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Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the

CATFISH, CRAB, SHRIMP, AND TUNA

Segment of the Canned and Preserved Seafood Processing

Point Source Category

June 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE FOR THE CATFISH, CRAB, SHRIMP, AND TUNA SEGMENTS OF THE CANNED AND PRESERVED SEAFOOD PROCESSING INDUSTRY POINT SOURCE CATEGORY

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ABSTRACT

This report presents the findings of a study of the farm-raised catfish, crab, shrimp, and tuna processing segments of the canned and preserved seafood processing industry for the purpose of developing effluent limitations guidelines for point source and and new source standards of performance for new sources in order to implement Sections 304, 306, and 307 of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

The seafood processing plants included in this study were those processing farm-raised catfish, crab, shrimp and tuna. Other aquatic and marine species are the subject of a separate study, which is to be published at a later date.

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available" and the "Best Available Technology Economically Achievable" which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth a degree of effluent reduction which is achievable through the application of the best available demonstrated control technology processes, operating methods or other alternatives.

The effluent limitations to be met by July 1, 1977 and the New Source Performance Standards are based on the best biological or physical-chemical treatment technology currently available. This technology is represented by aerated lagoons, activated sludge, or dissolved air flotation. The limitations to be met by July 1, 1983 are based on the best physical-chemical and biological treatment and in-plant control as represented by reduced water use and enhanced treatment efficiencies in pre-existing systems as well as new systems.

Supportative data and rationale for development of the effluent limitations guidelines and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

For the purpose of establishing effluent limitations guidelines for existing sources and standards of performance for new sources, the farm-raised catfish, crab, shrimp and tuna segments of the canned and preserved seafood processing industry are divided into fourteen subcategories:

a) Farm-Raised Catfish Processing
b) Conventional Blue Crab Processing
c) Mechanized Blue Crab Processing
d) Non-Remote Alaskan Crab Meat Processing
e) Remote Alaskan Crab Meat Processing
f) Non-Remote Alaskan Whole Crab and Crab Section Processing
g) Remote Alaskan Whole Crab and Crab Section Processing
h) Dungeness and Tanner Crab Processing in the Contiguous States
i) Non-Remote Alaskan Shrimp Processing
j) Remote Alaskan Shrimp Processing
k) Northern Shrimp Processing in the Contiguous States
l) Southern Non-Breaded Shrimp Processing in the Contiguous States
m) Breaded Shrimp Processing in the Contiguous States
n) Tuna Processing.

The major criteria for the establishment of the subcategories were:

1) variability of raw material supply;
2) variety of the species being processed;
3) degree of preprocessing;
4) manufacturing processes and subprocesses;
5) form and quality of finished product;
6) location of plant;
7) nature of operation (intermittent versus continuous); and
8) amenability of the waste to treatment.

The wastes from all subcategories are amenable to biological waste treatment under certain conditions and no materials harmful to municipal waste treatment processes (with adequate operational controls) were found.

A determination of this study was that the level of waste treatment throughout the farm-raised catfish, crab, shrimp, and tuna segments of the industry was generally inadequate. Technology exists at the present time, however, for significant reduction of respective waste water constituents within the industry. Because waste treatment, in-plant waste reduction, and effluent management are in their infancy in this industry, rapid progress is expected to be made in the near future.

SECTION II

RECOMMENDATIONS

Effluent limitations for discharge to navigable waters are based in general on the characteristics of well-operating screening systems, dissolved air flotation units, and biological treatment systems. Parameters designated to be of significant importance to warrant their routine monitoring in this industry, are 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), oil and grease (O&G), and pH.

The 1977 effluent limitations are presented in Table 1; The 1983 limitations, in Table 2; and new source performance standards, in Table 3.

Table 1 July 1, 1977 Guidelines

	Subcategory	Technology Basis	BOD Max 30-day Average	BOD Daily Max	TSS Max 30-day Average	TSS Daily Max	O+G Max 30-day Average	O+G Daily Max
A	Farm-Raised Catfish	S, GT	-	-	9.2	28	3.4	10
B	Conventional Blue Crab	S, GT	-	-	0.74	2.2	0.20	0.60
C	Mechanized Blue Crab	S, GT	-	-	12	36	4.2	13
D	Non-Remote Alaskan Crab Meat	S, GT	-	-	6.2	19	0.61	1.8
E	Remote Alaskan Crab Meat	Comminutors	*	*	*	*	*	*
F	Non-Remote Alaskan Whole Crab and Crab Sections	S, GT	-	-	3.9	12	0.42	1.3
G	Remote Alaskan Whole Crab and Crab Sections	Comminutors	*	*	*	*	*	*
H	Dungeness + Tanner Crab in the Contiguous States	S, GT	-	-	2.7	8.1	0.61	1.8
I	Non-Remote Alaskan Shrimp	S	-	-	210	320	17	51
J	Remote Alaskan Shrimp	Comminutors	*	*	*	*	*	*
K	Northern Shrimp	S	-	-	54	160	42	126
L	Southern Non-Breaded	S	-	-	38	114	12	36
M	Breaded Shrimp	S	-	-	93	280	12	36
N	Tuna	S, DAF	9.0	23	3.3	8.3	0.84	2.1

Parameter (kg/kkg or lbs/1000 lbs liveweight processed)

* No pollutants may be discharged which exceed 1.27 cm (0.5 inch) in any dimension.

S = screen; GT = simple grease traps; DAF = dissolved air flotation;

Table 2 July 1, 1983 Guidelines

	Subcategory	Technology Basis	Parameter (kg/kkg or lbs/1000 lbs liveweight processed) BOD		TSS		O+G	
			Max 30-day Average	Daily Max	Max 30-day Average	Daily Max	Max 30-day Average	Daily Max
A	Farm-Raised Catfish	S, GT, AL	2.3	4.6	5.7	11	0.45	0.90
B	Conventional Blue Crab	S, GT, AL	0.15	0.30	0.45	0.90	0.065	0.13
C	Mechanized Blue Crab	S, GT, AL, IP	2.5	5.0	6.3	13	1.3	2.6
D	Non-Remote Alaskan Crab Meat	S, DAF, IP	2.0	5.0	0.53	1.3	0.82	0.21
E	Remote Alaskan Crab Meat	S, GT, IP	-	-	5.3	16	0.52	1.6
F	Non-Remote Alaskan Whole Crab and Crab Sections	S, DAF, IP	1.3	3.3	0.33	0.83	0.048	0.12
G	Remote Alaskan Whole Crab and Crab Sections	S, GT, IP	-	-	3.3	9.9	0.36	1.1
H	Dungeness + Tanner Crab in the Contiguous States	S, DAF, IP	1.7	4.3	0.23	0.58	0.07	0.18
I	Non-Remote Alaskan Shrimp	S, DAF, IP	28	71	18	46	1.5	3.8
J	Remote Alaskan Shrimp	S, IP	-	-	180	270	15	45
K	Northern Shrimp	S, DAF, IP	27	68	4.9	12	3.8	9.5
L	Southern Non-Breaded Shrimp	S, DAF, IP	10	25	3.4	8.5	1.1	2.8
M	Breaded Shrimp	S, DAF, IP	17	43	7.4	19	1.0	2.5
N	Tuna	S, DAF, AS, IP	0.62	2.2	0.62	2.2	0.077	0.27

S = screen; GT = simple grease trap; Al = aerated lagoon; IP = in-plant change;
DAF = dissolved air flotation; AS = activated sludge system

Table 3 New Source Performance Standards

	Subcategory	Technology Basis	Parameter (kg/kkg or lbs/1000 lbs liveweight processed)					
			BOD		TSS		O+G	
			Max 30-day Average	Daily Max	Max 30-day Average	Daily Max	Max 30-day Average	Daily Max
A	Farm-Raised Catfish	S, GT, AL	2.3	4.6	5.7	11	0.45	0.9
B	Conventional Blue Crab	S, GT, AL	0.15	0.30	0.45	0.90	0.065	0.13
C	Mechanized Blue Crab	S, GT, AL, IP	2.5	5.0	6.3	13	1.3	2.6
D	Non-Remote Alaskan Crab Meat	S, GT, IP	-	-	5.3	16	0.52	1.6
E	Remote Alaskan Crab Meat	S, GT, IP	-	-	5.3	16	0.52	1.6
F	Non-Remote Alaskan Whole Crab and Crab Sections	S, GT, IP	-	-	3.3	9.9	0.36	1.1
G	Remote Alaskan Whole Crab and Crab Sections	S, GT, IP	-	-	3.3	9.9	0.36	1.1
H	Dungeness + Tanner Crab in the Contiguous States	S, DAF, IP	4.1	10	0.69	1.7	0.10	0.25
I	Non-Remote Alaskan Shrimp	S, IP	-	-	180	270	15	45
J	Remote Alaskan Shrimp	S, IP	-	-	180	270	15	45
K	Northern Shrimp	S, DAF, IP	62	155	15	38	5.7	14
L	Southern Non-Breaded Shrimp	S, DAF, IP	25	63	10	25	1.6	4.0
M	Breaded Shrimp	S, DAF, IP	40	100	22	55	1.5	3.8
N	Tuna	S, DAF, IP	8.1	20	3.0	7.5	0.76	1.9

S = screen; GT = simple grease trap; Al = aerated lagoon; IP = in-plant change;
DAF = dissolved air flotation

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act Amendments of 1972 (the Act) requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 304(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operational methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the canned and preserved seafoods source category. Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources for the canned and preserved seafoods source category, which was included in the list published January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of this list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the seafood industry category as delineated above, which was included within the list published January 16, 1973.

Industry Background

The seafood industry in the United States is an integral part of the food processing industry. The processors have been expanding and improving methods of production from the days of drying and salt curing to modern canning and freezing. Per capita consumption of fish and shellfish in 1972 was 5.5 kg (12.2 lbs); totaling 1,134,000 kkg (1,250,000 tons) in the United States. The source and dispositon of seafood are shown in Figure 1. The total value of these products in 1972, including animal feed and other by-products, was a record $2.3 billion, 23 percent above the previous year (N.M.F.S., 1973).

Regardless of the method of preservation, i.e., fresh-pack, freezing, canning, or curing, the four segments of the industry considered in this study (catfish, crab, shrimp and tuna) use variations of a common seafood processing method. Figure 2 schematically shows the general steps in this method: harvest, storage, receiving, evisceration, precooking, picking or cleaning, preservation and packaging. The following general industry description is expanded in detail in Section IV for each subcategory of the industry. This general description serves to introduce the reader to the basic steps in seafood processing and to provide a basic grasp of the processes prevalent among the subcategories.

Catfish are raised in the southeastern United States; processing is concentrated in Arkansas, Georgia, Alabama, Florida and Mississippi. In 1972, farm-raised catfish production totaled 35,400 kkg (39,000 tons); and wild catfish totaled 21,000 kkg (23,000 tons). The production of farm-raised catfish is growing rapidly, and has increased 180 percent since 1968.

The blue crab industry is located on the Eastern Seaboard and Gulf Coast. It comprises the largest crab landings in the U. S.; 65,800 kkg (72,500 tons) were landed in 1972. Alaska king crab followed the blue crab with 33,600 kkg (37,000 tons) landed. The Pacific Coast snow (tanner) and Dungeness crab catches were approximately 12,700 kkg (14,000 tons) in 1972 (N.M.F.S., 1973).

Shrimp are landed and processed on all three U. S. coastlines. In 1972 the largest U. S. commerical landings, 103,400 kkg (114,000 tons), were in the Gulf, followed by the Pacific fisheries, where landings totaled 48,100 kkg (53,000 tons). New England and the South Atlantic had landings of approximately 11,340 kkg (12,500 tons) each in 1972.

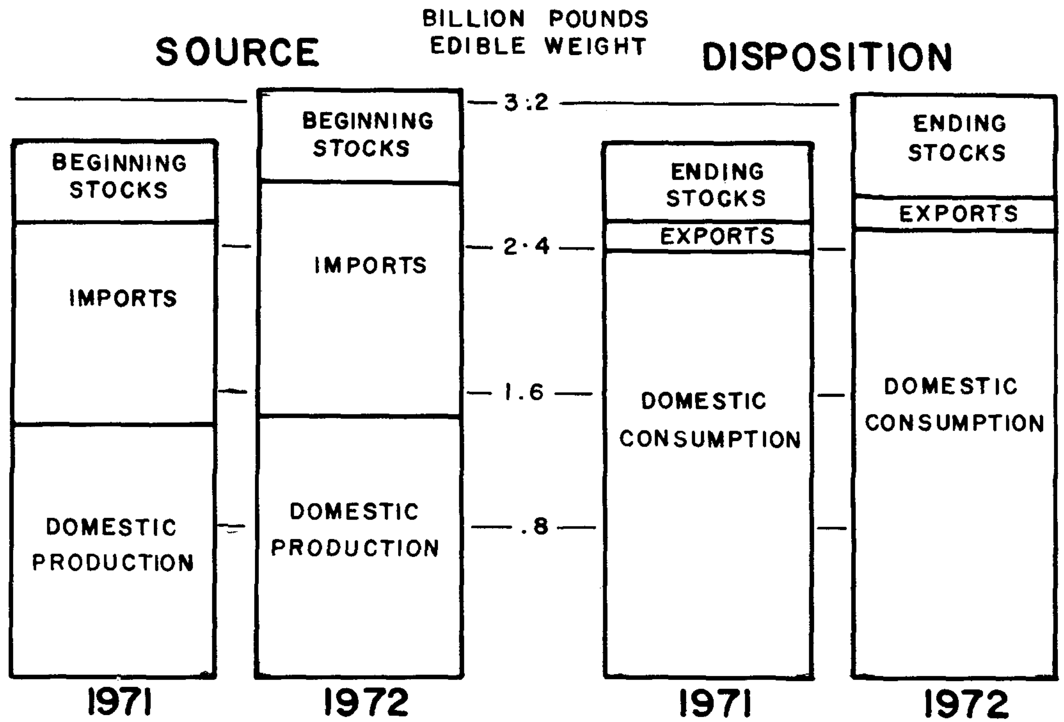


Figure 1 Source and disposition of edible fishery products.

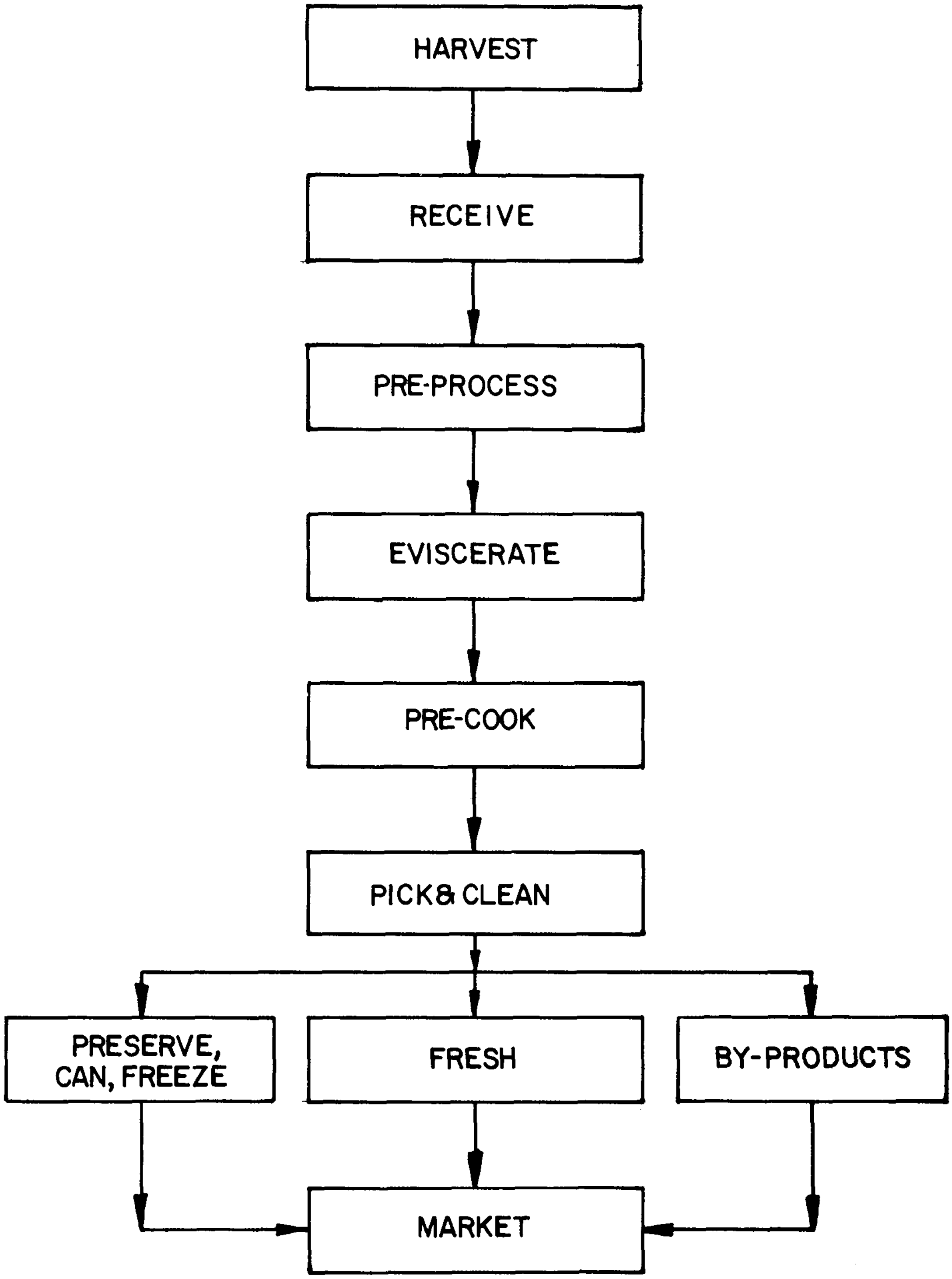


Figure 2 Typical seafood process diagram.

The tuna industry, like shrimp, is highly mechanized. United States landings for tuna in 1972 were 237,700 kkg (262,000 tons). Over 171,000 kkg (188,500 tons) of that total was landed in the Atlantic, Gulf and Pacific Coast states, including Hawaii. Puerto Rico had landings of 66,700 kkg (73,500 tons) in 1972. Significant tonnages of tuna are purchased from Japanese, Peruvian, and other foreign fishermen. As a part of this study the wastes emanating from processing plants in each of the major commodity areas of the United States were monitored. The plants selected for monitoring were representative of the industry from several standpoints: including size, age, level of technology, and geographical distribution. Figures 3 and 4 locate the plants sampled.

General Process Description

Harvesting utilizes some of the oldest and newest technologies in the industry. It may be considered a separate industry supplying the basic raw material for processing and subsequent distribution to the consumer. Harvest techniques vary according to species, and consist of four general methods: netting, trapping, dredging, and line fishing. Fishing vessels utilize the latest technology for locating fish and shellfish and harvest them in the most expedient and economical manner consistent with local regulations. Once aboard the vessel, the catch either is taken directly to the processor, or is iced or frozen for later delivery.

The receiving operation usually involves three steps: unloading the vessel, weighing, and transporting by conveyor or suitable container to the processing area. The catch may be processed immediately or transferred to cold storage.

Preprocessing refers to the initial steps taken to prepare the various fish and shellfish for the processes that follow. It may include washing of dredged crabs, thawing of frozen fish, beheading shrimp at sea, de-icing shrimp, and other operations to prepare the fish for butchering.

Wastes from the butchering and evisceration are usually dry-captured, or screened from the waste stream, and processed as a fishery by-product.

Except for the fresh market fish, some form of cooking or pre-cooking of the commodity may be practiced in order to prepare the fish or shellfish for the picking and cleaning operation. Precooking or blanching facilitates the removal of skin, bone, shell, gills, and other materials. The steam condensate, or stick water, from the tuna precook is often collected and further processed as a by-product.

The fish is prepared in its final form by picking or cleaning to separate the edible portions from non-edible portions. Wastes

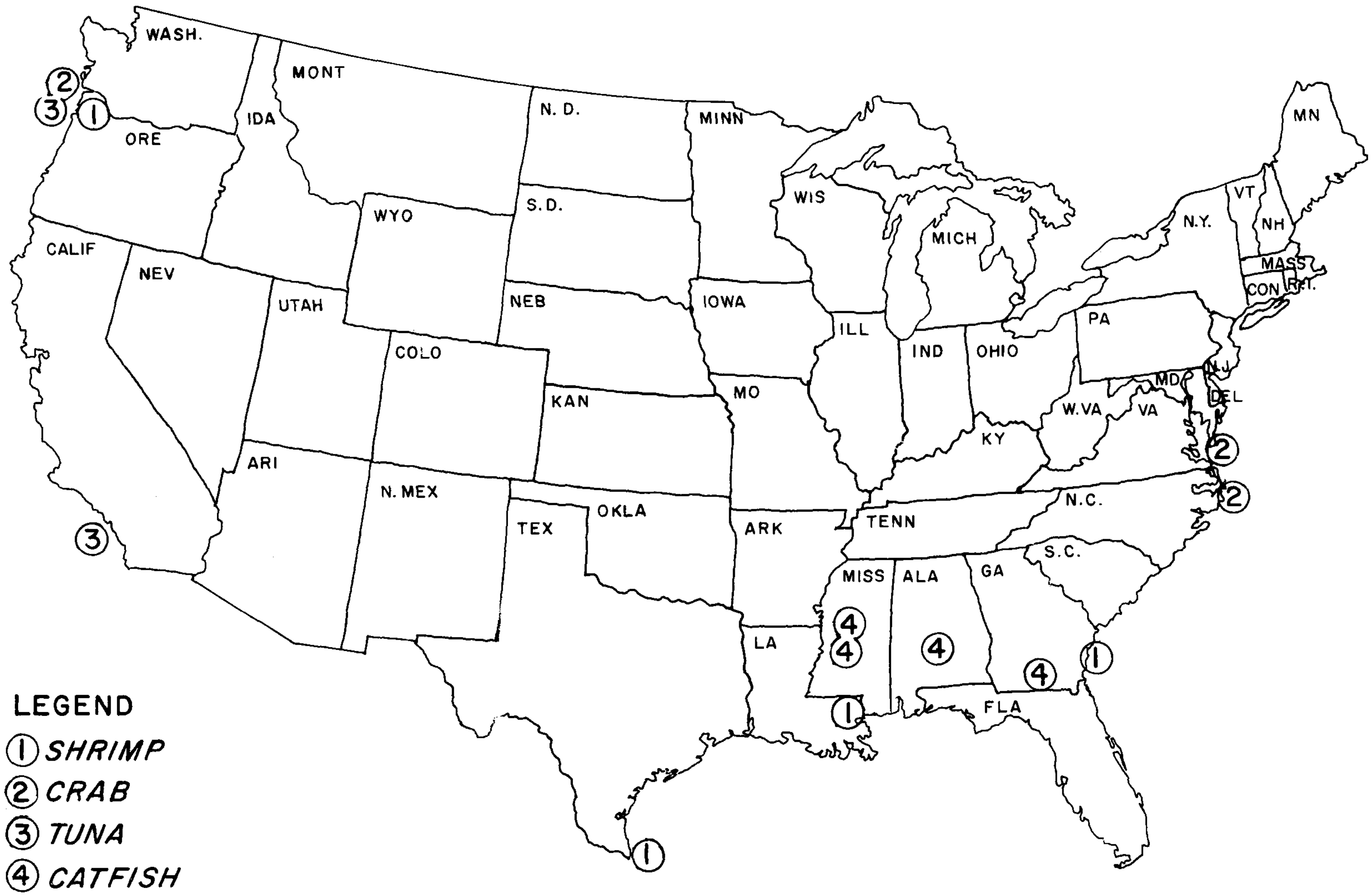


Figure 3 General location of fish and shellfish plants sampled.

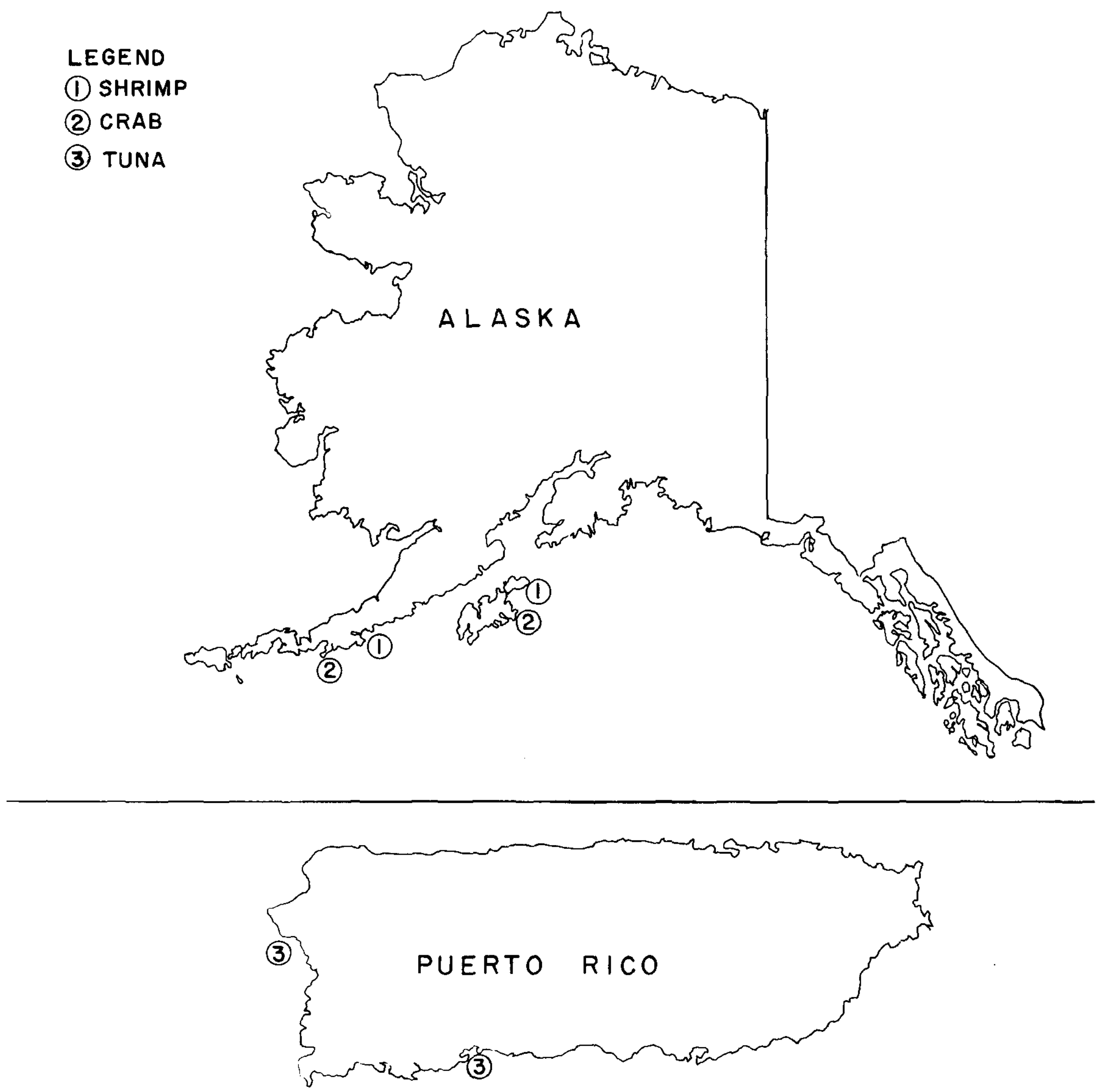


Figure 4 . General location of fish and shellfish plants sampled.

generated during this procedure are usually collected and saved for by-product processing. Depending on the species, the cleaning operation may be manual, mechanical, or a combination of both. With fresh fish and fresh shellfish, the meat product is packed into a suitable container and held under refrigeration for shipment to a retail outlet. If the product is to be held for extended periods of time before consumption, several forms of preservation are used to prevent spoilage caused by bacterial action and autolysis: freezing, canning, pasteurization and refrigeration.

Bacterial growth is arrested at temperatures below -9°C (16°F) (Burgess, 1967). For this reason, freezing is an excellent method of holding uncooked fish for an extended period of time. Freezing is also advantageous because the meat remains essentially unchanged, in contrast to canning, which alters the product form. However, autolysis still continues at a reduced rate, necessitating the consumption of the meat within approximately 6 months. Storage times vary from species to species. Blanching prior to freezing inactivates many enzymes and further slows autolysis.

Preservation by canning requires special equipment to fill the can, add preservatives and seasonings, create a partial vacuum and seal the can. A partial vacuum is necesary to avoid distortion of the can due to increased internal pressures during cooking. After sealing, the cans are washed and retorted (pressure-cooked) at approximately 115°C (240°F) for 30 to 90 minutes, depending on the can size. Although the enzymes are inactivated at rather low temperatures, high temperatures must be reached to insure the destruction of harmful anaerobic bacterial spores. Clostridium botulinum, the most harmful of these, must be subjected to a temperature of 116°C (240°F) for at least 8.7 minutes (Burgess, 1967). A longer cooking time is employed to achieve this temperature throughout the can and to insure total destruction of the bacteria. After the cook, the can is cooled with water and the canned fish or shellfish is transported to the labeling room for casing and shipment.

Process Summary

Catfish

Sixty percent of the catfish harvest is from farm ponds or raceways; the rest are caught wild. They are transported alive, iced, or "dry" (without ice), to the processing plant. At the plant the fish are kept in live-holding tanks until ready to be processed. They are usually stunned by electrocution. The fish are then conveyed into the plant where the heads and dorsal fins are removed. They are then eviscerated and skinned. A final cleaning removes adhering skin, fins, and blood. The fish are weighed and packaged according to size; larger fish are cut into steaks or filleted; smaller fish are packaged whole. All catfish are marketed fresh or frozen.

Solid wastes are subjected to rendering wherever facilities are available. Otherwise, they are deposited in landfills or dumps. Wastewater treatment is usually not practiced.

Blue Crab

Harvesting of blue crab is accomplished by dredging them from the mud, catching them with baited traps or lines, or scraping them from grassy shores during the molt. Transported live to the receiving dock, the crabs are unloaded into trolleys for immediate steam cooking at 121°C (250°F) for 10 to 20 minutes. After storage overnight in a cooling locker, the claws are removed (and saved for mechanical processing or hand picking) and the body of the crab is picked manually. The meat is packed into cans or plastic bags. In the mechanized plant the claws and sometimes the bodies, after removal of carapace and "back fin," are run through a mechanical picker which separates the meat from the shell. The meat is then frequently canned, retorted, and cased for shipment. The select "back fin" is hand packed in cans, pasteurized, and refrigerated.

Other Crab

Dungeness, tanner, and king crab are caught in baited pots and generally stored onboard the vessel in circulating seawater. In Alaska, where larger volumes of crab are caught, they are stored in live tanks at the processing plant. On the lower West Coast, where catches are much smaller and consist mainly of Dungeness crab, they are usually dry-stored and butchered early the day after delivery. Most plants utilize dry butchering; some, however, employ fluming to transport shell and viscera. The crabs are then cooked, cooled, picked, packaged, and stored. Meat extraction of "sections" (crab halves) is done either manually or mechanically. Mechanical picking is practiced mainly in Alaska, using rollers or high-pressure water. Hand picking is performed chiefly on Dungeness and imported tanner crabs in the lower West Coast states. Meat that has been picked from the crab is marketed either fresh, frozen or canned. Some crabs are cooked and marketed without butchering.

Waste from crab processing is rendered, if facilities are available. Otherwise, it is hauled to a sanitary landfill or discharged to the bay or to a municipal sewer, along with plant sanitary wastes.

Shrimp

Shrimp are caught by trawlers, vessels which "drag" the ocean with large nets. The shrimp are stored in ice until delivery to the processor. They are then de-iced, separated from debris, and weighed. The shell is peeled either manually or mechanically.

After being cleaned of debris the shrimp are usually blanched. They are then either frozen or canned. Variations of the process among Alaskan, West, Gulf, and Atlantic Coast shrimp are explained in Section IV. The shell and larger waste solids are sometimes screened from the waste stream and either rendered at another facility or removed to a sanitary landfill. In other instances, the solids are discharged to the bay with the untreated waste water.

Tuna

Tuna are harvested by line or by net. They are frozen onboard the vessel and thawed (usually by salt water) at the processing plant. The tuna are then butchered, precooked, cooled, and cleaned, before being packed in cans. Depending on the condition of the cleaned tuna, the meat is graded as solid, chunk, or flake style. The cans are subsequently retorted, labeled, cased, and shipped to the retailer. Viscera, precooker stick water and solid wastes are further processed into by-products. Some plants, however, do not practice press-liquor or stick water recovery. Such plants discharge these liquids to local waters with their untreated process waste waters, or barge them to sea.

SECTION IV

INDUSTRY CATEGORIZATION

INTRODUCTION

The initial categorization of this segment of the seafood processing industry logically fell along commodity lines. That is, four broad groups of subcategories were involved: catfish, crab, shrimp and tuna. Beyond this general breakdown, however, further fragmentation was necessary to develop subcategories of a relatively homogeneous nature, each of which could be considered as a unit in the process of developing (and ultimately applying) effluent limitations and standards. The following variables, in addition to type of seafood, were considered in the development of subcategories:

1. variability in raw material supply;
2. condition of raw material on delivery to the processing plant;
3. variety of the species being processed;
4. harvesting method;
5. degree of preprocessing;
6. manufacturing processes and subprocesses;
7. form and quality of finished product;
8. location of plant (taking into account such factors as climatic conditions, terrain, soil types, etc.);
9. age of plant;
10. production capacity and normal operating level;
11. nature of operation (intermittent versus continuous);
12. raw water availability;
13. amenability of the waste to treatment.

It remained then to define and establish subcategories whose uniqueness dictated the consideration of separate limitations based on the variables listed above. During the course of the study, the importance of all but one of these variables was confirmed. The only variable which was found to have little relationship to the ultimate development of subcategories was the "age of the plant." In the course of the field work, it became obvious that within a given industry, either 1) equally antiquated processes were being used by all processors (with minor modifications); 2) older plants had been remodeled periodically during the life of the industry so that similar processes were being employed in both old and new plants; or 3) (as was the case with catfish) the industry was so young that significant differences in plant age did not exist.

On the following pages will be found a description of the final subcategorization of the four segments of the seafood industry considered in this study. Included in each discussion is a detailed description of the industry within the subcategory, a description of the raw materials used, end products produced, methods and variations of production, and a review of the rationale for its designation as a separate unit. Much of the information contained in the initial description of each subcategory is based on an updating of the original seafoods "state of the art" report developed for EPA in 1970 (Soderquist, et al., 1970), together with supplemental material gathered on-site and developed through extensive communication with the industry.

In each case, a generalized flow diagram is presented for each major component of the subcategory. Variations on each of those general themes are then discussed in the text.

FARM-RAISED CATFISH PROCESSING (Subcategory A)

Background

Since 1963, the production of farm catfish has increased steadily (see Table 4). Four species (channel catfish, *Ictalurus punctatus*; blue catfish, *Ictalurus furcatus*; white catfish, *Ictalurus catus*; and brown bullhead catfish, *Ictalurus nebulosus*) have been grown and managed successfully in ponds. Catfish are considered a delicacy in the southern and southcentral states and markets have been (and continue to be) expanding rapidly. In 1969, the total harvest was 38 million kilograms (84 million pounds) (Jones, 1969). The National Marine Fisheries Service estimated that the total farm catfish production in 1975 will reach 51 million kilograms (112.5 million pounds) (Jones, 1969).

Continued high demand for the finished product, together with improvements in production technology, have stimulated rapid growth of the catfish processing industry over the past few years. In the mid-1960's, according to Mulkey and Sargent (1972), nearly all farm-raised catfish were sold to local consumers or were offered (at a price) to local sport fishermen in commercial "fish-out" lakes. In 1970, sixteen processing plants were operating in nine states and processing 2.9 million kilograms (6.4 million pounds) of raw material annually (Russell, 1972). Today at least thirty-seven plants are in operation, mostly in Alabama, Mississippi, and Arkansas.

Processing

The science of raising catfish involves planting six inch fingerlings which are fed a commercial ration through maturity. For detailed descriptions of catfish farming schemes, the reader is directed to Barksdale (1968), Grizell, et al. (1969), Boussu (1969), and Greenfield (1969). Harvesting is accomplished by a preliminary seining of the rearing pond followed by drainage of

Table 4 Total supplies of catfish in the U. S. 1963-68, with production projections estimates 1969-1975 (Jones, 1969).

Year	Wild Catfish		Catfish Imports		Farm Catfish	
	($kg \times 10^6$)	($lb \times 10^6$)	($kg \times 10^6$)	($lb \times 10^6$)	($kg \times 10^6$)	($lb \times 10^6$)
1963	21.9	(48.3)	0.2	(0.5)	1.1	(2.4)
1964	21.6	(47.6)	0.4	(0.8)	1.7	(3.8)
1965	20.4	(45.0)	0.5	(1.0)	3.2	(7.0)
1966	19.3	(42.5)	0.9	(2.0)	5.0	(11.0)
1967	18.8	(41.3)	1.4	(3.0)	7.5	(16.5)
1968	18.3	(41.3)	1.8	(4.0)	12.5	(27.5)
1969	19.3	(42.5)	2.3	(5.0)	19.1	(42.0)
1970	20.4	(45.0)	3.2	(7.0)	26.2	(57.6)
1971	20.4	(45.0)	3.6	(8.0)	32.5	(71.5)
1972	21.0	(46.3)	4.1	(9.0)	35.4	(78.0)
1973	21.0	(46.3)	4.1	(9.0)	41.3	(91.0)
1974	21.6	(47.5)	5.0	(11.0)	44.5	(98.0)
1975	21.6	(47.5)	6.4	(14.0)	50.1	(112.5)

the pond (during dry weather) and manual collection of the remaining fish lying in the bottom mud. The fish are generally shipped alive in aerated tank trucks to the processing plant where they are stored in holding tanks. Live hauling eliminates the need for meat preservation before processing but generates the problem of disposal of the feces-contaminated holding water. Alternatively, the fish are packed in ice and trucked to the processing plant. Local small producers frequently deliver their fish dry (and without ice) to the plant. Figure 5 depicts the process used in the catfish industry. The solid line depicts the product flow, the single dashed line depicts waste water flow and the double dashed line depicts primarily waste solids flow. The twin beheading saws (band saws) are followed by the evisceration table, skinning machines, the washing-grading area and the automatic weigher-sorter. A typical catfish plant employs twenty-four workers (for one shift) and processes about 5000 kg (11,000 lbs) of fish per eight-hour day.

The receiving area includes the holding tanks and the stunning tank, which may or may not be distinct from one another. The storage tanks require a non-chlorinated water supply to avoid toxicity to the fish. Sufficient dissolved oxygen must be provided through mechanical aeration or high water exchange rates. Prior to stunning, most processors attempt to "cull out" and discard dead fish.

Iced storage is more popular with processors who must transport their raw material long distances to the processing plant. When iced storage is used, the effluent load from the receiving area is reduced.

When processing begins, the live fish are first "stunned," which involves electrocution in water-filled tanks or dewatered cages. This method of killing is claimed to have the advantage of concentrating most of the blood in the head, thereby minimizing blood loss and discoloration of the flesh during subsequent processing (Billy, 1969). A possible disadvantage of this method was pointed out by Mulkey and Sargent (1972). This was the assumed tendency for the fish to defecate during stunning. The specific effects, however, of shocking on meat quality and on waste production remain to be determined.

After stunning, the fish are butchered. This process consists of beheading, eviscerating, and skinning and can be either manual or mechanical. At this point, under-size and "trash" fish are discarded. Catfish have traditionally been skinned before marketing. This is necessary to reduce off-flavor in "wild" catfish, but at least one writer questions the necessity to skin cultured catfish (Billy, 1969).

In some plants receiving fish on ice rather than alive, the beheading is preceeded by a pre-wash step that uses a significant amount of water. After loading onto a conveyor belt, the fish are spray-washed as they are transported into the plant.

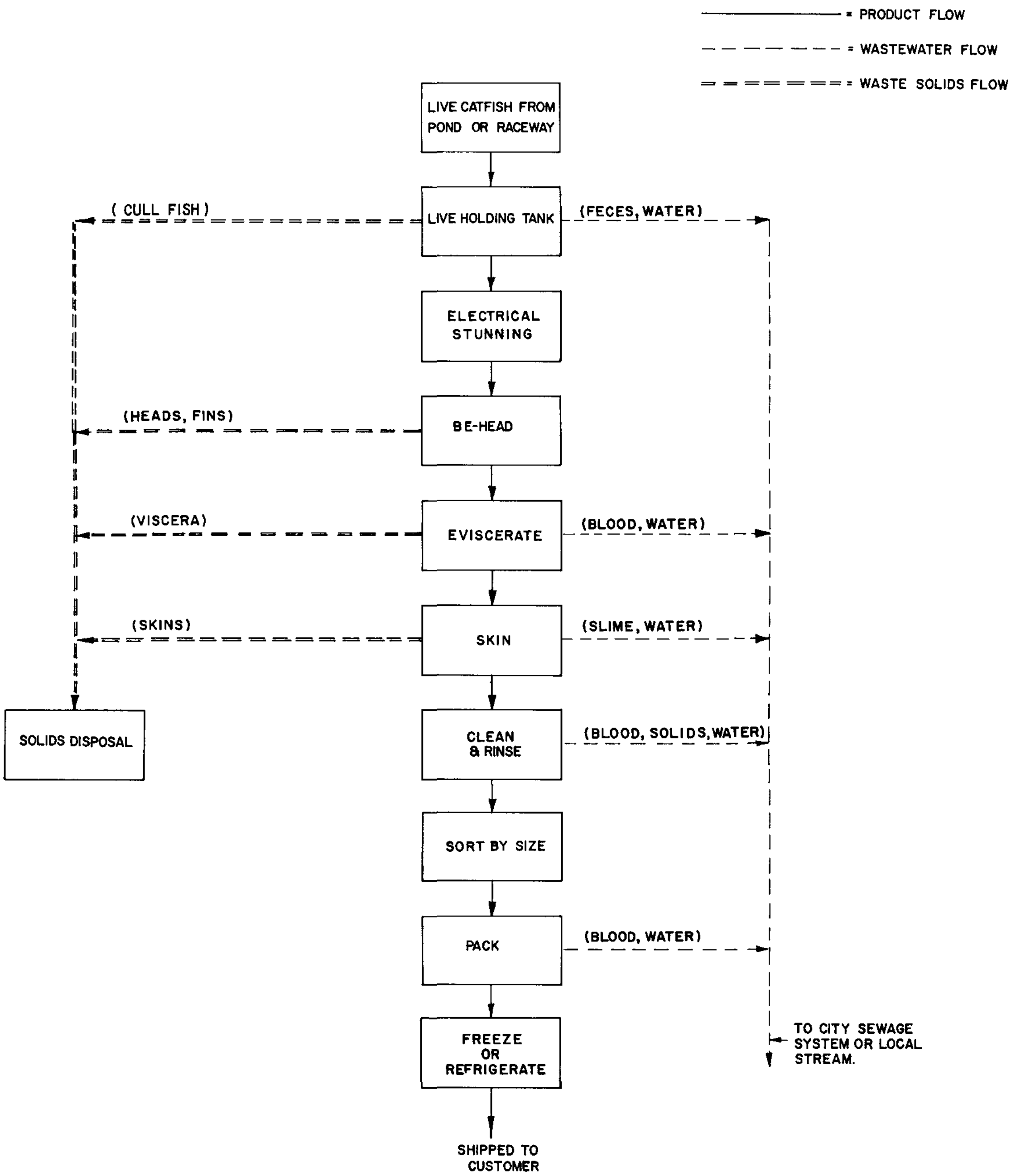


Figure 5 Catfish process.

Heads are usually removed with conventional band saws or table saws. The solid wastes, including the decomposed and under-size fish, are dry-captured at many plants; water is required only for periodic equipment cleaning.

Evisceration is accomplished either manually or with a vacuum system. In the latter case, after the body cavity is opened manually, the viscera are removed by vacuum "guns" and dry-captured for subsequent rendering, incorporation into pet food, or burial for final disposal. The manual method of evisceration is slower than the vacuum system. Whether evisceration is mechanical or manual, the majority of plants do employ dry-capture of the viscera for ultimate disposal.

Skinning is done either manually or mechanically; however, even the mechanical systems require considerable manual input. Manual skinning involves impaling of the carcass on a hook suspended a few feet above the work area and stripping of the skin from the carcass using a pliers-like tool. Mechanical skinning involves running the fish (manually) over a planer-like machine three times (once for each side and once for the back) and abrading and pulling the skin from the body of the fish. Surprisingly, mechanical skinning increases the product yield a small amount. This is because manual skinning tears off the abdominal flesh along with the skin, whereas mechanical skinning does not. Skins are either flumed to the main waste stream or are trapped at the skinner in a basket-type screen and dry-captured.

A third method of skinning, using sodium hydroxide, is still in the research stage. Development of the technique, analogous in some ways to the "dry caustic" peeling method now being adopted in the fruit and vegetable processing industries, is under way at Mississippi State University (Lorio, 1973). Large-scale acceptance of the method by the industry in the next few years is not anticipated.

After butchering, pieces of adhering skin and fins are removed and the fish are manually or automatically washed, where the body cavities are scrubbed with rotating brushes, and subjected to a final rinse. From this point, they are graded and inspected. After cleaning, the fish are sorted by weight and generally those under 0.45 kg (one pound) are packed in weight groups on ice and refrigerated or frozen to await shipment. Some plants, however, package individual fish in trays and seal them in plastic. Fish over 0.45 kg (one pound) are frequently filleted or cut into steaks.

The bulk of the product leaves the plant as fresh or frozen whole processed fish. A small market exists for fresh and frozen fillets and for frozen breaded fish sticks. Recently, liquid nitrogen freezing has proven successful in producing meat with improved quality. Pond-reared channel catfish can be kept frozen for as long as twelve months with only small losses in flavor (Billy, 1969).

Many plants have rearing or holding ponds on-site. A few discharge some or all of their process wastewaters (including holding tank waters) into these ponds.

Wastes Generated

Jones (1969) estimated 45 percent of the whole catfish to be waste and the National Marine Fisheries Service (1968), 40 percent. Using the 45 percent value, the total waste quantity projected for 1975 was calculated to be 23.0 million kilograms (50.6 million pounds).

Four main methods of disposal of catfish offal are currently practiced. These are: processing for pet food and catfish feed, rendering for fish meal, and burial (Billy, 1969). Catfish offal has been rendered to a meal containing over 45 percent protein. The distribution of essential amino acids in the proteins of the catfish offal makes it a good source of supplementary protein for animals. Several proximate analyses of catfish offal are available in the literature. One is detailed in Table 5.

Table 5. Proximate analysis of raw catfish offal

Constituent	Level
Moisture	58.6%
Crude fat	25.5%
Ash	3.1%
Crude protein	12.8%

The offal consists mainly of heads, skin, viscera and fat. Tables 6 and 7 reflect the percentages of each.

Table 6. Offal from tank-raised channel catfish (Heaton, *et al.*, 1970).

Component	Large Fish	Small Fish	Average
Finished product	63.9%	62.8%	63.4%
Head	22.5%	23.3%	22.9%
Skin	6.5%	6.5%	6.5%
Viscera	5.6%	6.1%	5.9%
Fat	1.5%	1.8%	1.7%

Table 7. Catfish Offal from cage-cultured channel catfish (Heaton, *et al.*, 1972).

Component	Level
Finished product	59.4%
Head	19.5%
Skin	6.4%
Viscera	7.6%
Fat	6.1%

Unlike the data available on solid wastes, very little data have been published on the nature of liquid wastes generated in catfish processing plants. The sole published source of information on catfish processing waste water characteristics prior to the current study was the paper by Mulkey and Sargent (1972) reporting on a three-day characterization program at a Georgia catfish processing plant. These investigators found the total plant effluent to exhibit the characteristics in Table 8.

Table 8. Catfish processing waste water characteristics (Mulkey and Sargent, 1972).

Parameter	Level			
	kg or l / 1000 fish	lb or gal / 1000 fish	kg or l / kkg raw mat'l	lb or gal / ton raw mat'l
Flow	7570	(2000)	16,400	(3920)
BOD	3.6	(8.0)	7.9	(15.7)
COD	4.9	(10.8)	10.6	(21.2)
TSS	2.3	(5.1)	5.0	(10.0)
TVSS	2.0	(4.5)	4.4	(8.8)
Grease and Oil	0.8	(1.7)	1.7	(3.3)

Their data were expressed in terms of pounds or gallons per fish or per 1000 fish processed. For comparative purposes, these data were converted to the forms shown in the table, based on the assumption that the average catfish processed weighed 0.46 kg (1.02 lbs) (as was indicated by Mulkey and Sargent).

Figures 6, 7, and 8 are respective plots of the catfish waste water flow, BOD_5, and suspended solids data gathered in this study. Each data point represents the summary data of each plant sampled.

Subcategorization Rationale

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 seafood processors, the catfish processors do not enjoy a constant supply of raw product. 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. In the Tennessee Valley region, for instance, the growing season lasts for about 150 days. Optimum growth occurs in the water temperature range of 28° to 31°C (82° to 88°F). During the winter months, the fish remain virtually dormant and grow very little. The harvesting season begins usually in the fall and continues through the winter and into the spring (as the weather

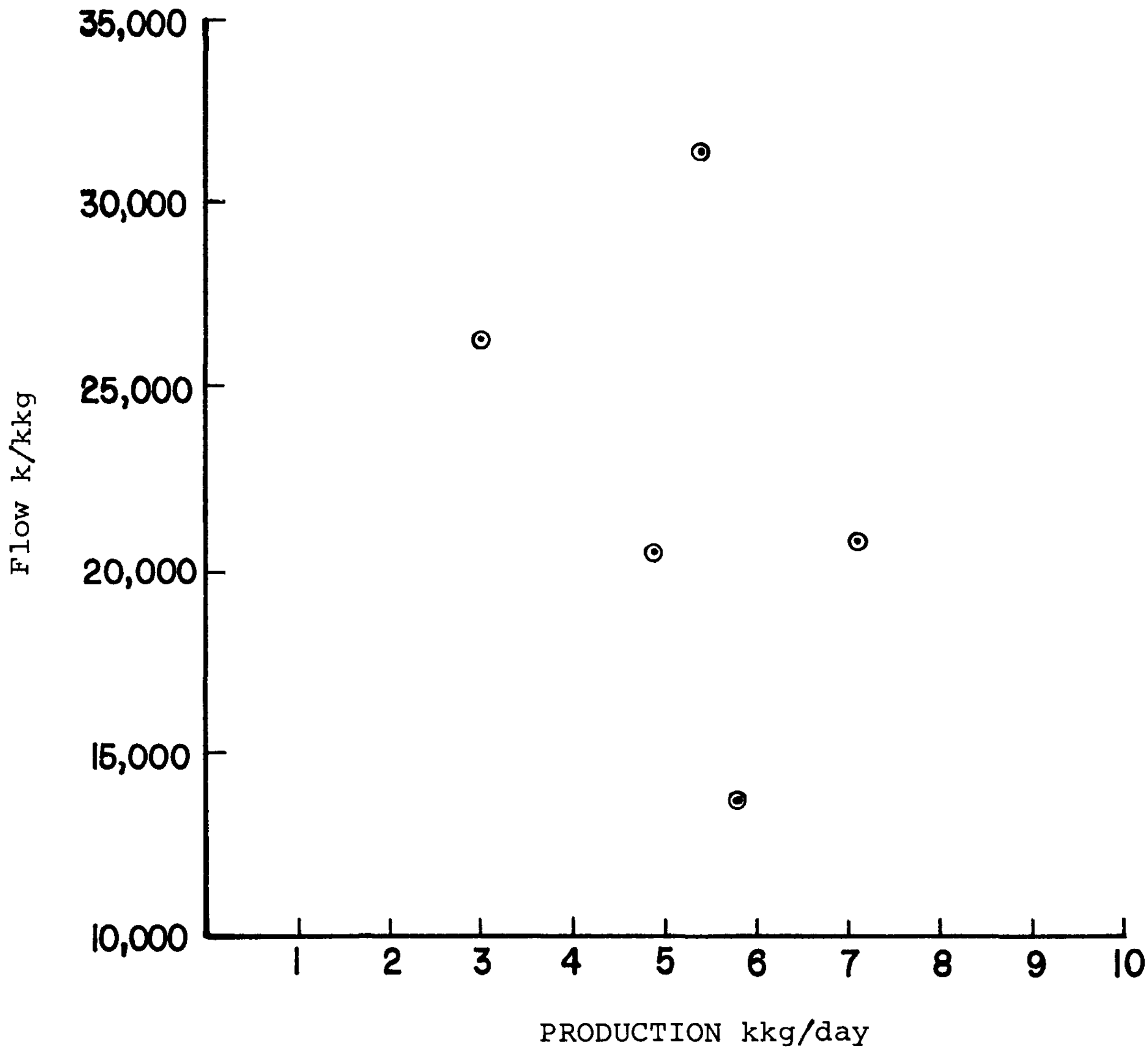


Figure 6

Catfish production rates and flow ratios

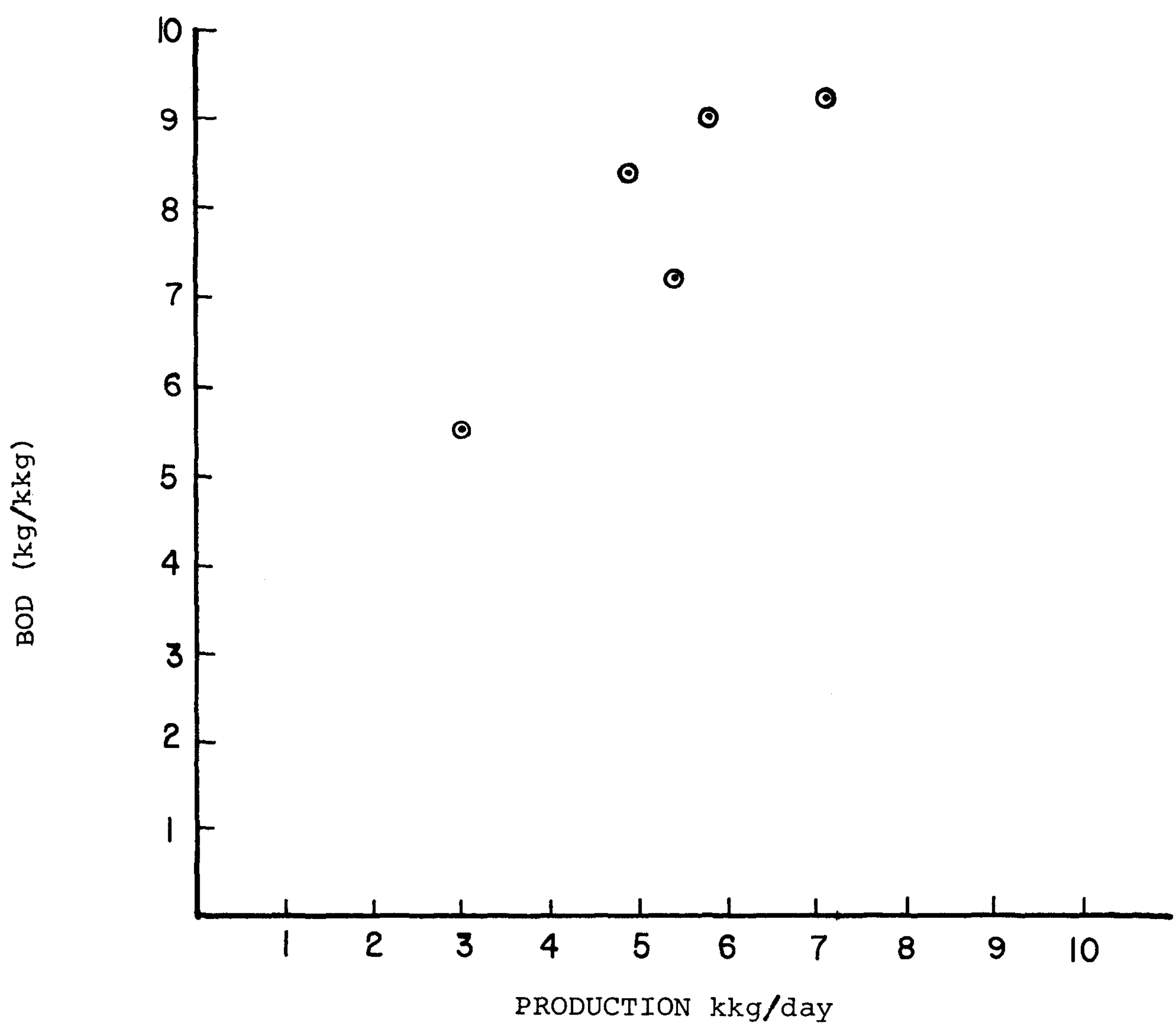


Figure 7

Catfish production rates and BOD5 ratios

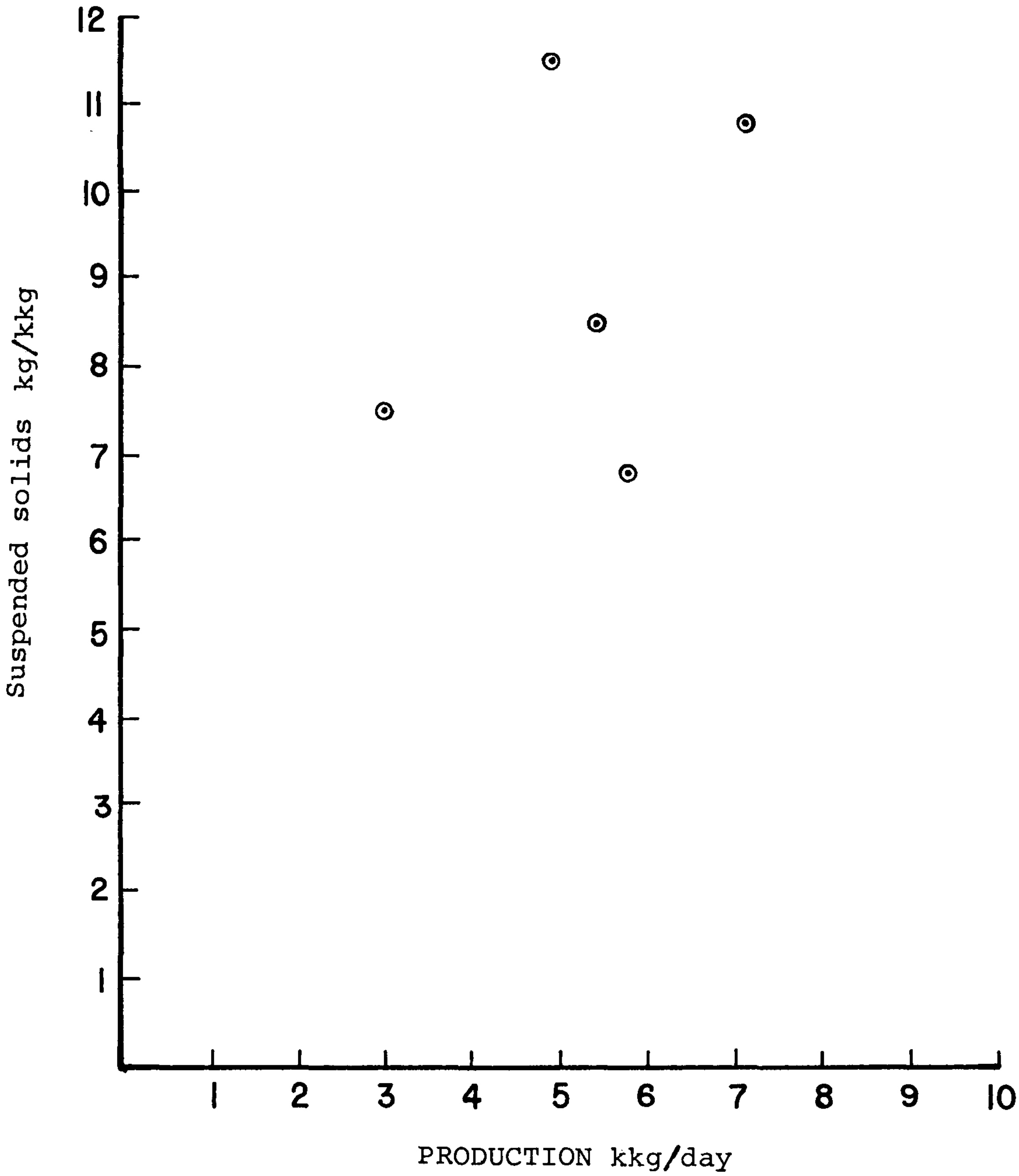


Figure 8

Catfish production rates and suspended solids ratios permits). Recently, as the processing industry has become more organized, the producers have been enticed to harvest (although on a reduced scale) through the summer months. Some processors, furthermore, have entered the production business, thereby assuring themselves more complete control over raw material supply. In the summer of 1972, as a result, most catfish processing plants operated at about 60 percent of full production capacity.

Another consideration in subcategorization was condition of raw material 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 waste waters 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. A significant amount of water is necessary for spray-washing before the fish are transported into the plant. 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 wastes from the processing of various species existed.

A fourth consideration in subcategorization was the method of harvesting. As discussed previously, harvesting methods are relatively uniform throughout the industry.

Degree of pre-processing, manufacturing processes and subprocesses, and form and quality of finished product, as have been discussed previously, are relatively uniform throughout the industry and present no bases for further subcategorization.

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. The soils present no severe construction problems, in general. 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 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.

The relatively unsophisticated level of the industry indicates that the production capacity, normal operating levels (percent of capacity) and nature of operation (intermittent versus continuous) do not appreciably affect the waste loadings generated by the processing plants.

The remaining two factors considered in subcategorization, raw water availability and waste treatability, do not appear to present insurmountable obstacles to the imposition of effluent guidelines and the industry's successful compliance with them. Fresh water is generally available to all processors in the industry and although virtually nothing is known about treatability of the specific wastes generated in catfish processing, no known toxicants are present in the waste streams, and the operations offer sufficient continuity to sustain some types of biological treatment systems.

For all the above reasons, the United States catfish processing industry was placed into a single subcategory for the purpose of designing and estimating the costs of treatment systems and for developing effluent standards and guidelines.

CRAB PROCESSING

The second segment of the seafood industry which was considered in this study was crab processing. Figures 9, 10, and 11 are plots of all crab flow, BOD_5, and suspended solids data (respectively) gathered in this study. The complete crab industry data is presented in Section V. An analysis of the flow data reveals that water use in the conventional blue crab process was less than one-tenth that of the other crab operations; furthermore the organic loading, in terms of BOD, from the mechanized blue crab process was more than double those from the processing of other species. It has been determined that blue crab should be designated a separate subcategory from the other species processed in the United States.

Within the blue crab industry, plants employing a claw picking machine (mechanized processing) generated waste waters significantly greater in quantity and in BOD loadings than conventional (manual) processors. Thus separate subcategroies were necessary.

Further review of the data indicates significant differences in water use between Alaskan and "lower 48" crab processors. Large differences in settleable solids were also noted. Whereas the average settleable solids concentration in the Alaskan samples was about 36 1/kkg, those from the Pacific Northwest averaged about 1600 1/kkg. These factors, together with others discussed later under "Subcategorization Rationale" led to the segregation of the two industries and designation of a separate subcategory for each.

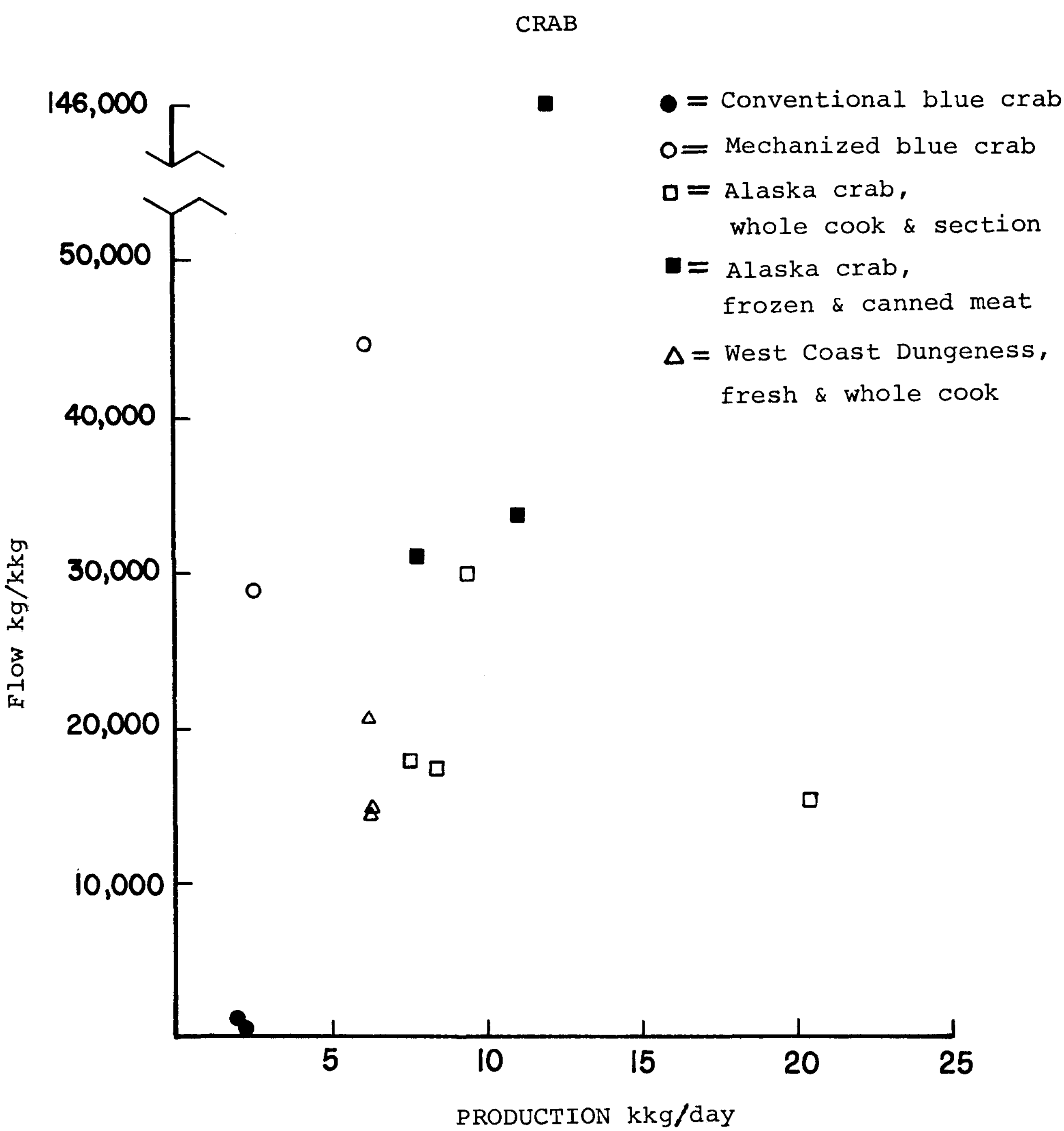


Figure 9

Crab production rates and flow ratios

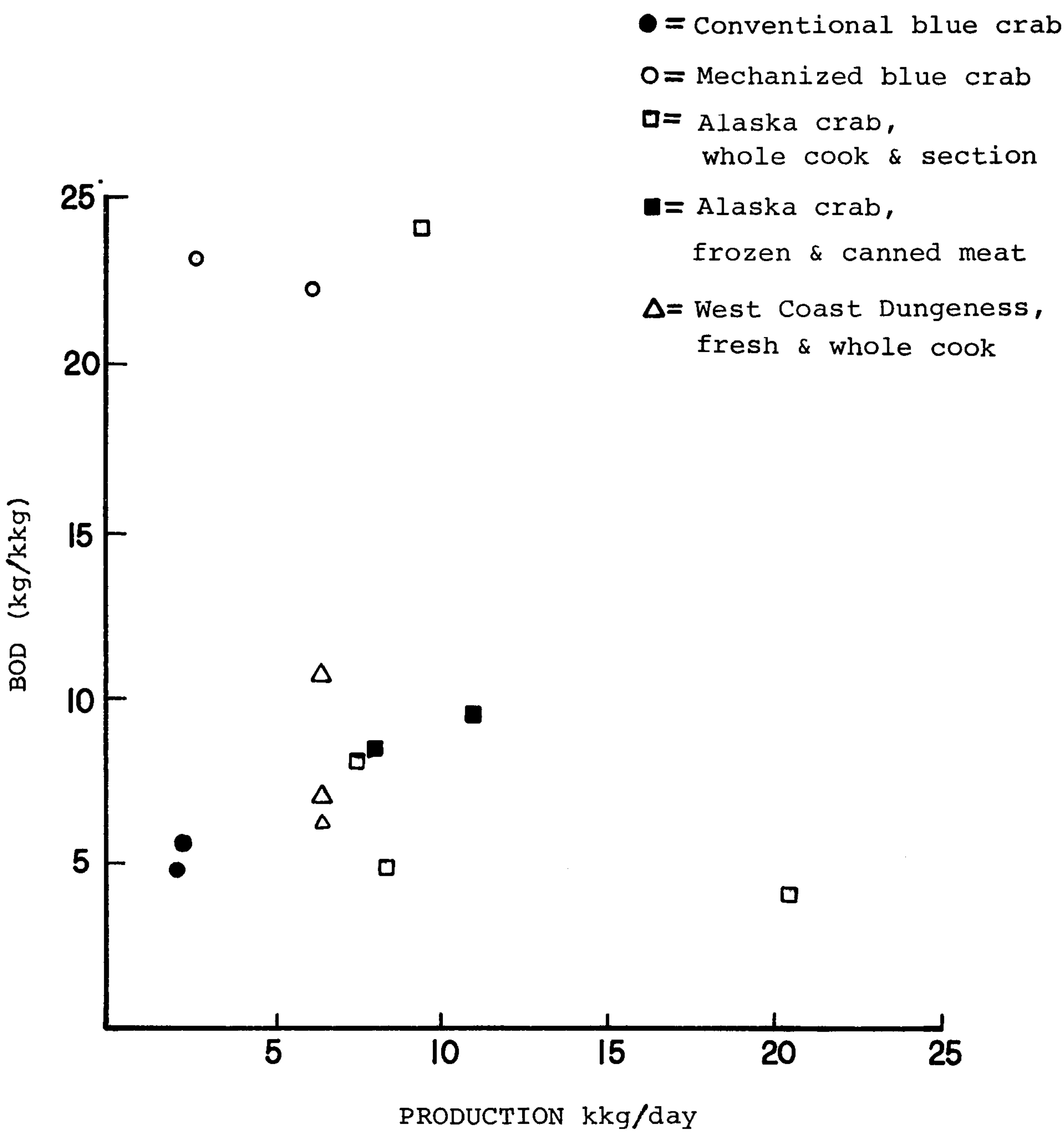


Figure 10

Crab production rates and BOD5 ratios

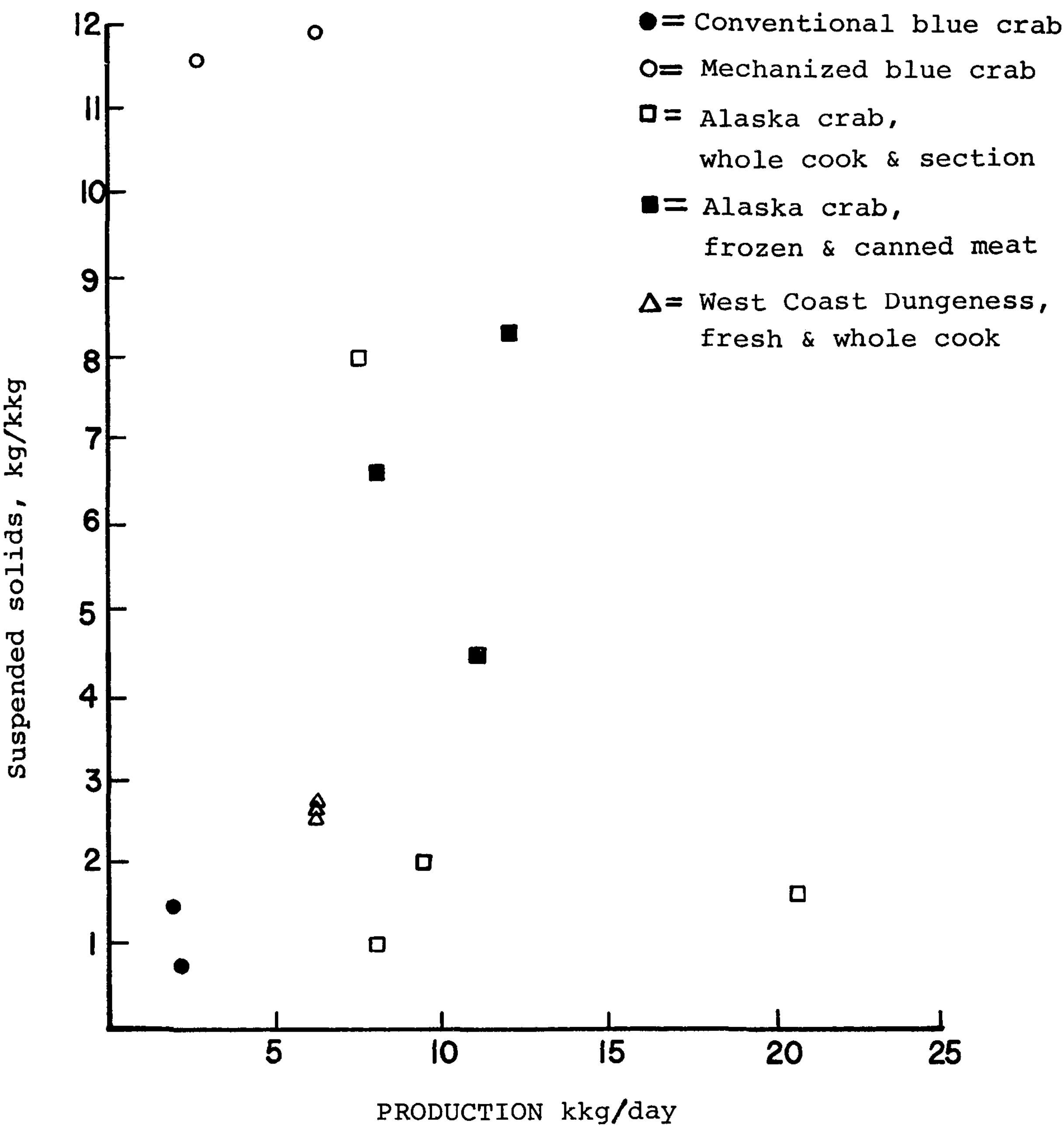


Figure 11

Crab production rates and suspended solids ratios

A final breakdown within the crab industry was based indirectly on type of final product. Referring again to the data in Section V, the Alaskan crab industry produced two distinctly different types of waste water streams: one from meat operations and one from whole-and-sections processes, the former producing 70 percent more flow, 62 percent fewer settleable solids and 90 percent more suspended solids.

In all, five different subcategories were ultimately designated for the crab industry: Conventional Blue Crab (Subcategory B); Mechanized Blue Crab (Subcategory C); Alaskan Crab Meat (Subcategories D and E); Alaskan Whole Crab and Crab Sections (Subcategories F and G); and Dungeness and Tanner Crab Outside of Alaska (Subcategory H).

Conventional Blue Crab Processing (Subcategory B)

Background

The blue crab, comprising 55 percent of the United States crab production, is harvested along the Gulf of Mexico and Atlantic coasts; a principal center of processing is the Chesapeake Bay area. Of the 184 plants in the United States, 90 are located in Maryland, Virginia, and North Carolina. These plants are typically small, locally owned businesses with highly variable production schedules.

The blue crab (*Callinectes sapidus*) is a much smaller (11-13 cm; 4.5-5 in capapace) variety than the West Coast and Alaskan crab. Most crab processed are caught locally (within a 50 mile radius of the plant), although during slack periods crab are imported from remote areas (with high spoilage losses). Transshipment from one production area to another is often practiced when local supplies are inadequate.

Crabs are harvested from shallow water in baited traps, on baited lines ("trot lines"), "scrapes," or dip nets, or they are dredged from the bottom mud. Rapid and careful handling is necessary to keep the crabs alive. Dead crabs must be discarded because of rapid deterioration.

"Cocktail claws" are considered prime products and are often packed separately. The meat is richer, with fuller texture than the more fibrous body meat.

Many blue crab hold eggs and are called "sponge" crab. These are generally accepted by most plants; personnel from some plants, however, claim that during cooking the eggs impart a permanent "iodine" flavor to the meat. Also, it is reasoned that the more egg-bearing crabs returned to the sea, the greater the possibility of sustained blue crab yields. For these reasons some processors refuse to accept sponge crabs. In addition, some states periodically prohibit harvesting of sponge crabs.

In some areas most of the crabs processed for meat in the blue crab industry are the females, called "sooks." The males, or "jimmies," are usually larger than the females; the processors frequently segregate the largest jimmies and market them alive.

Processing

The conventional blue crab processing scheme is shown in Figure 12. The first step is the cooking phase where the crabs are steamed at 121°C (250°F) for 10 minutes. On the Gulf Coast, the crabs are sometimes boiled, but boiled crab meat is prohibited in most states because the temperature available for microbial kill is lower in the boiling process. The vast majority (more than 80 percent) of blue crab processors today employ steam cooking. Cooking takes place in horizontal or vertical cookers. An average-size horizontal cooker can hold from 820 to 1230 kgs (1800 to 2700 lbs) per change. Vertical cookers average 410 kgs (900 lbs) capacity.

About 35 percent of the live weight of the crab is lost in the steam cooking process; condensates from the crab cookers have been shown to exhibit BOD's of 12,000 to 14,000 mg/l (Carawan, 1973).

After cooking, the crabs are normally butchered manually and the meat picked from the shell. An industry average for manual meat picking is 14 kg (30 lbs) of meat per picker per day (Paparella, 1973).

