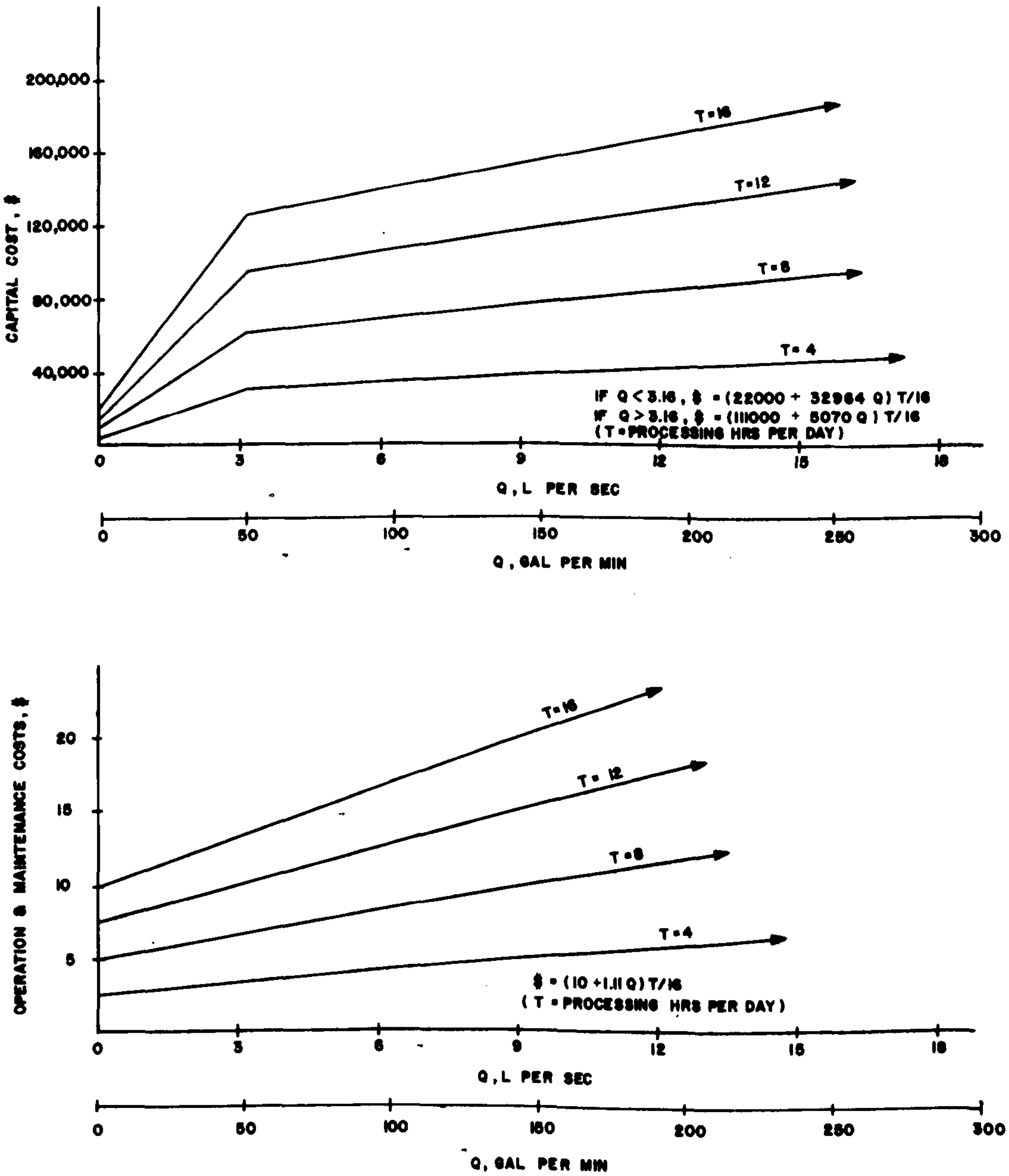


Figure 32. Capital and operating/maintenance costs for typical extended aeration activated sludge systems (Environmental Associates, Inc., 1974).

isms resistant to shock loads. Periodic sloughing produces a floc which settles rapidly; the shear-forces developed by rotation prevents disc media clogging and keeps solids in suspension until they are transferred out of the disc tank and into the final clarifier. Normally, sludge recycling shows no significant effect on treatment efficiency because the suspended solids in the mixed liquor represent a small fraction of the total culture when compared to the attached growth on the disc.

Removal efficiency can be increased by providing several stages of discs in series. European experience on multi-stage disc systems indicates that a four-stage disc plant can be loaded at a 30 percent higher rate than a two-stage plant for the same degree of treatment. Because the BOD removal kinetics approach those of a first order reaction (see Figure 33) the first stage should not be loaded higher than 120 g BOD/day/sq m disc surface. If removal efficiencies greater than 90 percent are required, three or four stages, depending on the flow, waste load, and disc surface area, should be installed. Mixtures of domestic and food processing wastes in high BOD concentrations can be treated efficiently by the RBC-type system.

Because 95 percent of the solids are attached to the disc system, the RBC unit is less sensitive to shock loads than activated sludge units, and for the most part is not upset by variations in hydraulic loading. Waste loads high enough to deplete the dissolved oxygen in the water can stress aerobic organisms; anaerobic conditions can result with production of malodorous gases. This can be avoided by pre-aerating the wastewater.

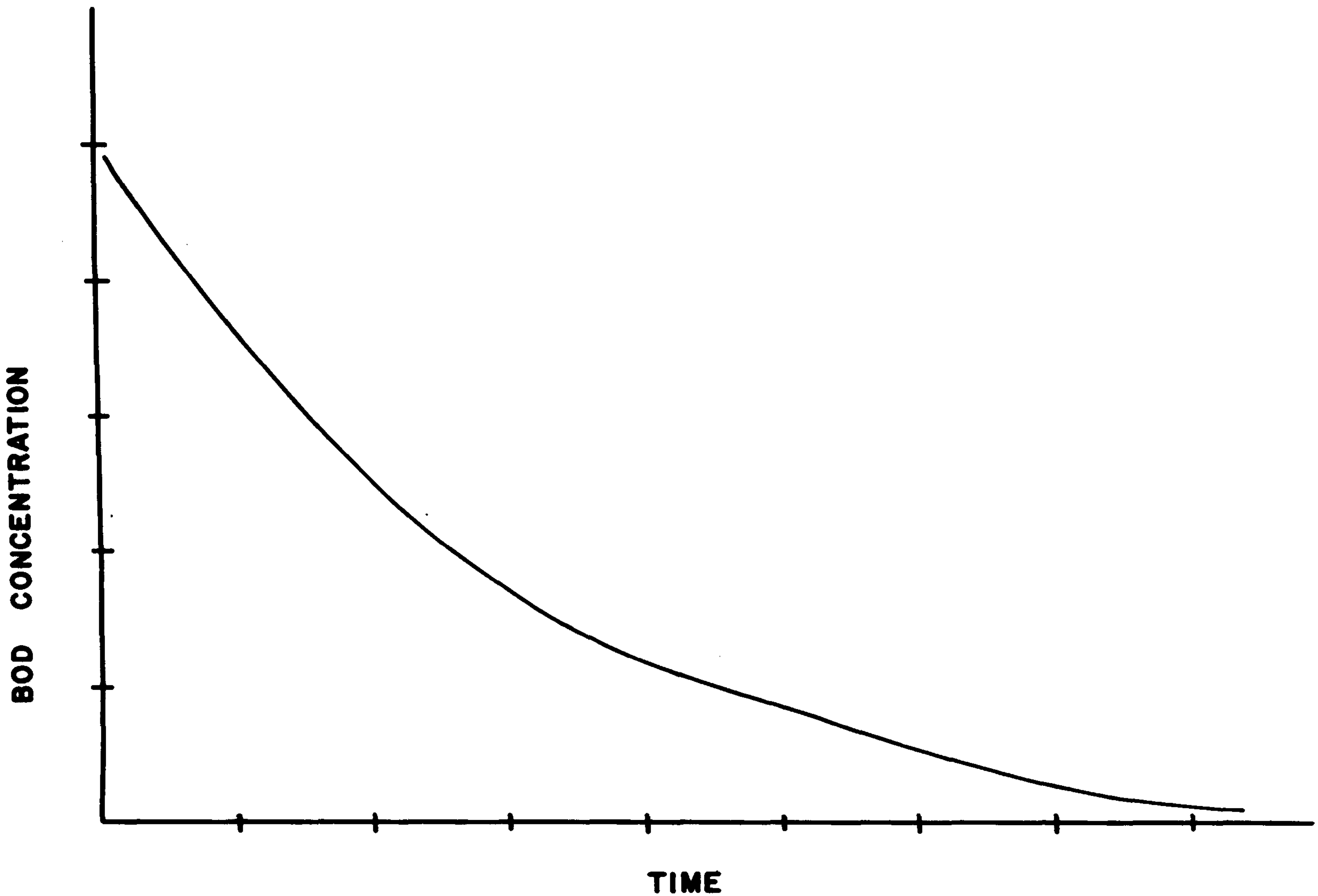


Figure 33. BOD removal curve for hypothetical biological treatment system.

Secondary benefits of the pre-aeration tank would include the dampening of pH, temperature, and organic peaks. During low flow periods the RBC unit yields effluents of higher quality than at design flow. During periods of no flow, effluents can be recycled for a limited time to maintain biological activity.

Both the Rotating Biological Contactor and the trickling filter process (discussed below) utilize an attached culture. However, with the rotating disc the biomass is passed through the wastewater rather than wastewater over the biomass. Continuous wetting of the entire biomass surface also prevents fly growth, often associated with conventional trickling filter operations.

The RBC process requires housing to protect the biomass from exposure during freezing weather and from damage due to heavy winds and precipitation. F.G. Claggett (1973) reported COD removals greater than 50 percent with a RBC unit treating salmon cannery wastewater.

2.3.3. High Rate Trickling Filter

Trickling filter consists of a vented structure containing a packed bed of media, which can be either rock, Fiberglas, plastic, or redwood material on which a growth of microorganisms develops (see Plate 3). Microbial growth is in the form of a slime. As wastewater flows downward over the structure the microbial mass assimilates and metabolizes the organic matter. The biomass continuously sluffs and is readily separated from the liquid stream by sedimentation. The resulting sludge requires

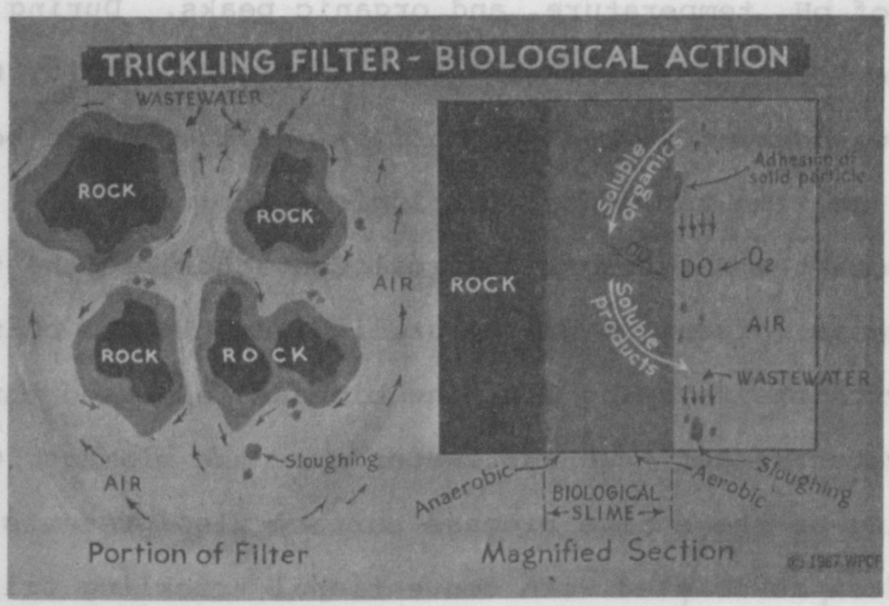


Plate 3. Trickling filter - biological action.

Plate 4. Surface view of a typical trickling filter with rock media.

further treatment and disposal, as described previously.

Artificial media promotes air circulation, and reduces clogging. As a result, artificial media beds can be over twice as deep as rock media beds and have correspondingly longer contact times. Longer contact times and recirculation of liquid flow enhance treatment efficiencies. The recirculation of settled sludge with the liquid stream is also claimed to improve treatment.

Typical systems, pictured in Plates 4 and 5 are simple to operate, the sole operational variable being recycle rate. The treatment efficiency of a well-designed deep-bed trickling filter tower of 14 feet or more with high recycle can be superior to that of a carelessly-operated activated sludge system. The system is not particularly sensitive to shock loadings, but is severely impaired by wastewater temperatures below 7°C (45°F). Below 2°C (35°F), treatment efficiency is minimal. The effect of grease and oil in trickling filter influent has not been evaluated; this would likely be detrimental. High-rate trickling filters can provide up to 85 percent reduction of BOD and influent wastewater. At this time, no cost data are available for high-rate trickling filters for the seafood industry.

2.3.4. Ponds and Lagoons

Aerated lagoons and basins of significant depth, 6 to 12 feet, in which oxygenation is accomplished by mechanical (Plate 6) or diffused aeration units. Oxidation ponds and facultative lagoons utilize natural aeration. The land requirements for ponds

Plate 5. Trickling filter with synthetic media.
(courtesy of Surfpac).

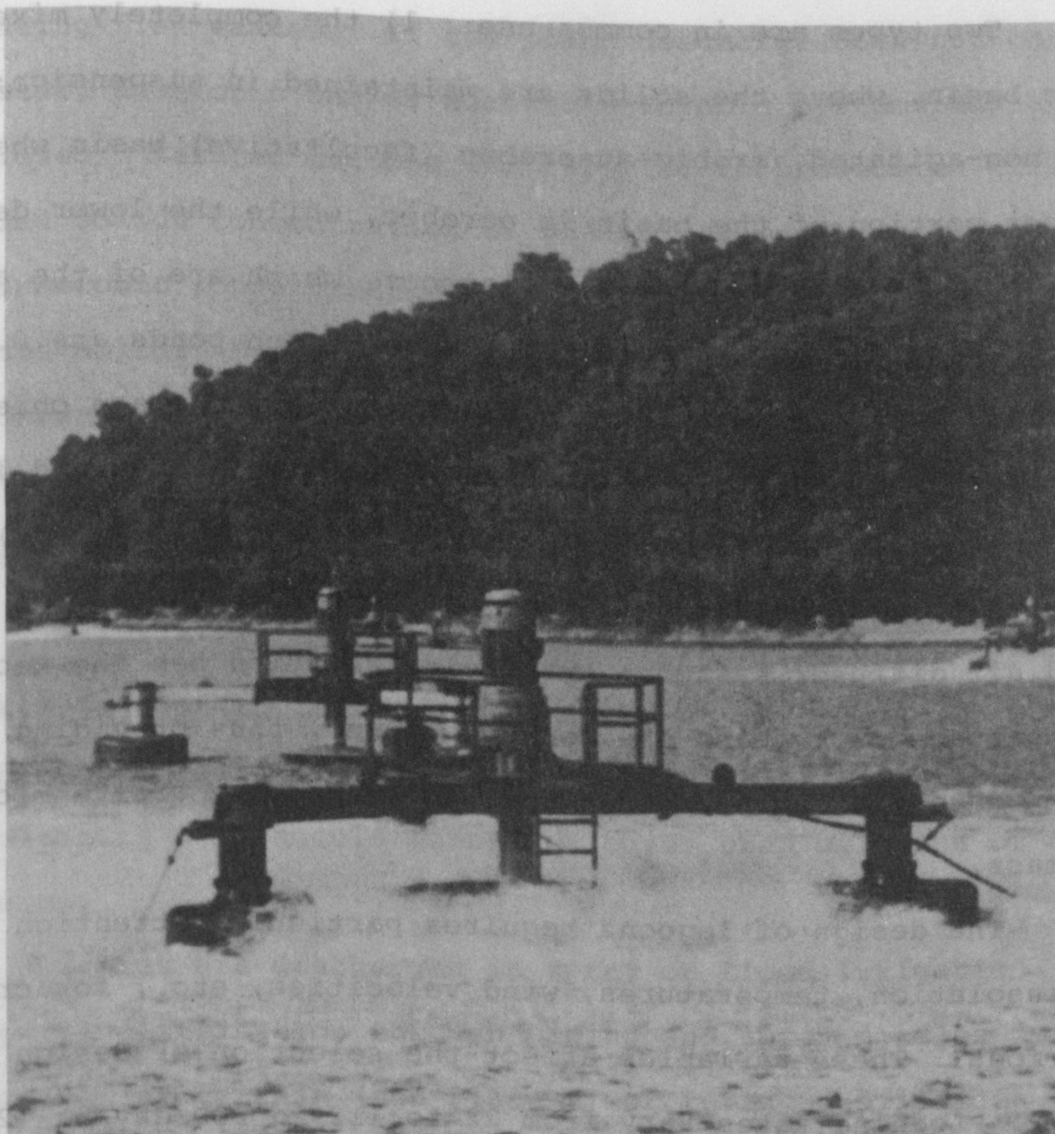


Plate 6. Aerated lagoon (courtesy Eimco Co.).

and lagoons limit the locations at which these facilities are practicable. Where conditions permit, they can provide reasonable treatment alternatives.

Two types are in common use: 1) the completely mixed aerobic basin, where the solids are maintained in suspension; 2) the non-agitated aerobic-anaerobic (facultative) basin where the upper portion of the basin is aerobic, while the lower depths are anaerobic. Naturally aerated lagoons, which are of the aerobic-anaerobic type are termed oxidation ponds. Such ponds are 0.9 to 1.2 m (3 to 4 feet deep), with oxidation taking place chiefly in the upper 0.45 meters (18 inches). Mechanically-aerated lagoons are mixed ponds over 1.8 m (6 feet) and up to 6.1 m (20 feet) deep, with oxygen supplied either by a floating aerator or a compressed air diffuser system. Artificial aeration has the secondary advantage of keeping the contents mixed, thus providing maximum contact between the organic matter and the active biological mass.

The design of lagoons requires particular attention to local insolation, temperatures, wind velocities, etc., for critical periods. These variables affect the selection of design criteria. Loading rates vary from 22 to 112 kg BOD/day/ha (20 to 100 lb/day/acre), and detention time, from 3 to 50 days.

Although not frequently used in the fish processing industry, lagoons are in common use in other food processing industries. Serious upsets can occur. The oxidation pond may produce great quantities of algae and the aerated lagoon may turn septic in zones of minimal mixing. Recovery from such upsets may take weeks. The major disadvantage of lagoons is the large land requirement. In regions where land is available and soil conditions make excavation feasible, the aerobic lagoon should find application in treating fish wastes. If the plant discharge does not contain salt water, anaerobic and/or anaerobic-aerobic systems may also be utilized. Aerated lagoons are reported to produce an effluent suspended solids concentration of 260 to 300 mg/l (mostly algae) while anaerobic ponds produce an effluent with 80 to 160 mg/l suspended solids (Metcalf and Eddy, 1972). Figure 34 shows the costs versus flow relationship for aerated lagoons.

2.4. Land Disposal of Wastewater

"Zero-discharge" technology is practicable where land is available upon which the processing wastewaters may be applied without jeopardizing groundwater quality. The site, surrounded by a retaining dike should sustain a cover crop of grass or other vegetation.

Wastes are discharged in spray or flood irrigation systems by 1) distribution through piping and spray nozzles over relatively flat terrain (see Plate 7) or terraced hillsides of moderate slope; or 2) pumping and disposal through ridge-and-furrow irrigation systems which allow a certain level of flooding on a given plot of land. Pretreatment for removal of solids is advisable to prevent plugging of the spray nozzles, or deposition in the furrows of a ridge-and-furrows system, which may cause odor problems or plug the soil.

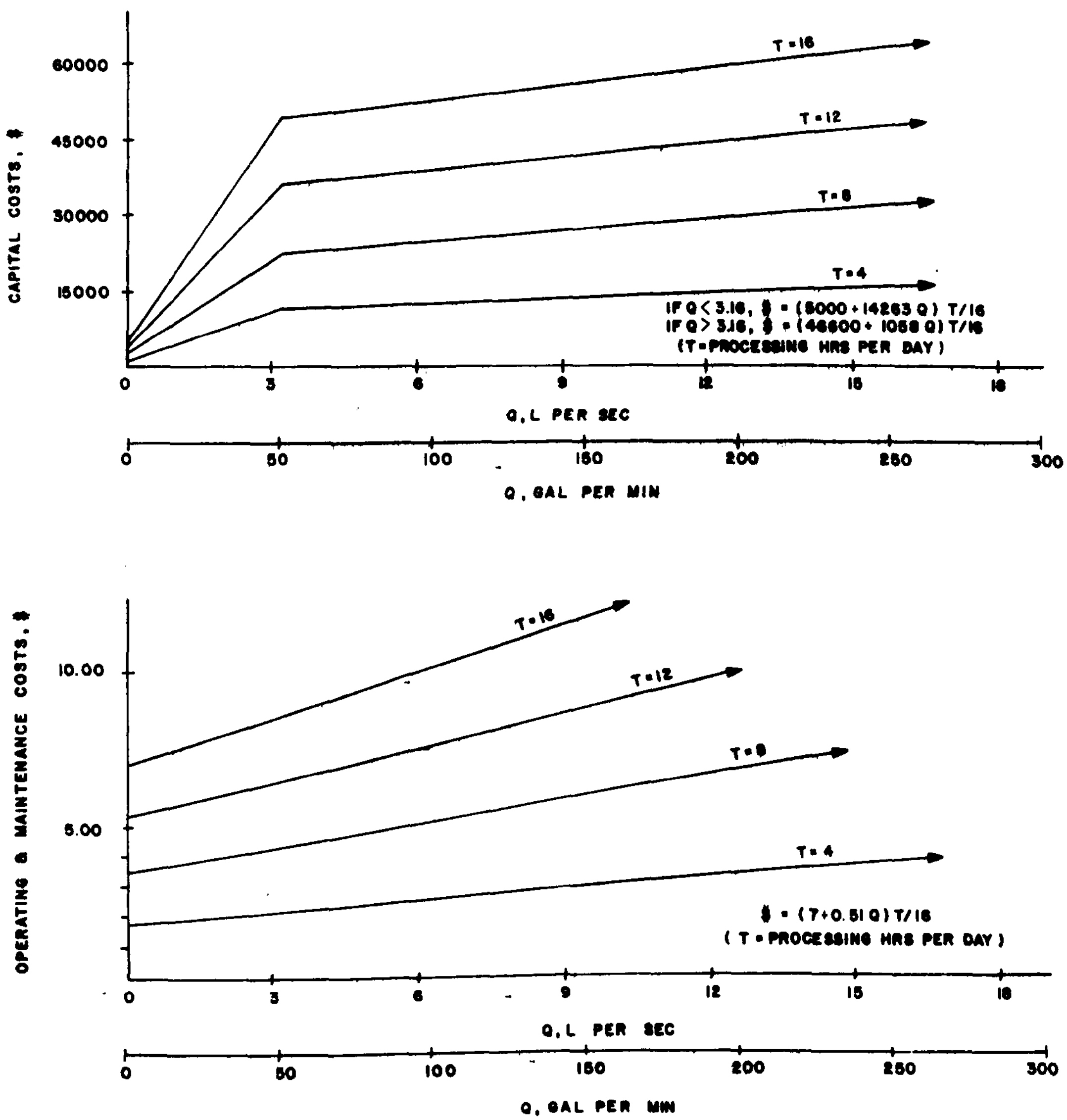


Figure 34. Capital and operating/maintenance costs for typical aerated lagoon systems (Environmental Associates, Inc., 1974).

Plate 7. Spray irrigation disposal system (courtesy Cape May Canning Co.).

In a flood irrigation system the waste loading in the effluent would be limited by the waste loading tolerance of the particular crop being grown on the land. It may also be limited by the soil conditions or potential for vector or odor problems.

Wastewater distributed in either manner percolates through the soil where the organic matter in the waste undergoes biological degradation. The liquid in the waste stream is either stored in the soil or passed into the groundwater. A variable percentage of the waste flow is also lost by evapotranspiration (the loss due to evaporation to the atmosphere through the leaves of plants). The following factors affect the ability of a particular land area to absorb wastewater: 1) character of the soil, 2) stratification of the soil profile, 3) depth to groundwater, 4) initial moisture content, 5) terrain and groundcover, 6) precipitation, 7) temperature, and 8) wastewater characteristics.

The greatest concern in the use of irrigation as a disposal system is the total dissolved solids content and especially the sodium content of the wastewater. Salt-water waste flows are incompatible with land application technology at most sites. Limiting values for total dissolved solids (TDS) which may be exceeded for short periods but not over an entire growing season were estimated (conservatively) (Talsma and Phillip, 1971) to be 450 to 1000 mg/l. Where land application is feasible it must be recognized that soils vary widely in their percolation properties. Experimental irrigation of a test plot is recommended in untried areas. Cold climate systems may be subjected to additional constraints, including storage needs.

The long-term reliability of spray or flood irrigation systems depends on the sustained ability of the soil to accept the wastewater. Problems in maintenance include 1) controlling salinity levels in the wastewater; 2) compensating for climatic limitations; and 3) sustaining pumping without failure. Many soils are improved by spray irrigation. Certain nutrient accumulations in the soil complex can be eliminated by physically removing or harvesting crops.

Removal efficiencies for this type of treatment are difficult to measure, but are assumed to be 100 percent by definition. Associated costs include pumps, piping, and spray nozzles. Maintenance and operating costs are at a minimum with this system.

2.5. Solids Disposal Methods

Disposing of the solid waste, generated by screens, biological systems, or one of the air flotation methods, is often a problem. Where reduction or other solid fish waste processing plants are not close by, other methods of solid waste disposal must be considered. The methods thought to be most practical for the seafood industry are sanitary landfill, land disposal, deep sea disposal, and incineration.

2.5.1. Sanitary Landfill and Land Disposal

Land disposal has in one form or another (often simply the open dump) been used as the mainstay of solid waste disposal since solid wastes became a problem. The only acceptable form of land disposal, however, is the sanitary landfill. Few land disposal operations across the U.S. today meet the criteria of a sanitary landfill, although they may carry the name. Moreover, many sites cannot meet the criteria without substantial design modifications.

The use of land disposal for such highly putrescible wastes as those from seafood processing requires sanitary landfills with daily cover and treatment of leachates. Without these conditions, found in well-operated and designed sanitary landfills, land disposal has substantial negative impacts on surrounding lands through attraction of rodents nd insects, emission of odors, and pollution of surface and subsurface waters. Land disposal can be an economical option if careful site selection is practiced and the site is properly engineered to take into account resulting environmental effects (Dehn, 1974).

2.5.2. Deep Sea Disposal

In addition to placement in or on the land, another ultimate disposal alternative is dispersion in the waters. Ocean disposal itself has come under considerable scrutiny over the past year. New federal legislation provides for closer supervision of ocean disposal by the federal government. Whether through an outfall directly from the cannery or via barging to deep sea sites, arguments in favor of this option center around the fact that it returns nutrients to the sea for the further support of marine life. Deep-sea disposal is costly in terms of equipment, particularly if large quantities of waste are involved and the cannery is distant from acceptable disposal areas. Grinding and out-fall discharge to deep water is more economical and can achieve adequate dispersion of solids to avoid substantial impacts on dissolved oxygen levels in receiving waters. No further solids disposal is needed with either of these methods.

Grinding and disposing of wastes in shallow, quiescent bays has been practiced in the past, but will undoubtedly be discontinued. Disposal depths of less than 13 m (7 fathoms), particularly in the absence of vigorous tidal flushing, may be expected to have detrimental effects on the marine environment and the local fishery, whereas (generally) a deep disposal site would not.

The identification of suitable sites for this practice undoubtedly demands good judgment and detailed knowledge of local conditions. Used in the right manner, however, deep sea disposal is an efficient and cost-effective technique second only to direct solids recovery and by-product manufacture.

2.5.3 Incineration

No known incineration of seafood solid wastes is currently being practiced. Incineration by means of multiple hearth furnaces has been effective with municipal wastes and sludges, when operated on a continuous basis. Intermittent start-up and shut-down is inefficient and shortens the useful life of the equipment. A technique for incinerating solid wastes in a molten salt bath is under development, with one unit in operation. The by-products are CO_2, water vapor, and a char residue which is skimmed from the combustion chamber. This device may prove to be viable in reasonably small units (Lessing, 1973). Pit incinerators have been used for many solid and semi-solid wastes and may be useful in disposing of seafood wastes. The incinerators are brick lined and have air supplies to aid particulate retention and ensure complete combustion. This disposal method is simple to operate and especially adaptable to situations requiring batch incineration (Nemerow, 1971).

Processing by incineration is popular for many types of waste materials and can be economical if wastes are relatively dry and contain substantial fuel value. Neither of these conditions is met by wastes from seafood processing, and additional costs might be incurred in waste processing and use of supplemental fuel. More stringent air pollution regulations may require costly additions to an incineration process for seafood wastes to eliminate odors from waste stack gases. Incombustible residues must still be landfilled or disposed at sea.

2.6. Waste Treatment Case Studies

Information on full-scale and pilot plant installations of waste treatment systems in the seafood industry is not plentiful. The main reasons for this are two fold: 1) many firms regard their waste treatment system performance and cost data proprietary; and 2) only a small percentage of firms processing fish and shellfish in the U.S. practice wastewater treatment to a significant extent.

Whenever possible, the organizers of this Technology Transfer Seminar attempted to arrange for the participation on the program of individuals with intimate knowledge of specific case studies. Accordingly, among the speakers at the seminar (and authors in this document) are: 1) Mr. Frank Mauldin of the engineering firm of Dominque, Szabo and Associates, Inc. (La Fayette, Louisiana), discussing the performance of a dissolved air flotation unit treating shrimp canning wastes at the Robinson Canning Company in Westwego, Louisiana; 2) Mr. Fred Claggett of the Canadian Environmental Protection Service, discussing tangential screening and dissolved air flotation of salmon and herring wastewaters at B.C. Packers' plant in Steveston, B.C.; and 3) Mr. Irving Snyder of the Carborundom Corporation discussing dissolved air flotation treatment of menhaden wastewaters at the Standard Products Company plant in Reedville, Virginia; dissolved air flotation treatment of shrimp processing wastewaters at the NEFCO plant in Kodiak, Alaska and dissolved air flotation treatment of crab processing wastewaters at the Roxanne Seafoods plant in Kodiak, Alaska. In the following paragraphs, additional case studies are discussed.

2.6.1. Case Study Number 1: Tangential Screening of Shrimp Processing Wastewater (Peterson, 1973b)

The National Marine Fisheries Service conducted a test in mid-1972 to analyze the performance of gravity-fed tangential screens in removal of solids from shrimp processing wastewaters at a plant in Kodiak, Alaska. A plant was selected which incorporated typical processing operations so that representative results could be obtained. The equipment selected consisted of Bauer Hydrasieves with equivalent openings of 30 mesh (0.040 inch). One 6 ft wide and one 18 inch wide screen was used. Effluent was pumped or flumed from discharge sumps or troughs.

The test was conducted at East Point Seafoods Company on July 14, 1972. This plant used Laitram Model A peelers in its shrimp canning operation (depicted in Figure 35). Plant flows averaged 900 gpm of which all intake water was fresh water. The 6 foot wide screen was used, and the wastewater was added at the top of the feed hopper (as opposed to the normal design of pumping it in at the bottom). The reductions obtained are tabulated in Table 81.

Table 81. Screening study results - shrimp processing wastewaters (Peterson, 1973b)

	Before Screening	After Screening	% Reduction
Total COD	2734 mg/l	2360 mg/l	14
Total solids	2680 mg/l	1900 mg/l	29
Total susp. solids	1160 mg/l	720 mg/l	38
Settleable solids	50-55 ml/l	6 ml/l	85
Turbidity	200-230 jtu	180-207	10

2.6.2. Case Study Number 2: Dissolved Air Flotation Treatment of Sardine Processing Wastes

In 1971 the Maine Sardine Council retained the Edward C. Jordan Company (Atwell, *et al.*, 1972) to study sardine

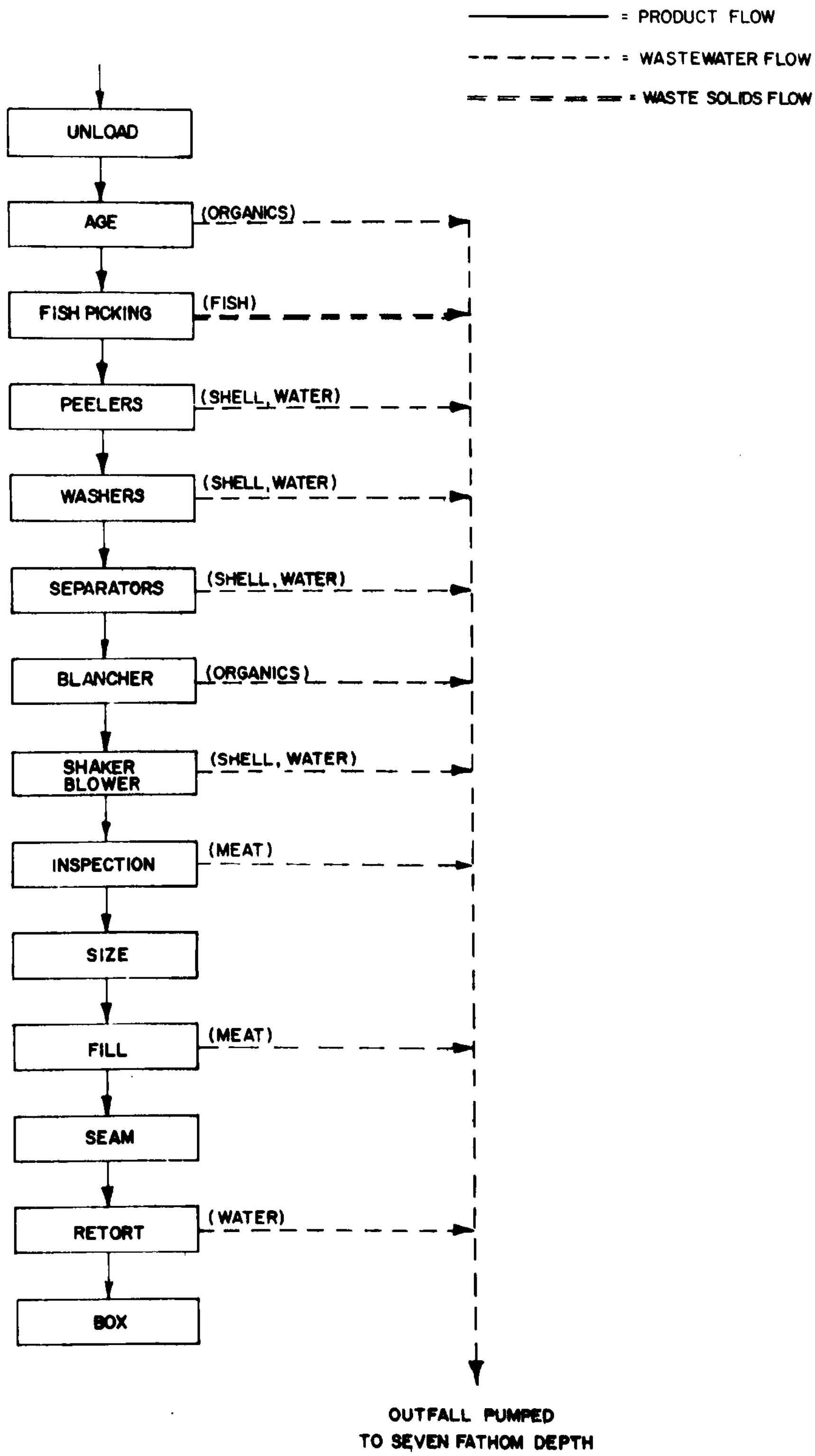


Figure 35. Alaska and west coast shrimp canning process (Environmental Associates, Inc., 1973).

processing wastewater and evaluate treatment systems applicable to such waste. Various systems were set up at the Stinson Canning Company in Prospect Harbor, Maine to test its performance on sardine packing wastewaters.