Yields in conventional blue crab processing plants vary from 9 to 15 percent (Thomas, 1973). In the conventional process, after the crabs are cooked, air cooled and picked, the meat is placed into cans or similar containers. Much of the crab meat is "sealed" in cans with snap-lids which are manually pressed into place, iced and sold fresh. In addition many cans are hermetically sealed, but are not retorted; rather they are pasteurized in a water bath at 89°C (192°F) for about 110 minutes. Some crab meat is canned (and retorted) in the conventional fashion, but most is not. In canning, additives such as EDTA (ethylenediaminetetracetic acid), alum, citric acid and other organic acids are used in very small amounts.

One exception to the above processes is that involving soft shell crab. In this instance, crabs are harvested during the molting process, kept in the plants in "live boxes" and checked every four hours for progress in shedding their shells. Immediately after the shell is discarded, the crab is marketed alive (packed in wet grass) as a "soft shell crab."

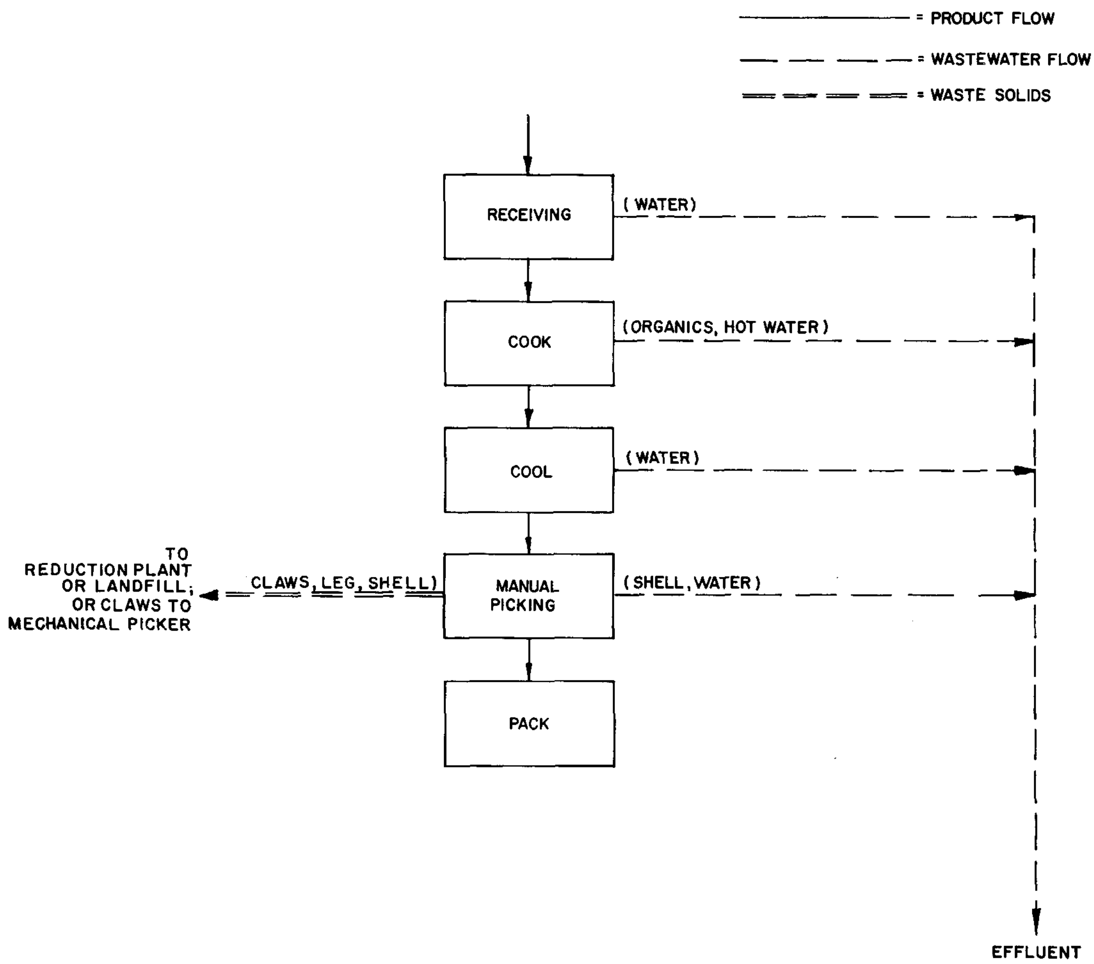


Figure 12 Conventional blue crab process.

Wastes Generated

Although some exploratory work has been conducted in the blue crab processing industry by North Carolina State University, the University of Maryland, and others, no comprehensive study of the waste waters produced in the processing of blue crab had been reported at the time this project was initiated.

In the conventional blue crab processing plant (Figure 12) the water usage is small. The overall pollutional load is attributable mainly to the cooking phase and to the plant clean up operation. Cooker condensates have a BOD of up to 14,000 mg/l, whereas plant clean up waters have organic strengths of perhaps one-tenth of that. Most conventional plants utilize ice-making machines which have a continuous cooling water stream (having no appreciable pollutant loading) which may flow 24 hours per day.

The major portion of the blue crab is not edible, and as a result is wasted in processing. This waste, consisting of body juices, shell and entrails, may range up to 86 percent of the crab by weight (Stansby, 1963), of which 25 percent is liquid lost in cooking. The solid waste load from the blue crab processing industry for 1971 was calculated to be 33.6 million kg (74 million lb) using 51 percent as the residual solids fraction of the waste. The actual waste volume was somewhat less, since a percentage of the total crab landed was marketed whole or butchered to remove only backs and entrails.

The composition of shellfish waste is largely determined by the exoskeleton, which is composed primarily of chitin, (a polysaccharide structural material), protein bound to the chitin, and calcium carbonate. While the major portion of the waste generally consists of exoskeletal materials, varying significant amounts of attached or unrecovered flesh and visceral materials are included. The protein concentration of crab waste is considered low compared to visceral fish wastes, reducing its value as an animal feed. However, most of the solid wastes from the blue crab processing industry are utilized in crab meal for eventual incorporation into animal feed.

Subcategorization Rationale

The characterization program for this study centered around the Chesapeake Bay area because of its large number of blue crab processors in a relatively small geographic area. The sampling schedule was established based on anticipated catches in the Virginia, Maryland and North Carolina area. Considerable delay was experienced when these harvests did not materialize on schedule. Conferences with local industrial representatives indicated that about once about every decade the early spring blue crab harvest is extremely poor, and 1973 happened to be one of those years. The poor harvest was attributed to locally heavy rainfall and subsequent dilution of the estuaries with fresh water.

Several active plants were finally located, and although the plants were operating intermittently or at reduced levels occasionally, the time constraints of the study forced the use of these plants for the monitoring program. They were sampled in depth over a period of several weeks.

The problems of seasonality and inavailability of raw material served to emphasize the need for careful consideration of these factors in the design of proposed treatment systems for the blue crab industry. It did not, however, provide any substantial basis for further subcategorization of the industry because it appeared that all segments of the blue crab industry were equally susceptible to inavailability of raw material at various times during the processing season.

The condition of the raw material on delivery to the processing plant was of considerable concern in the blue crab processing industry, especially with respect to dredged crab.

During several of the winter months, (December through March) most of the crabs that are processed have been dredged out of the mud in the estuaries where they have taken refuge during their dormant stage. In the harvesting process these crabs sustain a significantly greater incidence of injury than do those taken with other methods. The general condition of the crabs is poor and, therefore, the yield at the processing plant is markedly lower. Furthermore, a great deal of silt and mud is carried into the processing plant with the raw material and must be removed in a prewash step that is not normally employed with crabs harvested by other means. These combinations of factors likely cause the waste from the processing of dredged blue crab to be considerably different from those harvested by alternative measures. For the present, dredged crab have been included in Subcategories C and D (depending on whether they are processed mechanically or not) for the purpose of development of treatment system designs, estimation of expected effluent levels after treatment and estimation of treatment system costs. However, since no data are yet available on the actual percentage of solid and liquid wastes generated in the processing of dredged blue crab, this decision must be considered tentative. It remains to be confirmed (or refuted) during some future blue crab dredging season.

The variety of the species being processed appeared to be fairly uniform throughout the blue crab industry and was not a significant factor in the development of the subcategorization schemes.

A fourth item considered in subcategorization was "harvesting methods." As discussed above under "condition of raw material on delivery to the processing plant," the harvesting method employed influences the raw material condition, which in turn probably affects the waste water quantity and quality.

"Degree of preprocessing" was not a consideration in the blue crab industry because only live whole crabs delivered to the processing plant were incorporated into the finished product. The "manufacturing processes and subprocesses" were important factors affecting subcategorization, as discussed earlier.

"Form and quality of finished product," while they did have an impact on the total levels of waste water constituents, did not drastically alter the basic character of the waste stream and therefore, were not considered of sufficient importance to warrant further subcategorization.

"Location of plant" might conceivably be a significant variable in the blue crab industry. Blue crab processing plants are found from New Jersey to Texas and certainly along that vast coastline different climatic conditions, terrain and soil types are encountered. Clearly, diversities of site specificity are so complex and so important that they would overshadow any artificial geographical subdivision established in an attempt to define more homogeneous subcategories. An individual processing plant, faced with the problem of abating its pollution load, might be hindered by its location. Most commonly, the availability of significant land area with a low ground water table, sufficient drainage, etc. would be the goal. This is frequently not the case in the blue crab industry, where plants are often located on piers or on land with high ground water tables. In general, blue crab processing plants are either 1) located near small population centers, which eventually would permit joint industrial-municipal treatment or 2) situated physically in such a manner that onsite treatment of their waste waters may be technically feasible.

Additional considerations in subcategorization were "production capacity and normal operating level;" and "nature of operation (intermittent versus continuous)." By nature, the blue crab processing industry is an intermittent process (controlled by product availability) and production capacity is governed by such constraints as number of employees available, size of production area, size and number of cookers and retorts (where used) and availability of adequate storage. In the monitoring phase of this study, no evidence was found to indicate that either of these variables significantly affected the waste streams from the processing plants. Therefore, no subcategorization along these lines was attempted.

The last two variables considered in the subcategorization scheme were "raw water availability" and amenability of the waste to treatment." Raw water availability was not a consideration in the blue crab industry because no in-plant modifications or waste treatment additions would significantly increase the amount of raw water required by the processor. Waste treatability is not a significant factor for further subcategorization but is is partially responsible for separating the blue crab industry into Conventional and Mechanized.

For all of the above reasons, the United States blue crab processing industry was placed into two subcategories (Conventional and Mechanized discussed below) for the purpose of designing and estimating the costs of treatment systems and for developing effluent standards and guidelines.

Mechanized Blue Crab Processing (Subcategory C)

Processing

The mechanized blue crab processing scheme is shown in Figure 13. Initial processing is similar to that for conventional blue crab discussed earlier. Instead of complete manual processing a claw picking machine is utilized. It consists of a hammer mill followed by a brine separation chamber where the meat is floated away from the shell and exits the chamber via the brine overflow. The shell is removed counter-currently on an inclined belt. A few plants use this machine for pre-picked bodies and claws, not just for claws alone. Of the 184 plants in the industry perhaps ten plants employ the machine for crab claws. Perhaps another two or three employ the machine for complete body cavities ("cores"). Operating on claws alone, a typical mechanized plant utilizes the mechanical picker 5 to 10 hours per week, or more if additional claws are purchased from other plants.

The plants employing the claw picking machines enjoy a slightly higher percentage yield than the remainder of the plants. In addition, the back or lump "fin" meat is separated and marketed as a premium product.

The remainder of the processing steps is similar to those used in conventional blue crab processing.

Wastes Generated

In those operations employing claw machines, because of the nature of the process, the BOD loadings are significantly greater than those of the conventional plants, and water usage is increased many fold as shown in Section V. The waste water includes both the brine used in the flotation tanks and the wash water used to remove the brine from the meat after it has been separated from the shell. Whereas the waste waters from a conventional blue crab processing plant can be expected to be biodegradable, those from a plant employing a picking machine would likely present salt toxicity problems to some biological waste treatment systems. This, in fact, has already been noted in one location in the Eastern Shore area of Maryland, where the

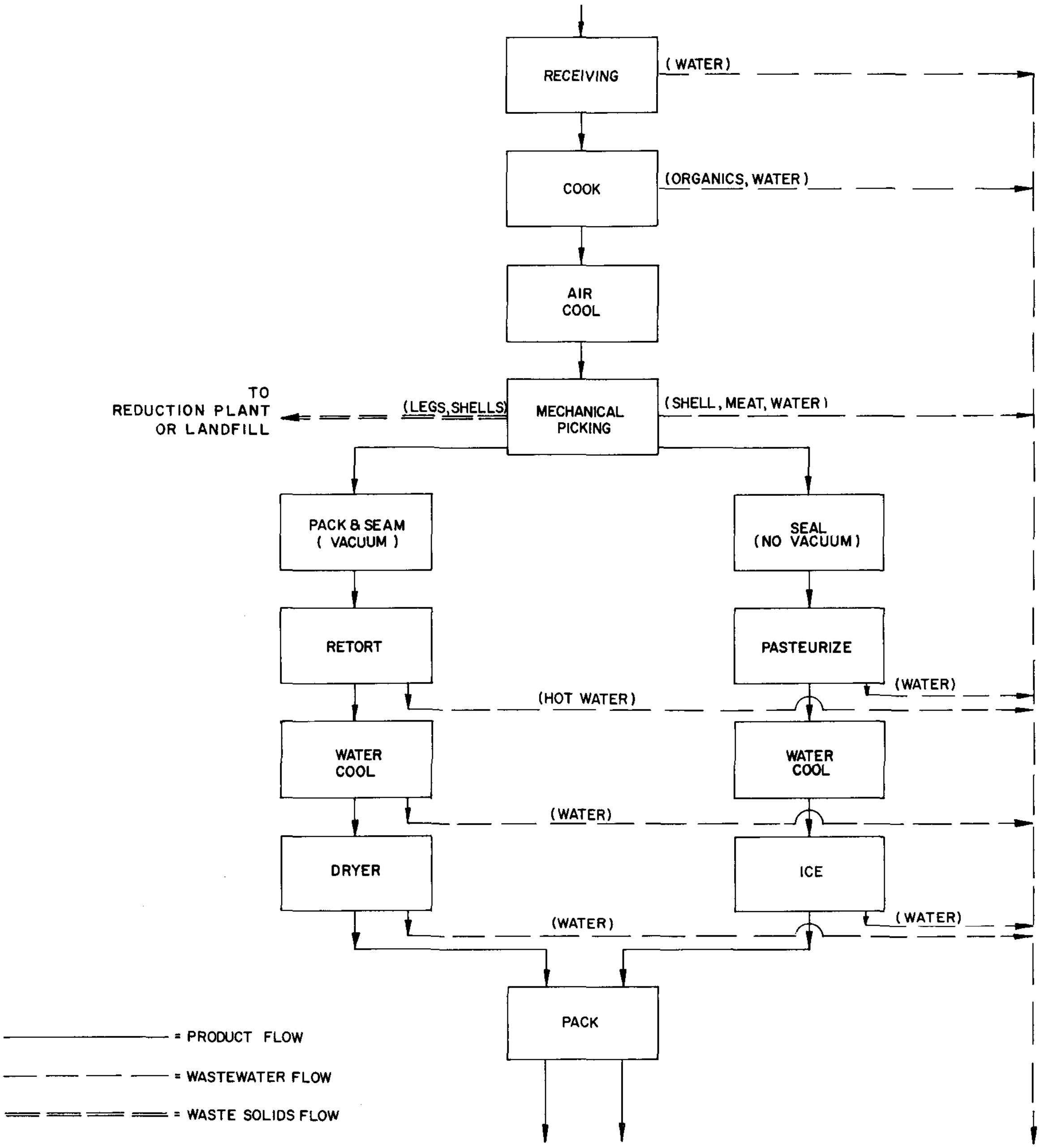


Figure 13 . Mechanized blue crab process.

digesters in the local municipal plant (receiving blue crab processing wastes) experience frequent upset conditions.

Subcategorization Rationale

As a result of this study the blue crab industry had to be broken down into at least two subcategories. The first (Subcategory B), encompassed conventional blue crab processing and the second (Subcategory C) included those blue crab processing plants employing claw picking machines for the removal of meat from claws or from body sections or both.

The utilization of the claw picking machine either for claws or for bodies, or for both, introduced significantly greater quantities of waste water, 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. Since the above factors would seriously affect all three main considerations in development of subcategorization schemes:

1. design configuration;
2. expected effluent levels after treatment; and
3. cost of treatment;

it was decided to subcategorize the industry based on the use of the claw picking machines.

The other considerations for potential subcategorization were discussed earlier under Subcategory B - Conventional Blue Crab Processing and the same conclusions are relevant to this subcategory.

Alaska Dungeness, King and Tanner Crab

The second major crab fishery in the United States (behind blue crab) is centered in the state of Alaska and is made up of three commercial species, Dungeness (<u>Cancer magister</u>), king (<u>Paralithodes camtschatica</u>), and tanner (<u>Chionecetes bairdii</u>) crab. The tanner crab is also referred to as the snow or spider crab. The Alaskan crab industry differs from that of the blue crab in that a relatively small number of processing plants handles a very large volume of product. Furthermore, the typical Alaska crab operation is considerably more mechanized than the typical blue crab operation. Based on these reasons and considerations of extreme seasonality, harsh climate, frequent inavailability of usable land, and high costs, the Alaskan crab industry was placed in a separate category from the remainder of the United States crab industry.

As discussed in the introduction to this section, the waste water characteristics from the processing of sections and whole crab differed significantly (see Section V) from those of the meat process waste stream, leading to the desingation of separate subcategories for each.

Alaskan Crab Meat Processing (Subcategories D and E)

Background

Until recently the major crab species processed in Alaska was the king crab. In 1970, for instance, of the more than 34.5 kkg (76 million pounds) of crab processed in Alaska, 68 percent were king crab, whereas 18 percent were tanner and 12 percent Dungeness crab. In the ensuing three years, however, tanner crab have become increasingly important and soon will challenge king crab for the leadership position in terms of quantity processed.

In contrast to the blue crab harvest, the Alaskan crab harvest takes place exclusively through the use of baited traps or "pots." Upon unloading from the pots the crabs are placed in "live tanks" on board the fishing vessel and are transported alive to the processing plant where, in most instances, the crab are transferred to on-site live tanks to await processing. In a few instances, on-site live tanks are not employed, the crab being processed immediately upon unloading from the fishing vessel. This practice has proven, however, to be inefficient and it is expected that the use of live tanks will continue into the forseeable future.

For each of the three species of crab processed in Alaska, seasonality is an important factor. Tanner crab enjoy the longest processing season, extending from January to May in the Kodiak area. The major season for king crab in the Kodiak area is about one and one-half months long during the months of August and September and for Dungeness crab the two month season peak begins in mid-June. These seasons are a function of location. Alaska is an extremely large state, having 58,000 km (36,000 miles) of shoreline (more than the total contiguous 48 states) and fishing boats range as far as 1600 km (1000 miles) from base to take advantage of crab availability during slack seasons locally.

Processing

Land-based live tanks are usually constructed of steel or wood. Capacities vary from 23 to 45 cu m (6000 to 12,000 gal). In

Alaska as much as 7300 kg (16,000 lb) of live crab are stored in a medium-sized live tank. The salt water in the live tanks is continuously recirculated from the local harbor. Residence times vary from ten minutes to one hour. In the past, in congested areas, high mortality rates in the live tanks have resulted from the use of poor quality intake water. This poor quality has been the result of pollution of the local area with processing wastes. Live tank intake lines are usually located on or near the bottom of the local waterway to prevent interference with navigation. Decomposing detritus on the bottom has created dissolved oxygen deficits and generated toxicants such as hydrogen sulfide which in turn have led to the high product losses in the live tanks. Live tank crab are normally processed as rapidly as possible and are seldom held for more than a few days. Tanner crab seem to be more sensitive to live tank storage conditions than the other two species (Hartsock and Peterson, 1971). This is because tanner are deep water crabs and exhibit a lower tolerance to overcrowded conditions and environmental changes.

Each of the three species handled in Alaska is processed into at least three different forms of finished product: canned meat, frozen meat, and sections and legs--sections being the term designating body halves. In addition, Dungeness crab, and to a very limited extent king crab, are processed for marketing whole. The section and leg processes and the Dungeness whole processes produce the least waste, while the meat processes for freezing and canning produce considerably greater quantities, although the characteristics, of course, are similar (see Section V).

The processes for frozen and canned meat products are depicted in Figures 14 and 15, respectively. All plants handling a given product utilize approximately the same unit operations with occasional small variations in the butchering, handling, storing and conveying procedures. These variations generally do not alter the waste water characteristics significantly.

Two operations common to all processes except the whole crab process are butchering and cooking. In the butchering process, the crab are transported from the live tanks to the butcher area either on belts or in steel tubs where they are placed in a holding area to await butchering. The live crab are butchered by impaling them on a metal plate. This cuts the body in two, allowing the viscera to fall to the floor while at the same time, removing the carapace (back) as a single piece. Next the gills are removed from the animal through the use of a rotary wire brush or paddle wheel. At one plant a paddle wheel is used to both butcher and gill in a single step. Currently, in most plants in Alaska the viscera, carapaces, and the gills are fed into a grinder intermittently. Dead crab are sorted out prior to butchering and are presently also ground. These grinders operate from 50 to 70 percent of the time during processing and the resulting waste load constitutes a large portion of the total solid and organic wastes emanating from the processing plant.

Two types of cookers are used in the crab processing industry in Alaska. They are distinguished by product flow and are termed either batch cookers or flow-through cookers. Both types are common. Some crab plants employ two cooking periods during the processing operation--a precook and a final cook. When the precook is used, it is designed to firm the meat, rinse off the residual blood from the butchering operation and minimize heat shock of the subsequent cooking step. Precooking at 60° to 66°C (140° to 150°F) normally lasts from one to five minutes. The main cook is conducted at about 99°C (210°F) for 10 to 20 minutes. Salt is usually added to the cooker water in concentrations of 50,000 to 60,000 mg/l NaCl (as chloride) (Soderquist, et al., 1972b). Batch-type cookers range in size from 760 to 3800 l (200 to 1000 gal). Makeup water is added periodically to replace losses from evaporation, product carryover, and water overflow. Steam is normally employed to heat the tanks to the desired temperature. The cookers are usually drained and the cooking water replaced once or twice per shift.

Flow-through cookers range in size from 1.9 to 9.5 cu m (500 to 2500 gal). The crab are conveyed through the cooker on a stainless steel mesh belt. Nearly all flow-through cookers in Alaska employ steam-heated hot water, although at least one plant was observed by the field crew using steam cooking directly. As was the case with batch cookers, flow-through cookers (also called "continuous cookers") are drained and refilled one to two times per shift (except steam cookers).

The following paragraphs discuss briefly the process variations employed in the preparation of different product forms.

King and Tanner Crab Frozen Meat Process

In the Alaskan plants processing king and tanner crab for the frozen meat market (Figure 14), the crab are stored in live tanks in the normal manner and transported to the butchering area as needed. The carapace, viscera and gills are removed in the butchering area. The butchering waste is currently ground and subsequently discharged through a submarine outfall, via a flume to a surface discharge point, or is sometimes simply dumped through a hole in the floor onto the water beneath the plant. After the crabs are butchered, the legs are separated from the shoulders on circular or stationary saws. Stationary saws consist simply of fixed saw blades along which the crab are passed to effect the separation of the legs from the shoulders. Next, the crab parts are precooked for four to five minutes at 60° to 66°C (140° to 150°F). Some processors collect the claws after the precook, brine freeze them and market them as "cocktail claws" much as is done in the blue crab industry. Others handle the claws as additional sources of picked meat and after the precook, the meat is "blown" from the claws and shorter more "meaty" leg sections with a strong jet of water. The meat from the

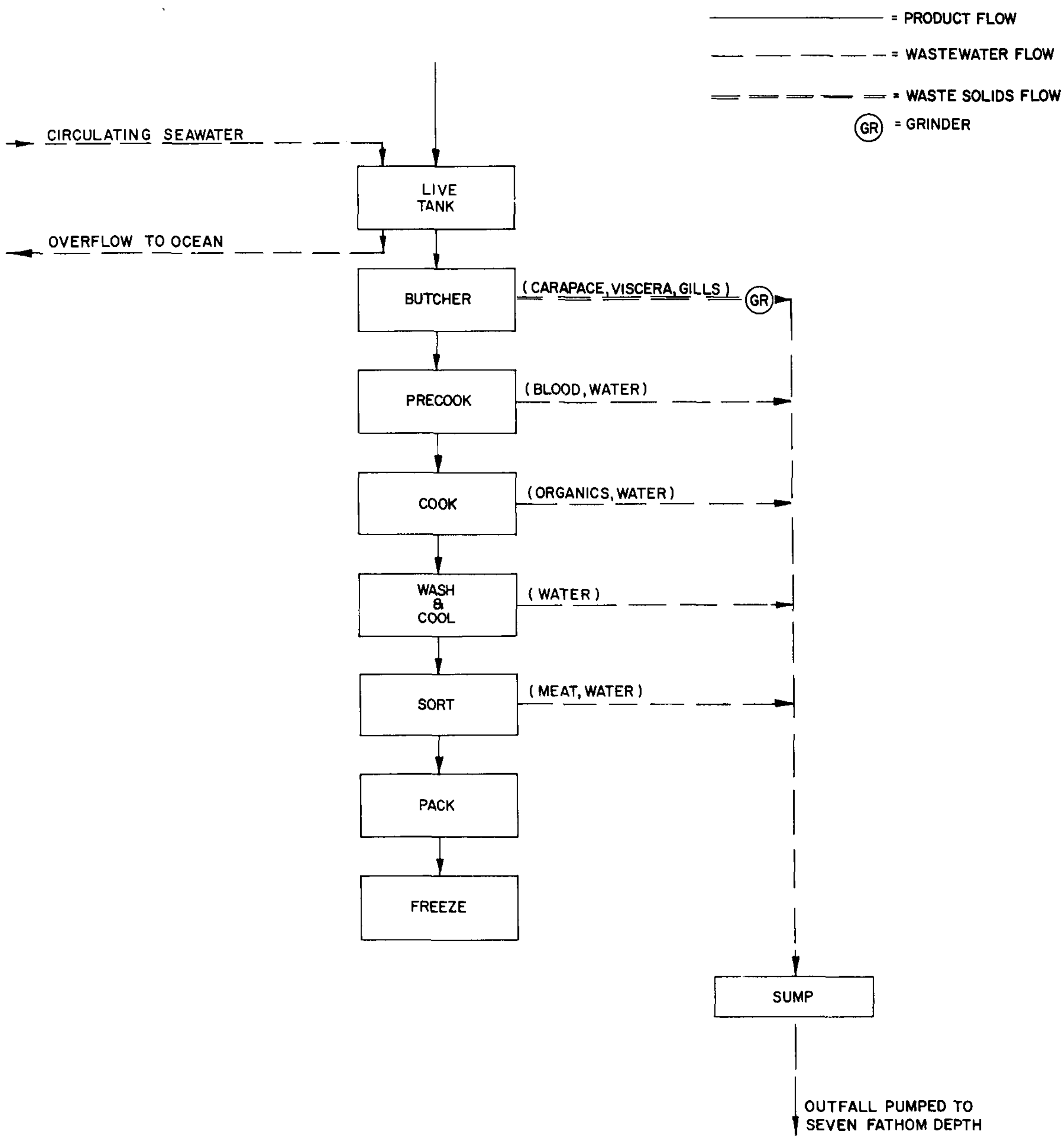


Figure 14 King and tanner crab frozen meat process.

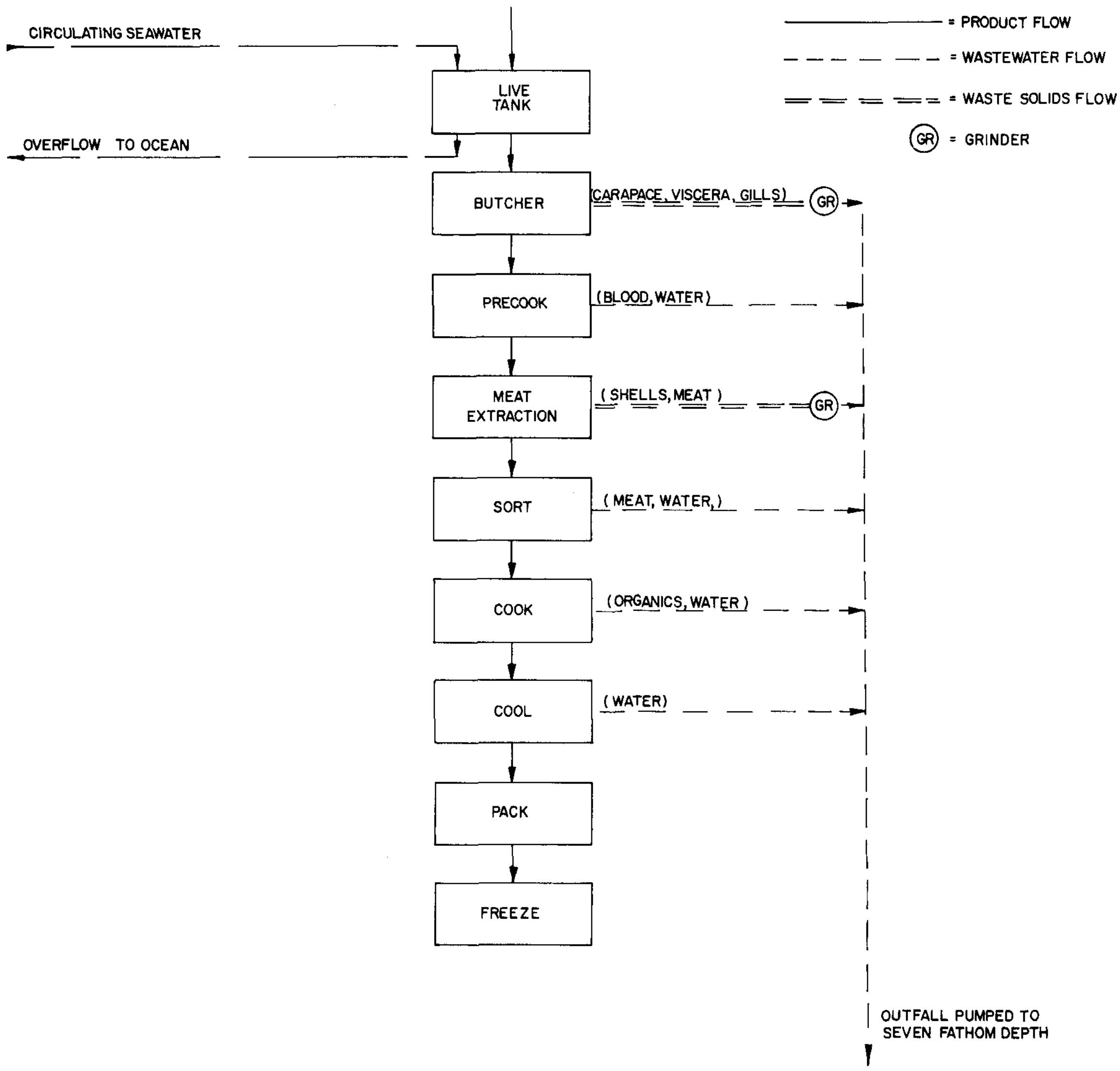


Figure 15 King and tanner crab canning process.

larger leg sections and from the shoulders is often extracted with rollers or shaken from the shell. In the roller operation the parts are placed manually or hydraulically between two rubber rollers (looking very much like those of an old-fashioned wringer-type washing machine) and the meat is squeezed from the shell as the legs or shoulders pass through the rollers. The shells are subsequently often flumed from the rollers to a grinder prior to entering the main waste stream.

Broken shell and other detritus are hand-picked from the meat. The meat is then manually segregated into three categories: claw meat, leg meat, and shredded meat. It is next cooked at 93° to 99°C (200° to 210°F) for 8 to 12 minutes, rinsed, and cooled with fresh water. At this point, the meat is packed into trays, usually in 6.8 kg (15 lb) batches and 180 to 350 ml (6 to 12 oz) of saline solution or ascorbic acid solution is added to each tray. The type and volume of additives employed varies from processor to processor. The trays are frozen and later boxed for shipping.

In at least one crab freezing operation in Alaska, no precook is used. The crab are simply cooked at 93°C (200°F) in a flow-through cooker for 10.5 minutes. This operation takes place with the gills still intact on the animals. After cooking the gills are manually separated and discarded. Legs are subsequently removed from the shoulders on stationary saws.

The major differences between the freezing of king and tanner crab legs and sections are the use of rollers almost exclusively for tanner (contrasted with their infrequent use for king crab) and small variations in cooking time. Wastewater characteristics for the two species are similar.

King and Tanner Crab Canning Process

In this operation (Figure 15) the crab meat is processed in much the same way as crab meat in the freezing process through the second cook. At that point the meat is manually packed into cans of various sizes, the most common one being 184 grams (6.5 oz) and a sodium chloride-citric acid tablet is added to each. Next, a vacuum is drawn on each can and the lid is sealed with a "double roll seamer." The cans are then placed into baskets and retorted for 50 to 60 minutes at 116°C (240°F). Cooling is normally accomplished in the retorts by flooding them with cold water for 7 to 12 minutes. The baskets are then removed from the retorts and the cans allowed to dry prior to boxing for shipment.

Dungeness Crab

The main Dungeness crab season begins in mid-June and lasts through mid-August in Alaska. As a result, onsite sampling was not conducted during maximum Dungeness crab processing activity;

however, some monitoring of Dungeness crab processing was accomplished in Kodiak, Alaska and the data resulting from these activities together with the data gathered previously in Oregon by Oregon State University (Soderquist, et al., 1972b) served as bases for the Dungeness crab recommendations in this report.

In Alaska, Dungeness crab are most frequently processed for sale as whole crab. When processed into canned or frozen meat products, processing schemes similar to those in Figures 14 and 15 are employed.

Projections

Harvesting of Dungeness crab are on the decline whereas king crab seemed until recently to have reached a plateau. In 1971 and 1972, however, harvests increased. Production appears to be determined in large part by the size of the previous year's survival of offspring. Recent catches are outlined on Table 9.

The relative stabilization of king crab harvests has been due largely to stricter controls imposed on the fishing industry by the Alaska Department of Fish and Game. The controls established a king crab fishing season lasting from five to seven months in Alaskan waters.

Tanner crab have been increasingly harvested in recent years. Abundant stocks exist off the northern Pacific Coast and production which has been accelerating rapidly, should continue to increase (Alverson, 1968) until the demand exceeds the supply or until stricter controls are established on the fishery by the Alaska regulatory authorities.

Wastes Generated

As is the case with blue crab, the major portion of the Alaskan harvest is not edible and as a result is wasted in processing. The yield for king crab and Dungeness crab meat operations have been listed as 20 percent (Jensen, 1965) and 27 pecent , respectively. Tanner crab yields are even lower than these two values. Using an average yield figure of 20 percent it can be concluded that 80 percent (on the average) of the Alaskan crab harvest is wasted. For the purpose of estimating solid waste volumes, furthermore, this figure might be reduced by 50 percent to account for leaching of solubles during cooking and to take into consideration the significant percentage of the harvest processed as sections or whole crab. Assuming, then, that 57 percent of the total harvest in Alaska eventually becomes solid waste, it was calculated that 23,400 kkg (25,800 tons) of solid wastes were generated by the Alaskan crab industry in 1972. As tanner crab harvests increase over the next few years, the percentage wastage figure will increase proportionately in Alaska and the total tonnages of crab waste produced will rise slowly.

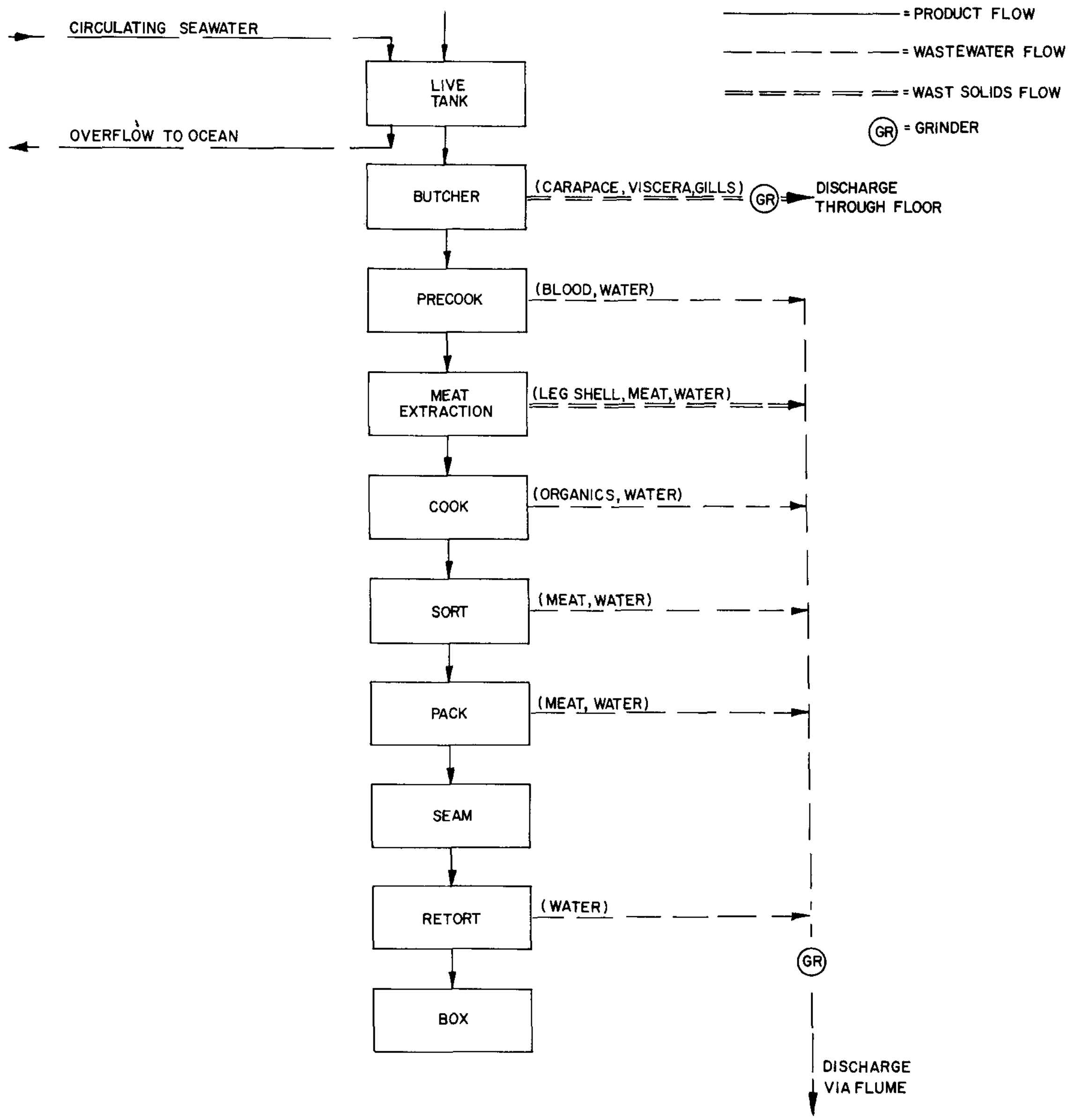


Figure 16 King and tanner crab section process.

Table 9

RECENT ALASKA CRAB CATCHES (NOAA-NMFS).

	1969		1970		1971		1972	
Species	kkg	(tons)	kkg	(tons)	kkg	(tons)	kkg	(ton)
Dungeness crab	22,300	(24,550)	26,500	(29,250)	19,400	(21,350)	11,800	(13.000)
King crab	25,300	(27,900)	23,600	(26,050)	31,900	(35,200)	33,600	(37,000)
Tanner crab	5,080	(5,600)	6,570	(7,240)	5,760	(6,350)	13,150	(14,500)

As mentioned in the blue crab discussion, the composition of crustacea waste is largely chitin, protein and calcium carbonate plus varying amounts of flesh and visceral materials. The Ketchikan Technological Laboratory of the National Marine Fisheries Service listed typical compositions of Alaskan crab waste as shown on Table 10. The protein concentration of crab waste is considered low compared to visceral waste, reducing its value as a potential source of animal feed. However, some work has been done involving fortification of crab meal with higher protein sources.

Table 10. Typical crab waste composition

Species	Source	Composition Protein (%)	 Chitin (%)	 $CaCO_3$ (%)
king crab	Picking line	22.7	42.5	34.8
tanner crab	Leg and claw shelling	10.7	31.4	57.9
tanner crab	Body butchering and shelling	21.2	30.0	48.8

Essentially no definitive comprehensive data on the character of Alaskan crab processing waste waters were available prior to the present study. A thorough characterization program, therefore, was conducted and the results are outlined in Section V.

Subcategorization Rationale

Subcategorization for the Alaskan crab industry was relatively complicated. At the beginning of this study it was assumed that as many as ten subcategories would be designated, one for each final product generated in the processing of each species:

1. frozen tanner crab meat
2. canned tanner crab meat
3. tanner crab sections
4. frozen king crab meat
5. canned king crab meat
6. king crab sections
7. whole Dungeness crab
8. frozen Dungeness crab meat
9. canned Dungeness crab meat
10. Dungeness crab sections

In the course of the field work it became evident that, although differences in the above processes existed, the variations in waste water flow and content noted were not significant when compared to the normal plant-to-plant and day-to-day variations within each of those preliminary subcategories, except in the general comparison of meat versus sections and whole crab.

The king, Dungeness and tanner crab processing industry in Alaska was 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.

The Alaskan crab industry is noted for its large processing plants. Although the plants process crab only a few months per year, their production levels are significantly greater than those of plants in other parts of the country processing similar crab (tanner and Dungeness). Raw material availability, furthermore, is very much a function of weather in Alaska; during periods of poor weather (which often occur even in the summer months), no raw material is available at the docks for processing.

The condition of raw material on delivery to the processing plant is fairly uniform in Alaska and was not considered justification for subcategorization. Although, as previously mentioned, the tanner crab mortality in the live tanks on the dock is significantly greater than that of Dungeness and king, those crabs which were processed (the live crabs) were of fairly uniform quality throughout the contractor's monitoring period.

This is not to say that product yield does not vary in the course of the processing season. Crabs taken during the springtime, having more recently molted, contain a lower percentage of usable meat than those harvested late in the season. This consideration, although it affects the waste water stream in the processing plant, should not prove to be a detriment to this study because sampling took place during that part of the year when yields were low and wastage was high. It is not expected that pollutant levels (in terms of production, such as kg of BOD per kkg raw material) would increase over the course of the season; rather, they would be expected to decrease somewhat (although, again, perhaps not significantly).

As mentioned above, the variety of the species being processed was initially taken into account in the monitoring phase of this program. The waste water characteristics, however, (Section V) indicate that this consideration is not sufficient to warrant the designation of a separate subcategory for each species.

"Harvesting methods" was another variable to be considered in subcategorization. As mentioned in the "processing" section of this discussion, crab processing in Alaska is uniformly restricted to the use of "pots," and therefore, little variability in harvesting methods exists.

Analogous to the discussion on "condition of raw material," "degree of preprocessing" was not a consideration in the Alaskan crab processing industry because, again, all animals enter the processing line alive.

"Form and quality of finished product," while initially considered to be possible bases for subcategorization, were rejected, based on the characterization data (Section V), except for the aforementioned distinction between crab meat and whole and sectioned crab.

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.

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 remote Alaska as 2.6 and Kodiak, Alaska as 2.5 based on a national average of 1.0) justifies the designation of a separate subcategory for these processors.

Furthermore, climatic conditions in the Alaska region are unlike those anywhere else in the United States. Water temperatures remain just above the freezing level and air temperatures can remain below freezing for several months without respite. In the northerly areas, permafrost interferes with normal construction and foundation design techniques. In the non-permafrost zones where top soil exists in any quantity, the ground freezes solid during the coldest months of the year, only to thaw in the spring and summer causing frost heaves and often producing extremely poor foundation conditions. It is frequently the case, especially in the gulf of Alaska and on the Aleutian Islands, that virtually no top soil exists. The only land available is solid rock and it is usually reposing at a steep angle. Consideration of waste treatment design involving equalization basins or treatment lagoons must contend with either blasting the basins from solid rock or constructing them of concrete, steel, or similar structural material.

Another consideration involves tidal fluctuations. Tidal fluctuations in Alaska are among the greatest in the world, approaching 12 meters (40 feet) at times. This phenomenon presents special problems when designing a waterside facility for transportation of solid wastes.

As was the case in the blue crab industry, the influence of production capacity, normal operating levels (percent of capacity), and nature of operation (intermittent versus continuous) did not vary significantly from species to species within the Alaskan crab industry and did not distinguish the Alaskan crab industry from the rest of the United States; furthermore, they did not appear to appreciably affect wastewater characteristics or anticipated design problems and therefore, were not judged bases for the designation of subcategories.

"Raw water availability" and "waste treatability" do not appear to present insurmountable obstacles to the imposition of effluent guidelines and to the industries' successful compliance with them. Although fresh water is extremely expensive in the Alaskan area (costing five to ten times Seattle prices), and in many areas is scarce to non-existent, the anticipated waste management schemes (discussed in Section VII) would not impose a significant additional demand on water supplies. Furthermore, the wastes from the processing of king, Dungeness and tanner crab can be logically thought to be treatable (under proper conditions) and no known toxicants are contained in the waste waters. Therefore, these two factors were not considered bases for subcategorization within the Alaskan crab industry.

As discussed in the "Economic Analysis of Effluent Guidelines, Seafood Processing Industry" (June 1974), there is substantial evidence that processors in isolated and remote areas of Alaska are at a comparative economic disadvantage to the processors located in population or processing centers in attempts to meet the effluent limitations guidelines. The isolated location of some existing Alaskan seafood processing plants eliminates almost all waste water treatment alternatives because of undependable access to ocean, land, or commercial transportation during extended severe sea or weather conditions, and the high costs of eliminating engineering obstacles due to adverse climatic and geologic conditions. However, those plants located in population or processing centers have access to more reliable, cost-effective alternatives such as solids recovery techniques or other forms of solids disposal such as landfill or barging.

For all of the above reasons the Alaskan Dungeness, king and tanner crab meat processing industries were placed into two subcategories for the purpose of designing and estimating the costs of treatment systems and for developing effluent standards and guidelines: non-remote Alaskan crab meat processing (Subcategory D), and remote Alaskan crab meat processing (Subcategory E).

Alaskan Whole Crab and Crab Section Processing
(Subcategories F and G)

The following paragraphs discuss briefly the process variations employed in the preparation of different product forms.

The most common method of perparation of king and tanner crab in Alaska for the domestic market is the sectioning process shown in Figure 16. After live tanking and butchering in the same manner as in the meat process, the legs are allowed to remain attached to the shoulders. The crab halves (or sections) are placed in wire baskets and rinsed with fresh water to remove residual blood. They are then precooked at 60° to 71°C (140° to 160°F) for 2 to 5 minutes. Following precooking, the crab are cooked for about 18 minutes at near-boiling temperatures; in addition to cooking the meat this process inactivates the "bluing" enzyme, a compound which, if not inactivated in this manner, causes the crab meat during storage to turn from white to an undesirable blue color. After cooking, the crab are rinsed and cooled in either a spray or a dip tank system with circulating fresh water (flow-through). In the next step the crabs are inspected, sections with missing legs or with cracked shells are shunted to the meat processing line, and parasites are removed from the shells manually with scrub brushes. The solid waste from this area is dry-collected and periodically shoveled through the butchering area grinder or occasionally a second grinder, specifically located in this area of the plant. At this point the cleaned crab sections are sorted according to size and quality, packed into boxes and frozen. Freezing takes place in either blast freezers or brine freezers. Those processors employing brine freezing use a dip tank subsequent to freezing to rinse off the adhering brine and to glaze the sections. The sections are then boxed and stored in a freezer prior to shipping.

In Alaska, Dungeness crab are most frequently processed for sale as whole crab. In this process the crab are held in live tanks until needed. After inspection for missing claws and legs they are cooked in either batch or flow-through cookers. Cooking lasts for 20 to 30 minutes at 99°C (210°F) in fresh water or in water containing 50,000 to 60,000 mg/l sodium chloride (as chloride). When salt is used, the main purpose is to impart a more desirable flavor to the crab rather than to effect any substantial change in meat characteristics.

After cooking, the Dungeness crabs are transferred to the packing area, usually by a belt, where they are spray rinsed. The workers tuck the legs under the body and place the crab into large steel baskets. The steel baskets are then immersed in circulating fresh water for 15 minutes to thoroughly cool the crab. Freezing of the crab is then accomplished by placing the steel baskets in a brine freezer for 30 minutes. After fresh water rinsing for 5 minutes to remove the excess brine and to glaze the crab they are packed in boxes and stored in a freezer, ready for shipment.

Dungeness crab that are missing claws or legs are butchered and processed as sections as previously described for king and tanner crab. The process is virtually identical for all three species.

There is little organic waste generated in the whole cook operation. Whenever the number of missing crab appendages is low, the largest source of organic waste in the whole cook operation is the cooker. The water usage in the whole cook operation is similar to that in the section process, the greatest water use taking place in the cooling and rinsing operation.

There is a significant difference in the amount of water used and the unit waste loads generated between the processing of whole crab and sections and the processing of meat products (see Section V). The discussion of subcategorization rationale for crab meat products (Subcategories D and E) also applies to this category. Therefore, the Alaskan Dungeness, king, and tanner crab sections and whole crab processing were placed into two separate subcategories: non-remote Alaskan whole crab and crab section processing (Subcategory F), and remote Alaskan whole crab and crab section processing (Subcategory G).

Dungeness and Tanner Crab Processing in the Contiguous States (Subcategory H)

Background

Although processing volumes are small compared to those of Alaska, a Dungeness and tanner crab processing industry does exist along the Pacific Coast of the contiguous 48 states. The predominant species processed in this region is Dungeness crab. The tanner crab processed in this region are not native; they are shipped frozen from Alaska during periods of surplus.

Most of the catch is picked for meat or cooked whole. Crab processing as practiced in the "lower 48" is virtually identical to that practiced in Alaska. The major difference between the two industries is one of scale. Whereas a large plant in Oregon, Washington, or California may pack 7.3 kkg (8 tons) of crab per shift at peak capacity, its counterpart in Alaska might pack four times that much.

Processing

The crab are removed from the pots and stored in live tanks aboard ship. The size of the daily catch ranges from 140 to 900 kg (300 to 2000 lbs). The boats usually deliver their catch each evening, unloading and storing the crabs out of water prior to butchering the following morning. The crab normally are in excellent physical shape prior to butchering for they are stored such short lengths of time and the quantity of crab is so small that there is hardly any weakening due to crowding, crushing or oxygen depletion.

The butchering process is as previously discussed; the backs are detached, the viscera removed and the legs separated from the bodies. Some plants flume waste solids from this process to a central screen but most employ dry-capture techniques. In the latter instance, the only flows from the butchering area are clean-up waters.

The next unit operation is bleeding and rinsing. The crab pieces are either conveyed via belt beneath a water spray or are packed in large steel baskets and submerged in circulating rinse water. In either case, a continuous waste water flow results. The crab parts (and whole crab) are then cooked in boiling water. Whole crab are usually boiled 20 to 30 minutes in a 50,000 to 60,000 mg/l (as chloride) sodium chloride solution, containing 650 to 800 mg/l citric acid. Whereas the salt is used for seasoning, the citric acid facilitates shell cleaning (by loosening adhering materials) in a subsequent processing step. Crab sections, on the other hand, are simply boiled for 12 minutes or so. The waste water flows from this step, of course, are intermittent, occuring whenever a cooker is discharged.

As in the bleeding and rinsing step, the next phase, cooling, is accomplished in two ways. The simpler method employs sprays to cool the hot crab, resulting in a continuous wastewater flow. Other plants employ immersion of the crab-filled baskets into tanks through which cooling water is constantly flowing. After 20 minutes, the baskets are removed and allowed to drain. The resulting waste waters consist of a continuous flow (the cooling tank overflow) and a discrete flow (the cooling tank "dump" plus crab-basket drainage).

In the plants of Oregon, Washington, and California picking of the meat from the shell is a manual operation. The "picking stock" includes bodies and legs. Yields from Dungeness vary from 17 to 27 percent. This variation is mainly a function of the maturity of the animal. Yields increase as the season progresses. No water need be used in this operation except during washdown.

The cleaned meat is conveyed to brining tanks where loose shell is separated from the meat by flotation, much as is practiced in the blue crab industry on the East Coast. The 100,000 to 200,000 mg/l (as chloride) sodium chloride solutions are discharged intermittently.

Most of the salt solution remaining on the meat is removed in the next unit operation, the (immersion) rinse tanks. The discharges from these tanks are continuous and contain 1500 to 2000 mg/l chloride.

After rinsing, the meat is drained and packed. Whether packing the meat in cardboard and plastic for the fresh market or canning, this operation contributes little to the waste water system except clean-up flows.

In those instances where the meat is canned, the final step is retorting. In those where fresh packing is practiced, the last step is refrigeration. Both processes require water but neither appreciably contaminates it.

Wastes Generated

The waste water flows from Dungeness and tanner crab operations in the "lower 48" are similar to those emanating from Alaskan operations with the singular exception that chloride concentrations are significantly higher and fluctuate strongly during the processing shift and from day-to-day (see Section V).

Subcategorization Rationale

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 (Subcategories D, E, F, and G).

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 to above, of course, included considerations of climate, topography, relative isolation of the processing plants, land availability, soil conditions, and availability of unlimited water. All of the these aspects then, together with the significant difference in waste water characteristics (chloride) between the two regions, resulted in the designation of different categories 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 effluent standards and guidelines.

SHRIMP PROCESSING

Alaskan Shrimp (Subcategories I and J)

In addition to crab, the other major Alaskan fishery monitored in this study was the Alaskan shrimp processing industry. The

Alaska pink shrimp (*Pandalus borealis*) are caught commercially in nets to a distance of approximately 80 km (50 miles) from shore. The shrimp are taken directly to a processing plant or to a wholesale marketing vessel. When long storage times are necessary, the shrimp are iced in the holds and re-iced every twelve hours.

Background

When commercial shrimp production began in Alaska over 50 years ago, hand picking was the basic peeling method used. In 1958, automatic peelers were introduced. The tremendous expansion experienced by the industry in the last decade can be attributed mainly to the introduction of these mechanical peelers. From 45 to 180 kg (100 to 400 lbs) of shrimp can be hand peeled per day, whereas the capacities of modern shrimp peeling machines vary from 1820 to 5450 kg (4000 to 12,000 lbs) per day (Dassow, 1963).

Table 11 lists the Alaskan shrimp processing regions and wastes generated in 1967. The shrimp season extends throughout the year in Alaska but the operation peaks from May through June. Over 4500 kkg (5000 tons) of wastes are generated annually in Alaska by this industry.

Table 11. Alaskan shrimp wastes, 1967 (Yonkers, 1969).

Region	Canneries	(kkg)	(tons)
Aleutian Islands	1	410	(450)
Kodiak Island	3	3540	(3900)
Southeastern Alaska	2	730	(800)
TOTAL	6	4681	(5150)

The Alaskan shrimp processing industry is centered around Kodiak, where shrimp represent the largest volume of landings. The shrimp processing waste waters are said (McFall, 1971) to constitute the major portion of the pollution load being discharged into Kodiak harbor. Approximately 50 machine peelers with a total capacity approaching 340 kkg (375 tons) of raw shrimp per day are located in processing plants in or immediately adjacent to the town of Kodiak. Up to 230 kkg (250 tons) of shrimp waste were discharged into the receiving waters each day during peak processing periods until the local waste handling plant opened in late spring of 1973. Most of the shrimp plants have from 4 to 9 machine peelers, each of which use about 380l (100 gallons) of process water per minute.

Shrimp are caught in large nets called "otter trawls." Large planing surfaces or "doors" are used in conjunction with a lead and float line to hold the mouth of the bag-like net open. Once onboard the boat, the shrimp are heavily iced in most instances and remain in the hold for as long as 5 days. The shrimp are then transported to port, unloaded at the plant and frequently stored for a few days to condition them for peeling. In Alaska, fish that are caught with the shrimp are brought to the dock with the catch and are later manually separated from the shrimp and discharged.

Processing

The Alaskan shrimp process is depicted in Figures 17 and 18. After unloading and storage, the shrimp are mechanically peeled in one of two main types of shrimp peelers: the Model PCA and the Model A, both of which are made by the Laitram Corporation of New Orleans, Louisiana. The PCA peeler employs a 1.5 minute steam precook to condition the shrimp prior to peeling. This facilitates the peeling step of the operation and allows significantly greater through-put of product. The Model A peeler does not employ a steam precook. In Alaska the PCA shrimp are nearly always subsequently frozen, while the Model A final product is canned or frozen.

After peeling the meats are inspected and then washed. If they are to be canned, the meats are blanched in a salt solution for about 15 minutes and then dried by various methods to remove surface moisture. Prior to final canning the shrimp are once again inspected.

When this study was initiated, three subcategories for Alaskan shrimp were designated in a preliminary fashion:

1. canned, Model A peeled shrimp;
2. frozen Model A peeled shrimp; and
3. frozen Model PCA peeled shrimp.

The results of the study (Section V) indicated that no significant differences in the waste waters from the processing of Model A peeled and canned shrimp versus Model A peeled and frozen shrimp exist. Furthermore, the differences in the waste characteristics between the monitored plants using Model A peelers and those using Model PCA peelers were only quantitative, not qualitative. Based on these observations, it was decided to designate the entire Alaskan shrimp processing industry as a single subcategory.

With both Models A and PCA peelers, the shrimp are fed into the machine on a broad belt. This insures an even distribution of shrimp across the width of the peeler. The PCA shrimp are steam precooked while on this belt. This precook helps "condition" the shrimp by loosening the shell, making them easier to peel. The processing rate for Model A peelers is higher than that for the

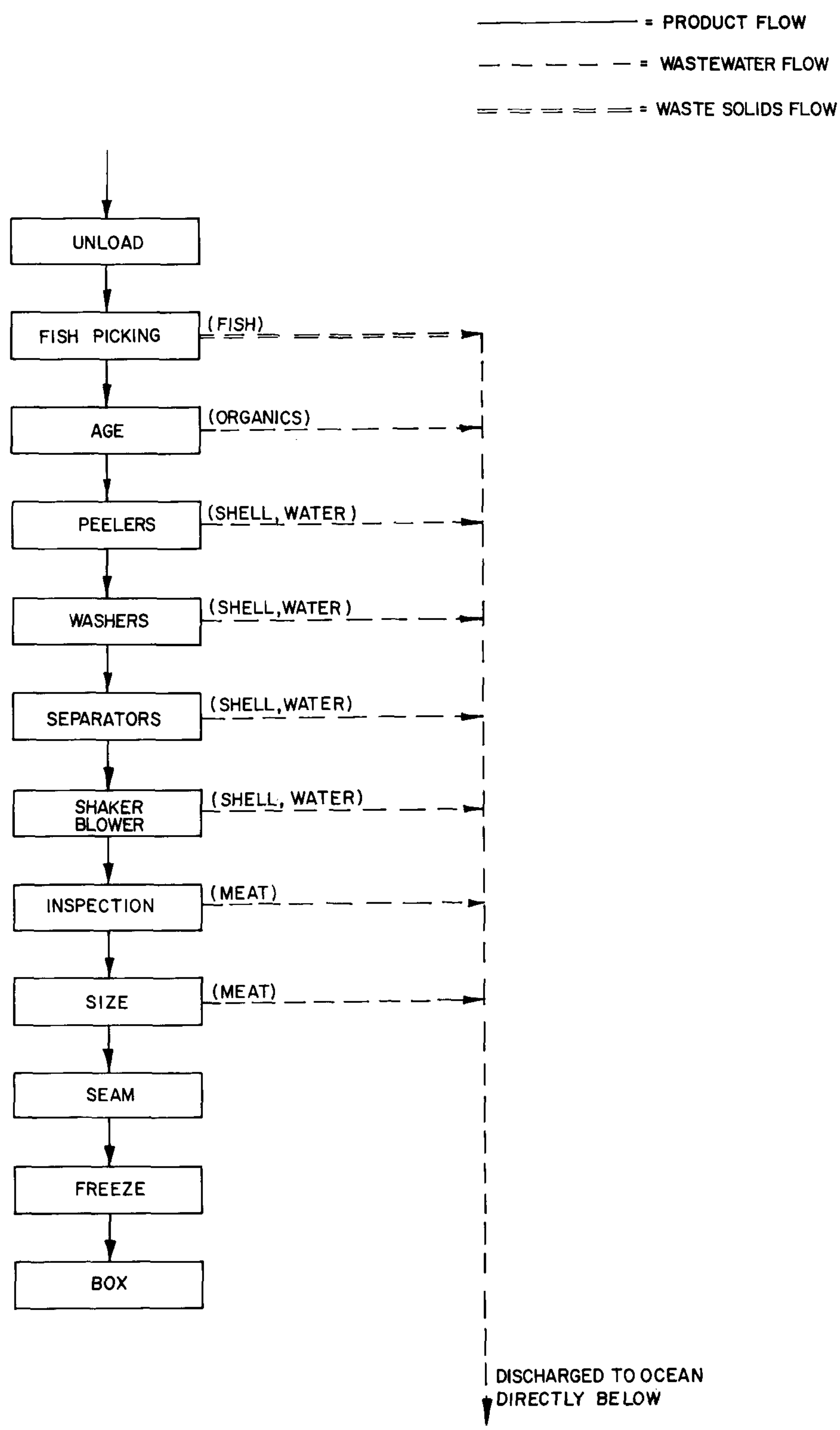


Figure 17 Alaska and west coast shrimp freezing process.

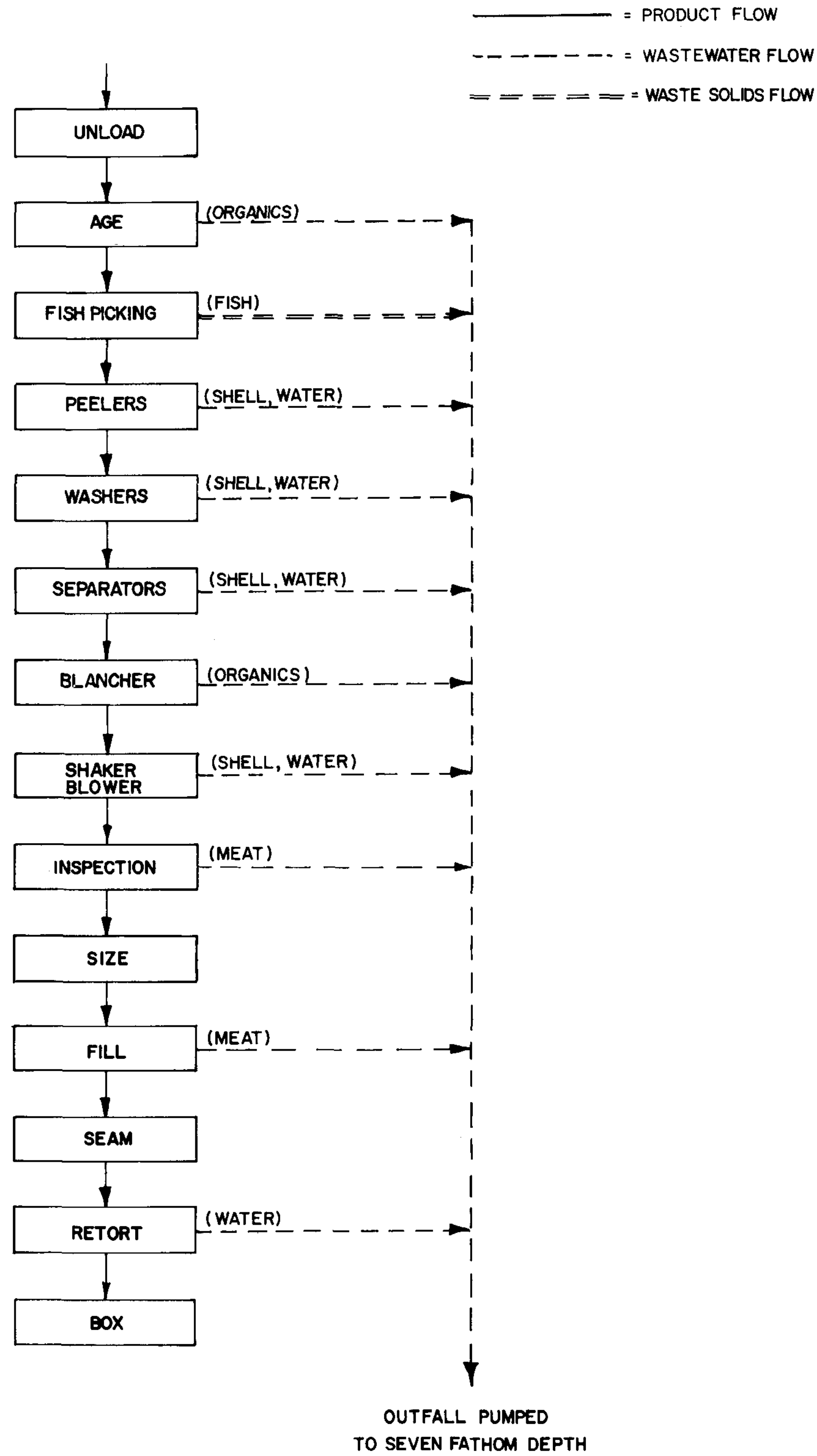


Figure 18 Alaska and west coast shrimp canning process.

PCA-type, but it is generally felt within the industry that the PCA peelers yield a higher quality product. Whereas the Model A can handle approximately 410 kg (900 pounds) of raw material per hour, Model PCA capacities are limited to about 230-270 kg (500-600 pounds) per hour. These processing rates, as mentioned earlier, vary greatly with condition of the incoming product.

On the peelers, the shrimp drop onto counter-rotating rollers that "grab" the feelers of the shrimp and roll the shell off the meat. The shrimp are pressed against these rollers by overhead racks. Considerable water is used in both types of peelers to transport the product and the shell away from the machines. This water may be either fresh water or salt water. Both types are used in Alaskan processing plants.

In an average plant approximately 50 percent of the total water use is in mechanical peelers. Frequently the shrimp meat is flumed from the peelers to the next step, the washers.

Two types of washers are used for peeled shrimp, one for raw shrimp and one for cooked. The Laitram Model C washer is designed for detaching "swimmerettes," gristle and other waste material and shell from raw shrimp, where the Laitram Model PCC cleaner is designed to wash peeled precooked shrimp. In the washers, agitators vigorously mix the shrimp in the trough of the washer, breaking loose any shell not removed in the peeling process. A few plants that use PCA peelers do not use subsequent washers because the violent agitation fragments some of the shrimp.

After washing, the shrimp meat is flumed to separators where the small meat fragments and remaining shell are automatically removed. Again, two different designs are used, one for peeled, precooked shrimp and one for peeled raw shrimp. After passing through the separators, the shrimp meat is flumed to a dewatering belt. Approximately 20 percent of the total plant waste water flow comes from the washing-separating area.

After dewatering, the Model A peeled shrimp are blanched in a salt solution for 15 to 17 minutes at 96°C (205°F). Only the shrimp which are to be subsequently canned are blanched. Usually neither the PCA peeled shrimp nor the Model A peeled shrimp to be frozen are subjected to the blanching step. The cooker used for blanching is normally discharged every four hours.

The next step is the final air-cleaning step in a "shakerblower" operation. This step is not universally used. In this step, the shrimp meats are dried and any extraneous shell is blown off. Following cleaning the shrimp are inspected and any shrimp with shell still adhering to them are removed and wasted. The meat is then further sized and graded either manually or by machine.

The shrimp to be canned move through the automatic filler and into the cans. Before the lids are placed on the cans, ascorbic acid is added. As in the crab industry, the ascorbic acid serves as a color preservative and prevents the undesirable "bluing" of the meat. In the next step, the cans are seamed, after which they are retorted for 20 minutes. Those Model A peeled shrimp which are not to be canned but which are to be frozen are packed without the use of additives.

PCA peeled shrimp, prior to freezing, are rinsed in a salt-ascorbic acid solution in some processing plants. In others, this step is omitted. The shrimp are then frozen in plastic bags or in 2.3 kg (5 lb) cans and stored to await shipment.

Wastes Generated

Jensen (1965) estimated that 78 to 85 percent of the shrimp is wasted in mechanical peeling.

The National Marine Fisheries Service listed the composition of shrimp waste as shown in Table 12.

Table 12. Composition of shrimp waste

	Composition (%)		
Source	Protein	Chitin	$CaCO_3$
Hand peeling	27.2	57.5	15.3
Mechanical peeling	22.0	42.3	35.7

A specialized market for shrimp waste has developed in the fish food industry. The red pigment of the shrimp (astaxanthin) supplies the pink color which is characteristic in wild trout but absent in farm trout (Mendenhall, 1971).

Crude waste from shrimp cannot provide the major source of protein in livestock feed because the amount of calcium would be excessive. However, a simple and inexpensive method for decalcifying meal has been developed (Mendenhall, 1971). Other uses for the solid waste produced in the shrimp processing industry are discussed in Section VII.

Little work has been done to date on the characterization of the waste waters generated in the Alaskan shrimp processing industry. Crawford (1969) reported that mechanical shrimp peeler effluents averaged 29,000 mg/l total solids and 6.4 percent total nitrogen (dry weight basis). Recent (and unpublished) work has been conducted by the Environmental Protection Agency and by the National Marine Fisheries Service in the shrimp plants of Kodiak, Alaska. The results of their studies are detailed in Chapter 5 (McFall, 1971 and Peterson, 1973a and 1973b,).

Subcategorization Rationale

The reasoning followed in the development of the Alaskan shrimp subcategory paralleled in many respects the reasoning followed in the designation of Subcategories D, E, F, and G. 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. The availability of raw material at the docks is determined by the fishermen's ability to set their nets and complete a "drag" through the shrimp fishing grounds.

Indications are that the condition of raw material on delivery to the processing plant influences the character of the waste water 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 a 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 affect the waste water characteristics. Although this study was of insufficient duration to determine the exact effect of maturity on waste water 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). 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 exact effect of maturity on waste water component levels remains to be determined.

As is the case with crab, the product yield tends to increase as the season progresses. This consideration, although it affects the waste water stream in the processing plant, should not prove a detriment to this study because the waste water characteristics developed (Section V) were generated during a period of relative immaturity of the animal and correspondingly lower yields than might be expected with mature animals. Therefore, it is not expected that pollutant levels, in terms of production, would increase over the course of the season. Rather they would be expected to decrease somewhat, although again perhaps not significantly. The third variable to be considered in subcategorization was "variety of the species being processed." This variable was not applicable to the Alaskan shrimp industry and was, therefore, not a justification for subcategorization.

As discussed in the "Background" section of this report, harvesting of Alaskan shrimp is carried out virtually exclusively through the use of otter trawls. Therefore, "harvesting method" was not an important variable in the subcategorization scheme.

Whereas, "degree of preprocessing" is significant in other shrimp fisheries where shrimp are sometimes beheaded at sea, and where trash fish are sometimes separated from the shrimp catch prior to returning to the processing plant, this is not the case in the Alaskan industry. No preprocessing of the Alaskan shrimp takes place prior to docking of the vessel next to the processing plant. Therefore, this variable was not considered a significant factor in the development of subcategories.

The variable "manufacturing process and subprocesses" does apply to the Alaskan shrimp processing industry. As discussed in the "Processing" section, two main types of peelers are used, Laitram Model A and Laitram Model PCA (with steam precook). Furthermore, those shrimp to be canned were subjected to a subsequent blanching step which was not a part of the process for shrimp which were to be frozen. While these variables are significant in the Alaskan shrimp processing industry, their importance fell short of dictating that a separate subcategory be established for Model A versus Model PCA peeled shrimp.

"Form and quality of finished product" was a variable that was considered in the subcategorization scheme and that indirectly has an effect on the waste water strengths in the Alaskan shrimp processing industry. That is, shrimp which are to be canned are processed using Model A peelers and those which are to be frozen are peeled on both. These differences, however, are covered above under "manufacturing process and subprocesses" and need not be further considered here.

"Location of plant" was 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 that are presented earlier in this chapter 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 effluent guidelines.

The effects of "production capacity and normal operating level" are apparent in the Alaskan shrimp industry because a large amount of the total plant flow passes through the peelers. That flow remains constant whether the peelers are running at full capacity or half capacity. Nevertheless, the influence of these variables was not sufficient to warrant subcategorization.

The "nature of the operation" was a consideration of near equal importance to "location of plant." The intermittent nature of the industry precludes the designation of treatment systems requiring constant or only mildly fluctuating influent waste streams and further limits the number of alternatives available to the sanitary engineer.

The variables "raw water availability, cost and quality" and "amenability of the waste to treatment" were of relatively small consequence in the designation of this subcategory. Although the maintenance of an adequate fresh water supply is a continual problem in Alaska, the anticipated waste management schemes (discussed in Section VII) would not impose a significant additional demand on present water supplies. Furthermore, the wastes from the processing of Alaskan shrimp can be thought to be treatable (under proper conditions) and no known toxicants are contained therein.

As discussed in the "Economic Analysis of Effluent Guidelines, Seafood Processing Industry" (June 1974), there is substantial evidence that processors in isolated and remote areas of Alaska are at a comparative economic disadvantage to the processors located in population or processing centers in attempts to meet the effluent limitations guidelines. The isolated location of some existing Alaskan seafood processing plants eliminates almost all waste water treatment alternatives because of undependable access to ocean, land, or commercial transportation during extended severe sea or weather conditions, and the high costs of eliminating the engineering obstacles due to adverse climatic and geologic conditions. However, those plants located in population or processing centers have access to more reliable, cost-effective alternatives such as solids recovery techniques or other forms of solids disposal such as landfill or barging.

For all of the above reasons the Alaskan shrimp processing industry was placed into two subcategories for the purpose of designing and estimating the costs of treatment systems and for developing effluent standards and guidelines: non-remote Alaskan shrimp processing (Subcategory I), and remote Alaskan shrimp processing (Subcategory J).

<u>Non-Alaskan Shrimp</u> (Subcategories K, L, and M)

Of the seafood commodities studied, the most wide ranging was shrimp. Significant shrimp fisheries are being exploited in waters off the coast of all the major regions in this country. In addition to the Alaskan industry a medium size shrimp canning and freezing industry exists on the lower Pacific Coast, a medium to large size canning industry operates on the Gulf Coast, centering around the Mississippi River delta area, a large breading and freezing industry extends from the east coast of Texas to the east coasts of Florida and Georgia, and a growing shrimp canning and freezing industry operates in the New England area.

Figures 19, 20, and 21 are plots of all shrimp flow, BOD_5, and suspended solids data (respectively) gathered in this study. A review of these plots and the shrimp data in Section V reveals that the breaded shrimp flows and suspended solids average about twice those from the non-breaded shrimp processors. The settleable solids in the waste waters from the northern shrimp processors, on the other hand, were nearly ten times those from southern shrimp processing, breaded or not. As was expected, the breaded shrimp suspended solids levels were nearly twice those of the non-breaded shrimp.

The breading of southern shrimp nearly doubled the waste water BOD. The northern shrimp BOD's were nearly three times those of the unbreaded southern shrimp, a phonomenon largely attributable to the differences in product size (as is discussed later). Paralleling this BOD relationship, the northern shrimp COD and oil levels were also considerably higher than those of the southern shrimp.

These obvious differences, together with contrasts in climate, land availability and other factors (discussed later) led to the designation of three subcategories for non-Alaskan shrimp: Northern Shrimp Processing in the Contiguous States (Subcategory K); Southern Non-Breaded Shrimp Processing in the Contiguous States (Subcategory L); and Breaded Shrimp Processing in the Contiguous States (Subcategory M).

Northern Shrimp Processing in the Contiguous States
(Subcategory K)

Background

The wastes generated in the shrimp canning and freezing industry of the contiguous United States were found to vary from region to region. The variations exhibited were easily traced to two main variables: differences in product size; and harvesting or preprocessing techniques. The basic shrimp process was found to be consistent from Astoria, Oregon to Brownsville, Texas to New Orleans, Louisiana to Brunswick, Georgia to Gloucester, Massachusetts.

In terms of total product marketed, shrimp in the United States are second only to tuna. The average United States shrimp harvest approaches 100,000 kkg (224 million pounds) (Langno, 1970). Lyles (see Table 13) presents considerably higher values. Table 14 shows the breakdown of the major products for 1970.

The principal species harvested in the Oregon, Washington, and California waters is the pink shrimp (*Pandalus jordani*). Prod-

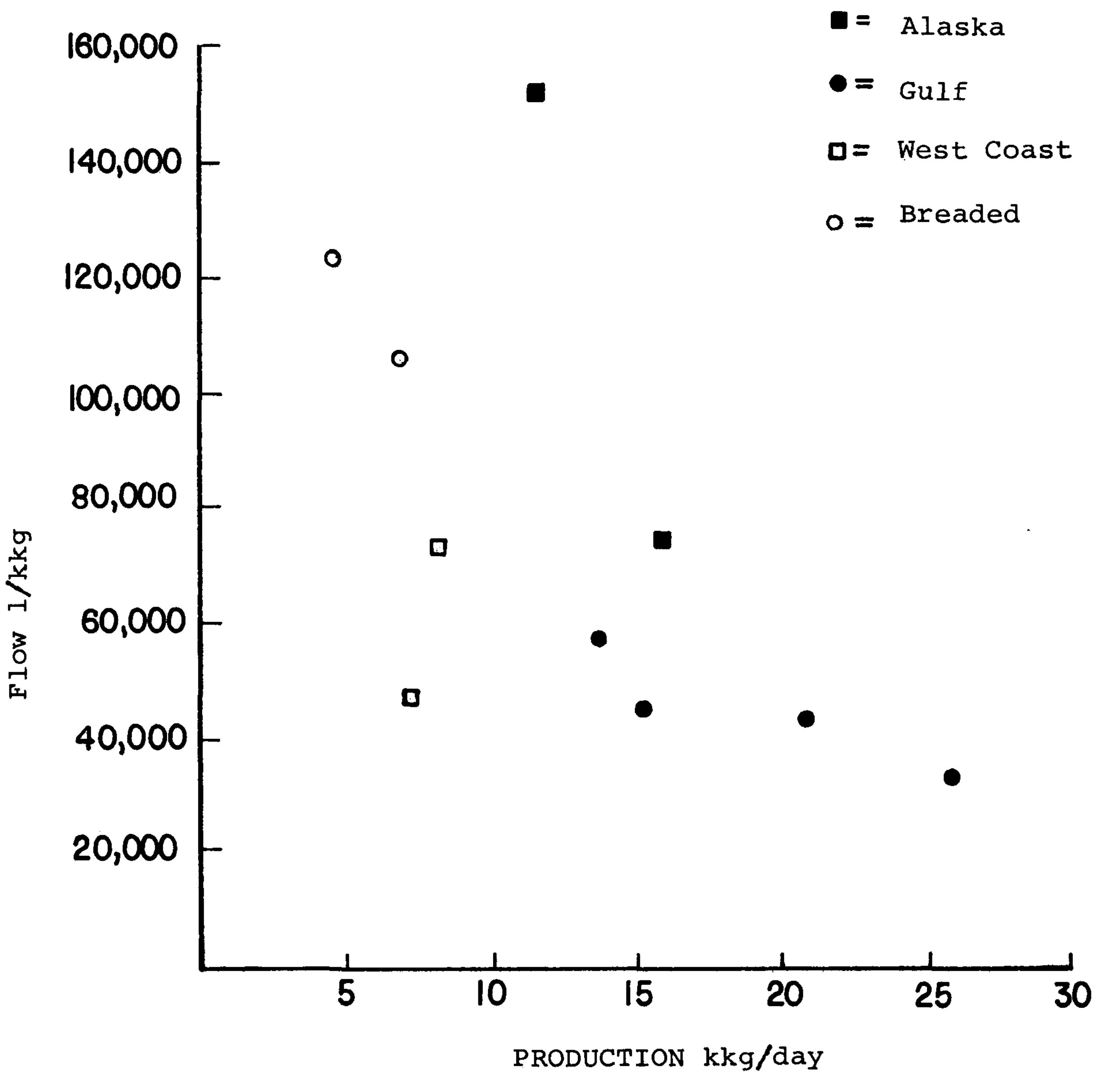


Figure 19

Shrimp production rates and flow ratios

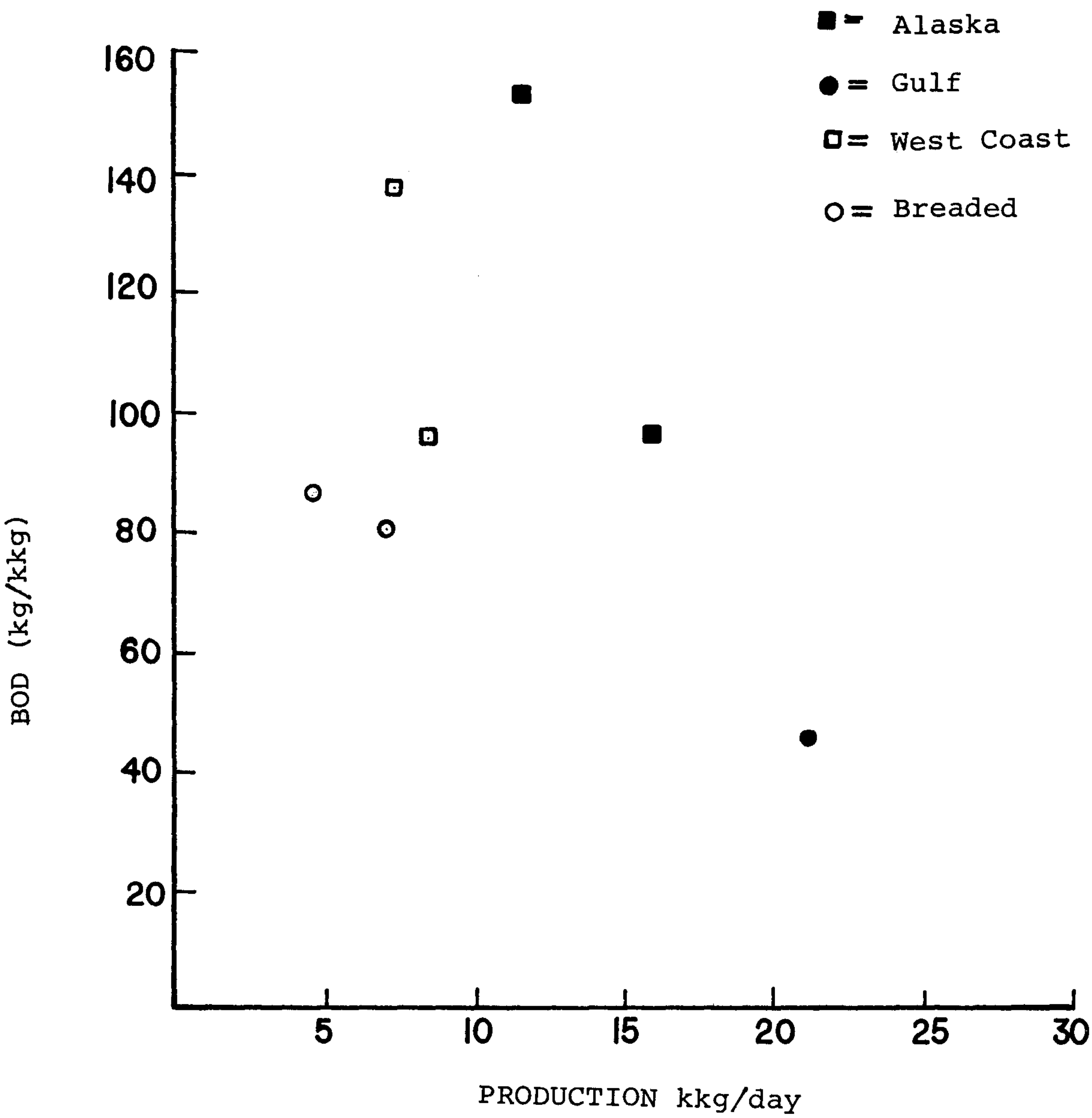


Figure 20

Shrimp production rates and BOD5 ratios

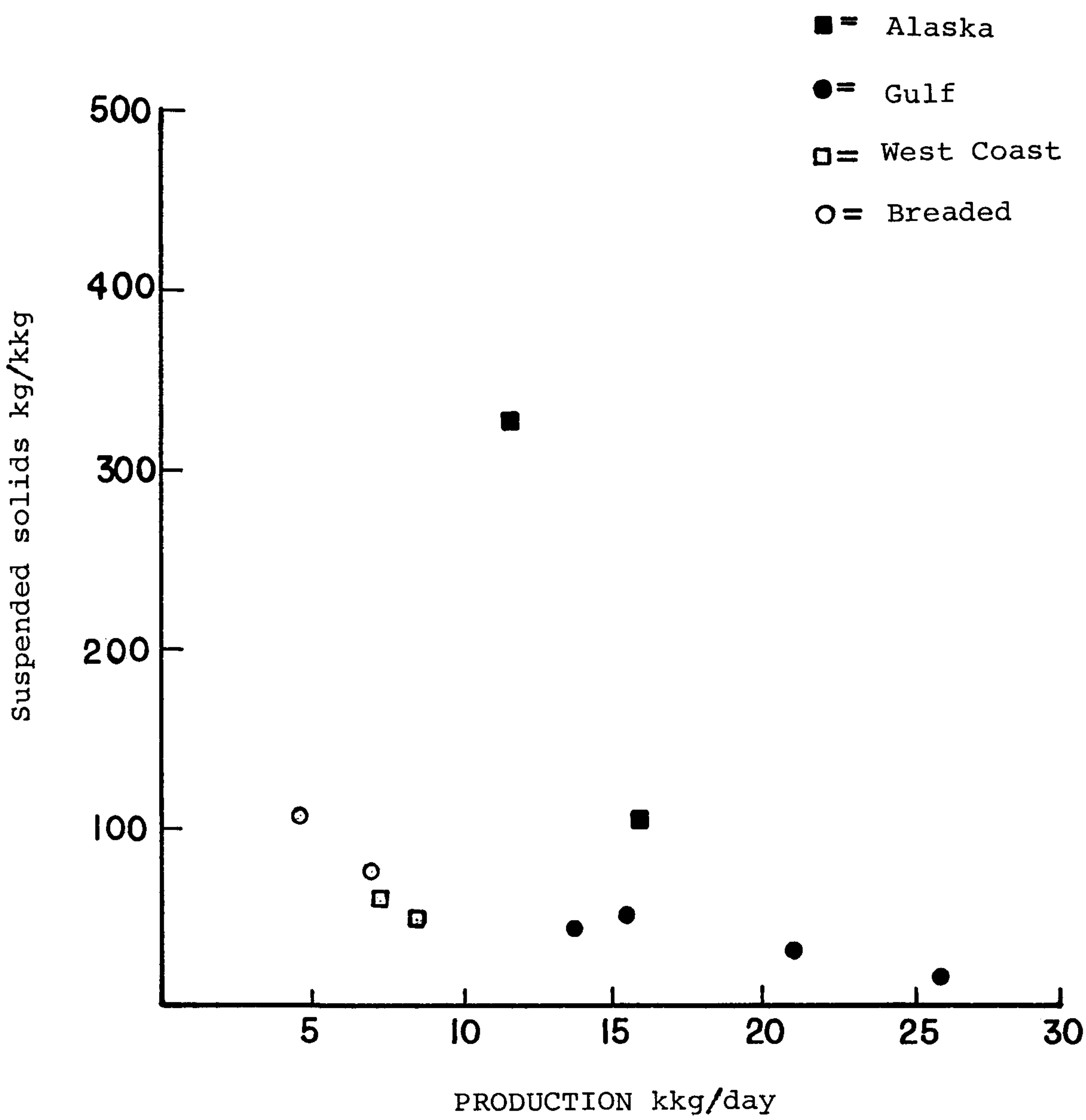


Figure 21

Shrimp production rates and suspended solids ratios

Table 13 Recent shrimp catches

Year	Quantity (kkg)	(tons)
1967	139,600	(153,900)
1968	132,300	(145,800)
1969	143,800	(158,550)
1970	167,000	(184,050)
1971	175,900	(193,950)
Average	151,700	(167,250)

Table 14 Shrimp products, 1970

Product	Quantity (kkg)	Quantity (tons)
Breaded	46,630	(51,400)
Canned	12,020	(13,250)
Frozen	41,860	(46,150)
Specialty products	140	(150)
Total	100,650	(110,950)

uction in this region approaches 6800 kkg (7500 tons) per year, more than 80 percent of which is delivered to Oregon and Washington processing centers (Soderquist, et al., 1970). According to the National Marine Fisheries Service, the West Coast stocks are capable of producing roughly twice that amount under ideal circumstances. The shrimp industry of the New England area is relatively new and has grown dramatically since 1965. From 1965 to 1969 harvests doubled yearly. In early years, the fishery was confined to the state of Maine but as harvests increased, processing spread south and a large processing center is now located at Gloucester, Massachusetts. Practically all Massachusetts shrimp landings take place at Gloucester. On Table 15 is a list of shrimp landings in Maine and in Massachusetts during the 1965 to 1969 period. The normal shrimp season in New England is from September through May with peak catches occurring from January to April. Shrimp processing techniques in the region are varied. They include canning and freezing of both peeled and unpeeled shrimp. The current trend in processing is toward peeled, fresh-frozen shrimp using standard automatic peeling machines, in plants operating up to 16 hours per day.

Processing

As mentioned earlier, the process for canned or frozen shrimp is fairly uniform throughout the United States (see Figures 17 and 18), also the reader is directed to the processing description in the sections dealing with Alaskan shrimp. Variations from that general scheme are discussed below.

On the lower Pacific Coast, shrimp are brought to the processing plant frequently (1-2 days). Very seldom are the shrimp held at sea more than a few days. After netting, the shrimp are brought onto the deck of the ship and the majority of the larger fish and debris is removed at that time. The shrimp are then stored whole in the hold of the boat. These shrimp are laid in a 5 to 8 cm (2 to 3 in.) mat with about 2 cm or more of ice put over them. This layering is very important, if not done properly, spoilage will occur quite rapidly. Although trash fish are removed from the catch prior to returning to port, approximately one percent of the delivered load still consists of trash fish and debris, and must be manually separated at the processing plant. In the New England area, the shrimp are delivered fresh daily to the processing plant, heads on. At the plant dock they are inspected and foreign material is removed; then they are weighed and iced.

The remainder of the shrimp canning and freezing operations on the lower West Coast, South Atlantic, and Northeast Coast are similar to those previously discussed in the section on Alaskan shrimp. In the shrimp canning industry of the Gulf Coast and of the West Coast, both Model A and PCA type peelers are employed. In the New England area, the PCA type peelers are prevalent. On the West Coast and in the New England area, some seawater is used

Table 15 New England shrimp landings,* 1965-1969 (Gibbs and Hill, 1972).

Year	Maine Landings		Massachusetts		Total**	
	(kkg)	(tons)	(kkg)	(tons)	(kkg)	(tons)
1965	942	(1038)	8	(9)	950	(1047)
1966	1738	(1916)	11	(12)	1766	(1947)
1967	3147	(3462)	10	(11)	3171	(3496)
1968					6545	(7200)
1969	11,110	(12,250)	2040	(2250)	13,110	(14,450)

*Heads on

**Entire New England shrimp fishery.

in a few plants for processing. Most plants, however, use fresh water exclusively.

Wastes Generated

The discussion of the wastes generated in the Alaskan shrimp processing industry is applicable to much of the remainder of the shrimp industry in the United States, especially the Pacific Northwest and the Northeast industries where the shrimp are of comparable size to the Alaskan shrimp.

The majority of the work on shrimp wastes has been conducted in the Gulf Coast area. A demonstration project is currently under way at a major shrimp cannery in Westwego, Louisiana. This program is designed to evaluate the efficacy of different screening and dissolved air flotation techniques.

Subcategorization Rationale

Subcategorization for the shrimp industry was relatively complicated. In addition to the previously mentioned factors which differentiate between northern, southern and breaded shrimp, other factors distinguish these subcategories from Alaskan shrimp and were discussed in the "Alaskan Shrimp" section. The major difference between larger Gulf and South Atlantic shrimp and smaller West Coast and New England varieties are due to geography and species diversity.

The condition of raw material on delivery to the processing plant does vary between the northern plants and the southeastern plants which may practice beheading at sea.

Harvesting methods, production capacity and normal operating levels are similar in all areas of the country sampled. 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 data (Section V) 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.

Raw water availability, cost and quality is definitely superior in the Pacific Northwest to that of the Gulf Coast and South Atlantic regions. However, no evidence has been put forth to suggest that this should justify consideration of separate subcategories.

SOUTHERN NON-BREADED SHRIMP PROCESSING IN THE CONTIGUOUS STATES

(Subcategory L)

Background

In the Gulf of Mexico and South Atlantic area, the shrimp industry is the most important seafood industry. The season in that part of the country runs from April to early June and again from August to early October. Three varieties of shrimp are processed in the Gulf area, the pink (*Penaeus duorarum*); the brown (*Penaeus aztecus*) and the white or gray shrimp (*Penaeus setiterus*). The latter is processed most heavily. In both the shrimp breading and shrimp canning industries, considerable importation of foreign stocks from points as distant as North Africa and Indonesia is practiced.

Processing

As mentioned earlier, the process for canned or frozen shrimp is fairly uniform throughout the United States (see Figures 17, 18 and 22), also the reader is directed to the processing description in the sections dealing with Alaskan shrimp. Variations from that general scheme are discussed below. In the Gulf of Mexico and South Atlantic fishery, the boats normally do not bring their catch directly to the processing plant. They commonly dock at central locations (buying stations) and unload their catch into waiting trucks. The shrimp are then iced down and hauled to the processing plant. Unlike other areas, the Gulf and South Atlantic shrimp fishery behead a significant portion of the catch at sea. This is done to minimize degradation of the product and permits extension of fishing trips. In a few instances, whole shrimp are brought to the unloading point where they are beheaded prior to being loaded onto the truck, for transport to the processing plants.

In addition to raw waste characteristics, the subcategorization rational follows the discussions presented above for Alaskan shrimp and northern shrimp processing.

BREADED SHRIMP PROCESSING IN THE CONTIGUOUS STATES
(Subcategory M)

A large percentage of the shrimp landed on the Gulf Coast are processed as a breaded product. This product was successfully developed during the 1950's and markets are continuing to expand.

Processing

The breaded shrimp industry pays a higher price for beheaded shrimp due to certain types of machinery that can only handle this type of product.

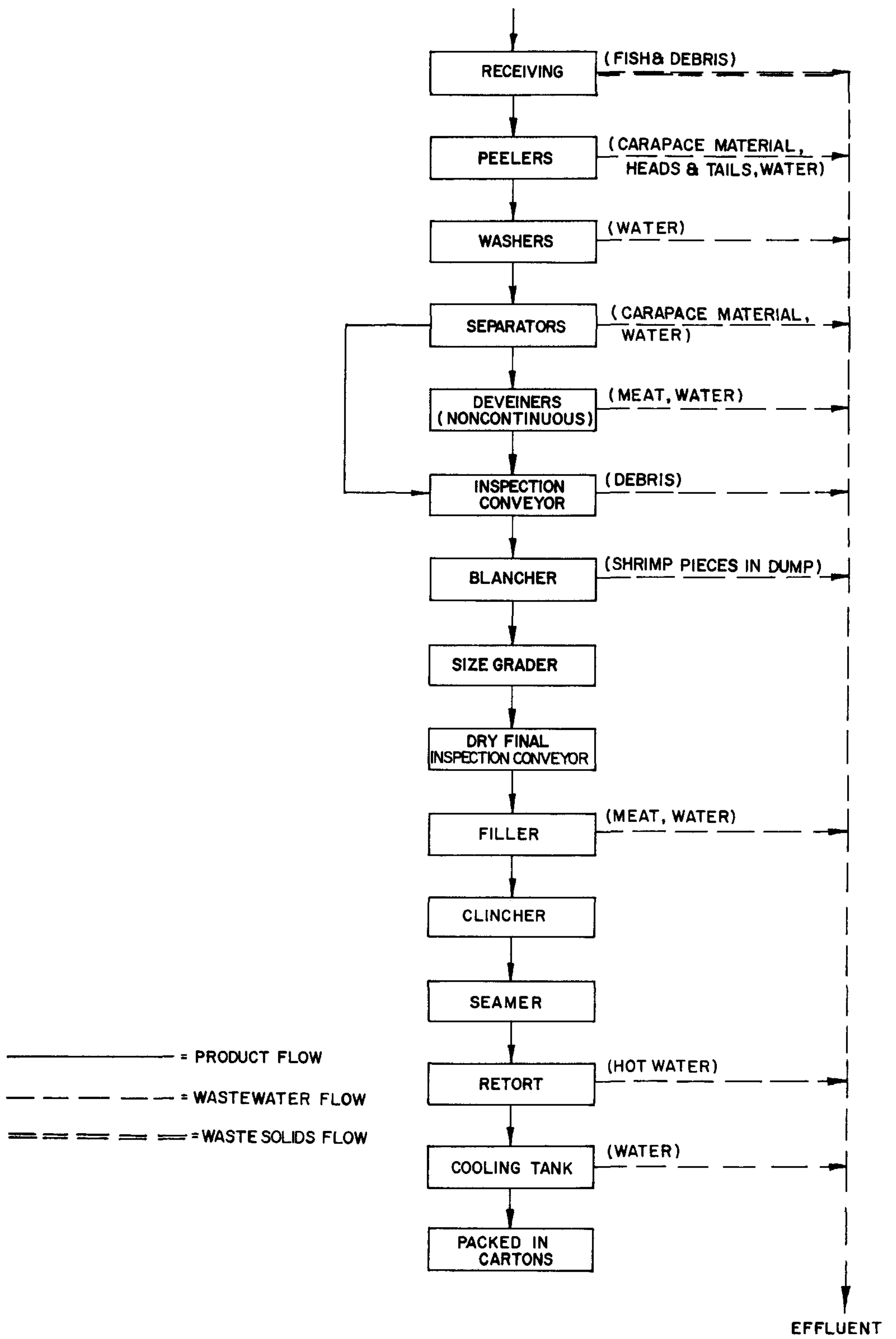


Figure 22 Southern non-breaded shrimp canning process

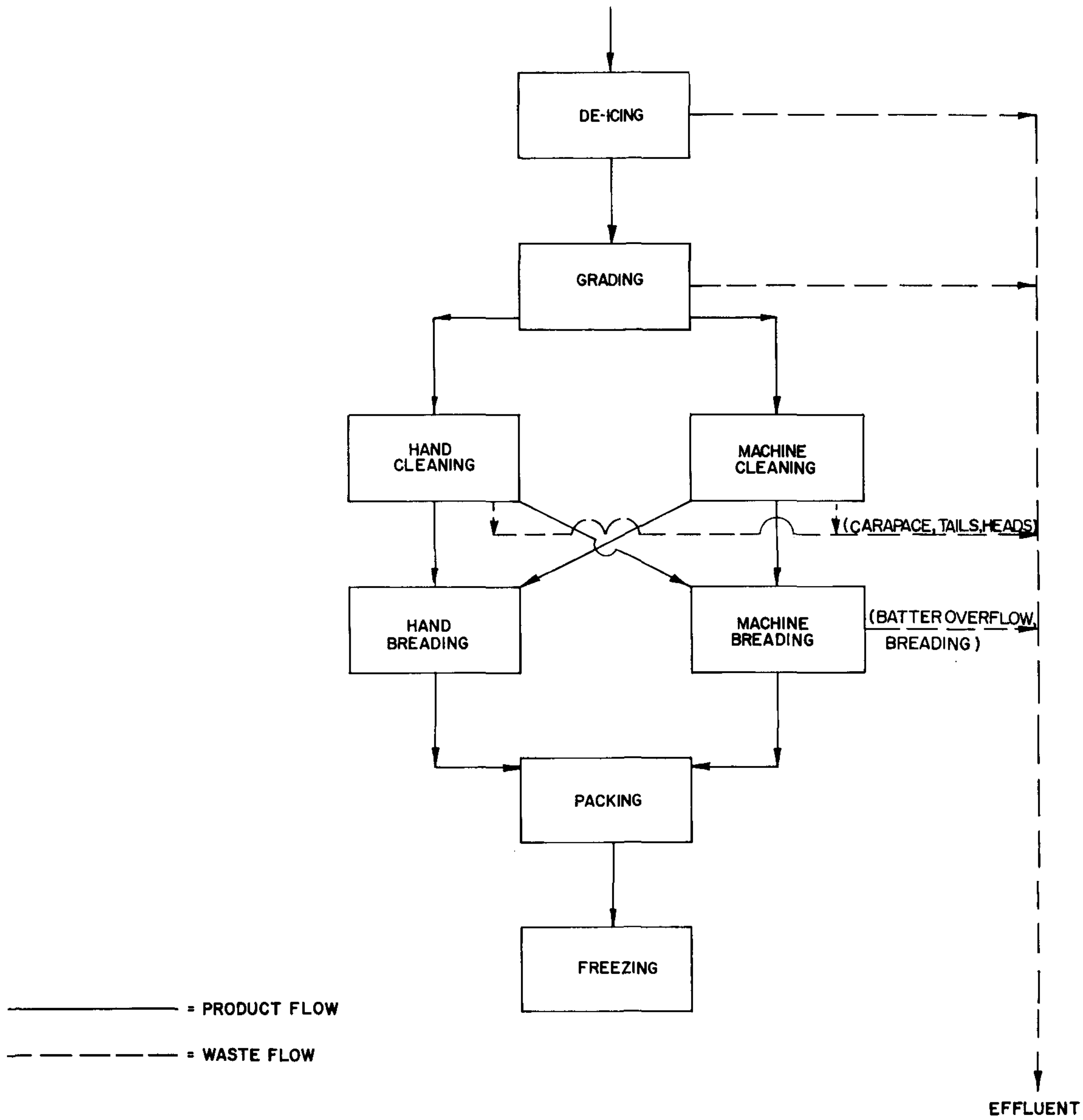


Figure 23 . Breaded shrimp process.

On the Gulf or South Atlantic Coast, where the breaded shrimp industry is prevalent, peeling is done either by machine or hand. Most plants utilize some form of hand peeling of shrimp. The breaded shrimp schemes are shown on Figure 23. Hand peeling is used because it gives a much nicer looking product than machine peeling. There are two different makes of machine peelers used: Johnson (P.D.I.) peelers, and Seafood Automatic peelers. The machines have a capacity of 1800 to 5500 kg (4000 to 12,000 lbs) per day depending on the make (Dewberry, 1964).

Two types of breading usually occur in each plant: hand and mechanical. Hand breading is done by experienced women who generally work with the best product. The shrimp are first dipped in batter, then in bread until the shrimp are coated, then they are boxed, weighed and sealed. Mechanical breading employs the same process as the hand breading and is sometimes called "Japanese Breading." The mechanical breading generally has two main waste flows: one from the holding tanks and the other is from the batter mixing tanks overflow. Each plant also has a de-breading station where improperly breaded shrimp are washed and rerun prior to boxing.

Shrimp that have been breaded are packaged either as "fantail" shrimp (shrimp that have the uropods portion of the tail left and are split part way up the back), or as "butterfly" (split whole shrimp with tail removed). Butterfly and whole shrimp (either glazed and frozen or breaded and frozen) are also packaged. The packages are then machine sealed and frozen. Shrimp are frozen either in blast freezers or I.Q.F. quick freezers.

The discussion of the wastes generated in the Alaskan shrimp processing industry is applicable to much of the remainder of the shrimp industry in the United States.

In addition to raw waste characteristics the subcategorization rational follows the discussions presented above for Alaskan shrimp and northern shrimp processing.

TUNA PROCESSING (Subcategory N)

The annual consumption of tuna in the United States each year far surpasses any other seafood. The raw material, processing methods and size of operation clearly distinguish the tuna industry from the other fisheries studied. For these reasons, tuna is considered a separate category. The industry may be divided into four main segments: harvesting, processing for human consumption, production of pet food, and by-product recovery. For the purpose of this report these four segments will be discussed with specific emphasis on the processsing of human food; pet food production and by-product utilization will be treated as waste recovery, although each is an integral and profitable part or the industry. Harvesting will be considered

SUPPLY OF CANNED TUNA, 1961-72

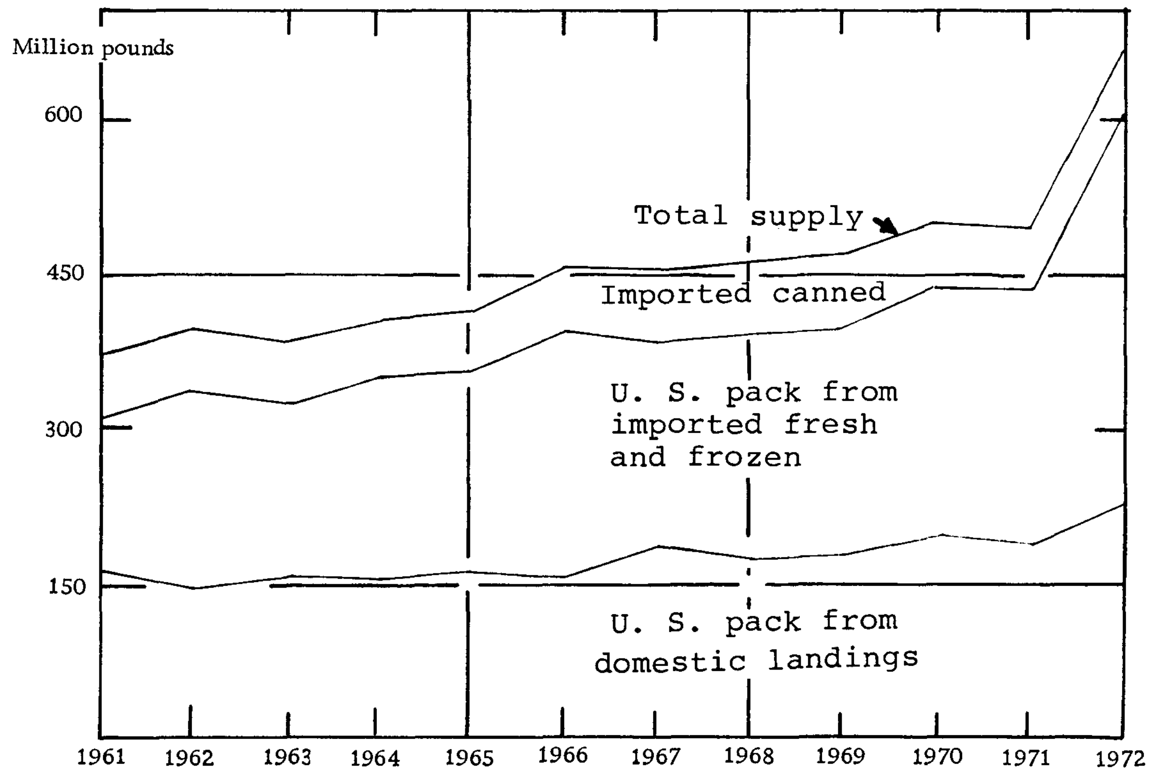


Figure 24

only from the standpoint of a raw materials source and shall not be dealt with in detail.

Background

The United States tuna industry began in 1903 with the production of 700 cases of Albacore tuna packed in California. By 1972, it had grown to over 31 million cases per year worth $632.5 million with plants located, not only in the continental United States, but also in Hawaii, Puerto Rico, and American Samoa. In recent years, the industry has been increasingly dependent on imports of fresh and frozen raw tuna to meet the demand. As indicated on Figure 24, only 34 percent of the U. S. supply was packed from domestic landings--compared with 39 percent in 1971 (N.M.F.S., 1973). The four main tuna species of interest to the tuna processors are the yellow fin (*Neothunus macropterus*), blue fin (*Thunnus thynnus*), skipjack (*Katsuwonus pelamis*), and Albacore (*Thunnus germo*). These species are divided into the white meat variety, exclusively Albacore, of which there is a limited catch, and the light meat varieties of blue fin, yellow fin and skipjack; the latter two comprise the majority of the tuna canned in the United States. White meat tuna is considered the "premium" product of the industry, because of its characteristically white color, firm texture and delicate flavor as compared with the darker, fuller flavored light meat. Harvesting with pole and line has given way in the past 20 years to the use of the purse seiner, which permits the catching of a large volume of fish in about one-fourth the time. (Albacore are primarily harvested with pole and line because they don't school). After locating a school of tuna, the fish are encircled with a large net which is then drawn closed at the bottom. The fish are subsequently crowded together and dipped out of the enclosure into the hold of the boat. Fish harvested locally, i.e., near the processor, are held in refrigerated cargo holds or wells in the ship. An alternate method of storage has been developed for a catch which must be transported from foreign water, often thousands of kilometers from the processing plant. This method entails brine freezing the fish and then holding them in a frozen state until near the plant where the fish are then thawed enough to be easily unloaded.

Processing

The processing of tuna is divided into several unit processes, specifically: receiving, thawing, butchering, precook, cleaning, canning, retorting, and finally, labeling and casing. Product flow, waste water flow, pet food production, and waste utilization is shown schematically in Figure 25.

The tuna are unloaded from the fishing boats into one ton bins and transported by fork lift trucks to the scale house for weighing. Then, depending on the condition of the fish, i.e.,

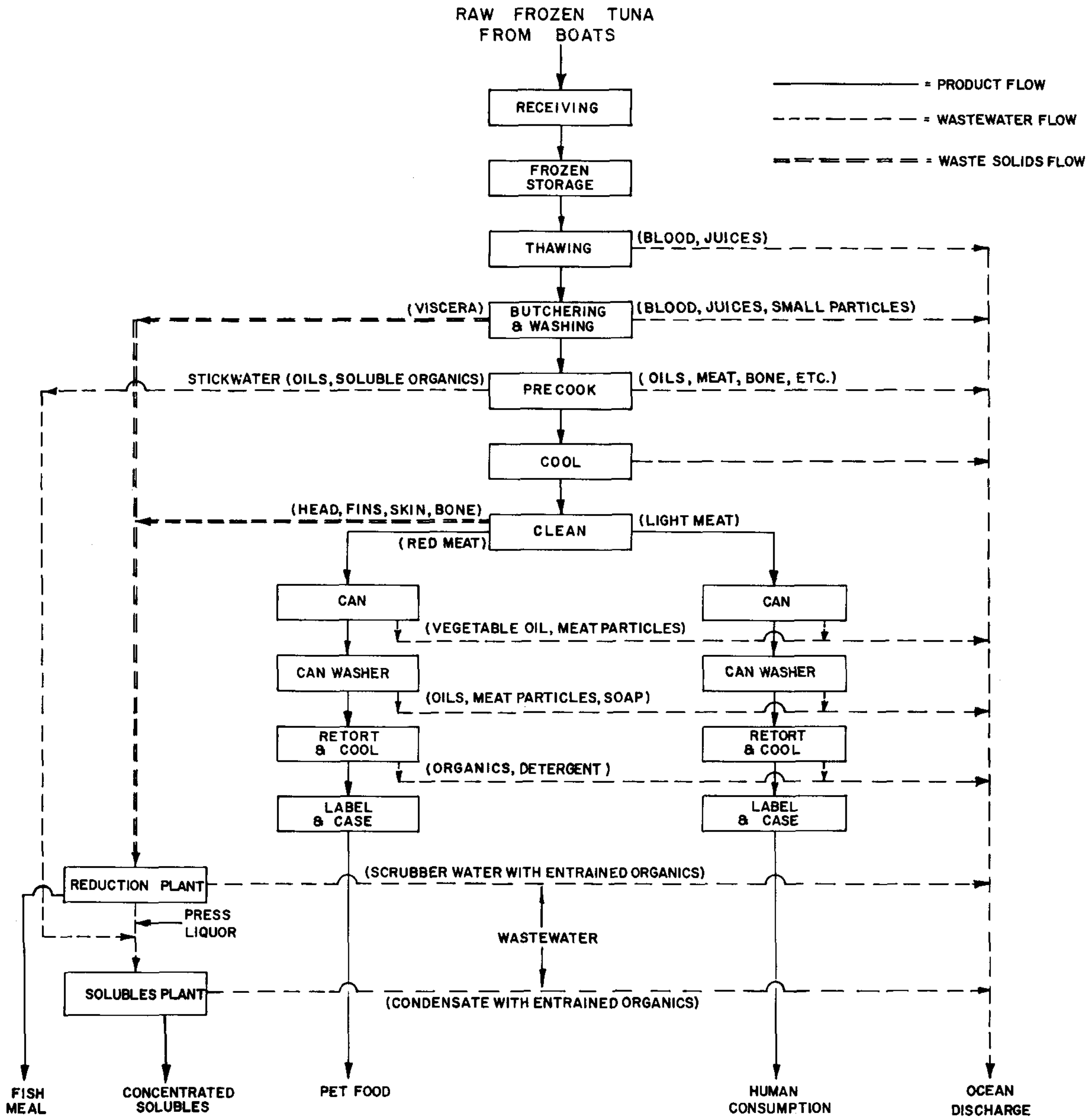


Figure 25 Tuna process.

soft or frozen, and the production backlog, they are either transferred to cold storage or directly to thawing tanks; soft fish which may be fresh or partially thawed are usually processed immediately. Imported fish, i.e., purchased from a foreign country, are also received to fill any gaps in domestic harvesting.

The fish are thawed in large tanks which hold 8 to 10 one ton bins. These tanks are equipped with a moveable end plate so that fork lift trucks can place the bins inside the tanks and subsequently remove them after the thaw. Once the bins are in place, the end plate is lowered and fresh water or seawater is pumped or sprayed into the tank. Thawing then takes place under either static or continuous flow conditions. Steam is used in some cases to heat the water.

The thaw time depends on three variables: 1) the condition of the fish with respect to temperature; 2) temperature of the thaw water, and 3) size of the fish. Smaller species, e.g., skipjack averaging 1.8 to 9.0 kg (4 to 20 lbs) and Albacore 4.5 to 18 kg (10 to 40 lbs), take from two to three hours to thaw whereas larger species, e.g., the yellow fin averaging 4.5 to 45 kg (10 to 100 lbs), take from five to six hours. Thawing time is increased for fish held in cold storage at -12 to -18°C (0 to 10°F). A substantial reduction in thaw time is achieved by heating the thaw water with the addition of steam. After thawing is completed, the tanks are drained into a collection ditch, the end plate is raised, and the bins are removed and placed on an automated dumper at the head of the butchering line.

The thawed fish are dumped onto a shaker conveyor which spreads them out and transports them to the butcher table. Equipped with a conveyor belt, wash screen, and circular saw the table is manned by 5 to 10 skilled workers who eviscerate each tuna. The viscera, which comprises 10 to 15 percent of the tuna by weight, is removed and placed in barrels along the line. The tuna is washed with a water spray and checked for freshness organoleptically, i.e., by a trained worker who inserts a hand into the cut made by the butchers and smells it for signs of putrifaction. Workers at the end of the line place the tuna in mobile racks containing 14 separate trays. The larger species of tuna are cut to standard size and set into trays for the precook process which follows.

A small water jet is usually sprayed onto the saws to keep them clean. The accumulated waste from the saw and wash screen drips onto the floor and is collected in a drain running parallel to, and underneath the butcher table. This drain also collects waters used to hose down the floor periodically during the day and the equipment washdown at the completion of the butchering process. The viscera is collected in barrels and sent to either the fish meal reduction plant or the fish solubles plant.

The tuna are precooked to facilitate the removal of edible from inedible portions. The precook process involves three main steps: 1) the steam cooking of the fish, 2) removal of the steam condensate or "stickwater," and 3) the cooling of the fish prior to cleaning.

The racks of butchered fish are wheeled into large steam cookers with a capacity of 10 tons of fish per cook. Depending upon the size of the fish or fish sections, the cook will last from 2 to 4 hours at a live steam temperature of 93°C (200°F). Steam condensate plus oils and moisture from the fish collects in the cookers and the resulting stickwater is pumped to a solubles plant which concentrates this and other by-product liquids.

After the precook, the racks are moved into a holding room and cooled about 12 hours. The holding or cooling room may be equipped with fine spray nozzles to hasten the heat loss, but in most cases cooling takes place under ambient conditions. Because of the time involved in the precook process, the fish are thawed, butchered, and precooked the day before they are cleaned and packed. From the cooling room the racks of cooked tuna are moved into the cleaning area of the packing room.

The trays of cooked tuna are wheeled to the packing room where the fish are removed from the racks and the tuna placed along the long cleaning lines which lead the packing machine. There may be from one to ten lines in a plant, depending upon its size, with about 100 people working each line. The line consists of a long double table, with an elevated shelf separating the two sides and a stainless steel conveyor belt in the middle of this shelf. At each position along the table is a hopper feeding another conveyor belt beneath the table. First the head, tail, fins, skin, and bone are manually removed from the fish and disposed of in the aforementioned hopper, conveyor system. This scrap is collected at the leading end of line and by means of an auger it is conveyed to a collection area for transport to the fish meal reduction plant. Depending on size and species, approximately 30 to 40 percent of the tuna by weight is comprised of this non-edible portion. Next, the red meat which constitutes 6 to 10 percent of the tuna is scraped from the lighter meat into a container for collection and transport to the pet food production area. Cleaned of all excess material, the meat is separated into four loins along natural dividing lines, i.e., down the back and along the sides. These loins along with broken portions of the loins are placed on the elevated conveyor to the can packing machine. Chunk style tuna is prepared from broken sections whereas whole loins are used for solid pack tuna. Automatic packing machines shape the tuna and fill the cans. A spillover of juices onto the floor from the compaction of the tuna results in the only flow of waste from what is otherwise a dry process. The cans are then filled with soybean or vegetable oil, a brine solution, and monosodium glutamate; the oil replaces the natural oils lost in cooking and lubricates the tuna to prevent sticking to the sides of the cans during the high temperatures reached in retorting. The oil delivery system has an overflow collection system which filters the oil and recirculates it, thereby minimizing loss.

After vacuum sealing in a lid seaming machine the cans are run through a can washer to remove all the particles and oil from the outside. The can washers usually have three phases: prerinse, soap rinse, and final rinse, all utilizing hot water. The first two phases are recirculated water from which the oils and solids are removed. A despotting agent is often added to the final rinse to protect against mineral deposits on the cans as the cans dry.

Conveyed by a series of belts, elevators, and wire enclosed gravity feed lines, the packed cans arrive at the cooker room on one of several lines, depending on can size. Retort cooker buggies, which are semi-circular in shape to fit into the cylindrical cookers, are filled with cans at each of these several can lines. When enough full buggies of a particular can size are loaded they are guided into the retorts on a set of rails and the doors are bolted shut.

The retorts are essentially large pressure cookers which measure 1.4 meters by 11.1 meters (4-1/2 ft by 37 ft) in which the tuna is sterilized at 121°C (250/F) for 1-1/2 hours. This procedure insures the destruction of all living organisms within the can which could destroy the product or more seriously in the case of <u>Clostridium</u> <u>botulinum</u> pose a fatal danger to the consumer. After the necessary time and temperature requirements have been satisfied for the particular can size, the pressure is reduced and the cans cooled with circulating cold water. A final water rinse contains a despotting agent as is sometimes used to protect against spotting when the cans dry. The buggies are removed from the retorts to a holding room for further cooling and drying.

Each can is coded at the time of sealing; a representative number are sampled, tested, and then that code is designated for a certain market or distributor. After the cans have cooled in the holding room, the buggies are dumped into a bin from which the cans are alined for the labeling machine. Application of the label and subsequent casing in corrugated fiber containers is the last step in the processing plant before either shipment or warehousing.

Pet Food Production

The dark colored meat scraped away from the lighter meat in the cleaning process is collected and packed as pet food; the industry refers to this darker meat as "red meat." The packing process differs from the human consumption line in that less attention is given to the style of pack. Other flavor ingredients are added and the can filling mechanisms deliver the correct quantity of tuna to the can without the extra process of compaction and shaping. The cans are vacuum sealed, rinsed and conveyed to the same cook room to be retorted. As these processes have been previously described, no further mention will be made of them here.

Non-Tuna Pet Food

In conjunction with the production of red meat tuna, some of the plants are also equipped for processing other types of pet foods. Viscera from the beef packing industry, egg, poultry parts, and other ingredients are prepared and cooked in large vats. The mixture is packed in cans using machinery very similar to that used in the red meat process and sealed, passed through can washers, and transferred to the cook room for retorting.

By-Product Recovery

No part of the tuna which enters the processing plant is regarded as waste by the industry. Stickwater, the non-edible portions, and the aforementioned red meat are all collected and further processed into other products. Red meat, although also a by-product, is discussed separately from this section because of the similarities and shared processes with the production of tuna for human consumption.

Fish Meal Reduction

All of the scrap removed to obtain the edible portions of tuna, the spilled scrap and meat cleaned up before washdown, and solids screened from the waste water are collected and transported to the reduction plant for further processing.

The waste solids are ground, cooked, and then pressed to remove valuable juices and oils before the resulting "press cake" is dried by one of several methods. Depending upon the specific process, small amounts of wastes are entrained in the various water flows, e.g., steam condensate, barometric leg waters, air scrubber waters, associated with drying. The resulting fish meal is bagged and marketed for many different uses, including fertilizer and animal feed additives.

The juices and oils collected from the pressing of the cooked solids, termed the press liquor, are pumped to the solubles plant which concentrates this liquor along with the stickwater, and also in many cases a slurry of ground viscera. The usual method is to heat the liquid with steam in the presence of a vacuum produced by a barometric leg. The solubles after concentration by 2 to 4 phases or "effects," are drained off for tuna oil removal or marketed as an animal feed additive and other uses. Wastes become entrained in the steam and aspirator waters of this process. Further information may be obtained from the literature regarding fishery by-product recovery.

Subcategorization Rationale

Consideration of the tuna industry as a subcategory of the seafood industry was provisionally segregated prior to sampling because of the homogeniety in the tuna processing methods, extensive by-product recovery, and the magnitude of production. This segregation was substantiated by the data and information obtained and subsequent comparison to the other subcategories. Figures 26, 27, and 28 are plots of all tuna flow, BOD_5, and suspended solids data (respectively) gathered in this study.

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 does 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 easily corrected to minimize differences and thus justify a common waste treatment technology amenable to all plants.

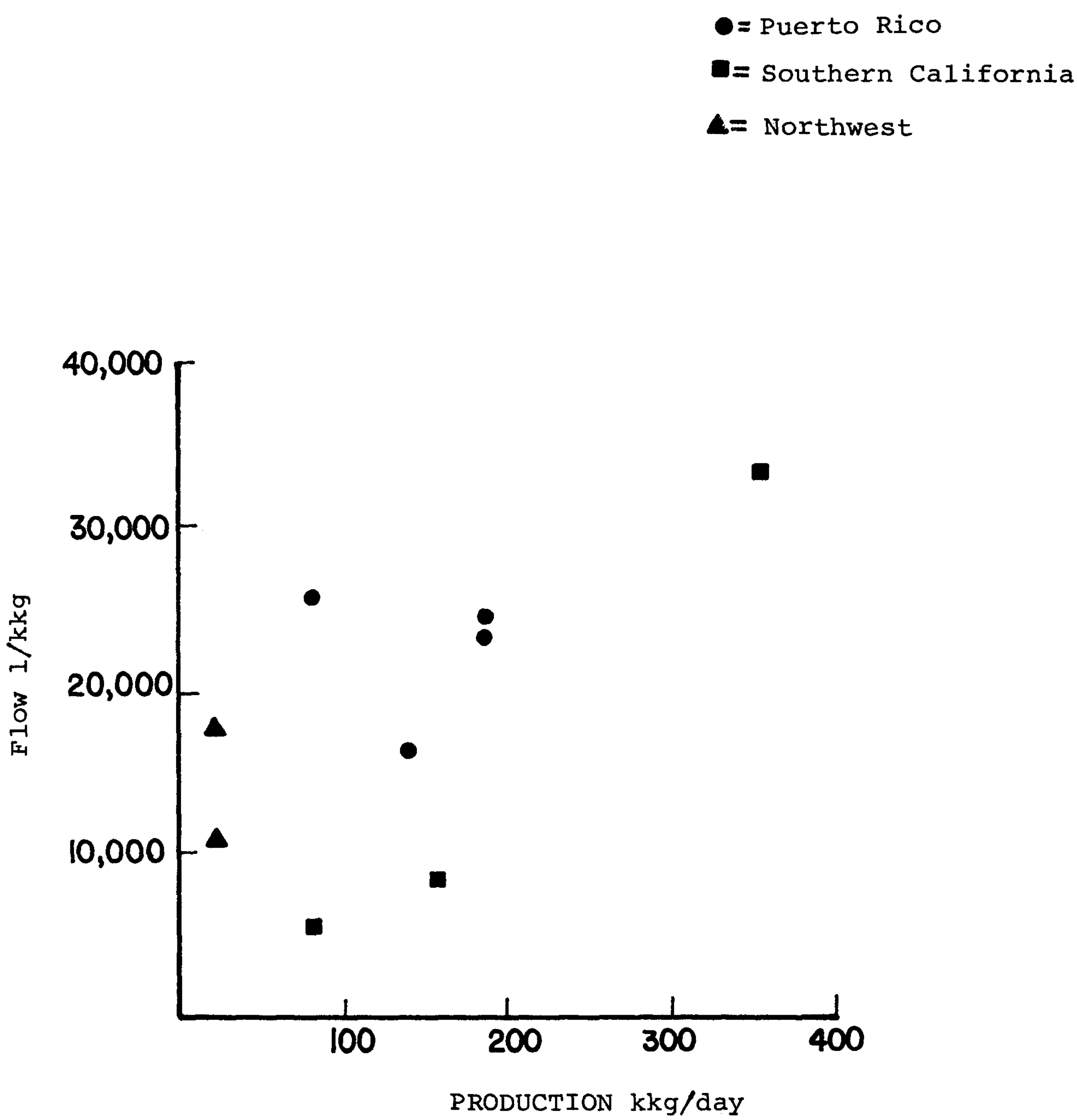


Figure 26

Tuna production rates and flow ratios

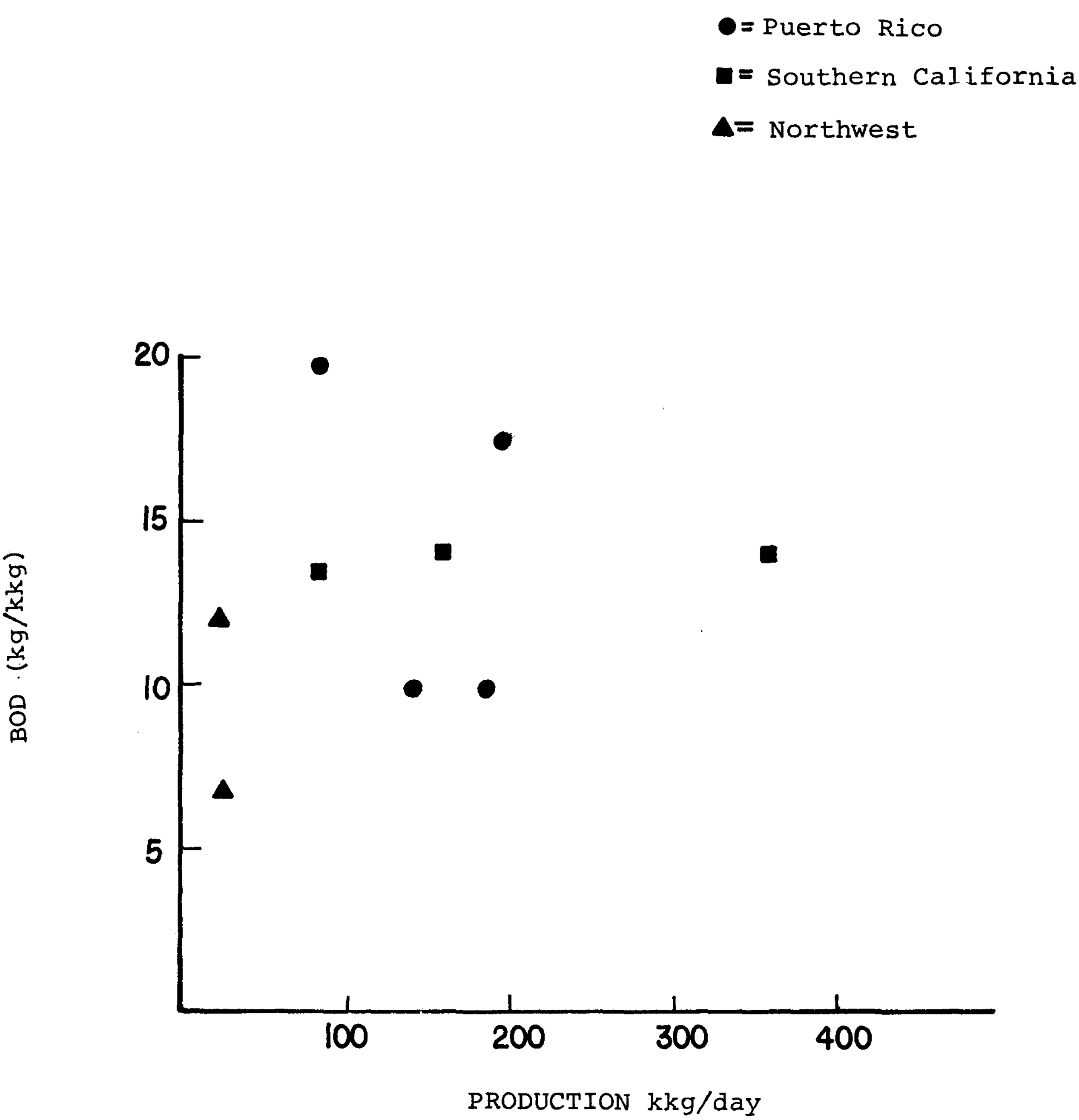


Figure 27

Tuna production rates and BOD5 ratios

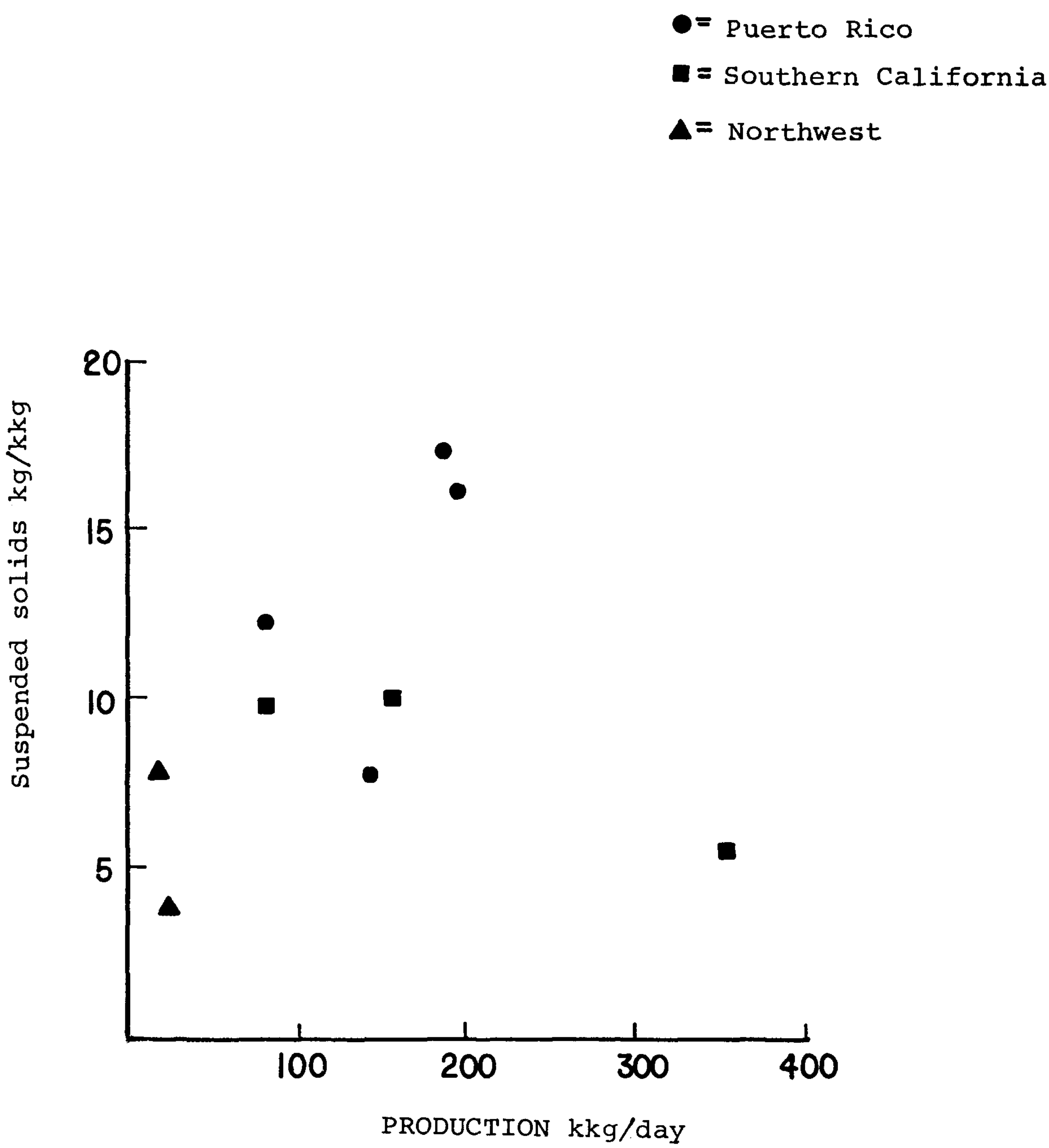


Figure 28
Tuna production rates and suspended solids ratios

SECTION V

WASTE CHARACTERIZATION

Introduction

A major effort in this study involved actual field characterization of the waste waters emanating from processing plants in each of the subcategories. This was necessary because a previously-completed literature review and interview program concluded that very little knowledge of the character and volume of canned and preserved seafood processing waste waters was available (Soderquist, et al., 1970).

The waste characteristics for the seafood processing industry were identified using a combination of judgment and statistical sampling methods. A preliminary stratification was first developed to define subcategories which were considered likely to be relatively homogeneous from the standpoint of the application of control and treatment standards. The processing plants in each subcategory were then treated as separate populations in terms of sample means and standard deviations for several important waste parameters.

In cases where the processing plants in a subcategory were located over a relatively wide area, consultations with knowledgeable industrial and university people were held and plants were identified which were considered to be typical of the whole group. Where the plants tended to be in groups, "cluster sampling" was utilized as the basis for the sample design.

Temporal averages of the desired parameters were obtained from the combined effluent streams and, when possible, from the most significant unit operations. The temporal averages from each process were then averaged to obtain a combined time and space representation for each subcategory. The spatial range and standard deviation of the temporal averages were then inspected to verify the adequacy of the preliminary subcategorization.

Where the sample coefficient of variation appeared to be relatively large for some of the parameters, the individual process data were reviewed to determine if a further breakdown of the subcategory should be undertaken. In general, variations could be traced to differences in unit operations between processes. Post-stratification was then employed and the more typical processing operations separated from the exceptions; or processors with the more similar operations were averaged together to obtain strata which were more internally uniform. In most cases it was decided that the creation of additional subcategories was not warranted. The averages for these "sub-subcategories" are included in this section to assist the reader in understanding the sources of variation.

Where the averages of different preliminary subcategories were similar, and review of the other pertinent subcategorization variables warranted the decision, all the plants in these subcategories were combined to obtain averages for more general subcategories.

Sampling Program Design

The preliminary subcategorization of the industry was developed through review of all significant literature, consultation with industry groups, related governmental represenatives and recognized experts in the areas of fish processing, and waste treatment and control, based on the factors discussed in Section IV. The processing plants in each subcategory were then handled as objects of separate universes.

Based on previous experience in examining wastes from the seafood processing industry, the parameters considered to be most important from the standpoint of waste control and treatment were: flow, settleable solids, screened solids, suspended solids, 5 and 20 day BOD, COD, grease and oil, organic nitrogen, ammonia, pH, raw material input rate, and food and by-product recovery.

Most of the processing plants in each subcategory were then identified by the respective trade organizations. Where the processing plants in a subcategory tended to be grouped together in certain geographical areas, the method of cluster sampling was adopted as being the most efficient in terms of information gained per unit cost. Cluster sampling is optimal in terms of reducing the sampling error when a collection of plants is grouped, such that the groups tend to be alike, while showing heterogenity within the group. This constrasts with "stratified sampling," where the collection of plants is grouped such that they tend to be homogeneous witin groups and heterogeneous between.

Cluster sampling is a natural choice in this industry because of a common organizational structure, while the variability within a group (or cluster) is often high as a result of plant age, processing level, management flexibility, and so on. In some cases, however, neighboring plants may be more alike than plants further apart, contrary to the principle that cluster sampling reduces error when clusters are more heterogeneous within than without; however, the cluster sampling method is still often the most efficient (and the only practical method). The primary criterion used to select the clusters was whether the cluster appeared to be a scaled-down version of the entire industry in the subcategory. This is contrary to the principle that clusters be selected by simple random sampling; however, it utilized prior knowledge of the industry to better advantage and presented the opportunity for valuable judgmental inputs.

An attempt was made to completely enumerate all the plants in each cluster; however, this was modified by factors such as raw material availability and accessibility to plant effluents. In some cases there was insufficient raw material to keep all plants operating during the monitoring period.

Individual Plant Sampling

Time-averaged estimates of the important parameters were obtained by sampling the total effluent, and in most cases significant unit operation contributions, over a period lasting from several days to several weeks for each plant selected. In most cases the effluent was being discharged at more than one point; therefore, each point was sampled and flow-proportioned to obtain a sample which would represent the total effluent.

Immediately after sampling, each aliquot was passed through a standard 20-mesh Tyler screen prior to adding it to the composite. This serves to remove the larger solids particles (such as crab legs, some shrimp shell, fish parts, etc.) and thereby greatly reduce the resultant "scatter" of the data points. The method is especially valuable when one is dealing with a limited number of samples and the development of a precise base-line value for each parameter is the goal. The alternatives to this approach were essentially three-fold:

1) to use a larger mesh size;
2) to blend or grind the samples; and
3) to leave all solids intact and in the sample.

A larger mesh size would have been less defensible than 20-mesh, since the latter represented the minimum mesh expected to be encountered in the final treatment designs. To grind the samples would have led to unrealistically high values for some parameters such as BOD and grease, because these values are surface-area dependent. Blending a food processing waste sample can increase its BOD by up to 1000 percent (Soderquist, et al, 1972a). Since the values obtained through this method (especially those for BOD--the single most important parameter in the guidelines) would be unrealistically high and would not relate to actual receiving-water conditions, this choice was rejected. As discussed above, the third alternative was not adopted because it would introduce unacceptable scatter into the results and throw into serious question the validity of the parameter averages obtained.

Although it was recognized that laboratory screening efficiencies would likely be significantly higher than full-scale field screening efficiencies (for the same mesh), smaller mesh sizes could be used in full-scale application to achieve the same results.

Adoption of the 20-mesh screening method provided accurate, reliable base-line data for each parameter in each subcategory for screened waste water, thereby permitting confident design of subsequent treatment components.

Screening of the fresh sample rather than the composited one minimized leaching from the solids, which would not normally be a contributor if the waste waters were routinely screened prior to discharge.

For estimates of removal efficiencies for the design and cost estimates, the literature was consulted to establish the relationship between screened and unscreened BOD_5 for each subcategory. This factor was applied in full recognition of the inherent inaccuracies associated with the "unscreened" value.

The flow rates, concentrations and production rates can be studied from the viewpoint of time-series analysis. An estimate of the true time average over an infinite interval can be obtained by taking the time average over a finite interval. Problems arise when the time series statistics are not independent of a time translation (time series is nonstationary). Typical causes are daily and seasonal periodicities. This can be obviated satisfactorily in many cases by considering the time series to be periodically stationary, since samples taken at intervals of the periodicity may be approximately stationary. The time average can be determined by considering the time functions in each period to be transient pulses, each with a beginning and end in the period; and then averaging the sample mean for each period over a number of periods.

Daily periodicities were handled in the manner described above; however, the monitoring interval was too short to include even one seasonal period. This problem was handled by considering the fact that most processing plants operate at a peak rate while the raw material supply lasts and then terminate the work shift. An increasing amount of raw product would then increase the length or number of shifts. A ratio of waste load to weight of raw material could then be estimated independently of the amount of raw material or shift length at the time of monitoring. Information on seasonal variation in raw material landings which is available from other sources can then be translated into waste load variation.

Estimates of the averages for each day were obtained by taking a number of samples during the day and then mixing volumes of all the samples together in proportion to the flow at the time each sample was taken. In the limit this is the same as taking a sample from the total volume of effluent produced during the day. Since mixing is approximately a linear operation for most of the parameters, a laboratory analysis of the one composite sample gives about the same results as taking the average of a series of separate analyses of individual samples.

The number of samples taken during the day was dependent on the variability of the waste load. For cases where the flow and concentration were judged to be relatively constant only a few samples were taken. When the flow was intermittent, but rather constant in volume and concentration a random sampling of intermittent flows was made and the number of times the flow occurred noted so an estimate of the total waste load from that source could be developed. Sampling effort was concentrated at points where the flows and concentrations were judged to be the most variable and significant to the study.

Data Reduction

The raw waste concentrations and loading per unit of raw product were estimated for each plant using the following methodology.

The time-averaged flow rate was estimated for each plant (where plant refers to an individual process at an individual plant) by expressing the flow rate for each day in terms of an eight hour day and then taking an unweighted average. The average production time per day was determined for each process; however, the eight hour day was used to present the water and product flow rates for each subcategory in a uniform manner.

An estimate of the ratio of each parameter, except pH, in terms of weight or volume per unit weight of raw material was obtained using the mean of the ratio's estimator. The ratio of the parameter to production volume based on an eight hour day was calculated for each day and an average of these ratios was determined over all days. The range shown on the tables is the lowest and highest daily ratio. The weight to weight ratios were expressed in terms of kg/kkg, which is equivalent to 1 lb/1000 lbs.

The parameter concentrations were expressed in terms of the ratio of the load per unit of raw material to the flow per unit production. This weights the concentration obtained from individual daily samples according to the daily flow and production volumes. The ranges shown on the tables are the unweighted daily low and high concentrations obtained.

When the parameter time averages were obtained for each plant, all the plants in a subcategory were averaged together using equal weights to obtain a composite time-space representation.

A waste water material balance was determined by averaging the flows from each unit operation in a manner similar to that described for the total. The resulting average and range were expressed as percents of the total average flow. The waste characteristics of the flow from each operation were tabularized when data were available, or described qualitatively from on-site observations.

Raw product material balances were determined by obtaining food and by-product production figures when possible and results were expressed as percents of raw material input. The waste percentages shown are the differences between the raw material inputs and the finished product outputs.

FARM-RAISED CATFISH PROCESSING (Subcategory A)

The farm-raised catfish processing industry is relatively new (many plants are less than 5 years old) and employs similar techniques. This was essentially substantiated by analysis of the waste loading data. One variation was the large difference in waste water production depending on whether the fish were delivered in live haul trucks, on ice, or dry.

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.

There was some difficulty in obtaining samples of the total effluent since the waste water sources of the processes sampled were quite diverse and often had several exits from the plant. This was usually the case where older buildings designed for other purposes had been converted to catfish processing plants.

Wastewater Sources and Flows

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 were called upon to receive the final effluent. Figure 5 shows a typical catifsh process flow diagram, and Table 16 gives a breakdown of the flow sources. The three main flows formed the effluent and its constituent waste loads. The average waste water flow from the process plants sampled was 116 cu m/day (0.031 mgd) with a moderately large variation of about plus or minus 50 percent due mainly to holding tank and cleaning differences as mentioned. 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.

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 one of the the lowest total daily flows. 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 two times the flow of Plant 4. The other plants reused holding tank water in varying degrees.

Table 16. Catfish process material balance.

Wastewater Material Balance Summary

Average Flow, 116 cu m/day (0.0306 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	live holding tanks	59	55 - 64
b)	butchering (be-heading, eviscerating)	--	-- - --
c)	skinning	4	2 - 7
d)	cleaning	14	9 - 18
e)	packing (incl. sorting)	3	1 - 5
f)	clean-up	7	5 - 9
g)	washdown flows	13	9 - 16

Product Material Balance Summary

Average Raw Product Input Rate, 5.19 kkg/day (5.72 tons/day)

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

Table 17. Catfish process summary (5 plants)

Parameter	Mean	Range
Flow Rate, cu m/day	116	79 - 170
(mgd)	(0.0306)	(0.021 - 0.045)
Flow Ratio, l/kkg	23,000	15,800 - 31,500
(gal/ton)	(5510)	(3780 - 7550)
Settleable Solids, ml/l	7.8	-- - --
Settleable Solids Ratio, l/kkg	180	7.1 - 650
Screened Solids, mg/l	140	-- - --
Screened Solids Ratio, kg/kkg	3.2	2.5 - 3.9
Suspended Solids, mg/l	400	-- - --
Suspended Solids Ratio, kg/kkg	9.2	6.8 - 12
5 day BOD, mg/l	340	-- - --
5 day BOD Ratio, kg/kkg	7.9	5.5 - 9.2
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	700	-- - --
COD Ratio, kg/kkg	16	10 - 19
Grease and Oil, mg/l	200	-- - --
Grease and Oil Ratio, kg/kkg	4.5	3.8 - 5.6
Organic Nitrogen, mg/l	27	-- - --
Organic Nitrogen Ratio, kg/kkg	0.62	0.51 - 0.75
Ammonia-N, mg/l	0.96	-- - --
Ammonia-N Ratio, kg/kkg	0.022	0.0045 - 0.045
pH	6.3	5.8 - 7.0

Holding tank flows ran into the tanks from stationary faucets and when the tanks were full the flow drained through standpipe 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 was mainly made up of feces, slime, and regurgitated organic matter, the processing and clean-up wastes 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.

Product Flow

Table 16 shows the average breakdown of the raw material into food product, by-products and waste. The percent recovered for food depends on the size of the fish and to a slight degree whether manual or mechanical skinning is used. The average is about 63 percent. Some plants in rural areas dump or bury the waste solids; however, most save the solids and ship them to a rendering plant.

The average production rate is about 5.2 kkg/day (5.7 tons/day) with a range from 3 to 7 kkg/day. The average shift length is about 8 hours but is quite variable in some plants due to raw material supply.

Raw Waste Loadings

Table 17 gives the combined average flow and loadings. Tables 18 through 22 list the flows and loadings for each of the five processing operations sampled. The average BOD loading was 7.9 kg/kkg with a range from 5.5 to 9.2 kg/kkg. The average BOD concentration was 350 mg/l.

In developing the Catfish Process Summary, Table 17, the flow data from Plant 2 was omitted. The excessive water use of 31,500 l/kkg was due to draining the holding tank completely each time

Table 18. Catfish process (plant 1).

Parameter	Mean	Range		
Flow Rate, cu m/day	148	136	-	155
(mgd)	(0.039)	(0.036	-	0.041)
Flow Ratio, l/kkg	20,900	18,400	-	24,500
(gal/ton)	(5020)	(4400	-	5880)
Settleable Solids, ml/l	1.2	--	-	--
Settleable Solids Ratio, l/kkg	25	6.6	-	44
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	530	--	-	--
Suspended Solids Ratio, kg/kkg	11	6.1	-	16
5 day BOD, mg/l	440	--	-	--
5 day BOD Ratio, kg/kkg	9.2	3.7	-	13
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	860	--	-	--
COD Ratio, kg/kkg	18	11	-	23
Grease and Oil, mg/l	270	--	-	--
Grease and Oil Ratio, kg/kkg	5.6	3.5	-	7.8
Organic Nitrogen, mg/l	36	--	-	--
Organic Nitrogen Ratio, kg/kkg	0.75	0.32	-	1.1
Ammonia-N, mg/l	2.2	--	-	--
Ammonia-N Ratio, kg/kkg	0.045	0.0046	-	0.095
pH	5.9	5.5	-	6.3

3 samples

Table 19. Catfish process (plant 2).

Parameter	Mean	Range
Flow Rate, cu m/day	170	102 - 204
(mgd)	(0.045)	(0.027 - 0.054)
Flow Ratio, l/kkg	31,500	24,400 - 37,000
(gal/ton)	(7550)	(5860 - 8860)
Settleable Solids, ml/l	0.4	-- - --
Settleable Solids Ratio, l/kkg	14	11 - 17
Screened Solids, mg/l	120	-- - --
Screened Solids Ratio, kg/kkg	3.9	3.2 - 4.6
Suspended Solids, mg/l	270	-- - --
Suspended Solids Ratio, kg/kkg	8.5	6.4 - 10
5 day BOD, mg/l	230	-- - --
5 day BOD Ratio, kg/kkg	7.2	6.3 - 7.9
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	540	-- - --
COD Ratio, kg/kkg	17	12 - 28
Grease and Oil, mg/l	120	-- - --
Grease and Oil Ratio, kg/kkg	3.9	2.7 - 4.3
Organic Nitrogen, mg/l	20	-- - --
Organic Nitrogen Ratio, kg/kkg	0.64	0.48 - 0.73
Ammonia-N, mg/l	0.51	-- - --
Ammonia-N Ratio, kg/kkg	0.016	0.014 - 0.018
pH	7.0	6.8 - 7.2

5 samples

Table 20. Catfish process (plant 3).

Parameter	Mean	Range		
Flow Rate, cu m/day	79	64	-	95
(mgd)	(0.021)	(0.017	-	0.025)
Flow Ratio, l/kkg	15,800	10,200	-	17,200
(gal/ton)	(3780)	(2450	-	4120)
Settleable Solids, ml/l	0.45	--	-	--
Settleable Solids Ratio, l/kkg	7.1	6.3	-	13
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	430	--	-	--
Suspended Solids Ratio, kg/kkg	6.8	5.2	-	7.9
5 day BOD, mg/l	570	--	-	--
5 day BOD Ratio, kg/kkg	9.0	7.3	-	10
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	1200	--	-	--
COD Ratio, kg/kkg	19	14	-	20
Grease and Oil, mg/l	260	--	-	--
Grease and Oil Ratio, kg/kkg	4.1	2.2	-	6.0
Organic Nitrogen, mg/l	42	--	-	--
Organic Nitrogen Ratio, kg/kkg	0.66	0.35	-	0.83
Ammonia-N, mg/l	0.28	--	-	--
Ammonia-N Ratio, kg/kkg	0.0045	0.002	-	0.005
pH	5.8	5.2	-	6.3

2 samples

Table 21. Catfish process (plant 4).

Parameter	Mean	Range		
Flow Rate, cu m/day	80	76	-	85
(mgd)	(0.0212)	(0.0201	-	0.0225)
Flow Ratio, l/kkg	26,300	23,400	-	28,400
(gal/ton)	(6310)	(5610	-	6810)
Settleable Solids, ml/l	25	--	-	--
Settleable Solids Ratio, l/kkg	650	640	-	670
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	290	--	-	--
Suspended Solids Ratio, kg/kkg	7.5	6.0	-	8.9
5 day BOD, mg/l	210	--	-	--
5 day BOD Ratio, kg/kkg	5.5	4.3	-	6.9
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	380	--	-	--
COD Ratio, kg/kkg	10	7.7	-	16
Grease and Oil, mg/l	140	--	-	--
Grease and Oil Ratio, kg/kkg	3.8	2.9	-	4.6
Organic Nitrogen, mg/l	20	--	-	--
Organic Nitrogen Ratio, kg/kkg	0.53	0.42	-	0.80
Ammonia-N, mg/l	0.53	--	-	--
Ammonia-N Ratio, kg/kkg	0.014	0.0085	-	0.020
pH	--	--	-	--

9 samples

Table 22. Catfish process (plant 5).

Parameter	Mean	Range
Flow Rate, cu m/day	102	68 - 125
(mgd)	(0.027)	(0.018 - 0.033)
Flow Ratio, l/kkg	20,500	12,100 - 28,000
(gal/ton)	(4910)	(2900 - 6720)
Settleable Solids, ml/l	9.3	-- - --
Settleable Solids Ratio, l/kkg	190	170 - 230
Screened Solids, mg/l	120	-- - --
Screened Solids Ratio, kg/kkg	2.5	2.1 - 3.2
Suspended Solids, mg/l	580	-- - --
Suspended Solids Ratio, kg/kkg	12	5.1 - 18
5 day BOD, mg/l	410	-- - --
5 day BOD Ratio, kg/kkg	8.4	-- - --
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	730	-- - --
COD Ratio, kg/kkg	15	8.7 - 22
Grease and Oil, mg/l	260	-- - --
Grease and Oil Ratio, kg/kkg	5.3	3.2 - 8.6
Organic Nitrogen, mg/l	25	-- - --
Organic Nitrogen Ratio, kg/kkg	0.51	-- - --
Ammonia-N, mg/l	1.5	-- - --
Ammonia-N Ratio, kg/kkg	0.031	-- - --
pH	6.6	6.5 - 6.7

8 samples

the fish were removed. Common practice in the industry includes holding tank water recycle with constant runoff and intermittent drainage.

CONVENTIONAL BLUE CRAB (Subcategory B)

Based on preliminary observations of blue crab processing operations it became rather obvious that this part of the industry should be divided into two subcategories depending on the use of hand or machine picking. Subsequent analysis of waste loading data confirmed this judgment. The only exception to the two categories was perhaps the modern, high volume, mechanized plants which contribute a relatively higher waste load per unit of raw material. Much of this would be avoidable, however, through concerted in-plant water use reduction.

The conventional process using manual picking was considered to be relatively uniform; therefore, only two processing operations were selected for sampling.

Wastewater Sources and Flows

All the plants sampled used domestic water supplies. The conventional process shown in Figure 12 produced a small amount of waste water, averaging only 2.52 cu m/day (660 gal/day). Table 23 gives a breakdown of the flow from each unit operation as a percent of the total. The majority of the flow (60 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 waste water streams.

Product Flow

The proportion of the raw material going into food products, by-products and waste is given on Table 23. About 14 percent of the crab is utilized for food (Soderquist, 1970). Up to 80 percent could be captured for by-products, which would leave about 6 percent entering the waste water flow.

The maximum conventional rate is about 500 kg/hr (1100 lbs/hr). The average production rate was about two-thirds of the maximum. During a day's operation the processing is continuous; however, the length of the shift and the number of days the plants operate is intermittent due to fluctuations in the raw material supply. The average processing time was 7.2 hrs/day for the conventional plant.

Table 23. Conventional blue crab process material balance.

Wastewater Material Balance Summary

Average Flow, 2.52 cu m/day (0.000665 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	6	-- - --

Table 24. Conventional blue crab process summary (2 plants).

Parameter	Mean	Range		
Flow Rate, cu m/day	2.52	2.38	-	2.65
(mgd)	(0.000665)	(0.00063	-	0.00070)
Flow Ratio, l/kkg	1190	1060	-	1310
(gal/ton)	(285)	(255	-	315)
Settleable Solids, ml/l	4.4	--	-	--
Settleable Solids Ratio, l/kkg	5.2	4.3	-	6.2
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	620	--	-	--
Suspended Solids Ratio, kg/kkg	0.74	0.7	-	0.78
5 day BOD, mg/l	4400	--	-	--
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	6300	--	-	--
COD Ratio, kg/kkg	7.5	7.2	-	7.8
Grease and Oil, mg/l	220	--	-	--
Grease and Oil Ratio, kg/kkg	0.26	0.21	-	0.30
Organic Nitrogen, mg/l	760	--	-	--
Organic Nitrogen Ratio, kg/kkg	0.90	0.80	-	1.0
Ammonia-N, mg/l	50	--	-	--
Ammonia-N Ratio, kg/kkg	0.06	--	-	--
pH	7.5	7.2	-	7.9

Table 25. Conventional blue crab process (plant 1).