The plant selected utilized the typical sardine process. The wastewater was characteristically high in grease and oil, the principal source of which was the pre-cook operation. The total composition of the plant's effluent is tabulated in Table 82.

Table 82. Sardine processing wastewater, industry average (mg/l).

BOD_5	COD	Total solids	Susp. Solids	Oil and grease
750	1850	32,500	600	400

Wastewater quantities depend on in-plant conservation practices from plant to plant. However, a working average is from 135,000 to 155,000 gallons per day.

The initial investigation of the wastewater treatability determined the presence of large quantities of large solid particles which could be easily screened from the flow. Preliminary testing of several screen designs indicated that tangential screen with 0.040 inch openings gave the most satisfactory results. Removals of 16-37 percent of the suspended solids and 14 percent of the BOD were achieved with this screen. Thus, a Bauer Hydrasieve tangential screen was incorporated in the test plant to pre-treat the effluent before subsequent treatment.

In attempting to find the most effective subsequent treatment system, the consultants had to deal with several factors affecting the sardine industry. Sardines are very seasonal and during the short season landings are erratic. Thus, waste flows are highly variable from day to day. In addition, the processes use large volumes of seawater, which severely affects biological treatment. It was decided, therefore, that a non-biological system must be found which could handle the wide fluctuations in waste flow. Based on these criteria, dissolved air flotation was determined to be the system of choice.

Two models of equipment were erected at the sardine plant, one designed by Pollution Control Engineering and one by CE NATCO. During the testing, the PCE unit performed as expected. The CE NATCO unit had mechanical difficulties and was not as effective. Little work was done on optimization of chemicals for most efficient removal. Alum was added at 200 ppm and a polymer was used at 2 ppm during the tests. Table 83 indicates the approximate removal efficiencies obtained during the tests.

Table 83. Dissolved air flotation and removal efficiencies on sardine processing wastewater.

BOD	Susp. solids	Oil and grease
57-71%	91-98%	80%

In summary, it was found that air flotation equipment was the most practicable method of treatment of sardine wastewater. Its ability to treat a wide range of waste flows and loadings, its relative insensitivity to saline wastes and "shock" loads, its relatively low cost and minimal land requirements make it the system of choice in the Maine sardine industry.

2.6.3. Case Study Number 3: Dissolved Air Flotation Treatment of Tuna Processing Wastes

A study was conducted to evaluate various wastewater treatment systems in treating tuna cannery waste. Treated effluent was to be brought to a level commensurate with government standards imposed on the plant. A short testing period was necessary to get the plant operating as soon as possible within the imposed limits, so the usefulness of the ata is somewhat attenuated by its brevity.

The plant processed tuna through a fairly typical operation, as depicted in Figure 36. Wastewater was generated by the operations depicted in the diagram. Several in-plant process changes were considered to decrease water usage. These changes were thought to change the total plant effluent character, so for the purposes of these tests, butcher sump water was used.

In evaluating the treatment systems and equipment for this project, several criteria were of primary importance. First, space requirements had to be minimized due to a lack of sufficient low-value land on which to construct a facility. Secondly, cost had to be minimized while still retaining a high removal efficiency. Since the treatment system was non-profitable to the plant, a large expenditure could not be justified. Finally, the unit

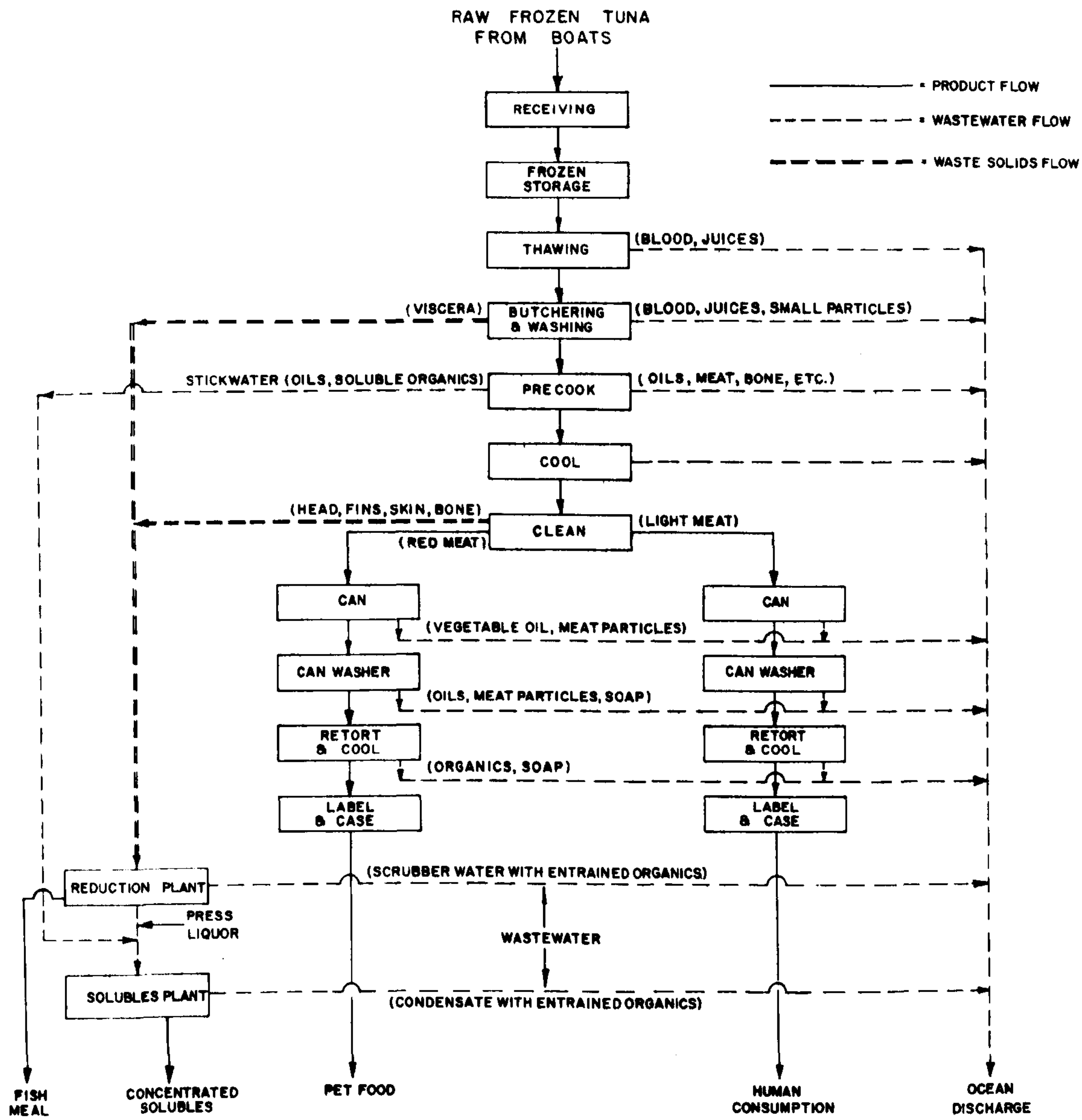


Figure 36. Tuna process (Environmental Associates, Inc., 1973).

selected must be flexible to handle changing waste loads resulting from future plant modification.

After preliminary investigation, the choice was narrowed to either dissolved air flotation or dispersed air flotation. Pilot scale equipment of each design was obtained and installed at the plant to treat the effluent from the butcher sump. The dispersed air flotation unit was a Depurator unit made by the Wemco Division of Envirotech. The dissolved air flotation system was a Flotator unit manufactured by the Eimco Division of Envirotech. In these systems, various chemicals were added to promote flocculation of suspended solids in the waste. For this study, several combinations of chemicals, consisting of alum, lime, ferric chloride and polymer products were tested on each system by conducting several extended pilot runs, each time using a different chemical combination. The effluents from the equipment were compared with the influent waste.

Based on three important wastewater parameters, (suspended solids, BOD, and oil and grease) the dissolved air flotation unit proved to be superior in terms of removal efficiency. It yielded average total removals of 60-66 percent, depending on the chemicals used. The dispersed air flotation unit did not produce similar results. Both systems produced highly variable and unsatisfactory results when operated without chemical additions.

In conclusion, it was found that dissolved air flotation would be the system of choice in this case due to its combination of low space requirement, flexibility of operation, relatively low cost, production of a more concentrated (and thus less voluminous) sludge, and production of an oxygen saturated effluent.

2.6.4. Case Study Number 4: Biological Treatment of Oyster Processing Wastes

The Ray J. Jones Seafood Company of Wittman, Maryland, in conjunction with the Maryland Water Resources Administration, conducted an on-line commercial test of a biological treatment system beginning in March of 1973. The plant processes hand-shucked oysters, blue crab, and some clams, and the treatment system was to be tested on the wastewater effluents from all three processes during 1973. Preliminary results are available for the oyster process and they indicate the system performs well.

The hand-shucked operation at the R.J. Jones plant is fairly typical of small oyster processors. The blowdown tanks and the shucking and washdown operations produce pracically all the wastewater, which, on a typical day of processing, amounts to approximately 2000 gal. This small waste flow makes most waste-water treatment systems difficult to operate and prohibitively costly to purchase.

For small processors such as this, treatment systems must be found which can meet several important criteria:

1) low cost - large expenditures required for waste treatment would simply put these processors out of business;

2) ease of operation - constant monitoring and maintenance of a waste treatment system cannot be economically justified by small processors, and

3) small size - many processors have limited land on which to construct treatment systems.

Preliminary analysis of the wastewater from the plant indicated that it was amenable to biological treatment. A review of available equipment and system designs indicated that an extended aeration system would probably be the design most capable of meeting the requirements.

A small package plant mounted in a 32 foot van was manufactured by the Cromoglass Corporation for use in this test. It consisted of a 900 gallon aerated "roughing" tank, a 1250 gallon settling tank, and a small chlorine contact chamber. Chlorination was supplied by solid tablets (sodium hypochlorite) added to the tank. Influent from the plant was screened through rough basket screens and pumped into the system. The capital cost of the system was $7000. Daily maintenance was minimal, requiring only screen cleaning and chlorine tablet addition. The whole unit was contained within the van.

Preliminary results indicate effective reduction of waste loadings using this system. The prime waste consists of dissolved and suspended organic matter, measured as BOD. Untreated effluent BOD levels of 400 to 1200 mg/l (ppm) were common. After treatment, BOD levels averaged approximately 160 mg/l. Overall BOD reductions averaged 80-90 percent.

This method of treatment fits the needs of small processors fairly well. It might be used to treat economically a wide variety of seafood wastes if conditions warrant its use.

2.6.5. Case Study Number 5: Centrifugal Wastewater Concentrator Treatment of Shrimp Wastes.

Environmental Associates, Inc., and the National Marine Fisheries Service conducted a study using the SWECO centrifugal wastewater concentrator at East Point Seafoods' South Bend Washington plant. The plant employs two Model A and two Model PCA Laitram peelers.

A positive displacement pump was used to pump the wastestream to the 0.020 inch Bauer Hydrasieve. Alum (220 ppm) and lime (250 ppm) were added to the screened effluent in the contact chamber. The slurry was then pumped through the SWECO concentrator (400 mesh) and into a skimming trough. Approximately 20 percent of the flow used to backwash the screen was discharged with the solids. In the skimming trough, the highly aerated wastewater was allowed sufficient retention time for the bubbles to float the solids to the surface. These solids were removed by a skimming mechanism.

The results of this study are shown in Table 84.

Table 84. Removal efficiencies of the screen, SWECO wastewater concentrator and skimming tank with and without chemical addition.

Parameter	Influent-mg/l (includes shell)	Removal Efficiencies (%)		
		After Sieve	After skimming trough	
			Without chem.	With chem.
Susp. Solids	1020	35	52	95
BOD	1320	18	24	81
COD	2160	13	28	75
Oil & Grease	80	--	--	85
Set. Solids (ml/l)	45	84	99	--

3. TREATMENT SYSTEM COSTS

3.1. Assumptions

Certain assumptions were necessary prior to development of the cost analyses for the treatment systems. These assumptions, the length of the processing day and processing season, the production and water use rate, and the water used per unit of product, are listed at the top of each table. Any deviations from these assumptions would vary the costs correspondingly. Theoretical effluent (BOD, suspended solids, and grease and oil) levels after application of each treatment system are also listed in each table. Plant location, plant and equipment age, variations in unit processes and waste treatment systems presently in use are also pertinent to the costs and are enumerated briefly for each process/product subcategory.

With respect to the tables, the costs of the treatment systems 1, 2, 3, 4 are cumulative. That is, the costs listed under number 2 are actually the costs of system 1 plus system 2. All cost data were based on the most recent Environmental Associates' study (1974) of the seafood industry.

3.2. Industrial and Finfish

3.2.1. Fish Meal

Fish meal plants are found with and without solubles plants. The large plants (those processing around 170,000 tons/year) usually have a solubles plant that evaporates the stickwater, bailwater and washwater. These plants use available surface water to draw a vacuum on barometric condenser. Presently, condenser water usually is used for one pass only before discharge to the source. If a cooling system is installed, the water can be recirculated through the system. A recirculation system with trickling filter was priced for a typical plant at about $325,000 capital costs with annual O and M costs of $16,500. Table 85 estimates the costs to install and operate either an extended aeration or aerated lagoon system at a fish meal with solubles plant.

Some of the smaller fish meal plants evaporate the stickwater but discharge the bailwater. Either the solubles plant can be enlarged to facilitate the bailwater or the bailwater can be treated separately. Table 86 shows the costs associated with treating bailwater from a typical plant.

The small fish meal plants usually do not have a solubles plant, these plants typically discharge both stickwater and bailwater. Barging is a disposal option that costs $0.010425 per gallon based on a 50-mile round trip. If the stickwater is barged, then only the bailwater requires treatment consideration. If the stickwater is not barged, it too must be treated.

The strength of stickwater without pretreatment makes the amenability of it to standard treatment very questionable. The University of Wisconsin (Quigley, 1972) performed a laboratory study on treatment of stickwater from the alewife reduction industry. They found coagulation with chemicals followed by filtration to be a plausible system. They estimated the equipment

TABLE 85. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : FISH MEAL WITH SOLUBLES PLANT

OPERATING DAY	22.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	38.6 TON/HR
	35.0 KKG/HR
PROCESS FLOW	1500.0 GPM
	94.7 L/SEC
HYDRAULIC LOAD	2333.8 GAL/TON
	9.7 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	892.	202.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	71.	16.
DEPRECIATION @ 10%	89.	20.
DAILY COSTS($)		
O&M	158.	76.
POWER	1.	1.
TOTAL ANNUAL COSTS($1000)	192.	52.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	60.	80.
-KG/KKG	0.58	0.78
TSS-MG/L	29.	34.
-KG/KKG	0.28	0.33
G&O-MG/L	38.	38.
-KG/KKG	0.37	0.37

TREATMENT SYSTEMS

1 EXTENDED AERATION

OR

2 AERATED LAGOON

Table 86. Water effluent treatment costs canned and preserved fish and seafood

Subcategory: Fish meal without solubles plant

Operating day	22.0 hours
Season	200.0 days
Production	8.2 ton/hr
	7.4 kkg/hr
Process flow	100.0 gpm
	6.3 l/sec
Hydraulic load	30.3 gal/ton
	0.1 cu m/kkg

Treatment system	1	2
Initial investment ($1000)	564.	105.
Annual costs ($1000)		
Capital costs @ 8%	45.	10.
Depreciation @ 10%	56.	12.
Daily costs ($)		
O & M	48.	145.
Power	1.	5.
Total annual costs ($1000)	111.	51.

Parameter	Resulting effluent levels	
BOD - mg/l	11396.	90.
kg/kkg	1.42	2.90
TSS - mg/l	2933.	28.
kg/kkg	0.37	1.10
G&O - mg/l	793.	22.
kg/kkg	0.10	0.69

Treatment systems (cumulative)

1. Flotation
2. Evaporator only

NOTE: Treatment 1 for bailwater only; treatment 2 for bailwater and stickwater.

costs for a plant processing 7 ton/hour to be about $30,000 (excluding drying). Chemical costs of $0.023/1000 lbs stickwater for HCl and $1.25/1000 lbs stickwater for glutenaldehyde were considered recoverable by solids value. They estimated the costs of anaerobic-aerobic lagoon system to handle the pretreated process water (1400 gpm) at $12,000 per year annual costs based on seven percent capital costs and ten percent depreciation.

We estimate that a double effort stickwater evaporator for a plant processing eight to ten tons/hour would cost $200,000 to $250,000.

Any cost estimate should consider the following:

1) location--the larger plants are located on pilings with a good deal of the plant extending onto the land. The medium plants are mostly inland, while the small plants are located on land near docking facilities. Plants on the East Coast run from Massachusetts to Florida, while on the West Coast they are located along the Northwest and Southern California coastline.

2) Plant age--the physical age of plants sampled runs between 20 to 60 years while the processing equipment varied from 20 years to new.

3) Plant production--the large plants produce nearly 170,000 tons per year, while small plants may produce 32,000 tons per year.

4) Processing hours--most fish meal plants operate almost continuously while fish are available. Some downtime for evaporator cleaning is needed.

5) Season--the processing season varies with location, usually running somewhere between May and December.

6) Unit operations--the methods used to achieve the saleable product are similar except that larger plants recover a larger percentage of the raw product with a solubles plant.

3.2.2. Salmon Canning

The costs associated with treatment in typical plants in Alaska are shown on Table 87 through 91; costs for typical plants in the Northwest are shown on Tables 92 and 93. A multiplier of 2.5 was used to adjust equipment costs to the Alaska location while power costs were increased by a factor of 10.

Based on a five-year average a large Alaska cannery produces over 80,000 cases annually, while a medium cannery (considered typical for treatment costs purposes) produces between 40,000 and 80,000 cases annually, and a small cannery averages less than 40,000 cases annually.

Based on a five-year average a large Northwest cannery (considered typical for treatment cost purposes) produces greater than 20,000 cases annually, while a small cannery produces less than 20,000 cases per year.

Salmon canning plants in Alaska are located near the fishing grounds and are, therefore, usually placed in the remote areas. Most plants are built on pilings to avoid rugged terrain in many areas, to speed and ease fish unloading and to dispose of wastes.

TABLE 37. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA SALMON CANNING - LARGE

OPERATING DAY	18.0 HOURS
SEASON	42.0 DAYS
PRODUCTION	8.3 TON/HR
	7.5 KKG/HR
PROCESS FLOW	600.0 GPM
	37.9 L/SEC
HYDRAULIC LOAD	4356.4 GAL/TON
	18.2 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	122.	838.	1687.	1081.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	10.	67.	135.	87.
DEPRECIATION @ 10%	12.	84.	169.	108.
DAILY COSTS($)				
O&M	21.	141.	200.	171.
POWER	4.	9.	19.	11.
TOTAL ANNUAL COSTS($1000)	23.	157.	313.	202.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	2918.	729.	109.	146.
-KG/KKG	53.00	13.25	1.99	2.65
TSS-MG/L	1541.	154.	60.	200.
-KG/KKG	28.00	2.80	1.09	3.63
O&G-MG/L	495.	50.	25.	25.
-KG/KKG	9.00	0.90	0.45	0.45

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 88. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA SALMON CANNING - MEDIUM

OPERATING DAY	18.0 HOURS
SEASON	42.0 DAYS
PRODUCTION	5.0 TON/HR
	4.5 KKG/HR
PROCESS FLOW	370.0 GPM
	23.4 L/SEC
HYDRAULIC LOAD	4477.4 GAL/TON
	18.7 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	88.	558.	1200.	758.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	7.	45.	96.	61.
DEPRECIATION @ 10%	9.	56.	120.	76.
DAILY COSTS($)				
O&M	15.	98.	139.	120.
POWER	2.	6.	12.	7.
TOTAL ANNUAL COSTS($1000)	17.	105.	222.	142.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	2839.	710.	106.	142.
-KG/KKG	53.00	13.25	1.99	2.65
TSS-MG/L	1500.	150.	60.	200.
-KG/KKG	28.00	2.80	1.12	3.73
G&O-MG/L	482.	48.	24.	24.
-KG/KKG	9.00	0.90	0.45	0.45

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 89. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA SALMON CANNING - LARGE

OPERATING DAY	18.0	HOURS
SEASON	42.0	DAYS
PRODUCTION	8.3	TON/HR
	7.5	KKG/HR
PROCESS FLOW	600.0	GPM
	37.9	L/SEC
HYDRAULIC LOAD	4356.4	GAL/TON
	18.2	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	122.	803.	1652.	1046.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	10.	64.	132.	84.
DEPRECIATION @ 10%	12.	80.	165.	105.
DAILY COSTS($)				
O&M	21.	51.	109.	80.
POWER	4.	9.	19.	11.
TOTAL ANNUAL COSTS($1000)	23.	147.	303.	192.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	2918.	1750	262	350.
-KG/KKG	53.00	31.8	0.30	9.54
TSS-MG/L	1376.	464	116	200.
-KG/KKG	25.00	8.4	0.27	3.63
G&O-MG/L	495.	50.	25.	25.
-KG/KKG	9.00	0.90	0.45	0.45

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLCTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 90. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA SALMON CANNING - MEDIUM

OPERATING DAY	18.0	HOURS
SEASON	42.0	DAYS
PRODUCTION	5.0	TON/HR
	4.5	KKG/HR
PROCESS FLOW	370.0	GPM
	23.3	L/SEC
HYDRAULIC LOAD	4477.4	GAL/TON
	18.7	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	88.	537.	1179.	737.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	7.	43.	94.	59.
DEPRECIATION @ 10%	9.	54.	118.	74.
DAILY COSTS($)				
O&M	15.	43.	83.	64.
POWER	2.	6.	12.	7.
TOTAL ANNUAL COSTS($1000)	17.	99.	216.	136.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	2839.	1750	262.	350.
-KG/KKG	53.00	31.8	0.30	9.54
TSS-MG/L	1339.	464	116	200.
-KG/KKG	25.00	8.4	0.27	3.73
G&O-MG/L	482.	48.	24.	24.
-KG/KKG	9.00	0.90	0.45	0.45

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 91. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA SALMON CANNING - SMALL

OPERATING DAY	18.0 HOURS
SEASON	42.0 DAYS
PRODUCTION	1.1 TON/HR
	1.0 KKG/HR
PROCESS FLOW	80.0 GPM
	5.0 L/SEC
HYDRAULIC LOAD	4356.4 GAL/TON
	18.2 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	46.	212.	594.	358.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	4.	17.	47.	29.
DEPRECIATION @ 10%	5.	21.	59.	36.
DAILY COSTS($)				
O&M	9.	32.	50.	43.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	9.	40.	109.	66.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	2918.	1750.	262.	350.
-KG/KKG	53.00	31.8	0.30	9.54
TSS-MG/L	1376.	464.	116.	200.
-KG/KKG	25.00	8.4	0.27	3.63
G&O-MG/L	495.	50.	25.	25.
-KG/KKG	9.00	0.90	0.45	0.45

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 92. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NORTHWEST SALMON CANNING -LARGE

OPERATING DAY	8.0 HOURS
SEASON	85.0 DAYS
PRODUCTION	5.0 TON/HR
	4.5 KKG/HR
PROCESS FLOW	370.0 GPM
	23.3 L/SEC
HYDRAULIC LOAD	4477.4 GAL/TON
	18.7 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	35.	157.	271.	192.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	3.	13.	22.	15.
DEPRECIATION @ 10%	4.	16.	27.	19.
DAILY COSTS($)				
O&M	7.	44.	62.	53.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	7.	32.	54.	39.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1178.	295.	60.	80.
-KG/KKG	22.00	5.50	1.12	1.49
TSS-MG/L	536.	54.	60.	200.
-KG/KKG	10.00	1.00	1.12	3.73
G&O-MG/L	337.	34.	17.	17.
-KG/KKG	6.30	0.63	0.32	0.32

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION -WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 93. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NORTHWEST SALMON CANNING - SMALL

OPERATING DAY	8.0 HOURS
SEASON	85.0 DAYS
PRODUCTION	1.9 TON/HR
	1.7 KKG/HR
PROCESS FLOW	140.0 GPM
	8.8 L/SEC
HYDRAULIC LOAD	4484.5 GAL/TON
	18.7 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	22.	90.	167.	117.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	7.	13.	9.
DEPRECIATION @ 10%	2.	9.	17.	12.
DAILY COSTS($)				
O&M	4.	25.	35.	30.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	18.	33.	24.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1176.	294.	60.	80.
-KG/KKG	22.00	5.50	1.12	1.50
TSS-MG/L	535.	53.	60.	200.
-KG/KKG	10.00	1.00	1.12	3.74
G&O-MG/L	337.	34.	17.	17.
-KG/KKG	6.30	0.63	0.32	0.32

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

Northwest salmon canneries are typically located in small coastal towns of Washington, Oregon and Northern California. They are built in much the same style as those in Alaska.

Plants are typically old in Alaska, with some structures dating back to the 1920's, while in the Northwest they vary more in age. Equipment, however, is continually updated by modifications, which tends to eliminate any effect age may have on the waste characteristics. Treatment installation costs may be higher at the older plants because of the probability of additional plumbing. The cost estimates presented in Tables 87 through 93 wer averaged from a wide range in plant age. Plants that are newer or older than the average should evaluate their individual facility and adjust the estimate costs accordingly.

A typical plant probably averages eight hours per day processing time. The hours vary from day to day and season to season with the size of the catch. The season in the Northwest appears to produce a more reliable catch than those in Alaska.

The season length also varies with the catch. Some Alaskan canneries do not process during very poor seasons. We estimate that canneries process on the average of 42 days per year in Alaska, and 85 days per year in the Northwest.

Unit operations are fairly consistent from plant to plant, however, some small Northwest plants use hand pack operations.

Presently, many plants in the Northwest use coarse screens to remove the larger solids which are used in by-product operations. At least one plant has installed a tangential screen system. A number of plants near major populations centers in Alaska are in the process of installing screening systems; however, canneries located in the remote areas of Alaska usually grind the solids and discharge to the surrounding water.

3.2.3. Fresh/Frozen Salmon

Table 94 through 101 lists the costs for typical plants in Alaska and on the West Coast, respectively.

The larger plants observed have an estimated annual throughput of 2500 tons of raw product. Smaller plants process less than 2500 tons per year.

Many of the larger plants in Alaska are located near major population centers, while small plants are often operated in conjunction with canneries frequently established in remote areas. The plants along the West Coast are scattered throughout the coastal cities of Washington, Oregon and California.

Plants vary in age, however, the processing operations are almost entirely manual and thus plant age has no noticeable affect on effluent characteristics.

The processing hours vary with the availability of the raw product. Most plants were observed working an eight hour day; however, the large plants average a longer shift length than the small because of a more consistent supply of raw product.

In Alaska the season is somewhat longer than the canning season because the species processed are not necessarily the same as those that are canned and a much smaller quantity of fish are required in a fresh/frozen operation.

TABLE 94. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA FRESH FROZEN SALMON -LARGE

OPERATING DAY	12.0 HOURS
SEASON	90.0 DAYS
PRODUCTION	4.4 TON/HR
	4.0 KKG/HR
PROCESS FLOW	90.0 GPM
	5.7 L/SEC
HYDRAULIC LOAD	1225.2 GAL/TON
	5.1 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	47.	183.	443.	281.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	4.	15.	35.	22.
DEPRECIATION @ 10%	5.	18.	44.	28.
DAILY COSTS($)				
O&M	6.	22.	34.	29.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	9.	35.	83.	53.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	333.	233.	60.	80.
-KG/KKG	1.70	1.19	0.31	0.41
TSS-MG/L	176.	53.	60.	200.
-KG/KKG	0.90	0.27	0.31	1.02
G&O-MG/L	59.	9.	5.	5.
-KG/KKG	0.30	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 95. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA FRESH FROZEN SALMON - SMALL

OPERATING DAY	12.0 HOURS
SEASON	90.0 DAYS
PRODUCTION	1.1 TON/HR
	1.0 KKG/HR
PROCESS FLOW	25.0 GPM
	1.7 L/SEC
HYDRAULIC LOAD	1361.4 GAL/TON
	5.7 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	27.	103.	242.	155.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	8.	19.	12.
DEPRECIATION @ 10%	3.	10.	24.	15.
DAILY COSTS($)				
O&M	5.	20.	29.	26.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	5.	21.	46.	30.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	299.	210.	60.	80.
-KG/KKG	1.70	1.19	0.34	0.45
TSS-MG/L	159.	48.	60.	200.
-KG/KKG	0.90	0.27	0.34	1.14
G&O-MG/L	53.	8.	5.	5.
-KG/KKG	0.30	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 96. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : N/W FRESH FROZEN SALMON - LARGE

OPERATING DAY	10.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	3.5 TON/HR
	3.2 KKG/HR
PROCESS FLOW	50.0 GPM
	3.2 L/SEC
HYDRAULIC LOAD	850.9 GAL/TON
	3.6 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	16.	48.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	4.
DEPRECIATION @ 10%	2.	5.
DAILY COSTS($)		
O&M	4.	10.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	10.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	366.	80.
-KG/KKG	1.30	0.28
TSS-MG/L	310.	200.
-KG/KKG	1.10	0.71
G&O-MG/L	37.	18.
-KG/KKG	0.13	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

TABLE 97. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : N/W FRESH FROZEN SALMON - LARGE

OPERATING DAY	10.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	3.5 TON/HR
	3.2 KKG/HR
PROCESS FLOW	50.0 GPM
	3.2 L/SEC
HYDRAULIC LOAD	850.9 GAL/TON
	3.6 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	16.	95.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	8.
DEPRECIATION @ 10%	2.	10.
DAILY COSTS($)		
O&M	4.	13.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	19.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	366.	60.
-KG/KKG	1.30	0.21
TSS-MG/L	310.	78.
-KG/KKG	1.10	0.27
G&O-MG/L	37.	18.
-KG/KKG	0.13	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 98. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : WEST COAST FRESH FROZEN SALMON -LARGE

OPERATING DAY	10.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	3.5 TON/HR
	3.2 KKG/HR
PROCESS FLOW	50.0 GPM
	3.2 L/SEC
HYDRAULIC LOAD	850.9 GAL/TON
	3.6 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	16.	62.	141.	93.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	5.	11.	7.
DEPRECIATION @ 10%	2.	6.	14.	9.
DAILY COSTS($)				
O&M	4.	21.	30.	27.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	14.	29.	20.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	366.	183.	60.	80.
-KG/KKG	1.30	0.65	0.21	0.28
TSS-MG/L	141.	14.	60.	200.
-KG/KKG	0.50	0.05	0.21	0.71
G&O-MG/L	37.	5.	5.	5.
-KG/KKG	0.13	0.02	0.02	0.02

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 99. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : N/W FRESH FROZEN SALMON - SMALL

OPERATING DAY	6.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	1.8 TON/HR
	1.6 KKG/HR
PROCESS FLOW	25.0 GPM
	1.6 L/SEC
HYDRAULIC LOAD	850.9 GAL/TON
	3.6 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	11.	21.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	0.	2.
DEPRECIATION @ 10%	1.	2.
DAILY COSTS($)		
O&M	2.	5.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	2.	5.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	366.	80.
-KG/KKG	1.30	0.28
TSS-MG/L	310.	200.
-KG/KKG	1.10	0.71
G&O-MG/L	37.	18.
-KG/KKG	0.13	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

TABLE 100. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : N/W FRESH FROZEN SALMON - SMALL

OPERATING DAY	6.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	1.8 TON/HR
	1.6 KKG/HR
PROCESS FLOW	25.0 GPM
	1.6 L/SEC
HYDRAULIC LOAD	850.9 GAL/TON
	3.6 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	11.	39.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	0.	3.
DEPRECIATION @ 10%	1.	4.
DAILY COSTS($)		
O&M	2.	7.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	2.	8.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	366.	60.
-KG/KKG	1.30	0.21
TSS-MG/L	310.	78.
-KG/KKG	1.10	0.27
G&O-MG/L	37.	18.
-KG/KKG	0.13	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 101. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : WEST COAST FRESH FROZEN SALMON - SMALL

OPERATING DAY	6.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	1.8 TON/HR
	1.6 KKG/HR
PROCESS FLOW	25.0 GPM
	1.6 L/SEC
HYDRAULIC LOAD	850.9 GAL/TON
	3.6 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	11.	41.	69.	51.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	0.	3.	6.	4.
DEPRECIATION @ 10%	1.	4.	7.	5.
DAILY COSTS($)				
O&M	2.	11.	16.	14.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	2.	9.	15.	11.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	366.	183.	60.	80.
-KG/KKG	1.30	0.65	0.21	0.28
TSS-MG/L	141.	14.	60.	200.
-KG/KKG	0.50	0.05	0.21	0.71
G&O-MG/L	37.	5.	5.	5.
-KG/KKG	0.13	0.02	0.02	0.02

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

On the West Coast, there are some salmon processed throughout the year; however, the majority of the processing occurs from late spring to early fall.

Plants located near a by-products operation usually collect the viscera, heads and fins, while plants in the remote regions of Alaska usually discharge the solids to the surrounding waters.

3.2.4. Herring Filleting

Tables 102 through 105 list the costs for the treatment of alternatives at a non-Alaska and Alaska plant. The herring filleting industry is located along the New England coast, and in Southeastern Alaska.

The processing equipment used in the Alaskan plant was new, while the New England plant sampled used machinery that was built in Europe in the 1940's and just recently installed at the New England plant which is much nearer the fishing grounds.

The newer equipment in Alaska gives that plant a potentially larger capacity than the New England plant. However, the Alaskan production rate has not yet been established. It has been estimated that it may vary from a few tons per year to over 1000 tons per year, depending on the catch, comparative price and demand for crab bait. The processing season in the two locations usually peaks in the spring and again in the fall. The solids are screened and utilized in a reduction plant at the New England plant,

TABLE 102. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN HERRING FILLETING

OPERATING DAY	12.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	14.9 TON/HR
	13.5 KKG/HR
PROCESS FLOW	520.0 GPM
	32.8 L/SEC
HYDRAULIC LOAD	2097.5 GAL/TON
	8.8 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	44.	313.	520.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	4.	25.	42.
DEPRECIATION @ 10%	4.	31.	52.
DAILY COSTS($)			
O&M	13.	84.	119.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	10.	65.	106.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	3659.	915.	137.
-KG/KKG	32.00	8.00	1.20
TSS-MG/L	2630.	263.	66.
-KG/KKG	23.00	2.30	0.58
G&O-MG/L	697.	70.	35.
-KG/KKG	6.10	0.61	0.31

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION

TABLE 103. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN HERRING FILLETING

OPERATING DAY	12.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	14.9 TON/HR
	13.5 KKG/HR
PROCESS FLOW	520.0 GPM
	32.8 L/SEC
HYDRAULIC LOAD	2097.5 GAL/TON
	8.8 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	44.	313.	520.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	4.	25.	42.
DEPRECIATION @ 10%	4.	31.	52.
DAILY COSTS($)			
O&M	13.	32.	67.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	9.	60.	101.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	3659.	2196	329
-KG/KKG	32.00	19.20	2.88
TSS-MG/L	2630.	789	197
-KG/KKG	23.00	6.90	1.72
G&O-MG/L	697.	70.	35.
-KG/KKG	6.10	0.61	0.31

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION

TABLE 104. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA HERRING FILLETING

OPERATING DAY	12.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	14.9 TON/HR
	13.5 KKG/HR
PROCESS FLOW	520.0 GPM
	32.8 L/SEC
HYDRAULIC LOAD	2097.5 GAL/TON
	8.8 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	110.	781.	1300.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	9.	63.	104.
DEPRECIATION @ 10%	11.	78.	130.
DAILY COSTS($)			
O&M	13.	84.	119.
POWER	2.	5.	13.
TOTAL ANNUAL COSTS($1000)	21.	150.	247.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	3659.	915.	137.
-KG/KKG	32.00	8.00	1.20
TSS-MG/L	2630.	263.	66.
-KG/KKG	23.00	2.30	0.58
G&O-MG/L	697.	70.	35.
-KG/KKG	6.10	0.61	0.31

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION

TABLE 105. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA HERRING FILLETING

OPERATING DAY	12.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	14.9 TON/HR
	13.5 KKG/HR
PROCESS FLOW	520.0 GPM
	32.8 L/SEC
HYDRAULIC LOAD	2097.5 GAL/TON
	8.8 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	110.	781.	1300.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	9.	63.	104.
DEPRECIATION @ 10%	11.	78.	130.
DAILY COSTS($)			
O&M	13.	32.	67.
POWER	2.	5.	13.
TOTAL ANNUAL COSTS($1000)	21.	144.	242.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	3659.	2196	329
-KG/KKG	32.00	19.20	2.88
TSS-MG/L	2630.	789	199
-KG/KKG	23.00	6.90	1.72
G&O-MG/L	697.	70.	35.
-KG/KKG	6.10	0.61	0.31

TREATMENT SYSTEMS
(CUMULATIVE)

1	SCREENING
2	FLOTATION WITHOUT CHEMICALS
3	EXTENDED AERATION

3.2.5. Tuna Canning

Table 106 shows the treatment alternative costs for the tuna canning industry. The tuna industry is located along the West Coast, Puerto Rico, and American Samoa.