Parameter	Mean	Range		
Flow Rate, cu m/day	2.65	2.50	-	6.43
(mgd)	(0.00070)	(0.00066	-	0.0017)
Flow Ratio, l/kkg	1310	1140	-	1520
(gal/ton)	(315)	(273	-	364)
Settleable Solids, ml/l	3.3	--	-	--
Settleable Solids Ratio, l/kkg	4.3	1.8	-	6.8
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	600	--	-	--
Suspended Solids Ratio, kg/kkg	0.78	0.2	-	1.5
5 day BOD, mg/l	3600	--	-	--
5 day BOD Ratio, kg/kkg	4.8	4.7	-	5.0
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	5500	--	-	--
COD Ratio, kg/kkg	7.2	6.8	-	7.8
Grease and Oil, mg/l	230	--	-	--
Grease and Oil Ratio, kg/kkg	0.30	0.24	-	0.37
Organic Nitrogen, mg/l	610	--	-	--
Organic Nitrogen Ratio, kg/kkg	0.80	0.66	-	1.0
Ammonia-N, mg/l	46	--	-	--
Ammonia-N Ratio, kg/kkg	0.06	0.05	-	0.08
pH	7.9	--	-	--

9 samples

Table 26. Conventional blue crab process (plant 2).

Parameter	Mean	Range		
Flow Rate, cu m/day	2.38	2.2	-	2.8
(mgd)	(0.00063)	(0.00058	-	0.00073)
Flow Ratio, l/kkg	1060	972	-	1270
(gal/ton)	(255)	(233	-	304)
Settleable Solids, ml/l	5.8	--	-	--
Settleable Solids Ratio, l/kkg	6.2	0	-	28
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	660	--	-	--
Suspended Solids Ratio, kg/kkg	0.7	0.2	-	1.2
5 day BOD, mg/l	5200	--	-	--
5 day BOD Ratio, kg/kkg	5.5	3.5	-	9.0
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	7400	--	-	--
COD Ratio, kg/kkg	7.8	5.4	-	12
Grease and Oil, mg/l	200	--	-	--
Grease and Oil Ratio, kg/kkg	0.21	0.14	-	0.36
Organic Nitrogen, mg/l	940	--	-	--
Organic Nitrogen Ratio, kg/kkg	1.0	0.55	-	1.2
Ammonia-N, mg/l	57	--	-	--
Ammonia-N Ratio, kg/kkg	0.06	0.04	-	0.07
pH	7.2	6.1	-	7.8

9 samples

Raw Waste Loadings

Table 24 gives the combined average conventional flows and loadings and Tables 25 and 26 list the average flows and loadings for each parameter for each of the two conventional processes sampled.

The waste loadings from the two conventional processes were quite similar. The flow ratio ranged from 1060 to 1315 l/kkg (255 to 315 gal/ton). The BOD ranged from 4.8 to 5.5 kg/kkg and the COD ranged from 7.2 to 7.8 kg/kkg.

Mechanized Blue Crab (Subcategory C)

The mechanized blue crab process using the claw picking machine had greater variability than the conventional process; ranging from an essentially conventional operation with a mechanical picker used intermittently for the claws, to modern facilities employing several mechanical pickers and a pastuerization operation to give longer product shelf life. A relatively poor harvest and time limitations, however, permitted only two mechanized processes to be sampled. This was a significant sample of the industry, however, because less than ten plants fall into the subcategory.

Conventional plants which employed mechanical claw pickers on an intermittent basis and were considered to be mechanized plants.

Wastewater Sources and Flow

The mechanized process shown in Figure 13 produced considerably more waste water than the conventional processes. The average flow was about 178 cu m/day (0.047 mgd), with the mechanical picker contributing about 90 percent of the volume. Table 27 gives a breakdown of the 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 liter (275 gal) and were dumped once a shift. The concentrations of sodium chloride were very high, being about 100,000 to 200,000 mg/l (as chloride).

Product Flow

The proportion of the raw material going into food products, by-products and waste is given in Table 27. About 14 percent of the crab is utilized for food (Soderquist, 1970). Up to 80 percent could be captured for byproducts, which would leave about 6 percent entering the waste water flow.

Table 27. Mechanized blue crab process material balance.

Wastewater Material Balance Summary

Average Flow, 176 cu m/day (0.0465 mgd)

Unit Operation	% of Average Flow	Range, %
a) machine picking	90.5	-- - --
b) brine tank	0.5	-- - --
c) washdown	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	6	-- - --

Table 28. Mechanized blue crab process summary (2 plants).

Parameter	Mean	Range	
Flow Rate, cu m/day	176	76 -	276
(mgd)	(0.0465)	(0.020 -	0.07[illegible]
Flow Ratio, l/kkg	36,800	29,000	- 44,600
(gal/ton)	(8830)	(6960	- 10,700)
Settleable Solids, ml/l	2.6	-- -	--
Settleable Solids Ratio, l/kkg	94	77 -	110
Screened Solids, mg/l	--	-- -	--
Screened Solids Ratio, kg/kkg	--	-- -	--
Suspended Solids, mg/l	330	-- -	--
Suspended Solids Ratio, kg/kkg	12	-- -	--
5 day BOD, mg/l	600	-- -	--
5 day BOD Ratio, kg/kkg	22	22 -	23
20 day BOD, mg/l	--	-- -	--
20 day BOD Ratio, kg/kkg	--	-- -	--
COD, mg/l	980	-- -	--
COD Ratio, kg/kkg	36	29 -	42
Grease and Oil, mg/l	150	-- -	--
Grease and Oil Ratio, kg/kkg	5.6	4.3 -	6.9
Organic Nitrogen, mg/l	98	-- -	--
Organic Nitrogen Ratio, kg/kkg	3.6	2.7 -	4.4
Ammonia-N, mg/l	5.4	-- -	--
Ammonia-N Ratio, kg/kkg	0.20	0.16 -	0.24
pH	7.0	6.9 -	7.2

The maximum mechanized production rate is about 1.8 kkg/hr (2 tons/hr) on a raw material basis. The average production rate was about two-thirds of the maximum. During a day's operation the processing is continuous; however, the length of the shift and the number of days the plants operate is intermittent due to fluctuations in the raw material supply. The average processing time was 4.1 hrs/day for the mechanized plant, on operating days.

Raw Waste Loadings

Table 28 gives the combined mechanized plant averages, and Tables 29 and 30 list the average flows and loadings for each of the two mechanized processes sampled.

The concentration of all the parameters were much higher for the conventional than the mechanized processes. For example, the average BOD_5 concentration from the conventional plants was 4410 mg/l and only 650 mg/l from the mechanized plants. However, this was due to the much greater water use in the mechanized process, which diluted the waste. The volume of water used per unit of raw material was about 30 times greater in the mechanized than the conventional process. The waste loads per unit of raw material were, therefore, much lower for the conventional process. For example, the average BOD_5 ratio from the conventional process was 5.2 kg/kkg, compared to 22.7 kg/kkg from the mechanized process.

The waste loading from the two mechanized processes were more variable than the conventional processes. The flow ratio ranged from 29,000 to 44,900 l/kkg (6960 to 10,760 gal/ton), and the COD ratio ranged from 29 to 42 kg/kkg. The reason for the larger variation was that one process, (Table 30) was a modern, high production operation, utilizing water in many subprocesses while the other was a more typical older facility.

ALASKA CRAB

The waste characteristics of the Alaska crab industry were monitored during a period from March through June 1973. The monitoring team attempted to sample each of the three crab species (king, Dungeness and tanner) processed in Alaska. However, the investigation was limited to mostly tanner crab because of seasonality and availability of raw product.

Plants were selected for sampling primarily on the basis of raw material availability, finished product form and accessibility of waste discharge points. Sampling efforts were centered around the three primary forms of finished product: canned meat, frozen meat, and frozen sections. Each plant marketing a given product uses the same basic unit operations with small process variations. King and tanner crab data were combined because the same equipment is used to process each and the waste strengths were found to be similar.

Table 29. Mechanized blue crab process (plant 3).

Parameter	Mean	Range		
Flow Rate, cu m/day	76	19	-	178
(mgd)	(0.020)	(0.005	-	0.047)
Flow Ratio, l/kkg	29,000	9850	-	50,900
(gal/ton)	(6960)	(2360	-	12,200)
Settleable Solids, ml/l	2.6	--	-	--
Settleable Solids Ratio, l/kkg	77	33	-	124
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	410	--	-	--
Suspended Solids Ratio, kg/kkg	12	8.3	-	16
5 day BOD, mg/l	790	--	-	--
5 day BOD Ratio, kg/kkg	23	12	-	32
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	1400	--	-	--
COD Ratio, kg/kkg	42	29	-	65
Grease and Oil, mg/l	150	--	-	--
Grease and Oil Ratio, kg/kkg	4.3	2.3	-	8.5
Organic Nitrogen, mg/l	150	--	-	--
Organic Nitrogen Ratio, kg/kkg	4.4	3.4	-	5.2
Ammonia-N, mg/l	8.3	--	-	--
Ammonia-N Ratio, kg/kkg	0.24	0.19	-	0.29
pH	6.9	6.1	-	7.8

4 samples

Table 30. Mechanized blue crab process (plant 4).

Parameter	Mean	Range		
Flow Rate, cu m/day	276	273	-	284
(mgd)	(0.073)	(0.072	-	0.075)
Flow Ratio, l/kkg	44,600	36,900	-	60,500
(gal/ton)	(10,700)	(8,840	-	14,500)
Settleable Solids, ml/l	2.5	--	-	--
Settleable Solids Ratio, l/kkg	110	57	-	160
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	270	--	-	--
Suspended Solids Ratio, kg/kkg	12	7.9	-	16
5 day BOD, mg/l	490	--	-	--
5 day BOD Ratio, kg/kkg	22	14	-	27
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	650	--	-	--
COD Ratio, kg/kkg	29	12	-	51
Grease and Oil, mg/l	150	--	-	--
Grease and Oil Ratio, kg/kkg	6.9	3.6	-	7.9
Organic Nitrogen, mg/l	60	--	-	--
Organic Nitrogen Ratio, kg/kkg	2.7	2.2	-	3.6
Ammonia-N, mg/l	3.6	--	-	--
Ammonia-N Ratio, kg/kkg	0.16	0.13	-	0.22
pH	7.2	6.9	-	8.2

3 samples

Each process sampled used a grinder to facilitate fluming of the solid waste from the butchering and meat extraction operations. It was obvious that this method increased the wastewater load, as opposed to handling the solids in a "dry" manner. To substantiate this, samples were taken with and without grinding. Flow proportioned samples of the total effluent were taken periodically during each sampling day. The individual samples were combined with the appropriate quantity of batch and intermittent flow wastes to approximate the average waste load for that particular shift.

The samples were screened with a 20 mesh Tyler screen and the screened solids weighed. The settleable solids and pH were determined in the field. Three aliquots of the screened sample were sent to the laboratory where the remaining parameters were analyzed. The relative waste load was then determined by relating the shift length and raw material weight to each parameter.

Wastewater Sources and Flow

Each of the plants sampled in Kodiak, Alaska uses city water for processing and water volumes and flow rates were easily obtained from water meter readings.

Plants outside of Kodiak use mostly salt water in processing except for the cooking operation which uses local surface waters.

Figures 14 through 16 show the process flow diagrams for the frozen and canned meat and section processes respectively. The average total waste water flow and the breakdown per unit operation is given in Table 31 for the section process, and in Table 32 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 31) 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 meat (60 percent) and contributed a medium amount of waste. The butcher and cooking operations contributed a high strength waste but were relatively low flows. The sorting, freezing and packing operations contributed low flow and low-strength wastes. Most of the water in the frozen and canned meat process (Table 32) 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 26 percent of the total volume.

Tables 33 and 34 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 170-230 l/min (45-60 gal/min). Most plants processing sections used only one grinder while almost all frozen and canned meat operations used two.

Product Flow

Table 31 shows the estimated breakdown of the raw material into food, by-product and waste. "Food" product recovery averaged about 64 percent for the tanner crab sections process. The amount of food product ranged from 10-20 percent for the frozen and canned meat plants using tanner crab. The wide range was due to two exceptional plants, one which discarded shoulder meat (a practice since changed), thus lowering their food product recovery and a second plant which employed a mechanical picker, brine separator, and belt water screening system which increased their recovery. The other three plants sampled were typical and had recovery ranges of between 14 and 17 percent.

Recovery varies with age of the crab as well as species. Yield from king crab varies from 25 to 36 percent (an exuviant weight) depending on age (Powel and Nickerson, 1963). The recovery increases until the crab reaches a certain age and then decreases as it grows older. Recovery also decreases after molting. This decrease in recovery means a greater percentage of the crab is wasted.

By-product recovery is a new phase of the Alaska crab industry. Tangential screens are presently being installed in regions with solids disposal facilities. Unfortunately only one screen was in operation while the field crew was in Kodiak and the monitoring was completed before the screening operation was standardized.

The by-product recovery figures listed were estimated by adding the settleable solids and suspended solids and then calculating the by-product as the difference between 100 percent and the sum of the waste and food product. By-product recovery estimates compare favorably with values listed by Peterson (1972). The raw material input rate was about the same for the sections, frozen and canned meat processes (12 to 13 kkg/day).

The shift length varied from plant to plant depending on plant policy and availability of personnel and raw material. During the peak season most plants ran two shifts daily, each from 8 to 10 hours. Otherwise the plants usually ran one 8 to 10 hour shift or until the raw material supply was depleted.

Raw Waste Loadings

Comparing the Alaskan crab whole cook and section process summary, Table 36, to the Alaskan crab frozen and canned meat process summary, Table 38, reveals significant differences between the product types. The meat process uses approximately twice as much water as the whole and section process, and the BOD_5 ratio is 60 percent higher for the meat process. These differences can be attributed to the fact that mechanical pickers are used to extract the meat from the shell in the canned and frozen meat process. In the whole and section process after removal of the viscera and gills the crabs are frozen whole or in sections with the shell in place.

Tables 39 through 42 list the flows and waste loads from the four section processes sampled without grinders. Tables 43 through 45 list the flows and waste loads from the three frozen and canned meat processes sampled without grinders. Tables 46 and 47 show the combined section and the combined freezing and canning processes respectively with grinding; it can be seen that the freezing load was significantly higher than that from 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.

Tables 48 through 51 list the flows and waste loads from the four section processes sampled with grinders. Tables 52 through 55 list the flows and waste loads from the four frozen and canned meat processes sampled with grinders.

Alaskan Crab Meat Processing (Subcategories D and E)

Table 37 lists the combined averages obtained from sampling one frozen and one canned meat process. It can be seen that the frozen and canned meat process used about 100 percent more water than the average whole cook or sections operation per kkg processed.

Tables 43 and 44 show the waste loading from the frozen and canned meat processes respectively. The water flow and waste loadings per unit of raw material were about the same for both plants. Table 45 shows the waste characteristics from a frozen meat process located in a remote area, Plant S-2. The water flow per unit of raw material was very high compared to the other plants sampled. This was due to the large amount of sea water used for fluming and cooling. The incoming BOD_5 was zero because of the large amount of chlorine used to disinfect the salt water. The apparent COD loading is relatively high because the water coming into the process averaged 145 mg/l COD. Chloride interference in the COD analysis is discussed in Section VI. Plant S-2 was omitted from the summary table because of its unusually high flows.

Table 31. Material balance - Alaska tanner and king crab sections process and Alaska Dungeness crab whole cooks (without waste grinding).

Wastewater Material Balance Summary

Average Flow, 220 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, 13.06 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

Table 32. Material balance - Alaska tanner crab frozen and canned meat process (without waste grinding).

Wastewater Material Balance Summary

Average Flow, 341 cu m/day (0.090 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, 12.27 kkg/day (13.53 tons/day)

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

* Canning operation only

Table 33. Material balance - Alaska tanner and king crab sections process (with waste grinding).

Wastewater Material Balance Summary

Average Flow, 364 cu m/day (0.096 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, 13.06 kkg/day (14.40 tons/day)

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

Table 34. Material balance - Alaska tanner crab frozen and canned meat process (with waste grinding).

Wastewater Material Balance Summary

Average Flow, 440 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, 8.40 kkg/day (9.25 tons/day)

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

* Canning operation only

Table 35. Alaska crab whole cook and section process summary - without grinding (3 plants).*

Parameter	Mean	Range
Flow Rate, cu m/day	200	136 - 318
(mgd)	(0.053)	(0.036 - 0.084)
Flow Ratio, l/kkg	16,900	15,400 - 17,800
(gal/ton)	(4040)	(3690 - 4260)
Settleable Solids, ml/l	2.7	-- - --
Settleable Solids Ratio, l/kkg	46	15 - 100
Screened Solids, mg/l	1300	-- - --
Screened Solids Ratio, kg/kkg	22	18 - 25
Suspended Solids, mg/l	210	-- - --
Suspended Solids Ratio, kg/kkg	3.5	1.0 - 8.0
5 day BOD, mg/l	330	-- - --
5 day BOD Ratio, kg/kkg	5.6	4.0 - 8.0
20 day BOD, mg/l	1200	-- - --
20 day BOD Ratio, kg/kkg	21	-- - --
COD, mg/l	710	-- - --
COD Ratio, kg/kkg	12	6.4 - 19
Grease and Oil, mg/l	30	-- - --
Grease and Oil Ratio, kg/kkg	0.5	0.3 - 0.7
Organic Nitrogen, mg/l	77	-- - --
Organic Nitrogen Ratio, kg/kkg	1.3	1.1 - 1.8
Ammonia-N, mg/l	2.9	-- - --
Ammonia-N Ratio, kg/kkg	0.05	0.02 - 0.08
pH	7.6	7.4 - 8.2

* process water only, table excludes data from plant K8 (Table 39).

Table 36. Alaska crab whole cook and section process - without grinding (3 plants), including clean-up.*

Parameter	Mean	Range
Flow Rate, cu m/day	220	-- - --
(mgd)	(0.058)	-- - --
Flow Ratio, l/kkg	18,600	-- - --
(gal/ton)	(4440)	-- - --
Settleable Solids, ml/l	2.8	-- - --
Settleable Solids Ratio, l/kkg	52	-- - --
Screened Solids, mg/l	1300	-- - --
Screened Solids Ratio, kg/kkg	24	-- - --
Suspended Solids, mg/l	210	-- - --
Suspended Solids Ratio, kg/kkg	3.9	-- - --
5 day BOD, mg/l	320	-- - --
5 day BOD Ratio, kg/kkg	6.0	-- - --
20 day BOD, mg/l	1200	-- - --
20 day BOD Ratio, kg/kkg	23	-- - --
COD, mg/l	700	-- - --
COD Ratio, kg/kkg	13	-- - --
Grease and Oil, mg/l	30	-- - --
Grease and Oil Ratio, kg/kkg	0.56	-- - --
Organic Nitrogen, mg/l	75	-- - --
Organic Nitrogen Ratio, kg/kkg	1.4	-- - --
Ammonia-N, mg/l	2.8	-- - --
Ammonia-N Ratio, kg/kkg	0.053	-- - --
pH	7.6	-- - --

* Clean up water is included in this table. The values were arrived at by adding a percentage to the flow rates and wasteload rations shown in Table 35. The percentages are 10, 10, 14, 10.5, 11, 8, 8, 7, 12.5, 5.6, 6 from top to bottom respectively. The ratio was then converted to mg/l.

Table 37. Alaska crab frozen and canned meat process summary - without grinding.*

Parameter	Mean	Range		
Flow Rate, cu m/day	310	246	-	375
(mgd)	(0.082)	(0.065	-	0.099)
Flow Ratio, l/kkg	32,700	--	-	--
(gal/ton)	(7840)	--	-	--
Settleable Solids, ml/l	0.49	--	-	--
Settleable Solids Ratio, l/kkg	16	11	-	22
Screened Solids, mg/l	3700	--	-	--
Screened Solids Ratio, kg/kkg	120	79	-	157
Suspended Solids, mg/l	170	--	-	--
Suspended Solids Ratio, kg/kkg	5.6	4.4	-	6.7
5 day BOD, mg/l	270	--	-	--
5 day BOD Ratio, kg/kkg	8.9	8.4	-	9.4
20 day BOD, mg/l	400	--	-	--
20 day BOD Ratio, kg/kkg	13	--	-	--
COD, mg/l	430	--	-	--
COD Ratio, kg/kkg	14	12	-	16
Grease and Oil, mg/l	22	--	-	--
Grease and Oil Ratio, kg/kkg	0.72	0.65	-	0.78
Organic Nitrogen, mg/l	73	--	-	--
Organic Nitrogen Ratio, kg/kkg	2.4	1.8	-	3.0
Ammonia-N, mg/l	2.4	--	-	--
Ammonia-N Ratio, kg/kkg	0.08	0.07	-	0.10
pH	7.4	7.4	-	7.5

* process water only

2 plants

Table 38. Alaska crab frozen and canned meat process--without grinding--including clean-up.*

Parameter	Mean	Range
Flow Rate, cu m/day	341	-- - --
(mgd)	(0.090)	-- - --
Flow Ratio, l/kkg	36,000	-- - --
(gal/ton)	(8620)	-- - --
Settleable Solids, ml/l	0.5	-- - --
Settleable Solids Ratio, l/kkg	18	-- - --
Screened Solids, mg/l	3600	-- - --
Screened Solids Ratio, kg/kkg	130	-- - --
Suspended Solids, mg/l	170	-- - --
Suspended Solids Ratio, kg/kkg	6.2	-- - --
5 day BOD, mg/l	270	-- - --
5 day BOD Ratio, kg/kkg	9.6	-- - --
20 day BOD, mg/l	390	-- - --
20 day BOD Ratio, kg/kkg	14	-- - --
COD, mg/l	420	-- - --
COD Ratio, kg/kkg	15	-- - --
Grease and Oil, mg/l	22	-- - --
Grease and Oil Ratio, kg/kkg	0.81	-- - --
Organic Nitrogen, mg/l	69	-- - --
Organic Nitrogen Ratio, kg/kkg	2.5	-- - --
Ammonia-N, mg/l	2.4	-- - --
Ammonia-N Ratio, kg/kkg	0.085	-- - --
pH	7.4	-- - --

* Clean up water is included in this table. The values were arrived at by adding a percentage to the flow rates and wasteload ratios shown in Table 37. The percentages are 10, 10, 14, 10.5, 11, 8, 8, 7, 12.5, 5.6, 6 from top to bottom respectively. The ratio was then converted to mg/l.

Table 39. Alaska Dungeness crab whole cook process without grinding (plant K8).*

Parameter	Mean	Range
Flow Rate, cu m/day	280	-- - --
(mgd)	(0.074)	-- - --
Flow Ratio, l/kkg	29,900	-- - --
(gal/ton)	(7160)	-- - --
Settleable Solids, ml/l	1.1	-- - --
Settleable Solids Ratio, l/kkg	33	-- - --
Screened Solids, mg/l	370	-- - --
Screened Solids Ratio, kg/kkg	11	-- - --
Suspended Solids, mg/l	67	-- - --
Suspended Solids Ratio, kg/kkg	2	-- - --
5 day BOD, mg/l	800	-- - --
5 day BOD Ratio, kg/kkg	24	-- - --
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	1500	-- - --
COD Ratio, kg/kkg	44	-- - --
Grease and Oil, mg/l	27	-- - --
Grease and Oil Ratio, kg/kkg	0.8	-- - --
Organic Nitrogen, mg/l	67	-- - --
Organic Nitrogen Ratio, kg/kkg	2.0	-- - --
Ammonia-N, mg/l	6.7	-- - --
Ammonia-N Ratio, kg/kkg	0.2	-- - --
pH	8.2	-- - --

* process water only

1 sample

Table 40. Alaska Dungeness crab whole cook process without grinding (plant K1).*

Parameter	Mean	Range
Flow Rate, cu m/day	144	-- - --
(mgd)	(0.038)	-- - --
Flow Ratio, l/kkg	17,400	-- - --
(gal/ton)	(4160)	-- - --
Settleable Solids, ml/l	0.86	-- - --
Settleable Solids Ratio, l/kkg	15	-- - --
Screened Solids, mg/l	1000	-- - --
Screened Solids Ratio, kg/kkg	18	-- - --
Suspended Solids, mg/l	57	-- - --
Suspended Solids Ratio, kg/kkg	1.0	-- - --
5 day BOD, mg/l	280	-- - --
5 day BOD Ratio, kg/kkg	4.8	-- - --
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	550	-- - --
COD Ratio, kg/kkg	9.6	-- - --
Grease and Oil, mg/l	29	-- - --
Grease and Oil Ratio, kg/kkg	0.5	-- - --
Organic Nitrogen, mg/l	100	-- - --
Organic Nitrogen Ratio, kg/kkg	1.8	-- - --
Ammonia-N, mg/l	4.6	-- - --
Ammonia-N Ratio, kg/kkg	0.08	-- - --
pH	8.2	-- - --

* process water only — 1 sample

Table 41. Alaska king crab sections process without grinding (plant K11).*

Parameter	Mean	Range
Flow Rate, cu m/day	318	284 - 356
(mgd)	(0.084)	(0.075 - 0.094)
Flow Ratio, l/kkg	15,400	12,600 - 17,600
(gal/ton)	(3690)	(3010 - 4230)
Settleable Solids, ml/l	1.6	-- - --
Settleable Solids Ratio, l/kkg	24	13 - 35
Screened Solids, mg/l	1600	-- - --
Screened Solids Ratio, kg/kkg	24	7 - 35
Suspended Solids, mg/l	100	-- - --
Suspended Solids Ratio, kg/kkg	1.6	1.2 - 2.6
5 day BOD, mg/l	260	-- - --
5 day BOD Ratio, kg/kkg	4.0	3.0 - 5.0
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	420	-- - --
COD Ratio, kg/kkg	6.4	4.5 - 7.5
Grease and Oil, mg/l	19	-- - --
Grease and Oil Ratio, kg/kkg	0.3	0.1 - 0.4
Organic Nitrogen, mg/l	71	-- - --
Organic Nitrogen Ratio, kg/kkg	1.1	0.8 - 1.4
Ammonia-N, mg/l	1.3	-- - --
Ammonia-N Ratio, kg/kkg	0.02	0.02 - 0.03
pH	7.4	7.1 - 7.7

* process water only

5 samples

Table 42. Alaska tanner crab sections process without grinding (plant K6).*

Parameter	Mean	Range
Flow Rate, cu m/day	136	132 - 144
(mgd)	(0.036)	(0.035 - 0.038)
Flow Ratio, l/kkg	17,800	14,200 - 21,300
(gal/ton)	(4260)	(3400 - 5100)
Settleable Solids, ml/l	5.6	-- - --
Settleable Solids Ratio, l/kkg	100	36 - 190
Screened Solids, mg/l	1400	-- - --
Screened Solids Ratio, kg/kkg	25	14 - 43
Suspended Solids, mg/l	450	-- - --
Suspended Solids Ratio, kg/kkg	8.0	5.0 - 11
5 day BOD, mg/l	450	-- - --
5 day BOD Ratio, kg/kkg	8.0	1.0 - 19
20 day BOD, mg/l	1200	-- - --
20 day BOD Ratio, kg/kkg	21	13 - 30
COD, mg/l	1100	-- - --
COD Ratio, kg/kkg	19	13 - 35
Grease and Oil, mg/l	39	-- - --
Grease and Oil Ratio, kg/kkg	0.7	0.5 - 1.0
Organic Nitrogen, mg/l	62	-- - --
Organic Nitrogen Ratio, kg/kkg	1.1	0.9 - 1.4
Ammonia-N, mg/l	2.8	-- - --
Ammonia-N Ratio, kg/kkg	0.05	0.04 - 0.7
pH	7.6	7.5 - 7.8

* process water only

4 samples

Table 43. Alaska tanner crab frozen meat process without grinding (plant K6).*

Parameter	Mean	Range
Flow Rate, cu m/day	375	-- - --
(mgd)	(0.099)	-- - --
Flow Ratio, l/kkg	32,700	-- - --
(gal/ton)	(7840)	-- - --
Settleable Solids, ml/l	0.67	-- - --
Settleable Solids Ratio, l/kkg	22	-- - --
Screened Solids, mg/l	4800	-- - --
Screened Solids Ratio, kg/kkg	157	-- - --
Suspended Solids, mg/l	130	-- - --
Suspended Solids Ratio, kg/kkg	4.4	-- - --
5 day BOD, mg/l	290	-- - --
5 day BOD Ratio, kg/kkg	9.4	-- - --
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	370	-- - --
COD Ratio, kg/kkg	12	-- - --
Grease and Oil, mg/l	20	-- - --
Grease and Oil Ratio, kg/kkg	0.65	-- - --
Organic Nitrogen, mg/l	92	-- - --
Organic Nitrogen Ratio, kg/kkg	3.0	-- - --
Ammonia-N, mg/l	3.0	-- - --
Ammonia-N Ratio, kg/kkg	0.10	-- - --
pH	7.5	-- - --

* process water only

1 sample

Table 44. Alaska tanner crab canned meat process without grinding (plant K8).*

Parameter	Mean	Range
Flow Rate, cu m/day	246	227 - 272
(mgd)	(0.065)	(0.060 - 0.072
Flow Ratio, l/kkg	32,700	29,400 - 36,100
(gal/ton)	(7840)	(7050 - 8650)
Settleable Solids, ml/l	0.34	-- - --
Settleable Solids Ratio, l/kkg	11	0.6 - 21
Screened Solids, mg/l	2400	-- - --
Screened Solids Ratio, kg/kkg	79	63 - 98
Suspended Solids, mg/l	200	-- - --
Suspended Solids Ratio, kg/kkg	6.7	4.8 - 9.4
5 day BOD, mg/l	260	-- - --
5 day BOD Ratio, kg/kkg	8.4	7.0 - 11
20 day BOD, mg/l	400	-- - --
20 day BOD Ratio, kg/kkg	13	9.2 - 19
COD, mg/l	490	-- - --
COD Ratio, kg/kkg	16	9.8 - 20
Grease and Oil, mg/l	24	-- - --
Grease and Oil Ratio, kg/kkg	0.78	0.24 - 1.4
Organic Nitrogen, mg/l	55	-- - --
Organic Nitrogen Ratio, kg/kkg	1.8	1.5 - 2.2
Ammonia-N, mg/l	2.1	-- - --
Ammonia-N Ratio, kg/kkg	0.07	0.06 - 0.08
pH	7.4	7.4 - 7.5

* process water only

4 samples

Table 45. Alaska tanner crab frozen meat process without grinding (plant S2).*

Parameter	Mean	Range		
Flow Rate, cu m/day	1740	1620	-	2000
(mgd)	(0.459)	(0.427	-	0.528)
Flow Ratio, l/kkg	146,000	125,000	-	167,000
(gal/ton)	(35,000)	(30,000	-	40,000)
Settleable Solids, ml/l	0.32	--	-	--
Settleable Solids Ratio, l/kkg	46	16	-	76
Screened Solids, mg/l	1400	--	-	--
Screened Solids Ratio, kg/kkg	210	140	-	290
Suspended Solids, mg/l	57	--	-	--
Suspended Solids Ratio, kg/kkg	8.3	0.8	-	12
5 day BOD, mg/l	--	--	-	--
5 day BOD Ratio, kg/kkg	--	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	340	--	-	--
COD Ratio, kg/kkg	50	32	-	77
Grease and Oil, mg/l	11	--	-	--
Grease and Oil Ratio, kg/kkg	1.6	0.9	-	2.4
Organic Nitrogen, mg/l	--	--	-	--
Organic Nitrogen Ratio, kg/kkg	--	--	-	--
Ammonia-N, mg/l	--	--	-	--
Ammonia-N Ratio, kg/kkg	--	--	-	--
pH	7.7	7.2	-	7.8

* process water only

8 samples

Alaskan Whole Crab and Crab Section Processing (Subcategories F and G)

Table 35 lists the combined average obtained from sampling three whole cook or sections processes.

Tables 39 and 40 show the waste loadings from the two whole cook process sampled and Tables 41 and 42 show the two section processes sampled. The water flow and the BOD_5 and COD loads per unit of raw material are quite similar except for the one whole cook process sample (Plant K-8) which had much higher flows and waste loads. Plant K-8 employed a brine freezing unit operation while the other plants used blast freezing. This process was sampled only one day and the sample was not included in the summary table.

DUNGENESS AND TANNER CRAB PROCESSING IN THE CONTIGUOUS STATES (Subcategory H)

The waste characteristics data used to typify the Dungeness crab industry outside of Alaska were taken from a study done by the Department of Food Science and Technology at Oregon State University (Soderquist, et al., 1972). The major differences between Alaska and lower West Coast crab plants (Washington, Oregon, California) are waste disposal and meat picking methods. West Coast plants do not grind their waste as do the Alaska plants and West Coast plants hand pick the meat rather than using mechanical leg pickers as do the Alaska plants. No tanner crab processes outside of Alaska were monitored during this study; however, the operations are the same as in Alaska except for the differences discussed above.

The previous study sampled three Dungeness whole and fresh frozen meat processes in Astoria, Oregon for three months starting in November, 1971. Two of the three plants sampled used solid waste fluming systems. This was not considered to be typical of "exemplary" processing plants. Therefore, composite samples were taken with and without the flumed waste flows.

Wastewater Sources and Flows

A general description of the steps in a Dungeness crab processing plant was presented in Section IV. All of the plants sampled follow the same general steps except for two unit operations. The first variation was in the bleed-rinse step. After the crabs are butchered the crab pieces are either conveyed via belt below a water spray or packed into large steel baskets and submerged in circulating rinsewater. In either case a continuous waste water flow results. There was no appreciable difference in the characteristics of the waste streams from each method. The second variation in processing is the cooling method following

Table 46. Alaska crab section process summary with grinding (4 plants).*

Parameter	Mean	Range		
Flow Rate, cu m/day	331	155	-	439
(mgd)	(0.088)	(0.041	-	0.116)
Flow Ratio, l/kkg	29,000	17,600	-	43,400
(gal/ton)	(6960)	(4220	-	10,400)
Settleable Solids, ml/l	11	--	-	--
Settleable Solids Ratio, l/kkg	330	50	-	750
Screened Solids, mg/l	10,000	--	-	--
Screened Solids Ratio, kg/kkg	300	28	-	470
Suspended Solids, mg/l	760	--	-	--
Suspended Solids Ratio, kg/kkg	22	7	-	32
5 day BOD, mg/l	1200	--	-	--
5 day BOD Ratio, kg/kkg	36	22	-	44
20 day BOD, mg/l	1600	--	-	--
20 day BOD Ratio, kg/kkg	47	31	-	63
COD, mg/l	2200	--	-	--
COD Ratio, kg/kkg	64	34	-	80
Grease and Oil, mg/l	280	--	-	--
Grease and Oil Ratio, kg/kkg	8.2	3	-	15
Organic Nitrogen, mg/l	180	--	-	--
Organic Nitrogen Ratio, kg/kkg	5.1	3.3	-	6
Ammonia-N, mg/l	4.8	--	-	--
Ammonia-N Ratio, kg/kkg	0.14	0.09	-	0.18
pH	7.3	7.1	-	7.5

* process water only

Table 47. Alaska crab frozen and canned meat process summary with grinding (4 plants).*

Parameter	Mean	Range		
Flow Rate, cu m/day	400	322	-	507
(mgd)	(0.106)	(0.085	-	0.134
Flow Ratio, l/kkg	51,700	32,800	-	85,500
(gal/ton)	(12,400)	(7870	-	20,500)
Settleable Solids, ml/l	12	--	-	--
Settleable Solids Ratio, l/kkg	640	150	-	1800
Screened Solids, mg/l	16,000	--	-	--
Screened Solids Ratio, kg/kkg	850	520	-	1200
Suspended Solids, mg/l	1000	--	-	--
Suspended Solids Ratio, kg/kkg	54	45	-	67
5 day BOD, mg/l	1300	--	-	--
5 day BOD Ratio, kg/kkg	66	54	-	89
20 day BOD, mg/l	2300	--	-	--
20 day BOD Ratio, kg/kkg	120	60	-	180
COD, mg/l	1900	--	-	--
COD Ratio, kg/kkg	100	86	-	140
Grease and Oil, mg/l	350	--	-	--
Grease and Oil Ratio, kg/kkg	18	4	-	31
Organic Nitrogen, mg/l	190	--	-	--
Organic Nitrogen Ratio, kg/kkg	10	8	-	13
Ammonia-N, mg/l	5.0	--	-	--
Ammonia-N Ratio, kg/kkg	0.26	0.2	-	0.35
pH	7.7	7.3	-	7.9

* process water only

Table 48. Alaska tanner crab sections process with grinding (plant K1).*

Parameter	Mean	Range		
Flow Rate, cu m/day	363	--	-	--
(mgd)	(0.096)	--	-	--
Flow Ratio, l/kkg	35,200	28,600	-	41,000
(gal/ton)	(8450)	(6860	-	9820)
Settleable Solids, ml/l	1.4	--	-	--
Settleable Solids Ratio, l/kkg	50	10	-	90
Screened Solids, mg/l	800	--	-	--
Screened Solids Ratio, kg/kkg	28	9	-	42
Suspended Solids, mg/l	200	--	-	--
Suspended Solids Ratio, kg/kkg	7	2	-	9
5 day BOD, mg/l	620	--	-	--
5 day BOD Ratio, kg/kkg	22	8	-	28
20 day BOD, mg/l	880	--	-	--
20 day BOD Ratio, kg/kkg	31	13	-	49
COD, mg/l	960	--	-	--
COD Ratio, kg/kkg	34	14	-	66
Grease and Oil, mg/l	85	--	-	--
Grease and Oil Ratio, kg/kkg	3	0.2	-	5
Organic Nitrogen, mg/l	94	--	-	--
Organic Nitrogen Ratio, kg/kkg	3.3	2.1	-	5.0
Ammonia-N, mg/l	2.6	--	-	--
Ammonia-N Ratio, kg/kkg	0.09	0.07	-	0.12
pH	7.5	7.4	-	7.7

* process water only

4 samples

Table 49. Alaska tanner crab sections process with grinding (plant K3).*

Parameter	Mean	Range		
Flow Rate, cu m/day	439	344	-	522
(mgd)	(0.116)	(0.091	-	0.138
Flow Ratio, l/kkg	43,400	28,400	-	60,500
(gal/ton)	(10,400)	(6800	-	14,500)
Settleable Solids, ml/l	3.0	--	-	--
Settleable Solids Ratio, l/kkg	130	23	-	270
Screened Solids, mg/l	7100	--	-	--
Screened Solids Ratio, kg/kkg	310	150	-	730
Suspended Solids, mg/l	690	--	-	--
Suspended Solids Ratio, kg/kkg	30	8	-	72
5 day BOD, mg/l	780	--	-	--
5 day BOD Ratio, kg/kkg	34	6.1	-	60
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	1800	--	-	--
COD Ratio, kg/kkg	80	30	-	160
Grease and Oil, mg/l	340	--	-	--
Grease and Oil Ratio, kg/kkg	15	5	-	54
Organic Nitrogen, mg/l	140	--	-	--
Organic Nitrogen Ratio, kg/kkg	6	2	-	11
Ammonia-N, mg/l	4.1	--	-	--
Ammonia-N Ratio, kg/kkg	0.18	0.08	-	0.45
pH	7.1	6.0	-	7.7

* process water only 15 samples

Table 50. Alaska tanner crab sections process with grinding (plant K6).*

Parameter	Mean	Range
Flow Rate, cu m/day	155	148 - 159
(mgd)	(0.041)	(0.039 - 0.042)
Flow Ratio, l/kkg	20,000	15,800 - 23,800
(gal/ton)	(4790)	(3800 - 5700)
Settleable Solids, ml/l	38	-- - --
Settleable Solids Ratio, l/kkg	750	460 - 1100
Screened Solids, mg/l	20,000	-- - --
Screened Solids Ratio, kg/kkg	410	250 - 620
Suspended Solids, mg/l	1600	-- - --
Suspended Solids Ratio, kg/kkg	32	23 - 40
5 day BOD, mg/l	2200	-- - --
5 day BOD Ratio, kg/kkg	44	14 - 65
20 day BOD, mg/l	3200	-- - --
20 day BOD Ratio, kg/kkg	63	48 - 77
COD, mg/l	3200	-- - --
COD Ratio, kg/kkg	63	48 - 84
Grease and Oil, mg/l	400	-- - --
Grease and Oil Ratio, kg/kkg	8	4 - 14
Organic Nitrogen, mg/l	250	-- - --
Organic Nitrogen Ratio, kg/kkg	5	4 - 6
Ammonia-N, mg/l	8.0	-- - --
Ammonia-N Ratio, kg/kkg	0.16	0.1 - 0.2
pH	--	-- - --

* process water only

4 samples

Table 51. Alaska tanner crab sections process with grinding (plant K11).*

Parameter	Mean	Range		
Flow Rate, cu m/day	367	333	-	405
(mgd)	(0.097)	(0.088	-	0.107)
Flow Ratio, l/kkg	17,600	14,800	-	19,000
(gal/ton)	(4220)	(3540	-	4560)
Settleable Solids, ml/l	22	--	-	--
Settleable Solids Ratio, l/kkg	380	36	-	800
Screened Solids, mg/l	27,000	--	-	--
Screened Solids Ratio, kg/kkg	470	260	-	800
Suspended Solids, mg/l	1100	--	-	--
Suspended Solids Ratio, kg/kkg	20	7	-	30
5 day BOD, mg/l	2500	--	-	--
5 day BOD Ratio, kg/kkg	44	22	-	69
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	4500	--	-	--
COD Ratio, kg/kkg	80	46	-	114
Grease and Oil, mg/l	400	--	-	--
Grease and Oil Ratio, kg/kkg	7	3	-	12
Organic Nitrogen, mg/l	340	--	-	--
Organic Nitrogen Ratio, kg/kkg	6	4	-	7
Ammonia-N, mg/l	8.5	--	-	--
Ammonia-N Ratio, kg/kkg	0.15	0.2	-	0.5
pH	--	--	-	--

* process water only — 5 samples

Table 52. Alaska tanner crab frozen meat process with grinding (plant K1)*

Parameter	Mean	Range
Flow Rate, cu m/day	356	318 - 409
(mgd)	(0.094)	(0.084 - 0.108)
Flow Ratio, l/kkg	46,700	32,900 - 75,100
(gal/ton)	(11,200)	(7880 - 18,000)
Settleable Solids, ml/l	5.8	-- - --
Settleable Solids Ratio, l/kkg	270	29 - 750
Screened Solids, mg/l	11,000	-- - --
Screened Solids Ratio, kg/kkg	520	120 - 1100
Suspended Solids, mg/l	1000	-- - --
Suspended Solids Ratio, kg/kkg	49	4 - 130
5 day BOD, mg/l	1400	-- - --
5 day BOD Ratio, kg/kkg	64	17 - 190
20 day BOD, mg/l	1300	-- - --
20 day BOD Ratio,** kg/kkg	60	13 - 97
COD, mg/l	2000	-- - --
COD Ratio, kg/kkg	92	14 - 220
Grease and Oil, mg/l	620	-- - --
Grease and Oil Ratio, kg/kkg	29	2 - 140
Organic Nitrogen, mg/l	210	-- - --
Organic Nitrogen Ratio, kg/kkg	10	4 - 15
Ammonia-N, mg/l	6.4	-- - --
Ammonia-N Ratio, kg/kkg	0.3	0.1 - 0.7
pH	7.3	6.6 - 8.1

* process water only
**based upon 7 observations

22 samples

Table 53. Alaska tanner crab frozen meat process with grinding (plant K6)*

Parameter	Mean	Range		
Flow Rate, cu m/day	412	310	-	454
(mgd)	(0.109)	(0.082	-	0.120)
Flow Ratio, l/kkg	41,600	33,600	-	53,800
(gal/ton)	(9960)	(8060	-	12,900)
Settleable Solids, ml/l	43	--	-	--
Settleable Solids Ratio, l/kkg	1800	1300	-	3100
Screened Solids, mg/l	29,000	--	-	--
Screened Solids Ratio, kg/kkg	1200	720	-	2200
Suspended Solids, mg/l	1600	--	-	--
Suspended Solids Ratio, kg/kkg	67	40	-	98
5 day BOD, mg/l	2100	--	-	--
5 day BOD Ratio, kg/kkg	89	34	-	170
20 day BOD, mg/l	4300	--	-	--
20 day BOD Ratio, kg/kkg	180	160	-	200
COD, mg/l	3400	--	-	--
COD Ratio, kg/kkg	140	110	-	210
Grease and Oil, mg/l	740	--	-	--
Grease and Oil Ratio, kg/kkg	31	10	-	100
Organic Nitrogen, mg/l	310	--	-	--
Organic Nitrogen Ratio, kg/kkg	13	10	-	17
Ammonia-N, mg/l	8.4	--	-	--
Ammonia-N Ratio, kg/kkg	0.35	0.25	-	0.57
pH	--	--	-	--

* process water only

7 samples

Table 54. Alaska tanner crab canned meat process with grinding (plant K8)*

Parameter	Mean	Range		
Flow Rate, cu m/day	322	246	-	341
(mgd)	(0.085)	(0.065	-	0.090)
Flow Ratio, l/kkg	32,800	25,900	-	40,000
(gal/ton)	(7870)	(6200	-	9600)
Settleable Solids, ml/l	9.8	--	-	--
Settleable Solids Ratio, l/kkg	320	110	-	1800
Screened Solids, mg/l	27,400	--	-	--
Screened Solids Ratio, kg/kkg	900	680	-	1700
Suspended Solids, mg/l	1400	--	-	--
Suspended Solids Ratio, kg/kkg	45	28	-	68
5 day BOD, mg/l	1600	--	-	--
5 day BOD Ratio, kg/kkg	54	19	-	71
20 day BOD, mg/l	3400	--	-	--
20 day BOD Ratio, kg/kkg	110	--	-	--
COD, mg/l	2600	--	-	--
COD Ratio, kg/kkg	86	52	-	130
Grease and Oil, mg/l	120	--	-	--
Grease and Oil Ratio, kg/kkg	4	2	-	8
Organic Nitrogen, mg/l	300	--	-	--
Organic Nitrogen Ratio, kg/kkg	10	6	-	16
Ammonia-N, mg/l	6.1	--	-	--
Ammonia-N Ratio, kg/kkg	0.2	0.1	-	0.3
pH	7.7	7.5	-	7.9

* process water only — 12 samples

Table 55. Alaska tanner crab frozen meat process with grinding (plant K10)*

Parameter	Mean	Range		
Flow Rate, cu m/day	507	431	-	553
(mgd)	(0.134)	(0.114	-	0.146)
Flow Ratio, l/kkg	85,500	60,900	-	123,000
(gal/ton)	(20,500)	(14,600	-	29,500)
Settleable Solids, ml/l	1.8	--	-	--
Settleable Solids Ratio, l/kkg	150	65	-	300
Screened Solids, mg/l	9000	--	-	--
Screened Solids Ratio, kg/kkg	770	470	-	1100
Suspended Solids, mg/l	650	--	-	--
Suspended Solids Ratio, kg/kkg	56	31	-	76
5 day BOD, mg/l	650	--	-	--
5 day BOD Ratio, kg/kkg	56	18	-	92
20 day BOD, mg/l	1300	--	-	--
20 day BOD Ratio, kg/kkg	110	80	-	140
COD, mg/l	1100	--	-	--
COD Ratio, kg/kkg	97	49	-	160
Grease and Oil, mg/l	82	--	-	--
Grease and Oil Ratio, kg/kkg	7	4	-	10
Organic Nitrogen, mg/l	94	--	-	--
Organic Nitrogen Ratio, kg/kkg	8	4	-	11
Ammonia-N, mg/l	2.3	--	-	--
Ammonia-N Ratio, kg/kkg	0.2	0.1	-	0.3
pH	7.9	7.5	-	8.2

* process water only

8 samples

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 56 gives the breakdown of the flow from each unit operation as a percentage of the total flow without fluming. The total average 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 a large flow but very 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.

Product Flow

The typical West Coast plant processed 5.4 to 7.2 kkg (6 to 8 tons) of crab per day. There is little variability in the crab processed. The size and sex restrictions as well as closure of the harvest season by government agencies during the molting season have standardized the raw material a great deal.

The influence of plant size on waste water values could not be reliably demonstrated in this study because the three plants monitored had similar production capacities. Comparison of waste water characteristics, however, with those of Alaskan plants indicates little effect.

Dungeness crab are prepared as whole cooked, or fresh, or frozen meat. Whole cooked (cooked unbutchered) crab usually make up a small percentage of the product; however, the contribution of BOD_5 and COD from the whole cooker is relatively significant because of the sodium chloride and citric acid added to the cooking water. The crab are only whole cooked for special orders and/or to supply the local retail outlets. Unlike the whole cooks in Alaska which are brine frozen after processing, these crab are only refrigerated prior to marketing.

Fresh meat is also not a large commodity. Like whole cooks, the shelf life of the product is short because the meat is refrigerated prior to marketing. The waste from this product is similar to that produced by the frozen meat process.

Meat is hand picked with a food product recovery ranging from 17 to 27 percent. This variation is a function of animal maturity, with yield increasing as the season progresses. Hand picking results in a higher yield than the mechanical meat extraction methods used in Alaska, where the yield is about 14 to 17 percent on tanner crab. The waste percentage shown in Table 56 was determined from the total solids remaining after screening. By-product was assumed to be the difference between 100 percent and the sum of waste and food product recovery.

The shift length was fairly consistent for each plant throughout the monitoring period. A normal shift consisted of about four to six hours of butchering and cooking and eight hours of hand picking. Those crab not picked by the end of the day were refrigerated and picked the next morning.

Raw Waste Loading

Table 57 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 average waste load characteristics of a typical plant would be similar to that generated by the meat picking process alone.

Tables 58 through 60 show the waste load for each plant. The water flow and loadings per unit of raw material were fairly consistent from plant to plant.

Samples from the waste flumes were composited with the other unit operations in two plants. Table 61 shows that waste fluming at Plant 2 increased the water usage 78 percent and the BOD_5, COD, and suspended solids ratios 21 to 24 percent. Table 62 shows that butcher waste fluming at Plant 3 increased water usage by 24 percent. The resultant waste loads increased for all parameters by about 20 percent.

ALASKA SHRIMP PROCESSING (Subcategories I and J)

An estimate of the waste characteristics of the Alaska shrimp industry was obtained by monitoring two processes during a period from March through June, 1973. The number of plants sampled was limited by the availability of raw material during the monitoring period. One plant sampled employs all new equipment which includes eight Laitram Model PCA peelers in conjunction with four Laitram Model PCC washers and eight Model PCS separators. The plant uses seawater and is located in a remote coastal region of Alaska. This plant is probably more efficient than most because of its new equipment. It is also larger than the plants around Kodiak where the size varies from four to nine peelers, with six to seven being average.

The other process monitored was a typical plant in Kodiak which uses seven Model A peelers in conjunction with seven washers and nine separators. This plant processes with fresh water.

Table 56. Material balance - Oregon Dungeness crab whole and fresh-frozen meat process (without fluming wastes).

Wastewater Material Balance Summary

Average Flow, 95 cu m/day (0.025 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

Table 57. West Coast Dungeness crab process summary without shell fluming (3 plants)

Parameter	Mean	Range	
Flow Rate, cu m/day	95	--	--
(mgd)	(0.025)	--	--
Flow Ratio, l/kkg	19,000	14,800	21,300
(gal/ton)	(4,560)	(3,560	5,100)
Settleable Solids, ml/l	84	--	--
Settleable Solids Ratio, l/kkg	1,600	1,300	2,000
Screened Solids, mg/l	--	--	--
Screened Solids Ratio, kg/kkg	--	--	--
Suspended Solids, mg/l	140	--	--
Suspended Solids Ratio, kg/kkg	2.7	2.6	2.9
5 day BOD, mg/l	430	--	--
5 day BOD Ratio, kg/kkg	8.1	6.6	11
20 day BOD, mg/l	--	--	--
20 day BOD Ratio, kg/kkg	--	--	--
COD, mg/l	680	--	--
COD Ratio, kg/kkg	13	11	16
Grease and Oil, mg/l	--	--	--
Grease and Oil Ratio, kg/kkg	--	--	--
Organic Nitrogen, mg/l	84	--	--
Organic Nitrogen Ratio, kg/kkg	1.6	1.4	2.0
Ammonia-N, mg/l	5.3	--	--
Ammonia-N Ratio, kg/kkg	0.10	0.075	0.14
pH	7.4	7.3	7.7

Table 58. West Coast Dungeness crab fresh meat and whole cook process -- without shell fluming (plant 1)

Parameter	Mean	Range		
Flow Rate, cu m/day	95	--	-	--
(mgd)	(0.025)	--	-	--
Flow Ratio, l/kkg	14,800	--	-	--
(gal/ton)	(3,560)	--	-	--
Settleable Solids, ml/l	88	--	-	--
Settleable Solids Ratio, l/kkg	1,300	590	-	2,200
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	180	--	-	--
Suspended Solids Ratio, kg/kkg	2.7	1.3	-	4.2
5 day BOD, mg/l	440	--	-	--
5 day BOD Ratio, kg/kkg	6.6	4.3	-	9.3
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	740	--	-	--
COD Ratio, kg/kkg	11	7.3	-	16
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	94	--	-	--
Organic Nitrogen Ratio, kg/kkg	1.4	0.86	-	2.1
Ammonia-N, mg/l	6.1	--	-	--
Ammonia-N Ratio, kg/kkg	0.09	0.06	-	0.14
pH	7.3	7.1	-	8.5

8 samples

Table 59. West Coast Dungeness crab fresh meat and whole cook process -- without shell fluming (plant 2)

Parameter	Mean	Range		
Flow Rate, cu m/day	--	--	-	--
(mgd)	--	--	-	--
Flow Ratio, l/kkg	21,300	--	-	--
(gal/ton)	(5,100)	--	-	--
Settleable Solids, ml/l	94	--	-	--
Settleable Solids Ratio, l/kkg	2,000	--	-	--
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	120	--	-	--
Suspended Solids Ratio, kg/kkg	2.6	--	-	--
5 day BOD, mg/l	320	--	-	--
5 day BOD Ratio, kg/kkg	6.8	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	520	--	-	--
COD Ratio, kg/kkg	11	--	-	--
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	66	--	-	--
Organic Nitrogen Ratio, kg/kkg	1.4	--	-	--
Ammonia-N, mg/l	3.5	--	-	--
Ammonia-N Ratio, kg/kkg	0.075	--	-	--
pH	7.3	6.9	-	8.7

4 samples

Table 60. West Coast Dungeness crab fresh meat and whole cook process -- without shell fluming (plant 3)

Parameter	Mean	Range		
Flow Rate, cu m/day	--	--	-	--
(mgd)	--	--	-	--
Flow Ratio, l/kkg	20,900	17,600	-	25,000
(gal/ton)	(5,010)	(4,220	-	5,990)
Settleable Solids, ml/l	72	--	-	--
Settleable Solids Ratio, l/kkg	1,500	1,300	-	1,800
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	140	--	-	--
Suspended Solids Ratio, kg/kkg	2.9	2.0	-	4.1
5 day BOD, mg/l	530	--	-	--
5 day BOD Ratio, kg/kkg	11	8.5	-	13
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	570	--	-	--
COD Ratio, kg/kkg	16	14	-	20
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	96	--	-	--
Organic Nitrogen Ratio, kg/kkg	2.0	1.5	-	2.4
Ammonia-N, mg/l	6.7	--	-	--
Ammonia-N Ratio, kg/kkg	0.14	0.08	-	0.16
pH	7.7	7.2	-	8.3

4 samples

Table 61. West Coast Dungeness crab fresh meat and whole cook process -- with shell fluming (plant 2).

Parameter	Mean	Range		
Flow Rate, cu m/day	--	--	-	--
(mgd)	--	--	-	--
Flow Ratio, l/kkg	38,000	--	-	--
(gal/ton)	(9,100)	--	-	--
Settleable Solids, ml/l	92	--	-	--
Settleable Solids Ratio, l/kkg	3,500	--	-	--
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	82	--	-	--
Suspended Solids Ratio, kg/kkg	3.1	--	-	--
5 day BOD, mg/l	230	--	-	--
5 day BOD Ratio, kg/kkg	8.7	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	370	--	-	--
COD Ratio, kg/kkg	14	--	-	--
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	47	--	-	--
Organic Nitrogen Ratio, kg/kkg	1.8	--	-	--
Ammonia-N, mg/l	2.4	--	-	--
Ammonia-N Ratio, kg/kkg	0.09	--	-	--
pH	7.3	--	-	--

4 samples

Table 62. West Coast Dungeness crab fresh meat and whole cook process -- with shell fluming (plant 3)

Parameter	Mean	Range		
Flow Rate, cu m/day	--	--	-	--
(mgd)	--	--	-	--
Flow Ratio, l/kkg	26,000	22,700	-	30,100
(gal/ton)	(6,240)	(5,450	-	7,220)
Settleable Solids, ml/l	69	--	-	--
Settleable Solids Ratio, l/kkg	1,800	1,600	-	2,200
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	120	--	-	--
Suspended Solids Ratio, kg/kkg	3.1	2.1	-	4.4
5 day BOD, mg/l	500	--	-	--
5 day BOD Ratio, kg/kkg	13	12	-	15
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	770	--	-	--
COD Ratio, kg/kkg	20	15	-	24
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	88	--	-	--
Organic Nitrogen Ratio, kg/kkg	2.3	1.7	-	2.8
Ammonia-N, mg/l	5.0	--	-	--
Ammonia-N Ratio, kg/kkg	0.13	0.08	-	0.18
pH	7.6	--	-	--

4 samples

Wastewater Sources and Flows

Figures 17 and 18 show the process flow diagrams associated with frozen shrimp and canned shrimp processes respectively in Alaska. The Model PCA peeler is normally associated with the frozen product, while Model A peelers are used either for canned or frozen commodities.

Either seawater or fresh water is used for 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 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 water is metered.

Table 63 lists the percentage of water used in each unit operation of a typical shrimp plant (either sea or freshwater). Tables 65 and 67 list average values for the process water of two shrimp processing plants. Flows in the former plant were double those in the latter. 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 29 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.

Product Flow

Table 63 shows the disposition of the raw material. The total product recovery ranged between 13 and 18 percent with the estimated by-product (solid waste) recovery estimated between 50 and 80 percent. The food product recovery varies seasonally (Collins, 1973). Collins' study indicated that the immature shrimp processed in the spring have a higher waste load than the larger, more mature shrimp processed later in the summer.

Jensen (1965) estimated a 15 to 22 percent food recovery using mechanical peelers. The 15 percent recovery average from the Jensen study may have been influenced by the fact that it may have been conducted in the spring.

By-product recovery is a new concept in the Alaska shrimp industry. Tangential screens have been recently installed in regions with solids disposal programs. The by-product percentage shown in Table 63 was estimated by totaling the by-product recovery as the difference between 100 percent and the sum of the waste and food product. Screened solids measurements were not used in this determination because of the trapped water, which often causes the wet weight of screened solids to be heavier than

Table 63. Canned and frozen Alaskan shrimp material balance.

Wastewater Material Balance Summary

Average Flow, 1170 cu m/day (0.310 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 (15.30 tons/day)

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

* Included in canning process only

Table 64. Alaska frozen shrimp process summary (plants S1 & K6)*

Parameter	Mean	Range		
Flow Rate, cu m/day	1170	--	-	--
(mgd)	(0.310)	--	-	--
Flow Ratio, l/kkg	73,400	--	-	--
(gal/ton)	(17,600)	--	-	--
Settleable Solids, ml/l	7.4	--	-	--
Settleable Solids Ratio, l/kkg	540	--	-	--
Screened Solids, mg/l	12,000	--	-	--
Screened Solids Ratio, kg/kkg	860	--	-	--
Suspended Solids, mg/l	2900	--	-	--
Suspended Solids Ratio, kg/kkg	210	--	-	--
5 day BOD, mg/l	1800	--	-	--
5 day BOD Ratio, kg/kkg	130	--	-	--
20 day BOD, mg/l	2300	--	-	--
20 day BOD Ratio, kg/kkg	170	--	-	--
COD, mg/l	3700	--	-	--
COD Ratio, kg/kkg	270	--	-	--
Grease and Oil, mg/l	230	--	-	--
Grease and Oil Ratio, kg/kkg	17	--	-	--
Organic Nitrogen, mg/l	150	--	-	--
Organic Nitrogen Ratio, kg/kkg	11	--	-	--
Ammonia-N, mg/l	6.8	--	-	--
Ammonia-N Ratio, kg/kkg	0.50	--	-	--
pH	7.7	--	-	--

* Average of Tables 68 and 66 with flow from Table 66 neglected.

Table 65.
Alaska frozen shrimp process - Model PCA peelers (plant S1) - sea water*

Parameter	Mean	Range		
Flow Rate, cu m/day	1,630	1,400	-	1,780
(mgd)	(0.430)	(0.370	-	0.470)
Flow Ratio, l/kkg	138,000	108,000	-	175,000
(gal/ton)	(33,000)	(26,000	-	42,000)
Settleable Solids, ml/l	5.5	--	-	--
Settleable Solids Ratio, l/kkg	760	360	-	1,100
Screened Solids, mg/l	4,800	--	-	--
Screened Solids Ratio, kg/kkg	670	420	-	990
Suspended Solids, mg/l	2,100	--	-	--
Suspended Solids Ratio, kg/kkg	290	190	-	370
5 day BOD, mg/l	1,000	--	-	--
5 day BOD Ratio, kg/kkg	140	60	-	210
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,000	--	-	--
COD Ratio, kg/kkg	280	160	-	360
Grease and Oil, mg/l	100	--	-	--
Grease and Oil Ratio, kg/kkg	14	4.5	-	18
Organic Nitrogen, mg/l	--	--	-	--
Organic Nitrogen Ratio, kg/kkg	--	--	-	--
Ammonia-N, mg/l	--	--	-	--
Ammonia-N Ratio, kg/kkg	--	--	-	--
pH	7.6	7.4	-	7.8

* process water only

8 samples

Table 66. Alaska frozen shrimp process,
Model PCA peelers (plant S1) -- Seawater, with clean-up.*

Parameter	Mean	Range
Flow Rate, cu m/day	1,790	-- - --
(mgd)	(0.473)	-- - --
Flow Ratio, l/kkg	152,000	-- - --
(gal/ton)	(36,300)	-- - --
Settleable Solids, ml/l	5.8	-- - --
Settleable Solids Ratio, l/kkg	880	-- - --
Screened Solids, mg/l	5,300	-- - --
Screened Solids Ratio, kg/kkg	800	-- - --
Suspended Solids, mg/l	2,100	-- - --
Suspended Solids Ratio, kg/kkg	320	-- - --
5 day BOD, mg/l	990	-- - --
5 day BOD Ratio, kg/kkg	150	-- - --
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	2,100	-- - --
COD Ratio, kg/kkg	320	-- - --
Grease and Oil, mg/l	99	-- - --
Grease and Oil Ratio, kg/kkg	15	-- - --
Organic Nitrogen, mg/l	--	-- - --
Organic Nitrogen Ratio, kg/kkg	--	-- - --
Ammonia-N, mg/l	--	-- - --
Ammonia-N Ratio, kg/kkg	--	-- - --
pH	7.6	-- - --

* Clean up water is included in this table. The values were arrived at by adding a percentage to the flow rates and wasteload ratios shown in Table 65. The percentages are 10, 10, 16, 20, 12, 6, 9, 14, 7, 1, 39 from top to bottom respectively. The ratio was then converted to mg/l.

Table 67. Alaska canned shrimp process - Model A peelers (plant K2) - fresh water*

Parameter	Mean	Range		
Flow Rate, cu m/day	1,070	700	-	1,440
(mgd)	(0.282)	(0.185	-	0.380)
Flow Ratio, l/kkg	66,800	54,200	-	100,000
(gal/ton)	(16,000)	(13,000	-	24,000)
Settleable Solids, ml/l	2.7	--	-	--
Settleable Solids Ratio, l/kkg	180	13	-	670
Screened Solids, mg/l	11,000	--	-	--
Screened Solids Ratio, kg/kkg	760	200	-	1,300
Suspended Solids, mg/l	1,300	--	-	--
Suspended Solids Ratio, kg/kkg	90	70	-	120
5 day BOD, mg/l	1,300	--	-	--
5 day BOD Ratio, kg/kkg	90	30	-	200
20 day BOD, mg/l	2,400	--	-	--
20 day BOD Ratio, kg/kkg	160	80	-	270
COD, mg/l	3,000	--	-	--
COD Ratio, kg/kkg	200	100	-	410
Grease and Oil, mg/l	270	--	-	--
Grease and Oil Ratio, kg/kkg	18	6	-	53
Organic Nitrogen, mg/l	160	--	-	--
Organic Nitrogen Ratio, kg/kkg	11	1.1	-	19
Ammonia-N, mg/l	5.4	--	-	--
Ammonia-N Ratio, kg/kkg	0.36	0.25	-	0.54
pH	8.1	7.6	-	8.5

* process water only

16 samples

Table 68. Alaska canned shrimp process - Model A peelers (plant K2) - fresh water, with clean up.*

Parameter	Mean	Range		
Flow Rate, cu m/day	1,180	--	-	--
(mgd)	(0.310)	--	-	--
Flow Ratio, l/kkg	73,500	--	-	--
(gal/ton)	(17,600)	--	-	--
Settleable Solids, ml/l	2.8	--	-	--
Settleable Solids Ratio, l/kkg	210	--	-	--
Screened Solids, mg/l	12,000	--	-	--
Screened Solids Ratio, kg/kkg	910	--	-	--
Suspended Solids, mg/l	1,400	--	-	--
Suspended Solids Ratio, kg/kkg	100	--	-	--
5 day BOD, mg/l	1,300	--	-	--
5 day BOD Ratio, kg/kkg	95	--	-	--
20 day BOD, mg/l	2,300	--	-	--
20 day BOD Ratio, kg/kkg	170	--	-	--
COD, mg/l	3,100	--	-	--
COD Ratio, kg/kkg	230	--	-	--
Grease and Oil, mg/l	260	--	-	--
Grease and Oil Ratio, kg/kkg	19	--	-	--
Organic Nitrogen, mg/l	150	--	-	--
Organic Nitrogen Ratio, kg/kkg	11	--	-	--
Ammonia-N, mg/l	6.8	--	-	--
Ammonia-N Ratio, kg/kkg	0.50	--	-	--
pH	8.1	--	-	--

* Clean up water is included in this table. The values were arrived at by adding a percentage to the flow rates and wasteload ratios shown in Table 67. The percentages are 10, 10, 16, 20, 12, 6, 9, 14, 7, 1, 39 from top to bottom respectively. The ratio was then converted to mg/l.

the raw weight of the shrimp. The 65 percent by-products figure is slightly more conservative than the 70 to 75 percent determined in a study by Peterson (1972).

The shift length at each plant varied with the availability of the product. When raw material was available, the plant would allow the shrimp to age the desired amount and then process the shrimp as rapidly as possible to avoid spoilage. Two shifts of from eight to ten hours daily were common.

Raw Waste Loadings

Table 66 summarizes the data from the Model PCA peeler plant using seawater and Table 68 summarizes the data from the Model A peeler plant using fresh water. The water flow per unit of raw material was about twice as high in the seawater plant. The BOD_5 and COD load per unit of raw material were 20 to 50 percent greater at the PCA peeler plant while the settleable solids (l/kkg) were four times that of the Model A plant. It is difficult to determine on the basis of existing data whether the increased load from the seawater plant was influenced more by the use of a PCA versus a Model A peeler or by the additional fluming used at this plant. Shrimp data for the West Coast indicated that PCA peelers may produce less waste than a Model A peeler; however, this was from a sample of one plant for each process. Table 64 presents the Alaskan shrimp processing summary data with the omission of the flow data from plant S-1.

SHRIMP PROCESSING IN THE CONTIGUOUS STATES

Preliminary study of the shrimp processing industry showed the Gulf and South Atlantic industry to be much more diverse than the Alaskan or West Coast industry. Further study indicated that, while the process variations for the Gulf and lower East Coast were many, the industry could be divided into three main sections as discussed in Chapter IV; Northern Shrimp Processing in the Contiguous States, Southern Shrimp Processing in the Contiguous States, and Breaded Shrimp Processing in the Contiguous States.

Northern Shrimp Processing in the Contiguous States (Subcategory K)

The shrimp processing industry in the Northern United States including the New England ,Pacific-Northwest, and California areas is similar to that in Alaska. Information from West Coast processes was available for two plants from a study done by the Oregon State University supported by funds from EPA Grant No. 801007, National Canners Association, and Oregon Agricultural Experiment Station.

Wastewater Sources and Flows

Figure 17 shows a typical West Coast shrimp process flow diagram and Table 69 gives a breakdown of the water used in each operation.

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 larger 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. 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.

Product Flow

West Coast shrimp 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 material input was about 9.0 kkg/day (9.9 tons/day) with the average shift length being 9 hours. The percent of raw material utilized for food was less than obtained from the Gulf and lower East Coast canned and breaded shrimp and averaged about 15 percent. The raw shrimp , 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 due to 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 waste water strength could not be substantiated by the data. The solid wastes which could be utilized for by-product totaled about 70 percent of the input. This was 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.

Raw Waste Loading

Table 70 shows the summary and Tables 71 and 72 show the flows and loadings from each of the two processes sampled. The PCA peeler process had a higher flow but lower waste load than the Model A peeler. This was contrary to the Alaska shrimp case

Table 69. Canned West Coast shrimp material balance.

Wastewater Material Balance Summary

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

	Unit Operation	% of Average Flow	Range, %
a)	de-icing tanks	6	4 - 8
b)	peelers (PCA & Model A)	61	57 - 78
c)	washer and separator	12	10 - 13
d)	blancher	2	1 - 2
e)	grading line	2	1 - 2
f)	can washer	3	0.002 - 6
g)	retort and cooling	5	4 - 7
h)	washdown	9	4 - 10

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

Table 70. West Coast canned shrimp process summary (2 plants)

Parameter	Mean	Range		
Flow Rate, cu m/day	472	341	-	602
(mgd)	(0.125)	(0.090	-	0.159)
Flow Ratio, l/kkg	60,000	47,100	-	73,000
(gal/ton)	(14,400)	(11,300	-	17,500)
Settleable Solids, ml/l	67	--	-	--
Settleable Solids Ratio, l/kkg	4,000	2,400	-	5,600
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	900	--	-	--
Suspended Solids Ratio, kg/kkg	54	47	-	60
5 day BOD, mg/l	2,000	--	-	--
5 day BOD Ratio, kg/kkg	120	95	-	140
20 day BOD, mg/l	2,500	--	-	--
20 day BOD Ratio, kg/kkg	150	--	-	--
COD, mg/l	3,300	--	-	--
COD Ratio, kg/kkg	200	160	-	230
Grease and Oil, mg/l	700	--	-	--
Grease and Oil Ratio, kg/kkg	42	39	-	44
Organic Nitrogen, mg/l	200	--	-	--
Organic Nitrogen Ratio, kg/kkg	12	--	-	--
Ammonia-N, mg/l	6.3	--	-	--
Ammonia-N Ratio, kg/kkg	0.38	0.32	-	0.45
pH	7.4	7.3	-	7.6

Table 71. West Coast canned shrimp (plant 1)

Parameter	Mean	Range		
Flow Rate, cu m/day	341	--	-	--
(mgd)	(0.090)	--	-	--
Flow Ratio, l/kkg	47,100	38,200	-	68,800
(gal/ton)	(11,300)	(9,150	-	16,500)
Settleable Solids, ml/l	120	--	-	--
Settleable Solids Ratio, l/kkg	5,600	1,700	-	11,000
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	1,300	--	-	--
Suspended Solids Ratio, kg/kkg	60	23	-	96
5 day BOD, mg/l	3,000	--	-	--
5 day BOD Ratio, kg/kkg	140	100	-	170
20 day BOD, mg/l	3,200	--	-	--
20 day BOD Ratio, kg/kkg	150	110	-	190
COD, mg/l	4,900	--	-	--
COD Ratio, kg/kkg	230	130	-	350
Grease and Oil, mg/l	830	--	-	--
Grease and Oil Ratio, kg/kkg	39	--	-	--
Organic Nitrogen, mg/l	250	--	-	--
Organic Nitrogen Ratio, kg/kkg	12	6	-	19
Ammonia-N, mg/l	9.6	--	-	--
Ammonia-N Ratio, kg/kkg	0.45	0.23	-	1.0
pH	7.3	--	-	--

12 samples

Table 72. West Coast canned shrimp (plant 2)

Parameter	Mean	Range		
Flow Rate, cu m/day	602	--	-	--
(mgd)	(0.159)	--	-	--
Flow Ratio, l/kkg	73,000	54,200	-	117,000
(gal/ton)	(17,500)	(13,000	-	28,000)
Settleable Solids, ml/l	33	--	-	--
Settleable Solids Ratio, l/kkg	2,400	2,100	-	2,700
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	640	--	-	--
Suspended Solids Ratio, kg/kkg	47	25	-	78
5 day BOD, mg/l	1,300	--	-	--
5 day BOD Ratio, kg/kkg	95	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,200	--	-	--
COD Ratio, kg/kkg	160	99	-	210
Grease and Oil, mg/l	600	--	-	--
Grease and Oil Ratio, kg/kkg	44	--	-	--
Organic Nitrogen, mg/l	160	--	-	--
Organic Nitrogen Ratio, kg/kkg	12	7.9	-	16
Ammonia-N, mg/l	4.4	--	-	--
Ammonia-N Ratio, kg/kkg	0.32	0.16	-	0.40
pH	7.6	--	-	--

9 samples

where the PCA process had the higher load; however, this may have been due to the fact that fluming was used extensively at the PCA plant in Alaska.

Southern Non-breaded Shrimp Processing in the Contiguous States (Subcategory L)

Three Gulf Coast shrimp canning processes, considered to be representative of the industry spectrum, were selected for sampling. The plants were 25 to 30 years old and most still employed floor gutters and holes in the wall for drainage. In addition to the data collected, historical data were available from one plant (Mauldin, 1973).

Wastewater Sources and Flows

Figure 22 shows a typical Gulf or lower East Coast canning process flow diagram and Table 73 gives the breakdown of the water used in each operation. In two of the three plants sampled, well water was used for de-icing, peeling and cooling of retorted cans. All other process waters (for belt washers, etc.) were city water. The COD and suspended solids concentration in the well water averaged approximately 55 mg/l each.

The plants in metropolitan areas pumped their waste waters directly to a sewage treatment facility whereas the other plants merely pumped their waste to large bodies of water. The total flow rates averaged about 788 cu m/day (0.208 mgd) and were very 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. 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 227 l/min (45 to 60 gpm) per peeler, but on days when a slow peel was desired, the flow was sometimes lowered to 57 to 76 l/min (15 to 20 gpm).

All of the Gulf Coast canning operations plants sampled used Model A peelers. The Gulf Coast and lower East Coast shrimp were larger and easier to peel than the Alaskan or West Coast shrimp.

Product Flow

The Gulf Coast canning plants produced the same general type of product, usually in the 6-1/2 oz size can. Brine was added to all cans at each of the plants, but a combination of lemon juice solution and brine was added mainly to "piece" cans (broken shrimp). The average raw material input was about 23.9 kkg/day (26.4 tons/day). The average shift length was 7-1/2 hours but ranged from 4 to 9 hours. The yield of the shrimp utilized for food is only about 20 percent (Table 73). The portion which could be used for by-products was about 65 percent; however, not

Table 73. Canned Gulf shrimp material balance.

Wastewater Material Balance Summary

Average Flow, 787 cu m/day (0.208 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	peelers (Model A)	58	42 - 73
b)	washers	9	8 - 10
c)	separators	7	5 - 9
d)	blancher	2	0.006 - 2
e)	de-icing	4	0.005 - 7
f)	cooling and retort	12	8 - 20
g)	washdown	8	7 - 10

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

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 into the mechanism. 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.

Raw Waste Loading

Table 74 gives the average flow and loadings from all three of the Gulf Coast canning processes sampled. It can be seen that the water flow per unit of raw material was relatively uniform with a mean of about 46,900 l/kkg. The COD loads were also uniform with a mean of 109 kg/kkg. BOD_5 was available only from Plant #1 and averaged 46 kg/kkg.

Tables 75 through 78 show the waste characteristics from each of the three plants sampled. The data collected by the field crew on Plant #1 are given in Table 75 and the data obtained from Mauldin (1973) are listed in Table 76.

Breaded Shrimp Processing in the Contiguous States (Subcategory M)

Two breaded shrimp processes, one on the Gulf and one on the South Atlantic Coast were sampled during November and December of 1972.

Waste Water Sources and Flows

Figure 23 shows a typical breaded shrimp process flow diagram and Table 79 gives a breakdown of the water used in each operation. The two plants sampled utilized both well and city water. The average flow was about 653 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. 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 compared to 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 51 percent of the total. It appeared that this flow could be reduced significantly with proper water management.

Table 74. Gulf Shrimp canning process summary (3 plants)

Parameter	Mean	Range		
Flow Rate, cu m/day	787	693	-	905
(mgd)	(0.208)	(0.183	-	0.239)
Flow Ratio, l/kkg	47,200	33,000	-	58,400
(gal/ton)	(11,300)	(7,900	-	14,000)
Settleable Solids, ml/l	11	--	-	--
Settleable Solids Ratio, l/kkg	520	180	-	980
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	800	--	-	--
Suspended Solids Ratio, kg/kkg	38	16	-	50
5 day BOD, mg/l	970	--	-	--
5 day BOD Ratio, kg/kkg	46	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,300	--	-	--
COD Ratio, kg/kkg	110	65	-	120
Grease and Oil, mg/l	250	--	-	--
Grease and Oil Ratio, kg/kkg	12	5.4	-	36
Organic Nitrogen, mg/l	200	--	-	--
Organic Nitrogen Ratio, kg/kkg	9.5	1.9	-	12
Ammonia-N, mg/l	10	--	-	--
Ammonia-N Ratio, kg/kkg	0.49	0.41	-	0.60
pH	6.7	6.5	-	7.0

Table 75. Gulf shrimp canning process (plant 1A)

Parameter	Mean	Range		
Flow Rate, cu m/day	855	757	-	950
(mgd)	(0.226)	(0.200	-	0.251)
Flow Ratio, l/kkg	33,000	32,100	-	45,900
(gal/ton)	(7,900)	(7,700	-	11,000)
Settleable Solids, ml/l	5.4	--	-	--
Settleable Solids Ratio, l/kkg	180	180	-	190
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	480	--	-	--
Suspended Solids Ratio, kg/kkg	16	16	-	17
5 day BOD, mg/l	--	--	-	--
5 day BOD Ratio, kg/kkg	--	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,000	--	-	--
COD Ratio, kg/kkg	65	42	-	93
Grease and Oil, mg/l	160	--	-	--
Grease and Oil Ratio, kg/kkg	5.4	4.8	-	6.4
Organic Nitrogen, mg/l	210	--	-	--
Organic Nitrogen Ratio, kg/kkg	6.9	6.1	-	8.0
Ammonia-N, mg/l	14	--	-	--
Ammonia-N Ratio, kg/kkg	0.46	0.42	-	0.52
pH	7.0	--	-	--

2 samples

Table 76. Gulf shrimp canning process (plant 1B)

Parameter	Mean	Range		
Flow Rate, cu m/day	905	840	-	969
(mgd)	(0.239)	(0.222	-	0.256)
Flow Ratio, l/kkg	41,700	35,500	-	58,400
(gal/ton)	(10,000)	(8,500	-	14,000)
Settleable Solids, ml/l	24	--	-	--
Settleable Solids Ratio, l/kkg	980	750	-	1,100
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	620	--	-	--
Suspended Solids Ratio, kg/kkg	26	7	-	30
5 day BOD, mg/l	1,100	--	-	--
5 day BOD Ratio, kg/kkg	46	41	-	51
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,600	--	-	--
COD Ratio, kg/kkg	110	87	-	120
Grease and Oil, mg/l	860	--	-	--
Grease and Oil Ratio, kg/kkg	36	22	-	53
Organic Nitrogen, mg/l	46	--	-	--
Organic Nitrogen Ratio, kg/kkg	1.9	1.1	-	2.9
Ammonia-N, mg/l	--	--	-	--
Ammonia-N Ratio, kg/kkg	--	--	-	--
pH	--	--	-	--

6 samples

Table 77. Gulf shrimp canning process (plant 2)

Parameter	Mean	Range		
Flow Rate, cu m/day	693	473	-	1,190
(mgd)	(0.183)	(0.125	-	0.314)
Flow Ratio, l/kkg	45,900	37,500	-	50,100
(gal/ton)	(11,000)	(9,000	-	12,000)
Settleable Solids, ml/l	13	--	-	--
Settleable Solids Ratio, l/kkg	580	480	-	830
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	1,100	--	-	--
Suspended Solids Ratio, kg/kkg	50	28	-	62
5 day BOD, mg/l	--	--	-	--
5 day BOD Ratio, kg/kkg	--	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,600	--	-	--
COD Ratio, kg/kkg	120	100	-	130
Grease and Oil, mg/l	150	--	-	--
Grease and Oil Ratio, kg/kkg	6.8	5.9	-	8.6
Organic Nitrogen, mg/l	260	--	-	--
Organic Nitrogen Ratio, kg/kkg	12	9.6	-	13
Ammonia-N, mg/l	13	--	-	--
Ammonia-N Ratio, kg/kkg	0.60	0.47	-	0.67
pH	6.5	--	-	--

4 samples

Table 78. Gulf Shrimp process - screened (plant 3)

Parameter	Mean	Range		
Flow Rate, cu m/day	787	715	-	1,280
(mgd)	(0.208)	(0.189	-	0.338)
Flow Ratio, l/kkg	58,400	50,100	-	66,800
(gal/ton)	(14,000)	(12,000	-	16,000)
Settleable Solids, ml/l	6.8	--	-	--
Settleable Solids Ratio, l/kkg	400	320	-	900
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	720	--	-	--
Suspended Solids Ratio, kg/kkg	42	21	-	65
5 day BOD, mg/l	--	--	-	--
5 day BOD Ratio, kg/kkg	--	--	-	--
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	2,100	--	-	--
COD Ratio, kg/kkg	120	93	-	140
Grease and Oil, mg/l	140	--	-	--
Grease and Oil Ratio, kg/kkg	8.5	4.7	-	12
Organic Nitrogen, mg/l	200	--	-	--
Organic Nitrogen Ratio, kg/kkg	12	8	-	13
Ammonia-N, mg/l	7.0	--	-	--
Ammonia-N Ratio, kg/kkg	0.41	0.22	-	0.54
pH	7.0	--	-	--

5 samples

Product Flow

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 79) was 75 to 85 percent, depending on: type of breading, method of peeling, size of shrimp, etc.

The raw material was generally in very good condition on arrival; if caught locally they were kept iced and in coolers until processed. Frozen shrimp are sometimes kept, 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. 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 material processed totaled 6.3 kkg/day (7.0 tons/day).

Raw Waste Loading

Table 80 shows the summary and Tables 81 and 82 show the flows and loadings from each of the two breaded shrimp processes sampled. The waste water flows and the loadings per unit of raw material were very similar for the two processes and quite similar to the Gulf and lower East Coast canned processes.

TUNA PROCESSING (Subcategory N)

Seven tuna processing plants were monitored during May and June of 1973. Three of the plants were located in Southern California and the other four in Puerto Rico. In addition, data from a study done by Oregon State University in the fall of 1972 at two plants in the Northwest were included (Soderquist, et al., 1972). These nine plants represented a good cross-section of the tuna industry with respect to size, age, and locality, and, in fact, encompassed nearly 50 percent of the total U. S. tuna industry.

The sampling methods described in the introduction to this section were employed at each of the plants. The "end-of-the-pipe" total flow and unit processes were sampled whenever possible. Most plants monitored included on-site pet food lines, many incorporated meal plants and some operated solubles plants, as well. In each case the "tuna process" flow referred to in this report includes all secondary processes on-site, with two exceptions: the barometric condensor flows and the air scrubber flows, each representing high volumes of water with neglegible contamination (in fact, these flows were frequently single-pass sea water). If more than one outfall was used a total plant effluent sample was obtained by mixing a flow proportioned composite of all outfalls. Samples were collected at various time intervals throughout the production day.

Table 79. Breaded Gulf shrimp material balance.

Wastewater Material Balance Summary

Average Flow, 653 cu m/day (0.172 mgd)

	Unit Operation	% of Average Flow	Range, %
a)	hand peeling	5	3 - 7
b)	thawing or de-icing	4	2 - 7
c)	breading area	2	1 - 3
d)	washdown	51	29 - 73
e)	automatic peelers	38	34 - 55

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

Table 80. Breaded shrimp process summary (2 plants)

Parameter	Mean	Range		
Flow Rate, cu m/day	653	564	-	742
(mgd)	(0.172)	(0.149	-	0.196)
Flow Ratio, l/kkg	116,000	108,000	-	124,000
(gal/ton)	(27,900)	(26,000	-	29,800)
Settleable Solids, ml/l	16	--	-	--
Settleable Solids Ratio, l/kkg	1,800	1,500	-	2,000
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	800	--	-	--
Suspended Solids Ratio, kg/kkg	93	76	-	110
5 day BOD, mg/l	720	--	-	--
5 day BOD Ratio, kg/kkg	84	81	-	87
20 day BOD, mg/l	860	--	-	--
20 day BOD Ratio, kg/kkg	100	--	-	--
COD, mg/l	1,200	--	-	--
COD Ratio, kg/kkg	140	--	-	--
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	50	--	-	--
Organic Nitrogen Ratio, kg/kkg	5.8	5.4	-	6.1
Ammonia-N, mg/l	0.95	--	-	--
Ammonia-N Ratio, kg/kkg	0.11	0.086	-	0.14
pH	7.8	7.7	-	7.9

Table 81. Breaded shrimp process (plant 1)

Parameter	Mean	Range		
Flow Rate, cu m/day	564	416	-	746
(mgd)	(0.149)	(0.110	-	0.197)
Flow Ratio, l/kkg	124,000	91,800	-	150,000
(gal/ton)	(29,800)	(22,000	-	36,000)
Settleable Solids, ml/l	16	--	-	--
Settleable Solids Ratio, l/kkg	2,000	1,700	-	2,400
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	890	--	-	--
Suspended Solids Ratio, kg/kkg	110	85	-	130
5 day BOD, mg/l	700	--	-	--
5 day BOD Ratio, kg/kkg	87	47	-	120
20 day BOD, mg/l	810	--	-	--
20 day BOD Ratio, kg/kkg	100	60	-	140
COD, mg/l	1,100	--	-	--
COD Ratio, kg/kkg	140	110	-	160
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	44	--	-	--
Organic Nitrogen Ratio, kg/kkg	5.4	3.3	-	7.9
Ammonia-N, mg/l	0.69	--	-	--
Ammonia-N Ratio, kg/kkg	0.086	0.075	-	0.12
pH	7.7	--	-	--

7 samples

Table 82. Breaded shrimp process (plant 2)

Parameter	Mean	Range		
Flow Rate, cu m/day	742	704	-	893
(mgd)	(0.196)	(0.186	-	0.236)
Flow Ratio, l/kkg	108,000	91,800	-	117,000
(gal/ton)	(26,000)	(22,000	-	28,000)
Settleable Solids, ml/l	14	--	-	--
Settleable Solids Ratio, l/kkg	1,500	790	-	1,800
Screened Solids, mg/l	--	--	-	--
Screened Solids Ratio, kg/kkg	--	--	-	--
Suspended Solids, mg/l	700	--	-	--
Suspended Solids Ratio, kg/kkg	76	70	-	130
5 day BOD, mg/l	750	--	-	--
5 day BOD Ratio, kg/kkg	81	65	-	120
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	1,300	--	-	--
COD Ratio, kg/kkg	140	100	-	190
Grease and Oil, mg/l	--	--	-	--
Grease and Oil Ratio, kg/kkg	--	--	-	--
Organic Nitrogen, mg/l	56	--	-	--
Organic Nitrogen Ratio, kg/kkg	6.1	5.3	-	8.5
Ammonia-N, mg/l	1.3	--	-	--
Ammonia-N Ratio, kg/kkg	0.14	0.098	-	0.22
pH	7.9	--	-	--

7 samples

As mentioned in Section IV, the techniques of tuna processing are fairly universal for the industry; the flow diagram (Figure 25) in that section applies to each of the plants with only slight variations.

Wastewater Sources and Flows

The processing of tuna 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. However, saline water may also be used in the latter stages where contamination of the cooked fish would present a problem. Table 83 lists the average flow from each unit operation.

Total water use ranged from 246 cu m/day (0.065 mgd) to 11,700 cu m/day (3.1 mgd) with an average of 3060 cu m/day (0.808 mgd), where a day was defined as one 8 hour shift. Flow rates and the ratio of water used to tons of raw material processed are summarized for all plants on Table 84. The variation for the flow ratio was relatively large and can be attributed to the wide variation in the amounts of water used in the thawing operation. A more detailed discussion of the wastes and waste flow from each unit operation will be presented later.

Product Flow

The estimated breakdown of the raw material into food, by-product and waste is shown on Table 83. The average raw product input was about 167 kkg/day (184 tons/day) but the plants sampled exhibited a wide range: from 25 to 350 kkg/ day. Food recovery averaged 45 percent. Very little of the raw material was wasted. The red meat was utilized for pet food: the viscera, head, fins, skin and bone were reduced to fish meal and the stickwater and press liquor from the reduction plant were sent to a solubles operation which produced a concentrated fish solubles product, as discussed in Section IV. The final waste represented only about 1 percent of the raw input.

Production in Southern California and the Northwest was usually on a one shift basis lasting 8 hours with occasional fluctuations of from 6 to 10 hours. Puerto Rico plants operated on a two shift schedule, the last shift running somewhat shorter than the first. For the purpose of data reduction and interpretation, flows and waste characteristics apply to a standard 8 hour shift.

Combined Raw Waste Loadings

Table 84 shows average flows and loadings of the combined effluent from all nine processes sampled. The amount of water used per unit of raw material varied considerably, as noted earlier.

It was also noted that the waste loads in terms of screened solids, BOD_5 and COD were relatively low compared to other seafood processing industries, due to good by-product recovery. Tables 85 through 93 show the average flows and waste water loads of the combined effluent for each plant sampled.

Unit Operation Characterization

Several unit processes were considered, including: receiving, thawing, butchering, cleaning, pak-shaping, can washing, retorting, and the plant washdown.

Receiving was normally a dry process with the exception of Plant 5 which used flumes to transport the fish to the scales and then to the thawing tanks; the latter flow was separate, and was used as the thaw water. This fluming water, pumped from the bay, flowed at an average rate of 110 l/sec or 3168 cubic meters for an 8 hour day and contained entrained organic wastes in the form of blood, scales, and juices, with a corresponding BOD_5 and suspended solids concentration of 4.6 kg and 2.1 kg, respectively, per kkg of fish unloaded. However, this plant is presently in the process of converting the fluming system (with its heavy use of water) to a dry system, as is used in other plants.

Plant 5 was also unique in that the fishing vessels pumped water from the bilges and brine holding tanks onto the docks where it entered the plant waste stream. The amount of this water was highly variable, as was the suspended solid concentration, which varied from 20 mg/l to 5830 mg/l.

The thawing process accounted for the largest water usage in this subcategory, with a mean of 65 percent of the total volume, but varied depending on whether the thaw took place under static or continuous flow conditions. The organic waste load picked up in this process included blood, juices, and scales. Separate flows and corresponding waste concentrations were obtained for three of the plants and are summarized on Table 94.

Because of the close proximity of the thawing and butchering processes it was not always possible to measure these flows separately, although several plants did the thawing at night, temporarily segregating the two flows, which allowed one or the other to be sampled. This temporal separation of flows was also helpful in segregating other mixed flows. The average flow was 7389 l/kkg with a BOD_5 of 2.96 kg/kkg, and 2.0 kg/kkg of suspended solids, or 65 percent, 40 percent, and 24 percent respectively, of the mean totals for these plants.

Approximately 10 percent of the flows came from the butchering areas and contained blood, juices, small particles of viscera, meat and scales. As mentioned in Section IV, the butcher waste flow arises from three sources: the wash screen, saw washer jet, and the periodic hose down. This water may be either fresh or salt, depending on the plant. The total use of water in butchering is presently restricted to points of necessity.

Comprising 10 to 15 percent by weight, the potential waste load from the butcher process is approximately 21 kkg/day from an average plant processing 167 kkg/day. However, as mentioned in Section IV, the viscera are saved and processed in either the fish meal plant or the fish solubles plant. The data for the waste loadings occurring in the butcher room from three plants are summarized on Table 94.

For these plants the butchering process contributed 24 percent of the suspended solids. Wastage also occurred as the butchered fish lay in wire racks prior to being cooked; blood and juices drained onto the floor and were hosed into one of several collection drains. This contribution was not isolated and must be considered under one of the unmeasured miscellaneous sources which add to the total plant effluent. Leakage of stickwater from the precookers presented a problem in that it, too, was not available for measurement, and therefore must also be added to the miscellaneous small flows. Stickwater was pumped from the precookers for reduction or separate discharge by barging to open sea; the latter was the case in only one plant sampled. Stickwater contains large amounts of fats, oils, and proteinaceous materials which could appreciably increase the concentration of the waste discharged if it were not treated separately. Samples of stickwater obtained from one of the plants had an average BOD_5 of 48.2 kg/kkg, COD of 123.5 kg/kkg, and 33.7 kg/kkg of suspended solids.

After precooking, the tuna were allowed to cool for several hours in a separate area between the precookers and cleaning rooms. Although cooling was accelerated in one plant with a fine spray of cold water, the fish were sufficiently leached of most of the oils and liquids in the precook so that a significant waste loading did not develop at this point. These wastes are grouped with the miscellaneous sources, and except for the one plant that used a spray mist, the air cooling process minimized waste loadings at this point.

The cleaning process which follows cooling (as discussed in Section IV) was a dry process with over 99 percent recovery of the wastes generated. These collected wastes were conveyed to a reduction plant which further processed them into various fishery by-products. A quantification of the waste loading occurring in this area is included in the washdown discussion since that is the only time water enters this process.

A small flow was associated with the pak-shaping machines and averaged 8720 l/per 8 hour day, which is less than 2 percent of the total effluent flow, but contributed 16 percent of the

Table 83. 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)	pak-shaper	2	1 - 3
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
Red meat	9	8 - 10
Waste	1	0.1 - 2

Table 84. Tuna process summary (9 plants).

Parameter	Mean	Range		
Flow Rate, cu m/day	3,737	246	-	13,600
(mgd)	(.987)	(0.065	-	3.59)
Flow Ratio, l/kkg	22,277	5,590	-	45,100
(gal/ton)	(5,338)	(1,340	-	10,800)
Settleable Solids, ml/l	1.42	--	-	--
Settleable Solids Ratio, l/kkg	31.8	7.0	-	51
Screened Solids, mg/l	71	--	-	--
Screened Solids Ratio, kg/kkg	1.3	0.95	-	1.7
Suspended Solids, mg/l	511	--	-	--
Suspended Solids Ratio, kg/kkg	10.8	3.8	-	17
5 day BOD, mg/l	698.9	--	-	--
5 day BOD Ratio, kg/kkg	14.6	6.8	-	20
20 day BOD, mg/l	--	--	-	--
20 day BOD Ratio, kg/kkg	--	--	-	--
COD, mg/l	1,585.6	--	-	--
COD Ratio, kg/kkg	35	14	-	64
Grease and Oil, mg/l	244	--	-	--
Grease and Oil Ratio, kg/kkg	5.65	1.7	-	13
Organic Nitrogen, mg/l	60.6	--	-	--
Organic Nitrogen Ratio, kg/kkg	1.23	0.75	-	3.0
Ammonia-N, mg/l	5.74	--	-	--
Ammonia-N Ratio, kg/kkg	.145	0.0052	-	.42
pH	6.75	6.2	-	7.2

Table 85 . Tuna process (plant 1).

Parameter	Mean	Range
Flow Rate, cu m/day [1] (mgd)	2120 (0.56)	2082-2158 .55-.57
Flow Ratio, l/kkg [2] (gal/ton)	25,700 (6160)	21,934-30,094 5260-7217
Settleable Solids, ml/l	1.2	1.05-6.8
Settleable Solids Ratio, l/kkg	30.6	26.9-174.6
Screened Solids, mg/l	---	----
Screened Solids Ratio, kg/kkg	---	----
Suspended Solids, mg/l	477	191-965
Suspended Solids Ratio, kg/kkg	12.3	4.9-24.8
5 day BOD, mg/l	777	268-1097
5 day BOD Ratio, kg/kkg	19.9	6.9-28.2
20 day BOD, mg/l	---	----
20 day BOD Ratio, kg/kkg	---	----
COD, mg/l	1930	1101-3155
COD Ratio, kg/kkg	49.6	28.3-81.1
Grease and Oil, mg/l	207	101-393
Grease and Oil Ratio, kg/kkg	5.3	2.6-10.1
Organic Nitrogen, mg/l	51.4	48.6-58.4
Organic Nitrogen Ratio, kg/kkg	1.33	1.25-1.50
Ammonia-N, mg/l	3.5	2.7-42.8
Ammonia-N Ratio, kg/kkg	0.09	.07-1.1
pH [3]	7.1	7.0-7.1

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

5 samples

Table 86 . Tuna process (plant 2).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	4539	3108 - 4542
(mgd)	(1.19)	(.821- 1.20)
Flow Ratio, l/kkg[2]	24,300	19,707 -25,616
(gal/ton)	(5830)	(4726 - 6143)
Settleable Solids, ml/l	1.8	1.6 - 11.0
Settleable Solids Ratio, l/kkg	46.8	38.9 - 267.4
Screened Solids[3], mg/l	67.1	-- - --
Screened Solids Ratio, kg/kkg	1.66	-- - --
Suspended Solids, mg/l	701	209 - 1049
Suspended Solids Ratio, kg/kkg	17.4	5.1 - 25.5
5 day BOD, mg/l	421	218 - 1008
5 day BOD Ratio, kg/kkg	9.98	5.3 - 24.5
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	1586	629 - 3547
COD Ratio, kg/kkg	38.5	15.3 - 86.2
Grease and Oil, mg/l	246	86.8 - 349
Grease and Oil Ratio, kg/kkg	5.97	2.11 - 8.5
Organic Nitrogen, mg/l	37.8	18.5 - 57.6
Organic Nitrogen Ratio, kg/kkg	0.94	.45 - 1.4
Ammonia-N, mg/l	7.3	3.7 - 8.2
Ammonia-N Ratio, kg/kkg	0.18	.09 - .20
pH[4]	6.7	6.2 - 7.1

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

12 samples

Table 87 . Tuna process (plant 3).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	4560	3562 - 5678
(mgd)	(1.21)	(.941- 1.5)
Flow Ratio, l/kkg[2]	23,200	20,508 -28,476
(gal/ton)	(5560)	(4918 - (6829)
Settleable Solids, ml/l	1.21	.7 - 6.1
Settleable Solids Ratio, l/kkg	28.5	16.2 - 141
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	708	457 - 948
Suspended Solids Ratio, kg/kkg	16.1	10.6 - 22.0
5 day BOD, mg/l	752	543 - 931
5 day BOD Ratio, kg/kkg	17.5	12.6 - 21.6
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	2740	1233 - 3840
COD Ratio, kg/kkg	63.8	28.6 - 89.1
Grease and Oil, mg/l	576	250 - 711
Grease and Oil Ratio, kg/kkg	13.2	5.8 - 16.5
Organic Nitrogen, mg/l	93.8	61.6 - 131
Organic Nitrogen Ratio, kg/kkg	2.18	1.43 - 3.05
Ammonia-N, mg/l	9.75	5.6 - 11.6
Ammonia-N Ratio, kg/kkg	0.23	0.13 - 0.27
pH[3]	6.8	6.7 - 7.1

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

5 samples

Table 88 . Tuna process (plant 4).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	2270	1715 - 2547
(mgd)	(0.6)	(0.453- 0.673)
Flow Ratio, l/kkg[2]	16,100	13,406 -17,680
(gal/ton)	(3860)	(3215 - 4240)
Settleable Solids, ml/l	1.6	0.1 - 2.5
Settleable Solids Ratio, l/kkg	24.5	1.6 - 40.2
Screened Solids[3], mg/l	59.9	-- - --
Screened Solids Ratio, kg/kkg	0.95	-- - --
Suspended Solids, mg/l	477	173 - 913
Suspended Solids Ratio, kg/kkg	7.69	2.8 - 14.7
5 day BOD, mg/l	608	172 - 930
5 day BOD Ratio, kg/kkg	9.79	2.77 - 14.98
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	1860	832 - 2441
COD Ratio, kg/kkg	28.4	13.4 - 39.3
Grease and Oil, mg/l	217	88 - 478
Grease and Oil Ratio, kg/kkg	3.49	1.42 - 7.7
Organic Nitrogen, mg/l	46	8.7 - 50.9
Organic Nitrogen Ratio, kg/kkg	0.75	0.14 - 0.82
Ammonia-N, mg/l	10.1	9.3 - 14.9
Ammonia-N Ratio, kg/kkg	0.16	0.15 - 0.24
pH[4]	6.5	6.0 - 6.9

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

9 Samples

Table 89. Tuna process (plant 5).

Parameter	Mean	Range
Flow Rate, cu m/day	13,600	9,780 - 16,700
(mgd)	(3.59)	(2.59 - 4.42)
Flow Ratio, l/kkg	45,100	35,700 - 53,100
(gal/ton)	(10,800)	(8,550 - 12,700)
Settleable Solids, ml/l	0.228	0.377 - 0.650
Settleable Solids Ratio, l/kkg	10.3	17.0 - 29.3
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	202	103 - 351
Suspended Solids Ratio, kg/kkg	9.12	4.64 - 15.8
5 day BOD, mg/l	428	236 - 1,070
5 day BOD Ratio, kg/kkg	19.3	10.6 - 48.4
COD, mg/l	1,060	362 - 3,110
COD Ratio, kg/kkg	47.6	16.3 - 140
Grease and Oil, mg/l	101	53.7 - 147
Grease and Oil Ratio, kg/kkg	4.57	2.42 - 6.62
Organic Nitrogen, mg/l	26.3	20.6 - 39.0
Organic Nitrogen Ratio, kg/kkg	1.19	0.927 - 1.76
Ammonia-N, mg/l	9.29	6.86 - 56.3
Ammonia-N Ratio, kg/kkg	0.419	0.310 - 2.54
pH	6.70	6.44 - 7.25

8 samples

Table 90. Tuna process (plant 6).

Parameter	Mean	Range
Flow Rate, cu m/day	4,120	3,900 - 4,310
(mgd)	(1.9)	(1.03 - 1.14)
Flow Ratio, l/kkg	20,600	19,000 - 22,000
(gal/ton)	(4,930)	(4,540 - 5,280)
Settleable Solids, ml/l	2.46	0.750 - 9.96
Settleable Solids Ratio, l/kkg	50.6	15.4 - 205
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	746	495 - 1,020
Suspended Solids Ratio, kg/kkg	15.3	10.2 - 21.0
5 day BOD, mg/l	896	-- - --
5 day BOD Ratio, kg/kkg	18.4	-- - --
COD, mg/l	1,390	1,050 - 2,130
COD Ratio, kg/kkg	28.6	21.7 - 43.9
Grease and Oil, mg/l	267	144 - 450
Grease and Oil Ratio, kg/kkg	5.49	2.95 - 9.24
Organic Nitrogen, mg/l	--	-- - --
Organic Nitrogen Ratio, kg/kkg	--	-- - --
Ammonia-N, mg/l	--	-- - --
Ammonia-N Ratio, kg/kkg	--	-- - --
pH	6.46	6.27 - 6.75

5 samples

Table 91. Tuna process (plant 7).

Parameter	Mean	Range
Flow Rate, cu m/day	1,850	1,840 - 1,855
(mgd)	(.488)	(.488 - .492)
Flow Ratio, l/kkg	17,200	16,800 - 17,500
(gal/ton)	(4,110)	(4,040 - 4,190)
Settleable Solids, ml/l	--	-- - --
Settleable Solids Ratio, l/kkg	--	-- - --
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	513	432 - 594
Suspended Solids Ratio, kg/kkg	8.80	7.40 - 10.2
5 day BOD, mg/l	1,060	-- - --
5 day BOD Ratio, kg/kkg	18.2	-- - --
COD, mg/l	869	1,030 - 1,260
COD Ratio, kg/kkg	14.9	17.7 - 21.6
Grease and Oil, mg/l	97.7	90.6 - 105
Grease and Oil Ratio, kg/kkg	1.68	1.55 - 1.80
Organic Nitrogen, mg/l	68.2	69.8 - 97.6
Organic Nitrogen Ratio, kg/kkg	1.17	1.20 - 1.67
Ammonia-N, mg/l	3.13	18.6 - 18.8
Ammonia-N Ratio, kg/kkg	0.054	0.319 - 0.323
pH	6.90	6.88 - 6.91

2 samples

Table 92 . Tuna process (plant 8).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	246	140 - 461
(mgd)	(0.065)	(.037- .122)
Flow Ratio, l/kkg[2]	10,730	6105 -20,328
(gal/ton)	(2570)	(1464 - 4875)
Settleable Solids, ml/l	--	-- - --
Settleable Solids Ratio, l/kkg	--	-- - --
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	357	251 - 615
Suspended Solids Ratio, kg/kkg	3.8	2.7 - 6.6
5 day BOD, mg/l	634	400 - 755
5 day BOD Ratio, kg/kkg	6.8	4.3 - 8.1
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	1310	568 - 2712
COD Ratio, kg/kkg	14.1	6.1 - 29.1
Grease and Oil, mg/l	--	-- - --
Grease and Oil Ratio, kg/kkg	--	-- - --
Organic Nitrogen, mg/l	80.2	30.7 - 127.7
Organic Nitrogen Ratio, kg/kkg	0.86	.33 - 1.37
Ammonia-N, mg/l	2.5	1.86 - 4.47
Ammonia-N Ratio, kg/kkg	0.0268	.020- .048
pH[3]	6.85	6.7 - 7.1

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

8 Samples

Table 93 . Tuna process (plant 9).

Parameter	Mean	Range
Flow Rate, cu m/day[1]	348	159 - 568
(mgd)	(0.092)	(.042- .150)
Flow Ratio, l/kkg[2]	17,593	7919 -28,410
(gal/ton)	(4216)	(1899 - 6813)
Settleable Solids, ml/l	--	-- - --
Settleable Solids Ratio, l/kkg	--	-- - --
Screened Solids, mg/l	--	-- - --
Screened Solids Ratio, kg/kkg	--	-- - --
Suspended Solids, mg/l	441	131 - 868
Suspended Solids Ratio, kg/kkg	7.76	2.31 - 15.28
5 day BOD, mg/l	676	318 - 835
5 day BOD Ratio, kg/kkg	11.9	5.6 - 14.7
20 day BOD, mg/l	--	-- - --
20 day BOD Ratio, kg/kkg	--	-- - --
COD, mg/l	1671	835 - 2916
COD Ratio, kg/kkg	29.4	14.7 - 51.3
Grease and Oil, mg/l	--	-- - --
Grease and Oil Ratio, kg/kkg	--	-- - --
Organic Nitrogen, mg/l	79.9	33.9 - 336
Organic Nitrogen Ratio, kg/kkg	1.41	.597- 5.72
Ammonia-N, mg/l	3.2	.74 - 11.6
Ammonia-N Ratio, kg/kkg	.052	.013- .204
pH		

1 day = 8 hrs

2 weight of raw product

8 Samples

suspended solids as calculated for one plant which used representative packing machines. The load from the pak-shaper is summarized in Table 94.

As described in Section IV the cans were washed in three places: water from the first two was recirculated (solids and non-emulsified fats being removed by screening and skimming); the final phase usually flowed continuously. The holding tanks varied from 1.9 cu m/day to 151 cu m/day and were dumped once or twice per shift; this washwater plus overflow and final rinse comprised roughly 2 percent of the total plant flow. The entrained wastes had an average BOD_5 of 0.65 kg/kkg, with 0.80 kg/kkg of suspended solids; the latter represents 9 percent of the total suspended solids for the plants considered. The waste load from the can washing operation is summarized on Table 94.

Retort cooling water comprised approximately 14 percent of the total plant flow or 428 cu m/day for the average plant. Because the cans were subjected to a three-phase rinse prior to being retorted, the possibility of significant pollutional loading of this water is greatly reduced. A sample of this cooling water contained 0.0095 kg/kkg of suspended solids, contributing less than 0.09 percent of the total suspended solids to the plant effluent. A correspondingly low BOD_5 of 0.14 kg/kkg and 0.18 kg/kkg of grease and oil was obtained.

The washdown or clean-up process accounted for 7 percent of the total plant effluent, or approximately 220 cu m/day for the average plant. The process occurred after the cleaning and packing was completed and lasted from 2 to 6 hours, depending on the size of the plant and the clean-up crew. Because of the addition of caustic cleaning agents, the effluent pH was elevated from a mean value of 6.17 to a value of 8.4. Waste from the cleaning operation which had accumulated on the floors near machinery was removed prior to the washing down of this area. Small pieces of bone, skin, meat and fins which escape the initial step were washed into drains and were removed by screening. The resulting effluent from this process contained an average of 1.39 kg/kkg BOD_5 and 2.53 kg/kkg of suspended solids or 18 percent and 32 percent respectively, of the total waste loading. During the cleaning process 41 percent of the weight of the tuna was removed; for the average plant processing 167 kkg/day, this represents 68 kkg of potential waste material. The material entering the waste stream, however, totaled much less than this. Most material was recovered and used in the production of pet food (red meat) and by-products.

As indicated in the preceding discussion of each unit process, segregation of these processes was not possible in each of the nine plants in the sample group. Separate flow and waste characterization was obtainable for each unit process in from 1 to 6 of the plants depending on the process. Therefore, the percentage contribution of each parameter applies only to the subsample group and therefore may or may not total 100 percent for the sum of the process.

Table 94 Percent of total plant waste by unit process for BOD_5 and suspended solids.

Process	Percent Total Flow	Percent Total BOD_5	Percent Total Suspended Solids
Thaw	65	40	24
Butcher	10	20	19
Pack Shaper	2	14	16
Can Wash	2	8	9
Retort	14	<0.1	<0.1
Washdown	7	18	32

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

WASTEWATER PARAMETERS OF POLLUTIONAL SIGNIFICANCE

The waste water parameters of major pollutional significance to the canned and preserved seafood processing industry are: 5-day (20°C) biochemical oxygen demand (BOD_5), suspended solids, and oil and grease. For the purposes of establishing effluent limitations guidelines, pH is included in the monitored parameters and must fall within an acceptable range. Of peripheral or occasional importance are temperature, phosphorus, coliforms, ultimate (20 day) biochemical oxygen demand, chloride, chemical oxygen demand (COD), settleable solids, and nitrogen.

On the basis of all evidence reviewed, no purely hazardous or toxic (in the accepted sense of the word) pollutants (e.g., heavy metals, pesticides, etc.) occur in wastes discharged from canned or preserved seafoods processing facilities.

In high concentrations, both chloride and ammonia can be considered inhibitory (or occasionally toxic) to micro- and macro-organisms. At the levels usually encountered in fish and shellfish processing waters, these problems are not encountered, with one class of exceptions: high strength (occasionally saturated) NaCl solutions are periodically discharged from some segments of the industry. These can interfere with many biological treatment systems unless their influence is moderated by some form of dilution or flow equalization.

Rationale For Selection Of Identified Parameters

The selection of the major waste water parameters is based primarily on prior publications in food processing waste characterization research (most notably, seafood processing waste characterization studies) (Soderquist, *et al.*, 1972a, and Soderquist, *et al.*, 1972b). The EPA seafoods state-of-the-art report "Current Practice in Seafoods Processing Waste Treatment," (Soderquist, *et al.*, 1970), provided a comprehensive summary of the industry. All of these publications involved the evaluation of various pollutant parameters and their applicability to food processing wastes.

The studies conducted at Oregon State University over the past two years involving seafood processing wastes characterization included the following parameters:

1. temperature
2. pH
3. settleable solids
4. suspended solids
5. chemical oxygen demand

6. 5-day biochemical oxygen demand
7. ultimate biochemical oxygen demand
8. oil and grease
9. nitrate
10. total Keldahl nitrogen (organic nitrogen and ammonia)
11. phosphorus
12. chloride
13. coliform

Of all these parameters, it was demonstrated (Soderquist, et al., 1972b) that those listed above as being of major pollutional significance were the most significant. The results of the current study (Section V) support this conclusion. Below are discussions of the rationale used in arriving at those conclusions.

1. Biochemical Oxygen Demand (BOD5)

Two general types of pollutants can exert a demand on the dissolved oxygen regime of a body of receiving water. These are: 1) chemical species which exert an immediate dissolved oxygen demand (IDOD) on the water body due to chemical reactions; and 2) organic substances which indirectly cause a demand to be exerted on the system because indigenous microorganisms utilizing the organic wastes as substrate flourish and proliferate; their natural respiratory activity utilizing the surrounding dissolved oxygen. Seafood wastes do not contain constituents that exert an immediate demand on a receiving water. They do, however, contain high levels of organics whose strength is most commonly measured by the BOD5 test.

The biochemical oxygen demand is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term "decomposable" may be interpreted as meaning that the organic matter can serve as food for the bacteria and energy is derived from this oxidation.

The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Seafood processing and other organic effluents exert a BOD during their processes of decomposition which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

The BOD_5 test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses in which aerobic conditions exist. The test is one of the most important in stream polluton control activities. By its use, it is possible to determine the degree of pollution in streams at any time. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacities of receiving bodies of water.

The BOD_5 test is essentially a bioassay procedure involving the measurement of oxygen consumed by living organisms while utilizing the organic matter present in a waste under conditions as similar as possible to those that occur in nature. The problem arises when the test must be standardized to permit its use (for comparative purposes) on different samples, at different times, and in different locations. Once "standard conditions" have been defined, as they have (Standard Methods, 1971) for the BOD_5 test, then the original assumption that the analysis simulates natural conditions in the receiving waters no longer applies, except only occasionally.

In order to make the test quantitative the samples must be protected from the air to prevent reaeration as the dissolved oxygen level diminishes. In addition, because of the limited solubility of oxygen in water (about 9 mg/l at 20°C), strong wastes must be diluted to levels of demand consistent with this value to ensure that dissolved oxygen will be present throughout the period of the test.

Since this is a bioassay procedure, it is extremely important that environmental conditions be suitable for the living organisms to function in an unhindered manner at all times. This requirement means that toxic substances must be absent and that accessory nutrients needed for microbial growth (such as nitrogen, phosphorus and certain trace elements) must be present. Biological degradation of organic matter under natural conditions is brought about by a diverse group of organisms that carry the oxidation essentially to completion (i.e., almost entirely to carbon dioxide and water). Therefore, it is important that a mixed group of organisms commonly called "seed" be present in the test. For most industrial wastes, this "seed" should be allowed to adapt to the particular waste ("acclimate") prior to introduction of the culture into the BOD_5 bottle.

The BOD_5 test may be considered as a wet oxidation procedure in which the living organisms serve as the medium for oxidation of the organic matter to carbon dioxide and water. A quantitative relationship exists between the amount of oxygen required to convert a definite amount of any given organic compound to carbon dioxide and water which can be represented by a generalized equation. On the basis of this relationship it is possible to interpret BOD_5 data in terms of organic matter as well as in terms of the amount of oxygen used during its oxidation. This concept is fundamental to an understanding of the rate at which BOD_5 is exerted.

The oxidative reactions involved in the BOD_5 test are results of biological activity and the rate at which the reactions proceed is governed to a major extent by population numbers and temperature. Temperature effects are held constant by performing the test at 20°C, which is more or less a median value for natural bodies of water. The predominant organisms responsible for the stabilization of most organic matter in natural waters are native to the soil.

The rate of their metabolic processes at 20°C and under the conditions of the test (total darkness, quiescence, etc.) is such that time must be reckoned in days. Theoretically, an infinite time is required for complete biological oxidation of organic matter, but for all practical purposes the reaction may be considered to be complete in 20 days. A BOD test conducted over the 20 day period is normally considered a good estimate of the "ultimate BOD." However, a 20 day period is too long to wait for results in most instances. It has been found by experience with domestic sewage that a reasonably large percentage of the total BOD is exerted in five days. Consequently, the test has been developed on the basis of a 5-day incubation period. It should be remembered, therefore, that 5-day BOD values represent only a portion of the total BOD. The exact percentage depends on the character of the "seed" and the nature of the organic matter and can be determined only by experiment. In the case of domestic and some industrial waste waters it has been found that the BOD_5 value is about 70 to 80 percent of the total BOD. This has been demonstrated (Section V) to be the case for seafoods processing waste waters as well. This is considered to be a large enough percentage of the total BOD so that 5-day values are used in many instances, (Sawyer and McCarty, 1967). Both the 5-day and the 20-day (ultimate) BOD tests were employed in this study with reasonable success.

2. Suspended Solids

This parameter measures the suspended material that can be removed from the waste waters by laboratory filtration but does not include coarse or floating matter that can be screened or settled out readily. Suspended solids are a vital and easily determined measure of pollution and also a measure of the material that may settle in tranquil or slow moving streams. Suspended solids in the raw wastes from seafood processing plants correlate well with BOD_5 and COD. Often, a high level of suspended solids serves as an indicator of a high level of BOD_5. Suspended solids are the primary parameter for measuring the effectiveness of solids removal systems such as screens, clarifiers and flotation units. After primary treatment, suspended solids no longer correlate with organics content because a high percentage of the BOD_5 in fish processing waste waters is soluble or colloidal.

Suspended solids include both organic and inorganic materials. The inorganic components may include sand, silt, and clay. The organic fraction includes such materials as grease, oil, animal and vegetable fats, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the receiving water with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises.

Solids may be suspended in water for a time, and then settle to the bed of the receiving water. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the receiving water bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the receiving water and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic, and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

3. Oil and Grease

Oil and grease exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to exhibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water insoluble components damage the plumage and costs of water animals and fowls. Oil and grease in a water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water.

Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines.

Although with the foregoing analyses the standard procedures as described in the 13th edition of Standard Methods (1971), are applicable to seafood processing wastes, this appears not necessarily to be the case for "floatables." The standard method for determining the oil and grease level in a sample involves multiple solvent extraction of the filterable portion of the sample with n-hexane or trichlorotrifluorethane (Freon) in a soxhlet extraction apparatus. As cautioned in Standard Methods, (1971) this determination is not an absolute measurement producing solid, reproducible, quantitative results. The method measures, with various accuracies, fatty acids, soaps, fats, waxes, oils and any other material which is extracted by the solvent from an acidified sample and which is not volatilized during evaporation of the solvent. Of course the initial assumption is that the oils and greases are separated from the aqueous phase of the sample in the initial filtration step. Acidification of the sample is said to greatly enhance recovery of the oils and greases therein (Standard Methods,1971). Oils and greases are particularly important in the seafoods processing industries because of their high concentrations and the nuisance conditions they cause when allowed to be discharged untreated to a watercourse. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Oil emulsion may adhere to the gills of fish or coat and destroy algae or other plankton. Also, oil and grease are notably resistant to anaerobic digestion and when present in an anaerobic system cause excessive scum accumulation, clogging of the pores of filters, etc., and reduce the quality of the final sludge. It is, therefore, important that oils and greases be measured routinely in seafood processing waste waters and that their concentrations discharged to the environment be minimized. Previous work with seafoods had indicated that the Standard Methods (1971) oil and grease procedure was inadequate for some species. In a preliminary study the standard method recovered only 16 percent of a fish oil sample while recovering 99 percent of a vegetable oil sample. However, because alternative methods for seafood process waste waters were not available, the Standards Methods (1971) oil and grease analysis was used in this study.

Recent work (March, 1973) by the staff of the Fishery Products Technological Laboratory of the National Marine Fisheries Service in Kodiak, Alaska, indicates that a modification of the Standard Methods (1971) oil and grease analysis markedly improves recovery from crab and shrimp processing effluents (Collins, 1972). The method of Collins was designed to be an improved, simplified replacement for the Standard Methods (1971) analysis, to be practicable in most industrial laboratories without significant investment in facilities. In addition to improving recovery, Collins' method allows the filtration of significantly larger samples, thereby increasing accuracy and reproducability of the technique. One feature of that method apparently is the key to its success: the filtration step employed. As mentioned above, the oils and greases in the seafoods waste water samples cannot be extracted by the organic solvent if they are not first filtered out of the aqueous sample. It is, furthermore, implied above that a significant portion of the oils and greases are not removed in the filtration step in the standard method. To improve recovery, Collins recommended a simple and fast filtration technique using a filter aid and a slurry of filter paper. This method appears to hold considerable promise and may be the secret to improved recoveries in the analysis of greases and oils in fish processing effluents.

4. pH, Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH, water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

For these reasons pH is included as a monitored effluent limitation parameter even though the majority of seafood processing waste waters is near neutrality prior to treatment.

Minor Parameters

Of the minor parameters mentioned in the introduction to this section, eight were listed: ultimate BOD, COD, phosphorus, nitrogen, temperature, settleable solids, coliforms, and chloride. Of these eight, two are considered peripheral and six are considered of occasional importance. Of peripheral importance are ultimate BOD and phosphorus. Phosphorus levels are sufficiently low to be of negligible importance, except under only the most stringent conditions, i.e., those involving eutrophication which dictate some type of tertiary treatment system. The ultimate BOD and phosphorus can be closely approximated with the COD test.

1. Chemical Oxygen Demand (COD)

The chemical oxygend demand (COD) represents an alternative to the biochemical oxygen demand, which in many respects is superior. The test is widely used and allows measurement of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water under severe chemical and physical conditions. It is based on the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acid conditions. Although amino nitrogen will be converted to ammonia nitrogen, organic nitrogen in higher oxidation states will be converted to nitrates; that is, it will be oxidized.

During the COD test, organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances; for instance, glucose and lignin are both oxidized completely. As a result, COD values are greater than BOD values and may be much greater when significant amounts of biologically resistant organic matter is present. In the case of seafood processing wastes, this does not present a problem, as is demonstrated by the data generated in this study and presented in Section V. The BOD to COD ratio of seafood processing wastes is approximately the same as the ratio for domestic wastes, indicating that the two types of wastes are approximately equally biodegradable. Another drawback of the COD test is its inability to demonstrate the rate at which the biologically active material would be stabilized under conditions that exist in nature. In the case of seafood processing wastes, this same drawback is applicable to the BOD test, because the strongly soluble nature of seafood processing wastes lends them to more rapid biological oxidation than domestic wastes. Therefore, a single measurement of the biochemical oxygen demand at a given point in time (5 days) is no indication of the difference between these two rates. The major advantage of the COD test is the short time required for evaluation. The determination can be made in about 3 hours rather than the 5 days required for the measurement of BOD. Furthermore, the COD requires less sophisticated equipment, less highly-trained personnel, a smaller working area, and less investment in laboratory facilities. Another major advantage of the COD test is that seed acclimation need not be a problem. With the BOD test, the seed used to inoculate the culture should have been acclimated for a period of several days, using carefully prescribed procedures, to assure that the normal lag time (exhibited by all microorganisms when subjected to a new substrate) can be minimized. No acclimation, of course, is required in the COD test. One drawback of the chemical oxygen demand is analogous to a problem encountered with the BOD also; that is, high levels of chloride interfere with the analysis. Normally, 0.4 grams of mercuric sulfate are added to each sample being analyzed for chemical oxygen demand. This eliminates the chloride interference in the sample up to a chloride level of 40 mg/l. At concentrations above this level, further mercuric sulfate must be added. However, studies by the National Marine Fisheries Service Technological Laboratory in Kodiak, Alaska, on seafood processing wastes have indicated that above certain chloride concentrations the added mercuric sulfate itself causes interference (Tenny, 1972).

With the possible exception of seawater samples, this does not present a problem in the fish processing industry, because organic levels are sufficiently high that dilution is required prior to COD analysis. This dilution, of course, reduces the chloride level in the sample as well as the organic level, thereby eliminating or reducing the chloride interference problem.

The possibility of substituting the COD parameter for the BOD_5 parameter was investigated during a subsequent study of the seafood industry which will be published in the near future. The BOD_5 and corresponding COD data from industrial fish, finfish, and shellfish waste waters were analyzed to determine if COD is an adequate predictor of BOD_5 for any or all of these groups of seafood. The analysis indicates tht the COD parameter is not a reliable predictor of BOD_5.

Moreover, the relationship between COD and BOD_5 before treatment is not necessarily the same after treatment. Therefore, the effluent limitations guidelines will include the BOD_5 parameter, since insufficient information is available on the COD effluent levels after treatment.

2. Settleable Solids

The settleable solids test involves the quiescent settling of a liter of waste water in an "Imhoff cone" for one hour, with appropriate handling (scraping of the sides, etc.). The method is simply a crude measurement of the amount of material one might expect to settle out of the waste water under quiescent conditions. It is especially applicable to the analysis of waste waters being treated by such methods as screens, clarifiers and flotation units, for it not only defines the efficacy of the systems, in terms of settleable material, but provides a reasonable estimate of the amount of deposition that might take place under quiescent conditions in the receiving water after discharge of the effluent.

3. Ammonia and Nitrogen

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process. Seafoods processing waste waters are highly proteinaceous in nature; total nitrogen levels of several thousand milligrams per liter are not uncommon. Most of this nitrogen is in the organic and ammonia form. These high nitrogen levels contribute to two major problems when the waste waters are discharged to receiving waters. First the nitrification of organic nitrogen and ammonia by indigineous microorganisms creates a sizable demand on the local oxygen resource. Secondly, in waters where nitrogen is the limiting element this enrichment could enhance eutrophication markedly. The accepted methods for measurement of organic and ammonia nitrogen, using the macro-kjeldahl apparatus as described in Standard Methods (1971), are adequate for the analysis of seafoods processing wastewaters. It should be remembered that organic strengths of seafood processing waste waters are normally considerably higher than that of normal domestic sewage; therefore, the volume of acid used in the digestion process frequently must be increased. Standard Methods (1971) alerts the analyst to this possibility by mentioning that in the presence of large quantities of nitrogen-free organic matter, it is necessary to allow an additional 50 ml of sulfuric acid - mecuric sulfate - potassium sulfate digestion solution for each gram of solid material in the sample. Bearing this in mind, the analyst can, with assurance, monitor organic nitrogen and ammonia levels in fish and shellfish processing waste waters accurately and reproducibly.

Nitrogen parameters are not included in the effluent limitation guidelines because the extent to which nitrogen components in seafood wastes is removed by physical-chemical or biological treatment, remains to be evaluated. Furthermore, the need for advanced treatment technology specifically designed for nitorgen removal has not been demonstrated through this study.

4. Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Temperature is important in those unit operations involving transfer of significant quantities of heat. These include evaporation, cooking, cooling of condensers, and the like. Since these operations represent only a minor aspect of the total process and their waste flows are generally of minor importance, temperature is not considered at this time to be a major parameter to be monitored.

5. Chloride

The presence of the chloride ion in the waters emanating from seafood processing plants is frequently of significance when considering biological treatment of the effluent. Those processes employing saline cooks, brine freezing, brine separation tanks (for segregating meat from shell in the crab industry, for instance) and seawater for processing, thawing, and/or cooling purposes, fall into this category. In consideration of biological treatment the chloride ion must be considered, especially with intermittent and fluctuating processes. Aerobic biological systems can develop a resistence to high chloride levels, but to do this they must be acclimated to the specific chloride level expected to be encountered; the subsequent chloride concentrations should remain within a fairly narrow range in the treatment plant influent. If chloride levels fluctuate widely, the resulting shock loadings on the biological system will reduce its efficiency at best, and will prove fatal to the majority of the microorganisms in the system at worst. For this reason, in situations where biological treatment is anticipated or is currently being practiced, measurement of chloride ion must be included in the list of parameters to be routinely monitored. The standard methods for the analysis of chloride ion are three fold: 1) the argentometric method, 2) the mercuric nitrate method and 3) the potentiometric method. The mercuric nitrate method has been found to be satisfactory with seafood processing waste waters. In some cases, the simple measurement of conductivity (with appropriate conversion tables) may suffice to give the analyst an indication of chloride levels in the waste waters.

6. Coliforms

Fecal coliforms are used as an indicator since they have originated from the intestinal tract of warm blooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, chlorea, vibriosis and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent. Fish, however, are cold blooded and no correlation has yet been developed between contamination by fish feces and effluent (or receiving water) coliform levels.

In a recent study undertaken by the Oregon State University under sponsorship of the Environmental Protection Agency, coliform levels (both total and fecal) in fish processing waste water were monitored routinely over a period of several months. Results were extremely inconsistent, ranging from zero to many thousands of coliforms per 100 ml sample. Attempts to correlate these variations with in-plant conditions, type and quality of product being processed, cleanup procedures, and so on, were unsuccessful. As a result, a graduate student was assigned the task of investigating these problems and identifying the sources of these large variabilities. The conclusions of this study can be found in the report; "Masters Project--Pathogen Indicator Densities and their Regrowth in Selected Tuna Processing Wastewaters" by H. W. Burwell, Department of Civil Engineering, Oregon State University, July 1973. Among his general conclusions were:

1. that coliform organisms are not a part of the natural biota present in fish intestines;
2. that the high suspended solid levels in waste water samples interferes significantly with subsequent analyses for coliform organisms and, in fact, preclude

the use of the membrane filter technique for fish waste analysis;

3. that the analysis must be performed within foru hours after collection of the sample to obtain meaningful results (thus eliminating the possibility of the use of full-shift composite samples and also eliminating the possibility of sample preservation and shipment for remote analysis);
4. that considerable evidence exists that coliform regrowth frequently occurs in seafood processing waste water processing wastes) and that the degree of regrowth is a function of retention, time, waste water strength, and temperature.

The above rationale indicated that it would be inadvisable to consider further the possibility of including the coliform test in either the characterization phase of this study or in the list of parameters to be used in the guidelines.

7. Phosphorus

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as an physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

IN-PLANT CONTROL TECHNIQUES AND PROCESSES

The concept of utilizing in-plant changes to reduce or prevent waste and pollution requires a major change in thinking on the part of industry and the consumer. Present waste and pollution comes from the fishing boats (where soluble components accumulate in the bilge and are often subsequently discharged into harbors adjacent to the plants) as well as the discharge water from plants, containing both solids and solubles. Not only do solubles create an unacceptable pollution problem, but they represent a valuable proteinaceous food material that should be recovered. Likewise, much of the solid waste currently being reduced to low-grade animal food or discarded as a waste product can and should be upgraded to human foods or high-grade animal feed components.

The seafood industry must rapidly reorient its efforts toward a "total utilization concept," wherein much of the current waste materials are viewed as "secondary raw materials." This reorientation is not only necessary for maintaining and improving environmental quality, but for utilization of the food that is now being wasted. Many phases of the industry are not compatible with the requirements of today's world and, even less, with those of tomorrow. The current industry allows the majority of the 70 million metric ton (77 million ton) world catch to be either reduced to low-grade animal feed or wasted, in the presence of an ever-expanding protein-hungry world that needs the nutritional components in the liquid and solid wastes.

One of the key points in trying to introduce conceptual changes into the seafood industry is to increase our horizons to maintain a broad perspective in terms of world fish production and consumption. Considering that approximately 100 grams of fish per day contains an adequate amount of animal protein to balance a man's protein diet in many areas of deficiency, there is enough animal protein in world seafood production to satisfy the protein requirements of 1.8 billion people or approximately one-half of the world's population.

At the present time more than two-thirds of the harvested seafood is not being directly utilized as human food and approximately one-half of this amount is being discarded. From a nutritional point of view, this wasted portion is comparable to the portion being marketed for human food and represents a tremendous potential for increasing the supply of animal protein needed by the world's population. Furthermore, effective utilization of food materials requires familiarization with the world eating habits. For example, ten years ago salmon eggs, which account for about five percent of the total weight of the fish, presented a waste disposal problem. Today the Japanese are paying as much as \$6.00 per kg (\$2.70 per lb) for salmon eggs to be used for caviar. On the other hand, people in the United States will not eat salmon egg caviar. Hence, waste from one nation is considered a delicacy by another.

Maintaining the theme of "total utilization," it is the object of this discussion to analyze the various factors involved in "closing the processing cycle" so that raw material is used to the fullest extent possible with the subsequent minimization of environmental pollution. The implementation of in-plant changes to accomplish this goal is certainly more logical than spending large amounts of money to simply treat food processing wastes at the end of the effluent pipe.

Interdependence of Harvesting and Processing

The harvesting of fishery products can be divided into two broad classifications, namely those involving the catching of large masses in a single effort and those of catching or harvesting individual animals. Mass harvesting of fish ordinarily requires expensive and sophisticated equipment compared to the catching of individual animals. Hence, the practice of mass harvesting, particularly as applied to the high seas fisheries, is limited to countries which can afford the expensive vessels and gear that are required. On the other hand, many fisheries of the world do not lend themselves to mass catch techniques, since the fish are not concentrated in accessible areas. With the exception of certain high seas longline operations that are used for catching individual fish such as halibut or tuna, small vessels with rather simple pole-and-line type fishing gear can be used in many parts of the world for harvesting individual specimens.

Even marketing of highly desirable seasonal fish, such as salmon, has been somewhat restricted by the gluts of raw material that are available during a short period of the year. Although the market demand and processor's profit are greater for quick-frozen salmon, he has continued to can much of the pack because adequate freezing and handling facilities have not been available. Furthermore, if a company cannot diversify into other fisheries and operate over a major portion of the year, capital investment versus profit greatly limits the degree to which new freezing and cold storage facilities can be purchased to handle larger portions of the seasonal catch. Hence, extensive efforts are being made by companies handling seasonal fish to diversify into other fisheries to justify their capital investment. This diversification should be beneficial to the environment in at least two ways. First, the longer processing season should justify increased capital expenditures on waste treatment systems (as well as processing facilities); and secondly, more regular and continuous processing schedules should increase the number of options available to the waste treatment system design engineer.

Furthermore, a constant supply of solid wastes may justify installation of fish meal plants in areas where they are currently economically infeasible.

Companies processing and marketing seafoods caught in small quantities sometimes face the problem of labor costs being more important than capital investment. Therefore, the fisheries that involve greater harvesting effort and/or that require more manual labor in processing generate products more costly to the consumer. Unfortunately, many of the most desirable products, such as shrimp, crabs, oysters, clams, and troll caught fishes, fall into this category. In many cases, these species are not only expensive to obtain, but represent dwindling resources.

Nutritive Value and Total Utilization

Protein Foods

Meat, fish, and fowl are commonly placed in the category of "animal protein" foods. Meats from these creatures, regardless of origin, have similar nutritional properties. They contain 15 to 20 percent protein, which has significant amounts of all essential amino acids.

Cereals and grains all contain protein. However, these proteins, called "vegetable proteins," are all lacking in certain essential amino acids. A large segment of the world's population, obtaining essentially all of its proteins from vegetable sources, suffers from various protein deficiencies. Furthermore, many people subsisting on vegetable protein not only are deficient in essential amino acids, but have a general low intake of total amino acids, due to the low level of protein found in cereal and grain products.

In general, areas of the world that consume animal protein as a normal part of their diet seldom are afflicted with the disease "kwashiorkor," caused by lack of protein (particularly the essential amino acids).

Although the protein content of fish ranges from 6 to 28 percent (on a wet basis), it usually lies between 12 and 18 percent. The amino acid content of fish is very similar to that in mammalian flesh. Hence, consumption of fish proteins represents a most effective way to supply all amino acid requirements of man and other animals. In the human diet, it is necessary to furnish those amino acids which cannot be synthesized by the tissues or organs of human beings. These essential amino acids occur abundantly in fish.

Fish lipids consist of saturated, mono-unsaturated, and poly-unsaturated fatty acids. Polyunsaturated fatty acids constitute the major portion. A large part of the twenty-carbon fatty acids of fish lipids is made up of pentenes (5 double bonds), whereas a large portion of the twenty-two carbon fatty acids consists of hexenes (6 double bonds). The latter are present in considerably greater amounts than the former in the phospholipids, a pattern which appears to be typical of fish flesh. Hence, it can be seen that fish flesh is not only highly desirable as a completely balanced protein food, but has fats or lipids that are currently in demand, since they are highly polyunsaturated.

A major problem in the marketing of fish as a protein food lies in the fact that the desirable unsaturated lipids tend to oxidize quite rapidly, resulting in rapid fish degradation. This problem is minimized by filleting, since the trimmings usually have a considerably higher lipid content and lower protein content than does the edible portion. These differences can be quite pronounced. Table 95 shows the approximate composition of various portions of dover sole. Although it can be seen that the edible flesh (the fillet) has a relatively small lipid content and will probably be much more stable to oxidation than the non-edible portion, it must also be pointed out that the non-edible portion accounts for as much as 70 percent of the original whole fish and contains almost as much protein as the original fish.

Hence, although fish is a highly desirable animal protein, marketing techniques in the future must not only improve the distribution and consumption of the so-called "edible portions," but must develop markets for the portions now being discarded or reduced to animal feed supplements.

Supplementary Additives

The fact that such a large portion of the world seafood production is being either discarded or used for animal feed has directed much recent research work into developing techniques for utilizing all portions of a fishery resource. One of the most promising methods for utilizing whole fish or waste portions lies in removing the lipid and water fractions, thus obtaining a high-protein dried "flour" that can be used for supplementing diets deficient in protein.

Table 95. Proximate composition of whole fish, edible flesh and trimmings of dover sole [Microstomus pacificus (Stansby and Olcott, 1963)]

Constituent	Whole Fish	Edible Portion	Non-Edible Portion (all parts except flesh)
Moisture	81.9%	83.6%	81.2%
Lipid	3.5%	0.8%	4.4%
Protein	12.7%	15.2%	11.7%
Ash	2.7%	1.1%	3.5%

The production of a concentrated fish protein has many advantages in areas where animal protein supplementation is desired: 1) the product can be inexpensive on a protein unit basis, thus making it more attractive to developing countries; 2) removal of water and lipid stabilizes the product so that it can be stored indefinitely under many different climatic conditions; 3) many populations of fish now considered to be scrap or industrial fishes can be diverted into the human food market. The latter not only utilizes a new source of protein, but expands or creates harvesting and processing industries in the countries concerned.

Most discussions regarding the utilization of concentrated fish proteins as food additives center around their use in developing countries having severe protein shortages. On the other hand, it is predicted that by 1980, of approximately one billion kilograms (2.2 billion lbs) of protein additives used in the United States, 0.86 billion kilograms (1.9 billion lbs) will come from proteins other than milk (Hammonds and Call, 1970). This means that soy, egg, cottonseed, certain nut, chicken, and fish proteins will become increasingly important. Since eggs and chickens are strongly dependent on fish meal to keep their prices down and the vegetable proteins are deficient in certain amino acids, fish will undoubtedly play a most important role in filling these future requirements. In fact, the processing of whole fish, as well as fish waste, will be a major source of protein in the more developed countries where this tremendous increase in concentrated proteins will be needed to support fortified cereal grain products, as well as prepared foods.

Non-Edible Products

Protein portions of fish and shellfish have high nutritive value and should be used in the totality for human or animal food. Another major fraction of the various shellfish harvested is the shell. The shell in several types of shellfish, particularly crab and shrimp, has a chemical composition containing materials that have potential as non-edible products for many phases of commerce.

Shells from crustacea, depending on species and time of year, contain 25 to 40 percent protein, 40 to 50 percent calcium carbonate, and 15 to 25 percent chitin. Chitin is an insoluble polysaccharide that serves as the "binder" in the shell. Chitin, or the deacytelated form, chitosan, has many outstanding properties for use in flocculating, emulsifying, thickening, coagulating, improving wet strength of paper, and many other uses. The protein that can be reclaimed from the shell is high quality and does not exhibit the amine odor found in fish flesh.

Another use for crustacea (i.e., shrimp and crab) shell is as a meal for animal feed. It is especially desirable for fish diets since the pigment imparts a pink color to the flesh of captive grown fish, increasing their market appeal. If effective means of collecting shell from all crustacea processed in the United States were available, in excess of 4500 kkg (5000 tons) of chitosan could be produced yearly. Even this amount would satisfy only a small portion of the overall world demand (Penniston, 1973).

In-Plant Changes Directed Toward Total Utilization

The previous discussion points out the need for maximizing the utilization of fishery products. Therefore, the optimal approach to solving the waste and pollution problems in the seafood industry is to utilize the raw material fully, rather than waste most of it and subsequently treat that waste.

There are relatively few unit operations and unit processes used in seafood processing. Furthermore, there are even fewer components in the residual solids and liquids. Essentially all fish waste components have desirable nutritional properties. Based on this analysis, the approach to in-plant changes is to analyze the various steps in each processing cycle, determine the form and amount of material available in each step, and then apply recovery techniques to produce marketable products from the secondary raw material.

In general, all processing results in visceral protions having essentially the same nutritive value and composition and in effluent streams that vary primarily in suspended solids and dissolved solids content. The dissolved solids vary from highly nutritious proteins to low molecular weight degradation products from the proteins. The breakdown products have limited or no nutritional value and increase, at the expense of the proteins, with the age of the raw material and the severity of the process.

The solids and effluents from all fish and shellfish operations consist of:

1. Hot and cold water (fresh or seawater) solutions containing dissolved materials (proteins and breakdown products), suspended solids consisting of bone, shell or flesh, and foreign material carried into the plant with the raw material.

2. Solid portions consisting of flesh, shell, bone, cartilage, and viscera. From the biological standpoint, all of these materials are either inert or have sufficient nutritive value to make them valuable as a food or food additive.

The in-plant changes that can be made to solve waste and pollution problems do not involve extensive study and development of each type of seafood processing procedure, but conversely, the development of a few basic techniques that will be applicable to any process. These include:

a. minimizing the use of water (thus minimizing loss of solubles);
b. recovery of dissolved proteins in effluent solutions; and
c. recovery of solid portions for use as edible products.

Effective use of these three procedures would reduce pollutant levels in effluents from seafood plants.

Minimizing Water Use

Without question the first step in improving the loss of nutritive material in a fish processing plant is to reduce the use of water. There are many areas in which this can be accomplished at once.

Prior to the heat denaturation of proteins (cooking), a water soluble fraction can be dissolved that can remove as much as 15 percent of the total protein. As will be discussed later, this protein can be recovered as a marketable product, but it is more costly and produces a less desirable product than that originally intended. The amount of protein loss by leaching is a function of the amount or volume of water used per unit weight or volume of seafood processed.

One of the first water-saving techniques employed should be to eliminate the extensive use of flumes for in-plant transport of product. There are few areas where dry handling of products could not replace flumes with, incidental, significant increases in product yields. Cleaning a dry belt or container requires a small fraction of the water that would be used for fluming. Many plants are now using pneumatic ducts rather than flumes for moving small particles - dry material such as shell, and wet screened solids.

Another water-saving technique would be the use of spring-loaded hose nozzles which automatically shut off when released by the user. Much more water is being used in the average butchering operation than is necessary. It is a common practice in a butchering line to open the valve and let it run without control even when no one is actively using the table position. Steam and water valves are frequently not repaired, allowing the loss of water and steam, and the discharge of condensate onto the floor. Water commonly is allowed to run through unused machines, overflow cleaning or cooling tanks, or pass through empty flumes.

Educating plant personnel to minimize water consumption is the first step in the process of reducing the industry's environmental impact.

Protein Recovery

Several techniques are available for reclaiming protein from the portions of the products now being wasted. The protein can be recovered in the wet form and made into high quality frozen items or it can be recovered as a meal or flour, ranging from tasteless-odorless fish flour to fish meal for animal feed. The market for these items is virtually unlimited, and the choice of process to be installed in a plant depends on such factors as initial capital investment, length of operating season, availability of transportation facilities and many other items peculiar to the specific operation. Four types of processes are either currently available or will be developed to the point of commercial feasibility in the near future. These warrant consideration in overall in-plant control programs and each are discussed briefly below.

1. Conventional Reduction Processes

The conventional reduction process for converting whole fish or fish waste to fish meal for animal feed has been used for many years. Plant capacities range from the massive plants of 1450 kkg/day input (1600 ton/day) for processing anchovy in Peru and Chile to the small package units for processing fish viscera and trimmings from a fish canning or freezing plant. As shown in Figure 29, a basic large production plant with a 18.2 kkg (20 ton) per hour input capacity costs about $600,000 for equipment, while the essential facilities for batch-processing 0.9 kkg (1 ton) of waste in 4 or 5 hours is around $15,000. Of course, there is a large variation in any plant investment depending on the building and associated facilities required for a given location. Frequently, the capital investment for a meal operation in an existing plant could be greatly reduced if there were building spaces, docks, steam and other items available for the addition.

In general, the cost of producing meal depends on the number of days per year in which the plant can be continuously operated.

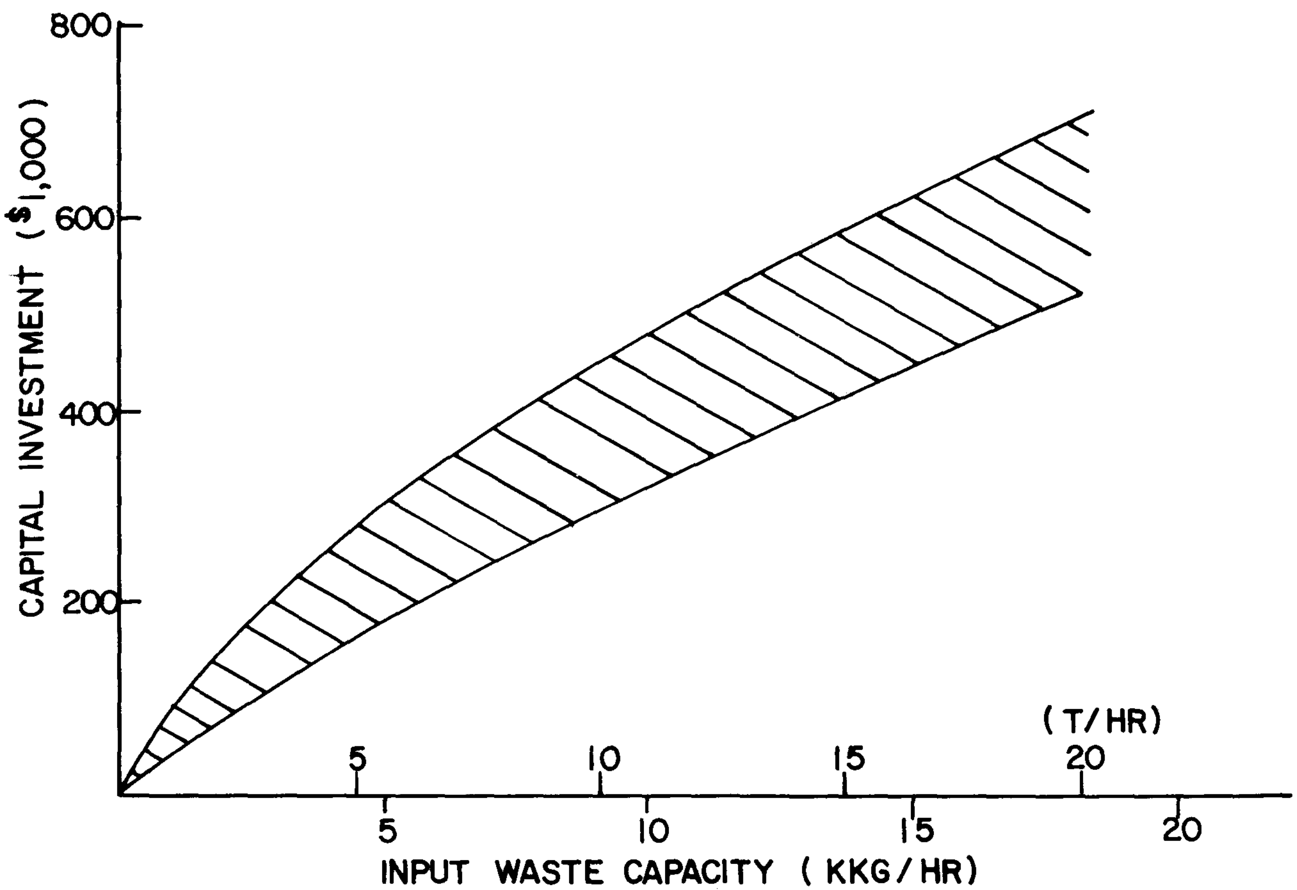


Figure 29 Convential meal plant capital costs.

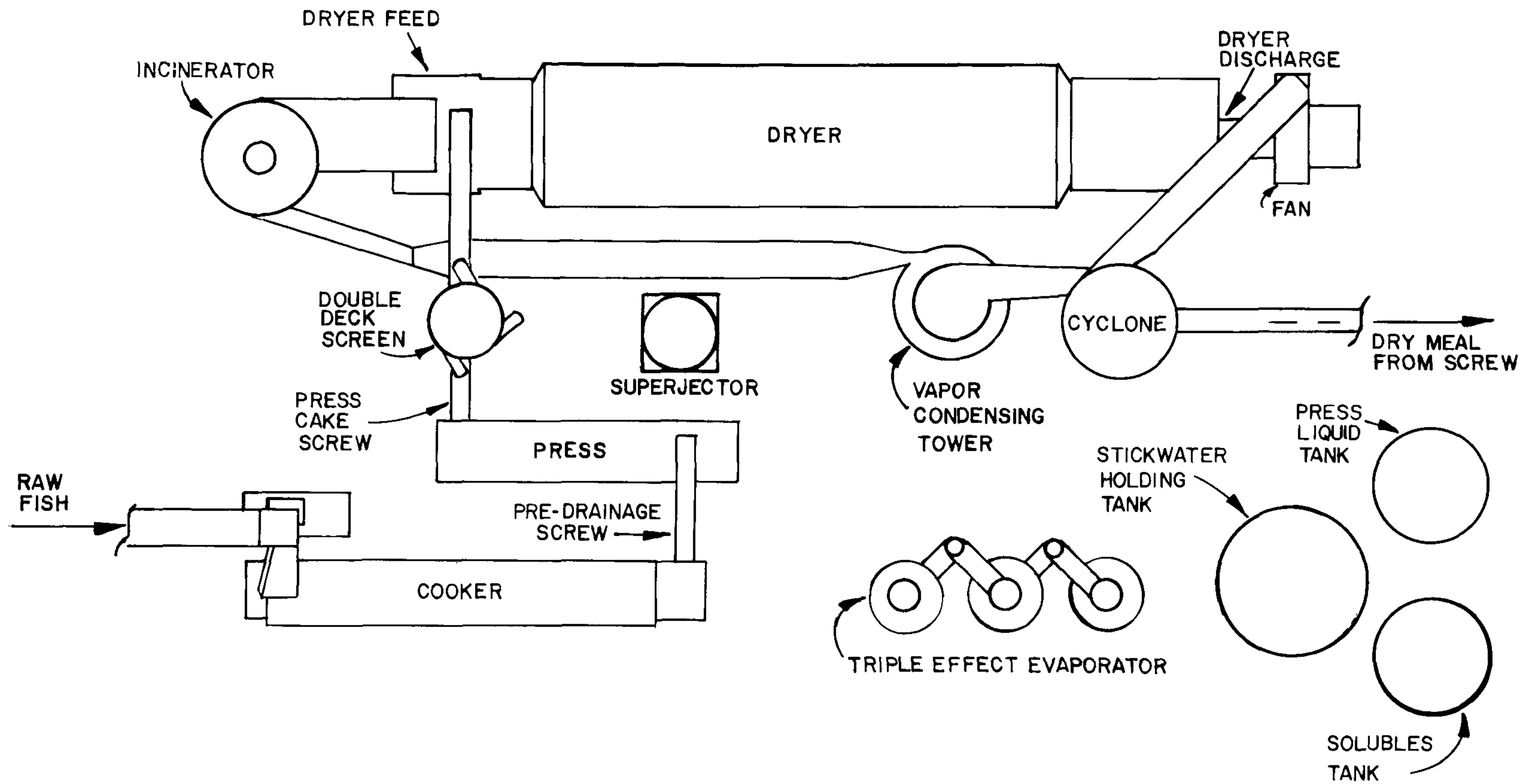


Figure 30 Continuous fish reduction plant with soluble recovery and odor control.

Of the categories currently under consideration, only large tuna plants, such as those in Terminal Island, California and Puerto Rico have sufficient waste material to justify continuous meal plants with the required odor control and stickwater processing facilities (Figure 30) where operating costs can be as low as $66 to $88 per kkg ($60 to $80 per ton) of product. Meal from these plants is also in greater demand since the small batch plants do not press the cooked fish to remove oil and the resulting product has an extremely high oil content. The oil content is the limiting factor in adding fish meal to an animal feed ration. The limit for conventional fish meal is 15% of the ration. More oily meals must be restricted to a lower level because the oil flavor is carried over into the flesh of the animal.

Unfortunately, with the possible exception of areas like Kodiak, Alaska, where some 14 plants can send both crab and fish waste to a central reduction plant, there is not sufficient volume in individual plants, especially those processing crab or shrimp, to justify installation of conventional reduction facilities. For example, the lowest cost batch reduction facility using the simple three-step process shown in Figure 31 would handle approximately 0.9 kkg (1 ton) of raw material producing about 182 to 200 kg (400 to 440 pounds) of meal in 4 to 5 hours. This unit, weighing approximately 5000 kkg (11,000 pounds) would be about 4.0 m (13 ft) long by 1.5 m (5 ft) wide by 2.0 m (6-1/2 ft) high and cost $15,000 to $20,000. Steam equivalent to that from a 7.5 kw (10 horsepower) boiler would also be required. The waste from 15.9 kkg (17.5 tons) of dressed fish or 5.7 kkg (6.25 tons) of shellfish could be processed in 24 hours yielding perhaps 0.9 kkg (1 ton) of fish meal and slightly more shellfish meal. The three mandays required for operation would cost considerably more than the sales price of crab or shellfish meal which is approximately $55-$165 per kkg ($50-$150 per ton). With the continuing high price of fish meal, however, prudent selection of a small meal plant for catfish and other finned-fish operations may be a less expensive means of waste disposal than other methods. It is almost impossible to accurately cost estimate fish meal operations at the present time since prices are at an unrealistically high level. Peru, normally the producer of one-half of the world's fish meal, has had greatly reduced output in 1972 and 1973 due to an unusual ocean current condition. Hence, there is essentially no fish meal available today (i.e., imports from Peru in January through April were 55 kkg (60.5 tons) in 1972 and 5.4 kkg (5.9 tons) this year), and the small stocks are selling up at to three or more times the 1971 prices. If this shortage continues, production of meal from waste will be practical, but at normal prices, the operating of small package plants to handle fish waste is marginal. It will be late 1973 or early 1974 before ocean stock assessments will allow accurate predictions of fish meal prices. However, the low value of shellfish meal offers little hope for economical disposal of crab and shrimp waste.

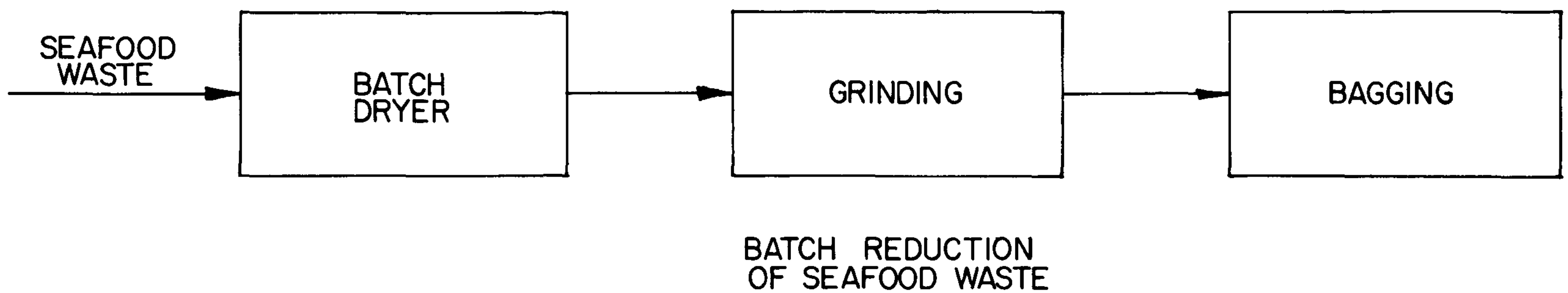


Figure 31 Low cost batch reduction facility.