The tuna canning process and equipment is basically the same from plant to plant. Plants in southern California, Puerto Rico, and American Samoa tend to be large and process the larger species of tuna. The smaller West Coast plants typically process the finer species (albacore).

Most tuna plants employ tangential or rotary screens with drying facilities for the solids. In the larger plants, the more concentrated wastewaters go to evaporator facilities. Deep sea disposal of the wastewaters is practiced by all plants. A pilot sized dissolved air flotation facility was installed at one Terminal Island plant.

3.2.6. Sardine Canning

The treatment costs for representative plants are listed on Tables 107 through 109. Presently the only plants in operation are located along the coast of Maine. The dramatic decline in the fish populations along the West Coast has temporarily halted California processing. Large sardine canning plants average an output of more than 60,000 cases annually; medium plants can 30,000 to 60,000 cases annually; while small plants produce less than 30,000 cases.

TABLE 106. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : TUNA

OPERATING DAY	16.0	HOURS
SEASON	290.0	DAYS
PRODUCTION	23.2	TON/HR
	21.0	KKG/HR
PROCESS FLOW	1700.0	GPM
	278.2	L/SEC
HYDRAULIC LOAD	4408.2	GAL/TON
	18.4	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	113.	606.	1260.	766.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	9.	49.	101.	61.
DEPRECIATION @ 10%	11.	61.	126.	77.
DAILY COSTS($)				
O&M	42.	308.	437.	370.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	33.	199.	355.	246.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	707.	177.	60.	80.
-KG/KKG	13.00	3.25	1.10	1.47
TSS-MG/L	549.	55.	60.	200.
-KG/KKG	10.10	1.01	1.10	3.68
G&O-MG/L	316.	32.	16.	16.
-KG/KKG	5.80	0.58	0.29	0.29

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION **WITH CHEMICALS**
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 107. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : SARDINE CANNING - LARGE

OPERATING DAY	8.0 HOURS
SEASON	60.0 DAYS
PRODUCTION	8.3 TON/HR
	7.5 KKG/HR
PROCESS FLOW	240.0 GPM
	15.1 L/SEC
HYDRAULIC LOAD	1742.6 GAL/TON
	7.3 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	28.	125.	218.	156.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	10.	17.	12.
DEPRECIATION @ 10%	3.	12.	22.	16.
DAILY COSTS($)				
O&M	6.	33.	46.	40.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	5.	25.	42.	31.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1376.	344.	60.	80.
-KG/KKG	10.00	2.50	0.44	0.58
TSS-MG/L	922.	92.	60.	200.
-KG/KKG	6.70	0.67	0.44	1.45
G&O-MG/L	261.	26.	13.	13.
-KG/KKG	1.90	0.19	0.10	0.10

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 108. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : SARDINE CANNING - MEDIUM

OPERATING DAY	8.0 HOURS
SEASON	60.0 DAYS
PRODUCTION	5.5 TON/HR
	5.0 KKG/HR
PROCESS FLOW	160.0 GPM
	10.1 L/SEC
HYDRAULIC LOAD	1742.6 GAL/TON
	7.3 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	23.	99.	180.	128.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	8.	14.	10.
DEPRECIATION @ 10%	2.	10.	18.	13.
DAILY COSTS($)				
O&M	5.	26.	37.	32.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	20.	35.	25.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1376.	344.	60.	80.
-KG/KKG	10.00	2.50	0.44	0.58
TSS-MG/L	922.	92.	60.	200.
-KG/KKG	6.70	0.67	0.44	1.45
G&O-MG/L	261.	26.	13.	13.
-KG/KKG	1.90	0.19	0.10	0.10

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 109. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : SARDINE CANNING - SMALL

OPERATING DAY	8.0 HOURS
SEASON	60.0 DAYS
PRODUCTION	2.1 TON/HR
	1.9 KKG/HR
PROCESS FLOW	60.0 GPM
	3.8 L/SEC
HYDRAULIC LOAD	1719.6 GAL/TON
	7.2 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	17.	68.	132.	93.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	5.	11.	7.
DEPRECIATION @ 10%	2.	7.	13.	9.
DAILY COSTS($)				
O&M	4.	18.	25.	22.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	3.	13.	25.	18.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1395.	349.	60.	80.
-KG/KKG	10.00	2.50	0.43	0.57
TSS-MG/L	934.	93.	60.	200.
-KG/KKG	6.70	0.67	0.43	1.43
G&O-MG/L	265.	26.	13.	13.
-KG/KKG	1.90	0.19	0.10	0.10

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

Plants are generally old, with most of them ranging from 30 to 50 years in age. Equipment age varies from 10 to 30 years, depending on the date of renovation. Most plants run an eight hour shift when the raw material is available. The season length is variable depending on the availability of the raw product. During a good year, the plants may operate 120 days per year.

Most plants use much the same unit operations. Some have replaced fish fluming with dry conveyance methods. Mechanical eviscerating machines have recently been introduced in some of the larger operations when the size of the fish merits their employment. All of the plants sampled coarse screened the solids which were collected and sold to by-products plants.

3.2.7. Jack Mackerel Canning

Jack mackerel plants are typically large and fall in the production range of large sardine plants. All of the plants are located in Southern California with the majority on Terminal Island. Jack mackerel plants operate year round but only produce for human consumption a couple of months each year. This production is based entirely on market demand. The peak landings occur in the spring and fall of the year.

A typical plant processes around eight hours per day; however, this varies somewhat with the daily catch. The processing equipment appears to be a conglomerate of old and new and ranges from 15 to 50 years old. The plant site is usually old with one site dating from 1917. The plants studied use coarse screens to remove solids which are then used in by-product recovery operations. The cost of waste treatment at a typical plant is depicted on Table 110.

3.2.8. Conventional Bottom Fish

Tables 111 through 118 list the treatment alternative and associated costs for plants in Alaska and the "lower 48," respectively. Processing plants in Alaska are typically located in isolated towns such as Sand Point, Kodiak, Seward, Juneau, Pelican, Sitka, Petersburg and Ketchikan. Bottom fish plants are scattered along much of the coastline of the lower 48 states.

Bottom fish processing in Alaska is almost exclusively halibut. Halibut processing is usually done in conjunction with various other fish and/or shellfish processing. Facilities vary in age but most processing operations are manual and thus waste load is unaffected by plant age. The larger plants (handling over 5000 tons raw product annually) freeze a large portion of the fish whole; whereas, the smaller plants fillet more of the product prior to freezing. The filleting operation tends to strengthen the waste load of the effluent.

Plants in the "lower 48" process a wide variety of bottom fish species and use a variety of processing methods.

Large plants are those with a throughput of more than 4000 tons of raw product annually. Medium plants process between 2000 and 4000 tons of raw product annually. Small plants process less than 2000 tons of raw product annually.

TABLE 110. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MACKEREL CANNING

OPERATING DAY	8.0	HOURS
SEASON	75.0	DAYS
PRODUCTION	19.3	TON/HR
	17.5	KKG/HR
PROCESS FLOW	1500.0	GPM
	94.6	L/SEC
HYDRAULIC LOAD	4667.6	GAL/TON
	19.5	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	102.	469.	764.	542.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	8.	38.	61.	43.
DEPRECIATION @ 10%	10.	47.	76.	54.
DAILY COSTS($)				
O&M	19.	137.	195.	165.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	20.	95.	152.	110.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	498.	125.	60.	80.
-KG/KKG	9.70	2.42	1.17	1.56
TSS-MG/L	339.	34.	60.	200.
-KG/KKG	6.60	0.66	1.17	3.89
G&O-MG/L	77.	8.	5.	5.
-KG/KKG	1.50	0.15	0.10	0.10

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 111. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA BOTTOM FISH - LARGE

OPERATING DAY	8.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	13.2 TON/HR
	12.0 KKG/HR
PROCESS FLOW	200.0 GPM
	12.6 L/SEC
HYDRAULIC LOAD	907.6 GAL/TON
	3.8 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	63.	259.	476.	333.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	5.	21.	38.	27.
DEPRECIATION @ 10%	6.	26.	48.	33.
DAILY COSTS($)				
O&M	5.	16.	28.	23.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	12.	48.	89.	63.
	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	396.	277.	60.	80.
-KG/KKG	1.50	1.05	0.23	0.30
TSS-MG/L	317.	95.	60.	200.
-KG/KKG	1.20	0.36	0.23	0.76
G&O-MG/L	132.	20.	10.	10.
-KG/KKG	0.50	0.07	0.04	0.04

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 112. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA BOTTOM FISH - SMALL

OPERATING DAY	8.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	1.7 TON/HR
	1.5 KKG/HR
PROCESS FLOW	16.0 GPM
	1.0 L/SEC
HYDRAULIC LOAD	580.9 GAL/TON
	2.4 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	23.	86.	155.	110.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	7.	12.	9.
DEPRECIATION @ 10%	2.	9.	15.	11.
DAILY COSTS($)				
O&M	3.	13.	19.	17.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	17.	30.	22.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	867.	607.	91.	121.
-KG/KKG	2.10	1.47	0.22	0.29
TSS-MG/L	784.	235.	60.	200.
-KG/KKG	1.90	0.57	0.15	0.48
G&O-MG/L	41.	6.	5.	5.
-KG/KKG	0.10	0.01	0.01	0.01

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 113. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH - LARGE

OPERATING DAY	10.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	4.3 TON/HR
	3.9 KKG/HR
PROCESS FLOW	100.0 GPM
	6.3 L/SEC
HYDRAULIC LOAD	1396.3 GAL/TON
	5.8 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	19.	77.	166.	110.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	6.	13.	9.
DEPRECIATION @ 10%	2.	8.	17.	11.
DAILY COSTS($)				
O&M	5.	27.	37.	33.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	5.	20.	38.	27.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	601.	301.	60.	80.
-KG/KKG	3.50	1.75	0.35	0.47
TSS-MG/L	309.	31.	60.	200.
-KG/KKG	1.80	0.18	0.35	1.16
G&O-MG/L	69.	7.	5.	5.
-KG/KKG	0.40	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 114. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH - LARGE

OPERATING DAY	10.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	4.3 TON/HR
	3.9 KKG/HR
PROCESS FLOW	100.0 GPM
	6.3 L/SEC
HYDRAULIC LOAD	1396.3 GAL/TON
	5.8 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	19.	53.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	4.
DEPRECIATION @ 10%	2.	5.
DAILY COSTS($)		
O&M	5.	11.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	5.	12.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	601.	120.
-KG/KKG	3.50	0.70
TSS-MG/L	412.	200.
-KG/KKG	2.40	1.16
G&O-MG/L	69.	34.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

TABLE 115. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH -MEDIUM

OPERATING DAY	9.0	HOURS
SEASON	200.0	DAYS
PRODUCTION	2.5	TON/HR
	2.3	KKG/HR
PROCESS FLOW	60.0	GPM
	3.8	L/SEC
HYDRAULIC LOAD	1420.6	GAL/TON
	5.9	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	17.	65.	138.	94.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	5.	11.	8.
DEPRECIATION @ 10%	2.	7.	14.	9.
DAILY COSTS($)				
O&M	4.	20.	28.	25.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	16.	31.	23.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	591.	295.	60.	80.
-KG/KKG	3.50	1.75	0.36	0.47
TSS-MG/L	304.	30.	60.	200.
-KG/KKG	1.80	0.18	0.36	1.18
G&O-MG/L	68.	7.	5.	5.
-KG/KKG	0.40	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 116. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY: NONALASKAN CONV. BOTTOM FISH - MEDIUM

OPERATING DAY	9.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	2.5 TON/HR
	2.3 KKG/HR
PROCESS FLOW	60.0 GPM
	3.8 L/SEC
HYDRAULIC LOAD	1420.6 GAL/TON
	5.9 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	17.	46.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	4.
DEPRECIATION @ 10%	2.	5.
DAILY COSTS($)		
O&M	4.	9.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	10.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	591.	118.
-KG/KKG	3.50	0.70
TSS-MG/L	405.	200.
-KG/KKG	2.40	1.18
G&O-MG/L	68.	34.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1	SCREENING
2	AERATED LAGOON

TABLE 117. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	1.3 TON/HR
	1.2 KKG/HR
PROCESS FLOW	30.0 GPM
	1.9 L/SEC
HYDRAULIC LOAD	1361.4 GAL/TON
	5.7 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	12.	46.	88.	62.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	0.	4.	7.	5.
DEPRECIATION @ 10%	1.	5.	9.	6.
DAILY COSTS($)				
O&M	3.	15.	22.	19.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	3.	12.	21.	16.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	617.	308.	60.	80.
-KG/KKG	3.50	1.75	0.34	0.45
TSS-MG/L	317.	32.	60.	200.
-KG/KKG	1.80	0.18	0.34	1.14
G&O-MG/L	70.	7.	5.	5.
-KG/KKG	0.40	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 118. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY: NONALASKAN CONV. BOTTOM FISH - SMALL

OPERATING DAY	8.0	HOURS
SEASON	200.0	DAYS
PRODUCTION	1.3	TON/HR
	1.2	KKG/HR
PROCESS FLOW	30.0	GPM
	1.9	L/SEC
HYDRAULIC LOAD	1361.4	GAL/TON
	5.7	CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	12.	28.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	0.	2.
DEPRECIATION @ 10%	1.	3.
DAILY COSTS($)		
O&M	3.	7.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	3.	7.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	617.	123.
-KG/KKG	3.50	0.70
TSS-MG/L	423.	200.
-KG/KKG	2.40	1.14
G&O-MG/L	70.	35.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

TABLE119. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY: NONALASKAN CONV. BOTTOM FISH - SMALL

OPERATING DAY	8.0 HOURS
SEASON	180.0 DAYS
PRODUCTION	1.0 TON/HR
	0.9 KKG/HR
PROCESS FLOW	50.0 GPM
	3.2 L/SEC
HYDRAULIC LOAD	3025.3 GAL/TON
	12.6 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	16.	64.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	5.
DEPRECIATION @ 10%	2.	6.
DAILY COSTS($)		
O&M	4.	14.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	14.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	793.	475
-KG/KKG	10.00	6.00
TSS-MG/L	650.	146
-KG/KKG	8.20	1.85
G&O-MG/L	166.	17.
-KG/KKG	2.10	0.21

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS

Many bottom fish plants run a standard shift of eight hours per day, if raw product is available, while others lengthen the work day as the availability of the raw product increases. During the sampling period the observed average shift length was seven hours for plants outside Alaska and near eight hours in Alaska.

The Pacific halibut season is regulated by the International Pacific Halibut Commission. Most of the catch occurs between March and October. Halibut carcasses and heads are usually frozen and sold for bait, while the large solids from non-Alaska bottom fish plants are utilized in by-product operations.

Most other bottom fish plants process year round; however, weather often hampers fishing operations during certain parts of the year.

3.2.9. Mechanized Bottom Fish

Most plants are located on the Atlantic and Gulf Coasts. These plants are typically larger than the conventional plants because of the high amount of mechanization results in a faster raw product flow through. Many of the unit operations that are done by hand in a conventional plant are done by machine in a mechanized operation. Large plants process over 7000 tons of raw product per year, whereas the smaller plants process less than 2000 tons annually. Plant ages vary; however, the equipment is usually periodically updated. The processing seasons are generally shorter since few species of fish are utilized.

Coarse screening and solids recovery systems are common. Some plants employ primary clarifiers before discharging wastewater. Solids are used in rendering plants or sold for bait. The costs associated with treatment are listed in Table 120 through Table 122.

3.2.10. Herring Pickling (Alewife)

The alewife processing industry is primarily based in Virginia with a few plants located in North Carolina and Maryland. Spring is the alewife season with the peak usually occurring in May. The plants only process about 20 days per year. Tables 123 and 124 list the treatment costs.

3.2.11. Catfish Processes

Catfish processing plants are located in the Central and Southern states in flat to moderately rolling terrain. Since this industry is of recent origin, most of the plants are relatively new. No significant variations in unit processes existed in this subcategory. Waste solids are frequently dry collected and taken to a reduction plant. Wastewaters from the holding tanks are occasionally discharged to rearing ponds. The cost information is shown in Table 125.

3.3. Shellfish

There are many operating conditions that apply to all of the subcategories in this group. Plant age cannot be con-

TABLE 120. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN MECH. BOTTOM FISH - LARGE

OPERATING DAY	8.0 HOURS
SEASON	180.0 DAYS
PRODUCTION	6.1 TON/HR
	5.5 KKG/HR
PROCESS FLOW	180.0 GPM
	11.4 L/SEC
HYDRAULIC LOAD	1782.2 GAL/TON
	7.4 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	24.	104.	188.	134.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	8.	15.	11.
DEPRECIATION @ 10%	2.	10.	19.	13.
DAILY COSTS($)				
O&M	5.	28.	39.	34.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	5.	24.	41.	31.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1346.	336.	60.	80.
-KG/KKG	10.00	2.50	0.45	0.59
TSS-MG/L	807.	81.	60.	200.
-KG/KKG	6.00	0.60	0.45	1.49
G&O-MG/L	283.	28.	14.	14.
-KG/KKG	2.10	0.21	0.11	0.11

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 121. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN MECH BOTTOM LARGE

OPERATING DAY	8.0 HOURS
SEASON	180.0 DAYS
PRODUCTION	6.1 TON/HR
	5.5 KKG/HR
PROCESS FLOW	180.0 GPM
	11.4 L/SEC
HYDRAULIC LOAD	1782.2 GAL/TON
	7.4 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	24.	104.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	8.
DEPRECIATION @ 10%	2.	10.
DAILY COSTS($)		
O&M	5.	16.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	5.	20.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	1346.	806.
-KG/KKG	10.00	6.00
TSS-MG/L	1103.	248
-KG/KKG	8.20	1.85
G&O-MG/L	283.	28.
-KG/KKG	2.10	0.21

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS

TABLE 122. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NONALASKAN MECH. BOTTOM FISH -SMALL

OPERATING DAY	8.0 HOURS
SEASON	180.0 DAYS
PRODUCTION	1.0 TON/HR
	0.9 KKG/HR
PROCESS FLOW	50.0 GPM
	3.1 L/SEC
HYDRAULIC LOAD	3025.3 GAL/TON
	12.6 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	16.	63.	126.	88.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	5.	10.	7.
DEPRECIATION @ 10%	2.	6.	13.	9.
DAILY COSTS($)				
O&M	4.	17.	24.	21.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	15.	28.	20.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	793.	198.	60.	80.
-KG/KKG	10.00	2.50	0.76	1.01
TSS-MG/L	476.	48.	60.	200.
-KG/KKG	6.00	0.60	0.76	2.52
G&G-MG/L	166.	17.	8.	8.
-KG/KKG	2.10	0.21	0.11	0.11

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 123. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : HERRING PICKLING (ALEWIVES)

OPERATING DAY	8.0 HOURS
SEASON	20.0 DAYS
PRODUCTION	6.1 TON/HR
	5.5 KKG/HR
PROCESS FLOW	285.0 GPM
	18.0 L/SEC
HYDRAULIC LOAD	2821.8 GAL/TON
	11.8 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	30.	128.	229.	161.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	10.	18.	13.
DEPRECIATION @ 10%	3.	13.	23.	16.
DAILY COSTS($)				
O&M	6.	37.	52.	45.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	6.	24.	42.	30.
	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	1385.	346.	60.	80.
-KG/KKG	16.30	4.07	0.71	0.94
TSS-MG/L	314.	31.	60.	200.
-KG/KKG	3.70	0.37	0.71	2.35
G&O-MG/L	5.	5.	5.	5.
-KG/KKG	0.06	0.06	0.06	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 124. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : HERRING PICKLING (ALEWIVES)

OPERATING DAY	8.0 HOURS
SEASON	20.0 DAYS
PRODUCTION	6.1 TON/HR
	5.5 KKG/HR
PROCESS FLOW	285.0 GPM
	18.0 L/SEC
HYDRAULIC LOAD	2821.8 GAL/TON
	11.8 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	30.	128.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	10.
DEPRECIATION @ 10%	3.	13.
DAILY COSTS($)		
O&M	6.	18.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	6.	23.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	1385.	833
-KG/KKG	16.30	9.80
TSS-MG/L	314.	93.
-KG/KKG	3.70	1.11
G&O-MG/L	5.	5.
-KG/KKG	0.06	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS

TABLE 125. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CATFISH

OPERATING DAY	8.0	HOURS
SEASON	150.0	DAYS
PRODUCTION	0.8	TON/HR
	0.7	KKG/HR
PROCESS FLOW	65.0	GPM
	4.1	L/SEC
HYDRAULIC LOAD	5056.5	GAL/TON
	21.1	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	17.	67.	133.	93.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	5.	11.	7.
DEPRECIATION @ 10%	2.	7.	13.	9.
DAILY COSTS($)				
O&M	4.	18.	26.	23.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	15.	28.	21.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	375.	187.	60.	80.
-KG/KKG	7.90	3.95	1.27	1.69
TSS-MG/L	427.	43.	60.	200.
-KG/KKG	9.00	0.90	1.27	4.22
G&G-MG/L	213.	21.	5.	5.
-KG/KKG	4.50	0.45	0.11	0.11

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

sidered a factor influencing the waste strength especially in hand-shucked operations where there is very little mechanization. Age influence on mechanized operations is partially nullified by periodic equipment modifications. Plant age can affect treatment costs somewhat by the potential plumbing costs that exist at some of the older plants. Most plants attempt to process eight hours per day but it usually varies with raw product availability and therefore averages somewhat less than eight hours.

Clam, oyster and abalone plants salvage the shell. In those mechanized subcategories where the shell is broken during the meat removal operation, some plants have installed settling basins to facilitate shell fragment removal. Other plants use coarse screening for this purpose.

3.3.1. Alaska Crab

Table 126 shows the costs and removal efficiencies associated with the various recommended treatment systems. Most crab processing plants located in Alaska are either in remote areas or in towns with concentrations of seafood processors such as Kodiak and Petersburg.

The crab processing equipment is essentially the same within each process (meat, sections and whole). The number of processes employed varies from plant to plant. Most plants process king, Dungeness and tanner crab.

Plants where solids recovery facilities are available use tangential screens. By far the greatest portion of the Alaska process grind and discharge their waste.

TABLE 126. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA CRAB

OPERATING DAY	16.0 HOURS
SEASON	100.0 DAYS
PRODUCTION	1.7 TON/HR
	1.5 KKG/HR
PROCESS FLOW	150.0 GPM
	343.6 L/SEC
HYDRAULIC LOAD	5445.5 GAL/TON
	22.7 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	45.	183.	499.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	4.	15.	40.
DEPRECIATION @ 10%	4.	18.	50.
DAILY COSTS($)			
O&M	9.	51.	71.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	9.	38.	97.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	467.	233.	60.
-KG/KKG	10.60	5.30	1.36
TSS-MG/L	225.	22.	60.
-KG/KKG	5.10	0.51	1.36
O&G-MG/L	40.	5.	5.
-KG/KKG	0.90	0.11	0.11

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION

3.3.2. West Coast Crab

Table 127 shows the recommended treatment systems and their related removal efficiencies. Most crab processors are located in small coastal towns.

The West Coast plants process both tanner and Dungeness crab either as hand-picked meat or whole. Solid wastes are generally screened and taken to a rendering plant. Little variations in processes exist between plants.

3.3.3. Blue Crab Processes

The blue crab industry was divided into "mechanized" and "conventional" because of the increased water and waste loads produced when a mechanical picking machine is used. The plants are typically located in the coastal areas of the Atlantic and Gulf regions of the United States. Regional variations in costs exist in this large area but were not considered in constructing the tables. Few waste treatment systems are presently in use.

Tables 128 and 129 list the costs of the respective treatment systems for the conventional and mechanized blue crab industry.

3.3.4. Alaska and Northwest Shrimp

Tables 130 and 131 show the treatment system costs for an average Alaska and Northwest Coast shrimp plant. Alaska plants are typically located in isolated regions or in remote towns while Northwest plants are in small coastal towns.

TABLE 127. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : WEST COAST DUNGENESS CRAB

OPERATING DAY	10.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	0.9 TON/HR
	0.8 KKG/HR
PROCESS FLOW	67.0 GPM
	287.8 L/SEC
HYDRAULIC LOAD	4560.6 GAL/TON
	19.0 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	17.	67.	149.	99.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	5.	12.	8.
DEPRECIATION @ 10%	2.	7.	15.	10.
DAILY COSTS($)				
O&M	5.	23.	32.	29.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	17.	34.	24.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	421.	210.	60.	80.
-KG/KKG	8.00	4.00	1.14	1.52
TSS-MG/L	142.	14.	60.	200.
-KG/KKG	2.70	0.27	1.14	3.80
G&O-MG/L	5.	5.	5.	5.
-KG/KKG	0.10	0.10	0.10	0.10

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 128. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CONVENTIONAL BLUE CRAB

OPERATING DAY	10.0 HOURS
SEASON	160.0 DAYS
PRODUCTION	0.3 TON/HR
	0.3 KKG/HR
PROCESS FLOW	1.4 GPM
	<0.1 L/SEC
HYDRAULIC LOAD	254.1 GAL/TON
	1.1 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	6.	22.	37.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	0.	2.	3.
DEPRECIATION @ 10%	0.	2.	4.
DAILY COSTS($)			
O&M	4.	16.	23.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	2.	7.	11.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	4907.	2454.	368.
-KG/KKG	5.20	2.60	0.39
TSS-MG/L	1132.	113.	60.
-KG/KKG	1.20	0.12	0.06
G&O-MG/L	377.	38.	6.
-KG/KKG	0.40	0.04	0.00

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION

TABLE 129. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED BLUE CRAB

OPERATING DAY	10.0 HOURS
SEASON	160.0 DAYS
PRODUCTION	0.7 TON/HR
	0.6 KKG/HR
PROCESS FLOW	98.0 GPM
	6.2 L/SEC
HYDRAULIC LOAD	8894.3 GAL/TON
	37.1 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	19.	76.	165.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	2.	6.	13.
DEPRECIATION @ 10%	2.	8.	16.
DAILY COSTS($)			
O&M	5.	26.	37.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	4.	18.	36.

	RESULTING EFFLUENT LEVELS		
PARAMETER			
BOD-MG/L	612.	306.	60.
-KG/KKG	22.70	11.35	2.23
TSS-MG/L	315.	32.	60.
-KG/KKG	11.70	1.17	2.23
G&O-MG/L	151.	15.	5.
-KG/KKG	5.60	0.56	0.19

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION

TABLE 130. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKA SHRIMP (KODIAK)

OPERATING DAY	16.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	2.2 TON/HR
	2.0 KKG/HR
PROCESS FLOW	646.0 GPM
	1109.9 L/SEC
HYDRAULIC LOAD	17588.9 GAL/TON
	73.4 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	103.	800.	1433.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	8.	64.	115.
DEPRECIATION @ 10%	10.	80.	143.
DAILY COSTS($)			
O&M	20.	47.	102.
POWER	1.	2.	4.
TOTAL ANNUAL COSTS($1000)	23.	154.	279.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	1663.	1164.	175.
-KG/KKG	122.00	85.40	12.81
TSS-MG/L	2904.	871.	131.
-KG/KKG	213.00	63.90	9.58
G&G-MG/L	232.	35.	5.
-KG/KKG	17.00	2.55	0.38

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION

TABLE 131. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : NORTHWEST SHRIMP

OPERATING DAY	12.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	1.2 TON/HR
	1.1 KKG/HR
PROCESS FLOW	258.0 GPM
	805.9 L/SEC
HYDRAULIC LOAD	12772.1 GAL/TON
	53.3 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	29.	135.	279.	182.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	11.	22.	15.
DEPRECIATION @ 10%	3.	13.	28.	18.
DAILY COSTS($)				
O&M	9.	26.	47.	37.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	7.	30.	60.	41.

RESULTING EFFLUENT LEVELS

PARAMETER	1	2	3	4
BOD-MG/L	2178.	1525.	229.	305.
-KG/KKG	116.00	81.20	12.18	16.24
TSS-MG/L	1014.	304.	60.	200.
-KG/KKG	54.00	16.20	3.20	10.65
G&G-MG/L	789.	118.	18.	59.
-KG/KKG	42.00	6.30	0.94	3.15

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

The only variations in the processes are in the number and type of peelers used and whether the peeled shrimp is canned or frozen. Most of the processors in metropolitan areas screen their wastewater. The solids are typically disposed of by further processing for animal feed. Isolated processors in Alaska grind and discharge or just discharge their waste without grinding.

3.3.5. Gulf Shrimp Processes

The gulf shrimp industry was divided into "canned" and "breaded" subcategories, for the purpose of developing the cost tables. Costs did not vary significantly within the Gulf coast region. Within each of the subcategories, unit processes did not vary enough to significantly alter the costs.

Tables 132 and 133 list the costs for waste treatment systems for canned and breaded shrimp operations. Most processors employed either tangential or rotary screens to treat their wastewater before discharging to the receiving waters.

3.3.6. Clams

Most clam processing plants are located along the central coast of the Eastern Seaboard. Large conventional plants produce over 5000 tons of clam meat annually, while the majority of the mechanized operations average around 7000 tons per year. The processing season averages between 180 and 200 days per year. Tables 134 through 143 show the treatment costs for a typical mechanized and conventional plant, respectively.

TABLE 132. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CANNED GULF SHRIMP

OPERATING DAY	10.0 HOURS
SEASON	210.0 DAYS
PRODUCTION	2.6 TON/HR
	2.4 KKG/HR
PROCESS FLOW	433.0 GPM
	27.3 L/SEC
HYDRAULIC LOAD	9824.6 GAL/TON
	41.0 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	39.	185.	340.	232.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	3.	15.	27.	19.
DEPRECIATION @ 10%	4.	19.	34.	23.
DAILY COSTS($)				
O&M	9.	25.	50.	38.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	9.	39.	72.	50.

RESULTING EFFLUENT LEVELS

PARAMETER	1	2	3	4
BOD-MG/L	1123.	786.	118.	157.
-KG/KKG	46.00	32.20	4.83	6.44
TSS-MG/L	920.	276.	60.	200.
-KG/KKG	37.70	11.31	2.46	8.19
O&G-MG/L	268.	40.	6.	20.
-KG/KKG	11.00	1.65	0.25	0.82

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION **WITH CHEMICALS**
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 133. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : BREADED GULF SHRIMP

OPERATING DAY	10.0 HOURS
SEASON	210.0 DAYS
PRODUCTION	0.8 TON/HR
	0.7 KKG/HR
PROCESS FLOW	360.0 GPM
	22.7 L/SEC
HYDRAULIC LOAD	28005.4 GAL/TON
	116.9 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	35.	159.	300.	203.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	3.	13.	24.	16.
DEPRECIATION @ 10%	3.	16.	30.	20.
DAILY COSTS($)				
O&M	8.	23.	45.	35.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	8.	34.	64.	45.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	719.	504.	76.	101.
-KG/KKG	84.00	58.80	8.82	11.76
TSS-MG/L	788.	236.	60.	200.
-KG/KKG	92.00	27.60	7.01	23.36
G&O-MG/L	5.	5.	5.	5.
-KG/KKG	0.58	0.58	0.58	0.58

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 134. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED CLAMS - LARGE

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	33.1 TON/HR
	30.0 KKG/HR
PROCESS FLOW	900.0 GPM
	56.8 L/SEC
HYDRAULIC LOAD	1633.6 GAL/TON
	6.8 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	66.	331.	530.	385.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	5.	27.	42.	31.
DEPRECIATION @ 10%	7.	33.	53.	38.
DAILY COSTS($)				
O&M	12.	88.	124.	106.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	15.	78.	121.	91.