Since the batch process does not remove any oil from the fish, the process makes a rather undesirable product from oily fish. In this case the continuous or semi-continuous equipment should be used whereby the cooked fish is pressed to remove some of the oil. This approximately doubles the cost of a small plant.

Another drawback to a conventional meal plant is the odor caused by the drier. In areas where large processing plants are located, the odor problem has never been solved. Scrubbing has been the most successful technique, but is expensive. Air from the drier is frequently introduced into the furnace supplying heat to the dryer, where the temperature is approximately 760°C (1400°F), thus partially burning the malodorous materials left in the process air. This air is then exhausted to the stacks. One small plant might be acceptable in an area, but where there are many reduction plants the cumulative effect, even under the best control conditions, is quite obnoxious.

2. Aqueous Extraction

The only way that protein waste can be processed into a high grade flour for human consumption is to remove the oil from the product, thus preventing the development of a rancid flavor and odor. Over the past ten years, considerable research effort has been expended by government and industry to develop extraction techniques for removing oil and other components from fish proteins prior to drying them into flours. An excellent product can be generated by some of the methods but they are all based on organic solvent extraction, which is much too sophisticated and expensive for installation in a seafood plant, especially a seasonal one.

A recent development in oil extraction has involved changing from an organic solvent to salt water or brine (Chu, 1971). The first phase of this process can be carried out in small as well as large processing plants with no highly skilled plant operators required. In order to be practical for commercialization, this process should be capable of handling any portion of fish scrap as well as whole industrial fish. This would make the process applicable to low grade fertilizer products, high grade animal feed and fish protein concentrate for human consumption. The process should also require only the low cost facilities available to small companies. It should, furthermore, not require highly trained operating personnel and should not produce a waste that will contribute to the pollution problem.

Figure 32 shows the general brine-acid process used for treating the fish waste or raw fish which is presently being studied on a pilot plant scale. The material is ground and homogenized in various concentrations of water or brine and hydrochloric acid. The sodium chloride tends to decrease the solubility of various constituents and the acid minimizes the protein solubility. After varying incubation times the material is then centrifuged so that the lipid and water fractions separate from the solid residue. For animal feed this solid residue can then be dried and ground to the necessary particle size. Further washing and extracting is necessary if it is to be used for human consumption. In fact, a high quality product can be obtained if it is further extracted with an organic solvent to remove final traces of taste and odor-causing components. The pre-extracted product is much easier to extract with an organic solvent than is fresh fish because there is no problem with water dilutions and subsequent emulsions and loss of solubles in the solvent fraction.

One distinct possibility for utilizing this process in remote areas having limited drying capacity is to extract and separate the solids for subsequent shipment to other areas where drying facilities and refining equipment are available. It has been found that the brine-acid press cake can be stored for some time without serious degradation. Thus, it would be possible to transfer damp press cake from many plants to one central finishing area.

A major advantage of this process is that it can be adapted for the output from any size plant that has an extremely variable load. Since the major limitation to processing capacity is drying, the extracted press cake can be bulk stored and shipped to the central drying and finishing plant by normal surface transportation. The primary extraction equipment consists of stirred tanks, centrifuges and filters. Figure 33 indicates approximate equipment costs for the extraction phase of the process.

A relatively small volume of concentrated effluent, approximately 0.43 liter per kg of waste extracted (0.25 gal per pound), must be treated to remove the high BOD_5 load that ranges from 40,000 mg/l in stream 1 (Figure 32) to 5000 mg/l in streams 2 and 3. Much of the BOD_5 from stream 1 is solubilized protein which can be removed almost stoichiometrically by precipitation with sodium hexametaphosphate. A study of the complete chemical and biological treatment of the effluent streams will be completed by the end of this year (Pigott, 1973).

Preliminary cost estimates from pilot plant studies indicate that the operating cost for producing meal from the brine-acid process will be between 11 and 18 cents per kg (5 and 8 cents per lb). This will be a high-grade meal that will not have many of the present limitations of conventional fish meal. The lower oil content will allow incorporation into animal and fowl diets at higher levels than are currently possible without adversely affecting the flesh flavor.

3. Enzymatic Hydrolysis Process

The use of enzymes to hydrolyze fish protein has been reported by several laboratories. Tryptic digestive enzymes, pepsin hydrolysis, papain, and many other enzymatic processes have been

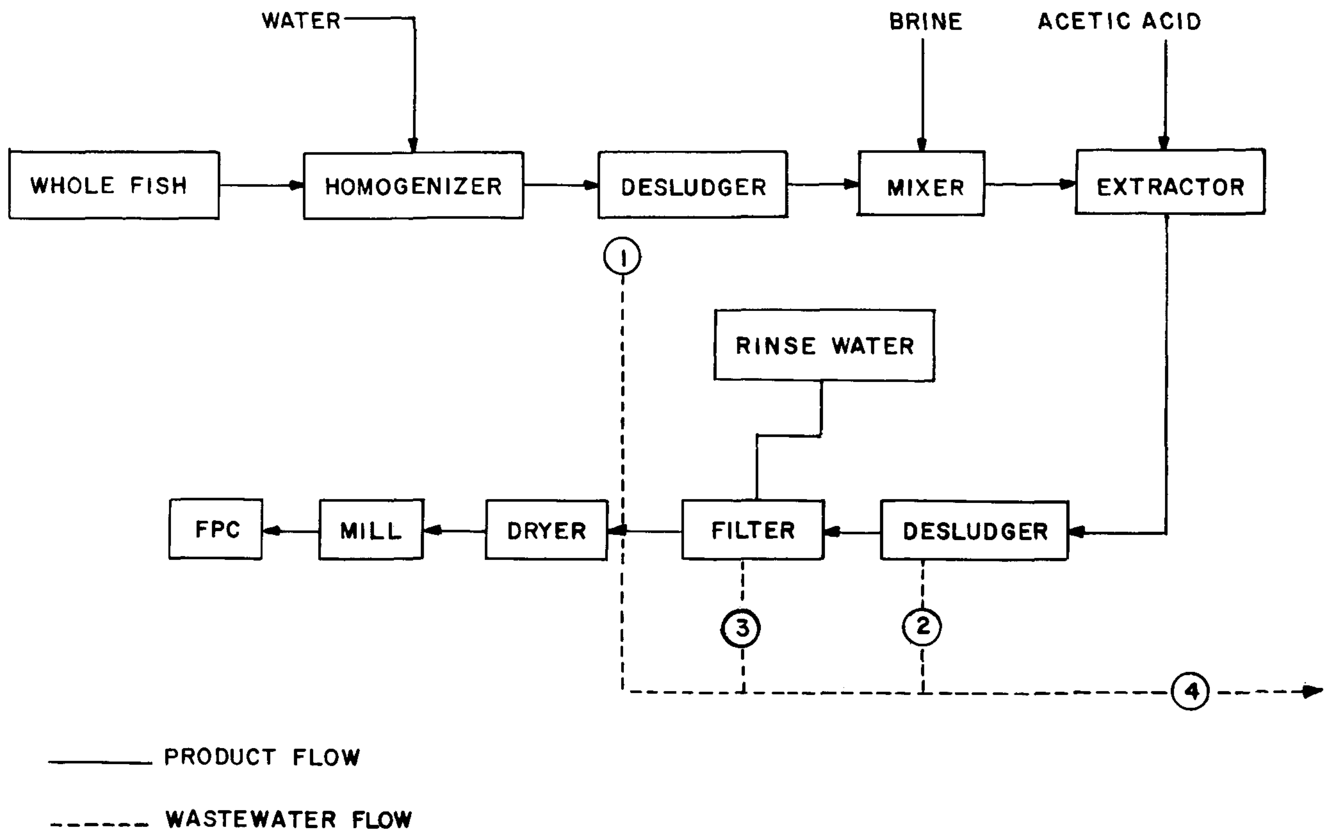


Figure 32 Brine-acid extraction process.

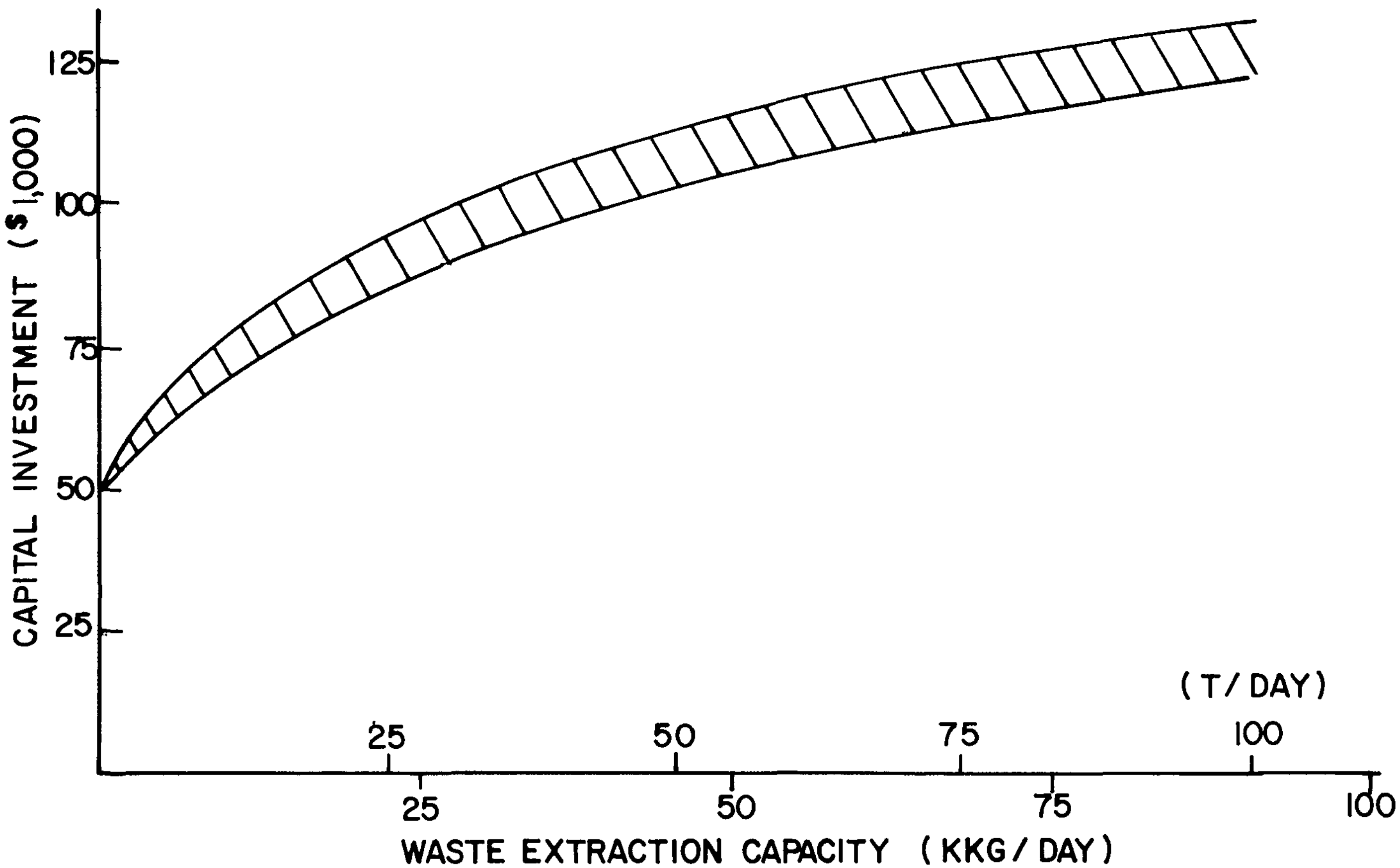


Figure 33 Brine-acid extraction primary facility costs (excluding dryer).

tried in an effort to produce a highly functional protein concentrate. In general, pepsin digestion with continuous pH control at 2.0 has proven to be one of the best procedures for producing a high quality bacteria-free product (Tarky and Pigott, 1973).

The basic procedure consists of adding pepsin to a homogenized fish waste substrate to which equal volumes of water have been added. The pH is lowered to 2.0 with hydrochloric acid and the mixture is then continuously stirred at 37°C (99°F). In general, this procedure yields about 12 percent product based on the raw material. The product has essentially no fat content and, when spray dried, is a highly functional powder which is low in only tryptophan. However, when added to vegetable proteins having sufficient tryptophan, the total protein is extremely high in quality.

The enzymatic hydrolysis process should be well developed within the next decade and will yield a valuable product from fish waste. If the FDA ever permits the use of waste portions for human food, then a large portion of the future protein supplements in prepared food dishes may come from this source. The material is cheaper to produce than milk [current estimate, 40 to 55 cents/kg (18 to 25 cents/lb)] and equal or better in protein value when added as a supplement. The process flow sheet is shown in Figure 34.

This process will probably never be as effective as the brine acid extraction technique for handling the large volumes of seasonal protein waste in the seafood industry since it requires longer times for the hydrolysis reaction and is a more sophisticated technique. However, the future will see large volumes of both fish waste and whole industrial fish processed in this manner for high quality functional protein derivitives.

4. Protein Precipitation from Effluent Streams

Some streams of plant processing water and the effluent from the brine-acid process have high concentrations of dissolved protein. As previously discussed, laboratory work has shown protein to be recoverable almost stoichiometrically by precipitation with sodium hexametaphosphate. The protein phosphate complex is highly nutritional and can be used as a high grade animal feed supplement.

This process may have application in some streams of sufficient concentration to warrant the treatment. This is especially true for concentrated cooking and blanching solutions that have high levels of proteins which have been solubilized during contact with the product.

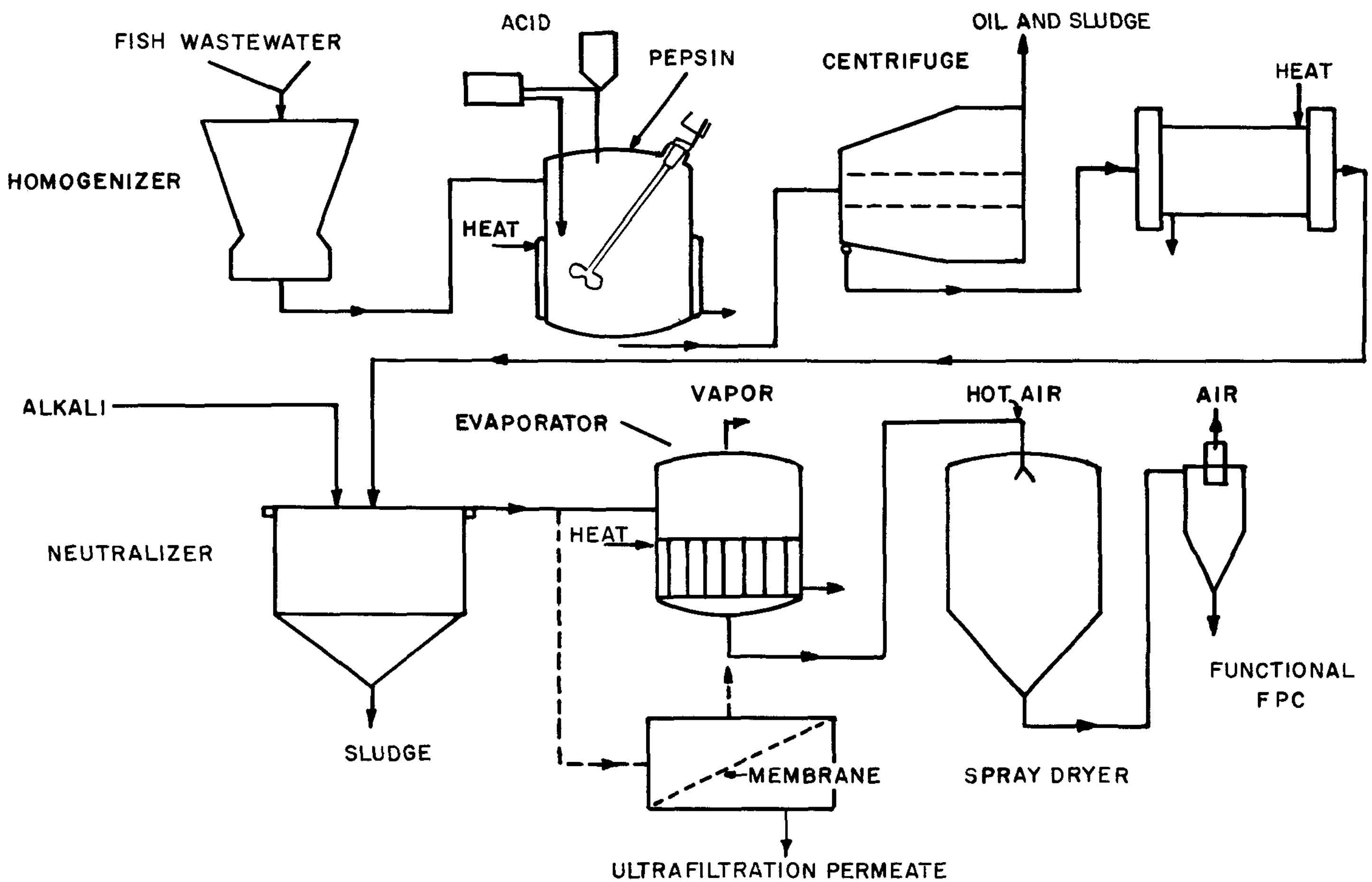


Figure 34 Enzymatic hydrolysis of solid wastes.

Solids Recovery

As previously mentioned, shellfish waste consists of the shell portion (which is a three component material) and the soft portion which includes the meat and soft waste material that adheres to the shell. The previously discussed methods of recovering dried protein material are all applicable to the soft portions which can be washed or mechanically removed from the shell. However, the meal from the shell portion has relatively little value and, in the forseeable future, it is not going to be economically feasible to process shell into meal. This is particularly the case in remote areas.

During the past two years a process for producing chitin and other by-products from shellfish waste has reached the semi-commercial pilot plant scale. As shown in Figure 35, the chitosan process consists primarily of caustic extraction to remove the proteins from the shell, followed by a hydrochloric acid extraction to produce a calcium chloride brine from the calcium salts normally found in the shell. The remaining material, commonly called chitin, is the structural material that holds the shell together.

The pilot plant is capable of processing several hundred kilograms of shell per day, producing a chitosan product of the following properties: less than ? percent ash; 8 percent or greater nitrogen (dry basis); soluble in acetic acid, viscosity of 12 centipoises (0.00025 lb-sec/sq ft) in 1 percent solution of 0.5 N acetic acid at 25°C (77°F).

The process begins when the incoming shell is conveyed from a hopper into a grinder. This results in a coarsely ground material of the proper size for further extraction and processing. The ground shell is extracted in sodium hydroxide in a trough screw conveyor. This solubilizes the protein so that the resulting solid contains only calcium salts and chitin. The solid is then placed in a wooden tank where the added hydrochloric acid extracts the calcium chloride as a soluble brine, leaving only chitin as a residue. Following washing and basket centrifugation, the chitin particles are dried in a rotating drum dryer. This primary product is then ground to the desired particle size and packaged for market or further processed to produce chitosan by deacetylation in hot caustic.

Through a cooperative effort with industry, the University of Washington Sea Grant Program has made available sample quantities of chitin and chitosan to research laboratories and industry for their experimental use. A wide interest has developed for the product which is stimulating the commerical demand for the material in many areas. In addition, a good market exists for calcium chloride and the protein derived from the shell.

On the near horizon are package units that can be put into a large or small seafood plant for the purpose of pretreating shell

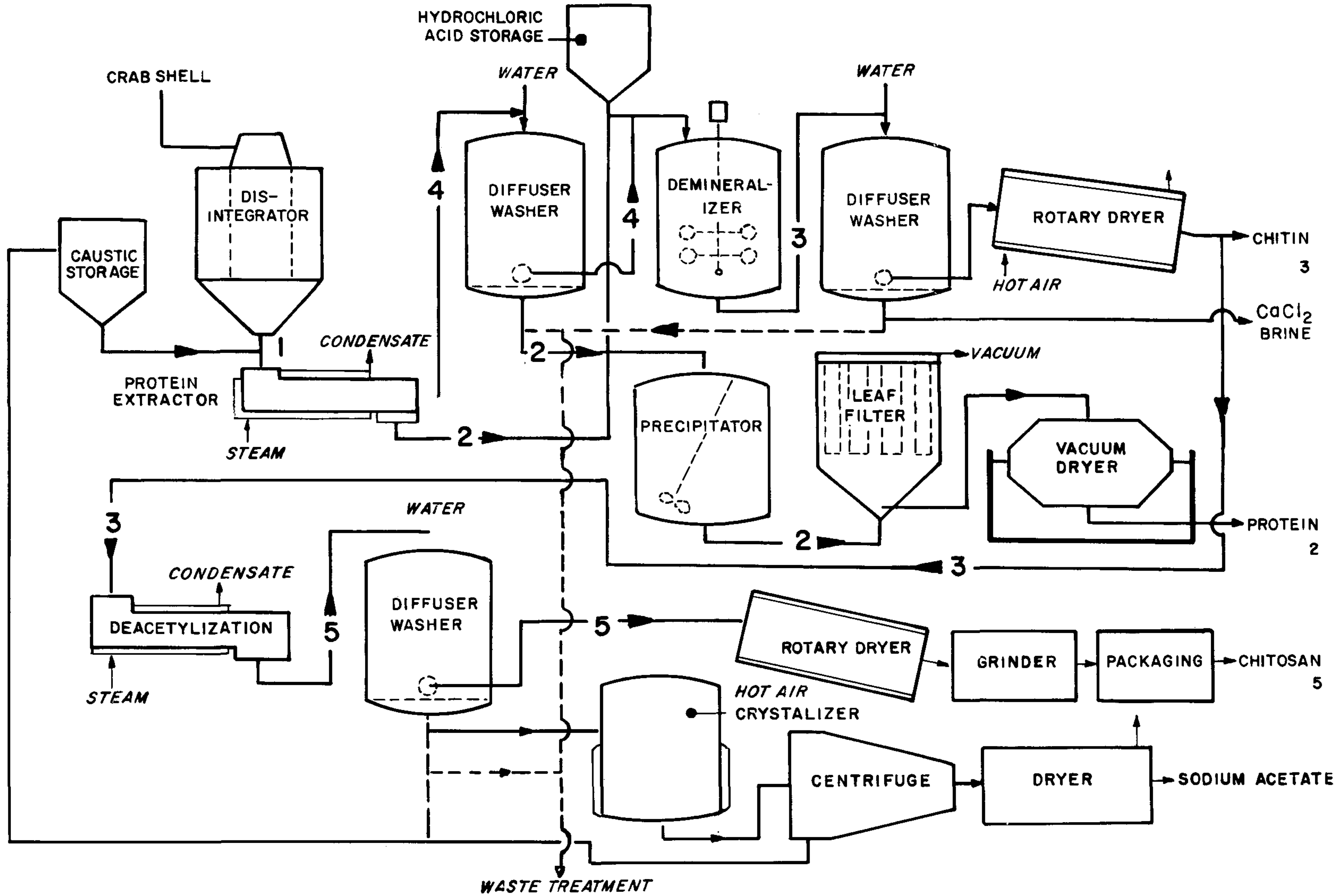
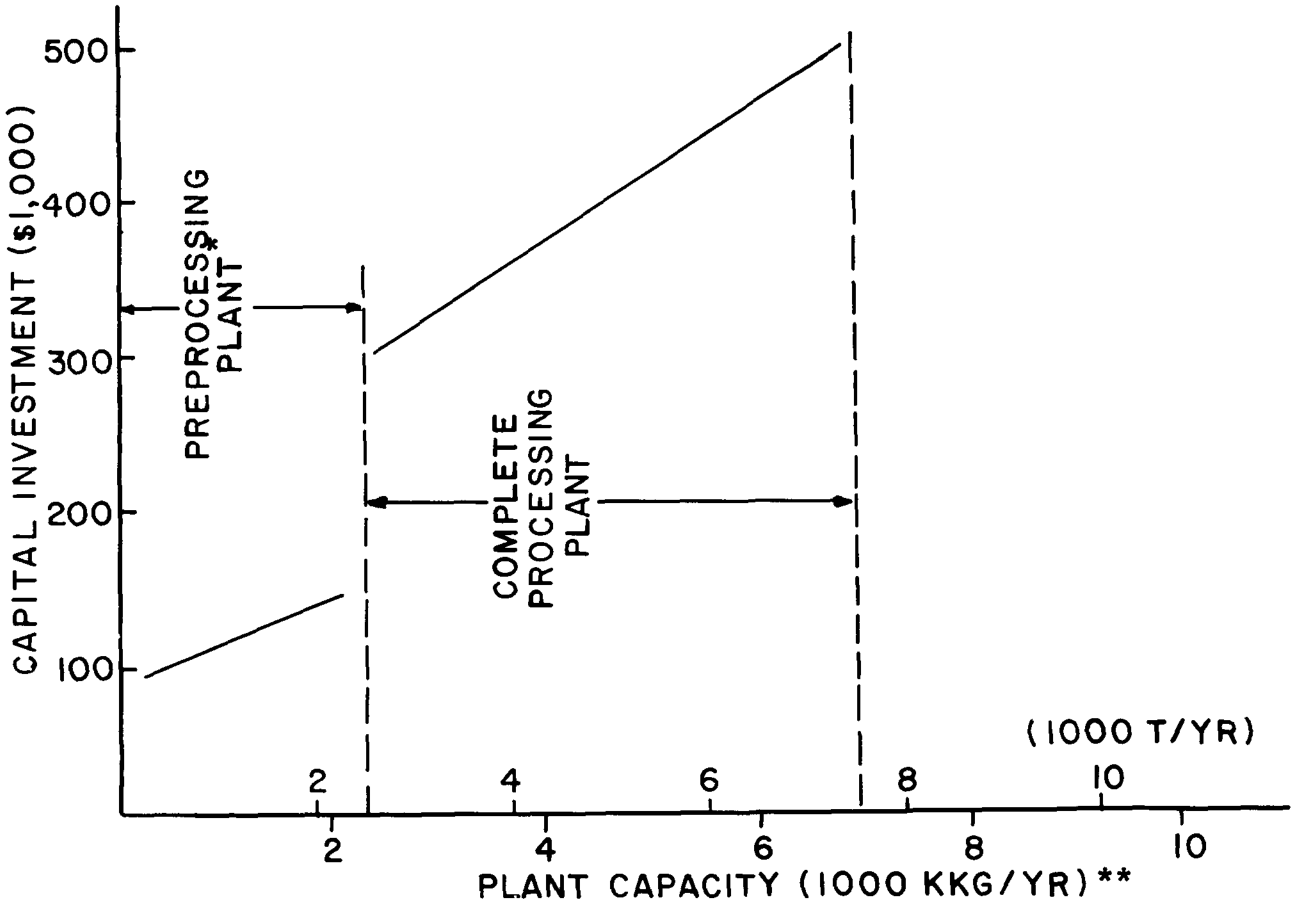


Figure 35 Chitin-chitosan process for shellfish waste utilization.



* Below 2,500 T/YR it is not economical for a complete processing plant. Waste must be hauled to a central facility.

** Based on full production for 3 to 4 months per year.

Figure 36 Approximate plant investment for extracting basic chemicals from shellfish waste (Peniston, 1973) and then sending the partially extracted product to a centrally located plant for final extraction and finishing. Selling all three of the products produced from shell may prove a profitable venture for both the packer and the owner of the central plants. Although the data are preliminary, Figure 36 indicates the estimated costs of producing chitin in various size plants.

Deboning and Extruding

One of the most successful developments in the seafood industry in many years is the carcass deboning technique that will effectively debone any piece of fish, leaving the meat separated from a dry mixture of bone, scales, skin and cartilage. The principle of the operation is to extrude the meat through extremely small openings inaccessible to the unwanted components in the carcass. A machine capable of producing up to 0.9 kkg (one ton) of product per hour costs about $20,000.

Although processes utilizing the deboning machines are now being used on fish, current developments will result, in the near future, in techniques for processing shellfish waste, as well as carcass waste, to yield ground meat often equal in quality to that now being extracted from the raw material. This process also stimulates the desire for a processor to minimize the use of water while handling his waste because dry raw material is easier to debone than solids suspended in water. The waste from the deboning operation is a dry material that is quite easy to dispose of in conventional landfills or other acceptable disposal methods. Also, the material can be dried and added to fish meal.

The deboned meat can be used in:

a. portion controlled extruded products;
b. battered and breaded items; and
c. molded and power-cleaved steaks.

Not only will deboning techniques improve the profitability of many fish processors, but it will be a major factor in alleviating waste disposal problems. For example, up to 25 percent of the total weight of fin fish is currently being discarded in the waste since the meat is so located that it cannot be removed from the carcass. Using deboning equipment, this meat can be be removed and sold for a price approaching that of the normal finished product.

Summary and Conclusions - In-Plant Control Techniques and Processes

It has been the purpose of this discussion to outline several of the major in-plant developments that are either ready for use by seafood processors or will be available within the next few years. These techniques, combined with good management to minimize water use and product wastage, should reduce most of the waste disposal problems now encountered by industry and will utilize a much greater portion of raw material entering the plants.

END-OF-PIPE CONTROL TECHNIQUES AND PROCESSES

Historically, seafood plants have been located near or over receiving waters which were considered to have adequate waste assimilative capacities. The nature of the wastes from seafood processing operations are such that they are generally readily biodegradable and do not contain substances at toxic levels. There are even several instances where the biota seem to thrive on the effluent, although there is generally a shift in the abundance of certain species. Consequently, most seafood processors have little, if any, waste treatment.

Increasing concern about the condition of the environment in recent years has stimulated activity in the application of existing waste treatment technologies to the seafood industry. However, to date there are few systems installed, operational data are limited and many technologies which might find application in the future are unproved. The following section describes the types of end-of-pipe control techniques which are available, and discusses case histories where each have been applied to the seafood industry on either a pilot plant or full-scale level. Several techniques or systems are closely associated with trade names. The mention of these trade name systems, however, does not constitute endorsement; they are cited for information purposes only.

Waste Solids Separation, Concentration and Disposal

Nearly all fish processors produce large volumes of solids which should be separated from the process water as quickly as possible. A study done on freshwater perch and smelt (Riddle, 1973) shows that a two hour contact time between offal and the carriage water can increase the COD concentration as much as 170 percent and increase suspended solids and BOD about 50 percent (see Figure 37). Fish and shellfish solids in the waste streams have commercial value as by-products only if they can be collected prior to significant decomposition, economically transported to the subsequent processing location, and marketed.

Many processors have recognized the importance of immediate capture of solids in dry form to retard biochemical degradation. Some end-of-pipe treatment systems generate further waste solids ranging from dry ash to putrescible sludges containing 98 to 99.5 percent water. Sludges should be subjected to concentration prior to transport. The extent and method of concentration required depends on the origin of the sludge, the collection method, and the ultimate disposal operation. The descriptions which follow are divided into separation, concentration, disposal (including recycling and application to the land), and wastewater treatment.

Separation methods

Screening and sedimentation are commonly used separation techniques employing a combination of physical chemical forces.

Screening is practiced, in varying degrees, throughout the U.S. fish and shellfish processing industries for solids recovery, where such solids have marketable value, and to prevent waste solids from entering receiving waters or municipal sewers. Screens may be classified as follows:

a. revolving drums (inclined, horizontal, and vertical axes);
b. vibrating, shaking or 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.

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 between bars may be called equivalent to a 40-mesh screen. The particles retained may be smaller than 0.076 cm diameter, however, because of hydrodynamic effects.

Revolving drums consist of a covered cylindrical frame with open ends. The screening surface is a perforated sheet or woven mesh. Of the three basic revolving drums, the simplest is the inclined plane (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.

Horizontal drums usually have the bottom portion immersed in the wastewater. The retained solids are held 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 38. F.G. Claggett (1973) tested this type rotary screen using a size 34-mesh on salmon canning wastewater and also on bailwater from herring boats. The results are listed in Table 96.

Inclined and horizontal drum screens have been used successfully in several seafood industries, such as the whiting, herring filleting, and fish reduction plants.

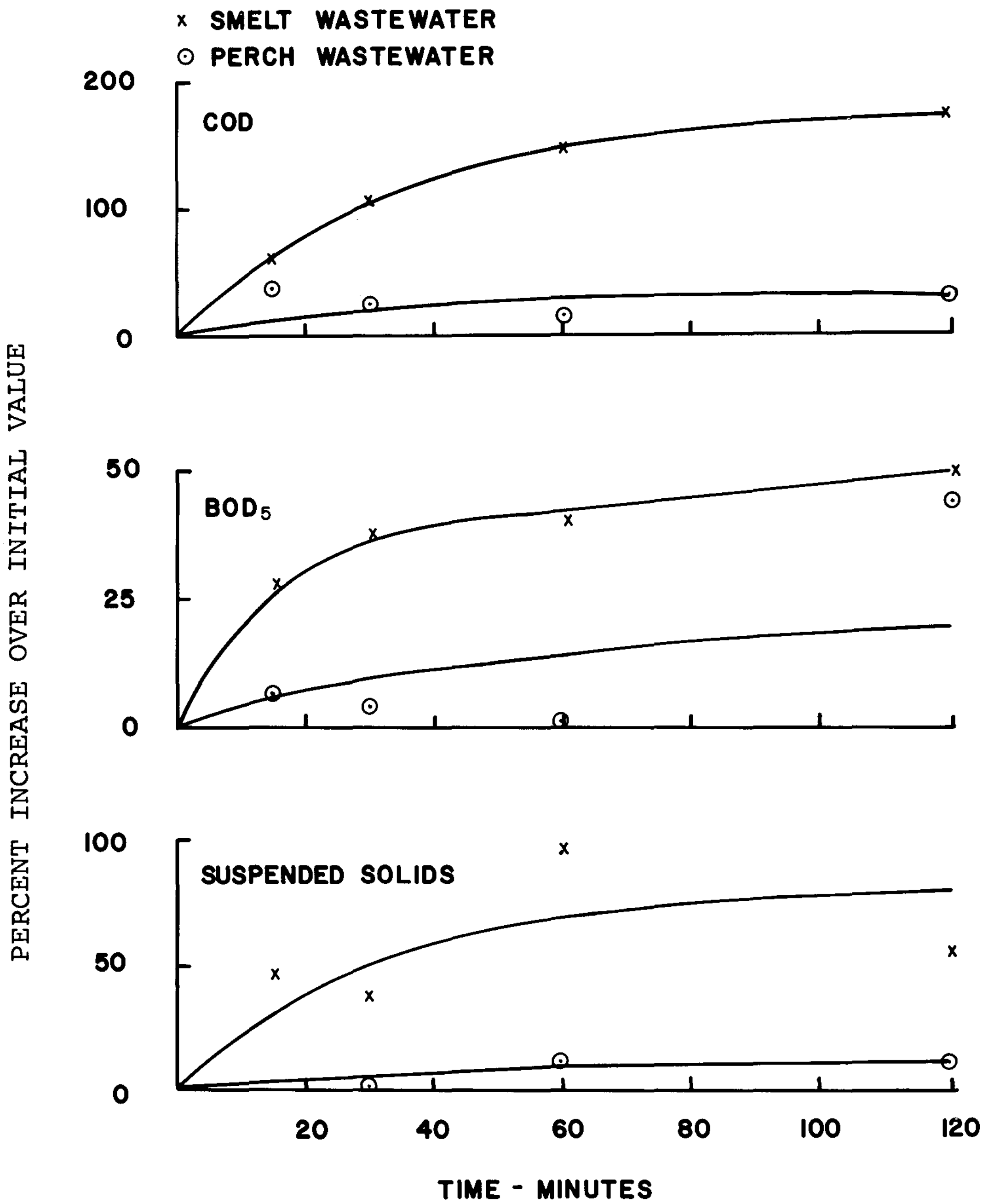


Figure 37 Increase in waste loads through prolonged contact with water. (Riddle, 1973).

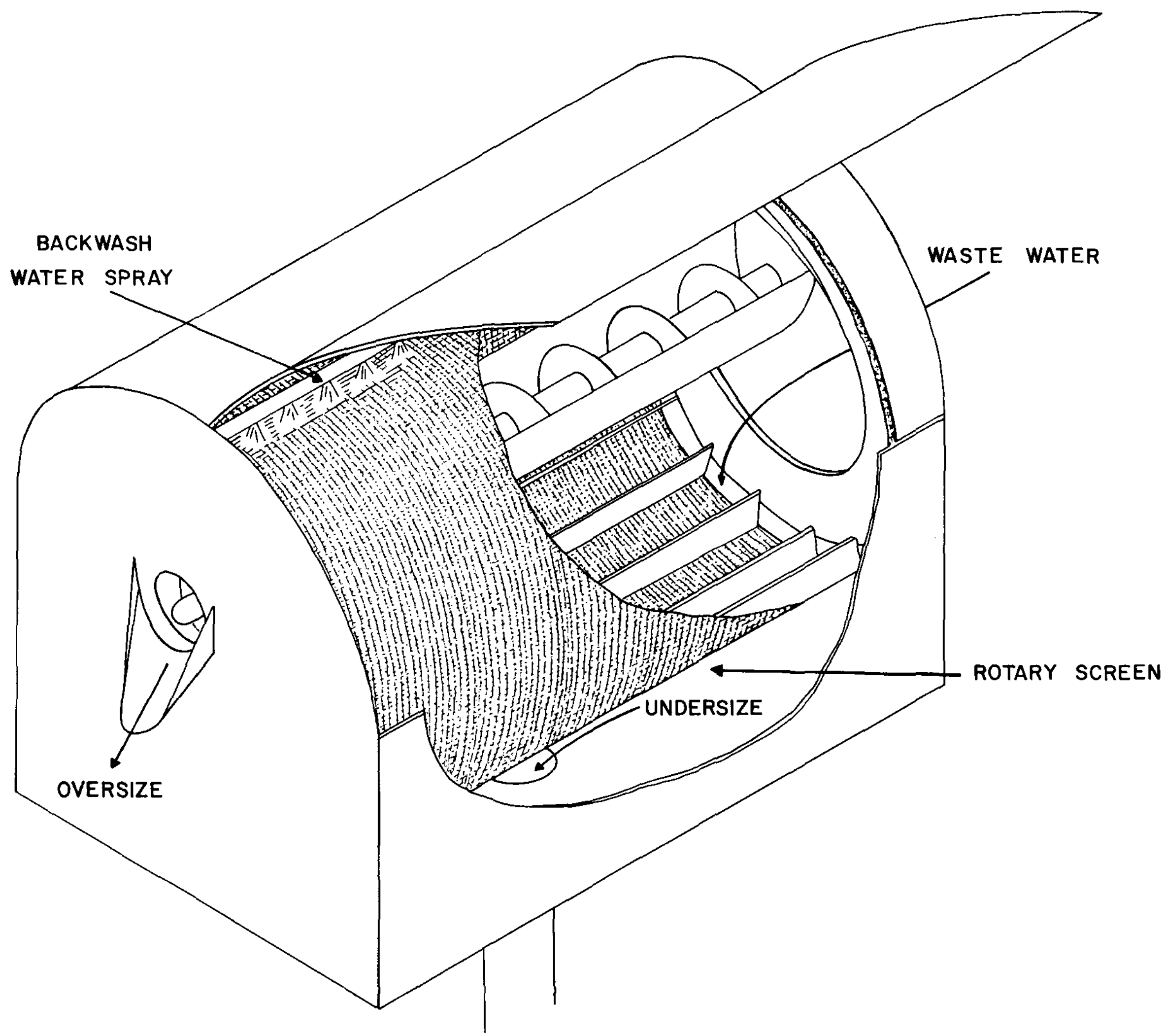


Figure 38 **Typical horizontal drum rotarv screen.**

At least one commercial screen available employs a rapidly rotating (about 200 rpm) drum with 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" since only a portion 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 efficacy of this, and other systems, in treating shellfish and seafood wastes have been investigated on a pilot scale in the Washington salmon industry, and the Alaskan crab and shrimp industries (Peterson, 1973b) with some success. The results of these studies are shown in Table 97.

Vibratory screens are more commonly used in the seafood industry as unit 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 for discharge at the periphery. Other vibratory-type screens impart a linear motion to retained particles by eccentrics. Blinding is a problem with vibratory screens handling seafood wastewaters. Salmon waste is 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 98 shows the results of the National Canners Association study on salmon canning wastewaters which included tests using a vibrating screen. It can be seen that the removal efficiencies are lower than for the horizontal drum screen or the SWECO concentrator. The vibratory screen was also more sensitive to flow variations and the solids content of the wastewater.

Tangential screens are finding increasing acceptance because of their inherent simplicity, reliability and effectiveness. A typical tangential screen is shown in Figure 39. It consists of a series of parallel triangular or wedgeshaped bars oriented perpendicular to the direction of flow. The screen surface is usually curved and inclined about 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. 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.

Tangential screens have met with considerable acceptance in the fish and shellfish industry. They currently represent the most advanced waste treatment concept voluntarily adopted by broad segments of the industry. One reason for this wide acceptance

Table 96 Northern sewage screen test results.

Wastewater Source	Percentage Reduction In Total Solids (34-mesh screen) (Claggett, 1973)
Salmon canning	57
Herring bailwater	48

Table 97 SWECO concentrator test results.

Wastewater Source	Parameter	Percentage Reduction 165-mesh	325-mesh
Salmon (______. 1972c)	Settleable solids	--	100
	Suspended solids	53	34
	COD	36	36
Shrimp peeler (Peterson, 1973b)	Settleable solids	99	--
	Suspended solids	73	--
	COD	46	--

Table 98 . SWECO vibratory screen performance on salmon canning wastewaters

Parameter	Percentage Reduction (40-mesh screen)
Settleable solids	14
Suspended solids	31
COD	30

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 99

Large solids should be separated before fine screening to improve performance and prevent damage to equipment. One method is to cover floor drains with a coarse grate or drilled plate with holes approximately 0.6 cm (0.25 in.) in diameter. This coarse grate and a magnet can prevent oversize or unwanted objects such as polystyrene cups, beverage cans, rubber gloves, tools, nuts and bolts or broken machine belts from entering the treatment system. Such objects can cause serious damage to pumps and may foul the screening system.

Salmon canneries 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 conveyer. 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 40. A sump is useful in maintaining a constant wastewater feed rate to the screen. It also helps to decrease fluctuations in the wastewater solids load such as occur in batch processes. Some form of agitator may be required to keep the suspended solids in suspension. Ideally, the sump should contain a one-half hour or more 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, however, this type of pump tends to pulverize solids as they pass through. During an experiment on shrimp wastes the level of settleable solids dramatically increased after screening (30-mesh screen) when the waste water was passed through a centrifugal pump (Peterson, 1973). Positive displacement or progressing cavity non-clog pumps are recommended. Screens should be installed with the thought that auxiliary 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 stream. Salmon waste is particularly difficult to screen. One cannery has reduced plugging by installing mechanical brushes over the face of their tangential screen.

Many of the screen types mentioned above produce solids containing considerable excess water which must be removed either mechanically or 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

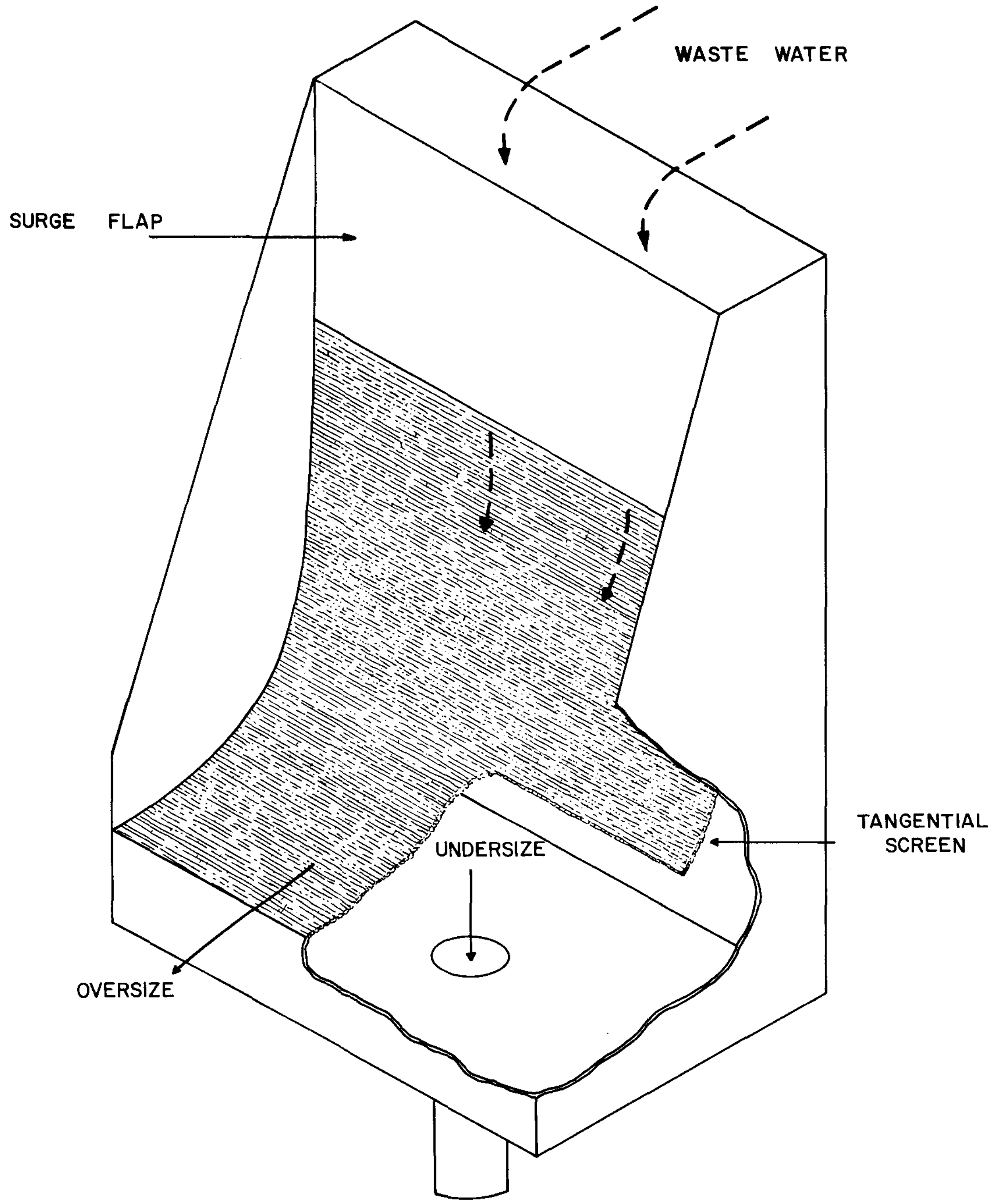


Figure 39 Typical tangential screen.

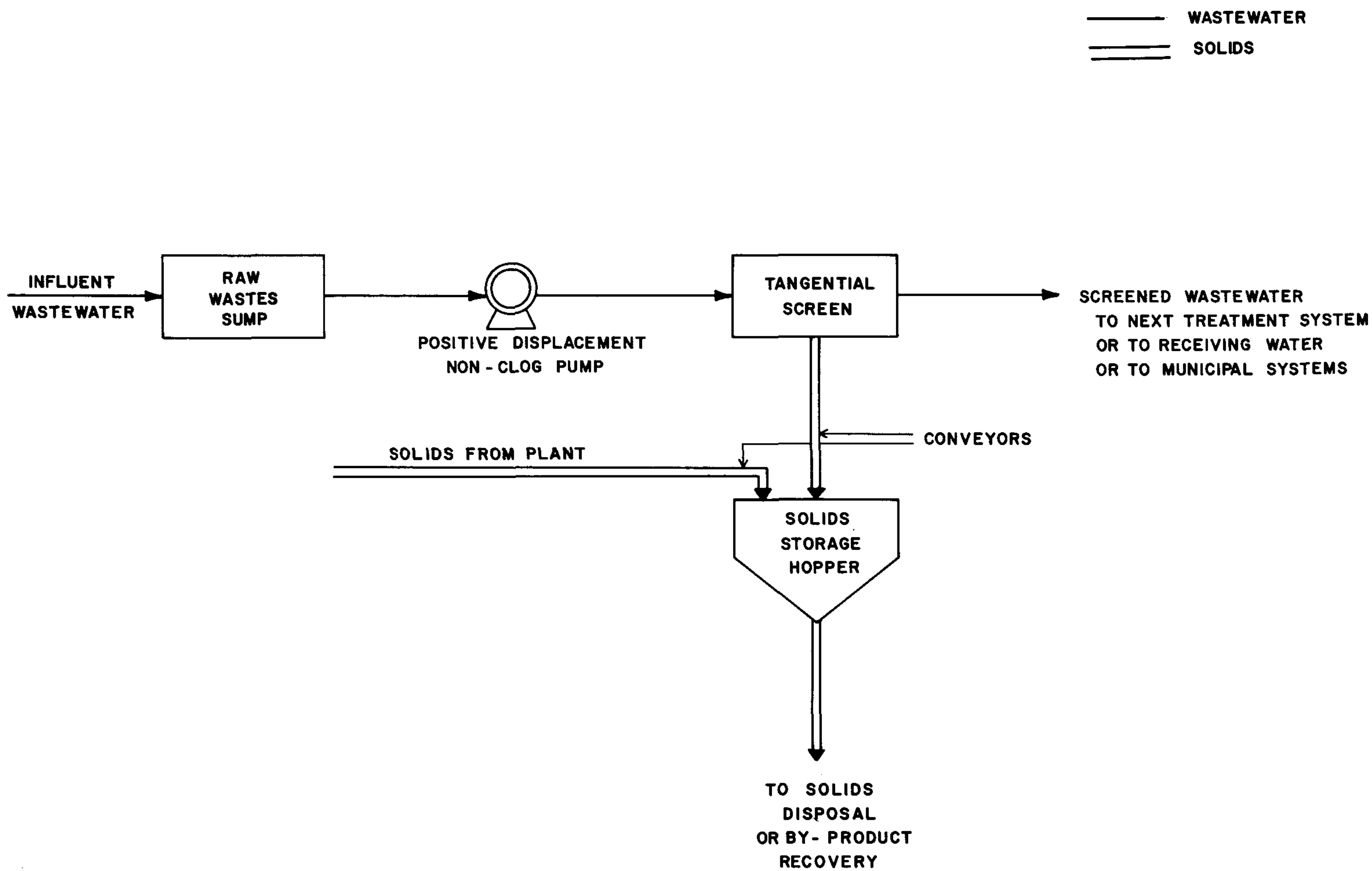


Figure 40. Typical screen system for seafood processing operations.

Table 99. Tangential screen performance.

Wastewater Source	Parameter	Percentage Reduction 30 mesh	40 mesh	50 mesh	100 mesh	150 mesh
Sardines (Atwell, et at., 1972)	SS	26	--	--	--	--
	BOD	9	--	--	--	--
Salmon (______. 1972)	Set. solids	--	--	--	35	86
	SS	--	--	--	15	36
	COD	--	--	--	13	25
Shrimp (Peterson, 1973b)	Set. solids	88	--	93	83	--
	SS	46	--	43	58	--
	COD	21	--	18	23	--
Salmon (Peterson, 1973b)	Set. solids	50	--	--	--	--
	SS	56	--	--	--	--
	COD	55	--	--	--	--
King Crab (Peterson, 1973b)	Set. solids	83	--	--	--	--
	SS	62	--	--	--	--
	COD	51	--	--	--	--
Salmon (Claggett, 1973)	Total solids	--	56	--	--	--
Herring (Claggett, 1973)	Total solids	--	48	--	--	--

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 size of particulates. On-site testing is required for optimum selection in all cases.

Some thought should be given to installing multiple screens to treat different streams separately within the process plant. Some types of screens are superior for specific wastewaters and there may be some economy in using expensive or sophisticated screens only on the hard-to-treat portions of the waste flows.

Microscreens 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.

Screens of most types are relatively 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, 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.

Sedimentation

Sedimentation, or settling of solids, effects solids-liquid separation by means of gravity. Nomenclature for the basins and equipment employed for this process includes terms such as grit chamber, catch basin, and clarifier, depending on the position and purpose of the particular unit in the treatment train. The design of each unit, however, is based on common considerations. These include; the vertical settling velocity of discrete particles to be removed, and 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. Grit chambers to remove sand and shell particles are common in the clam and oyster industries, however, the current absence of settling basins or clarifiers in the fish industries indicates the desirability of simple on-site settling rate studies to determine appropriate design parameters for liquid streams undergoing such treatment. Section V of this study presents the results of settleable solids tests, which were determined using the Imhoff cone method, for each seafood process monitored.

Removal of settled solids from sedimentation units is accomplished by drainoff, scraping, and suction-assisted scraping. Frequent removal is necessary to avoid putrefaction. Seafood processors using brines and sea water must consider the corrosive effect of salts on mechanism operation. Maintenance of reliability 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, 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.

Sedimentation tests run on a combined effluent from a fresh water perch and smelt plant produced an average of approximately 20 percent BOD and 9 percent suspended solids removal after a 60 minute detention time (M.J. Riddle, 1972). The nature of most fish and shellfish wastewater require 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. F-FLOK is a derivative of lignosulfonic acid marketed by Georgia Pacific Corporation. In a test on salmon wastewater, reported by E. Robbins (1973), the floc formed slowly but, after formation, sedimentation rates of four feet per hour were achieved. Table 100 shows the results of the test.

Properly designed and operated sedimentation units incorporating chemical coagulants can remove most particulate matter. Dissolved material, however, will require further treatment to achieve necessary removals.

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

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

<u>Concentration methods</u>

Although screenings from seafood wastewater usually do not require dewatering; sludges, floats, and skimmings from subsequent treatment steps must usually be concentrated or dried to

Table 100. Gravity clarification using F-FLOK coagulant (Robbins, 1973).

Coagulant Concentration (mg/l)	Total Solids Recovery (%)	Protein Recovery (%)
5020	68	92
4710	60	80
2390	47	69

Table 101 Results of dispersed air flotation on tuna wastewater (Jacobs Engineering Co., 1972).

Chemical Additive	Parameter	Influent (mg/l)	Reduction %
		(Average of five runs)	
Treto lite 7-16 mg/l	BOD	4400	47
	O&G	273	68
	SS	882	30
		(Average of eight runs)	
Drew 410 3-14 mg/l	BOD	211	47
	O&G	54	50
	SS	245	30

economize storage and transport. The optimum degree of concentration and the equipment used must be determined in light of transportation costs and sludge characteristics, and must be tailored to the individual plant's location and production.

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 will require conditioning before dewatering. Such conditioning may be accomplished by means of chemicals or heat treatment. 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 quantity and type of chemical treatment must be determined in light of the ultimate fate of the solids fraction. For example, lime may be deposited on the walls of 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 byproduct recovery.

A large variety of equipment is available for sludge dewatering and concentration, each unit having particular advantages. These units 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 to a semi-dry cake of 12 percent solids, with final pressing to a dry cake of over 30 percent solids. 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.

In the seafood industry only fish meal plants currently use solids dewatering and concentration equipment. Smaller installations with flows under about 757 cum/day (200,000 gpd) probably cannot utilize dewatering equipment economically.

Disposal methods

A high degree of product recovery is practiced by industries in locations where solubles and meal plants are available. The pet food, animal food and bait industries also use a considerable amount of solids from some industries. Where such facilities do not exist, alternative methods of solids disposal such as incineration, sanitary landfill and deep sea disposal must be considered.

Incineration of seafood solids wastes has not been tried in most fish industries. 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 skimmed from the combustion chamber. This device may prove to be viable in reasonably small units (Lessing, 1973).

Both types of incineration waste beneficial nutrients while leaving an ash which requires ultimate disposal. Fuel costs are also high and air pollution control equipment must be installed to minimize emissions.

Sanitary landfill is most suitable for stabilized (digested) sludges and ash. In some regions, disposal of seafood waste solids in a public landfill is unlawful. Where allowed and where land is available, private landfill may be a practical method of ultimate disposal. Land application of unstablized, putrescible solids as a nutrient source may be impractical because of the nuisance conditions which may result. The application of stabilized sludges as soil conditioners may have local feasibility.

The practicality of landfill or surface land disposal is dependent on the absence of a solids reduction facility, and the presence of a suitable disposal site. The nutritive value of the solids indicates that such methods are among the least cost-efficient currently available.

In addition to placement in or on the land and dispersal in the atmosphere (after incineration), the third (and only remaining) ultimate disposal alternative is dispersion in the waters. Deep sea disposal of fish wastes can be a means of recycling nutrients to the ocean. This method of disposal does not subject the marine environment to the potential hazards of toxicity and pathogens associated with the dumping of human sewage sludges, municipal refuse and many industrial wastes. The disposal of seafood wastes in deep water or in areas subject to strong tidal flushing can be a practical and possibly beneficial method of ultimate disposal. In some locations, the entire waste flow could be ground and pumped to a dispersal site in deep water without adverse effects. The U.S. Congress recognized the unique status of seafood wastes when, in 1972, they specifically exempted fish and shellfish processing wastes from the blanket moratorium on ocean dumping contained in the so-called "Ocean Dumping Act."

Grinding and disposing of wastes in shallow, quiescent bays has been practiced in the past, but should be discontinued. Disposal depths of less than 13 m (7 fathoms), particularly in the absence of vigorous tidal flushing, may be expected to have a detrimental effect on the marine environment and the local fishery, whereas discharge into a deep site generally 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.

Wastewater Treatment

Wastewater treatment technology to reduce practically any effluent to any degree of purity is available. The cost effectiveness of a specific technology depends in part on the contaminants to be removed, the level of removal required, the scale of the operation, and most importantly on local factors, including site availability and climate. Because these factors vary widely among individual plants in the fish processing industries, it is difficult to attempt to identify a technology which may prove superior to all others within an industrial subcategory.

The following general description is divided into physical-chemical and biological methods for the removal of contaminants.

Physical-chemical treatment

Physical-chemical treatment is capable of achieving high degrees of wastewater purification in significantly smaller areas than biological methods. This space advantage is often accompanied by the expense of high equipment, chemical, power, and other operational costs. The selection of unit operations in a physical-chemical or biological-chemical treatment system cannot be isolated cost-effectively from the constraints of each plant site. The most promising treatment technologies for the industries under consideration are chemical coagulation and air flotation. There is yet little practical application for demineralization technology including reverse osmosis, electrodialysis, electrolytic treatment, and ion exchange, or for high levels of organic removal by means of carbon adsorption.

Chemical Oxidation

Chlorine and ozone are the most promising oxidants, although chlorine dioxide, potassium permanganate, and others are capable of oxidizing organic matter found in the process wastewaters. This technology is not in common use because of economic feasibility restrictions.

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 de-aerated wastewater. De-aeration 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 practicability of small units, have not been evaluated in the seafood processing industry (McNabney and Wynne, 1971).

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. The buoyancy of released air bubbles rising through the wastewater lifts materials in suspension to the surface. These materials include substantial dissolved organics and chemical precipitates, under controlled conditions. Floated, agglomerated sludges are skimmed from the surface, collected and dewatered. Adjustment of pH to near the isoelectric point favors the removal of dissolved protein from fish processing wastewaters. 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 the process in operation. Present flotation equipment consists of three types of systems for wastewater treatment: 1) vacuum flotation; 2) dispersed air flotation; and 3) dissolved air flotation.

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 at 30 seconds, and require only about 185 to 370 cc/l (0.025 to 0.05 cu ft/gal) of air (Nemerow, 1971). A partial vacuum of about 0.02 atm (9 in. of water) 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 air-tight structure needed to maintain the vacuum. Any leakage from the atmosphere adversely affects performance.

2. Dispersed air flotation: Air bubbles are generated in this process by the mechanical shear of propellers, through diffusers, or by homogenization of gas and liquid streams. The results of a pilot study on tuna wastewater are shown in Table 101 and indicate that a dispersed air flotation system could be successful. The unit was a WEMCO HydroCleaner with five to 10 minute detention time. The average percent reduction of five-day BOD, grease and oil, and suspended solids was estimated using two types of chemical additives. Each run consisted of one hour steady state operation with flow proportioned samples taken every five minutes. It should be noted that the average of five runs with different chemical additions are presented rather than the optimum.

3. Dissolved air flotation: The dissolved air can be introduced by one of the methods: 1) total flow pressurization; 2) partial flow pressurization; or 3) recycle pressurization. In this process, the 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 which is at ambient pressure. In recycle pressurization the recycle stream is held in the pressure unit for about one minute before being mixed with the unpressurized main stream just before entering the flotation tank.

The flotation system of choice depends on the characteristics of the waste and the necessary removal efficiencies. Mayo (1966) found use of the recycle gave best results for industrial waste and had lower power requirements. Recycling flows can be adjusted to insure uninterrupted flow to the flotation cell. This can be very useful in avoiding system shutdowns. A typical dissolved air flotation system is shown in Figure 41, and a typical dissolved air flotation unit is shown in Figure 42.

Air bubbles usually are negatively charged. Suspended particles or colloids may have a significant electrical charge providing either attraction or repulsion with the air bubbles. Flotation aids can be used to prevent air bubble repulsion. 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 removal (Mayo, 1966).

Emulsified grease or oil normally cannot be removed without chemical coagulation (Kohler, 1969). The emulsified 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 that which would be needed without recycle.

The water temperature determines the solubility of the air in the water under pressurization. With lower water temperature, a lower quantity of recycle is necessary to dissolve the same quantity of air. The viscosity of the water increases with a decrease in temperature so that flotation units must be made larger to compensate for the slower bubble rise velocity at low temperatures. Mayo (1966) recommended that flotation units for

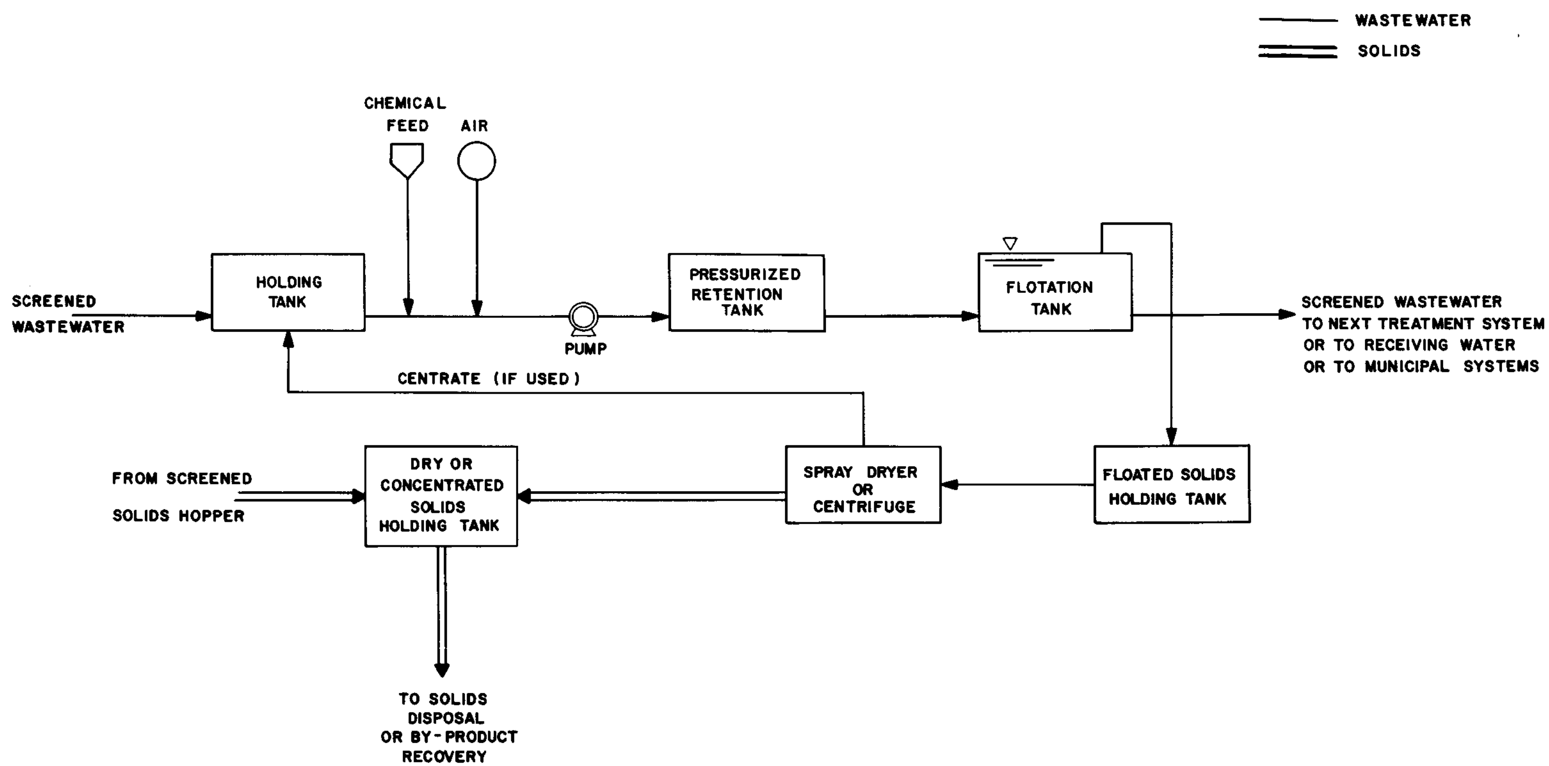


Figure 41 Typical dissolved air flotation system for seafood processing operations.

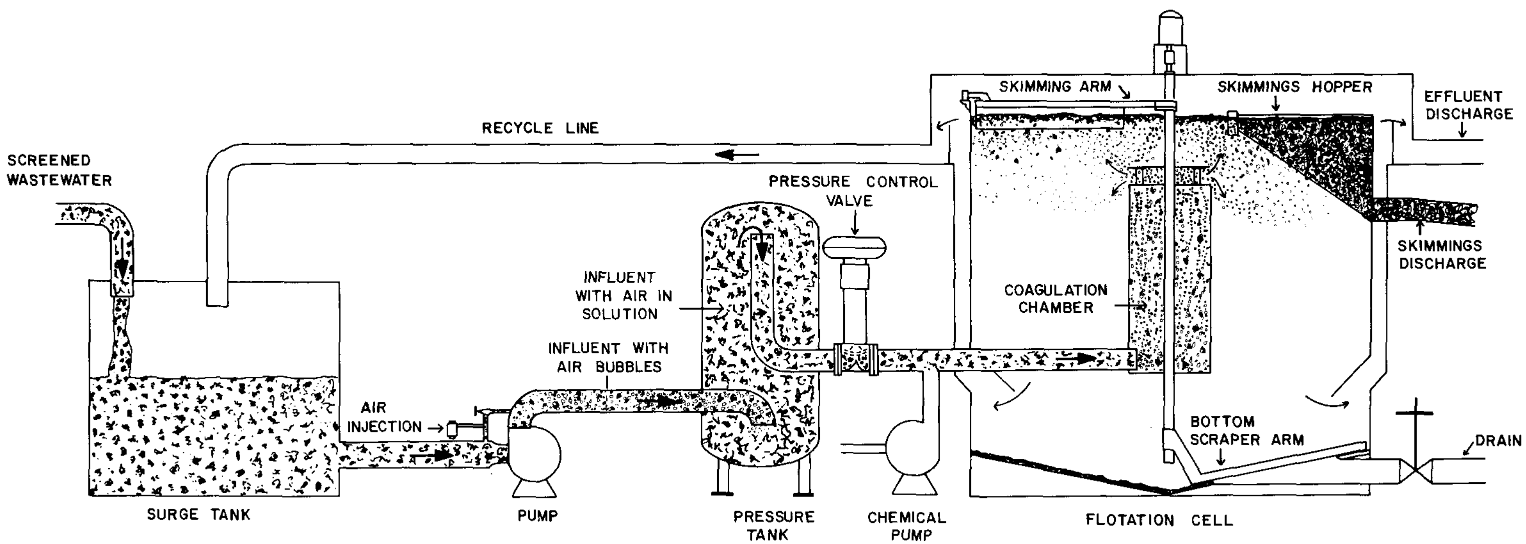


Figure 42 **Dissolved air flotation unit (Carborundum Company).**

industrial application be sized on a flow basis for suspended solids concentrations less than 5000 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 among food processors for wastewater treatment. 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. A full scale dissolved air flotation unit was recently installed at a tuna plant on Terminal Island, California. Table 102 shows the results of the pilot plant study that preceeded the full scale unit and Table 103 gives the percent reductions calculated from the samples collected in 1973. Operational difficulties are thought to have reduced the effectiveness of the unit. The pilot plant treated a flow of 0.5 to 1.0 l/sec (7.5 to 15 gpm) with a constant recycle of 0.5 l/sec (7.5 gpm). The full scale plant treated a flow of 28 l/sec (450 gpm) with no recycle.

Two more full scale dissolved air flotation units for tuna plants have been ordered and are due to start in early 1974 according to Robbins of Envirotech Corporation.

At least two significant pilot plant studies have been performed on shrimp wastewater, one in Louisiana and the other in Alaska. Table 104 and Table 105 list the results of the respective studies.

The Louisiana shrimp study was conducted by Region VI E.P.A. and Dominique, Szabo, and Associates, Inc. using a Carborundum Company dissolved air flotation pilot unit which treated a 3.1 l/sec (50 gpm) flow using 1:1 recycle, and 170 l/hr (6 cu ft/hr) air at a pressure of 2.7 atm (40 psig).

The Alaska shrimp study was conducted by the National Marine Fisheries Service Technology center, using a Carborundum Company dissolved air flotation pilot unit, which treated a 3.1 l/sec (50 gpm) flow using 10 percent recycle.

Preliminary indicators from the Louisiana shrimp show that alum at 75 ppm and a polyelectrolyte at 0.5 - 5.0 ppm produce the best removal efficiencies (see Figure 43).

Various chemical additives and concentrators were tested in Alaska with inconclusive results. All flocculants worked better than no additives but none were significantly better than alum alone at around 200 mg/l. Sea water apppeared to reduce the effectiveness of the polyelectrolyte used during the test.

Table 102. Efficiency of EIMCO flotator pilot plant on tuna wastewater (Jacobs Engineering Co., 1972).

Chemical Additive	Parameter	Influent (mg/l)	Reduction %
		(Based on one run)	
Lime (pH 10.0 - 10.5)	BOD-5	3533	65
Polymers:			
Cationic, 0.05 mg/l	O&G	558	66
Anionic, 0.10 mg/l	SS	1086	66
Lime, 400 mg/l	BOD-5		22
Ferric chloride, 45 mg/l	O&G		81
	SS		77

Table 103 Efficiency of EIMCO flotator full scale plant on tuna wastewater (Environmental Associates, Inc., 1973).

Chemical Additive	Parameter	Influent (mg/l)	Reduction %
		(Based on two runs)	
Sodium Aluminate 120 mg/l	COD	2850	37
Polymer	SS	1170	56
		(Based on one run)	
Alum	COD	5100	58
Polymer	SS	667	65

During the summer of 1972 a study was conducted by the National Marine Fisheries Service to investigate means of reducing waste discharge problems as a result of fish meal and oil production. Bailwater used to unload menhaden was treated using a pilot scale dissolved air flotation unit. This treatment allowed increased recirculation of bailwater, decreasing the soluble plant load. The removal efficiencies are listed in Table 106. The plant treated 4.1 l/sec (65 gpm) with 50 percent recycle and 50 psig. The results showed that dissolved air flotation units can extend bailwater re-use, but that sludge disposal must be resolved.

A full scale dissolved air flotation unit has also been installed in the sardine industry, however, mechanical problems have hindered operation thus far. Results are shown in Table 107.

The Canadians have constructed a demonstration wastewater treatment plant capable of handling the estimated flow of 47 l/sec (750 gpm) from a salmon and ground fish filleting plant. It was later modified to treat herring bailwater and roe recovery operations as well. Results of the study by The Fisheries Research Board of Canada on this operation are shown in Table 108.

The previous air flotation case studies have shown various removal efficiencies depending on species, chemical additives and effluent concentrations. One reason for the various removal efficiencies reported appears to be due to the efficiency being a function of influent concentration. Figure 44 plots the percent removal versus COD concentration using the results of the sardine, menhaden, Gulf shrimp and tuna air flotation studies. The removals are probably a function of the species being processed; however, there appears to be a strong tendency for the efficiency to increase as the concentration increases. The tuna and shrimp concentrations and removal efficiencies were lower than the sardine and menhaden concentrations and removal efficiencies. This relation also holds for the sardine wastewater where the efficiency appears to increase about 25 percent as the COD concentration increases by a factor of four, from 5000 to 20,000 mg/l. The case studies documented in this report indicate that air flotation systems can provide good removal of pollution loads from seafood processing wastewater, however, the results are highly dependent on operating procedure. In most cases, optimum removal efficiencies are yet to be established, but it is expected that the technology should become standardized over the next few years as an increasing number of units are tested. It also appears that the COD removal efficiency is a function of concentration, increasing as the influent concentrations increase.

The air flotation technology can also be operated at lower efficiencies to serve as "primary" treatment in advance of a

Table 104 Efficiency of Carborundum pilot plant on Gulf shrimp wastewater (Mauldin, 1973).

Chemical Additive	Parameter	Influent (mg/l)	Reduction %
	(Average of five runs, one each with 5, 4, 2, 1, and 0.5 mg/l polymer)		
Acid (to pH 5)	BOD-5	1428	70
Alum 75 mg/l	COD	3400	64
Polymer	SS	559	83
	(Average of two runs, one each at 75 gpm and 25 gpm with 2 mg/l polymer)		
Acid (to pH 5)	COD	3400	51
Alum 75 mg/l	SS	440	68
Polymer	O&G	852	85

Table 105 Efficiency of Carborundum pilot plant on Alaska shrimp wastewater

Chemical Additive	Parameter	Reduction %
	(Average of twenty-two runs)	
Alum 200 mg/l	COD	73
Polymer	SS	77

Table 106 Efficiency of Carborundum pilot plant on menhaden bailwater (Baker and Carlson, 1972).

Chemical Additive	Parameter	Influent (mg/l)	Reduction %
	(Average of five runs)		
Alum or	COD	94,200	80
Acid pH 5-5.3	SS	--	87
Polymer	O&G	--	near 100

Note: SS and O&G determined by volume change.

Table 107 Efficiency of full scale dissolved air flotation on sardine wastewater (Atwell, 1973).

Chemical Additive	Parameter	Reduction %
	(Average of seven runs)	
Alum	COD	74
Polymer	O&G	92
	SS	87

Table 108 Efficiency of full scale dissolved air flotation on Canadian seafood wastewater (Claggett, 1972).

Chemical Additive	Species	Removal Percentage BOD	Oil	SS
	Salmon	84	90	92
Alum	Herring	72	85	74
Polymer	Groundfish	77	--	86
	Stickwater	--	95	95

Comments: Sludge represents about three percent of flow.

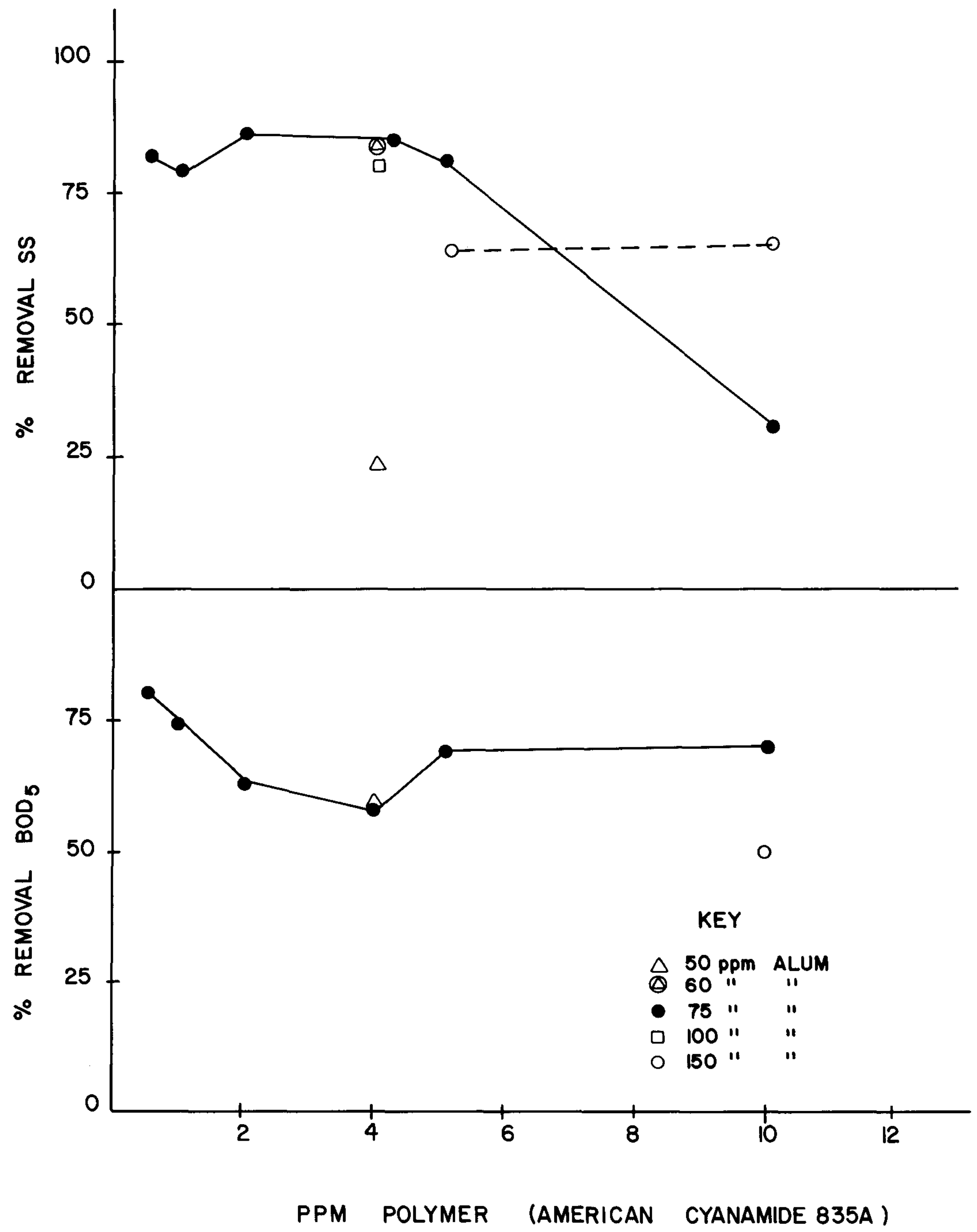


Figure 43 Removal efficiency of DAF unit used in Louisiana shrimp study - 1973 results (Dominique, Szabo Associates, Inc.).

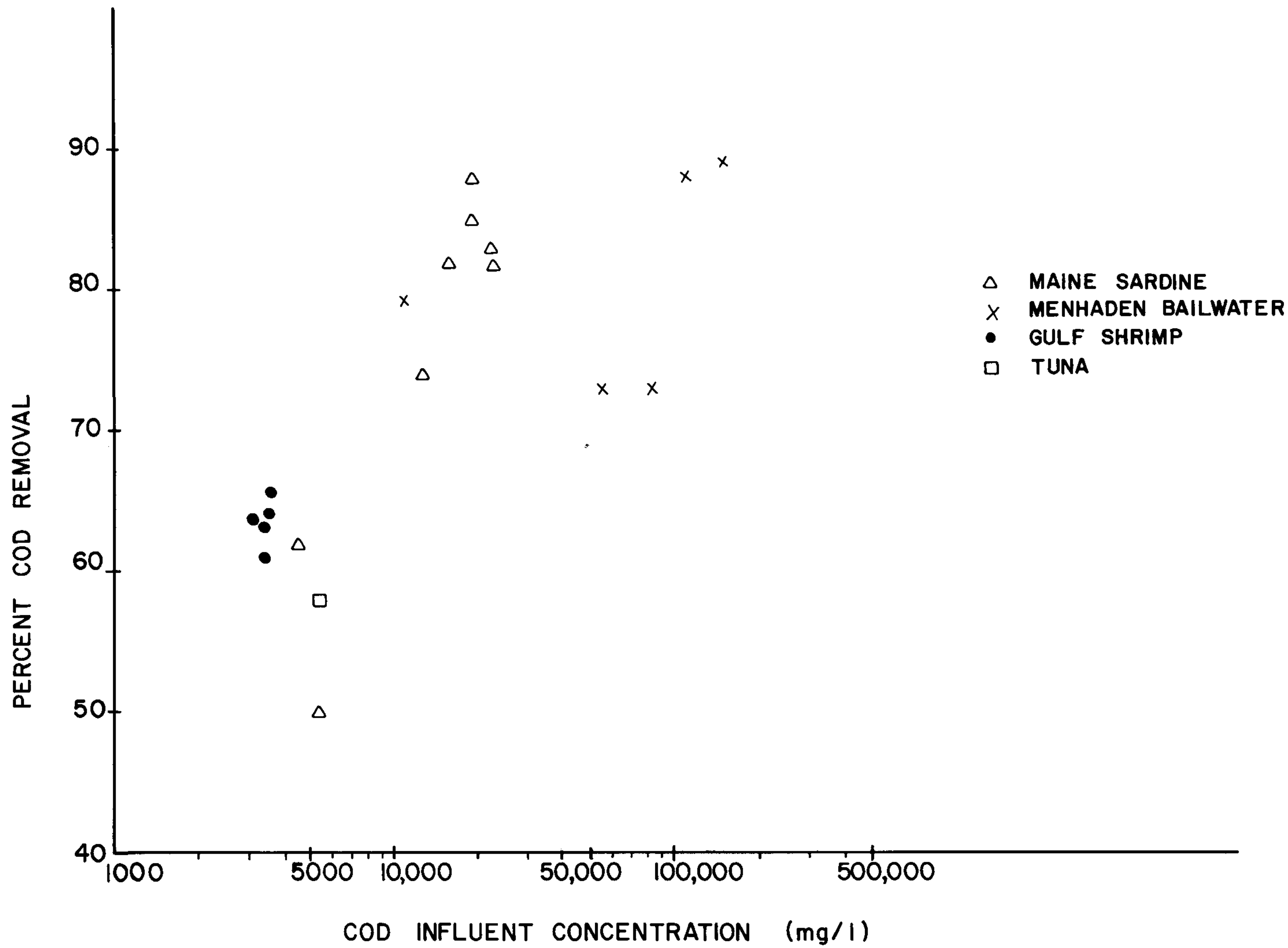


Figure 44 Air flotation efficiency versus influent COD concentration for various seafood wastewaters.

physical-chemical or biological polishing step, if that mode proves advantageous from the standpoint of cost-effectiveness.

Appendices A and B contain selected bibliographies of air flotation use within the seafood industry and meat and poultry industry, respectively.

Biological treatment

Biological treatment is not practiced in U.S. seafood industries except for a small pilot project in Maryland at a blue crab processing plant and full-scale systems at two shrimp plants in Florida. Sufficient nutrients are available in most seafood wastewaters, however, to indicate that such wastewaters are amenable to aerobic biological treatment.

Primary stage removal of solids and oil and greases should precede biological treatment. Without this pretreatment, several problems can develop: 1) oil and grease can interfere with oxygen transfer in an activated sludge system; and 2) solids can clog trickling filters.

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 in 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 at full scale for the treatment of saline wastes of reasonably constant chloride levels. The effectiveness of any form of biological oxidation, however, remains to be demonstrated under the extreme variations common in the fish processing industry.

Activated Sludge

The activated sludge process consists of suspending a concentrated microbial mass in the wastewater in the presence of oxygen. Carbonaceous matter is oxidized mainly to carbon dioxide and water. Nitrogenous matter is concurrently oxidized to nitrate. The conventional activated sludge process is capable of high levels of treatment when properly designed and skillfully operated. Flow equilization by means of an aerated tank can minimize shock loadings and flow variations, which are highly detrimental to treatment efficiency. The process produces a sludge which is composed largely of microbial cells, as described above. Oily materials can have an adverse effect. A recent study concluded the influent (petroleum-based) oil levels should be limited to 0.10 kg/day/kg MLSS (0.10 lb/day/lb MLSS).

The nature of the waste stream, the complexity of the system and the difficulties associated with dewatering waste activated sludge indicate that for most applications the activated sludge system of choice would be the extended aeration modification.

A typical extended aeration system which could be used for a seafood processing operation is shown in Figure 45 and is similar to conventional activated sludge, except that the mixture of activated sludge and raw materials is maintained in the aeration chamber for longer periods of time. The common detention time in extended aeration is one to three days, in contrast to the conventional six hours. This prolonged contact between the sludge and raw waste provides ample time for the organic matter to be assimilated by the sludge and also for the organisms to metabolize the organics. This allows for substantial removals of organic matter. In addition, the organisms undergo considerable endogenous respiration, which oxidizes much of the cellular 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. The system is relatively resistant to shock loadings, provided the clarifier has sufficient surface area to prevent the loss of biomass during 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 several days to a few weeks if the unit is shut down or the processing plant ceases to operate for significant periods of time.

Riddle (1972) studied the efficiency of biological systems on smelt and perch wastewater. He found a 90 percent removal of unfiltered BOD-5 after 10 days aeration, and 90 percent removal of filtered BOD-5 after two days aeration in a batch reactor (see Figures 46, 47). Tests in a continuous reactor showed that maximum BOD-5 removal (80 percent soluble and 45 percent unfiltered) could be achieved with a 7.5 hour detention time, sludge recycle and a three day sludge age or a five day detention time with no sludge recycle.

Robbins (1973) reports that an activated sludge plant in Japan has been especially designed for fish wastes. The wastewater flow is approximately 0.27 mgd and the 5 day BOD concentration ranges from 1000 to 1900 mg/l. The results of pilot plant studies conducted using a 10 hour separation time and the organic and hydraulic loadings listed are shown in Table 109. Bulking occurred when the organic loading rate exceeded 0.31 lb/cu ft/day.

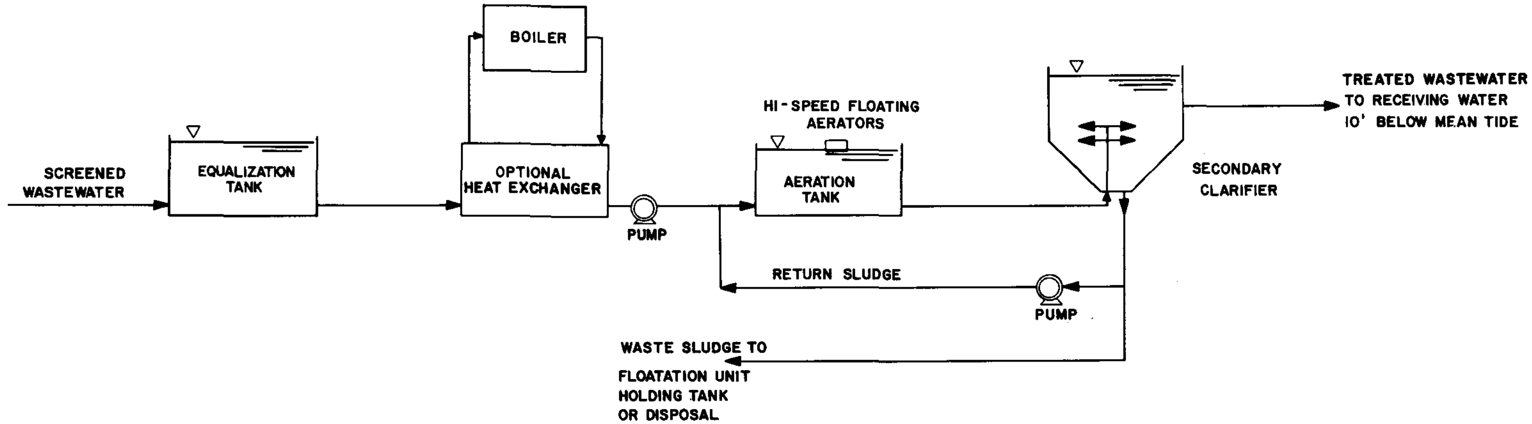


Figure 45 **Typical extended aeration system for seafood processing operations.**

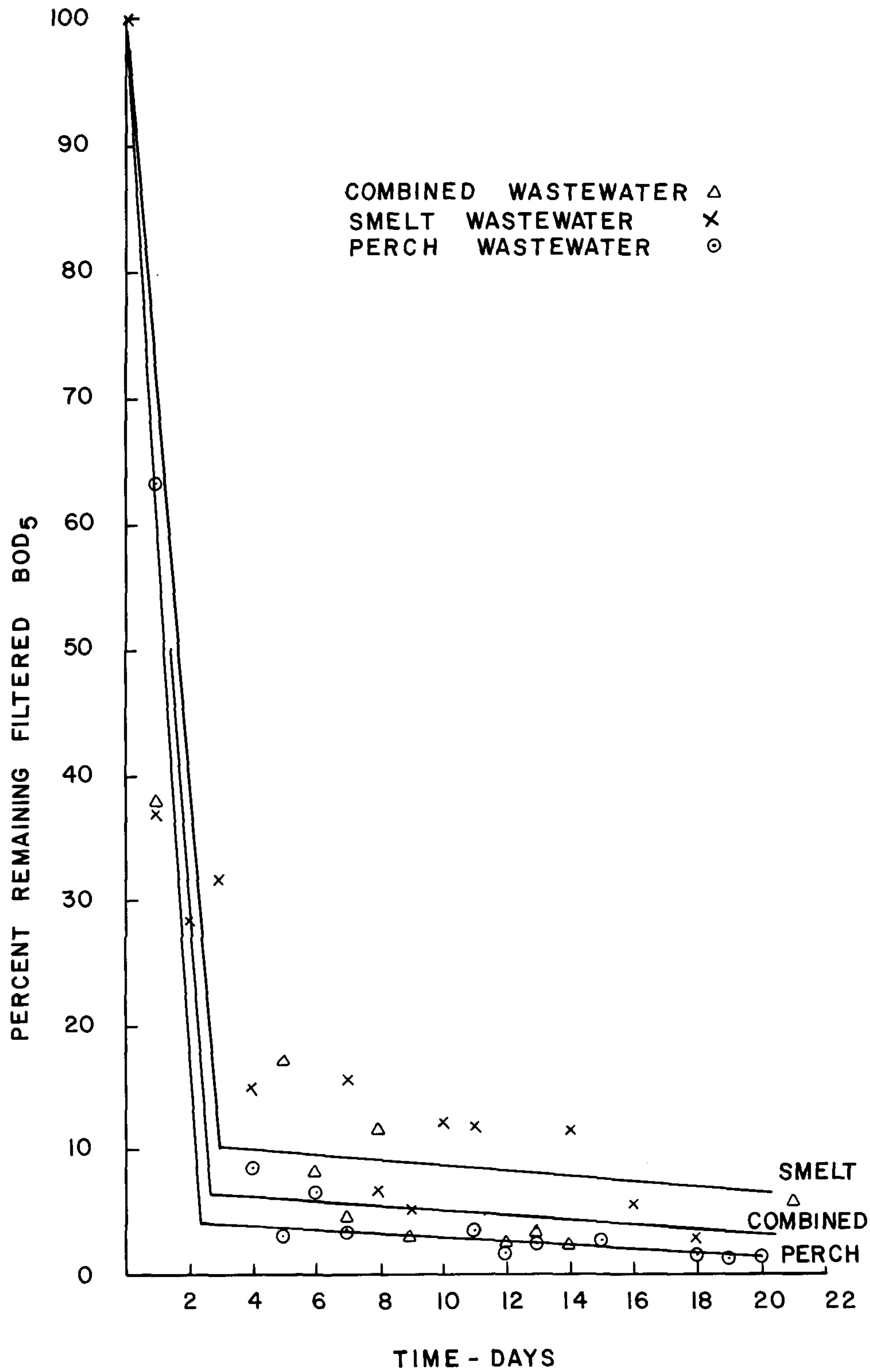


Figure 46 Removal rate of filtered BOD in a batch aeration reactor.

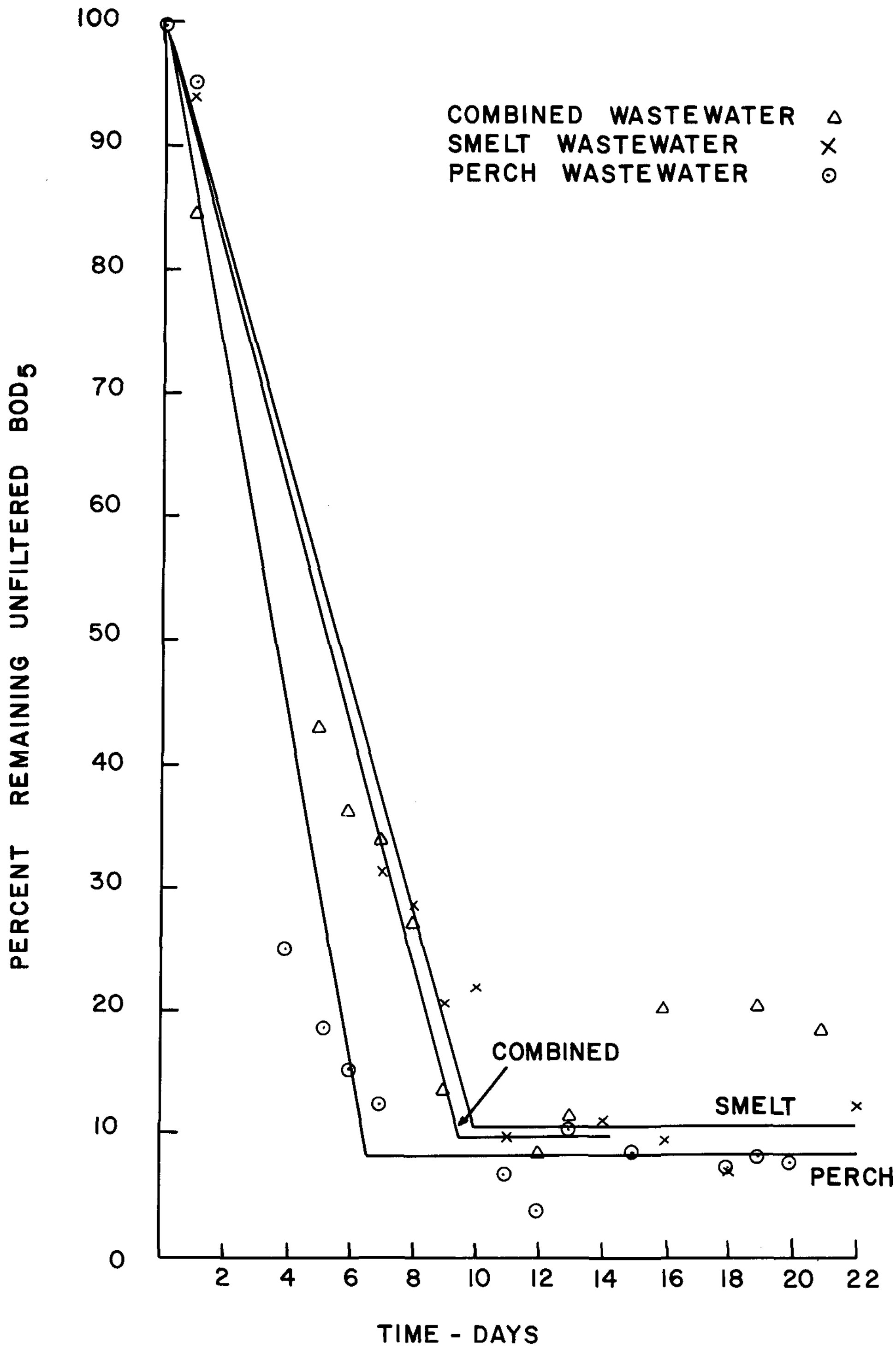


Figure 47 Removal rate of unfiltered BOD in a batch aeration reactor.

Table 109 Activated sludge
pilot plant results (Robbins, 1973).

Parameter	Raw Waste	BOD Loading (lb/cu ft/day)			
		0.075	0.14	0.21	0.26
BOD-5 (mg/l)	1000	5	10	13	27
% Removal	--	99.5	99.0	98.7	97.3

Table 110 Efficiency of Chromaglas package plant
on blue crab and oyster wastewater

Parameter	Influent	Percentage Reduction
BOD	400-1200 mg/l	80 - 90%
Suspended Solids	--	Effluent level = 160 mg/l

Although treatment units are available in all size ranges, it is unlikely activated sludge will prove to be the most cost-effective treatment where processing is intermittent, or 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 installations.

Table 110 shows the effectiveness of a package unit on wastewater from a plant processing Atlantic oysters and blue crab. The flow from this plant was quite low, averaging only 0.09 l/sec (2000 gpd).

Rotating Biological Contactor

The Rotating Biological Contactor (RBC), or Biodisc unit, consists of light-weight discs approximately 1.3 cm (0.5 in.) thick and spaced at 2.5 to 3.8 cm (1 to 1.5 in.) on centers. The cylindrical discs, which are up to 3.4 m (11 ft) in diameter, are mounted on a horizontal shaft and placed on a semicircular tank through which the wastewater flows. Clearance between the discs and the tank wall is 1.3 to 1.9 cm (0.5 to 0.75 in.). The discs rotate slowly, in the range of five 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 provides a high level of active organisms resistant to shock loads. Periodic sloughing produces a floc which settles rapidly; and 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 a first order reaction, 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 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 discs, the RBC unit is less sensitive to shock loads than activated sludge units, and is not upset by variations in hydraulic loading. 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 systems utilize an attached culture. However, with the rotating disc the biomass is passed through the wastewater rather than wastewater over the biomass, resulting in less clogging for the RBC unit. Continuous wetting of the entire biomass surface also prevents fly growth, often associated with conventional trickling filter operations.

The RBC system requires housing to protect the biomass from exposure during freezing weather and from damage due to heavy winds and precipitation.

A pilot RBC system has been studied in Canada on salmon canning wastewater, which had previously been treated by an air flotation system (Claggett, 1973). The pilot plant was obtained from Autotrol Corporation and was rated at about 0.44 l/sec (7 gpm). The pilot system consists of a wet well, a three stage treatment system and a secondary clarifier with a rotating sludge scoop. In general, the unit performed quite well, with reductions of over 50 percent in COD being obtained two days after start-up. The discs reached a steady state condition in one week. The unit operated satisfactorily at loadings up to 20 lbs COD/1000 sq ft/day, showing good stability in the face of fluctuating loads. Under light solids loading algal growth developed in the clarifier and the last disc section. Consequently, all effluent samples were filtered prior to COD analysis. Under moderate flow conditions the clarifier functioned well, but occasionally the suspended solids level rose about 50 mg/l, indicating some problems in this area. This carry-over became very pronounced under heavy solids loading. About 80 percent removal of applied COD was obtained for loadings of up to 20 lbs COD/1000 sq ft/day. Removal of COD at each stage is highly variable, and does not appear to be a function of the applied load. In general, up to one-half of the COD removal was achieved in the first section, up to 20 percent was removed in the second stage, and up to 15 percent removed in the third stage.

High-Rate Trickling Filter (HRTF)

A trickling filter consists on a vented structure of rock, fiberglas, plastic, or redwood media on which a microbial flora develops. As wastewater flows downward over the structure, the microbial flora assimilates and metabolizes the organic matter. The biomass continuously sloughs and is readily separated from the liquid stream by sedimentation. The resulting sludge requires further treatment and disposal as described previously.

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

The system is simple in operation, the only operational variable being recycle rate. The treatment efficiency of a well-designed deep-bed trickling filter tower of 14 ft 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 73°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. They would likely be detrimental.

Ponds and Lagoons

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

Lagoons are ponds in which wastewater is treated biologically. Naturally aerated lagoons are termed oxidation ponds. Such ponds are 0.9 to 1.2 m (3 to 4 ft) deep, with oxidation taking place chiefly in the upper 0.45 m (18 in.). Mechanically aerated lagoons are mixed ponds over 1.8 m (6 ft) and up to 6.1 m (20 ft) deep, with oxygen supplied by a floating aerator or compressed air diffuser system. The design of lagoons requires particular attention to local insulation, temperatures, wind velocities, etc. for critical periods. These variables affect the selection of design parameters. Loading rates vary from 22 to 112 kg BOD/day/ha (20 lb to 100 lb/day/acre), and detention times from three to 50 days. A typical aerated lagoon system which could be used for a seafood processing operation is shown in Figure 48.

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 too much algae, the aerated lagoon may turn septic in zones of minimal mixing, etc.; and 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. Where the plant discharges

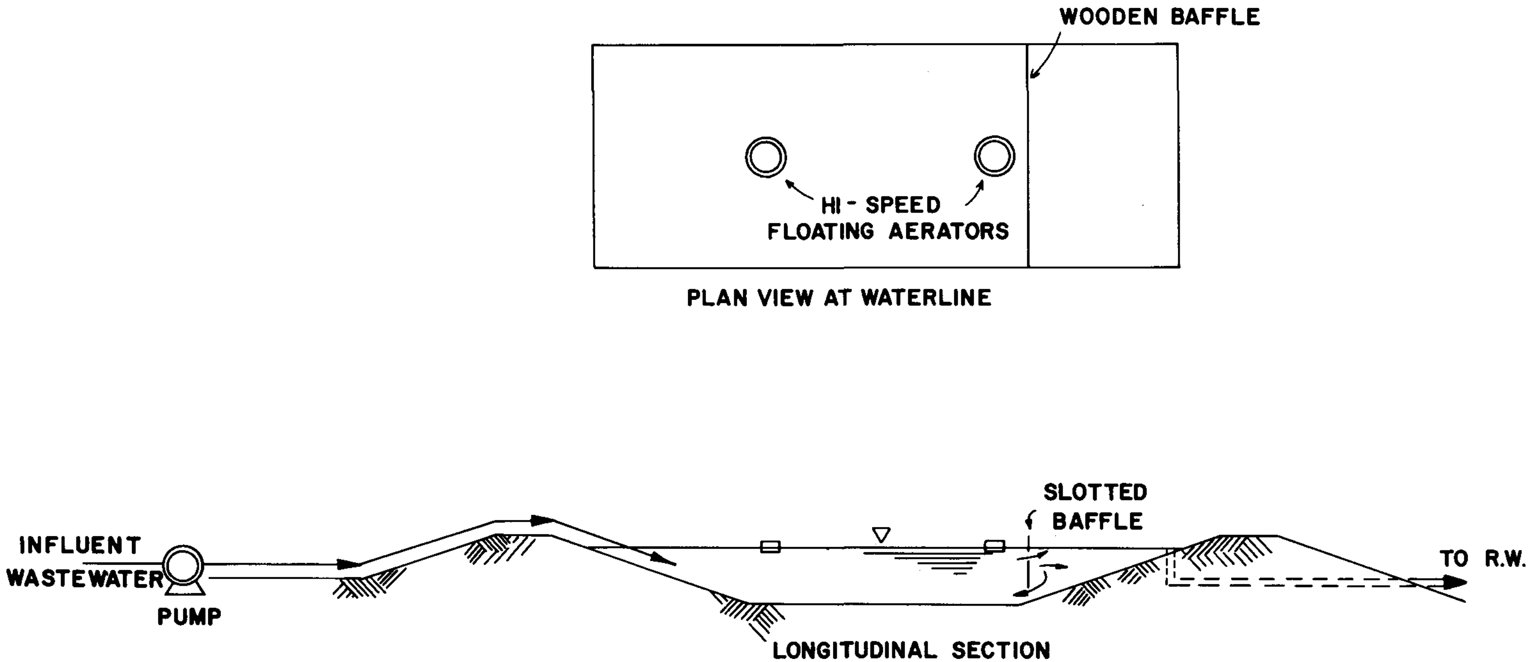


Figure 48. Typical aerated lagoon system.

no salt water, anaerobic and anaerobic-aerobic types of ponds 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, p. 557). A combined activated sludge lagoon system in Florida is reported to remove 97 percent of the BOD and 94 percent of the suspended solids from shrimp processing wastewater.

Land disposal

"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. Where such sites exist, serious consideration can be given to land application, particularly spray irrigation, of treated wastewaters.

Wastes are discharged in spray or flood irrigation systems by: 1) distribution through piping and spray nozzles over relatively flat terrain 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-furrow system, which may cause odor problems or clog the soil.

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 and the organic matter in the waste undergoes biological degradation. The liquid in the waste stream is either stored in the soil or discharged into the groundwater. A variable percentage of the waste flow can be 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 would be incompatible with land application technology at most sites. Limiting values 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.

Multi-Process Treatment Design Consideration

Waste characterization studies reveal the general ranges and concentrations of each specific processing subcategory; however, for design purposes it may often be necessary to know the nature of the combined waste stream from several commodities being processed simultaneously. Short term on-site waste and wastewater investigations are suggested so that any synergistic and/or antagonistic interactors can be determined. A combined waste stream could conceivably be more amenable to treatment than a single source because of possible smoothing of peak hydraulic and/or organic loading, neutralization of pH or dilution of saline conditions.

Each stream may individually dictate the design considerations. For instance, the fibrous nature of salmon canning waste will likely dictate the screening method used or a waste stream with high flow will likely dictate hydraulic loading of the system.

Another design problem is caused by sequential seasonal processing of different commodities. This condition is also prevalent in the seafood industry. Optimum waste treatment design conditions for one effluent will normally not be identical to those for the next. As an example, the sequential processing of shrimp and oysters would cause problems. Even though their effluent concentrations are similar, the wastewater flow volume is approximately eight times higher in the typical shrimp processing plant. Problems such as this will necessitate adaptations to normal design procedures or perhaps even demand the use of more than one treatment train.

During on-site waste management studies consideration should also be given to segregation of certain unit process streams. Significant benefits may be realized by using this technique. For example, treatment of a high concentrated waste flow can be more efficient and economical. In addition, by-product development normally centers on the segregation and concentration of waste producing processes. Uncontaminated cooling water should remain isolated from the main wastewater effluent. This water could either be reused or discharged directly.

TREATMENT DESIGN ALTERNATIVES

A summary of the equipment efficiencies and design assumptions for the technology alternatives is presented in Table 111.

Farm-Raised Catfish

Figures 45, 49, 50, and 51 depict the proposed treatment schemes, screening, aerated lagoon-oxidation pond, extended aeration, and aerated lagoon-spray irrigation alternatives for final disposal of the treated catfish processing waste waters. The designs were based on the waste water characteristics and volumes for a typical well-controlled catfish processing plant. Other bases included:

1) 8 hours per shift, 2 shifts per day, 5 days per week operation;

2) production volume of 13.6 kkg per day (15 tons per day);

3) further growth experienced during the design period (10 years) would be balanced partially by anticipated water use reduction realized through increased in-plant control;

4) availability of adequate land area; and

5) availability of adequate labor.

The basis for the designs and the estimates of effluent levels from the lagoons for catfish were 100 mg/l BOD_5 and 250 mg/l suspended solids. These numbers were chosen in consideration of the fact that under the climatic conditions in that part of the country large concentrations of algae will be a continuing problem, and also many of the lagoons will contain catfish.

The design for the extended aeration alternate assumed an effluent quality of 60 mg/l BOD_5 and 60 mg/l suspended solids.

An obtainable 25 percent reduction of grease and oil was assumed through the use of simple grease traps. A 90 percent reduction was assumed for grease traps coupled with subsequent treatment systems.

Conventional Blue Crab

Figures 40, 45, and 48 depict the proposed screning, extended aeration, and aerated lagoon alternative treatment schemes for conventional blue crab processors. The designs were based on the waste water characteristics and volumes for typical well-controlled processing plants. Assumptions included:

TABLE 111

EQUIPMENT EFFICIENCY AND DESIGN ASSUMPTIONS

Segment and Technology Alternatives	Effluent Concentration or Percent Reduction of Screened Sample Data					
	BPCTCA + NSPS			BATEA		
	BOD	TSS	O&G (1)	BOD	TSS	O&G (1)
Catfish						
Screen (2)	-	-	25%			
Stabilization Ponds	100 mg/l	150 mg/l	90%			
Lagoon System	100 mg/l	250 mg/l	90%	100 mg/l	250 mg/l	90%
Extended Aeration				60 mg/l	60 mg/l	90%
Land Irrigation (7)	-	-	-			
Conventional Blue Crab						
Screen (2)	-	-	25%			
Lagoon System	125 mg/l	375 mg/l	75%	125 mg/l	375 mg/l	75%
Extended Aeration				100 mg/l	100 mg/l	90%
Mechanized Blue Crab						
Screen (2)	-	-	25%			
Lagoon System	80 mg/l	200 mg/l	75%	80 mg/l	200 mg/l	75%
EXtended Aeration				60 mg/l	60 mg/l	90%
Alaskan Crab Meat						
Screen (2)	-	-	25%			
Air Flotation (4)				40%	70%	(3)
Lagoon System				80 mg/l	200 mg/l	5 mg/l
Extended Aeration				60 mg/l	60 mg/l	5 mg/l
Alaskan Whole Crab and Crab Section						
Screen (2)	-	-	25%			
Air Flotation (4)				40%	70%	(3)
Lagoon System				80 mg/l	200 mg/l	5 mg/l
Extended Aeration				60 mg/l	60 mg/l	5 mg/l
Dungeness & Tanner Crab in the Contiguous States						
Screen (2)	-	-	25%			
Air Flotation (5)	40%	70%	(3)	75%	90%	(6)
Lagoon System				80 mg/l	200 mg/l	5 mg/l
Extended Aeration				60 mg/l	60 mg/l	5 mg/l
Alaskan Shrimp						
Screen	-	-	-			
Air Flotation (4)				40%	70%	(3)
Lagoon System				80 mg/l	200 mg/l	5 mg/l

TABLE 111 (cont.)

EQUIPMENT EFFICIENCY AND DESIGN ASSUMPTIONS

Segment and Technology Alternatives	Effluent Concentration or Percent Reduction of Screened Sample Data					
	BPCTCA + NSPS			BATEA		
	BOD	TSS	O&G (1)	BOD	TSS	O&G (1)
Northern Shrimp						
Screen (2)	-	-	-			
Air Flotation (5)	40%	70%	(3)	75%	90%	(6)
Lagoon System				80 mg/l	200 mg/l	5 mg/l
Extended Aeration				60 mg/l	60 mg/l	5 mg/l
Southern Non-breaded Shrimp						
Screen (2)	-	-	-			
Air Flotation (5)	40%	70%	(3)	75%	90%	(6)
Lagoon System				80 mg/l	200 mg/l	5 mg/l
Extended Aeration				60 mg/l	60 mg/l	5 mg/l
Breaded Shrimp						
Screen (2)	-	-	-			
Air Flotation (5)	40%	70%	(3)	75%	90%	(6)
Lagoon System				80 mg/l	200 mg/l	5 mg/l
Extended Aeration				60 mg/l	60 mg/l	5 mg/l
Tuna						
Air Flotation (5)	40%	70%	(3)	75%	90%	(6)
Roughing Filter				260 mg/l	100 mg/l	5 mg/l
Activated Sludge				40 mg/l	40 mg/l	5 mg/l

(1) The numbers include removals due to in-plant recovery such as sumps and grease traps coupled with the end-of-pipe technology.

(2) The design assumptions are based on the summary of sampling data which were screened prior to analysis. No further reduction was assumed for plant scale screening.

(3) Eighty-five percent (85%) removal or the level of detection (5 mg/l) of the oil and grease test, whichever is higher.

(4) Reductions are based on operation as a non-optimized chemical system.

(5) Reductions are based on operation as a non-optimized chemical system for 1977, and an optimized chemical system for 1983.

(6) Ninety percent (90%) removal or the level of detection (5 mg/l) of the oil and grease test, whichever is higher.

(7) The assumptions for catfish are based on spray irrigation of process wastewater and partial recycle of live fish holding tank water with overflow and discharge to fish holding ponds.

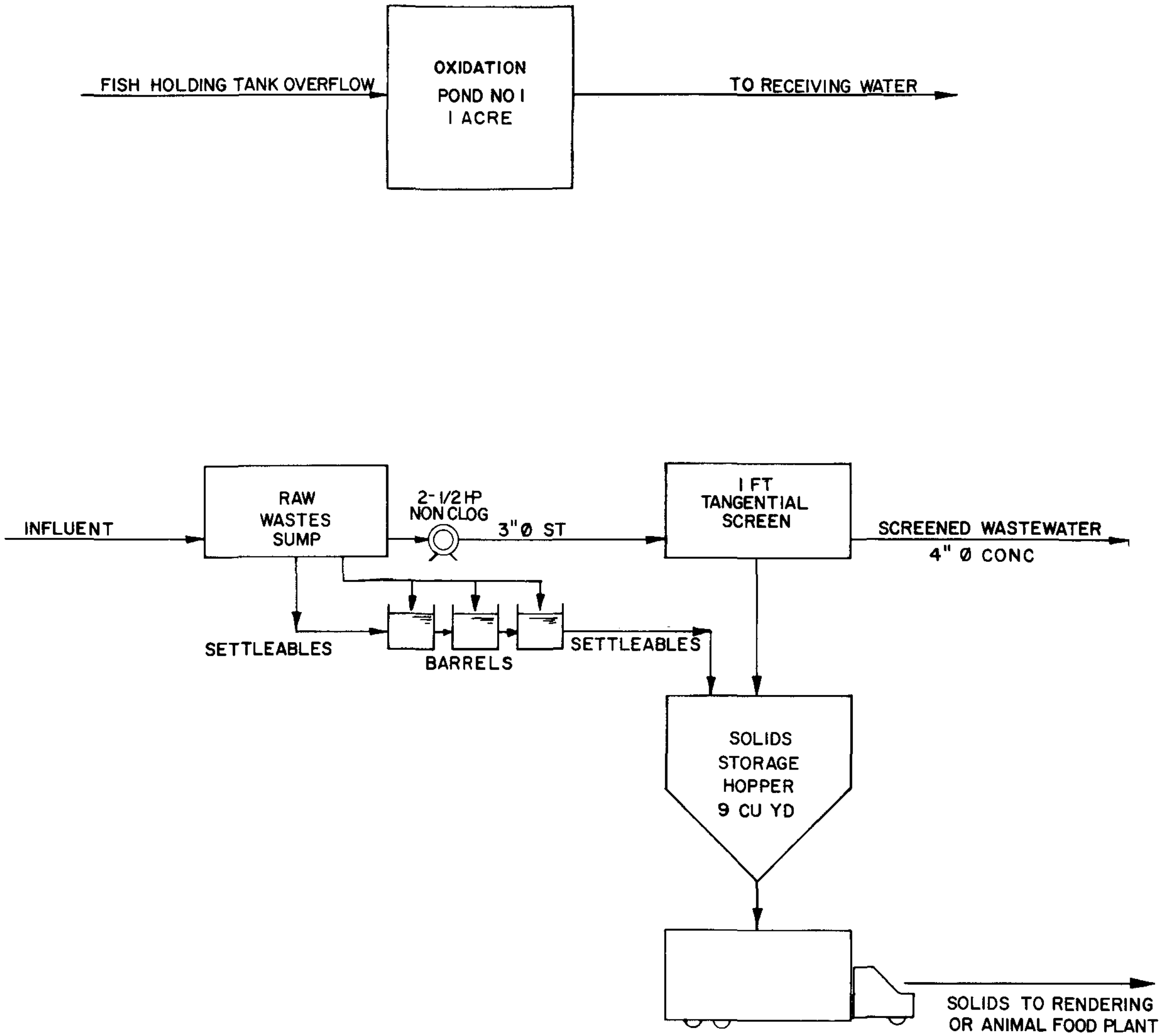


Figure 49 Catfish processing, initial treatment.

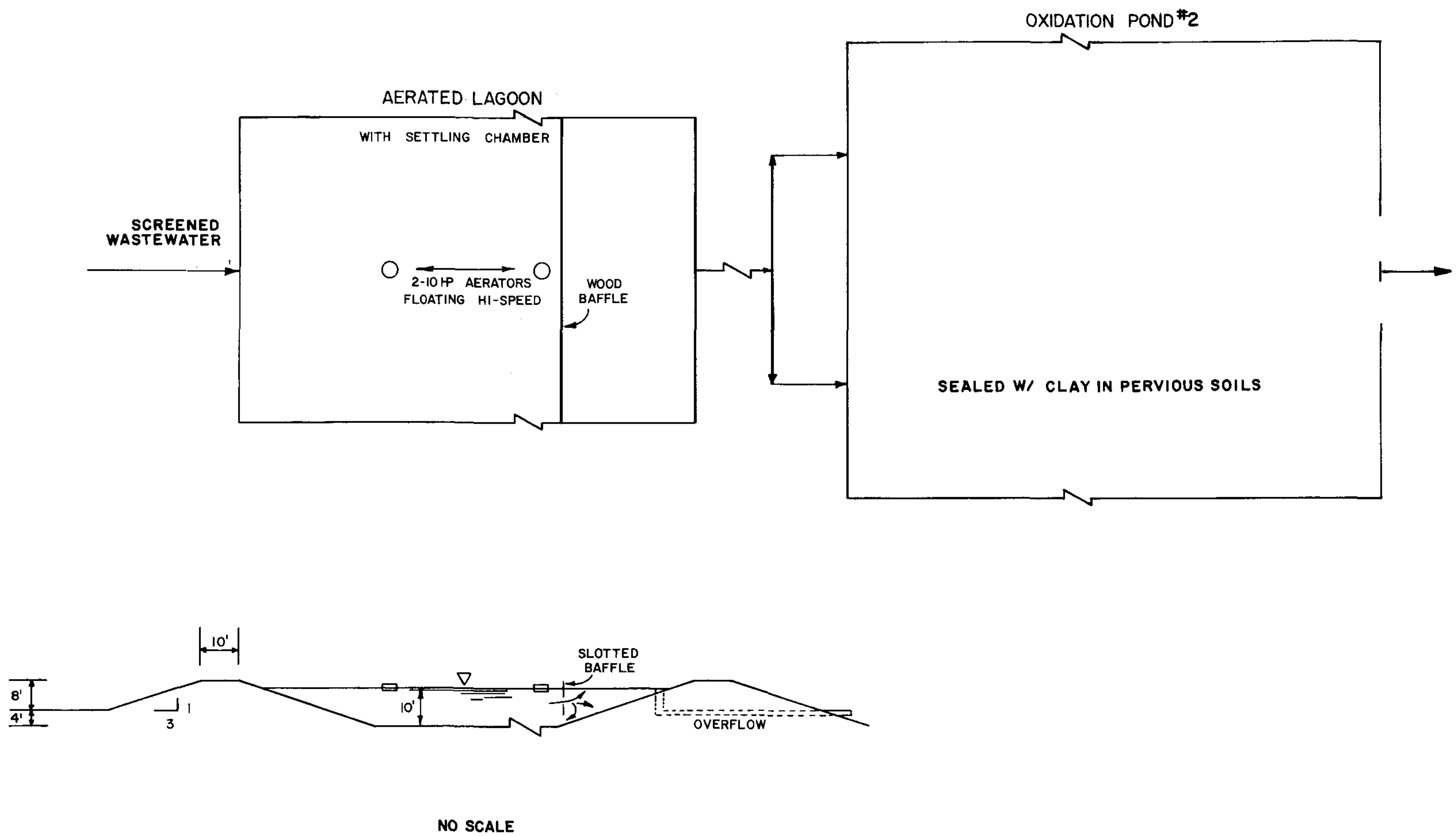


Figure 50 Catfish processing, oxidation pond alternative.

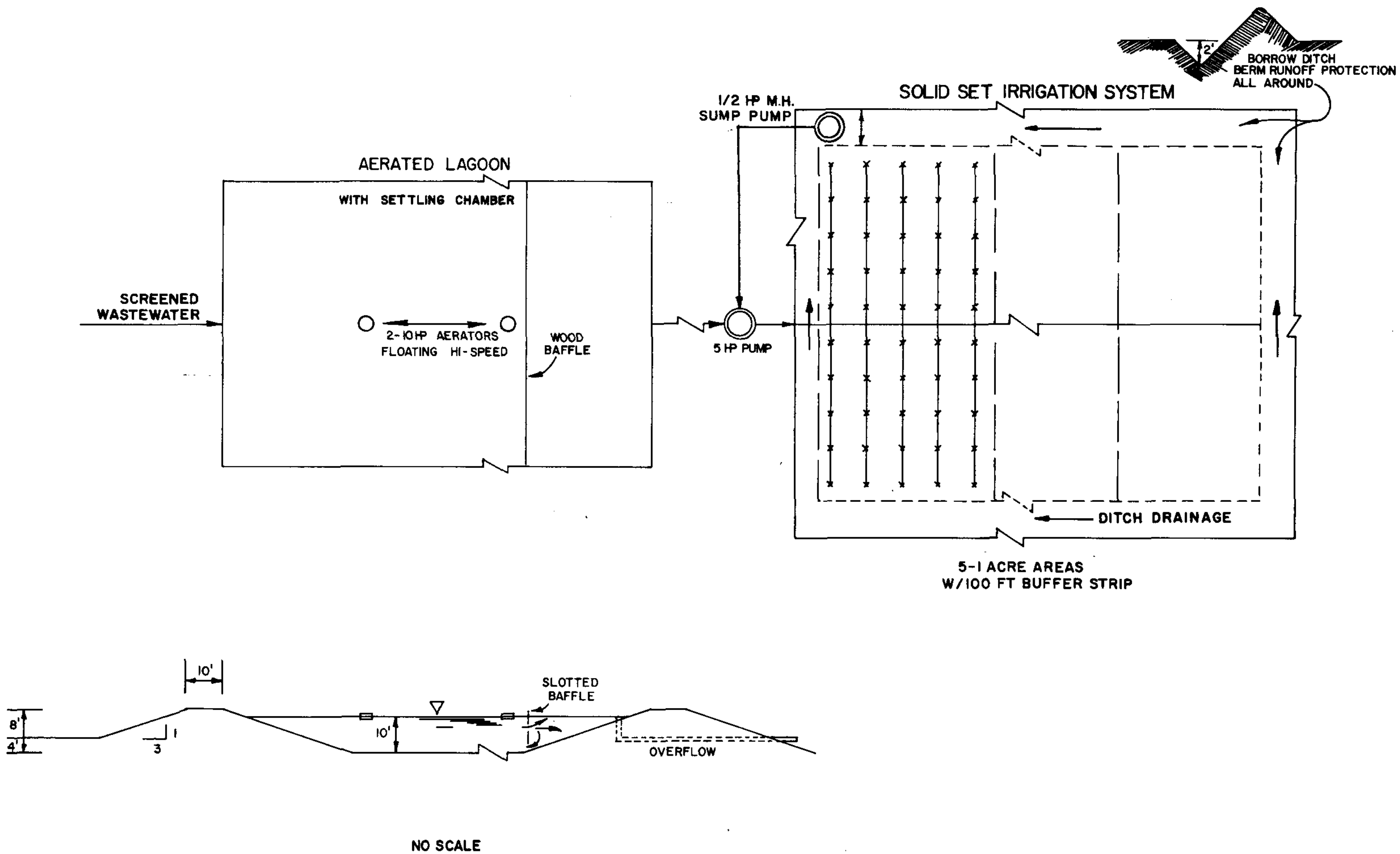


Figure 51 . Catfish processing,
spray irrigation alternative.

1) 8 hours per shift, 2 shifts per day, 5 days per week operation;

2) a production volume of 5.5 kkg/day (6 tpd)

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased inplant control; and

4) skilled treatment system operators would be available.

With the aerated lagoon system it was assumed that BOD_5 would be about 125 mg/l and suspended solids 375. With the extended aeration process and the difference in the basic biota of the systems and the prevalence of endogenous respiration, concentrations of 100 mg/l BOD_5 and 100 mg/l suspended solids were assumed.

The grease and oil removal due to sumps and simple grease traps was assumed to be 25 percent. A total reduction of 75 percent was assumed for the aerated lagoon system and 90 percent for the extended aeration system.

Mechanized blue crab

Figures 40, 45 and 48 depict the proposed screning, extended aeration, and aerated lagoon alternative treatment schemes for mechanized blue crab processors. The designs were based on the waste water characteristics and volumes for typical well-controlled processing plants. Assumptions included:

1) 8 hours per shift, 2 shifts per day, 5 days per week operation;

2) a production volume of 10.9 kkg/day (12 tpd);

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased inplant control; and

4) skilled treatment system operators would be available.

Water use reduction was first considered in the design basis. It was assumed that a 15 percent reduction in water use could be effected for the 1983 and new source guidelines, which would result in about a 5 percent overall BOD_5 reduction. Then, considering the aerated lagoon alternative for mechanized blue crab, it was assumed that an aerated lagoon could achieve about 80 mg/l BOD_5 and 200 mg/l suspended solids. Extended aeration was assumed to achieve an effluent concentration of 60 mg/l BOD_5 and 60 mg/l suspended solids.

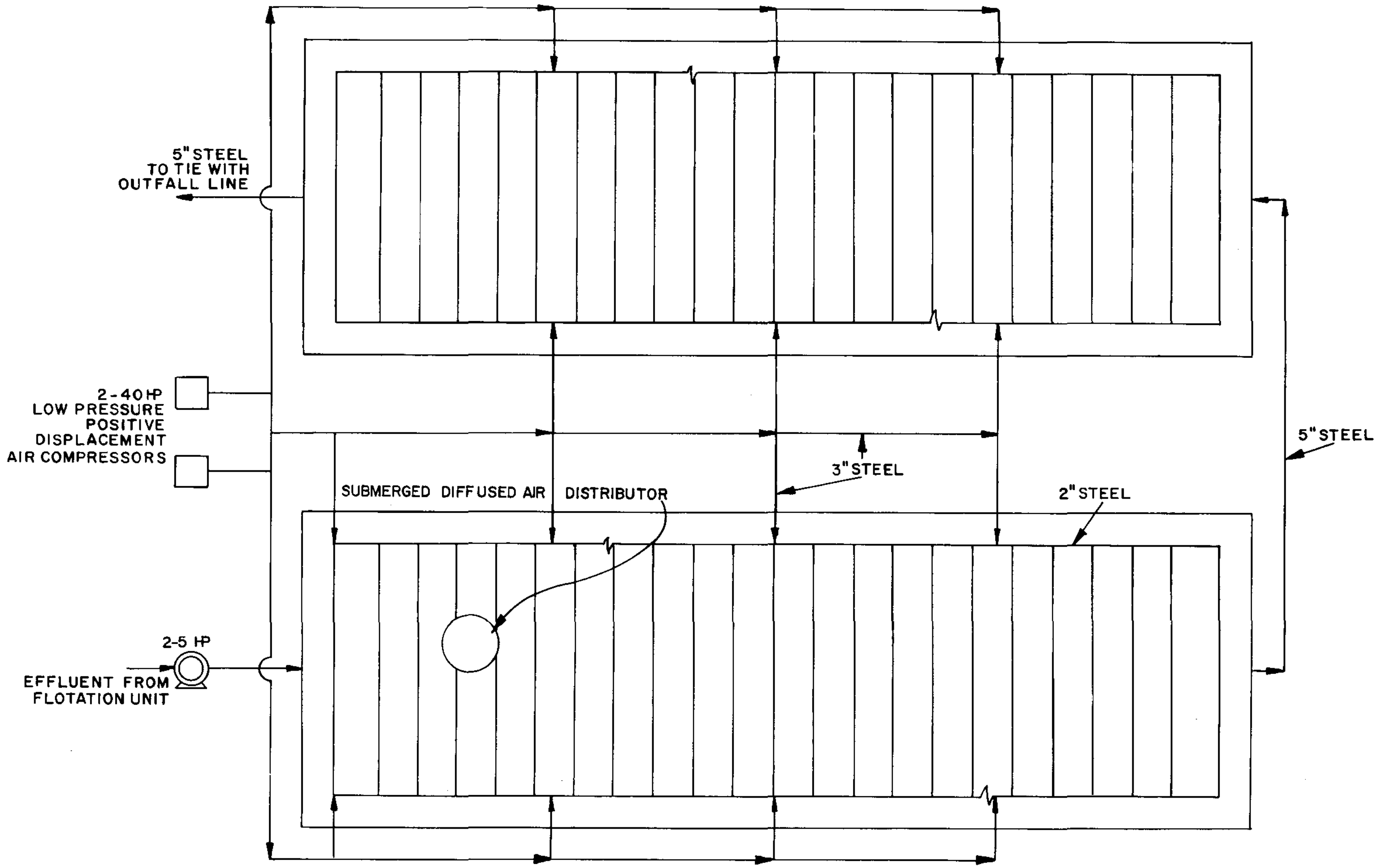


Figure 52 Alaska crab processing, aerated lagoon alternative

The grease and oil removal due to sumps and simple grease traps was assumed to be 25 percent. A total reduction of 75 percent was assumed for the aerated lagoon system and 90 percent for the extended aeration system.

Alaskan Crab Meat Processing

Figures 40, 41, 45, 52, and 53 depict the proposed screening, dissolved air flotation, extended aeration, aerated lagoon, and grinding alternative treatment schemes for Alaskan Dungeness, tanner and king crab processors. Assumptions for the designs included:

1) 8 hours per shift, 2 shifts per day, 5 days per week operation;

2) a production volume of 45.4 kkg/day (50 tpd);

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased inplant control; and

4) skilled treatment system operators would be available.

Alaskan crab processing plants are larger-scale operations than those in the "lower 48" states, but the waste waters are still intermittent, seasonal and of relatively high strength.

The design basis assumed complete retention of the 20-mesh screenable solids on a screen in a full-scale operation. As discussed in Section V, the plant samples were screened on a 20-mesh sieve in order to create a base level for comparing data among plants. It was assumed that 90 percent of the remaining suspended solids would be removed in the flotation unit and that the BOD_5 removal would be 75 percent. This assumes significant removals on a screen prior to flotation, so overall BOD_5 removals would be considerably higher.

For the 1983 and new source guidelines the in-plant modifications were assumed to effect a 50 percent water reduction with a commensurate 15 percent BOD_5 reduction.

The extended aeration alternative design was based on the research and development efforts of the U.S. Army Corps of Engineers Anchorage, Alaska. Their experience with biological waste treatment was limited to domestic waste only, as was the case throughout Alaska. It was assumed that, with proper design, concentrations of 60 mg/l BOD_5 and 60 mg/l suspended solids could be achieved.

The aerated lagoon alternative in Alaska is not going to perform as well as an extended aeration system. This is due mainly to two factors: one is algae growth, because of the longer

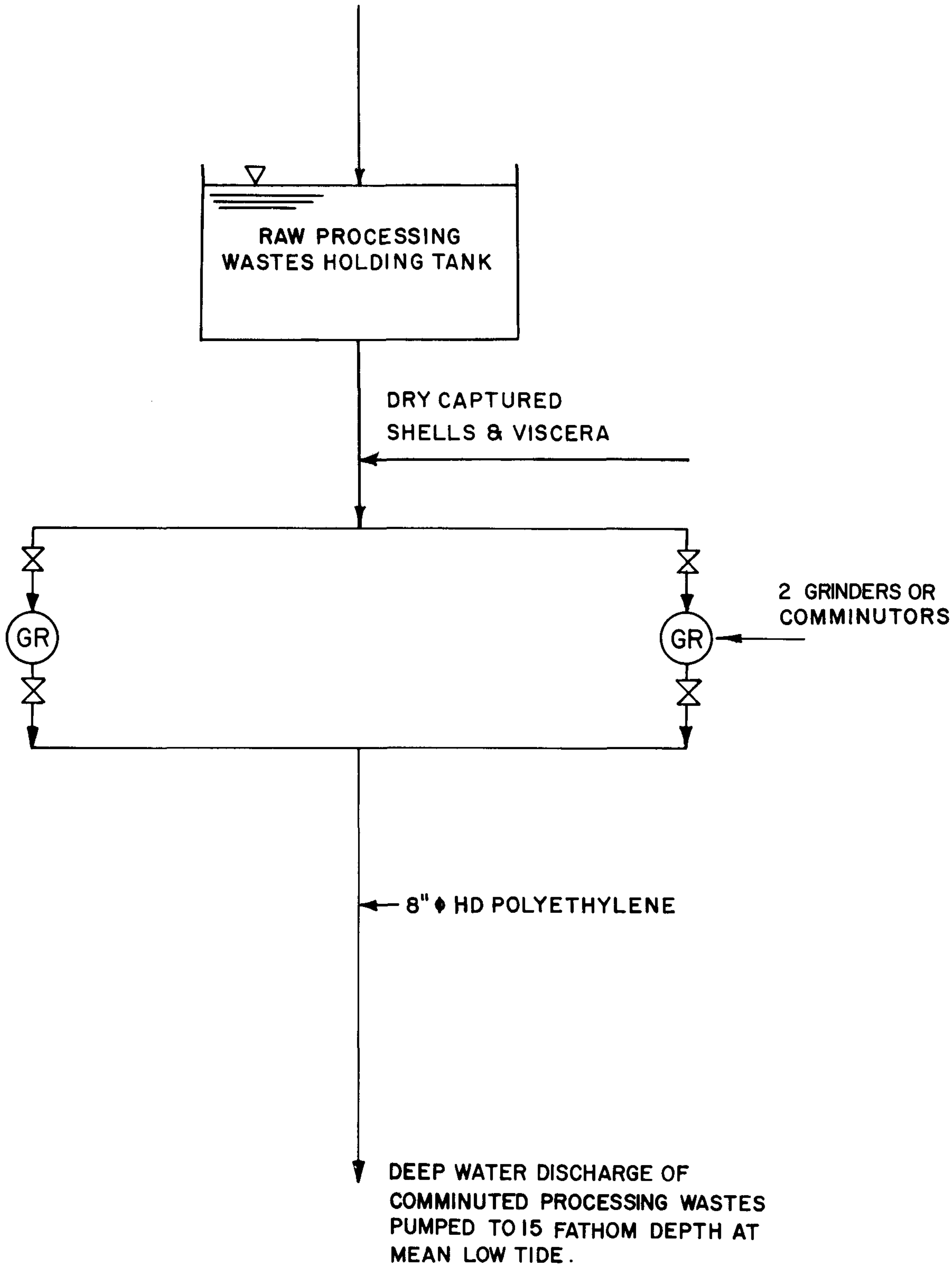


Figure 53 Alaskan physical treatment alternative, remote plants with adequate flushing available.

retention time in the system, the exposure to the long days of sunlight during the summertime; and the poor settleability of the type of floc that is developed in an aerated lagoon as compared to an extended aeration system. It was assumed that the aerated lagoon alternative for Alaska would produce an effluent concentration of 80 mg/l BOD5 and 200 mg/l suspended solids.

The grease and oil removal was assumed to be 25 percent due to a sump prior to screening, an overall 85 percent after air flotation, and removal to the level of detection for the grease and oil test, 5 mg/l, after the biological systems.

An alternative for the remote, isolated processor includes grinding and discharge to deepwater where adequate flushing is available.

Alaskan Whole Crab and Crab Section Processing

Figures 40, 41, 45, 52, and 53 depict the proposed screening, dissolved air flotation, extended aeration, aerated lagoon, and grinding alternative treatment schemes for Alaska Dungeness, tanner and king crab processors. All of the design assumptions are the same as in the pervious section for Alaskan Crab Meat Processing.

Dungeness and Tanner Crab Processing in the Contiguous States

Figures 40, 41, 45, and 48 depict the proposed screening, dissolved air flotation, extended aeration, and aerated lagoon alternative treatment schemes for Dungeness and tanner crab processors in the contiguous states. Assumptions for the design included:

1) 8 hours shift, 2 shifts per day, 5 days per week operation;

2) a production volume of 12.7 kkg/day (14 tpd);

3) further growth (if any) experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased in-plant control; and

4) skilled treatment system operators would be available.

The effluent design assumptions are the same as in previous sections. For dissolved air flotation the assumed reductions were 40 percent for BOD5 and 70 percent for suspended solids for the 1977 and new source guidelines. It was assumed for the 1983 guidelines that the operation of the flotation unit between 1977 and 1983 would be significantly improved due to increased operator skill, optimization of chemical type and dosage, and development of new chemical coagulants and flocculents. It was estimated that by 1983, a 75 percent BOD_5 removal in the flotation unit, and 90 percent suspended solids removal would be obtainable. The extended aeration process assumed a design effluent quality of 60 mg/l BOD_5 and 60 mg/l suspended solids; the effluent quality for aerated lagoons was assumed to be 80 mg/l BOD_5 and 200 mg/l suspended solids.

The 1983 and new source in-plant modifications were assumed to effect a 40 percent waste water flow reduction with a commensurate 15 percent BOD_5 reduction.

The grease and oil removal was assumed to be 25 percent due to sumps and simple grease traps, on overall 85 percent or the level of detection of the grease and oil test, (5 mg/l), whichever was higher after the flotation systems and the level of detection after the biological systems.

The historical data for Dungeness and tanner crab processing did not include the oil and grease parameter. Because of the similarity of the waste water characteristics for similar processing techniques of the Alaskan and Pacific Northwest Dungeness and tanner crab operations, the value for the oil and grease parameters of the Pacific Northwest process was extrapolated from the Alaskan process.

Alaskan Shrimp Processing

Figures 40, 41, 45, 48, and 53 depict the proposed screening, dissolved air flotation, extended aeration, aerated lagoon, and grinding treatment alternatives for Alaskan shrimp processors. The designs were based on wastewater characteristics and volumes for a typical medium-size plant. Assumptions for design included:

1) 8 hours per shift, 2 shift per day, 5 days per week operation;

2) a production volume of 31.8 kkg/day (35 tpd);

3) further growth experienced during the desgin period (10 years) would be partially balanced by anticipated water use reductions realized through increased inplant control; and

4) skilled treatment system operators would be available.

The effluent design assumptions are the same as in previons sections. For disolved air flotation the assumed reductions were 75 percent for BOD_5 and 90 percent for suspended solids for the 1983 guidelines. The extended aeration process assumed a design effluent quality of 60 mg/l BOD_5 and 60 mg/l suspended solids;

the effluent quality for aerated lagoons were assumed to be 80 mg/l BOD_5 and 200 mg/l suspended solids.

The 1983 and new source in-plant modifications were assumed to effect a 40 percent waste water flow reduction with a commensurate 13 percent BOD_5 reduction.

The grease and oil removal due to sumps and simple grease traps was assumed to be negligible because of the emulsified nature of the shrimp processing greases and oils. A 90 percent removal was assumed for the air flotation effluents, and removal to the level of detection, 5 mg/l, after the biological systems.

Northern Shrimp Processing in the Contiguous States

Figures 40, 41, 45, and 48 depict the screening, dissolved air flotation, extended aeration, and aerated lagoon alternative treatment schemes. The designs were based on waste water characteristics and volumes for typical medium-size plants. (The same treatment train is applied to northern shrimp processing, southern shrimp processing and breaded shrimp processing in the contiguous states. Only the sizes of the systems require changing.) Assumptions included:

1) 8 hours per shift, 2 shifts per day, 5 days per week operation;

2) a production volume of 18.2 kkg/day (20 tpd) for northern shrimp processing;

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased in-plant control; and

4) skilled treatment system operators would be available.

The design basis assumed complete retention of the 20-mesh screenable solids on a screen in a full-scale operation. As discussed in Section V, the plant samples were screened on a 20-mesh sieve in order to create a base level for comparing data among plants. It was assumed that 90 percent of the remaining suspended solids would be removed in the flotation unit. At the same time that the flotation unit will reduce the suspended solids by 90 percent, it was estimated that the BOD_5 removal will be 75 percent. This assumes significant removals on a screen prior to flotation, so overall BOD_5 removals would be considerably higher.

The 1983 and new source in-plant modifications were assumed to effect a 20 percent waste water flow reduction with a commensurate 10 percent BOD_5 reduction.

The extended aeration process assumed a design effluent quality of 60 mg/1 BOD_5 and 60 mg/1 suspended solids; the effluent quality for aerated lagoons was assumed to be 80 mg/1 BOD_5 and 200 mg/1 suspended solids.

An overall grease and oil removal of 90 percent was assumed for the flotation system and reduction to the level of detection for the biological systems. The grease and oil removal due to sumps and simple grease traps was assumed to be negligible because of the emulsified nature of the shrimp processing greases and oils.

Southern Shrimp Processing in the Contiguous States

Figures 40, 41, 45 and 48 depict the proposed screening, dissolved air flotation, extended aeration, and aerated lagoon treatment schemes. The designs were based on waste water characteristics and volumes for typical medium-size plants. Assumptions included:

1) 8 hours per shift; 2 shifts per day; 5 days per week operation;

2) a production volume of 36.4 kkg/day (40 tpd) for southern shrimp processing;

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased in-plant control; and

4) skilled treatment system operators would be available.

The effluent design assumptions are the same as in the previous section on northern shrimp processing for the treatment alternatives.

The 1983 and new source in-plant modifications were assumed to effect a 20 percent waste water flow reduction with a commonsurate 10 percent BOD_5 reduction.

Breaded Shrimp Processing in the Contiguous States

Figures 40, 41, 45, and 48 depict the proposed screening, dissolved air flotation, extended aeration, and aerated lagoon treatment schemes for breaded shrimp processing. The designs were based on waste water characteristics and volumes for typical medium-size plants.

1) 8 hours per shift; 2 shifts per day; 5 days per week operation;

2) a production volume of 12.7 kkg/day (14 tpd) for breaded shrimp processing;

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use reductions realized through increased in-plant control; and

4) skilled treatment system operators would be available.

The effluent design assumptions are the same as in the previous section on northern shrimp processing for the treatment alternatives.

The 1983 and new source in-plant modifications were assumed to effect a 50 percent waste water flow reduction with a commensurate 20 percent BOD_5 reduction.

No data was available for the grease and oil content of the breaded shrimp processing waste water effluent. However, considering the fact that similar species are processed in the southern shrimp subcategory the same level was assumed for the breaded shrimp grease and oil summary.

Tuna Processing

Figure 54 depicts the proposed screening, dissolved air flotation, roughing filter, and activated sludge treatment schemes for the tuna processing 1977, 1983, and new source guidelines. The designs were based on wastewater characteristics and volumes for a typical medium-to-large size plant. Because production levels of this order are currently found in the industry, the size was designated a "full size" plant for purposes of design and cost estimation. Design assumptions included:

1) 8 hours per shift, 2 shifts per day, 5 days per week operation;

2) a production volume of 340 kkg/day (375 tpd);

3) further growth experienced during the design period (10 years) would be partially balanced by anticipated water use redution realized through increased in-plant control; and

4) skilled treatment system operators would be available.

The 1983 and new source in-plant modifications were assumed to effect a 30 percent waste water flow reduction with a commensurate 10 percent BOD_5 reduction.

The effluent design assumptions are the same as in previous sections. For dissolved air flotation the assumed reductions were 40 percent for the 1977 and new source guidelines. It was

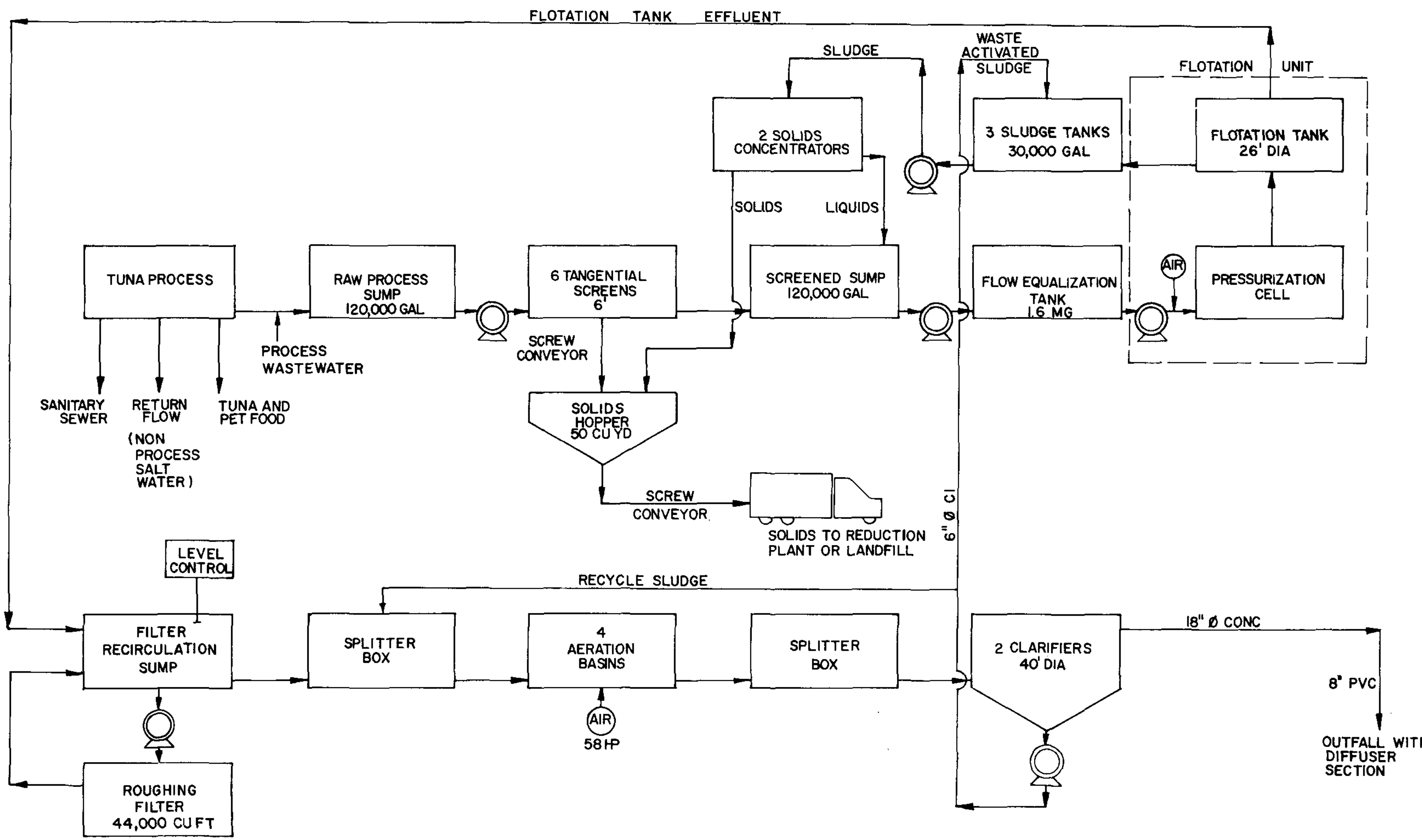


Figure 54 Tuna processing

assumed for the 1983 guidelines that the operation of the flotation unit between 1977 and 1983 would be significantly improved due to increased operator skill, optimization of chemical type and dosage, and the development of new chemical coagulants and flocculents. It was estimated that by 1983, a 75 percent BOD_5 removal in the flotation unit, and 90 percent suspended solids removal would be obtainable.

The roughing filter was assumed to effect a 40 percent BOD_5 reduction and the clarifier about a 45 percent suspended solids reduction to reach 260 mg/l BOD_5 and 95 mg/l suspended solids. The activated sludge system was assumed to produce an effluent of about 40 mg/l BOD_5 and 40 mg/l suspended solids.

The overall grease and oil removal was assumed to be 85 percent for the flotation system and 90 percent for the biological systems or the level of detection, whichever was higher.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS SUMMARY

The waste waters from seafood processing plants are, in general, considered to be amenable to treatment using standard physical-chemical and biological systems. Wastewater management in the form of increasing by-product recovery, in-plant control and recycling is not practiced uniformly throughout the industry. Of all the types of seafood processing monitored during this study, the most exemplary from this viewpoint was the tuna industry. Even in this case there was a relatively wide range in the amount of water used per unit of raw material. The concepts of water conservation and by-product recovery are at early stages in most parts of the industry. Therefore, in addition to applying treatment to the total effluent, there is much room for the improvement of water and waste management practices. These will reduce the size of the required treatment systems or improve effluent quality, and in many cases, conserve or yield a product that will help offset or often exceed the costs of the changes.

Typical in-plant control costs and benefits in terms of BOD_5 reduction and waste water flow are summarized in Tables 112 and 113 for each subcategory. It can be seen that for some cases a relatively moderate investment can result in a significant reduction in water used. The BOD_5 reduction represents the amount of BOD_5 input avoided by reducing the product-water contact time through decreased water use.

Typical treatment costs and benefits in terms of BOD_5 remaining in the effluent per unit of product are listed in Table 113 and shown in Figures 55 through 65. It is possible, using these figures, to get an indication of the marginal costs and benefits associated with each level of treatment. Depending on the value placed on the quality of the effluent, the marginal cost and benefit curves can be used to determine the most cost-effective treatment alternative.

The operation and maintenance costs (O and M costs) for each treatment level for each subcategory are listed with the capital costs in Table 113. The O and M costs tend to increase with level of treatment but are also dependent on the type of treatment selected. O and M costs are from 50 percent to 300 to 400 percent higher for the 1983 alternatives than the 1977 alternatives depending on the industry and the alternative.

Energy costs are included in the O and M costs and are not considered to be a significant factor except in remote areas of Alaska where biological systems may require heat inputs at certain times of the year. The cost of electrical energy in Kodiak, Alaska is about 10 times the cost in the "lower 48" and in remote areas of Alaska it is 20 times as much.

Table 112 Estimated practicable in-plant wastewater flow reductions and associated pollutional loadings reductions

Subcategory	Wastewater Flow Reduction, % of Total	BOD Reduction, % of Total
Catfish	0	0
Conventional blue crab	0	0
Mechanized blue crab	15	5
Alaskan crab meat	50	15
Alaskan whole crab and sections	50	15
Other Dungeness and tanner crab	40	15
Alaskan shrimp	40	13
Northern shrimp	20	10
Southern canned, frozen and fresh shrimp	20	10
Breaded shrimp	50	20
Tuna	30	10

TABLE 113 TREATMENT EFFICIENCIES AND COSTS

	TREATMENT ALTERNATIVES	EFFLUENT BOD KG/KKG	COSTS 1971 $ CAPITAL COSTS			DAILY O & M COSTS		
Farm-Raised Catfish	(Processing Rate)		(10tpd)	(5tpd)	(3tpd)	(10tpd)	(5tpd)	(3tpd)
	Present	9.9	0	0	0	0	0	0
	S, GT	7.9	13,000	8,000	6,000	5	3	2
	S, GT, AL	2.3	71,300	47,100	34,600	24	16	11
	S, GT, AL, LI	0.1	98,000	65,100	47,400	26	18	12
	S, GT, EA	1.4	72,900	48,100	35,400	27	18	13
Conventional Blue Crab	(Processing Rate)		(12tpd)	(8tpd)	(4tpd)	(12tpd)	(8tpd)	(4tpd)
	Present	7.5	0	0	0	0	0	0
	S, GT	5.2	$5,900	$4,600	$3,000	3	2	2
	S, GT, AL	0.15	9,100	7,100	4,700	9	7	5
	S, GT, EA	0.12	44,000	34,500	22,700	20	15	10
Mechanized Blue Crab	(Processing Rate)		(24tpd)	(12tpd)	(6tpd)	(24tpd)	(12tpd)	(6tpd)
	Present	33	0	0	0	0	0	0
	S, GT	22	8,900	5,900	3,800	5	3	2
	S, GT, AL	3.0	23,000	15,200	10,000	14	9	6
	S, GT, AL, IP	2.5	26,800	17,700	11,700	14	9	6
	S, GT, IP, EA	1.9	181,000	119,500	78,000	36	24	16

TABLE 113 (cont.) TREATMENT EFFICIENCIES AND COSTS

	TREATMENT ALTERNATIVES	EFFLUENT BOD KG/KKG	COSTS 1971 $ CAPITAL COSTS			DAILY O & M COSTS		
Alaska Crab (meat process)	(Processing Rate)		(18tpd)	(12tpd)	(8tpd)	(18tpd)	(12tpd)	(8tpd)
	Present	19	0	0	0	0	0	0
	S, GT	9.6	102,000	80,000	63,000	100	80	63
	S, GT, barge solids	9.6	273,000	214,000	168,000	248	194	152
	S, GT, reduce solids	9.6	730,000	572,000	449,000	567	445	349
	S, GT, IP	8.1	135,000	106,000	83,000	100	80	63
	S, GT, IP, DAF, barge	2.0	1,168,000	916,000	718,000	372	292	228
	S, GT, IP, DAF, AL, barge	1.4	2,648,000	2,076,000	1,628,000	809	634	497
	Grind and deep outfall (1500 ft. of pipe)	-	96,000	75,000	59,000	33	25	20
Alaska Crab (whole + sections processes)	(Processing Rate)		(25tpd)	(11tpd)	(5tpd)	(25tpd)	(11tpd)	(5tpd)
	Present	12	0	0	0	0	0	0
	S, GT	6.0	84,000	51,000	32,000	84	51	32
	S, GT, barge solids	6.0	225,000	137,000	86,000	204	125	78
	S, GT, reduce solids	6.0	408,000	249,000	155,000	324	198	123
	S, GT, IP	5.1	124,000	75,000	47,000	84	51	32
	S, GT, IP, DAF, barge	1.3	961,000	587,000	366,000	306	187	117
	S, GT, IP, DAF, AL, barge	0.74	2,178,000	1,330,000	829,000	665	406	253
	Grind and deep outfall (1500 ft. of pipe)	-	117,000	71,000	45,000	40	24	15

TABLE 113 (cont.) TREATMENT EFFICIENCIES AND COSTS

	TREATMENT ALTERNATIVES	EFFLUENT BOD KG/KKG	COSTS 1971 $					
			CAPITAL COSTS			DAILY O & M COSTS		
Dungeness & Tanner Crab (in the contiguous states)	(Processing Rate)		(15tpd)	(6tpd)	(2tpd)	(15tpd)	(6tpd)	(2tpd)
	Present	13	0	0	0	0	0	0
	S, GT	8.1	26,000	15,000	8,000	6	4	2
	S, GT, IP,	6.9	68,000	39,000	20,000	6	4	2
	S, GT, IP, DAF	1.7	153,000	88,000	45,000	35	20	11
	S, GT, IP, DAF, AL	0.9	210,000	121,000	63,000	45	26	13
Alaskan Shrimp	(Processing Rate)		(44tpd)	(20tpd)	(10tpd)	(44tpd)	(20tpd)	(10tpd)
	Present	212	0	0	0	0	0	0
	S	130	297,000	185,000	122,000	298	186	123
	S, barge solids	130	652,000	406,000	268,000	502	313	207
	S, reduce solids	130	1,238,000	771,000	509,000	995	620	408
	S, IP	113	343,000	214,000	141,000	298	186	123
	S, IP, DAF, barge	28	2,182,000	1,360,000	897,000	8	542	357
	S, IP, DAF, AL, barge	3.5	3,307,000	2,061,000	1,360,000	870	542	357
	Grind and deep outfall (1500 ft. of pipe)	-	220,000	137,000	90,000	94	57	39

TABLE 113 (cont.) TREATMENT EFFICIENCIES AND COSTS

	TREATMENT ALTERNATIVES	EFFLUENT BOD KG/KKG	COSTS 1971 $ CAPITAL COSTS			DAILY O & M COSTS		
Northern Shrimp	(Processing Rate)		(70tpd)	(35tpd)	(20tpd)	(70tpd)	(35tpd)	(20tpd)
(in the contigu-	Present	145	0	0	0	0	0	0
ous states)	S	120	93,000	62,000	44,000	11	7	5
	S, IP	108	114,000	76,000	54,000	11	7	5
	S, IP, DAF	27	311,000	206,000	147,000	40	27	19
	S, IP, DAF, AL	3.8	382,000	252,000	180,000	61	41	29
	S, IP, DAF, EA	2.9	969,000	639,000	457,000	76	50	36
Southern Non-	(Processing Rate)		(100tpd)	(50tpd)	(25tpd)	(100tpd)	(50tpd)	(25tpd)
Breaded Shrimp	Present	58	0	0	0	0	0	0
(in the contigu-	S	46	107,000	71,000	47,000	12	8	5
ous states)	S, IP	41	124,000	82,000	55,000	12	8	5
	S, IP, DAF	10	351,000	232,000	154,000	46	31	20
	S, IP, DAF, AL	3.0	433,000	286,000	186,000	71	47	31
	S, IP, DAF, EA	2.3	1,109,000	591,000	422,000	88	50	34

TABLE 113 (cont.) TREATMENT EFFICIENCIES AND COSTS

	TREATMENT ALTERNATIVES	EFFLUENT BOD KG/KKG	COSTS 1971 $ CAPITAL COSTS			DAILY O & M COSTS		
Breaded Shrimp	(Processing Rate)		(22tpd)	(8tpd)	(2tpd)	(22tpd)	(8tpd)	(2tpd)
	Present	105	0	0	0	0	0	0
	S	84	104,000	56,000	25,000	26	14	6
	S, IP	67	183,000	99,000	44,000	26	14	6
	S, IP, DAF	17	407,000	222,000	97,000	104	56	25
	S, IP, DAF, AL	4.6	476,000	259,000	113,000	127	69	30
	S, IP, DAF, EA	3.5	599,000	326,000	142,000	153	84	36
Tuna	(Processing Rate)		(450tpd)	(150tpd)	(40tpd)	(450tpd)	(150tpd)	(40tpd)
	Present	15	0	0	0	0	0	0
	S, DAF	2.25	471,000	244,000	110,000	178	92	42
	S, DAF, IP	2.0	537,000	279,000	126,000	178	92	42
	S, DAF, IP, HRTF, AS	0.52	1,653,000	855,000	387,000	547	283	128

S = screen; GT = grease trap; AL = aerated lagoon; IP = in-plant changes; LI = land irrigation;
EA = Extended aeration; DAF = dissolved air flotation; HRTF = high rate trickling filter;
AS = activated sludge

Since solids disposal can be a significant problem in some areas, several of the treatment levels have different solids disposal alternatives. The costs of each of these is shown in Table 113. The use of biological treatment systems, such as aerated lagoons and oxidation ponds can cause problems, if not operated properly. It is important that trained personnel be associated with these installations.