RESULTING EFFLUENT LEVELS

PARAMETER	1	2	3	4
BOD-MG/L	2114.	1057.	159.	211.
-KG/KKG	14.40	7.20	1.08	1.44
TSS-MG/L	881.	88.	60.	200.
-KG/KKG	6.00	0.60	0.41	1.36
G&O-MG/L	59.	6.	5.	5.
-KG/KKG	0.40	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 135. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED CLAMS - LARGE

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	33.1 TON/HR
	30.0 KKG/HR
PROCESS FLOW	900.0 GPM
	56.8 L/SEC
HYDRAULIC LOAD	1633.6 GAL/TON
	6.8 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	66.	265.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	5.	21.
DEPRECIATION @ 10%	7.	27.
DAILY COSTS($)		
O&M	12.	49.
POWER	1.	3.
TOTAL ANNUAL COSTS($1000)	15.	58.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	2114.	317.
-KG/KKG	14.40	2.16
TSS-MG/L	881	220
-KG/KKG	6.00	1.5
G&O-MG/L	59.	29.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 136. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED CLAMS - LARGE

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	33.1 TON/HR
	30.0 KKG/HR
PROCESS FLOW	900.0 GPM
	56.8 L/SEC
HYDRAULIC LOAD	1633.6 GAL/TON
	6.8 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	66.	120.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	5.	10.
DEPRECIATION @ 10%	7.	12.
DAILY COSTS($)		
O&M	12.	30.
POWER	1.	3.
TOTAL ANNUAL COSTS($1000)	15.	28.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	2114.	423.
-KG/KKG	14.40	2.88
TSS-MG/L	881	264
-KG/KKG	6.00	1.8
G&O-MG/L	59.	29.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

TABLE 137. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED CLAMS - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	9.8 TON/HR
	8.9 KKG/HR
PROCESS FLOW	270.0 GPM
	17.0 L/SEC
HYDRAULIC LOAD	1652.0 GAL/TON
	6.9 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	29.	133.	231.	166.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	11.	19.	13.
DEPRECIATION @ 10%	3.	13.	23.	17.
DAILY COSTS($)				
O&M	6.	35.	50.	43.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	7.	31.	52.	39.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	2090.	1045.	157.	209.
-KG/KKG	14.40	7.20	1.08	1.44
TSS-MG/L	871.	87.	60.	200.
-KG/KKG	6.00	0.60	0.41	1.38
G&O-MG/L	58.	6.	5.	5.
-KG/KKG	0.40	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 138. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED CLAMS - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	9.8 TON/HR
	8.9 KKG/HR
PROCESS FLOW	270.0 GPM
	17.0 L/SEC
HYDRAULIC LOAD	1652.0 GAL/TON
	6.9 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	29.	128.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	10.
DEPRECIATION @ 10%	3.	13.
DAILY COSTS($)		
O&M	6.	20.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	7.	27.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	2090.	314.
-KG/KKG	14.40	2.16
TSS-MG/L	881	220
-KG/KKG	6.00	1.5
G&O-MG/L	58.	29.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1	SCREENING
2	EXTENDED AERATION

TABLE 139. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : MECHANIZED CLAMS - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	9.8 TON/HR
	8.9 KKG/HR
PROCESS FLOW	270.0 GPM
	17.0 L/SEC
HYDRAULIC LOAD	1652.0 GAL/TON
	6.9 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	29.	62.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	5.
DEPRECIATION @ 10%	3.	6.
DAILY COSTS($)		
O&M	6.	14.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	7.	14.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	2090.	418.
-KG/KKG	14.40	2.88
TSS-MG/L	881.	264
-KG/KKG	6.00	1.8
G&O-MG/L	58.	29.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

TABLE 140. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CONVENTIONAL CLAMS - LARGE

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	5.7 TON/HR
	5.2 KKG/HR
PROCESS FLOW	120.0 GPM
	7.6 L/SEC
HYDRAULIC LOAD	1256.7 GAL/TON
	5.2 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	21.	98.	126.	96.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	8.	10.	4.
DEPRECIATION @ 10%	2.	10.	13.	5.
DAILY COSTS($)				
O&M	4.	23.	28.	9.
POWER	1.	2.	3.	2.
TOTAL ANNUAL COSTS($1000)	5.	23.	29.	11.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	1259.	630.	126.	19.
-KG/KKG	6.60	3.30	0.66	0.99
TSS-MG/L	2481.	248.	200.	60.
-KG/KKG	13.00	1.30	1.05	3.84
G&O-MG/L	76.	8.	5.	38.
-KG/KKG	0.40	0.04	0.03	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 AERATED LAGOON
4 SCREENING + EXTENDED AERATION

TABLE 141. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CONVENTIONAL CLAMS - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	3.4 TON/HR
	3.1 KKG/HR
PROCESS FLOW	70.0 GPM
	4.4 L/SEC
HYDRAULIC LOAD	1229.6 GAL/TON
	5.1 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	18.	78.	144.	104.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	1.	6.	12.	8.
DEPRECIATION @ 10%	2.	8.	14.	10.
DAILY COSTS($)				
O&M	4.	19.	26.	23.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	4.	18.	32.	24.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	1287.	644.	97.	129.
-KG/KKG	6.60	3.30	0.50	0.66
TSS-MG/L	2535.	254.	63.	200.
-KG/KKG	13.00	1.30	0.33	1.03
G&O-MG/L	78.	8.	5.	5.
-KG/KKG	0.40	0.04	0.03	0.03

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 142. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CONVENTIONAL CLAMS - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	3.4 TON/HR
	3.1 KKG/HR
PROCESS FLOW	70.0 GPM
	4.4 L/SEC
HYDRAULIC LOAD	1229.6 GAL/TON
	5.1 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	18.	84.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	7.
DEPRECIATION @ 10%	2.	8.
DAILY COSTS($)		
O&M	4.	11.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	18.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	1287.	193.
-KG/KKG	6.60	0.99
TSS-MG/L	2145.	536.
-KG/KKG	11.00	2.75
G&O-MG/L	78.	39.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 143. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CONVENTIONAL CLAMS - SMALL

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	3.4 TON/HR
	3.1 KKG/HR
PROCESS FLOW	70.0 GPM
	4.4 L/SEC
HYDRAULIC LOAD	1229.6 GAL/TON
	5.1 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	18.	43.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	3.
DEPRECIATION @ 10%	2.	4.
DAILY COSTS($)		
O&M	4.	8.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	10.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	1287.	257.
-KG/KKG	6.60	1.32
TSS-MG/L	2145.	644.
-KG/KKG	11.00	3.30
G&O-MG/L	78.	39.
-KG/KKG	0.40	0.20

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING

2 AERATED LAGOON

3.3.7. Steamed and Canned Oysters

Steamed oyster plants are located along the coastline of Chesapeake Bay. Canned oyster plants are known to be located along the Gulf Coast and Washington State Coast. The season runs through the fall to an early spring with approximately 160 days per year of processing. Table 144 shows treatment cost for a typical plant.

3.3.8. Hand-Shucked Oysters

Plants are usually found in small towns along the Pacific, Eastern and Gulf Coasts. Processing methods are very similar in each area. Treatment systems have been costed out for a typical operation in Tables 145 through 151.

3.3.9. Scallops

Scallops are caught and processed the year round in Alaska. The costs for an Alaska operation are listed in Table 152. The costs for a non-Alaska plant are shown in Table 152.

3.3.10. Abalone and Sea Urchin

Plants studied are located near the waterfront in Southern California. Plants usually vary in processing time from one to eight hours per day; however, they probably only average three hours per day. The abalone season is closed from the month of February to August. All of the plants studied ran their wastewater

TABLE 144. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : STEAMED OR CANNED OYSTERS

OPERATING DAY	8.0	HOURS
SEASON	110.0	DAYS
PRODUCTION	0.9	TON/HR
	0.8	KKG/HR
PROCESS FLOW	220.0	GPM
	13.9	L/SEC
HYDRAULIC LOAD	14975.1	GAL/TON
	62.5	CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	26.	123.	213.	153.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	10.	17.	12.
DEPRECIATION @ 10%	3.	12.	21.	15.
DAILY COSTS($)				
O&M	5.	31.	44.	38.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	5.	26.	44.	32.

PARAMETER	RESULTING EFFLUENT LEVELS			
BOD-MG/L	641.	160.	60.	80.
-KG/KKG	40.00	10.00	3.75	5.00
TSS-MG/L	1249.	125.	60.	200.
-KG/KKG	78.00	7.80	3.75	12.49
G&O-MG/L	30.	5.	5.	5.
-KG/KKG	1.90	0.31	0.31	0.31

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

TABLE 145. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : EASTERN HAND SHUCKED OYSTERS - LARGE

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	0.4 TON/HR
	0.4 KKG/HR
PROCESS FLOW	60.0 GPM
	3.8 L/SEC
HYDRAULIC LOAD	9335.1 GAL/TON
	39.0 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	17.	65.	130.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	1.	5.	10.
DEPRECIATION @ 10%	2.	6.	13.
DAILY COSTS($)			
O&M	4.	14.	21.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	4.	15.	28.

	RESULTING EFFLUENT LEVELS		
PARAMETER			
BOD-MG/L	360.	252.	60.
-KG/KKG	14.00	9.80	2.34
TSS-MG/L	283.	85.	60.
-KG/KKG	11.00	3.30	2.34
G&O-MG/L	18.	5.	5.
-KG/KKG	0.70	0.19	0.19

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION

TABLE 146. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY EASTERN HAND SHUCKED OYSTERS - MEDIUM

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	0.2 TON/HR
	0.2 KKG/HR
PROCESS FLOW	25.0 GPM
	1.6 L/SEC
HYDRAULIC LOAD	8508.6 GAL/TON
	35.5 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	11.	41.	78.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	1.	3.	6.
DEPRECIATION @ 10%	1.	4.	8.
DAILY COSTS($)			
O&M	3.	13.	19.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	3.	11.	19.

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	395.	276.	60.
-KG/KKG	14.00	9.80	2.13
TSS-MG/L	310.	93.	60.
-KG/KKG	11.00	3.30	2.13
G&O-MG/L	20.	5.	5.
-KG/KKG	0.70	0.18	0.18

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION

TABLE 147. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - LARGE

OPERATING DAY	8.0 HOURS
SEASON	110.0 DAYS
PRODUCTION	0.4 TON/HR
	0.4 KKG/HR
PROCESS FLOW	115.0 GPM
	7.3 L/SEC
HYDRAULIC LOAD	15655.8 GAL/TON
	65.3 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	20.	94.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	7.
DEPRECIATION @ 10%	2.	9.
DAILY COSTS($)		
O&M	4.	13.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	4.	19.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	429.	64.
-KG/KKG	28.00	4.20
TSS-MG/L	199.	60.
-KG/KKG	13.00	3.92
G&C-MG/L	28.	14.
-KG/KKG	1.80	0.90

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 148. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - MEDIUM

OPERATING DAY	8.0 HOURS
SEASON	110.0 DAYS
PRODUCTION	0.2 TON/HR
	0.2 KKG/HR
PROCESS FLOW	50.0 GPM
	3.2 L/SEC
HYDRAULIC LOAD	13613.7 GAL/TON
	56.8 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	16.	79.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	1.	6.
DEPRECIATION @ 10%	2.	8.
DAILY COSTS($)		
O&M	4.	10.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	3.	16.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	493.	74.
-KG/KKG	28.00	4.20
TSS-MG/L	229.	60.
-KG/KKG	13.00	3.41
G&O-MG/L	32.	16.
-KG/KKG	1.80	0.90

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 149. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : PACIFIC HAND SHUCKED OYSTERS -MEDIUM

OPERATING DAY	8.0 HOURS
SEASON	110.0 DAYS
PRODUCTION	0.2 TON/HR
	0.2 KKG/HR
PROCESS FLOW	50.0 GPM
	3.2 L/SEC
HYDRAULIC LOAD	17017.1 GAL/TON
	71.0 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	16.	63.	79.
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	1.	5.	6.
DEPRECIATION @ 10%	2.	6.	9.
DAILY COSTS($)			
O&M	4.	14.	11.
POWER	1.	2.	2.
TOTAL ANNUAL COSTS($1000)	3.	13.	15.
	RESULTING EFFLUENT LEVELS		
PARAMETER			
BOD-MG/L	395.	237.	60.
-KG/KKG	28.00	16.80	4.26
TSS-MG/L	606.	182.	152.
-KG/KKG	43.00	12.90	10.70
G&O-MG/L	25.	5.	12.
-KG/KKG	1.80	0.35	0.90

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 OR EXTENDED AERATION

TABLE 150. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - SMALL

OPERATING DAY	8.0 HOURS
SEASON	90.0 DAYS
PRODUCTION	0.0 TON/HR
	0.0 KKG/HR
PROCESS FLOW	13.0 GPM
	0.8 L/SEC
HYDRAULIC LOAD	17697.8 GAL/TON
	73.9 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	8.	33.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	0.	3.
DEPRECIATION @ 10%	0.	3.
DAILY COSTS($)		
O&M	3.	9.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	2.	7.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	379.	60.
-KG/KKG	28.00	4.43
TSS-MG/L	176.	60.
-KG/KKG	13.00	4.43
G&O-MG/L	24.	12.
-KG/KKG	1.80	0.90

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 EXTENDED AERATION

TABLE 151. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - SMALL

OPERATING DAY	8.0 HOURS
SEASON	90.0 DAYS
PRODUCTION	<0.1 TON/HR
	<0.1 KKG/HR
PROCESS FLOW	13.0 GPM
	0.8 L/SEC
HYDRAULIC LOAD	17697.8 GAL/TON
	73.9 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	8.	32.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	0.	3.
DEPRECIATION @ 10%	0.	3.
DAILY COSTS($)		
O&M	3.	13.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	2.	7.

	RESULTING EFFLUENT LEVELS	
PARAMETER		
BOD-MG/L	379.	228.
-KG/KKG	28.00	16.80
TSS-MG/L	583.	175.
-KG/KKG	43.00	12.90
G&O-MG/L	24.	5.
-KG/KKG	1.80	0.37

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS

TABLE 152. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : ALASKAN SCALLOPS
(NON-ALASKAN SCALLOP COSTS IN PARENTHESIS)

OPERATING DAY	12.0 HOURS
SEASON	60.0 DAYS
PRODUCTION	1.7 TON/HR
	1.5 KKG/HR
PROCESS FLOW	55.0 GPM
	3.5 L/SEC
HYDRAULIC LOAD	1996.7 GAL/TON
	8.3 CU M/KKG

TREATMENT SYSTEM	1	2	3
INITIAL INVESTMENT($1000)	42.(17)	158.(63)	281.(113)
ANNUAL COSTS($1000)			
CAPITAL COSTS @ 8%	3.(1)	13.(5)	22.(9)
DEPRECIATION @ 10%	4.(2)	16.(6)	28.(12)
DAILY COSTS($)			
O&M	5.	21.	31.
POWER	1.	2.	3.
TOTAL ANNUAL COSTS($1000)	8.(4)	30.(12)	52.(23)

PARAMETER	RESULTING EFFLUENT LEVELS		
BOD-MG/L	384.	269.	60.
-KG/KKG	3.20	2.24	0.50
TSS-MG/L	108.	32.	60.
-KG/KKG	0.90	0.27	0.50
G&O-MG/L	12.	5.	5.
-KG/KKG	0.10	0.04	0.04

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITHOUT CHEMICALS
3 SCREENING AND EXTENDED AERATION

through a small settling tank prior to discharge into the municipal sewer. The costs of the treatment are shown in Table 153.

3.3.11. Lobster and Conch Canning

Spiny lobster water effluent treatment costs are shown in Table 154. Spiny lobster plants are located along the Southern California and Florida coastlines. The Southern California spiny lobster season is closed from April to October. No treatment was considered necessary for the American lobster plants since no processing is accomplished.

Conch canning plants are located on the Eastern Seaboard. There are no seasons on the harvesting of conchs, the majority of the catch being caught incidently with clams. Conch canning costs are shown in Table 155.

TABLE 153. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : **ABALONE/SEA URCHIN**

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	0.9 TON/HR
	0.8 KKG/HR
PROCESS FLOW	10.0 GPM
	0.6 L/SEC
HYDRAULIC LOAD	680.7 GAL/TON
	2.8 CU M/KKG

TREATMENT SYSTEM	1	2
INITIAL INVESTMENT($1000)	26.	47.
ANNUAL COSTS($1000)		
CAPITAL COSTS @ 8%	2.	4.
DEPRECIATION @ 10%	3.	5.
DAILY COSTS($)		
O&M	10.	15.
POWER	1.	2.
TOTAL ANNUAL COSTS($1000)	7.	12.

PARAMETER	RESULTING EFFLUENT LEVELS	
BOD-MG/L	1762.	264.
-KG/KKG	5.00	0.75
TSS-MG/L	423.	106.
-KG/KKG	1.20	0.30
G&O-MG/L	39.	19.
-KG/KKG	0.11	0.06

TREATMENT SYSTEMS
(CUMULATIVE)

1 FLOTATION WITHOUT CHEMICALS
2 EXTENDED AERATION

TABLE154. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : SPINY LOBSTER

OPERATING DAY	8.0 HOURS
SEASON	120.0 DAYS
PRODUCTION	0.4 TON/HR
	0.3 KKG/HR
PROCESS FLOW	3.0 GPM
	31.2 L/SEC
HYDRAULIC LOAD	495.0 GAL/TON
	2.1 CU M/KKG

TREATMENT SYSTEM	1
INITIAL INVESTMENT($1000)	19.
ANNUAL COSTS($1000)	
CAPITAL COSTS @ 8%	1.
DEPRECIATION @ 10%	2.
DAILY COSTS($)	
O&M	10.
POWER	1.
TOTAL ANNUAL COSTS($1000)	5.

PARAMETER	RESULTING EFFLUENT LEVELS
BOD-MG/L	1085.
-KG/KKG	2.24
TSS-MG/L	174.
-KG/KKG	0.36
G&O-MG/L	19.
-KG/KKG	0.04

TREATMENT SYSTEMS
(CUMULATIVE)

1 FLOTATION- WITH CHEMICALS

TABLE 155. WATER EFFLUENT TREATMENT COSTS

CANNED AND PRESERVED FISH AND SEAFOOD

SUBCATEGORY : CLAM/CONCH CANNING

OPERATING DAY	8.0 HOURS
SEASON	200.0 DAYS
PRODUCTION	1.1 TON/HR
	1.0 KKG/HR
PROCESS FLOW	250.0 GPM
	859.0 L/SEC
HYDRAULIC LOAD	13613.7 GAL/TON
	56.8 CU M/KKG

TREATMENT SYSTEM	1	2	3	4
INITIAL INVESTMENT($1000)	28.	116.	211.	148.
ANNUAL COSTS($1000)				
CAPITAL COSTS @ 8%	2.	9.	17.	12.
DEPRECIATION @ 10%	3.	12.	21.	15.
DAILY COSTS($)				
O&M	6.	34.	47.	41.
POWER	1.	2.	3.	3.
TOTAL ANNUAL COSTS($1000)	6.	28.	48.	35.

	RESULTING EFFLUENT LEVELS			
PARAMETER				
BOD-MG/L	722.	361.	60.	80.
-KG/KKG	41.00	20.50	3.41	4.54
TSS-MG/L	173.	17.	60.	200.
-KG/KKG	9.80	0.98	3.41	11.35
G&O-MG/L	19.	5.	5.	5.
-KG/KKG	1.10	0.28	0.28	0.28

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

ACKNOWLEDGEMENTS

This project was directed by Michael R. Soderquist, P.E., assisted by Bruce A. Montgomery, and James M. Reiman. The Project Manager for Sea Resources Engineering, Inc., Dr. George Pigott, was assisted by Dr. Om Agarwala and Richard van Dyke. Also involved in the technical portion of the seminars were Fred Claggett of Environment Canada, Irvin Snider, Jr. of Carborundum Corporation and Frank Mauldin of Dominque, Szabo and Associates, Inc.

Participants from the Environmental Protection Agency included John Osborne, Edwin L. Coate, Dennis Cannon, Dan Bodien and Kenneth Dostal. Other contributors included Roy Martin, National Fisheries Institute; Charles Marshall, J. A. Commins and Associates, Inc.; David Dressel and Donald Whitaker, National Marine Fisheries Service; and Walter Mercer, National Canners Association.

Special appreciation is extended to EPA Project Officer Dennis Cannon of the Office of Technology Transfer.

We wish to thank the Water Pollution Control Federation, Wemco division of Envirotech Corporation, Eimco division of Envirotech Corporation, SWECO, Surfpac, Carborundum Corporation, New England Fish Company and the Cape May Canning Company for the use of plates showing their equipment.

It goes without saying that the most valued contributions of all in this endeavor came from the cooperating industrial concerns and industry representatives themselves. Although listing all of their names would be prohibitive, their assistance is gratefully acknowledged.

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Terms Applicable to Waste Treatment and the Seafood Industry

Activated Sludge Process: Removes organic matter from wastewater by saturating it with air and biologically active sludge.

Aeration Tank: A chamber for injecting air or oxygen into water.

Aerobic Organism: An organism that thrives in the presence of oxygen.

Algae (Alga): Simple plants, many microscopic, containing chlorophyll. Most algae are aquatic and may produce a nuisance when conditions are suitable for prolific growth.

Algorithm: Any mechanical or repetitive computational procedure.

Ammonia Stripping: Ammonia removal from a liquid, usually by intimate contact with an ammonia-free gas, such as air.

Anadromous: Type of fish that ascend rivers from the sea to spawn.

Anaerobic: Living or active in the absence of free oxygen.

Aquaculture: The cultivation and harvesting of aquatic plants and animals.

Bacteria: The smallest living organisms which comprise, along with fungi, the decomposer category of the food chain.

Bailwater: Water used to facilitate unloading of fish from fishing vessel holds.

Barometric Leg: Use of moving streams of water to draw a vacuum; aspirator.

Batch Cooker: Product remains stationary in cooker (water is periodically changed).

Benthic Region: The bottom of a body of water. This region supports the benthos, a type of life that not only lives upon but contributes to the character of the bottom.

Benthos: Aquatic bottom-dwelling organisms. These include (1) sessile animals, such as the sponges, barnacles, mussels, oysters, some of the worms, and many attached algae; (2) creeping forms, such as insects, snails and certain clams; and (3) burrowing forms, which include most clams and worms.

Bight: An indentation or recess in the shore of a sea; a bay.

Biological Oxidation: The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable matter.

Biological Stabilization: Reduction in the net energy level or organic matter as a result of the metabolic activity of organisms, so that further biodegradation is very slow.

Biological Treatment: Organic waste treatment in which bacteria and/or biochemical action are intensified under controlled conditions.

Blow Tank: Water-filled tank used to wash oysters or clam meats by agitating with air injected at the bottom.

BOD (Biochemical Oxygen Demand): Amount of oxygen necessary in the water for bacteria to consume the organic sewage. It is used as a measure in telling how well a sewage treatment plant is working.

BOD-5: A measure of the oxygen consumption by aerobic organisms over a 5-day test period at 20°C. It is an indirect measure of the concentration of biologically degradable material present in organic wastes contained in a waste stream.

Botulinus Organisms: Those that cause acute food poisoning.

Breading: A finely ground mixture containing cereal products, flavorings and other ingredients, that is applied to a product that has been moistened, usually with batter.

Brine: Concentrated salt solution which is used to cool or freeze fish.

BTU: British thermal unit, the quantity of heat required to raise one pound of water 1°F.

Building Drain: Lowest horizontal part of a building drainage system.

Building Drainage System: Piping provided for carrying wastewater or other drainage from a building to the street sewer.

Bulking Sludge: Activated sludge that settles poorly because of low-density floc.

Canned Fishery Product: Fish, shell fish, or other aquatic animals packed singly or in combination with other items in hermetically sealed, heat sterilized cans, jars, or other suitable containers. Most, but not all, canned fishery products can be stored at room temperature for an indefinite period of time without spoiling.

Carbon Adsorption: The separation of small waste particles and molecular species, including color and odor contaminants, by attachment to the surface and open pore structure of carbon granules or powder. The carbon is "activated," or made more adsorbent by treatment and processing.

Case: "Standard" packaging in corrugated fiberboard containers.

Centrifugal Decanter: A device which subjects material in a steady stream to a centrifugal force and continuously discharges the separated components.

COD (Chemical Oxygen Demand): A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water.

Chemical Precipitation: A waste treatment process whereby substances dissolved in the wastewater stream are rendered insoluble and form a solid phase that settles out or can be removed by flotation techniques.

Clarification: Process of removing undissolved materials from a liquid. Specifically, removal of solids either by settling or filtration.

Clarifier: A settling basin for separating settleable solids from wastewater.

Coagulant: A material, which, when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that adsorb and precipitate colloidal and suspended solids. The floc particles can be removed by sedimentation. Among the most common chemical coagulants used in sewage treatment are ferric chloride, alum and lime.

Coagulation: The clumping together of solids to make them settle out of the sewage faster. Coagulation of solids is brought about with the use of certain chemicals such as lime, alum, or polyelectrolytes.

Coefficient of Variation: A measure used in describing the amount of variation in a population. An estimate of this value is $S/\bar{X}$ where "S" equals the standard deviation and $\bar{X}$ equals the sample mean.

Coelom: The body cavity of a specific group of animals in which the viscera is located.

Coliform: Relating to, resembling, or being the colon bacillus.

Comminutor: A device for the catching and shredding of heavy solid matter in the primary stage of waste treatment.

Concentration: The total mass (usually in micrograms) of the suspended particles contained in a unit volume (usually one cubic meter) at a given temperature and pressure; sometimes, the concentration may be expressed in terms of total number of particles in a unit volume (e.g., parts per million); concentration may also be called the "loading" or the "level" of a substance; concentration may also pertain to the strength of a solution.

Condensate: Liquid residue resulting from the cooling of a gaseous vapor.

Contamination: A general term signifying the introduction into water of microorganisms, chemical, organic, or inorganic wastes, or sewage, which renders the water unfit for its intended use.

Correlation Coefficient: A measure of the degree of closeness of the linear relationship between two variables. It is a pure number without units or dimensions, and always lies between -1 and +1.

Crustacea: Mostly aquatic animals with rigid outer coverings, jointed appendages, and gills. Examples are crayfish, crabs, barnacles, water fleas, and sow bugs.

Cultural Eutrophication: Acceleration by man of the natural aging process of bodies of water.

Cyclone: A device used to separate dust or mist from gas stream by centrifugal force.

Decomposition: Reduction of the net energy level and change in chemical composition or organic matter because of actions or aerobic or anaerobic microorganisms.

Denitrification: The process involving the facultative conversion by anaerobic bacteria of nitrates into nitrogen and nitrogen oxides.

Deviation, Standard Normal: A measure of dispersion of values about a mean value; the square root of the average of the squares of the individual deviations from the mean.

Digestion: Though "aerobic" digestion is used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds or both. Organic matter may be decomposed to soluble organic acids or alcohols, and subsequently converted to such gases as methane and carbon dioxide. Complete destruction of organic solid materials by bacterial action alone is never accomplished.

Dissolved Air Flotation: A process involving the compression of air and liquid, mixing to super-saturation, and releasing the pressure to generate large numbers of minute air bubbles. As the bubbles rise to the surface of the water, they carry with them small particles that they contact.

Dissolved Oxygen (D.O.): Due to the diurnal fluctuations of dissolved oxygen in streams, the minimum dissolved oxygen value shall apply at or near the time of the average concentration in the stream, taking into account the diurnal fluctuations.

Echinodermata: The phylum of marine animals characterized by an unsegmented body and secondary radial symmetry, e.g., sea stars, sea urchins, sea cucumbers, sea lilies.

Ecology: The science of the interrelationship between living organisms and their environment.

Effluent: Something that flows out, such as a liquid discharged as a waste; for example, the liquid that comes out of a treatment plant after completion of the treatment process.

Electrodialysis: A process by which electricity attracts or draws the mineral salts from sewage.

Enrichment: The addition of nitrogen, phosphorus, carbon compounds and other nutrients into a waterway that increases the growth potential for algae and other aquatic plants. Most frequently, enrichment results from the inflow sewage effluent or from agricultural runoff.

Environment: The physical environment of the world consisting of the atmosphere, hydrosphere, and the lithosphere. The biosphere is that part of the environment supporting life and which is important to man.

Estuary: Commonly an arm of the sea at the lower end of a river. Estuaries are often enclosed by land except at channel entrance points.

Eutrophication: The normally slow aging process of a body of water as it evolves eventually into a terrestiral state as effected by the enrichment of the water.

Eutrophic Waters: Waters with a good supply of nutrients. These waters may support rich organic productions, such as algal blooms.

Extrapolate: To project data into an area not known or experienced, and arrive at knowledge based on inferences of continuity of the data.

Facultative Aerobe: An organism that although fundamentally an anerobe can grow in the presence of free oxygen.

Facultative Anaerobe: An organism that although fundamentally an aerobe can grow in the absence of free oxygen.

Facultative Decomposition: Decomposition of organic matter by facultative microorganisms.

Fish Fillets: The sides of fish that are either skinned or have the skin on, cut lengthwise from the backbone. Most types of fillets are boneless or virtually boneless; some may be specified as "boneless fillets."

Fish Meal: A ground, dried product made from fish or shellfish or parts thereof, generally produced by cooking raw fish or shellfish with steam and pressing the material to obtain the solids which are then dried.

Fish Oil: An oil processed from the body (body oil) or liver (liver oil) of fish. Most fish oils are a by-product of the production of fish meal.

Fish Solubles: A product extracted from the residual press liquor (called "stickwater") after the solids are removed for drying (fish meal) and the oil extracted by centrifuging. This residue is generally condensed to 50 percent solids and marketed as "condensed fish solubles".

Filtration: The process of passing a liquid through a porous medium for the removal of suspended material by a physical straining action.

Floc: Something occurring in indefinite masses or aggregates. A clump of solids formed in sewage when certain chemicals are added.

Flocculation: The process by which certain chemicals from clumps of solids in sewage.

Floc Skimmings: The flocculent mass formed on a quiescent liquid surface and removed for use, treatment, or disposal.

Flume: An artificial channel for conveyance of a stream of water.

Grab Sample: A sample taken at a random place in space and time.

Groundwater: The supply of freshwater under the earth's surface in an aquifier or soil that forms the natural reservoir for man's use.

Heterotrophic Organism: Organisms that are dependent on organic matter for food.

Identify: To determine the exact chemical nature of a hazardous polluting substance.

Impact: (1) An impact is a single collision of one mass in motion with a second mass which may be either in motion or at rest. (2) Impact is a word used to express the extent or severity of an environmental problem; e.g., the number of persons exposed to a given noise environment.

Incineration: Burning the Sludge to remove the water and reduce the remaining residues to a safe, non-burnable ash. The ash can then be disposed of safely on land, in some waters, or into caves or other underground locations.

Influent: A liquid which flows into a containing space or process unit.

Ion Exchange: A reversible chemical reaction between a solid and a liquid by means of which ions may be interchanged between the two. It is in common use in water softening and water deionizing.

Iron Chink: A machine used in the salmon processing industry to butcher salmon.

Kg: Kilogram or 1000 grams, metric unit of weight.

Kjeldahl Nitrogen: A measure of the total amount of nitrogen in the ammonia and organic forms.

KWH: Kilowatt-hours, a measure of total electrical energy consumption.

Lagoons: Scientifically constructed ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a secondary treatment plant.

Landings, Commercial: Quantities of fish, shellfish, and other aquatic plants and animals brought ashore and sold. Landings of fish may be in terms of round (live) weight or dressed weight. Landings of crustaceans are generally on a live weight basis except for shrimp which may be on a heads-on or heads-off basis. Mollusks are generally landed with the shell on but in some cases only the meats are landed (such as scallops).

Live Tank: Metal, wood, or plastic tank with circulating seawater for the purpose of keeping a fish or shellfish alive until processed.

M: Meter, metric unit of length.

Mm: Millimeter = 0.001 meter.

Mg/l: Milligrams per liter; approximately equal parts per million; a term used to indicate concentration of materials in water.

MGD: Millions galls per day.

Mesenteries: The tissue lining the body cavities and from which the organs are suspended.

Microstrainer/microscreen: A mechanical filter consisting of a cylindrical surface of metal filter fabric with openings of 20-60 micrometers in size.

Milt: Reproductive organ (testes) of male fish.

Mixed Liquor: The name given the effluent that comes from the aeration tank after the sewage has been mixed with activated sludge and air.

Municipal Treatment: A city or community-owned waste treatment plant for municipal and, possibly, industrial waste treatment.

Nitrate, Nitrite: Chemical compounds that include the NO_3^- (nitrate) and NO_2^- (nitrite) ions. They are composed of nitrogen and oxygen, are nutrients for growth of algae and other plant life, and contribute to eutrophication.

Nitrification: The process of oxidizing ammonia by bacteria into nitrites and nitrates.

Organic Content: Synonymous with volatile solids except for small traces of some inorganic materials such as calcium carbonate which will lose weight at temperatures used in determining volatile solids.

Organic Detritus: The particulate remains of disintegrated plants and animals.

Organic Matter: The waste from homes or industry of plant or animal origin.

Oxidation Pond: A man-made lake or body of water in which wastes are consumed by bacteria. It is used most frequently with other waste treatment processes. An oxidation pond is basically the same as a sewage lagoon.

Pelagic Region: The open water environment of the ocean consisting of water both over and beyond the continental shelf and which is inhabited by the free swimming fishes.

Per Capita Consumption: Consumption of edible fishery products in the United States, divided by the total civilian population.

pH: The pH value indicates the relative intensity of acidity or alkalinity of water, with the neutral point at 7.0. Values lower than 7.0 indicate the presence of acids; above 7.0 the presence of alkalies.

Phylum: A main category of taxonomic classification into which the plant and animal kingdomes are divided.

Plankton (Plankter): Organisms of relatively small size, mostly microscopic, that have either relatively small powers of locomotion or that drift in the water with waves, currents, and other water motion.

Polishing: Final treatment stage before discharge of effluent to a water course, carried out in shallow, aerobic lagoon or pond, mainly to remove fine suspended solids that settle very slowly. Some aerobic microbiological activity also occurs.

Ponding: A waste treatment technique involving the actual holdup of all wastewaters in a confined space with evaporation and percolation the primary mechanisms operating to dispose of the water.

Pound net: A net laid perpendicularly out from the shoreline with a circular impoundment at the seaward end.

Ppm: Parts per million, also referred to as milligrams per liter (mg/l). This is a unit for expressing the concentration of any substance by weight, usually as grams of substance per million grams of solution. Since a liter of water weighs one kilogram at a specific gravity of 1.0, one part per million is equivalent to one milligram per liter.

Press cake: In the wet reduction process for industrial fishes, the solid fraction which results when cooked fish (and fish wastes) are passed through the screw presses.

Press Liquor: Stickwater resulting from the pressing of fish solids.

Primary Treatment: Removes the material that floats or will settle in sewage. It is accomplished by using screens to catch the floating objects and tanks for the heavy matter to settle in.

Process Water: All water than comes into direct contact with the raw materials, intermediate products, final products, by-products, or contaminated waters and air.

Processed Fishery Products: Fish, shellfish and other aquatic plants and animals, and products thereof, preserved by canning, freezing, cooking, dehydrating, drying, fermenting, pasteurizing, adding salt or other chemical substances, and other commercial processes. Also, changing the form of fish, shellfish or other aquatic plants and animals from their original state into a form in which they are not readily identifiable, such as fillets, steaks, or shrimp logs.

Purse Seiner: Fishing vessel utilizing a seine (net) that is drawn together at the bottom, forming a trap or purse.

Receiving Waters: Rivers, lakes, oceans, or other water courses that receive treated or untreated wastewaters.

Recycle: The return of a quantity of effluent from a specific unit or process to the feed stream of that same unit. This would also apply to return of treated plant wastewater for several plant uses.

Regression: A trend or shift toward a mean. A regression curve or line is thus one that best fits a particular set of data according to some principle.

Retort: Sterilization of a food product at greater than 284°F with steam under pressure.

Re-use: Water re-use, the subsequent use of water following an earlier use without restoring it to the original quality.

Reverse Osmosis: The physical separation of substances from a water stream by reversal of the normal osmotic process, i.e., high pressure, forcing water through a semi-permeable membrane to the pure water side leaving behind more concentrated waste streams.

Rotating Biological Contactor: A waste treatment device involving closely spaced light-weight disks which are rotated through the wastewater allowing aerobic microflora to accumulate at each disk and thereby achieving a reduction in the waste content.

Rotary Screen: A revolving cylindrical screen for the separation of solids from a waste stream.

Round (Live) Weight: The weight of fish, shellfish or other aquatic plants and animals as taken from the water; the complete or full weight as caught.

Sample, Composite: A sample taken at a fixed location by adding together small samples taken frequently during a given period of time.

Sand Filter: Removes the organic wastes from sewage. The wastewater is trickled over a bed of sand. Air and bacteria decompose the wastes filtering through the sand. The clean water flows out through drains in the bottom of the bed. The sludge accumulating at the surface must be removed from the bed periodically.

Sand Trap: Basin in sewage line for collection of high density solids, specifically sand.

Sanitary Sewers: In a separate system, are pipes in a city that carry only domestic wastewater. The storm water runoff is taken care of by a separate system of pipes.

Sanitary Landfill: A site for solid waste disposal using techniques which prevent vector breeching, and control air pollution nuisances, fire hazards and surface or groundwater pollution.

Scatter Diagram: A two dimensional plot used to visually demonstrate the relationship between two sets of data.

Secondary Treatment: The second step in most waste treatment systems in which bacteria consume the organic parts of the wastes. It is accomplished by bringing the sewage and bacteria together in trickling filters or in the activated sludge process.

Sedimentation Tanks: Help remove solids from sewage. The wastewater is pumped to the tanks where the solids settle to the bottom or float on top as scum. The scum is skimmed off the top, and solids on the bottom are pumped out to sludge digestion tanks.

Seine: Any of a number of various nets used to capture fish.

Separator: Separates the loosened shell from the shrimp meat.

Settleable Matter (Solids): Determined in the Imhoff cone test and will show the quantitative settling characteristics of the waste sample.

Settling Tank: Synonymous with "Sedimentation Tank."

Sewers: A system of pipes that collect and deliver wastewater to treatment plants or receiving streams.

Shaker Blower: Dries and sucks the shell of with a vacuum, leaving the shrimp meat.

Skimmer Table: A perforated stainless steel table used to dewater clams and oysters after washing.

Shock Load: A quantity of wastewater or pollutant that greatly exceeds the normal discharged into a treatment system, usually occurring over a limited period of time.

Sludge: The solid matter that settles to the bottom of sedimentation tanks and must be disposed of by digestion or other methods to complete waste treatment.

Slurry: A solids-water mixture, with sufficient water content to impart fluid handling characteristics to the mixture.

Sliming Table: Fish processing vernacular referring to the area in which fish are butchered and/or checked for completeness of butcher.

Spatial Average: The mean value of a set of observations distributed as a function of position.

Species (Both Singular and Plural): A natural population or group of populations that transmit specific characteristics from parent to offspring. They are reproductively isolated from other populations with which they might breed. Populations usually exhibit a loss of fertility when hydridizing.

Standard Deviation: A statistical measure of the spread or variation of individual measurements.

Steam Box: A form of cooker which precooks the product with the use of steam in order to remove oils and water from fish.

Stickwater: Water and entrained organics that originate from the draining or pressing of steam cooked fish products.

Stoichiometric Amount: The amount of a substance involved in a specific chemical reaction, either as a reactant or as a reaction product.

Stop Seine: A net placed across a stream or bay to catch or retain fish.

Stratification: A partition of the universe which is useful when the properties of sub-populations are of interest and used for increasing the precision of the total population estimation when stratum means are sufficiently different and the within stratum variances are appreciably smaller than the total population variance.

Sump: A depression or tank that serves as a drain or receptacle for liquids for salvage or disposal.

Suspended Solids: The wastes that will not sink or settle in in sewage.

Surface Water: The waters of the United States including the territorial seas.

Synergism: A situation in which the combined action of two or more agents acting together is greater than the sum of the action of these agents separately.

Temporal Average: The mean value of a set of observations distributed as a function of time.

Tertiary Waste Treatment: Waste treatment systems used to treat secondary treatment effluent and typically using physical-chemical technologies to effect waste reduction. Synonymous with "Advanced Waste Treatment."

Troll Dressed: Refers to salmon which have been eviscerated at sea.

Total Dissolved Solids (TDS): The solids content of wastewater that is soluble and is measured as total solids content minus the suspended solids.

Trickling Filter: A bed of rocks or stones. The sewage is trickled over the bed so the bacteria can break down the organic wastes. The bacteria collect on the stones through repeated use of the filter.

Viscera: The internal organs of the body, especially those of the abdominal and thoracic cavities.

Viscus (pl. Viscera): Any internal organ within a body cavity.

Water Quality Criteria: The levels of pollutants that affect the suitability of water for a given use. Generally, water use classification includes: public water supply; recreation; propagation of fish and other aquatic life; agricultural use and industrial use.

Weir: A fence, net, or waffle placed across a stream or bay to catch or retain fish. In engineering use it is a dam over which, or through a notch in which, the liquid carried by a horizontal open channel is constrained to flow.

Zero Discharge: The discharge of no pollutants in the wastewater stream of a plant that is discharging into a receiving body of water.

APPENDIX A

List of Equipment Manufacturers

Automatic Analyzers

Hach Chemical Company, P. O. Box 907, Ames, Iowa 50010.

Combustion Equipment Association, Inc., 555 Madison Avenue New York, N.Y. 10022.

Martek Instruments, Inc., 879 West 16th Street, Newport Beach, California 92660

Eberbach Corporation, 505 South Maple Road, Ann Arbor, Michigan 48106

Tritech, Inc., Box 124, Chapel Hill, North Carolina 27514

Preiser Scientific, 900 MacCorkle Avenue, S.W., Charleston, West Virginia 25322

Wilks Scientific Corporation, South Norwalk, Connecticut 06856

Technicon Instruments Corporation, Tarrytown, New York 10591

Bauer - Bauer Brothers Company, Subsidiary Combustion Engineering, Inc., P. O. Box 968, Springfield, Ohio 45501

Centrifuges

Beloit-Passavant Corporation, P. O. Box 997, Jonesville, Wisconsin 53545

Bird Machine Company, South Walpole, Massachusetts 02071

DeLaval Separator Company, Poughkeepsie, New York 12600

Flow Metering Equipment

Envirotech Corporation, Municipal Equipment Division, 100 Valley Drive, Brisbane, California 95005

Laboratory Equipment and Supplies

Hach Chemical Company, P. O. Box 907, Ames, Iowa 50010

Eberbach Corporation, 505 South Maple Road, Ann Arbor, Michigan 48106

National Scientific Company, 25200 Miles Avenue, Cleveland, Ohio 44146

Preiser Scientific, 900 MacCorkle Avenue S.W., Charleston, West Virginia 25322

Precision Scientific Company, 3737 Cortland Street, Chicago, Illinois 60647

Horizon Ecology Company, 7435 North Oak Park Avenue, Chicago, Illinois 60648

Markson Science, Inc., Box NPR, Del Mar, California 92014

Cole-Parmer Instrument Company, 7425 North Oak Park Avenue, Chicago, Illinois 60648

VWR Scientific, P. O. Box 3200, San Francisco, California 94119

Sampling Equipment

Preiser Scientific, 900 MacCorkle Avenue S.W., Charleston, West Virginia 25322

Horizon Ecology Company, 7435 North Oak Park Avenue, Chicago, Illinois 60648

Sigmamotor, Inc., 14 Elizabeth Street, Middleport, New York 14105

Protech, Inc., Roberts Lane, Malvern, Pennsylvania 19355

Quality Control Equipment, Inc., 2505 McKinley Avenue, Des Moines, Iowa 50315

Instrumentation Specialties Company, P. O. Box 5347, Lincoln, Nebraska 68505

N-Con Systems Company, Inc., 410 Boston Post Road, Larchmont, New York 10538

Screening Equipment

SWECO, Inc., 6033 E. Bandine Blvd., Los Angeles, California 90054

Bauer-Bauer Brothers Company, Subsidiary Combustion Engineering, Inc., P. O. Box 968, Springfield, Ohio 45501

Hydrocyclonics Corporation, 968 North Shore Drive, Lake Bluff, Illinois 60044

Jeffrey Manufacturing Company, 961 N. 4th Street, Columbus, Ohio 43216

Dorr-Oliver, Inc., Havemeyer Lane, Stanford, Connecticut 06904

Hendricks Manufacturing Company, Carbondale, Pennsylvania 18407

Peobody Welles, Roscoe, Illinois 61073

Clawson, F.J. & Associates, 6956 Highway 100, Nashville, Tennessee 37205

Allis-Chalmers Manufacturing Company, 1126 S. 70th Street, Milwaukee, Wisconsin 53214

DeLaval Separator Company, Poughkeepsie, New York 12600

Envirex, Inc., 1901 S. Prairie, Waukesha, Wisconsin 53186

Liak Belt Environmental Equipment, FMC Corporation, Prudential Plaza, Chicago, Illinois 60612

Productive Equipment Corporation, 2924 W. Lake Street, Chicago, Illinois 60612

Simplicity Engineering Company, Durand, Michigan 48429

Wastewater Treatment Systems

Cromaglass Corporation, Williamsport, Pennsylvania 17701

ONPS, 4576 SW 103rd Avenue, Beaverton, Oregon 97225

Tempco, Inc., P. O. Box 1087, Bellevue, Washington 98009

Zurn Industries, Inc., 1422 East Avenue, Erie, Pennsylvania 16503

General Environmental Equipment, Inc., 5020 Stepp Avenue, Jacksonville, Florida 32216

Envirotech Corporation, Municipal Equipment Division, 100 Valley Drive, Brisbane, California 95005

Jeffrey Manufacturing Company, 961 N. 4th Street, Columbus, Ohio 43216

Carborundum Corporation, P. O. Box 87, Knoxville, Tennessee 37901

Graver, Division of Ecodyne Corporation, U.S. Highway 22, Union, New Jersey 07083

Beloit-Passavant Corporation, P. O. Box 997, Janesville, Wisconsin 53545

Black-Clawson Company, Middletown, Ohio 54042

Envirex, Inc., 1901 S. Prairie, Waukesha, Wisconsin 53186

Environmental Systems, Division of Litton Industries, Inc., 354 Dawson Drive, Camarillo, California 93010

Infilco Division, Westinghouse Electric Company, 901 S. Campbell Street, Tuscon, Arizona 85719

Keene Corporation, Fluid Handling Division, Cookeville, Tennessee 38501

Komline-Sanderson Engineering Corporation, Peapack, New Jersey 07977

Permutit Company, Division of Sybron Corporation, E. 49 Midland Avenue, Paramus, New Jersey 07652

Conversion Table

Conversion Table

MULTIPLY (ENGLISH UNITS)		by		TO OBTAIN (METRIC UNITS)
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig+1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

* Actual conversion, not a multiplier

ENVIRONMENTAL PROTECTION AGENCY

TECHNOLOGY TRANSFER SEMINAR

"UPGRADING SEAFOOD PROCESSING FACILITIES

TO REDUCE POLLUTION"

"DISSOLVED AIR FLOTATION TREATMENT OF SEAFOOD WASTES"

BY

IRVIN F. SNIDER, JR.

MARKET DEVELOPMENT MANAGER

CARBORUNDUM ENVIRONMENTAL SYSTEMS, INC.

KNOXVILLE, TENNESSEE

I. DESCRIPTION OF DISSOLVED AIR FLOTATION PROCESS

Dissolved air flotation is quite different from the vacuum and froth flotation processes previously mentioned. The earliest mass application of dissolved air flotation was about 25 years ago in the petroleum production fields for separation of small amounts of oil from large amounts of water. This helped to make dissolved air flotation a universally accepted means of recoving oil from waste streams with the accent on recovery rather than pollution control.

Several years later, a leading red meat processor discovered that one hog in every ten put through their processing plant was going down the drain -- and about 70 percent of that hog was grease. So they decided to recover this material as it represented potential profit. Since grease naturally floats on water, it was found that dissolved air flotation would aid in increased grease recovery. To date we have 40 such installations for this company which not only recover 90 percent of the grease but also serve as a means of pollution control.

Dissolved air flotation utilizes "Henry's Law" to obtain solubility of gas in a liquid.

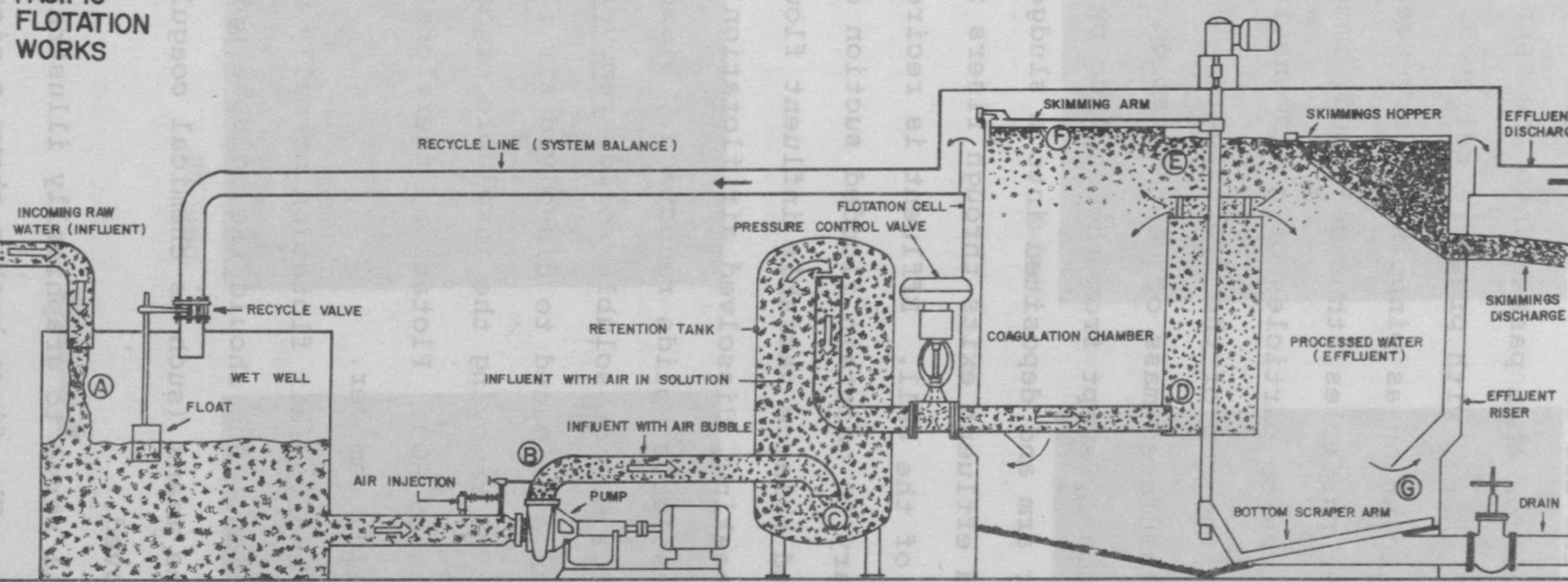
The amount of gas which a liquid can dissolve at a given temperature is determined by Henry's Law, which states that the partial pressure of a gas in equilibrium with a solution is equal to a constant times its concentration in the solution or: $P = CX$. The constant "C" is different for each system and for each temperature. The liquid can be saturated with dissolved air under pressure, and when the pressure is released under proper hydraulic conditions, the air comes out of solution in minute bubbles or molecular form. We see this regularly in carbonated beverages; before being opened the presence of gas is not visually apparent but removal of the cap and subsequent loss (or equilization) of pressure permits the gas to burst from solution and rise to the surface in bubble form. The combined matri, due to its reduced combined specific gravity, floats to the surface.

A gas coming out of solution from a liquid will preferentially form a bubble on a finite nucleus. In accordance with the nucleus theory, molecules tend to attach themselves to a nucleus, which, in wastewater treatment, is the contaminant. In seconds, a sufficient number of molecules have collected to form "life-savers" around the contaminant nuclei and float them to the surface. The combined air solids mass has a specific gravity less than the liquid, and material that would eventually settle or perhaps remain in suspension can be easily removed from the top of the separator tank.

The basic flotation system operates as follows: (See Figure I)

1. Raw or pretreated (screened, clarified, etc.) wastewater enters the wet well.
2. Wastewater (influent) from the wet well is pumped to the retention tank, air is introduced into the system by venturi action.

HOW PACIFIC FLOTATION WORKS

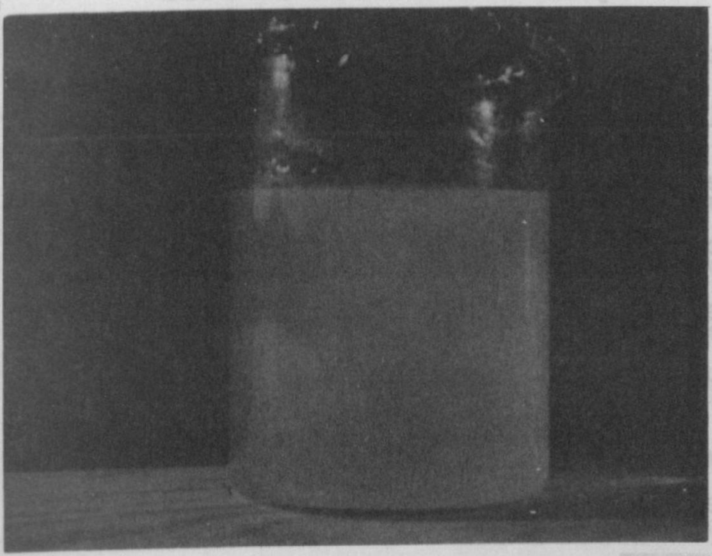


3. As the mixture enters the retention tank, pressure forces the air into true solution with the liquid.
4. The solution then passes into the open coagulation chamber where, with pressure relieved, air comes out of solution as pinpoint effervescence.
5. Tiny air particles, thus released, immediately attach themselves to particles of contamination and float them to the top of the flotation cell.
6. The accumulated mass of contamination (or "float") is continuously swept from the surface by the top scraper arm and deposited into a sludge hopper.
7. Treated effluent exits through risers from near the bottom of the cell. Effluent is recirculated as necessary to maintain flooded suction on the influent pump and balance variable influent flows.

Generally speaking, dissolved air flotation is capable of 90 percent insoluble solids reduction. Dissolved air flotation is not a BOD or soluble solids remover as such. Any BOD reduction attributed to dissolved air flotation occurs as a result of removing the insoluble organic solids and their associated BOD. Flotation, therefore, is strictly an insoluble solids remover.

Likewise, dissolved air flotation normally will not remove soluble solids. But should the soluble portion be made insoluble by some means (such as chemical coagulation), then they can be removed.

Figure 2 will serve to graphically illustrate the flotation principle. The first beaker shows a picture of a



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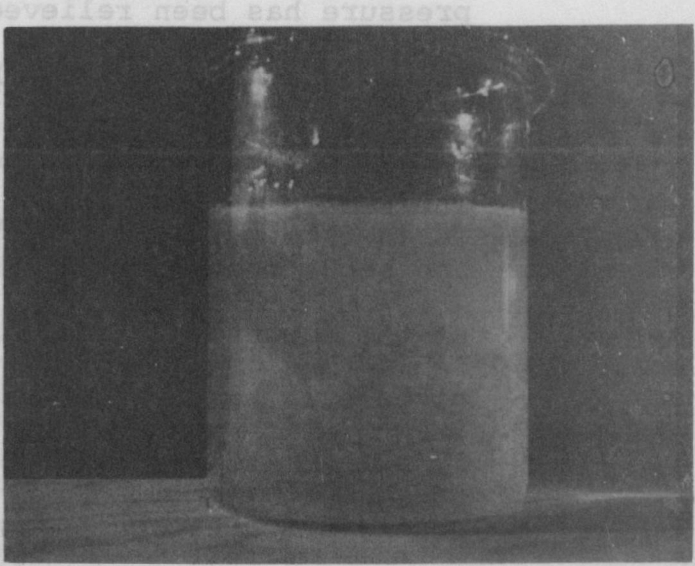

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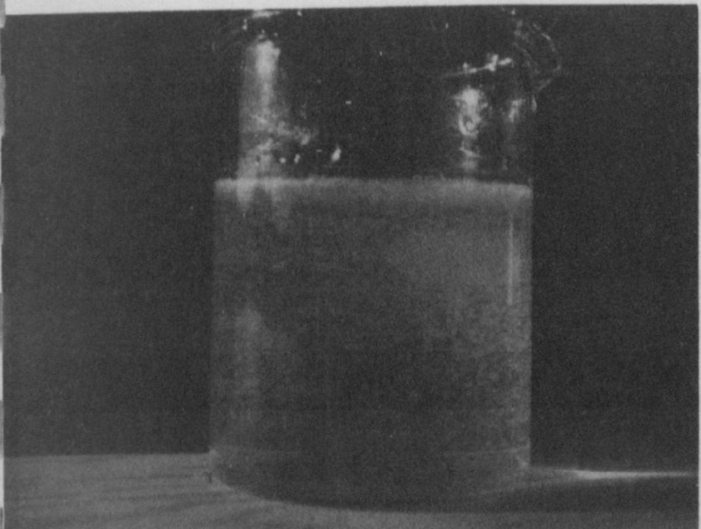
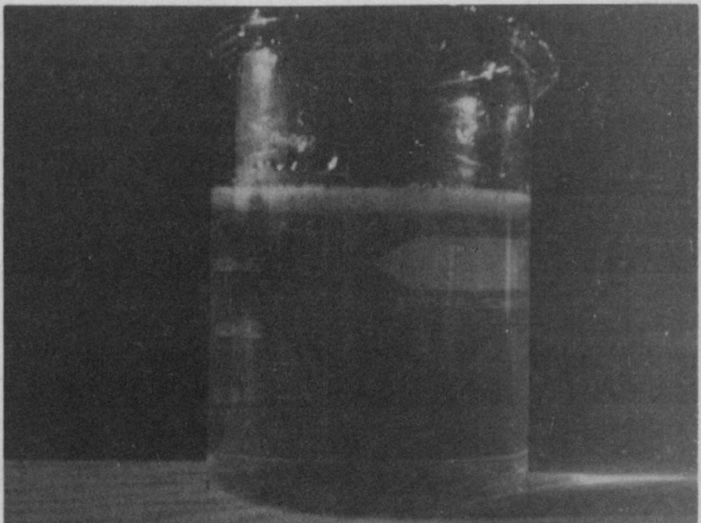


20 sec



60 sec

Figure 2.

sample of wastewater containing chemicals just after the pressure has been relieved and it begins to come out of solution. The next picture shows the same beaker 10 seconds after the floc has formed and is beginning its upward path. The next picture is taken 10 seconds after the previous one and shows that most of the insoluble solids have arrived at the top and are a distinct skimmings layer. The final picture is taken after one minutes total elapsed time. Nearly all of the insoluble solids have been removed and are neatly compacted on the surface for removal.

II. MODES AND CONFIGURATIONS

There are three basically different modes of dissolved air flotation systems in which the foregoing separation may be employed for industrial wastewater treatment, all of which are dependent on Henry's Law.

The systems differ in mechanical design and piping arrangement but the successful performance of any system is more dependent on proper application and careful evaluation of the waste stream than on the mode of operation.

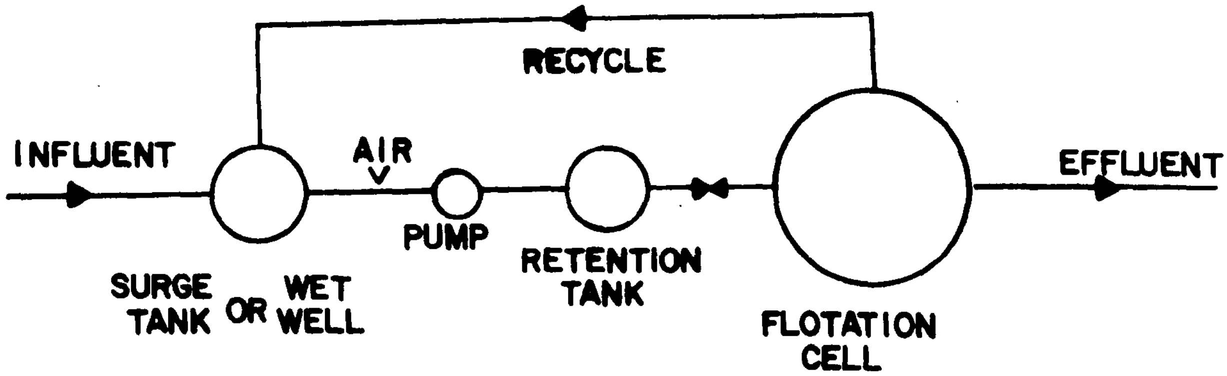
These three types of dissolved air flotation are:

1. Total pressurization
2. Partial Pressurization
3. Recycle Pressurization

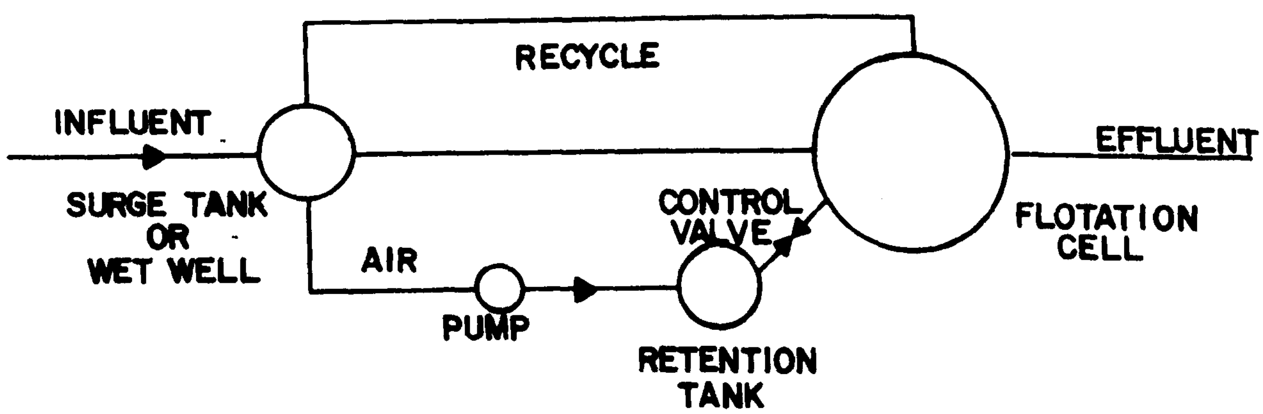
Full flow pressurization is just what the term implies. The total plant flow with air injected into it is pressurized and held in the retention tank before entering the flotation cell. The flow is straight through and single pass.

As opposed to full flow pressurization, partial pressurization indicates that only part of the total plant flow is pressurized and the remainder of the plant flow enters the separator, bypassing the air and dissolution system. Recycle is employed only to protect the process pump during low flow and plays no significant role in the process. This water make up line is not necessarily a part of either partial pressurization or recycle pressurization.

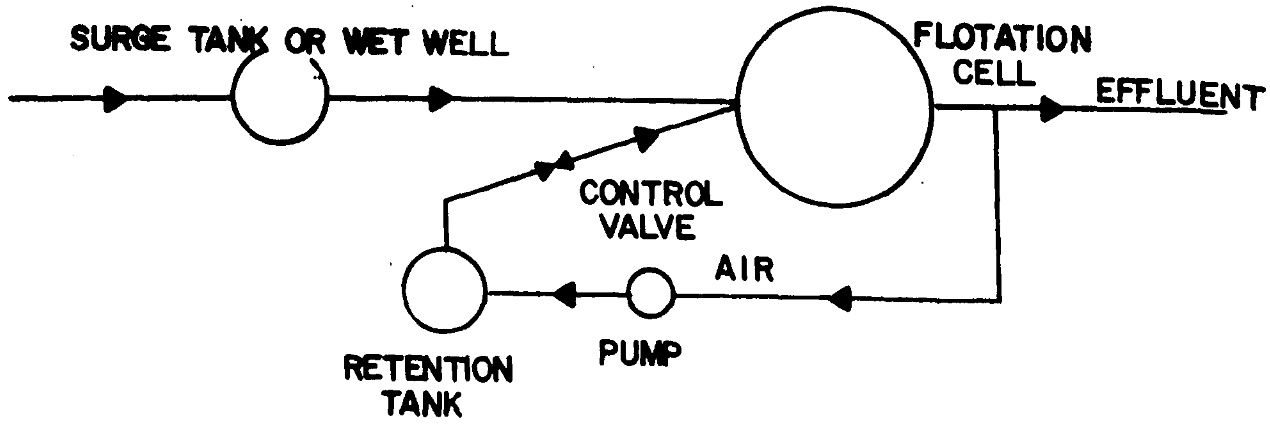
FULL FLOW PRESSURIZATION



PARTIAL PRESSURIZATION



RECYCLE PRESSURIZATION



This type permits a smaller process pump where gravity flow is possible and smaller pressure system. However, the system must operate at higher pressures in order to achieve an air to liquid ratio comparable to total pressurization.

Recycle pressurization represents the most significant deviation from the previous modes. Clarified effluent is recycled for the purpose of adding air and then injected into the raw wastewater.

In this system, a stream of the effluent, usually 20 to 50 percent of the incoming flow, is pressurized with air added usually by a compressor; maybe air ejector. The recycled flow is blended with the raw flow either in the flotation cell or in an inlet manifold.

III. DESIGN INFORMATION

There are three design parameters involved in sizing of flotation equipment, and these are:

1. Hydraulic loading
2. Solids loading
3. Air to solids ratio

Hydraulic loading is simply the flow rate of water through the flotation cell in gallons/minute divided by the surface area in ft.^{2} of the flotation cell. As an example, let us assume that we have a flotation cell with 50 ft^2 of flotation area handling 100 gpm of waste. The hydraulic loading can be found by dividing the flow rate (100) by the surface area (50). This results in a hydraulic loading of 2 gpm/ft^2. Normal hydraulic loading design criteria for flotation cells run from 1 to 2 gpm/ft^2.

In comparing these figures with other types of equipment it should be noted that clarifiers are sized based on 1 gpm/ft^2 or less because the flow must be slowed to provide a relatively still condition to allow settling.

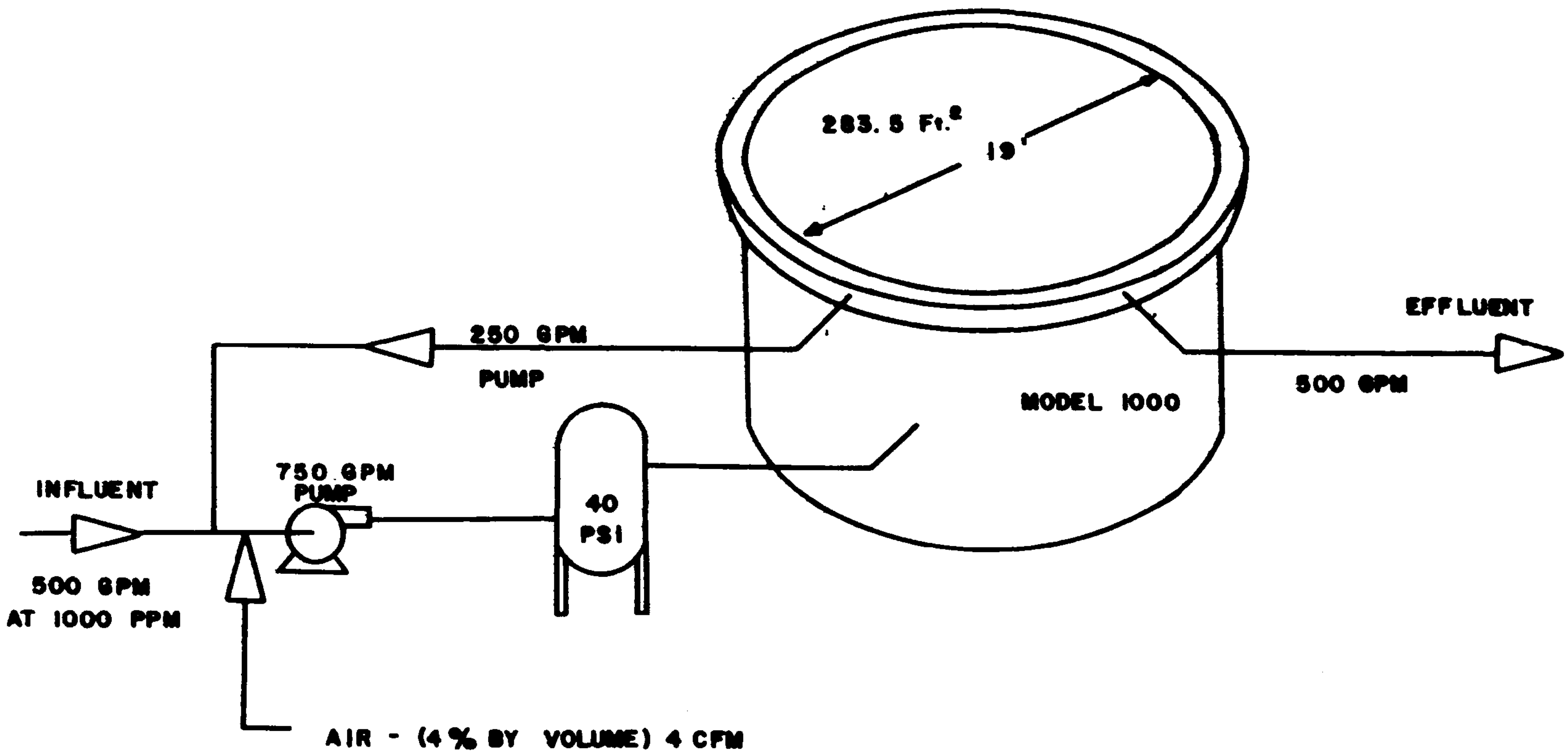
In addition to sizing to handle for flow rate through the unit some allowance must be made for the insoluble solids that are to be removed. For this we use the term pounds of insoluble solids/hour/ft^2 to quantify the solids loading to the unit. As an example, let's assume that the influent to the system contains 1000 ppm of insoluble solids and is flowing at 500 gpm. This is 4.17# of solids per minute or

250 pounds per hour. We therefore have 250 pounds per hour or solids to be removed in a flotation cell of 283 ft^2. Dividing the 250 pounds/hour by the 283 ft^2 we arrive at a solids loading of 0.88#/hour/ft^2.

The third design parameter, the air to solids ratio, is used to insure that sufficient air is added to float the solids. This term is derived by dividing the amount of air being added/hour by the solids loading (#/hour). Most applications call for an air/solids ratio of approximately 0.01 to 0.1.

To further illustrate the parameters we have just defined, let's take an example for a system treating 500 gpm of plant waste. Figure 4 shows a flotation system with a 750 gpm process pump and a flotation cell with 283.5 ft^2 (19' diameter) of flotation surface area. The design parameters are easily calculated and are fairly self-explanatory.

Again I would like to emphasize that successful performance of any system is more dependent on proper application and careful evaluation of the waste stream than on the mode of operation.



DESIGN CONDITIONS

1. Hydraulic loading - 750 GPM/ 283.5 sq ft = 2.64 GPM/ sq ft

2. Solids/hour - 8.34#/1000 Gallons of 8.43#/min x 60 minutes = 250.2#/hour

3. Solids loaking - 250.2#/hour/ 283.5 sq ft = 0.88#/hour/sq ft

4. Air/hour - 4 CFM x 0.08#/cu ft = 0.32#/min or 0.64#/1000 gallons

5. Air/solids ratio - 0.64#/1000 gallons ÷ 8.34#/1000 gallons = 0.077

IV. ECONOMICS

Now that we have discussed equipment sizing, we should turn our attention to the costs involved.

Let's take the case of a shrimp processor whose plant effluent has a maximum peak flow of 300 gpm. The basic equipment cost would be approximately $48,000. This includes flotation cell, retention tank, process pump plus one stand-by, 2 chemical addition systems, pH control, skimmings pump and tank, screen, freight, and erection. To pipe, wire, and pour the necessary concrete work to complete the system might cost an additional $45,000.

For the case of a shrimp processor who has twice the flow as in the previous example, the total equipment cost for a 600 gpm system is about $62,000. To complete the system might cost another $55,000. It is important to note that because the size of the flow doubled, the total cost of the total system did not double but only increased by 25 percent. These examples are two specific cases. To apply them to your specific plant would require some modification to fit your particular labor and materials situation.

In addition to the above capital costs, the following operating costs should be considered:

Chemical Costs:	3¢ - 8¢/1000 gallons	(depending on waste concentration)
Operator Labor:	4 - 8 man hours/day	(depending on operator ability, compatability of system design)
Maintenance:	$300 - $1200/year	

The single most important element which will determine the success or failure of any system is the operator. If he doesn't care if the system operates properly then it will not. Therefore, careful consideration should be given to the proper selection of an operator. I don't mean to imply that he should have a degree, but should be mechanically inclined and above all interested in making the system work.

V. CASE HISTORIES

During the past four years I have been involved in treating wastes from several seafood processing plants and have enjoyed some measure of success. I would now like to give a brief description of each.

A. Shrimp Processing - New England Fish Co. - Kodiak, Alaska. The study was performed by the National Marine Fisheries Service, Seattle Laboratory, in July and August of 1972. Based on an average (see Figure 5) the flotation system after screening achieved 76.9 percent suspended solids removal and 73.4 percent COD removal. Problems noted were as follows:

1. Proper screening prior to flotation is required.
2. pH control should be provided so as to attain consistent results.
3. High salt content of processing water will effect ultimate COD discharge levels.

B. King Crab Processor - Roxanne Co. - Kodiak, Alaska. This study was also performed by the National Marine Fisheries Service, Seattle Laboratory, in August of 1972. Only three test runs were made due to lack of time and supply of raw product. Because of the high degree of variability of plant effluent and the short time available for testing, the results are somewhat inconclusive. Problems encountered were as follows:

Figure 5. SHRIMP PROCESSING - NEW ENGLAND FISH CO. - KODIAK, ALASKA

AS REPORTED BY MR. PALMER PETERSON, NATIONAL MARINE FISHERIES SERVICE, SEATTLE

Parameter	Before Flotation	After Flotation	Average % Reduction of Screened Liquid	Approximate % Overall Reduction
COD (mg/l)	$4227\ ^{+1177}_{-825}$	$1123\ ^{+347}_{-367}$	73.4	80
Suspended Solids (mg/l)	$1090\ ^{+285}_{-190}$	$252\ ^{+198}_{-112}$	76.9	90
Settleable Solids (mg/l)	$22.1\ ^{+5.2}_{-8.8}$	$2.5\ ^{+2}_{-2}$	88.8	96
Protein (%)	.201	.114	43.3	--
Turbidity (FTU)	500	100	80	--

NOTE: Raw processing water contained 500-600 ppm of COD.

1. Insufficient means of collecting the plant wastes at one central collection point prevented treatment of waste more in line with actual waste discharge.
2. Variable flow conditions pointed out need for precise chemical control.

Figure 6. KING CRAB PROCESSOR - ROXANNE CO. - KODIAK, ALASKA

AS REPORTED BY MR. PALMER PETERSON,
NATIONAL MARINE FISHERIES SERVICE

	Suspended Solids		COD	
	In	Out	In	Out
	3130 - 180	710 - 47	2680 - 105	940 - 95
% Reduction*	68.9%		64.8%	

*Average for 3 runs

C. Shrimp Processor - American Shrimp Canners Association - New Orleans, Louisiana. This study was conducted under a Federal Water Pollution Control grant and was conducted at the Robinson Canning Co. in West Wego, Louisiana. Mr. Mauldin will cover the study in more detail. However, in general, he found that approximately 70 percent BOD, 65 percent COD, and 80 percent suspended solids removal was possible (See Figure 7).

FIGURE 7. SHRIMP PROCESSORS - AMERICAN SHRIMP CANNERS ASSOCIATION - WEST WEGO, LA

AS REPORTED BY MR. FRANK MAULDIN; DOMINGUE, SZABO & ASSOCIATES

	BOD_5		COD		Suspended Solids	
	In	Out	In	Out	In	Out
	1200	240	3200	1150	625	110
% Reduction	80.0		64.1		82.4	

D. Menhaden Processing Plant - National Marine Fisheries Service Reedville, Virginia. This study was run from June 13 to July 25, 1972, at the Standard Products Plant in Reedville, Virginia. Tests were run on bailwater, stickwater, and several other miscellaneous streams. As a result of this work, it was found that dissolved air flotation treatment was effective in reducing the solids and oil from the bailwater. It was also demonstrated that stickwater could be treated in the same way. Test results for processing of bailwater appear in Figure 10 and are similar to those of treating stickwater.

During the 1973 season a full-scale system was installed at the Standard Products Plant in Reedville, Virginia for the purpose of treating bailwater and with provisions for treating stickwater as permitted. By the end of the season the water in the system had been used for approximately one month and had unloaded some 18 million fish. Also at the end of the season stickwater was run through the system with apparent excellent results.

Problems encountered with the system are as follows:

1. Improper screening of the solids out of the bailwater resulted in operating problems.
2. During the hotest months of the season when the fish are unloaded in an advance state of

Figure 8. MENHADEN - REEDVILLE, VIRGINIA

AS REPORTED BY MR. DAN BAKER, NATIONAL MARINE FISHERIES SERVICE, GLOUCHESTER LAB.

	In	Out	% Reduction
Insoluble Solids	30,000	2,800	91
Soluble Solids	20,000	10,000	50
COD	83,000	16,000	81
Protein	20,000	7,200	64
Oil and Grease	13,480	560	97

BOD = 547

degradation an occasional phenomenon known as "foaming" occurred. This was a problem because it was impossible to contain the water as it would climb the walls of the vessel. Several attempts to reduce the foaming were only moderately successful. It is felt that refrigeration would go a long way to pervent degradation of the raw product and eliminate "foaming".

E. Salmon Plant - B.C. Packers - Stevston, B.C., Canada. This study was begun back in 1969 by the Fisheries Research Board of Canada. Test results for that work appear in Figure 9. This work has been quite successful as not only was it shown that flotation was effective in cleaning the water, but it also demonstrated that the recovered material (skimmings and screenings) could be reused and represented potential profit.

Figure 9. SALMON - B.C. PACKERS

AS REPORTED BY FISHERIES RESEARCH BOARD OF CANADA; TECHNICAL REPORT NO. 286

	In	Out	% Reduction
Insoluble Solids	959	61	92
Soluble Solids	1,590	1,075	28
COD	5,635	15	84
Protein	1,545	567	61
Oil and Grease	360	20	94

CASE STUDY

TREATMENT OF GULF SHRIMP PROCESSING AND CANNING WASTE

By:
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A. J. Szabo

Domingue, Szabo & Associates, Inc.
Consulting Engineers
Lafayette, Louisiana

Prepared For:

Technology Transfer Seminar

UPGRADING SEAFOOD PROCESSING FACILITIES
TO REDUCE POLLUTION

Environmental Protection Agency
National Fisheries Institute
National Canners Association

Seattle, Washington
April 2 and 3, 1974

CASE STUDY

TREATMENT OF GULF SHRIMP PROCESSING AND CANNING WASTE

INTRODUCTION

The American Shrimp Canners Association sponsored this study for the purpose of seeking to develop an economical, practicable method of effectively and efficiently, treating the waste waters from shrimp canning plants. The association consists of twenty-two member firms. The joint efforts through the association were aimed at accomplishing that which many small, individual canners could not individually do.

The shrimp canning plants generally process from ten (10) to twenty (20) tons of raw shrimp per day on a single shift basis. The largest plants are capable of processing up to sixty (60) tons per day with a two-shift operation. These plants receive their raw shrimp from small commercial fishing vessels of two or three-man size and a few larger vessels headquartered between Key West, Florida and Brownsville, Texas. In the central Gulf area alone, there are more than 10,000 registered small commercial fishing boats. These represent the livelihood of more than 30,000 families. The canning plants themselves employ more than 4,000 workers during the peak operating season. Some of these fishermen and plant workers live in remote coastal areas where canneries represent the principal or, in some cases, the only employment available. These shrimp canning plants, many of which are remotely located, are now discharging wastes into rivers, bayous, bays or other adjacent waterways. Some are located in communities where public sewer systems receive the wastewater.

The shrimp fishery in the Gulf of Mexico has been for years one of the most valuable in the United States. Raw shrimp production in Louisiana alone has increased from approximately 5,000 tons at the turn of the century to over 500,000 tons annually in some recent years. Catches of white shrimp (Penaeus setiferous), brown shrimp (Penaeus astecus), and pink shrimp (Penaeus duorarum) are the most common in the Gulf of Mexico. These shrimp spawn during the spring and summer. Eggs are deposited directly into the waters where they drift with tides and currents. The eggs hatch into tiny creatures similar to mites or ticks which grow to about one quarter of an inch size and begin to move into the shallow waters of the bays and bayous. These inside waters serve as nursery grounds for the young shrimp. They grow rapidly as the water begins to warm and migrate to larger bodies of water, eventually reaching the Gulf of Mexico and/or the Atlantic. Because of this continuing cycle, the size of the individual shrimp in a catch varies constantly with the larger sizes occurring in the outside waters.

Shrimp are caught primarily in coastal waters using trawls drawn on the floor of the water body. Most of the shrimp are dead when brought to the surface and the remainder die shortly thereafter. Continued refrigeration (usually with ice) is necessary to preserve this very perishable commodity. Of necessity, the raw shrimp processor must locate close to the fishing grounds and must be able to process the catch rapidly when it is docked. Much of the Gulf Coast catch is handled as a raw product directly to markets and consumers, some is processed and frozen, and up to 50 percent is canned.

The canning of shrimp was first successfully done in 1867 by George W. Dunbar, an enterprising New Englander who settled in New Orleans and operated a cannery after the Civil War. From this difficult and trying beginning, an industry has developed which consists of approximately 70 shrimp canners in the United States, 25 of which are located on the Coast of the Gulf of Mexico. The Gulf Coast Canneries are primarily in Louisiana and Mississippi on bays, or bayous or within short trucking distance of the docks. These canning plants have for many years been and most remain family enterprises. The canneries compete for the available supplies of raw shrimp and generally obtain and process the smaller sizes. Therefore, the economical operating period is generally during the short spring and fall seasons when shrimp may be taken in the regulated coastal waters. Because of the controlled seasons, the variables of supply and the market price, the competition for the raw shrimp is great and no plant is assured that it will operate on a continuous schedule. Nevertheless, each plant which operates must be able to handle its perishable raw shrimp supply in a short time. Therefore, plants have developed along the same, most efficient mechanical operating basis. Most of the equipment is of the same or similar manufacture and the wastes created by the operating units have very similar characteristics.

SHRIMP PROCESSING AND CANNING WASTEWATERS

The operations in a shrimp cannery are basically the same the world over as shown in Figure 1. Raw shrimp are first thoroughly washed and separated from debris or trash and unsuitable materials. The raw shrimp are peeled and deveined with mechanical devices developed especially for the shrimp industry. Heads and hulls are removed, pieces of shell and legs are separated and the remaining tail meat is separated from the waste.

The average wastewater characterization from the peeling operation is shown in Table 1. As can be seen the greatest percentage of pollutants discharged originate at the peeling operation. Miscellaneous operations include canning wastewaters, gravity flume dumps and miscellaneous washdowns during the processing times. The values shown in Table 1 do not include washdown.

In the deveining operation the back of the shrimp is split by a unique razor edge device. The shrimp with the exposed vein then drops into a rotating drum with inside "fingers" which remove the veins. The veins are then washed out of the drum and discharged with the wastewater. The

Figure 1

GENERAL PROCESS SCHEMATIC
SHRIMP CANNING

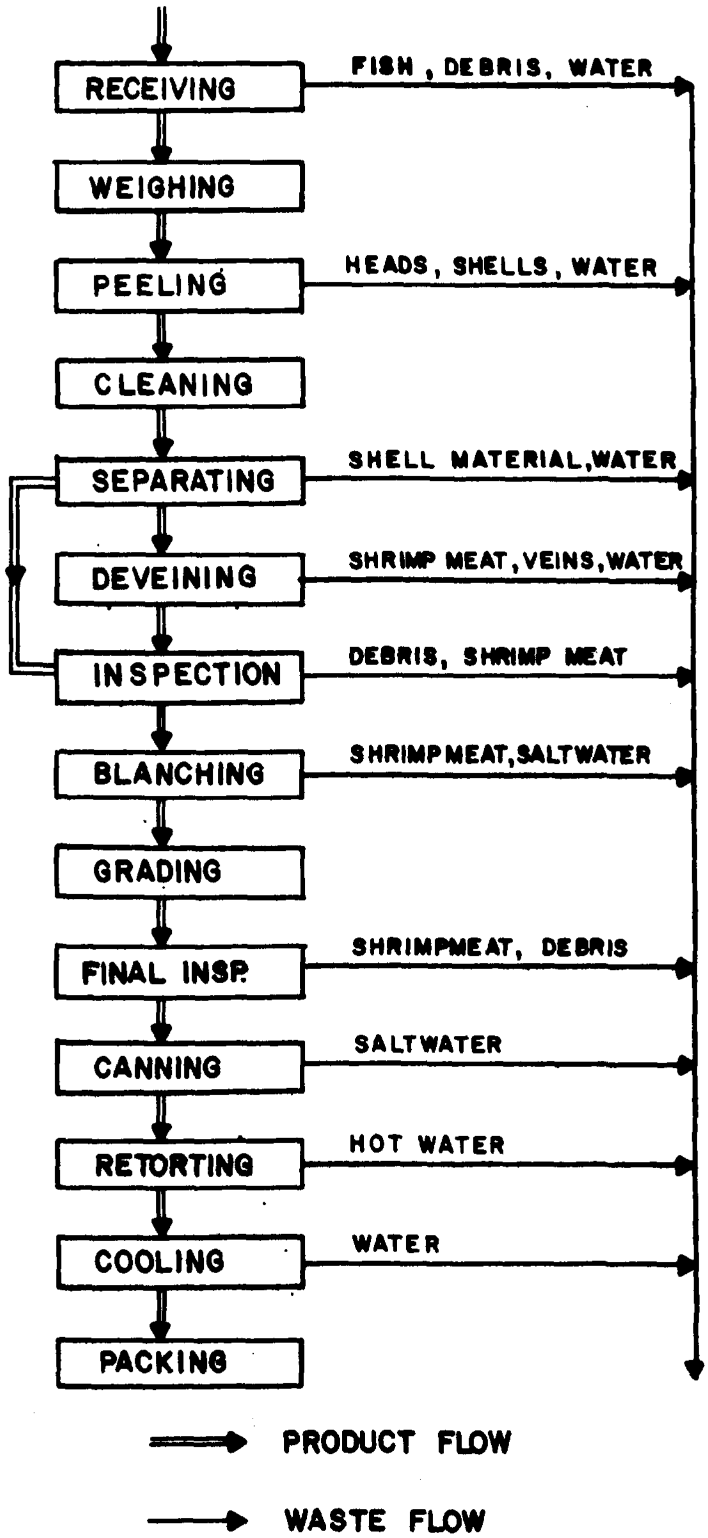


TABLE 1
WASTEWATER CHARACTERIZATION
SHRIMP PROCESSING AND CANNING

	BOD-5 lbs/100 lbs Shrimp	% Total Discharge	Suspended Solids lbs/100 lbs Shrimp	% Total Discharge
Peeling	4.89	72	2.63	68
Deveining	0.51	7	0.45	12
Blanching	0.15	2	0.19	5
Receiving & Raw Washing	0.66	10	0.25	6
Miscellaneous	0.62	9	0.35	9
Total Discharge Processing Only (No Washdown)	6.83	100	3.87	100

deveining operation is generally not used on all shrimp processed but only on the larger shrimp. From Table 1 it can be seen that the deveining operation contributes a significant percentage of the total discharged pollutants.

After deveining the shrimp are pre-cooked or blanched for approximately 3 minutes in a boiling brine solution which curls the meat, extracts moisture and solubles and develops the pink or red color of the finished product. Blanching can either be a batch process where the blanching water is dumped several times daily or continuous where the shrimp are fed through the tank on a conveyor and brine water is continuously added and washed from the tanks.

After cooling, drying, further inspection and grading, the shrimp are packed, on a scaled weight basis into the appropriate size can, then mechanically sealed and retorted for 12 minutes at 250°F. After cooling, the cans are labeled and are ready for shipment to market.

TREATMENT BY SCREENING

The purpose of the screening tests was to evaluate the efficiency and ease of operation of several types of screens. Several of the larger canners had obtained experience in screening the shells and heads from their peeler wastewater with vibrating screens. These screens operated satisfactorily performing this function. None of the canners, however, had experience in screening the total wastewater from a plant, which it was hypothesized would be harder to screen than the peeler wastewater. The total wastewater would contain shrimp veins, meat fragments and small shell fragments which would tend to blind a screen much quicker than the larger shells and heads. It was felt that ease of operation and economical maintenance should be a prime consideration in evaluating the pilot screens.

Pilot testing work was performed on raw peeler wastewater and total discharge wastewater with raw peeling water prescreened. The test plant screened the raw peeler wastewater with a plant scale vibrating screen so the testing of total discharge wastewater with unscreened peeler water included was impossible.

The following screens were tested with raw peeler wastewater:

1. Vibrating Screen
2. Rotating Screen
3. Tangential Screens A, B and C from three different manufacturers.

A description and evaluation of each of these screens follows:

Vibrating Screen. This screen was 48" in diameter with a 20 mesh (approximately 0.84 mm opening) screen fabric. This screen is circular, mounted on coil springs, and wastewater enters from the top. The underflow passes through the screen and the screened solids are vibrated with a spiral rolling motion to the sides of the screen where they are discharged through two ports 180 degrees apart. The vibrations are caused by an electric motor whose shaft is eccentrically loaded. This screen was a permanent installation at the test plant. Wastewater from eight peeling machines and four separators was pumped by centrifugal pumps to the screen. With eight peeling machines operating (the usual practice) the flow to the screen was approximately 500 gpm.

This screen removed suspended solids very efficiently; the removal efficiency approached 40%. The screen, however, was not nearly as efficient in removing settleable solids; the removal was less than 60% leaving a mean settleable solids residual of approximately 20 ml/l in the underflow. BOD-5 and total solids removal appear to be average at around 15% removal. The screened solids were fairly dry with an average value of 84% moisture.

Rotating Screen. The screen had a diameter of 25 inches and a length of 24 inches. The unit had a screen opening of 0.5 mm (32 mesh equivalent). The cylindrical screen had the appearance of well screen with a wedge wire grid. The unit was equipped with a weir influent box for even influent distribution to the screen. The water passes through the screen openings on the top of the screen, falls through the center of the cylinder and passes through the screen openings again on the bottom, thus backwashing any solids trapped in the screen. The solids are carried on the top surface of the screen to a scraper bar where the solids are removed.

The removal of suspended and settleable solids was somewhat less for this screen than for the vibrating screen even though the screen opening for the rotating screen (0.5 mm) was less than for the vibrating screen (0.84 mm). The screened solids, however, were fairly dry. One sample was tested at 22% dry solids.

Tangential Screen A. This pilot screen was 18 inches wide and 33.5 inches high. The test screen was supplied with four different screen openings: 0.020 inches (32 mesh), 0.030 inches (22 mesh), 0.040 inches (16 mesh) and 0.060 inches (11 mesh).

This screen had a headbox and an influent weir for even influent distribution and had a mechanism to feed the wastewater on the screen tangentially. The screen bars were wedgewire and run transverse across the screen. The wedgewire bars curved downward between the vertical supports to cause the flow to divide into separate streams between the vertical supports. The manufacturer claims this helps prevent clogging and blinding.

This screen was tested as a primary screen on raw peeler wastewater. All the screen openings available were tested at 50 gpm (0.00315 m^3/sec). The evaluation was limited, however, because only one short run was made with each screen opening. These results indicate that the 0.020 inch (0.50 mm) opening screen produced the best results. This screen, however, tended to blind fairly quickly with a slime buildup. This unit with a 0.030 inch (0.75 mm) opening screen performed excellently during the short test run. Residual settleable solids in the under-flow was only 14 ml/l. The other screen openings (1.0 mm and 1.5 mm) also performed without blinding problems but solids removal was inferior to the 0.75 mm opening screen. The screened solids were extremely wet when first leaving the screen but tended to gravity drain very quickly. The screenings were 92% moisture at the point of leaving the screen. This was due probably to a noticeable amount of water continuously trickling from the end of the screen. The test unit was probably several years old and the seals between the sides of the wedge wire screen and frame were worn causing water to channel down the inside walls. This was the major cause of wet screening solids.

Tangential Screen B. This pilot screen was 12 inches wide and approximately 6 feet tall. Test runs with screen openings of 0.5 mm, 0.71 mm, and 1.0 mm were made. The velocity across the face of the screen was very fast and as a consequence a slight blinding of the 0.5 mm screen caused a complete failure because of water discharged at the end of the screen. With the 0.71 mm opening screen residual settleable solids of only 13 ml/l in the underflow was tested. The 1.00 mm opening had a residual settleable solids of 18 ml/l. No indication of blinding was observed with these two screens. The screened material had approximately 82% moisture when leaving the screen.

Tangential Screen C. This screen was also tested with raw peeler wastewater. This screen was similar in design to the Tangential Screen A but with several differences, which include: the screening surface was actually three separate screens, all at slightly different angles to the vertical; the influent weir did not direct the water tangentially to the screen but was actually a small jump; and the screening surface of the screen test unit was about one foot longer than the Screen A. Tangential Screen C unit was also apparently new and in excellent condition.

The differences in the screen design was apparently significant. The residual settleable solids in the underflow was 22 ml/l. This was considerably higher than the Tangential Screen A. However, screened solids from the Screen C screen were approximately 18% dry solids when leaving the screen. This was due to the solids staying on the screen much longer and also no noticeable amount of water was observed trickling from the end of the screen. Only one test run was made with this screen and a 0.020 inch (0.5 mm) screen opening was used at 50 gpm. No blinding problems were observed during the test run.

Figures 2 and 3 show a comparison of effluent and screening quality with the screens tested with raw peeler wastewater.

The following screens were tested with total composite discharge wastewater:

1. Tangential Screen A
2. Centrifugal Screen

An evaluation of this testing follows:

<u>Tangential Screen A</u>. This unit was used for pretreatment of wastewaters for the DAF pilot plant. The wastewater

Figure 2
PILOT SCREEN EVALUATION
WITH
PEELER WASTEWATER

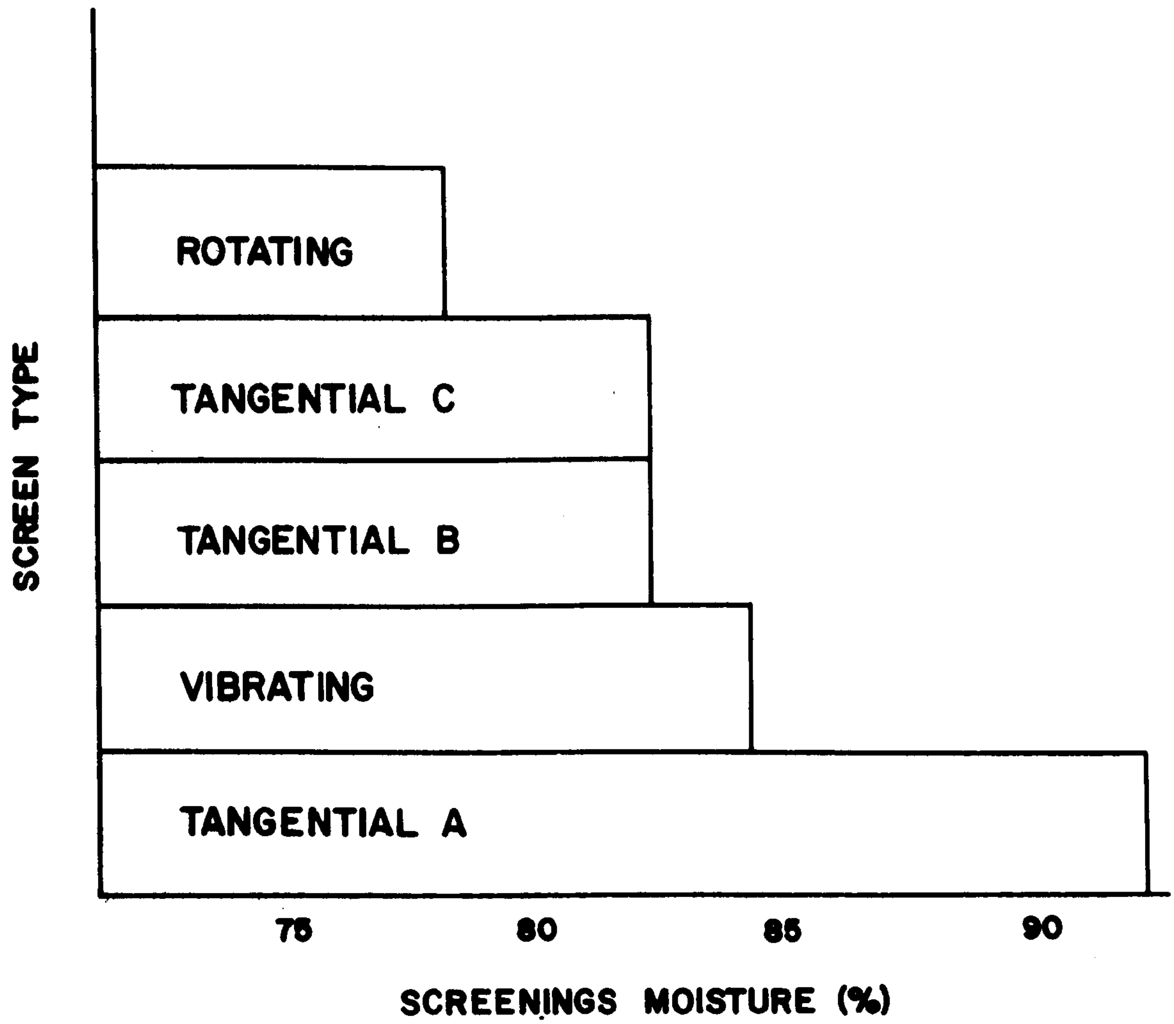
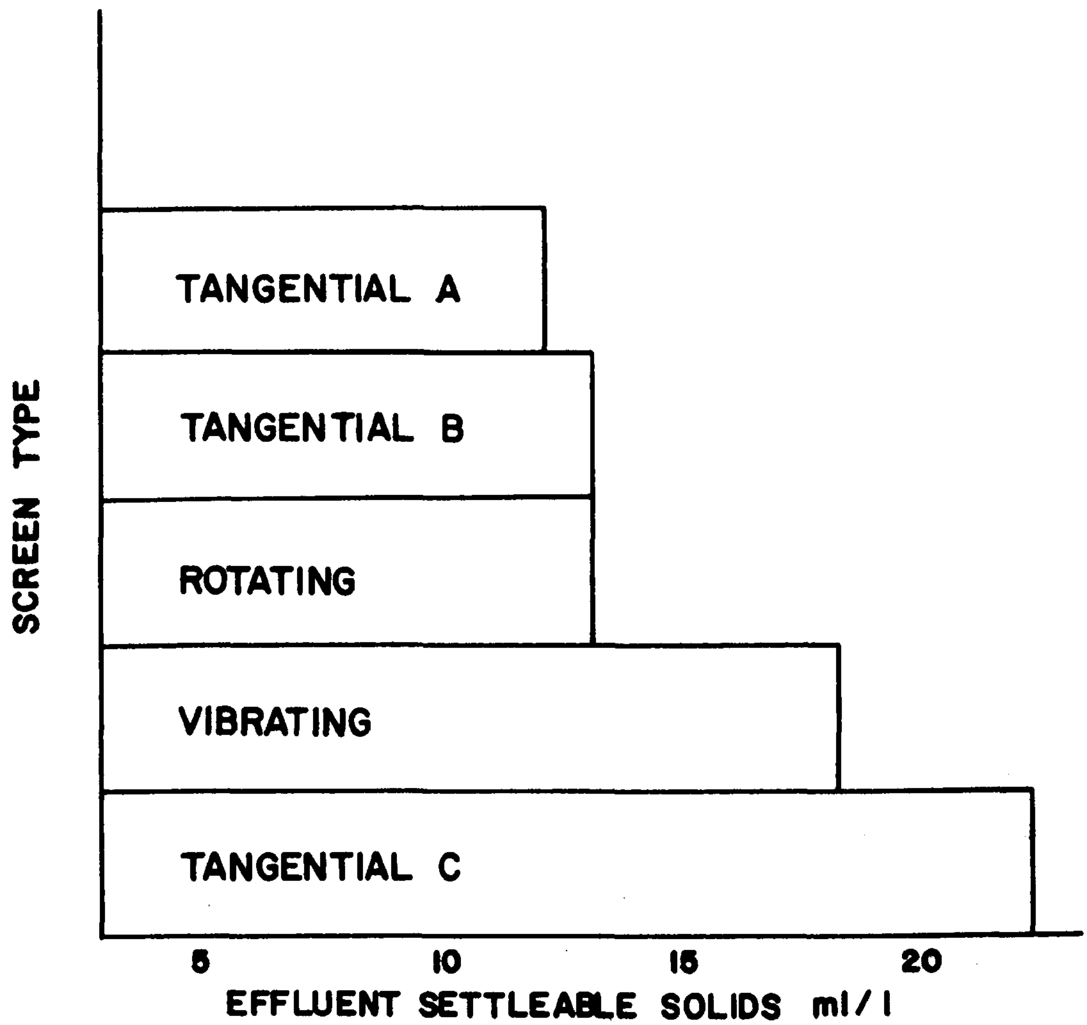


Figure 3
PILOT SCREEN EVALUATION
WITH
PEELER WASTEWATER



screened at this location was total composite process wastewater. Therefore, the tangential screen was operating as a secondary screen in series with the vibrating screen for peeler wastewaters and operating as a primary screen for the remainder of wastewaters produced in the plant (deveining, fluming, blanching, canning and raw receiving). The average results are shown in Table 2.

The results indicate a very poor removal efficiencies of COD, total solids and suspended solids but fairly good removal of settleable solids. The average results above are all from runs using a 0.040 inch (1.0 mm) screen opening. Trials were made with a 0.020 inch (0.5 mm) opening screen but severe blinding resulted.

Centrifugal Screen. This screen was a 12-inch diameter centrifugal type. With this unit wastewater is pumped to the middle of a spinning cylindrical screen. The liquid is spun through the screen and is removed as effluent. The solids too large to pass through the screen drop out and are removed as concentrated solids. The manufacturer claims that the screens rotational velocity in combination with the impingement velocity of the influent results in a vector velocity that allows the screen to remove particles smaller in size than the wire openings.

The unit was tested on total composite discharge wastewater during plant processing. The operating variables available were: interchangeable 400 mesh (0.035 mm opening) and 165 mesh (0.097 mm opening) screens and flow rate. Seven

TABLE 2
TANGENTIAL SCREEN EVALUATION
POLLUTANT REMOVAL EFFICIENCIES
TOTAL PLANT DISCHARGE[a]

Parameter	Mean Removal %	Mean Removal %	Mean Removal %
COD	4.4	36.0	0
Total Solids	4.7	40.0	0
Suspended Solids	0	47.0	0
Settleable Solids	55.6	80.0	39.0

[a] Peeler water prescreened with 20 mesh vibrating screen.

TABLE 3
CENTRIFUGAL SCREEN EVALUATION
TOTAL PLANT DISCHARGE[a]

Parameter	Mean Removal %	Mean Removal %	Mean Removal %
BOD-5	8.6	16.7	0.0
Suspended Solids	17.2	37.6	3.4
Settleable Solids	89.0	93.3	84.7

[a] Peeler water prescreened with 20 mesh vibrating screen.

test runs were made in which operating conditions were varied on each. Average results are shown in Table 3.

On screening peeling wastewaters, the following comments are offered:

Of the three types of screens the tangential screens produced the best effluent with the lowest residual settleable solids concentration in the effluent. The rotating screen produced the worst effluent and the driest screenings and the vibrating screen performed midway to the other two types for both criteria.

The tangential screens consumed no power, therefore, were best for this category. The vibrating screen was the worst and the rotating screen which required only a fractional horsepower motor was midway. The rotating screen was only slightly behind the tangential screens in this respect because it was much lower than the tangential screens and the pumping heat required would be lower.

In ease of operation the rotating screen was best. During a short evaluation it showed no tendency to blind or clog. The vibrating screen required a frequent water hosing and was midway in this category. The tangential screens required frequent hosings and periodic brushing with a steel brush.

In anticipated operating cost, the rotating screen appears to be the best because no operator would probably be required and maintenance should be minimal. The tangential screen should be midway in this category even though no maintenance costs are likely but an operator will probably be needed. The vibrating screen because of its mechanical nature is last because of expected high maintenance costs and the need for an operator.

On screening total composite wastewater the following comments are offered:

The centrifugal screen produced the best effluent with a residual settleable solids concentration of about 1.0 ml/l. This screen, however, removed only an average of 8.6% of BOD-5 and 17.2% suspended solids so the residual concentrations in the screened effluent were still very high. The disadvantage of this screen was the very voluminous concentrate flow. This flow would need to be treated separately. Treatability of the concentrate flow was not evaluated.

The tangential screen removed settleable solids to a residual of about 10 ml/l, removed an average of 4.5% of BOD-5 and on an average removed no suspended solids. The screenings tended to be very wet because of a continual blinding problem which resulted in water discharged off the end of the screen. The screen tended to blind because of a slime layer which could only be removed with a wire brush.

TREATMENT BY DISSOLVED AIR FLOTATION (DAF)

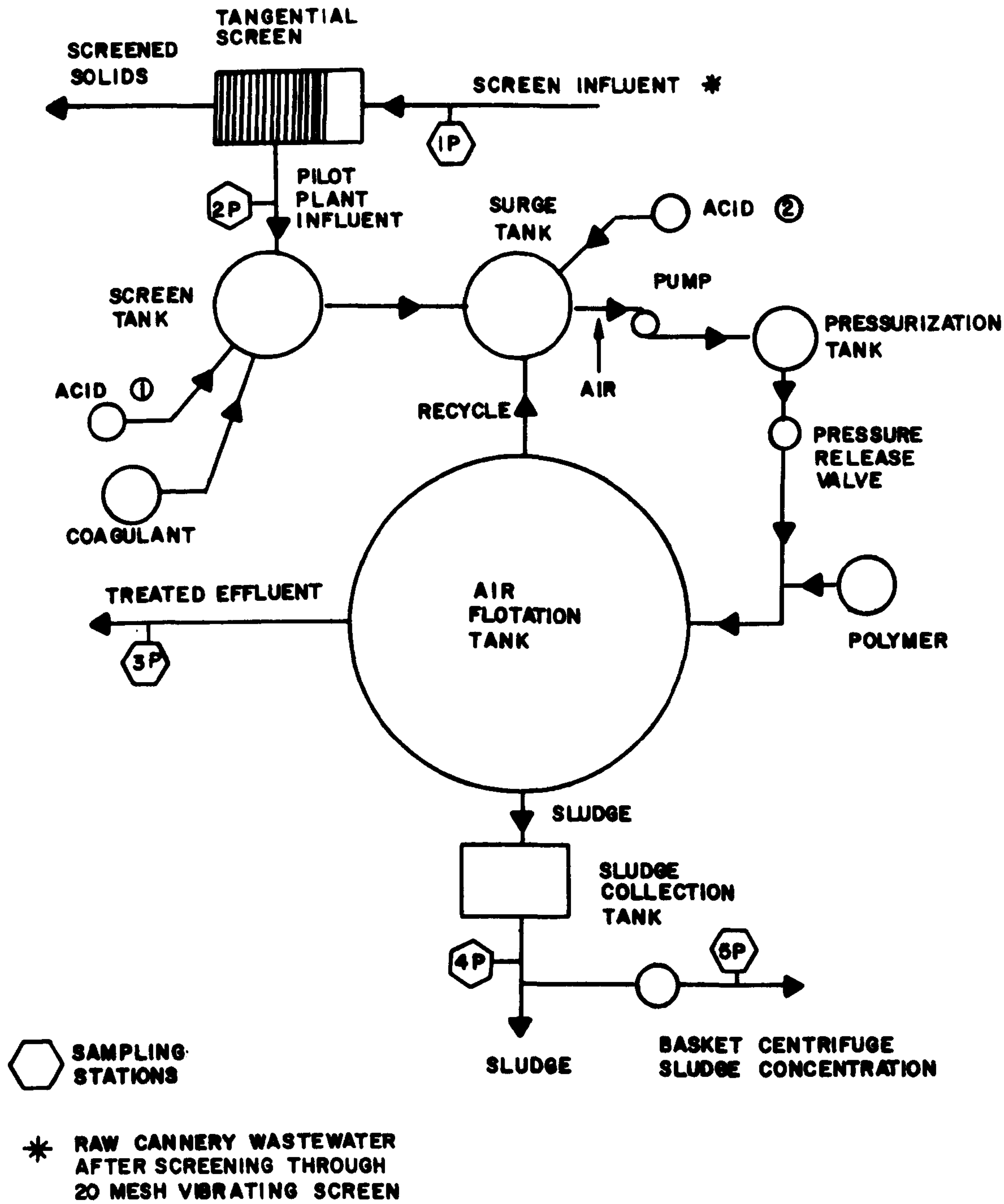
The DAF pilot plant evaluation was made during the summer, 1973 canning season. Objectives were to intensely evaluate the operational variables of the DAF process while treating shrimp canning wastewaters.

The ultimate objective of pilot plant studies is to develop design criteria for full scale plants. The purpose of a DAF treatment system is to separate and concentrate suspended and colloidal particles in the feed wastewater. Larger particles of the settleable solids size should be removed prior to DAF treatment by screens and cyclones if high density particles are present. Separation of small suspended and colloidal solids depends more on their structure and surface properties than on their size and density. Therefore, DAF treatment plants cannot be designed theoretically or rationally by mathematical equations but by the use of laboratory (bench scale) and pilot scale studies. Factors of greatest importance in designing DAF plants are as follows:

1. Chemical coagulants.
2. Feed solids concentration.
3. Quantity of pressurized air used.
4. Overflow rate.
5. Retention Time.
6. Recycle/Pressurization Mode.

A schematic of the DAF pilot plant is shown in Figure 4. A total pressurization, circular type DAF plant was used

Figure 4
DISSOLVED AIR FLOTATION
PILOT PLANT SCHEMATIC
AND SAMPLING STATIONS



for the testing program. The unit contained chemical injection pumps for coagulants and pH control; an automatic pH controller; a sludge scraper and drive; and a sludge collection hopper and sludge pump.

Table 4 shows the average operating conditions of the DAF unit used during the testing program. Several test runs were made with chemical coagulants, pH, injected air and influent flow rate being varied in order to determine optimum conditions.

The pollutant removal efficiencies of the DAF pilot testing is shown in Table 5.

With the test runs alum coagulant dosages ranged from 150 mg/l to 50 mg/l and polymer dosages from 10 to 0.5 mg/l. Best pollutant removals were obtained at alum and polymer dosages of 75 mg/l and 2 mg/l respectively. A pH of 5.0 ± 0.2 was maintained for most runs. a pH of 9.0 was maintained for one run and extremely poor treatment resulted. For three runs pH values from 6.1 to 6.5 were maintained and poor treatment resulted.

The effluent with good runs was almost crystal clear with a turbidity of less than 20 units. A small amount of floc carryover persisted and caused this small amount of turbidity. The effluent was visually crystal clear between floc particles. The effluent BOD-5 for good runs was below 400 mg/l, the effluent COD was below 1200 mg/l, the effluent suspended solids was below 100 mg/l and the effluent protein was below 600 mg/l.

TABLE 4
DAF PILOT PLANT
AVERAGE OPERATING CONDITIONS

Flow:	50 gpm
Pressurization:	40 psig
Air/Solids:	0.14
Cell Solids Loading:	0.33 lbs/hr./ft^2
Acid Addition:	Surge Tank
Alum Addition:	Screen Tank
Polymer Addition:	Flotation Cell Influent

TABLE 5
DAF PILOT PLANT EVALUATION
Pilot Plant Phase, Summer, 1973
Pilot Series 1 - Chemical Optimization
Pollutant Removal Efficiencies

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
BOD-5	65.1	80.0	50.0
COD	59.0	69.5	43.5
Total Solids	14.9	42.9	0.0
Suspended Solids	65.6	85.8	7.0
Protein	52.5	91.1	25.7
Turbidity	83.0	97.5	61.9
Ortho Phosphate	27.5	38.2	15.4
Total Organic Carbon	61.4	62.8	60.0

Three runs were made for the purpose of optimizing the solids loading rate. All of the runs were performed with optimum chemical dosages developed previously. Three runs were completed with influent flow rates of 25 gpm, 50 gpm, and 75 gpm. The influent suspended solids concentration for each run was slightly different so, therefore, flow and solids loading were not directly proportional. The results are shown in Figure 5.

From Figure 5 it appears that optimum cell solids loading is approximately 0.25 lbs/hr./ft^2 and for the particular pilot unit tested, the optimum influent flow is approximately 40 gpm.

Several values of air/solids ratios were computed from similar runs made during the testing program. The results of these computations are shown in Figure 6 where A/S ratios are plotted against removal of suspended solids. From Figure 6 it appears optimum A/S ratios are within the range of 0.10 and 0.15.

The concentration and flow rate of the flotation sludge was measured for most of the pilot runs. Mean results are shown in Table 6.

SLUDGE DEWATERING BY CENTRIFUGATION

The flotation sludge skimmed from the top of the DAF pilot plant was concentrated in a basket type pilot centrifuge. The centrifuge had the following characteristics:

Figure 5
PILOT DAF PLANT EVALUATION
SOLIDS LOADING VS. TURBIDITY REMOVAL

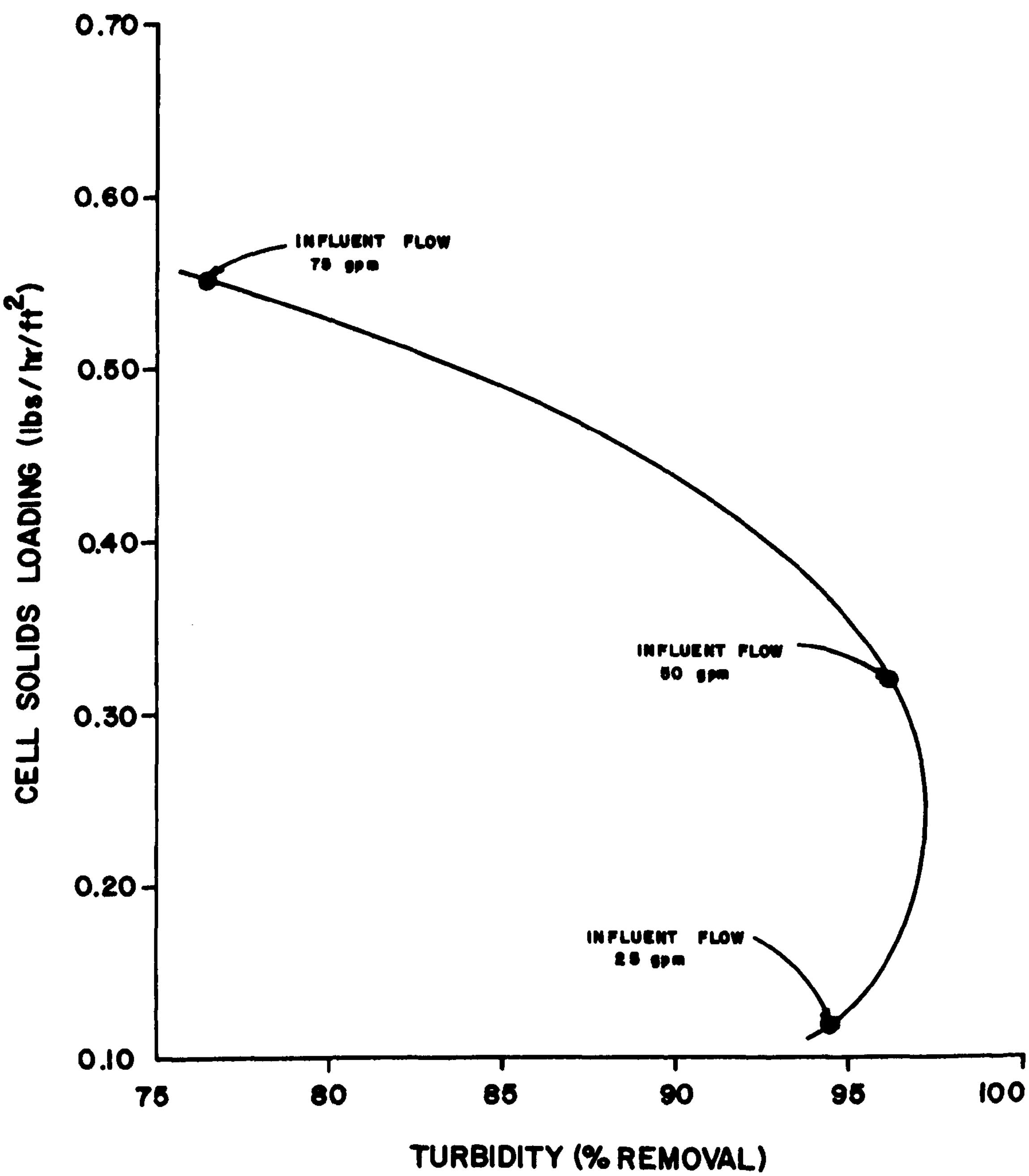
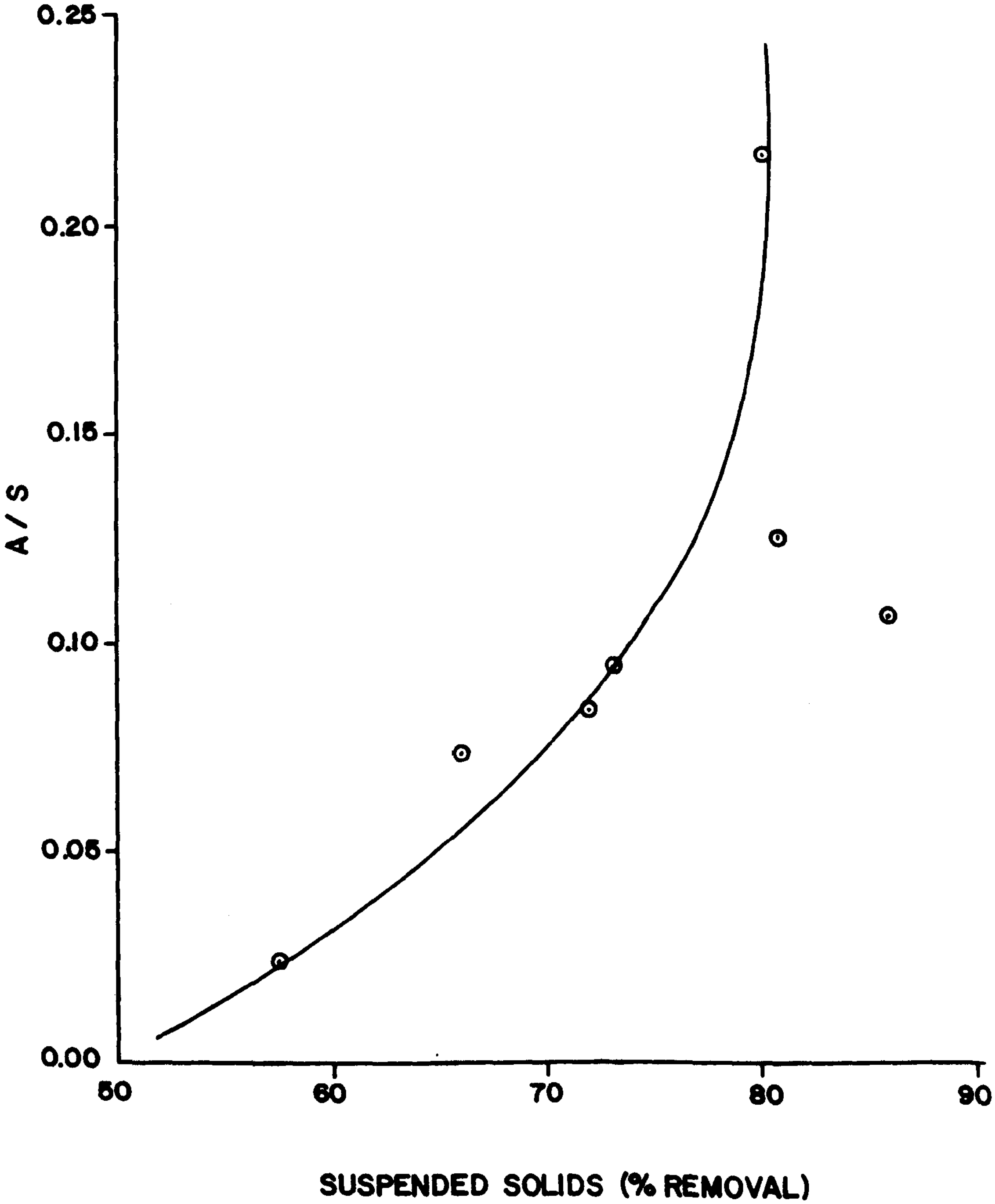


Figure 6
PILOT DAF PLANT EVALUATION
A/S RATIO VS. SUSPENDED SOLIDS REMOVAL



Method of Feed:	Batch
Feed Volume:	2.5 gallons (9.47 liters)
Basket Type:	Solid
Material Removal Method:	Skimmer

Average results obtained are shown in Table 7.

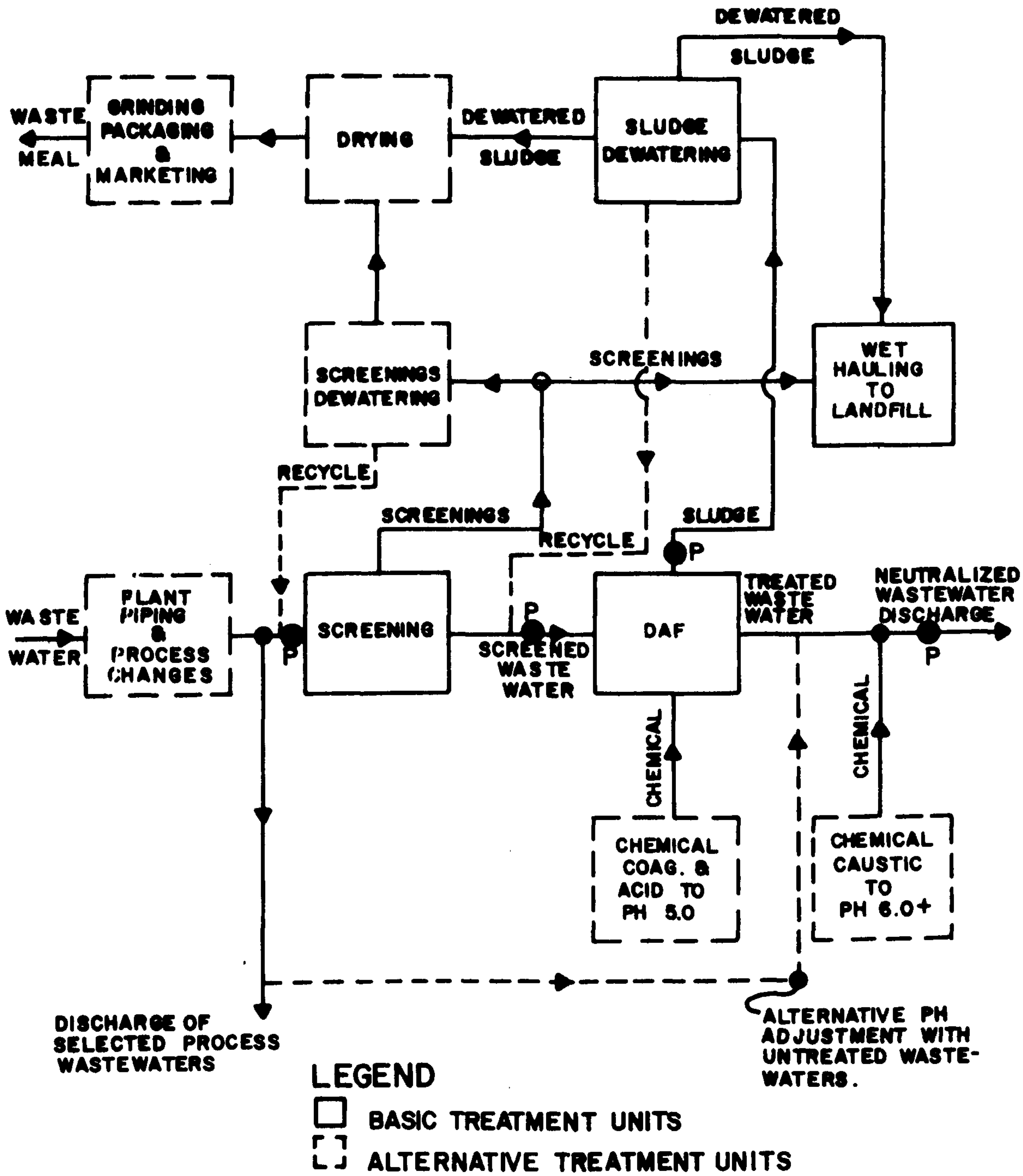
TABLE 6
DAF PILOT PLANT EVALUATION
Flotation Sludge Characteristics

Parameter	Units	Mean	Maximum	Minimum
Dry Solids	%	2.98	4.02	1.58
Flow	gpm	4.28	5.97	1.17
Protein	mg/l	15,819	26,318	6,963

TABLE 7
PILOT CENTRIFUGE EVALUATION
Mean Results

Parameter	Mean % Dry Solids	Mean Volume (gallons)
Feed Sludge	3.36	2.50
Centrifuge Cake	6.23	0.58
Centrate	1.05	0.98
Air	0.0	0.94

Figure 7
PROPOSED
SHRIMP CANNING WASTEWATER
TREATMENT SCHEMATIC



Treatment Technology in Canada

- Physical Treatment (Screening)

by

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1. SCREENING

Water is widely used in the fish processing industry, and consequently various methods have evolved for separation of the coarse fish solids prior to discharge. Studies have shown that the longer the solids are in contact with water, the more highly contaminated the water will become due to leaching of blood, oil and soluble protein. Plant design should include methods of dry handling and rapid separation of coarse solids wherever feasible. For achievement of the latter, a knowledge of the types of coarse and fine screens applicable to the fish processing operation is required.

2. SCREENING SIZES

In discussing screen sizes, the term "mesh" is frequently used to designate the screen size. Where mesh is referred to as a number, the reference is to the number of openings per linear inch. The mesh is determined by starting from the centre of one wire and counting the number of openings in a specified length. If applicable, a fraction may be included.

The actual opening between the wires is "space", and is a much better way of specifying the ability of fine screens to remove suspended material. Thus, 0.25 inch space, 0.135 wire will adequately define a screen. For fine screen, the space is often given in thousandths (e.g. 0.030) or in millimeters (e.g. 0.71 mm).

2.1 Coarse Screens

Up to the present time, most screening devices are only used to remove coarse solids, hence the space is seldom less than 0.25 inch (0.6 cm). Attempts at using conventional screens in finer sizes have failed due to the ability of raw protein and fish oil to blind fine screens. The raw protein is easily forced into screen openings, preventing passage of further solids and water. Where solids are large enough to pull free of the screen during inversion, no problems develop. Since the protein is quite "sticky", fine particles do present a special problem, and are required to be removed by sprays or brushes.

Oil adds a further dimension to the problem. Droplets will spread over a fine screen opening, and the surface tension of the drop will prevent passage of water or solids. Proper choice of flow patterns across the screen surface will greatly reduce this tendency.

One of the simplest dewatering devices used is the screw drain. Here a rotating screw carries the solids and water through a perforated or slotted pipe. The close fit between the screw and sleeve is supposed to ensure that the perforations are kept clean. This system works best where large volumes of water must be removed from relatively few coarse pieces (i.e. crab shells, etc.).

The most widely used coarse screening device is the rotary trommel screen. Water and solids are discharged into a perforated cylinder which rotates at speeds of up to 15 RPM. The trommel surface is usually a stainless steel mesh wrapped on a frame. The screen sizes are typically of four to 10 mesh. The water passes through the screen and is collected in troughs while the solids are carried to the end of the cylinder by gravity or by flights. Water sprays are often mounted to keep the screen surfaces clean.

In some plants coarse solids are also separated from water by the use of wire mesh belts. The water easily passes through the belt, while the larger solids collect and are carried to a discharge chute where the belt passes around a roller which inverts the screen surface.

2.2 Fine Screens

The type of fine screen most familiar to the industry is the vibrating screen, such as is supplied by SWECO or CAISSON. These are typically of 60 to 100 mesh or finer. This type has proven of value where the solids have been heat-denatured (such as in press liquor treatment) or in screening waste from shrimp and crab operations. Although satisfactory for the latter treatment, maintenance costs are generally high. Many thousands of dollars have been spent in numerous attempts to separate raw fish waste from water, with little or no success reported.

The SWECO (Southwest Engineering Company) has recently introduced a centrifugal concentrator, which has been tested on several types of fish processing effluent. In general it has proven capable of concentrating solids present in the effluent into a flow of about one quarter of the original volume. It is slightly more successful on shrimp waste. It does not, however, appear to be as applicable as the other types detailed.

3. STATIC OR SIDE-HILL SCREENS

During the past several years, a substantial number of "static" screens have been installed in many processing operations to recover suspended matter from liquid flows. Highly successful applications have been made in meat packing, tanning, canning, textile and paper products, as well as in domestic sewage treatment.

The primary function of a static screen is to remove "free" or transporting liquid. Several types have developed, which have proven themselves in numerous applications.

3.1 DSM Screen

A concavely curved screen developed and patented in the 1950's for mineral classification by Dutch States Mines Corporation has been applied by Dorr-Oliver for use in the process industries. This design employs bar interference to the slurry, which knives off thin layers of the flow as it cascades over the curved surface.

By far the most data for screening of fish processing plant effluent are available for this type of screen, since it was the type chosen for use in the demonstration waste treatment plant at Steveston, B.C. A similar screen has been in use for some time at a New England Fishing Company plant in Washington State.

Two 6-foot Dorr-Oliver 45° DSM screens were chosen for the demonstration plant. The screened surfaces have 0.7 and 1.0 mm (0.3 and 0.4 in.) aperatures (corresponding roughly to 25 and 18 mesh) in 304 stainless steel. The box was of mild steel. The initial installation also had installed a battery of cone-jet nozzles for cleaning purposes.

A 1500-gallon (56781) equalization tank stabilizes the feed to the screens at about 720 GPM (45.4 l/sec). From the tank a 4-inch (10 cm) centrifugal pump transports the water to a manifold feeding the two screens. The flow pattern to each is controlled by positioning of butterfly valves. A manually-adjusted by-pass valve connects the pump discharge to the tank. Cracking of this valve ensures that the pump impeller is kept wet at all times.

The screened liquid flows by gravity to a wet well from where it is pumped either to the treatment plant or to the river outfall. The oversize solids are carried by screw conveyor for transfer to the reduction plant.

Shortly after startup of this plant, some blinding problems developed, and modifications were made to the spray system to enable the maintenance of an automated spray flushing of the screen surface, consisting of a 30-second burst every three minutes. Results obtained over a two-year operating period are shown in Table 1.

Table 1. Treatment of fish processing effluent by DSM screens.

Waste-water	Optimum flow GPM/ft (l/sec/cm)	Oversize flow GPM (l/sec)	Dry solids recovery lb/hour (kg/hour)	Suspended solids reduction (%)
Salmon	60 (0.13)	4 (0.25)	20 (9.1)	40
Ground-fish	90 (0.19)	1 (0.06)	15 (6.8)	35
Herring Roe	48 (0.1)	10 (0.63)	1000 (454)	75

Experimentation continues with the screens, and two late developments appear interesting. On one screen the pattern spray has been replaced by an ordinary garden oscillating sprinkler, and appears to be working well. On the other screen a brush has been installed, and is doing an adequate job without increasing the wastewater flow. In both cases the solids coming off the screens are do dry that water is being added to them to enable them to be pumped.

3.2 The Hydraseive

Beginning in 1969, U.S. and foreign patents were allowed on a three-slope static screen made of specially coined curved wire. This concept used the Coanda or wall attachment phenomena to withdraw the liquid from the underlayers of a slurry stratified by controlled velocity over the screen. Construction of the screen is detailed in Figure 4.

This screen has been tested on shrimp and crab plant effluents in Alaska and Louisiana, and successful installations have been made at the Omstead Plant, Wheatley, Ontario, and the Freshwater Fish Marketing Board plant in Winnipeg. A similar installation operating on effluents from a Maine sardine plant has had steam jets installed to assist in preventing blinding.

3.3 The Hydrocyclonics Hydrascreen

This screen is basically a combination of the previous two. Bar interference is used on three separate sloping surfaces. Tests have been performed on effluents from a salmon hand-butchering operation with very encouraging results.

In general, any of these screens appear useful for fish processing effluent screening. It might be advisable to purchase the screen chosen without either sprays or brush, and add these as needed, unless it has been shown in a very similar installation that either a brush or spray system will be needed.

4. THE HYDROCYCLONICS ROTOSTRAINER

A recent entry into the field of fine screens appears to offer promise to the screening of fish processing plant effluents. The rotostrainer comprises relatively few moving parts: a fractional horsepower motor, variable speed gear reducer, and a cylindrical screen. All parts are made of stainless steel. The head box is designed to minimize influent turbulence and to ensure a steady flow over the weir.

The water to be screened passes over the weir and through the slowly rotating screen. The solids which cannot pass through the screen spaces ride over the top of the screen and are removed by a wiper system. The wiper blade is designed to channel the dewatered solids away from the screen into the collection and removal system.

The effluent, meantime, passes through the top of the screen, falling through its interior, and exits through the mesh at the bottom. In doing so it effectively backwashes the screen, thereby providing a reliable self-cleaning action.

Rotation of the screen is variable between one and 10 RPM with increasing rotational velocity allowing greater throughput at the expense of water carryover in the solids.

Tests have been performed on the 24-inch (61 cm) model using 0.030 inch (0.07 cm) screens at B.C. Packers Imperial Plant, Steveston, B.C. and at the Bumblebee Seafoods Plant in Bellingham, Washington. In the latter case, the test was concluded to be highly satisfactory, while in the former, modifications to the location of the wiper blade were felt to be necessary to ensure that the solids which are removed from the screen are immediately carried away so as to not interfere with subsequent wiper operation. Flows as high as 150 GPM per foot (0.315 l/sec/cm) of screen appear quite possible, with removal efficiencies similar to those reported for the static screens.

5. CHEMICAL TREATMENT AND AIR FLOTATION

5.1 Introduction

Fine screening is able to achieve considerable reduction in settleable solids, but does little to reduce the levels of suspended and soluble solids. Various chemicals may be used to flocculate emulsified and colloidally dispersed solids, and pH adjustment can lower the solubility of proteins. Gravity separation may then be used (Pavia and Tyagi, 19th) to separate the solids. Since the effluents from many fish processing operations have fat associated with the proteins, a three-phase separation is necessary. Separation of the phases under these conditions, is slow, and anaerobic conditions, due to bacterial action, may develop, leading to odour problems. Proper selection of the chemicals, combined with dissolved air flotation, was shown by us to allow a rapid separation of the solids and fat fractions as a single phase.

6. CHEMICAL TREATMENT

Various chemicals and combinations thereof have been used to flocculate suspended organic materials (Kato and Ishikawa, 1969; Touseth and Berridge, 1969; Schultz, 1956). Among those tested by us in the laboratory and pilot plant were ferric chloride, sodium alluminate, aluminum sulphate, each of the above with various polyelectrolytes, and pH adjustment using acids.

We also investigated the use of lignosulphonic acid (LSA) to separate soluble proteins, as reported by Touseth and Berridge. Under laboratory conditions exceptional results could be obtained with this system. The system was discontinued after pilot plant tests due to the following conclusions:

1. The reaction requires a fairly definite LSA:protein ratio, which requires either an extensively buffered system, or development of a system capable of monitoring protein levels.
2. The floc resulting from the protein:LSA interaction is very fragile, forcing the use of recycle pressurization, and hence oversized flotation equipment.
3. The system operates at a pH of 4, requiring the use of corrosion-resistant materials.

Best results in our studies were obtained using aluminum sulphate, either with added alkalinity, or anionic polyelectrolytes. The mode of action of the aluminum sulphate (alum) can be postulated as follows:

As alum is added to the wastewater, the cations are attracted to the charged particles, thus coating them and forming microflocs. If alkalinity is present, the excess alum reacts to form a voluminous hydroxide floc. The microfloc, which has a positive charge in the acid range, agglomerates to this floc, or may be physically enmeshed along with other colloids or particles. Surface adsorption is also active. The high molecular weight anionic polyelectrolytes of the polyacrylamide type are also effective in agglomerating microflocs. The floc of either type is easily separated by air flotation, resulting in a good, dense sludge blanket.

Our pilot plant studies were conducted using alum and sodium hydroxide (Claggett and Wong, 1969), as was the first year of operation of a demonstration unit (Claggett, 1971). We were able to show (Table 2) that not only could a good clarification be achieved, but that the sludge solids could be recovered for safe use in poultry feeds.

7. DISSOLVED AIR FLOTATION

This unit operation utilizes the buoyant effect of air bubbles to float suspended solids and oil. Some or all of the wastewater is mixed with air and pressurized to force an air-water solution. When the pressure is released, the air comes out of solution as pin-point bubbles, gathering on any available interface. A further study of air flotation principles may be found in the work by Vnablik (1937).

The equipment normally used for total flow pressurization is shown in Figure 1. Water from the collection tank is pressurized by a centrifugal pump and control valve to about three atmospheres. Air is metered into the pump suction at about two percent by volume, using either an aspirator or a compressor. A retention tank with a residence time of about one minute allows intimate air-water contact, ensuring a maximum solution of the air. The control valve provides a rapid pressure drop which decreases the air solubility. It also causes extreme turbulence, so floc formation should take place downstream of this point. The air bubbles coming out of solution attach themselves to the solids present, and as the mixture enters the flotation cell, carries the solids to the tank surface. Here a paddle arrangement carries away the solids. Clarified water is removed from the bottom of the cell by standpipes.

Table 2. Operating data on flotation cell, 1971, using caustic alum on salmon canning effluent.

Stream	Suspended solids (mg/l)	Soluble solids (mg/l)	COD (mg/l)	Oil (mg/l)	Tirbidity (JCU)
Influent	956 ± 360	1590 ± 2498	5635 ± 2498	360	2500
Effluent	61 ± 28	1075 ± 155	815 ± 125	20	200
Removal	92 ± 5	28 ± 16	84 ± 6		

Sludge volume flow was 2 to 3% of cell flow

Sludge average solids content was 7.2%

Alum was 235 mg/l

The flotation cell may be circular or rectangular. Both types were tested on a pilot plant scale with similar results. Based on these results, it was decided to install a full-scale demonstration unit.

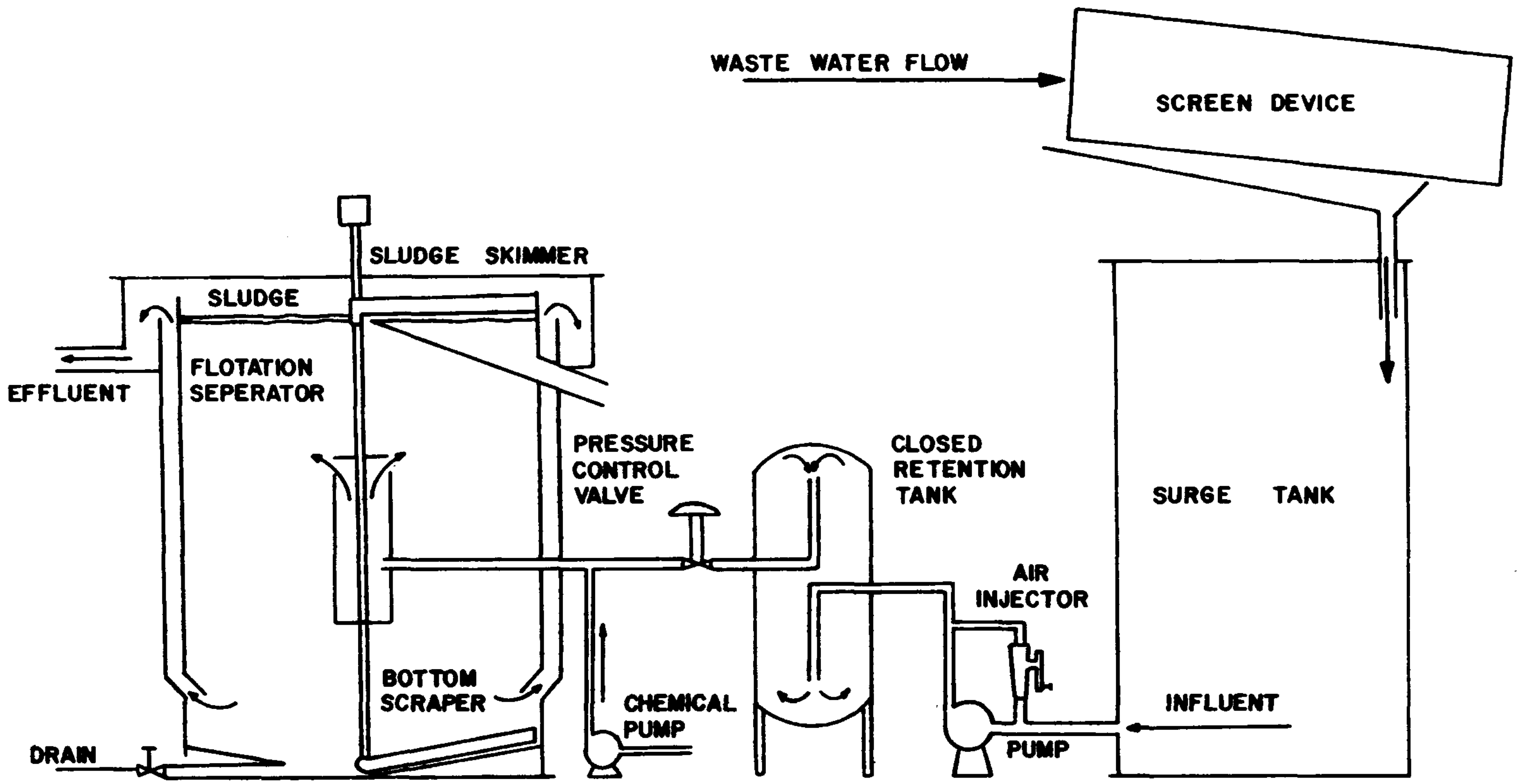

Figure 1. Total flow pressurization.

8. THE AIR FLOTATION DEMONSTRATION UNIT

8.1 Plant Design

In a cooperative effort between the Fisheries Association of British Columbia and Environment Canada (Fisheries Research Board, and the Industrial Development Branch of Fisheries Service), a demonstration wastewater treatment plant was designed and erected, based on the results of our pilot plant studies. The system was sized to handle an estimated flow of 900 GPM (57 l/sec) originating from either the salmon cannery or groundfish operation of B.C. Packers Imperial Plant. The flotation cell was designed at an overflow rate of 2 g/sq ft/min (7032 l/cm^2/min). Other design criteria may be found in our Technical Report Number 14 (Claggett, 1970).

Although much existing plant equipment was utilized in the construction in order to minimize the capital investment, the plant was designed to allow calculation of capital and operating costs as well as to solve problems expected to be encountered in operating a demonstration unit.

A flow diagram of the plant is shown in Figure 2. The chemical addition system included a 1000 gal. (3785 l) Koroseal-lined caustic tank, a 6000 gal. (22710 l) Fiberglas alum tank, and two 200 gal.(757 l) polyelectrolyte tanks. A Milton-Roy diaphragm duplex pump rated at 80 U.S. gal. per min. (5 l/sec) was used for the 30 percent alum and an 18

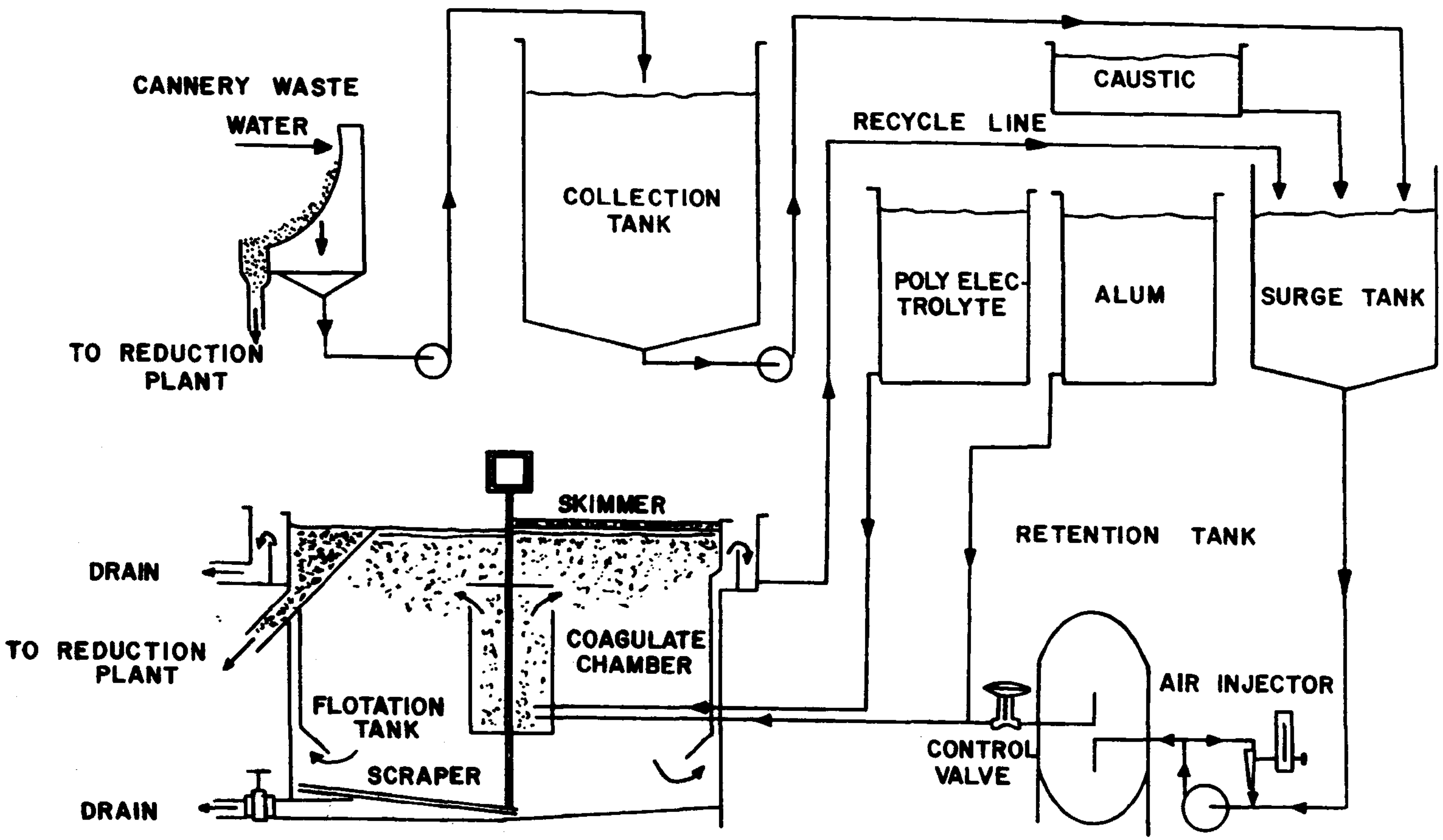

Figure 2. Flow diagram of demonstration plant.

gal. per min. single head pump for the 50 percent sodium hydroxide. The polyelectrolyte addition was made from a 0.5 percent solution by a rotary vane pump rated at 5 gal. per min. (0.3 l/sec) of water.

The Beckman pH monitoring system is shown schematically in Figure 3. It included two Series III flow chambers containing a standard glass and a Lazaran reference electrode connected through a manual electrode switch to a Model 940 Beckman pH analyzer. This system allowed the checking of either the caustic addition or the pH of the incoming water as well as the amount of pH depression obtained from the addition of the alum. Most of the chemical and water lines in this system were of 1/2 or 3/4 inch (1.3 or 1.9 cm) polyethylene tubing with stainless steel fittings. Subsequent testing indicated that the alum addition could be automated by pH control, with alum added through signal from the pH analyzer to position the plunger on a Minton-Roy control diaphragm pump. The desired pH appears to be about 5.4 for most wastewaters.

The flotation cell was equipped with two sludge scrapers to handle the heavy volume of sludge encountered in various wastewaters. Sludge was discharged through a hopper into a 3-inch (7.6 cm) line leading to a 3-inch Viking gear pump equipped with a 5 HP motor. The solids were pumped about 100 years through a 3-inch (7.6 cm) line to the reduction plant for sludge recovery.

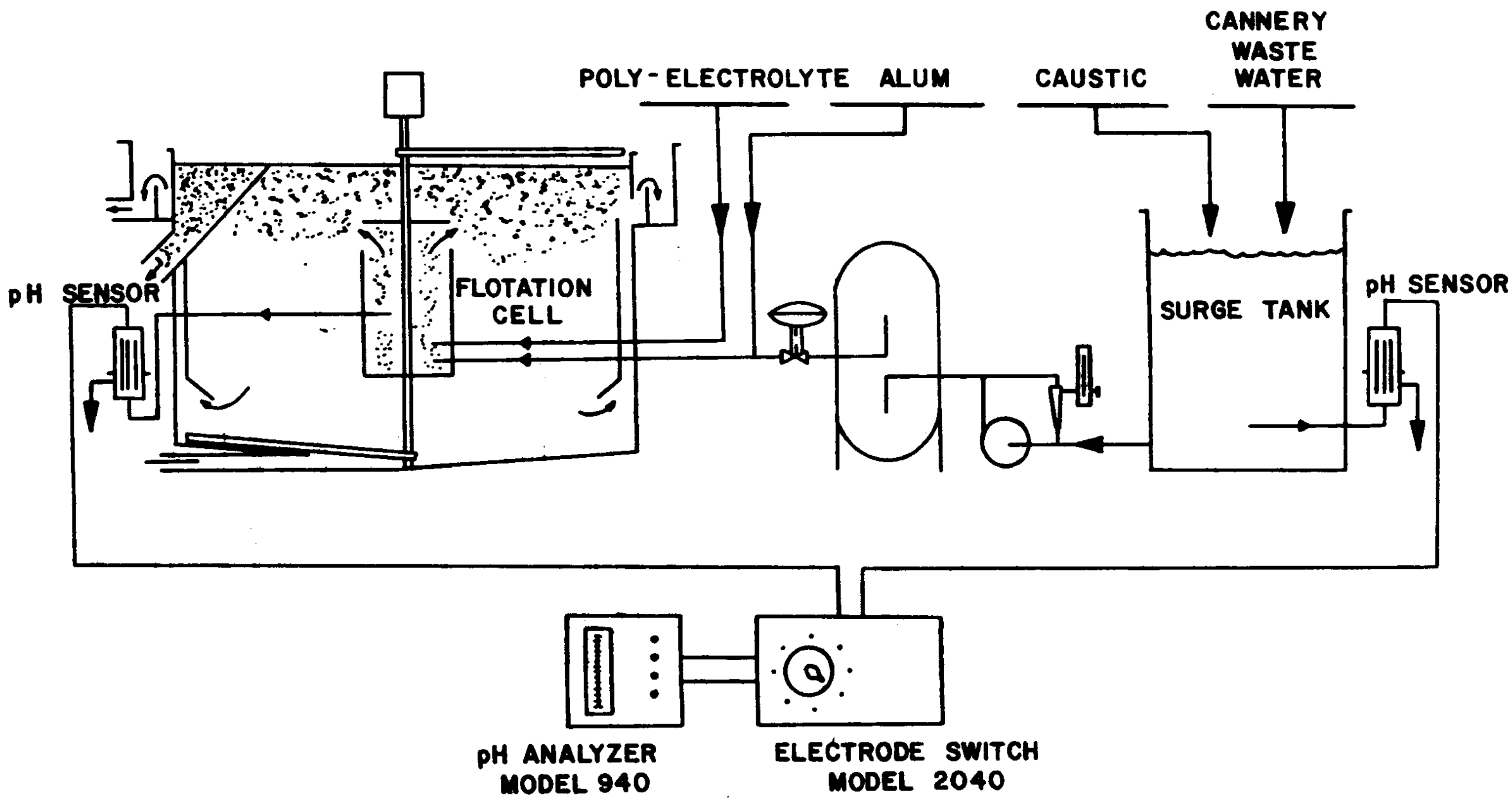

Figure 3. pH monitoring system

Problems encountered with air-locking in the Viking gear pump indicates that a diaphragm pump such as supplied by Marlow would be a better choice.

The results obtained in the first year of testing with the caustic-alum combination are detailed in Table 3. Although the sludge could be recovered as a 15 percent solids cake in a basket centrifuge after heat treatment, the recovery is difficult. When the alum is flocculated with an anionic polyelectrolyte, the solids content of the cake can be increased to 20 percent, with a recovery of about 90 percent. Preliminary tests indicate that a decanter (horizontal bowl) centrifuge might be applicable and a small Super D-Canter will be tested in the spring of 1974.

Table 3. Operating data on flotation cell, 1972, using alumanionic polyelectrolyte on salmon canning effluent.

Stream	Suspended solids (mg/l)	Soluble solids (mg/l)	COD (mg/l)	(mg/l)	Turbidity (JCU)
Influent	1450 ± 520	1850 ± 360	6120 ± 1880	440	2500
Effluent	200 ± 40	1280 ± 170	960 ± 300	30	350
Removal	86 ± 6	30 ± 20	84 ± 8		

Sludge volume flow as 3 to 4 percent of cell flow

Sludge average solids was 4.9 percent

Using the alum-polyelectrolyte combination, the data obtained are detailed for effluents from groundfish, salmon canning and herring roe operations in Tables 3, 4 and 5.

Table 4. Operating data on flotation cell, 1972, using alum-polyelectrolyte on groundfish filleting effluent.

Stream	Suspended solids (mg/l)	Soluble solids (mg/l)	COD (mg/l)	BOD (mg/l)
Influent	265	448	1295	500
Effluent	55	312	550	245
Removal	95%	34%	58%	51%

Sludge volume flow was about 1 percent of cell flow

Alum usage averaged 20 mg/l

Polyelectrolyte usage averaged 0.5 mg/l

Table 5. Operating data on flotation cell, 1973, using alum-polyelectrolyte on herring roe recovery effluent.

Stream	Suspended solids (mg/l)	Soluble solids (mg/l)	COD (mg/l)
Influent	1240	6337	5087
Effluent	344	4823	1774
Removal	74%	24%	66%

Sludge flow is 6 to 7 percent of cell flow

Alum usage is 180 mg/l

Polyelectrolyte usage is 4 mg/l

Table 6. Polyelectrolyte sources and costs.

Polyelectrolyte trade name	Supplier	Price per lb
Polyfloc 1200	Beta Laboratories	$1.80
Magnafloc 835A	Cyanamid	1.95
Magnafloc A-100	Cyanamid	1.25

8.2 Applicable Polyelectrolytes

The only polyelectrolytes found to be effective in our tests are the anionic polyacrylaminde copolymers with molecular weights of 5 to 15 million. Table 6 shows the ones found to be satisfactory, their suppliers, and approximate price. Similar materials are available from other polyelectrolyte polymers.

Although the dosages are in the one to five mg/l range, the polyelectrolyte is concentrated in the sludge with a potential level of 500 mg/l being possible. A supplier of the material states that toxicity studies on rats have proven negative, and that materials with this high a molecular weight would not be absorbed by the stomach of animals. Approval of the recovered sludge solids has been approved by the Canadian Department of Agriculture, based on feeding trials performed on poultry at the University of British Columbia.

9. OUTFALLS TO MARINE ENVIRONMENTS

The success of an outfall depends mainly on the ability of the receiving water to assimilate or disperse the waste discharge. This, in turn, is dependent on such factors as tide, wind, wave and current action. The ability to predict adverse effects of an outfall also requires a knowledge of the uses to which the receiving water may be put, such as recreation, bathing, shellfish growing and the like.

Tidal currents are the water movements which accompany the tide changes. These are periodic in nature, and vary widely with the geography of each area.

Since floating material from an outfall will move faster than the effluent discharged at an outfall due to wave and wind action, a knowledge of these is important.

Coastal currents are major sustained movements of water, often parallel to the coast. Their effect near shore is usually minimal, but occasionally an eddy or counter current may be induced which can greatly assist in proper effluent discharge.

Density, salinity and temperature of the receiving water can markedly effect the dispersion of wastes. A density gradient at the outfall can prevent the effluent mixture from reaching the surface.

Submarine outfalls which discharge relatively untreated wastes will have some effect on the marine environment, at least near the outfall. Proper design of an outfall, using knowledge of the previously mentioned factors, can greatly minimize deleterious physical, chemical and biological effects.

The physical effects depend mostly on the location of the outfall and the degree of treatment. Deposition of significant amounts of solids in the discharge area is common for fish processing plants at present. Fine screen will significantly reduce this effect. Temperature changes due to the discharge will be of little importance due to the large dilution available.

Submarine outfall disposal of naturally occuring organic wastes will have little effect on the chemical characteristics of the receiving water. The change in salinity is only marked in the close proximity to the outfall. Oxygen deficiency resulting from the biochemical utilization of the wastes may occur where dilution is restricted for any reason. This is not normally of significance for properly located outfalls.

The suitability of a particular ocean outfall may be governed by its proximity to marine shellfish beds. Because certain shellfish concentrate bacteria, restrictions are required on either the location of outfalls in proximity to the beds, or in the harvesting of such shellfish.

Since the effluent from fish processing operations is not either as noxious or as liable to contain pathogens, outfalls should be designed more for aesthetics than from public health consideration. Consequently, the restrictions on outfalls listed by the Pollution Control Branch, B.C. Government in the October, 1971 policy statement for municipal discharges may be too restrictive. If these were applied, however, plants discharging over 10,000 gpd (37850 l/day) would require an outfall located 50 feet (15 m) below low-water, and at least 100 feet (30 m) from shore.

CHARACTERIZATION AND TREATMENT OF CANADIAN FISH MEAL AND CRAB PROCESSING PLANT WASTEWATERS

Report Presented at the
U. S. Environmental Protection Agency
Office of Technology Transfer
Seminars on Upgrading
Seafood Processing Facilities to
Reduce Pollution

by

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Seattle, Washington
April 2 and 3, 1974

EFFLUENT CHARACTERIZATION

The Environmental Protection Service of Environment Canada has undertaken a number of studies to characterize the effluents from fish processing plants. Of interest to the attendees at this seminar would be the results from crab processing and fish meal operations.

Crab Processing

The process flow diagram for crab processing is illustrated in Figure 1. The crab are unloaded live from the holds of the vessels into tubs and then trucked to holding rooms at the processing plant. Once in the holding rooms they are packed in ice or held in refrigerated rooms prior to processing. The first stage of crab processing is butchering which involves removal of the legs and shoulders from the main body of the crab. The main body is flumed to a disposal pit, while the legs and shoulders are flumed to a continuous cooker. After the legs and shoulders of the crab have been cooked, they are flumed to shaking tables where meat and shell are separated. The fluming not only transports the crab, but also serves to cool them as the crab leave the cooker. At the shaking tables the meat is removed from the shell by any means possible, usually by persistent pounding. After inspection, the crab meat is dipped in a

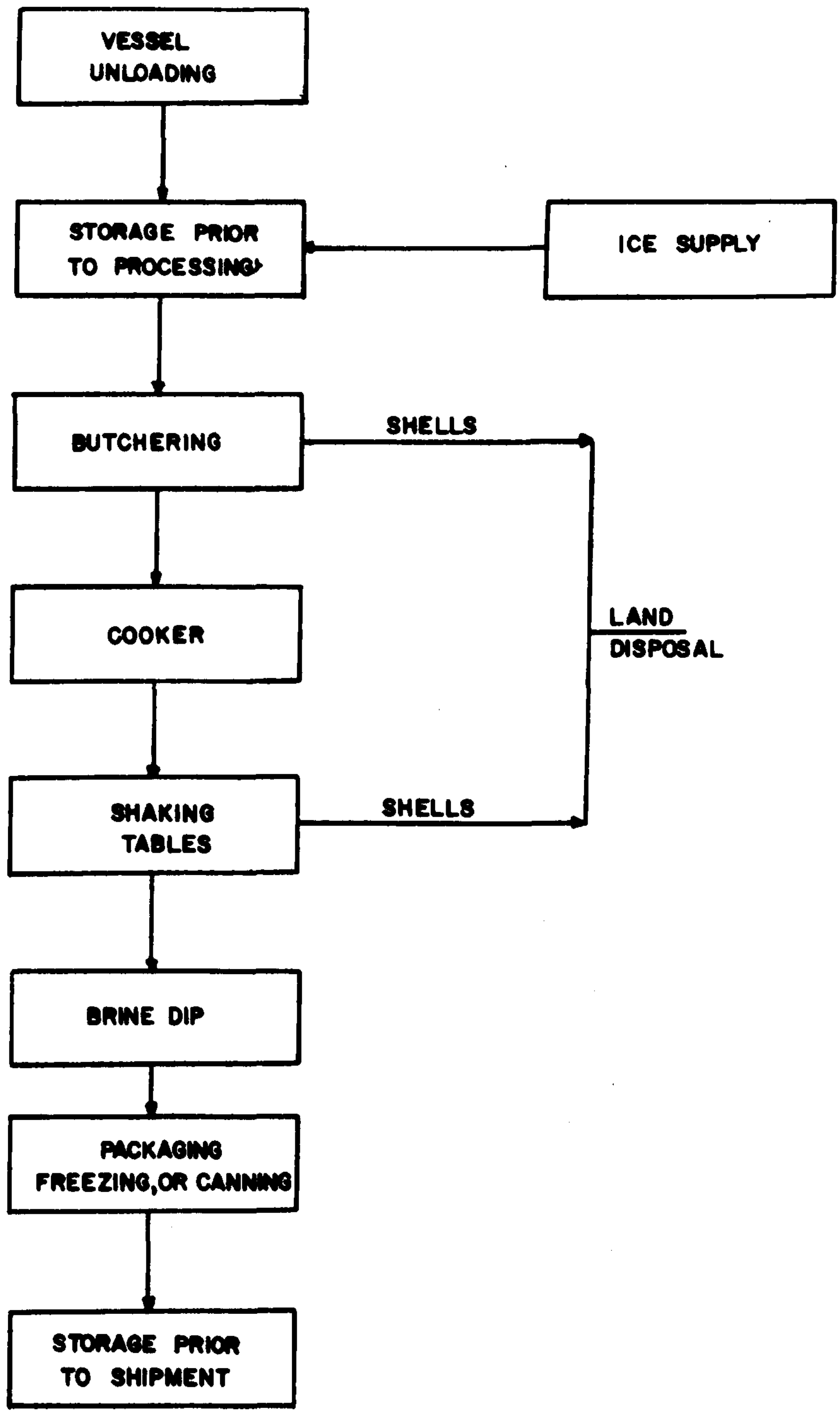

Figure 1. Process flow diagram
crab processing plant.

brine solution to preserve and maintain the natural taste of the meat and is then packed for shipment to the consumer market. It is sold in either a frozen or canned state.

Wastes in the crab processing industry originate at the butchering stations, the cooker, the shaking tables, and general clean-up; and are usually flumed to discharge via a system of floor drains. Prior to direct discharge into the receiving water, however, the bodies of the crab remaining after butchering and the leg shells from the shaking tables are removed and disposed of on land using normal sanitary land-fill techniques.

Two plants freezing queen crab were sampled for a five day period. Samples of plant effluent were taken every 30 minutes. Flow proportioned composites were made twice daily, one set of composite samples for the morning operation and one for the afternoon. All samples were taken prior to the discharge of the waste through screens. Tables 1, 2 and 3 show the results of this study.

Table 1. Waste characteristics of the queen crab process expressed as concentrations.

Characteristic	Concentration Range	Average
BOD_5	320 - 1000 mg/l	676 mg/l
SS	135 - 661 mg/l	301 mg/l
Oil	0.01 - 0.09%	0.03%

Table 2. Waste characteristics of the queen crab process expressed as pounds of waste produced per pound of product.

Characteristic	lb/1000 lb Product Landed	lb/1000 lb Product Produced
BOD_5	40	270
SS	19	84
Oil	21	93

Table 3. Water consumption per pound of product in the queen crab process.

Water Source	Gal/1000 lb Product Landed	Gal/1000 lb Product Produced
Fresh	739	3,312
Salt	5447	24,567

Fish Meal Operations

In the processing of most species of fish for food purposes from 30 to 80 percent of the raw material is wasted. 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 waters 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 2. 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 centrifuges followed by oil separation in nozzle centrifuges. The oil is further clarified in polishing 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 into the meal. The condenser water used in the evaporators does pick up volatile solids and gases,

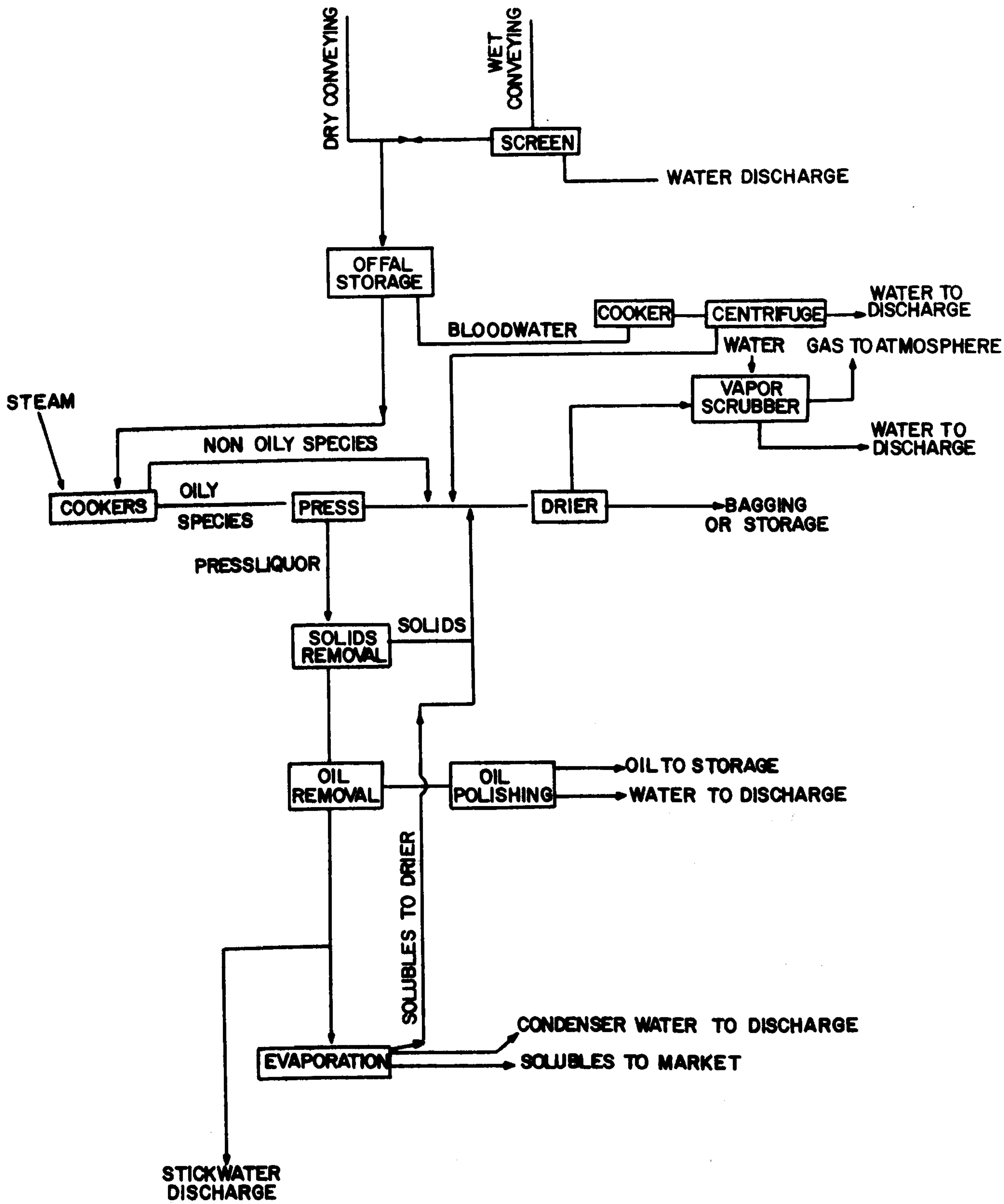

Figure 2. Flow diagram for fish meal production.

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 vapors 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.

The processing of fish meal can lead to the discharge of high strength wastes. A review of Table 4 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 directly to the receiving water.

Table 4. Average effluent characteristics from fish meal 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

Biological Treatment

Batch biological studies were carried out on the perch, smelt and combined perch and smelt wastewater. The characterization data for these process are shown in Tables 5 and 6. Sampling and analyses of the contents of the batch reactors were performed daily. The batch reactors used were filled with 15 liters of fish waste and 2 liters of liquor from the aerated lagoon. It was assumed this lagoon liquor would provide the source of acclimatized micro-organisms

Table 5. Average effluent characteristics

Process	BOD_5 (mg/l)	COD (mg/l)	Suspended Solids (mg/l)
Perch effluent	1867	3350	935
Smelt effluent	1152	1965	599
Combined effluent	3044	4796	1397

Table 6. Combined perch and smelt wastewater characteristics. (units pounds/1000 pounds of landed fish processed)

Statistic	BOD_5	COD	S.S.
Mean	4.5	8.0	2.3
Standard deviation	±2.0	±3.6	±1.3
Coefficient of variation	45.4%	47.7%	58.7%
Number of samples	29	27	29

necessary for each batch test. Air was supplied to the reactor at a rate of 3,5000 c.c. per minute.

Figure 3 indicates the percentage of filtered BOD_5 remaining in the reactor for perch, smelt and combined wastewater. As the best fit could be obtained by a straight line on arithmetic paper for the three wastes considered, the reactions were considered to be "zero-order" with respect to the degradation of filtered BOD_5.

Stickliquor was added to the three reactors to monitor its effect on the biological degradation of the waste

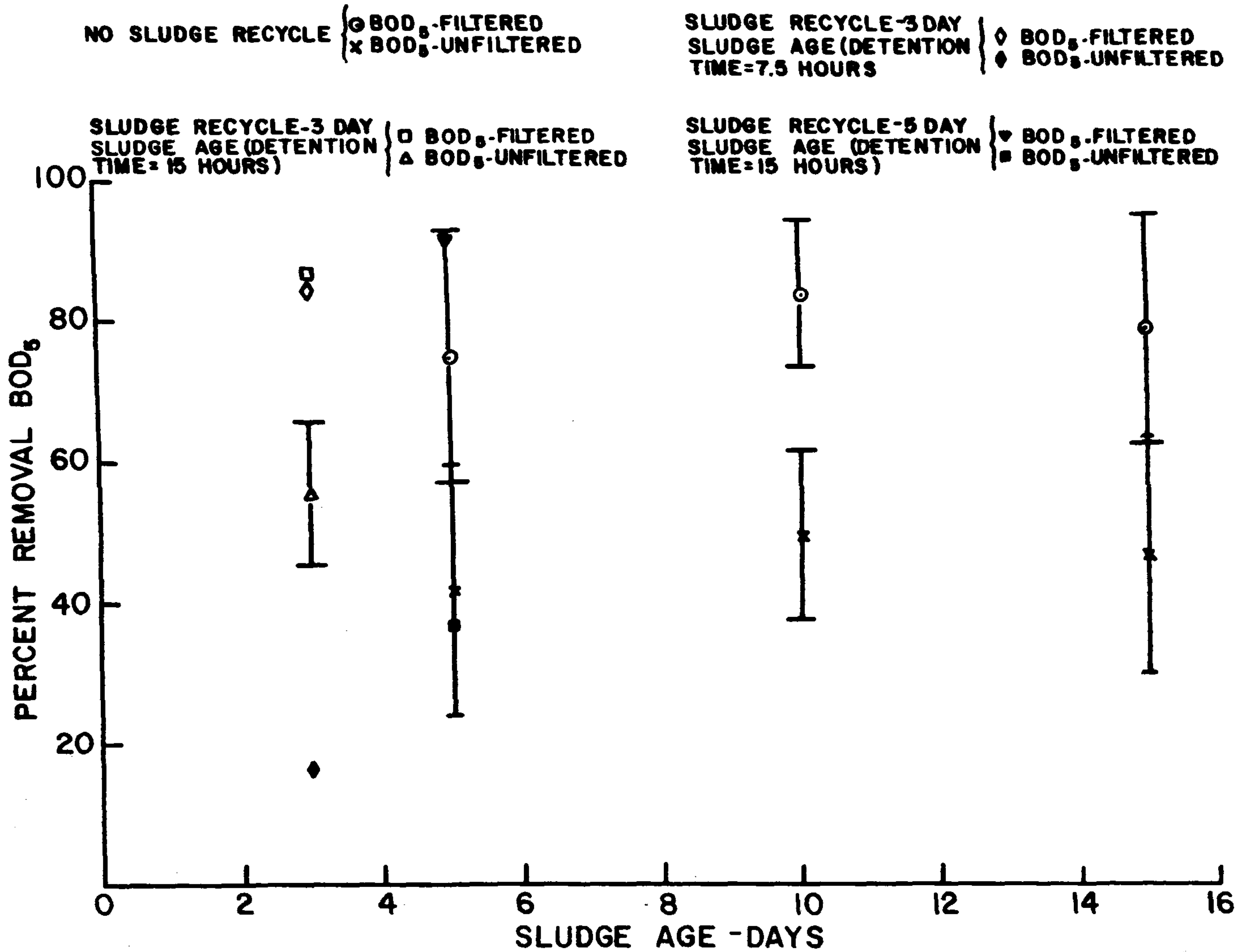

Figure 4. Continuous reactor studies-BOD_5 (combined wastewater).

material. The addition of stickliquor did not appear to alter the "rate" of the various reactions monitored.

The batch studies of perch, smelt and combined wastewater indicated removals of 90 percent of BOD_5 and in excess of 65 percent of soluble organic carbon during 10 days of aeration. Further aeration time would not substantially increase the removal efficiency. The addition of stickliquor markedly affected the biological system, causing a drop in treatment efficiency. It was concluded that the batch reactor did not reach a steady state in the 20 days following stickliquor addition.

Following batch studies, continuous reactors having detention times of 7.5 and 15 hours, 5, 10 and 15 days were employed. The 5, 10, and 15 days detention time reactors had no sludge recycle and the sludge age equaled the detention time. (Sludge age is defined as the total active mass divided by the mass withdrawn daily from the treatment system.) The 7.5 and 15 hour detention time reactors initially had a 3-day sludge age which was subsequently increased to 5 days by varying the amount of sludge recycled from the clarifier to the reactors.

Figure 4 is a plot of average percent removal of unfiltered and filtered BOD_5 against sludge age. It is a combination plot derived from data obtained from each continuous reactor. The figure gives mean percent removals and the standard deviations. Figure 4 indicates that a sludge age in excess of 3 days is required for maximum percentage removal of BOD_5, both filtered and unfiltered.

Figure 4 incorporates data from reactors with a short detention time and sludge recycle and data from long detention time reactors with no sludge recycle. Examination of figure 4 indicates that increasing sludge age above 3 days with or without sludge recycle did not markedly affect the percent removal of filtered and unfiltered BOD_5. The removal for 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 removal could be achieved by either a short detention time reactor (7.5 hours) with sludge recycle and 3-day sludge age, or a larger detection time reactor (5 days) with no sludge recycle.

Table 7 gives the residuals and percentage removals of BOD_5 for a batch reactor operated for 20 days. The percent removals of unfiltered and filtered BOD_5 in the batch reactor are 89 and 98 percent, respectively, for combined wastewater. These compare with 40 to 45 percent and 80 to 90 percent removals for unfiltered and filtered BOD_5 respectively in the continuous reactors.

If a 5-day detention time reactor is used for biological treatment of the combined wastewater, the nutrient concentrations in the effluent will be in the order of 140 mg/l for total Kjeldahl nitrogen and 30 mg/l for unfiltered

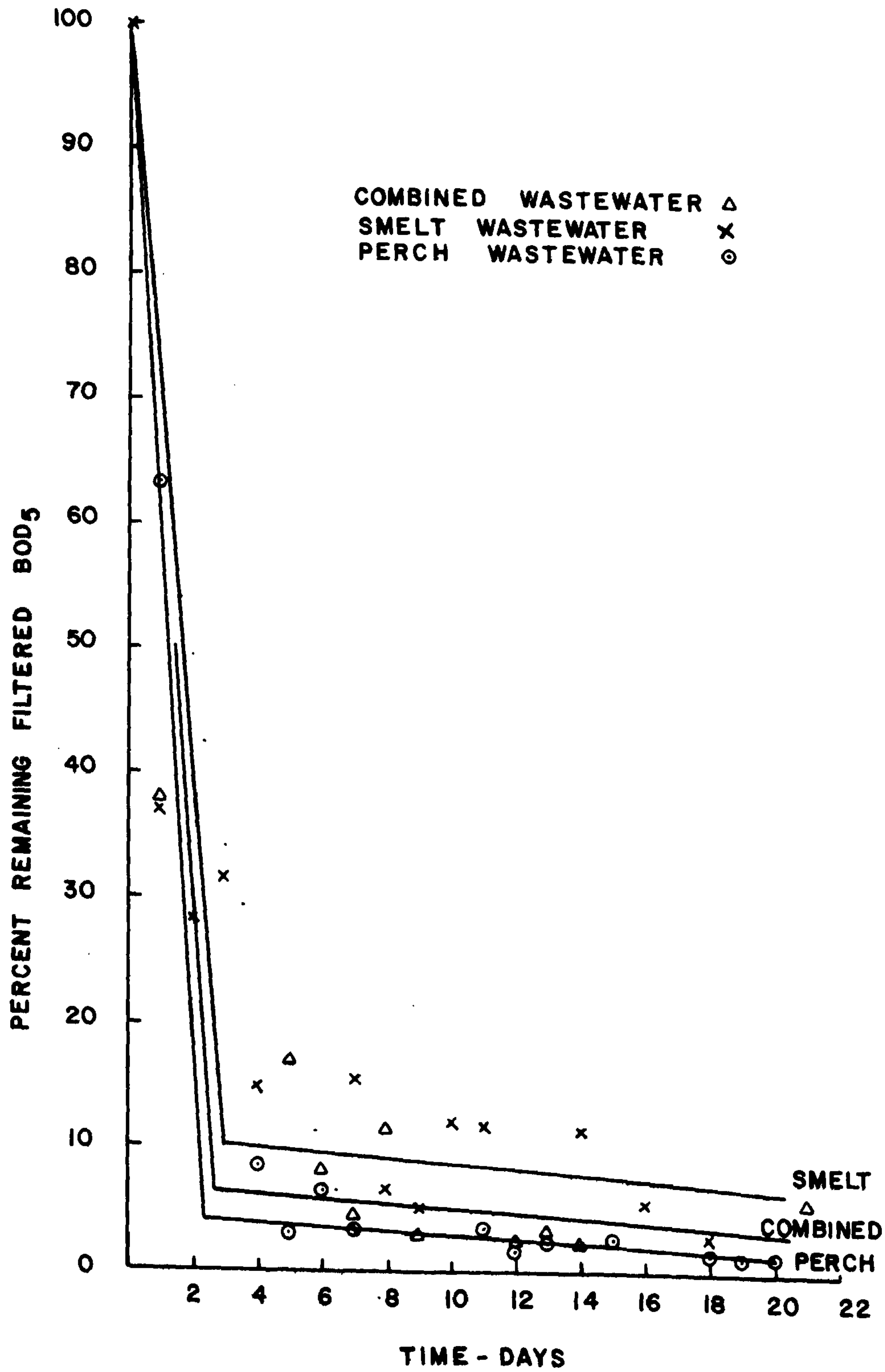

Figure 4. Batch reactor studies-filtered BOD_5

Table 7. Residuals following biological treatment and percent removal of BOD_5 of the combined wastewater. (Batch reactors operated for 20 days.)

Process	BOD_5 Filtered (mg/l)	BOD_5 Unfiltered (mg/l)	Percent Removal of BOD_5 Filtered	Percent Removal of BOD_5 Unfiltered
Perch wastewater	10	150	97	92
Smelt wastewater	40	150	94	88
Combined wastewater	9	190	98	89

phosphate. Increasing the detention time to 10 days would reduce the effluent concentration of total Kjeldahl nitrogen to about 85 mg/l, while having little effect on the phosphate concentration. A further increase in detention time to 15 days produces an effluent with approximately the same nutrient concentration as from the 10-day detention time reactor.