Typical Plant

Hypothetical system engineering designs were developed for each alternative of each treatment level for each seafood processing subcategory. Each design was based on a two shift production rate using waste parameters determined from the monitoring program. The waste water characteristics of each industry subcategory were reviewed in order to estimate the treatment efficiency of various technological systems, at each level of application. Where operating data or published results from other seafood waste facilities were absent, the probable effluent reductions were estimated. The assumptions were based on engineering experience with industrial waste treatment, practical familiarity with alternative treatment operations and the variables which affect their performance, and extensive working knowledge of seafood processing methods and systems. Schematic drawings of each treatment design are presented and discussed in Section VII.

The capital costs of each of these designs were then computed based on 1971 Seattle construction costs as shown in Table 114. The costs were then scaled for different geographical areas, such as Alaska, using the U. S. Army Corps of Engineers Geographical Index (Table 115). Operation and maintenance costs given for each design include labor, power, chemical, and fuel prices and are based on the costs shown in Table 116. Costs for other size facilities were computed using an exponential scale factor of 0.6 and listed in Table 113.

For reference, the raw material processing rates in tons per day are listed for each subcategory. These rates are an index of the scale of production assumed for design and cost estimation purposes. The costs, however, are suitable chiefly for comparing the cost-efficiencies of alternatives. Their use for estimating construction costs of a proposed treatment facility, referenced to a known raw production scale, is not recommended. The actual costs of construction are intimately tied to terrain, climate, transport, labor, land availability, and other site constraints, which are best evaluated on an individual basis by experienced professionals in the field. Every precaution has been taken to gear the design costs to representative conditions within each subcategory, yet each plant has unique constraints which distinguish it from the hypothetical, average plant.

To aid in visualizing the relative cost-effectiveness of alternatives, the tabulations of Table 113 are shown in graphical

Table 114 1971 Seattle construction costs.

Item	1971 Seattle Cost
Earthwork	$ 1.75/cu yd
Piers	
300 PSF Loading	20.00/sq yd
1000 PSF Loading	32.00/sq yd
Concrete (linear sliding scale)	
Less than 1 cu yd	500.00/cu yd
Over 50 cu yd	200.00/cu yd
Buildings	9.00/sq ft
Process piping	18.00/sq ft
Metal work and equipment	
1. steel tanks	0.25/gal
2. hoppers and package units motors, pumps, mechanisms	from manufacturers
Outfall lines	20.00/ft
Electrical	8% of concrete buildings, process piping, metal work, and equipment
Land	Not included in the estimate

Table 115 U. S. Army Geographical Index*

Area	Index
Washington, D. C.	1.0
Seattle, Washington	1.15
Kodiak, Alaska	2.5
Remote Alaska	2.6
Texas	0.96
Louisiana	0.96
Los Angeles, California	1.7
San Francisco, California	1.2
Delaware and Maryland	1.06
Maine	0.95

*Relative Prices Around The World. Civil Engineering, October, 1971, pp. 91, 92.

Table 116 Operation and maintenance costs.

Item	Cost	Location
Power	$0.01/kwh	48 states
	0.10/kwh	Kodiak, Alaska; Hawaii; Samoa
	0.20/kwh	Outside Kodiak
Labor	7.00/hr	Alaska
	5.00/hr	48 states
Treatment chemicals	0.10/1000 gal	48 states
	0.20/1000 gal	Alaska
Equipment maintenance	5% of equipment capital cost/year	

form in Figures 55 through 65. The marginal cost is indicated by the slope of the curve. An attempt has been made to illustrate the point that improved effluent quality is achieved in discrete steps as opposed to a smoothly increasing cost as a function of treatment level desired. The convex line attempts to indicate that a large incremental investment is usually required in order to move to the next "quantum" level of performance. The treatment system, when operating properly, should achieve the removal rates indicated at the point where the next level starts. However, it is possible, when the system is not operated or maintained correctly, that it will operate off the curve to the left.

BOD_5 was selected as the parameter of greatest environmental significance for most wastes and receiving waters. The percentage removal of solids and grease in most technologies listed is roughly (but not consistently) parallel to that of BOD_5. Other common contaminants such as phosphate, pathogens, total dissolved solids, and toxins are not present in sufficient concentrations to be of concern in the seafood industry.

Such parameters may require attention where water recycling within a processing plant is contemplated. Processors have not yet found such recycling to be cost-effective for most operations. Furthermore, federal regulations (FDA) restrict movement in this direction.

In general, the total cost curves show that the marginal cost curves resemble a series of peaks with the height of the peak generally increasing as the level of treatment increases. This is in agreement with published data (e. g. Metcalf and Eddy, 1972). The highest levels of treatment have the highest marginal costs requiring that a higher value be put on the benefit of improved water quality in order to have a cost-effective system.

Solids

The costs of solids disposal are frequently regarded as supplemental costs and estimated separately. In the estimates given in Tables 112 and 113, however, solids volumes were calculated and their handling costs are included. The reason for this is that the solids handling costs can be extremely variable. For example, the costs of barging solids to a reduction plant from a remote point in Alaska would be much higher than the typical costs. In some cases the location of a solids reduction process near the food processing plant can be an alternative for solids disposal.

The nutritive value of seafood solids, and their importance in the world food balance, have been discussed in Section VII. It is estimated that solids disposal at Koiak, Alaska can be accomplished at a profit of $ .70 per kkg ($ .75 per ton).

Air Quality

The maintenance of air quality, in terms of particulates, is unaffected by waste water treatment facilities except when incineration is practiced. To reduce solids the alternative for solids disposal is not consistent with the conservation of valuable nutrients and is also not cost-effective on a small scale with suitable effluent control.

Odor from landfills, from lagoons, and from oxidation ponds can be a problem when these systems are not operated or maintained properly. Covers or enclosures can be used in some cases to localize a problem installation.

Noise

Principal noise sources at treatment facilities are mechanical aerators, air compressors, and pumps. By running air compressors for the diffused air system in activated sludge treatment below their rated critical speed and by providing inlet and exhaust silencers, noise effects can be combated effectively. In no proposed installation would noise levels exceed the guidelines established in the Occupational Safety and Health Standards of 1972.

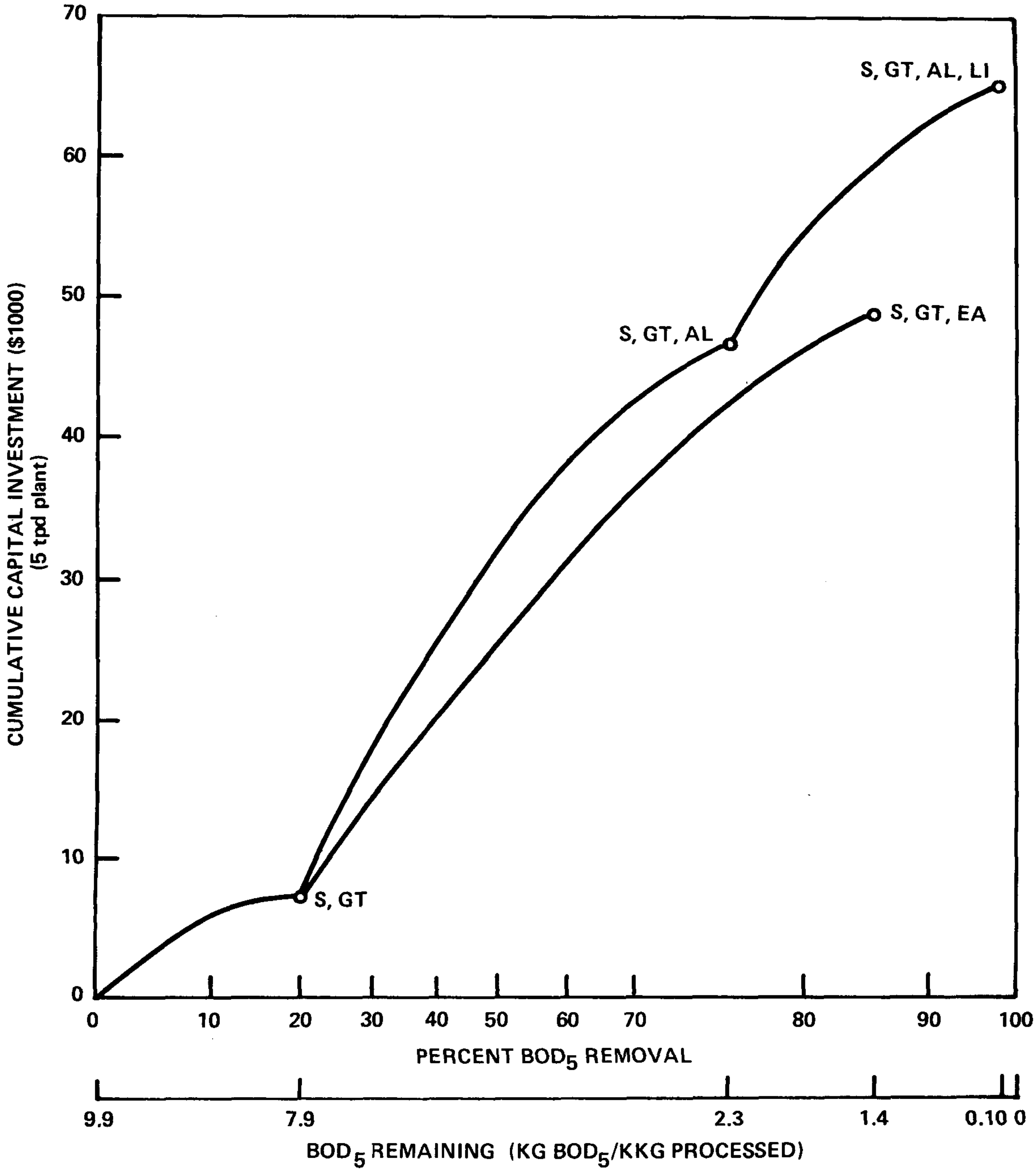


Figure 55

Catfish treatment efficiencies and costs

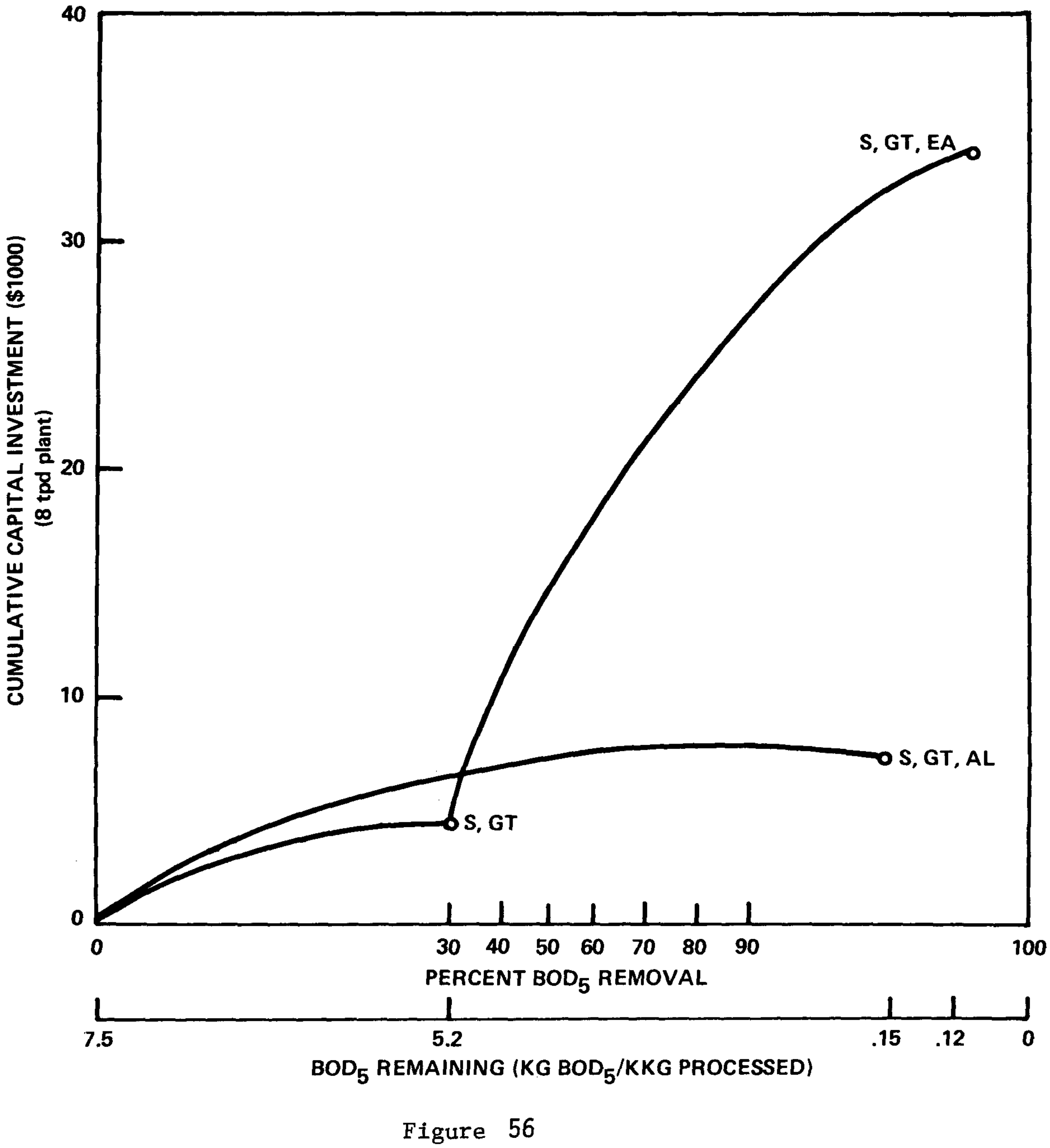


Figure 56

Conventional blue crab treatment efficiencies and costs

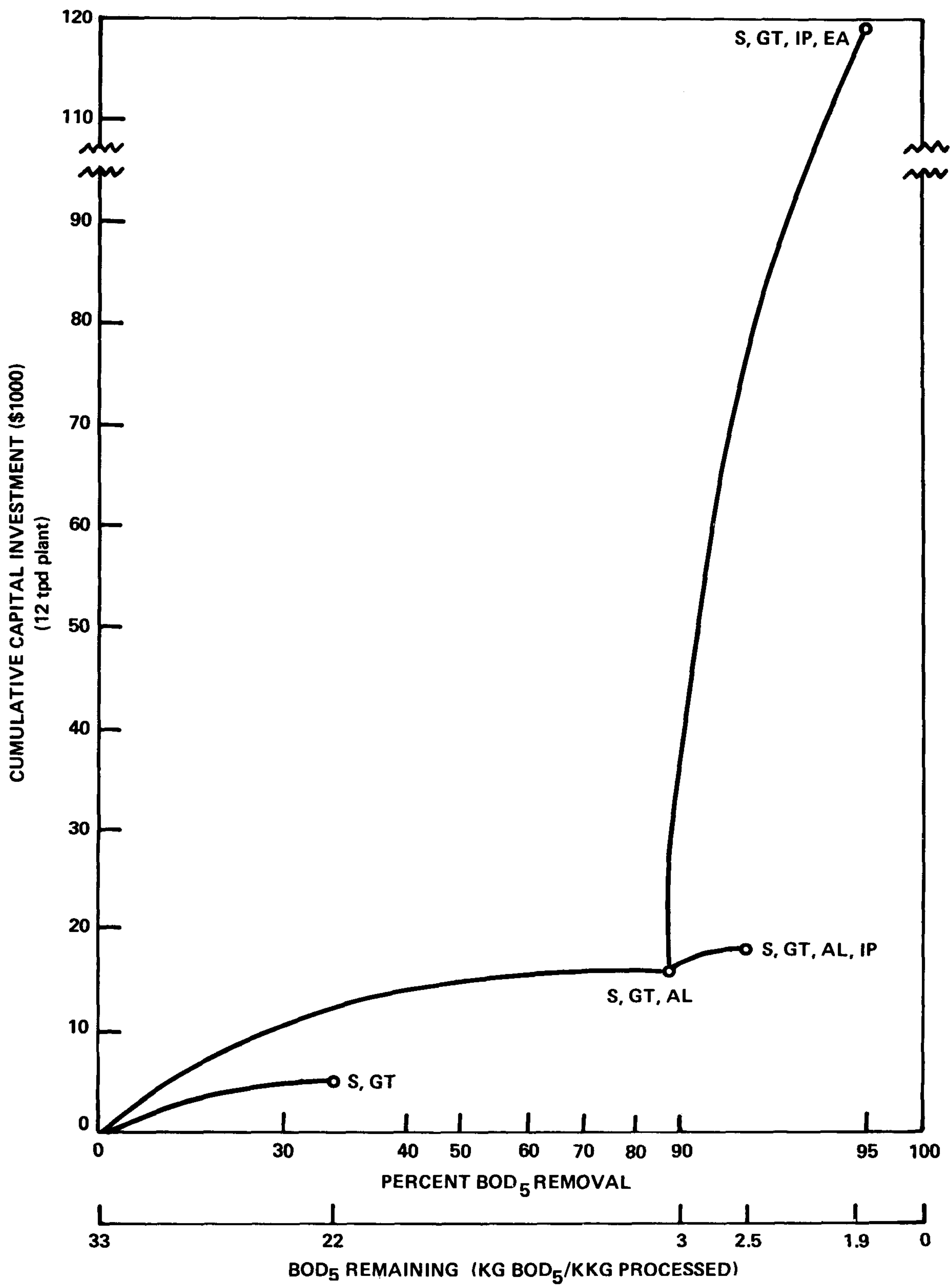


Figure 57

Mechanized blue crab treatment efficiencies and costs

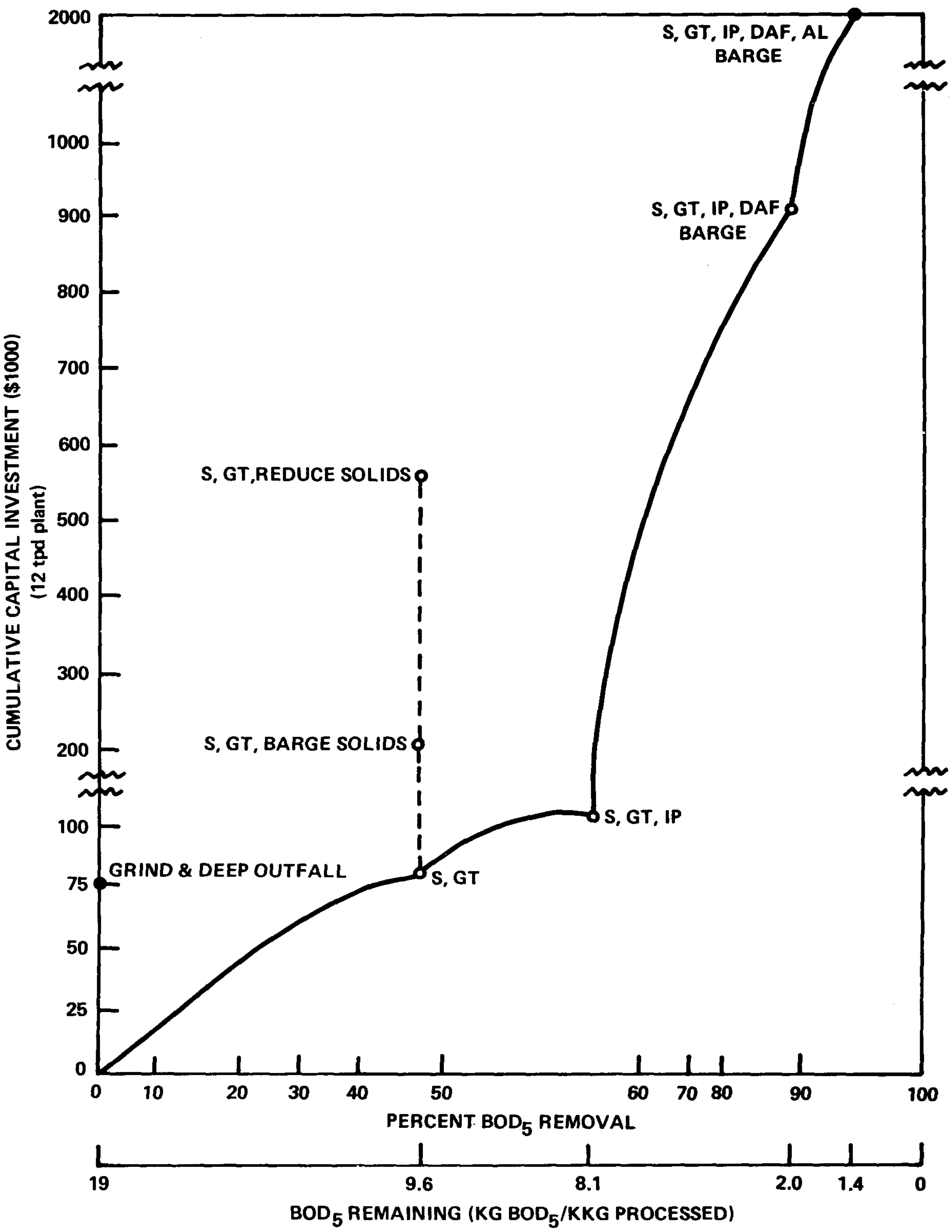


Figure 58

Alaska crab meat treatment efficiencies and costs

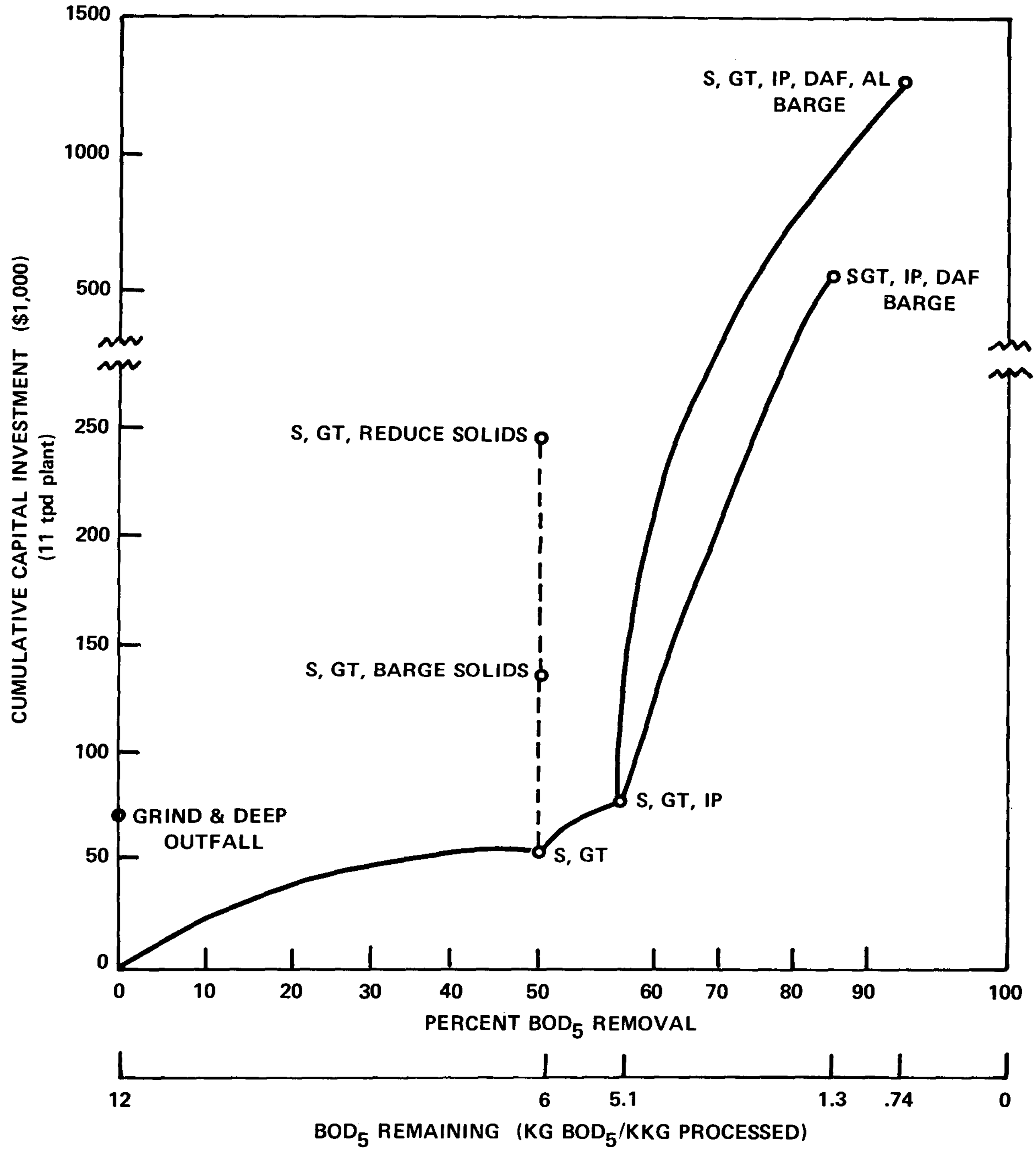


Figure 59

Alaska crab whole and sections treatment efficiencies and costs

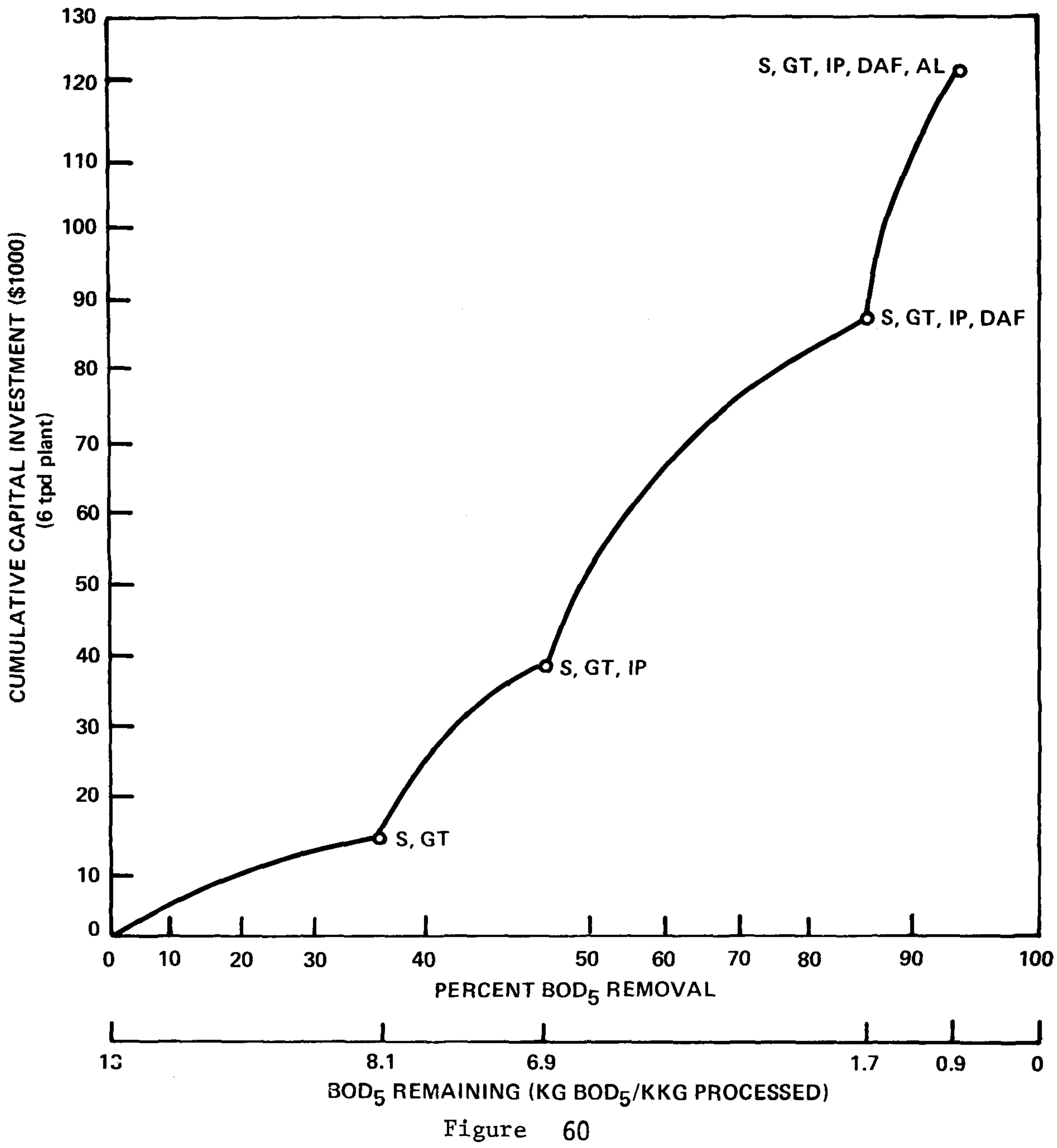


Figure 60

Dungeness and tanner crab other than Alaska treatment efficiencies and costs

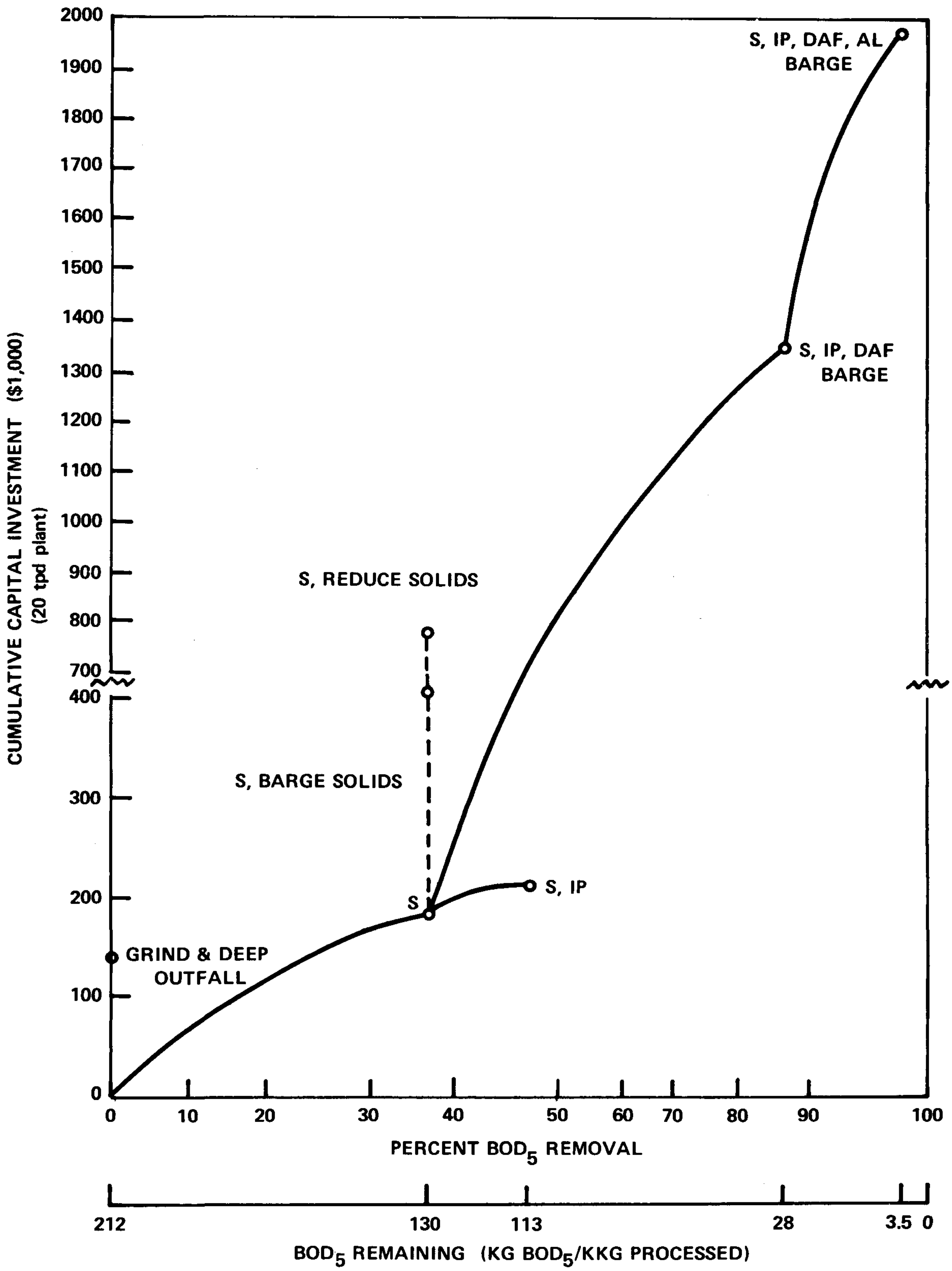


Figure 61

Alaska shrimp treatment efficiencies and costs

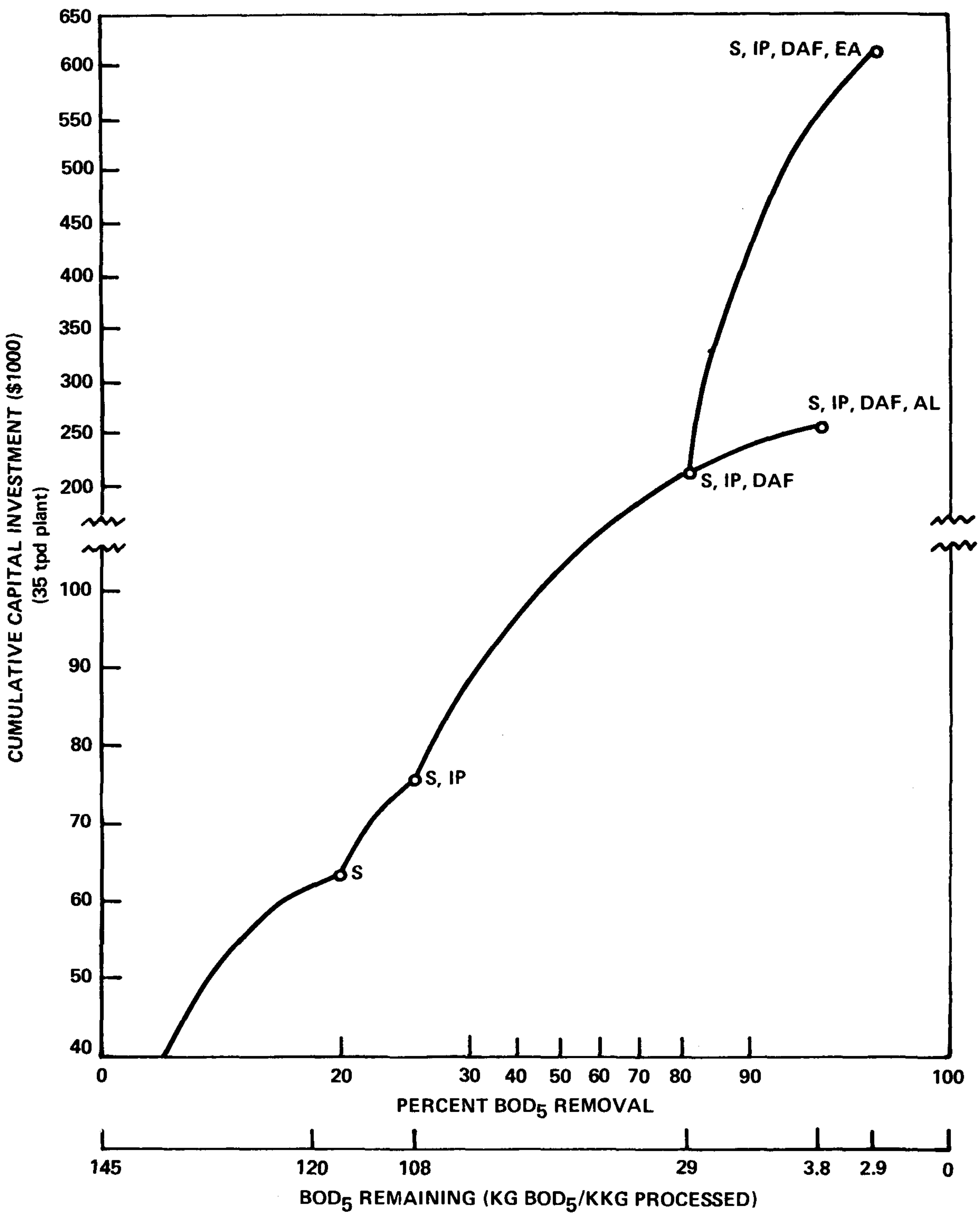


Figure 62

Northern shrimp treatment efficiencies and costs

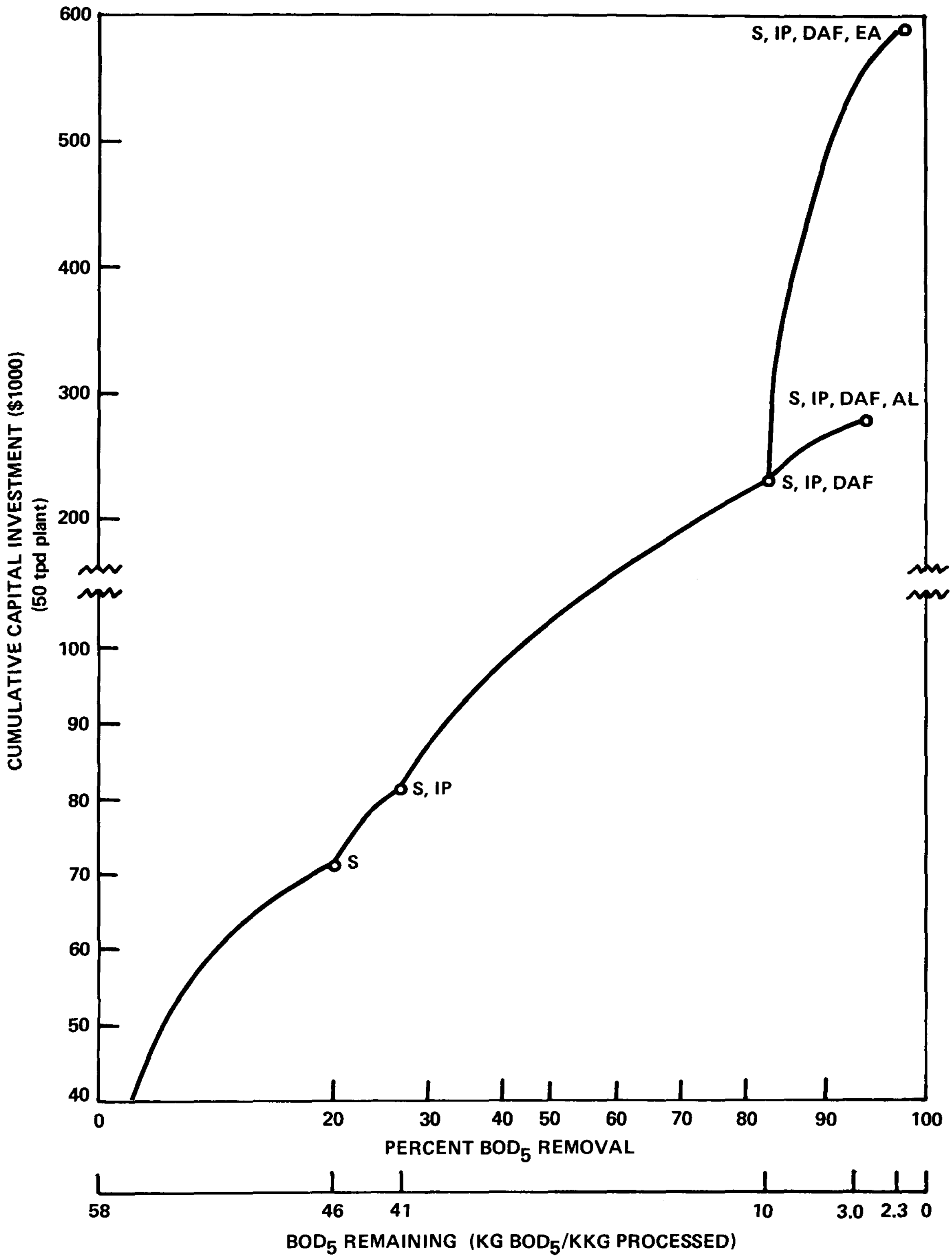


Figure 63

Southern non-breaded shrimp treatment efficiencies and costs

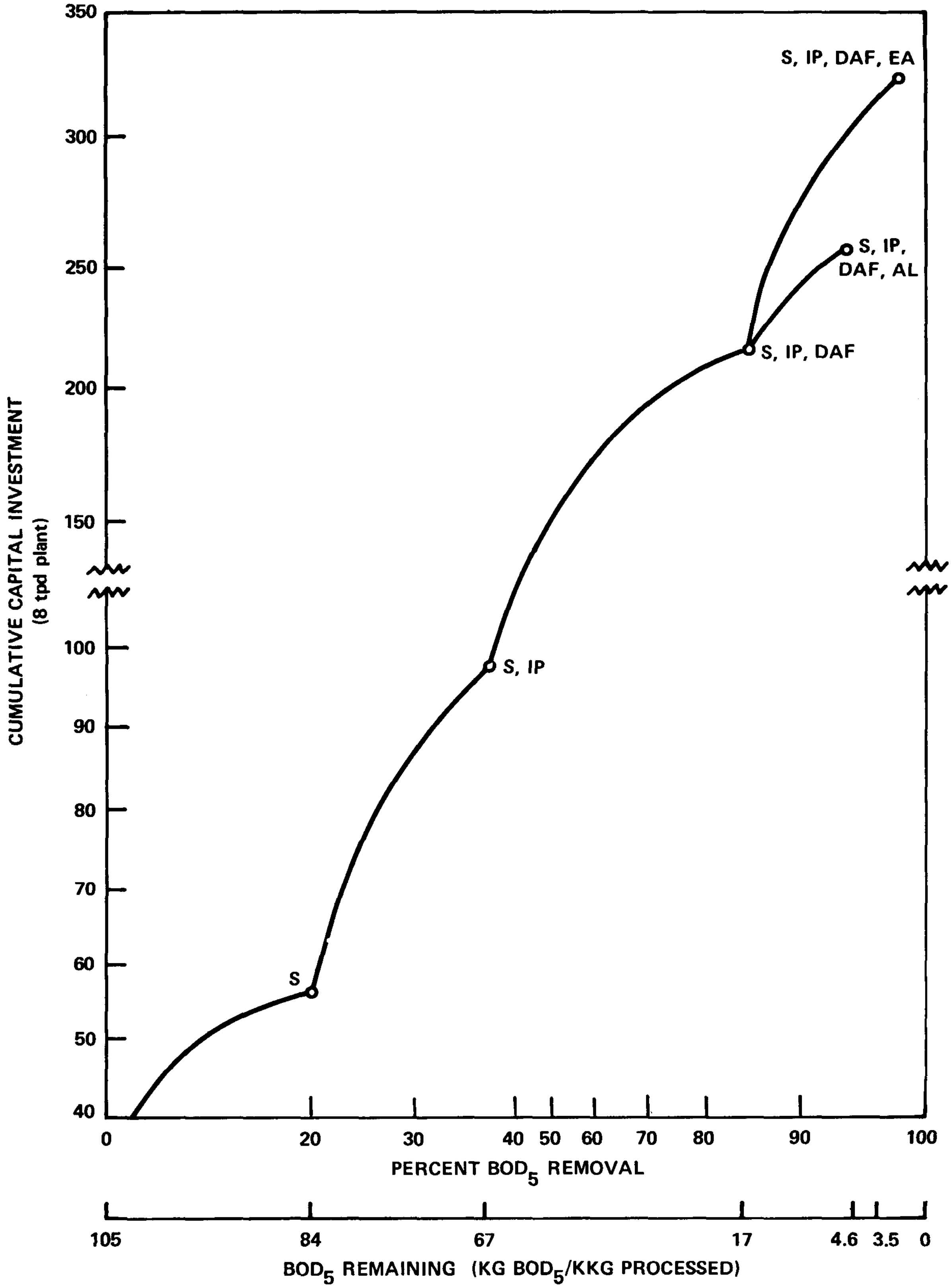


Figure 64

BREADED SHRIMP TREATMENT EFFICIENCIES AND COSTS

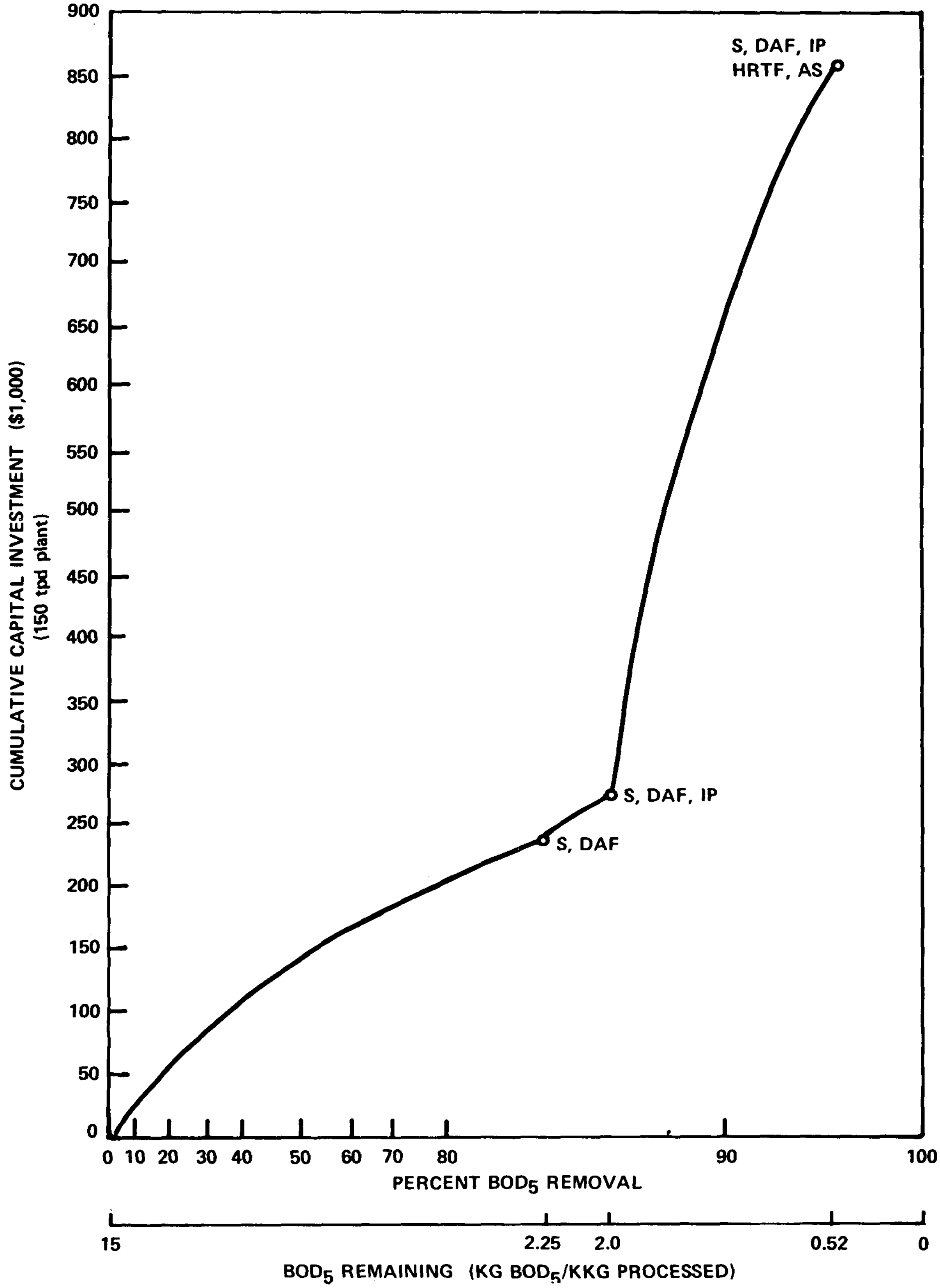


Figure 65

Tuna treatment efficiencies and costs

SECTION IX

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE, GUIDELINES AND LIMITATIONS

For each subcategory within the canned and preserved seafood processing industry, the "best practicable control technology currently available" (BPCTCA) must be achieved by all plants not later than July 1, 1977. The 1977 technology is not based on "the average of the best existing performance by plants of various sizes, ages and unit processes within each... subcategory," but, rather, represents the highest level of control that can be practicably applied by July 1, 1977 because present control and treatment practices are generally inadequate within the farm-raised catfish, crab, shrimp, and tuna segments of the canned and preserved fish and seafood processing industry.

Consideration of the following factors has been included in the establishment of BPCTCA:

1) the total costs of application of technology in relation to the effluent reduction benefits to be achieved from this application,
2) the age of equipment and facilities involved,
3) the processes employed,
4) the engineering aspects of the application of various types of control techniques,
5) process changes, and
6) non-water quality environmental impact.

Furthermore, the designation of BPCTCA emphasized end-of-pipe treatment technology, but included "good housekeeping" practices which are considered normal practice within the seafood processing industry, such as turning off faucets and hoses when not in use or using spring-loaded hose nozzles, and do not assume significant equipment changes. The large variation in water usage for the same process configuration among different plants indicated that there was ample opportunity for the reduction of water usage without adversely affecting the quality of the product.

An important consideration in the designated process was the degree of economic and engineering reliability required to determine the technology to be "currently available." In this industry, the reliability of the recommended technologies was established based on pilot plants, demonstration projects, and technology transfer, the latter mainly from the meat packing industry, municipal waste treatment systems and other segments of the seafood as well as the food processing industries.

Because there are little or no existing waste water treatment facilities at the plant level, the 30-day and the daily maximum limitations are based on engineering judgment and the consideration of the operating characteristics of similar treatment systems as mentioned in the previous paragraph. The daily maximum limitation for the screening systems is three times the thirty day limitation; for air flotation systems, 2.5 times the thirty day limitation; for aerated lagoon systems, two times the thirty day limitation; for extended aeration system; three times the thirty day limitation; and for activated sludge systems, 3.5 times the thirty day limitation. An exception for the total suspended solids for screening in the Alaskan shrimp processing subcategory was made due to the high initial level of the parameter. The daily maximum limitation of total suspended solids for the Alaskan shrimp processing subcategory is 1.5 times the thirty day limitation.

Application of the effluent limitations to the single product and the multiproduct processing plant: A primary reason for establishing effluent limitations guidelines on the basis of production of raw material, is to provide the means to consider the single product as well as the multiproduct seafood processor without setting separate guideline numbers for every possible combination of species and processing rates.

When a plant is subject to effluent limitations covering more than one subcategory, the plant's effluent limitation shall be the aggregate of the limitations applicable to the total production covered by each subcategory. For example, if a plant processes several species concurrently, then the plant's effluent limitation may be the sum of the products of the volume of each species processed and the respective effluent limitation. If a plant processes several species in series, then the effluent limitation may be based on the subcategory classification of the individual species while it is beging processed. In other words, the aggregate effluent limitation guideline number may vary as a function of the product mix at any particular point in time.

Since publication of the proposed effluent limitations in the Februay 6, 1974 Federal Register (39 F.R. 4708), the Agency has received substantial economic and financial data. A reevaluation of the economic impact of the proposed regulations produced changes in the final effluent limitations which are based on economic consideration discussed in detail in the "Economic Analysis of Effluent Limitations Guidelines For Selected Segments of the Seafood Processing Industry - Catfish, Crab, Shrimp and Tuna," June, 1974.

The proposed 1977 regulations for large shrimp processors in the contiguous states were based on dissolved air flotation as the best practicable control technology currently available.

After careful reevaluation of available data and consultation with recognized seafood waste water treatment experts, the Agency believes that dissolved air flotation can be regarded as best practicable control technology currently available for shrimp processing facilities in the contiguous States. The technology is "available" and "transferrable" as evidenced by pilot plant work discussed in Section VII. However, several organizations question whether the total number of shrimp processing plants affected can design, secure, construct, and line-out this particular equipment alternative by July 1, 1977. For this reason, the Agency has combined the respective, proposed subcategories for the large and small shrimp processors in the contiguous States and based the final July 1, 1977 effluent limitations guidelines on screening systems instead of dissolved air flotation systems.

Farm-Raised Catfish Processing (Subcategory A)

The effluent limitations for farm-raised catfish processing facilities are presented in Table 117. The best practicable control technology currently available includes efficient in-plant water and waste water management, partial recycle of live fish holding tank water, solids or by-product recovery, screening of the waste water effluent, and simple grease traps as discussed in Section VII and illustrated in Figure 49.

CONVENTIONAL BLUE CRAB PROCESSING (Subcategory B)

The effluent limitations for conventional blue crab processing are presented in Table 117. The best practicable control technology currently available includes efficient in-plant water and waste water management, simple grease traps, screening of the waste water effluent, and solids or by-product recovery as discussed in Section VII and illustrated in Figure 40.

MECHANIZED BLUE CRAB PROCESSING (Subcategory C)

The effluent limitations for mechanized blue crab processing are presented in Table 117. The best practicable control technology currently available includes efficient in-plant water and waste water management simple grease traps, screening of the waste water effluent, and solids or by-product recovery as discussed in Section VII and illustrated in Figure 40.

NON-REMOTE ALASKA CRAB MEAT PROCESSING (Subcategory D)

The effluent limitations for non-remote Alaskan crab meat processing are presented in Table 117. The best practicable control technology currently available consists of efficient in-plant water and waste water management, by-product recovery or ultimate disposal of solids, simple grease traps, and screening of the waste water effluent as illustrated in Figure 40. It is important, in considering "best practicable" treatment schemes,

Table 117 July 1, 1977 Guidelines

	Subcategory	Technology Basis	BOD Max 30-day Average	BOD Daily Max	TSS Max 30-day Average	TSS Daily Max	O+G Max 30-day Average	O+G Daily Max
			Parameter (kg/kkg or lbs/1000 lbs liveweight processed)					
A	Farm-Raised Catfish	S, GT	-	-	9.2	28	3.4	10
B	Conventional Blue Crab	S, GT	-	-	0.74	2.2	0.20	0.60
C	Mechanized Blue Crab	S, GT	-	-	12	36	4.2	13
D	Non-Remote Alaskan Crab Meat	S, GT	-	-	6.2	19	0.61	1.8
E	Remote Alaskan Crab Meat	Comminutors	*	*	*	*	*	*
F	Non-Remote Alaskan Whole Crab and Crab Sections	S, GT	-	-	3.9	12	0.42	1.3
G	Remote Alaskan Whole Crab and Crab Sections	Comminutors	*	*	*	*	*	*
H	Dungeness + Tanner Crab in the Contiguous States	S, GT	-	-	2.7	8.1	0.61	1.8
I	Non-Remote Alaskan Shrimp	S	-	-	210	320	17	51
J	Remote Alaskan Shrimp	Comminutors	*	*	*	*	*	*
K	Northern Shrimp	S	-	-	54	160	42	126
L	Southern Non-Breaded	S	-	-	38	114	12	36
M	Breaded Shrimp	S	-	-	93	280	12	36
N	Tuna	S, DAF	9.0	23	3.3	8.3	0.84	2.1

* No pollutants may be discharged which exceed 1.27 cm (0.5 inch) in any dimension

S = screen; GT = simple grease traps; DAF = dissolved air flotation;

to strongly emphasize the unique physical situation of the Alaskan processor when recommending effluent levels.

Alaskan crab processing plants are larger-scale operations than those in the "lower 48" states, but the waste waters are still intermittent, seasonal, and of relatively high strength. Many processing plants are located along very rugged, mountainous coasts, frequently with no level land available. Thus, treatment facilities would have to be located on dock area constructed on piling over water.

Foundation conditions often involve solid rock--adding to the expense of dock facilities or excavation for basins or lagoons. Shipping costs for construction materials, chemicals and fuel are high. The rigorous climate, particularly the low temperatures (including the waste water temperatures) inhibits the applicability of biological treatment, especially when compounded with the intermittent and highly seasonal flows. High winds and large tidal fluctuations contribute to the difficulties of constructing and operating treatment facilities.

Neither solids reduction plants nor suitable sites for landfills or lagoons are generally available for solids disposal; and the number of technically qualified personnel is severely limited.

<u>REMOTE ALASKAN CRAB MEAT PROCESSING</u> (Subcategory E)

The effluent limitations for remote Alaskan crab meat processing are presented in Table 117. The best practicable control technology currently available consists of physical treatment of the pollutants to reduce particle sizes through the use of comminutors or grinders as discussed in Section VII and illustrated in Figure 53.

<u>NON-REMOTE ALASKAN WHOLE CRAB AND CRAB SECTION PROCESSING</u> (Subcategory F)

The effluent limitations for non-remote Alaskan whole crab and crab section processing are presented in Table 117. The best practicable control technology currently available consists of efficient in-plant water and waste water management, by-product recovery or ultimate disposal of solids, simple grease traps, and screening of the waste water effluent as illustrated in Figure 40.

As discussed in previous sections, it is important, in considering "best practicable" treatment schemes, to strongly emphasize the unique physical situation of the Alaskan processor when recommending effluent levels.

<u>REMOTE ALASKAN WHOLE CRAB AND CRAB SECTION PROCESSING</u> (Subcategory G)

The recommended effluent limitations for remote Alaskan whole crab and crab section processing are presented in Table 117. The best practicable control technology currently available consists of physical treatment of the pollutants to reduce particle sizes through the use of comminutors or grinders as illustrated in Figure 53.

DUNGENESS AND TANNER CRAB PROCESS IN THE CONTIGUOUS STATES (Subcategory H)

The effluent limitations for Dungeness and tanner crab processing in the contiguous states are presented in Table 117. The best practicable control technology currently available consists of efficient in-plant water and waste water management, simple grease traps, solids or by-product recovery techniques, and screening of the waste water effluent as discussed in Section VII and illustrated in Figure 40.

NON-REMOTE ALASKA SHRIMP PROCESSING (Subcategory H)

The effluent limitations for non-remote Alaskan shrimp processing are presented in Table 117. The best practicable control technology currently available consists of efficient in-plant water and waste water management, by-product recovery or ultimate disposal of solids, and screening of the waste water effluent as illustrated in Figure 40 and discussed in Section VII.

As discussed in the previous sections on Alaskan crab processing, it is important, in considering "best practicable" treatment schemes, to strongly emphasize the unique physical situation of the Alaskan processor when recommending effluent levels.

REMOTE ALASKAN SHRIMP PROCESSING (Subcategory J)

The effluent limitation for remote Alaskan shrimp processing are presented in Table 117. The best practicable control technology currently available consist of physical treatment of the pollutants to reduce particle sizes through the use of comminutors or grinders as shown in Figure 53.

NORTHERN SHRIMP PROCESSING IN THE CONTIGUOUS STATES (Subcategory K)

The effluent limitations for northern shrimp processing facilities in the contiguous states are presented in Table 117. The best practicable control technology currently available for this subcategory consists of efficient in-plant water and waste water management, and screening systems for removal of solids from the effluent stream as illustrated in Figure 40.

SOUTHERN NON-BREADED SHRIMP PROCESSING IN THE CONTIGUOUS STATES (Subcategory L)

The effluent limitations for southern non-breaded processing facilities in the contiguous states are presented in Table 117. The best practicable control technology currently available for this subcategory consists of efficient in-plant water and waste water management and screening systems for removal of solids from the effluent stream as shown in Figure 40.

BREADED SHRIMP PROCESSING IN THE CONTIGUOUS STATES (Subcategory M)

The effluent limitations for breaded shrimp processing facilities in the contiguous states are presented in Table 117. The best practicable control technology currently available for this subcategory consists of efficient in-plant water and waste water management, and screening systems for removal of solids from the effluent stream as shown in Figure 40 and discussed in Section VII.

The effluent limitations for tuna processing are presented in Table 117. The best practicable control technology currently available consists of efficient in-plant water and waste water management, solids and by-product recovery techniques screening of the waste water effluent and dissolved air flotation systems as shown in Figure 54.

Tuna processing is a very large scale operation compared to the other seafood processes studied. Generally, tuna plants incorporate a high degree of in-plant by-product processing whereby much of the otherwise undesirable meat, other solids and oils are recovered. As a result these waste waters tend to be of medium strength though large in volume.

SECTION X

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE, GUIDELINES AND LIMITATIONS

For each subcategory within the canned and preserved seafood processing industry, the "best available technology economically achievable" (BATEA) must be realized by all plants not later than 1 July 1983. The 1983 technology is, for this industry, not ". . . the very best control and treatment technology employed by a specific point source within the industrial category or subcategory . . .," but represents technology based on pilot plants, demonstration projects, technology transfer, the latter mainly from the meat packing industry, municipal waste treatment systems, and other segments of the seafood as well as the food industry. This was necessary because present waste water control and treatment practices are generally inadequate within the farm-raised catfish, crab, shrimp, and tuna segments of the canned and preserved seafood processing industry.

Consideration of the following factors has been included in the establishment of BATEA:

1) equipment and facilities age,
2) processes employed,
3) engineering aspects of various control technique applications,
4) process changes,
5) costs of achieving the effluent reduction resulting from the application of BATEA, and
6) non-water quality environmental impact.

Furthermore, much greater emphasis in the designation of 1983 technology was given to in-plant controls, than has been considered as BPCTCA. Those in-process and end-of-pipe controls recommended for 1983 were subjected to the criterion that they be demonstrated at the pilot plant, semi-works, or other level to be technologically and economically justifiable. This is not to say that a complete economic analysis of each proposed system and its relationship to one or more subcategories has been undertaken. Rather, sound engineering judgment has been applied in the consideration of all alternatives and those with a reasonable chance of "viability" in application to a significant number of actual processing plants within a subcategory have been considered in detail.

The waste water treatment technology and in-process changes which serve as the basis for the effluent limitations represents only one of many treatment alternatives open to the processor. Innovations in by-product recovery, water and waste water management, and treatment technology during the interim before July 1, 1983 may eliminate the necessity of employing biological treatment in order to comply with the 1983 effluent limitations.

Table 118 July 1, 1983 Guidelines

	Subcategory	Technology Basis	Parameter (kg/kkg or lbs/1000 lbs liveweight processed)					
			BOD		TSS		O+G	
			Max 30-day Average	Daily Max	Max 30-day Average	Daily Max	Max 30-day Average	Daily Max
A	Farm-Raised Catfish	S, GT, AL	2.3	4.6	5.7	11	0.45	0.90
B	Conventional Blue Crab	S, GT, AL	0.15	0.30	0.45	0.90	0.065	0.13
C	Mechanized Blue Crab	S, GT, AL, IP	2.5	5.0	6.3	13	1.3	2.6
D	Non-Remote Alaskan Crab Meat	S, DAF, IP	2.0	5.0	0.53	1.3	0.82	0.21
E	Remote Alaskan Crab Meat	S, GT, IP	-	-	5.3	16	0.52	1.6
F	Non-Remote Alaskan Whole Crab and Crab Sections	S, DAF, IP	1.3	3.3	0.33	0.83	0.048	0.12
G	Remote Alaskan Whole Crab and Crab Sections	S, GT, IP	-	-	3.3	9.9	0.36	1.1
H	Dungeness + Tanner Crab in the Contiguous States	S, DAF, IP	1.7	4.3	0.23	0.58	0.07	0.18
I	Non-Remote Alaskan Shrimp	S, DAF, IP	28	71	18	46	1.5	3.8
J	Remote Alaskan Shrimp	S, IP	-	-	180	270	15	45
K	Northern Shrimp	S, DAF, IP	27	68	4.9	12	3.8	9.5
L	Southern Non-Breaded Shrimp	S, DAF, IP	10	25	3.4	8.5	1.1	2.8
M	Breaded Shrimp	S, DAF, IP	17	43	7.4	19	1.0	2.5
N	Tuna	S, DAF, AS, IP	0.62	2.2	0.62	2.2	0.077	0.27

S = screen; GT = simple grease trap; Al = aerated lagoon; IP = in-plant change;
DAF = dissolved air flotation; AS = activated sludge system

This section of the report sets forth the 1983 guidelines and limitations as developed from studies and consultations conducted, data developed and literature available. The material is presented below by subcategory, as was done in Section IX.

The operating characteristics of the specific treatment system which provided the basis for the effluent limitations were considered in establishing the daily maximum limitations. The factors are the same as in the previous chapter.

<u>FARM-RAISED CATFISH PROCESSING</u> (Subcategory A)

The effluent limitations for farm-raised catfish processing are presented in Table 118. The best available technology economically achievable includes efficient in-plant water and waste water management, partial recycle of live fish holding tank water, solids or by-product recovery as illustrated in Figure 49, and aerated lagoon systems as illustrated in Figure 50.

Those catfish processors employing live hauling and holding tanks should consider the use of iced delivery and storage. A recent study, soon to be published by Boggess, et al. (1973), indicates that iced storage causes skinning problems not encounterd with live-tank stored fish; however, the water consumption decrease realized (40 to 50 percent) may justify the action. It must be noted that little, if any, BOD_5 reduction would accrue from this change, since the BOD_5 contribution of the holding tanks to the total plant effluent is only about 5 percent. It should further be mentioned that a large number of processors now employ iced storage, so this recommendation will not have a profound effect on the industry.

Few specific further in-plant water reduction techniques can reasonably be expected of the catfish industry, because the average plant processing and clean up water consumption is already extremely low. Installing squeeze-nozzles and turning off water flows during work breaks should reduce waste water flows by at least 1900 l (500 gal) per shift.

<u>CONVENTIONAL BLUE CRAB PROCESSING</u> (Subcategory B)

The effluent limitations for conventional blue crab processing are presented in Table 118. The best available technology economically achievable is based on solids or by-product recovery and on aerated lagoon systems as illustrated in Figures 40 and 48 and discussed in Section VII.

The conventional blue crab process uses less water than any other industry subcategory reviewed in this study. Average plant flows are well under 3.8 cu m (1000 gal) per shift. Although inadvertently, the industry is a model of water conservation.

MECHANIZED BLUE CRAB PROCESSING (Subcategory C)

The effluent limitations for mechanized blue crab processing are presented in Table 118. The best available technology economically achievable is based on solids or by-product recovery, in-process modifications which promote efficient water and waste water management, and an aerated lagoon system as illustrated in Figures 40 and 48 and discussed in Section VII.

The mechanized blue crab process uses water freely--in product fluming, in shell separation, and in spray-washing of brine from the meat. Redesign of the meat-shell separation system and subsequent spray washing network, plus elimination of the few flumes existant in the industry should effect the 15 percent water use reduction (with concomitant 5 percent BOD_5 reduction) reflected in the 1983 effluent limitations guidelines listed in Table 118. An ultimate goal should be the elimination of the brine flotation system entirely; perhaps through replacement by a pneumatic system such as is used as a final loose peel remover in some shrimp plants, or another suitable device.

ALASKAN CRAB MEAT PROCESSING

The effluent limitations for non-remote and remote Alaskan crab meat processing, subcategories D and E respectively are presented in Table 118. The best available technology economically achievable is based on by-product recovery or ultimate disposal of solids, in-process modifications which promote efficient water and waste water management, and an air flotation system as illustrated in Figures 40 and 41 and discussed in Section VII. Air flotation offers the possibility of effective treatment while still being able to cope with the problems of intermittent and variable waste water flows and rigorous climatic, geographic and isolation conditions. Secondary treatment processes (Figures 41 and 52) could not be expected to perform adequately under these limitations.

The Alaskan crab meat industry is a large water user, compared to the other industries in this study. Elimination of fluming, additional employment of dry capture techniques, redesign of process flow patterns and general in-plant emphasis on water conservation should effect the 50 percent water use reduction (with resulting 15 percent BOD_5 reduction) reflected in the 1983 effluent limitations guidelines.

ALASKAN WHOLE CRAB AND CRAB SECTION PROCESSING

The effluent limitations for Alaskan whole crab and crab section processing, subcategories F and G respectively, are presented in Table 118. The best available technology economically achievable is based on by-product recovery or ultimate disposal of solids, in-process modifications which promote efficient water and waste water management, and an air flotation system as illustreated in Figures 40 and 41 and discussed in Section VII.

As discussed in the previous section, air flotation offers the possibility of effective treatment while still being able to cope with the problems of intermittent and variable waste water flows and rigorous climate, geographic and isolation conditions. Elimination of fluming, additional employment of dry capture techniques, redesign of process flow patterns and general in-plant emphasis on water conservation should effect the 50 percent water use reduction (with resulting 15 percent BOD5 reduction) reflected in the 1983 effluent limitations guidelines. listed in Table 118.

DUNGENESS AND TANNER CRAB PROCESSING IN THE CONTIGUOUS STATES (Subcategory H)

The Dungeness and tanner crab industry outside of Alaska is somewhat more conservative in water use practices than their northern counterpart. Nonetheless, considerably more attention could be paid to water conservation in the industry, along the same lines as outlined for the Alaskan crab industry in the previous subsections. Employing good water management in-plant, the industry should be capable of effecting a 40 to 50 percent reduction in water consumption, and thereby reduce waste water BOD5 loadings by at least 15 percent. These reductions, together with the expected improved treatment efficiencies due to optimization of dissolved air flotation as a chemical treatment system as discussed in Section VII , were the bases for the development of the 1983 effluent limitations guidelines listed in Table 118.

It should be mentioned that the majority of processors in this subcategory are located in or near population centers of sufficient size to justify construction of municipal treatment facilities. In such cases the processors will likely elect to cooperate with the municipalities in a joint treatment scheme. These industrial wastes are expected to be compatible with domestic biological treatment systems.

ALASKAN SHRIMP PROCESSING

As proposed for Subcategories D, E, F, and G - Alaska crab, above; for non-remote and remote Alaska shrimp, Subcategories I and J respectively, proposes flotation as the process of choice (see Figures 40 and 41). Rationale for this selection parallels that for Alaskan crab meat and whole crab section processing.

The Alaska shrimp industry, like their counterpart crab industry, is a heavy water user. In fact, even a moderately well-controlled shrimp plant in Alaska uses about three times the water per pound of raw material that a crab plant does. This is attributable largely to the fact that the shrimp process is considerably more mechanized, especially in the peeling phase. From 40 to 70 percent of the total plant flow passes over the Model A or PCA peelers.

As a consequence, shrimp plants have not the opportunity to cut water consumption as dramatically and drastically as crab plants. Nevertheless, reduction of water use by 40 percent (and more, in plants which employ considerable fluming) are achievable by 1983. Concomitant BOD_5 reductions of at lease 13 percent can be expected. These values, plus the improvements in flotation systems efficiency mentioned earlier, form the bases for the effluent limitations guidelines outlined in Table 118.

NORTHERN SHRIMP PROCESSING IN THE CONTIGUOUS STATES

The effluent limitations for northern shrimp processing in the contiguous states (Subcategory K) are presented in Table 118. The best available technology economically achievable is based on solids or by-product recovery, in-process modifications which promote efficient water and waste water management, and dissolved air flotation systems as illustrated in Figures 40 and 41 and discussed in Section VII.

Even though the northern shrimp processor uses considerably less water, on the average, than the typical Alaskan processor, water use reductions of 20 percent are achievable by 1983. Concomitant BOD_5 reduction of at least 10 percent can be expected. These reductions, together with the expected improved treatment efficiencies due to optimization of dissolved air flotation as a chemical treatment system, were the bases for the development of the 1983 effluent limitations guidelines.

SOUTHERN NON-BREADED SHRIMP PROCESSING IN THE CONTIGUOUS STATES

The effluent limitations guidelines for southern non-breaded shrimp processing in the contiguous states (Subcategory L), Table 118, are based on the same technology and follow the same rational as presented in the previous section for northern shrimp processing.

BREADED SHRIMP PROCESSING IN THE CONTIGUOUS STATES

The effluent limitations guidelines for breaded shrimp in the contiguous states (Subcategory M), Table 118, are based on the same technology and follow the same rational as presented in the section for northern shrimp processing.

The breaded shrimp industry is a heavy water user, employing twice as much water per pound of raw material as northern and southern non-breaded shrimp processors. A water use reduction of 50 percent (and more, in plants which employ considerable fluming) is achievable by 1983. Concomitant BOD_5 reductions of at least 20 percent can be expected.

TUNA PROCESSING (Subcategory N)

Tuna was the only high seas species covered. The typical processing plant is several orders of magnitude larger than those found in the blue crab or catfish industries. Tuna companies were found to operate more like the large industrial concerns they are, rather than in the provincial manner in which some small processors were managed. Accordingly, their waste streams flowed more continuously, broadening the scope of available treatment alternatives.

BATEA (see Figure 54) for the tuna processing industry proposes roughing trickling filters combined with conventional activated sludge because this combination of biological processes can result in compactness, flexibility, and ability to handle variable loads.

On a relative scale the tuna industry is clean. By-product development in the form of pet food, fish meal, solubles and stick water recovery have been developed to a high degree.

Areas in which improvements could be made (in some plants) include adoption of dry receiving, rather than fluming of the fish from the boat to the plant, installation of bilge water handling systems to prevent the pumping of bilges into the local waters, adoption of air cooling of the tuna following the precook, and development of recirculating (immersion) thaw tank water systems.

Utilization of some or all of these concepts, together with conservation programs, could lead to water consumption savings of 30 percent, with concomitant BOD_5 reductions of 10 percent.

Realization of these goals, together with the progressive improvement of treatment system efficiencies, provides the basis for the effluent levels listed in Table 118 for the tuna industry.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

The effluent limitations that must be achieved by new sources are termed "Performance Standards." The New Source Performance Standards apply to any source for which construction starts after the publication of the proposed regulations for the standards. The standards were determined by adding to the consideration underlying the identification of the "Best Practicable Control Technology Currently Available" a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, New Source Performance Standards are based on an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods, or other alternatives were considered. A further determination made was whether a standard permitting no discharge of pollutants is practicable.

Consideration must also be given to:

1) operating methods;
2) batch as opposed to continuous operations;
3) use of alternative raw materials and mixes of raw materials;
4) use of dry rather than wet processes (including a substitution of recoverable solvents for water); and
5) recovery of pollutants as by-products.

With the exception of the Alaskan crab and shrimp subcategories, the new source performance standards are based on a level of technology above screening. Aerated lagoon systems form the basis of the effluent limitations for the catfish and conventional and mechanized blue crab subcategories. "Non-optimized" dissolved air flotation systems form the basis of the effluent limitations of the Dungeness and tanner crab, northern shrimp, southern non-breaded shrimp, breaded shrimp and tuna subcategories. Optimization of dissolved air flotation performance is not required until 1983 because the technology is relatively new for most of the seafood processing industry and requires careful selection of chemicals and dosages, as well as skilled operation for optimum pollution abatements. These new source performance standards which are based on dissolved air flotation reflect the Agency's best engineering assessment of the effluent reduction attainable by this technology without chemical optimization. Because of the unique physical problems encountered in Alaska, discussed in previous Sections, the new source performance standards are based on screening systems for the remote and non-remote Alaskan crab and shrimp subcategories rather than on a higher level of technology.

Table 119 New Source Performance Standards

	Subcategory	Technology Basis	Parameter (kg/kkg or lbs/1000 lbs liveweight processed) BOD Max 30-day Average	BOD Daily Max	TSS Max 30-day Average	TSS Daily Max	O+G Max 30-day Average	O+G Daily Max
A	Farm-Raised Catfish	S, GT, AL	2.3	4.6	5.7	11	0.45	0.90
B	Conventional Blue Crab	S, GT, AL	0.15	0.30	0.45	0.90	0.065	0.13
C	Mechanized Blue Crab	S, GT, AL, IP	2.5	5.0	6.3	13	1.3	2.6
D	Non-Remote Alaskan Crab Meat	S, GT, IP	-	-	5.3	16	0.52	1.6
E	Remote Alaskan Crab Meat	S, GT, IP	-	-	5.3	16	0.52	1.6
F	Non-Remote Alaskan Whole Crab and Crab Sections	S, GT, IP	-	-	3.3	9.9	0.36	1.1
G	Remote Alaskan Whole Crab and Crab Sections	S, GT, IP	-	-	3.3	9.9	0.36	1.1
H	Dungeness + Tanner Crab in the Contiguous States	S, DAF, IP	4.1	10	0.69	1.7	0.10	0.25
I	Non-Remote Alaskan Shrimp	S, IP	-	-	180	270	15	45
J	Remote Alaskan Shrimp	S, IP	-	-	180	270	15	45
K	Northern Shrimp	S, DAF, IP	62	155	15	38	5.7	14
L	Southern Non-Breaded Shrimp	S, DAF, IP	25	63	10	25	1.6	4.0
M	Breaded Shrimp	S, DAF, IP	40	100	22	55	1.5	3.8
N	Tuna	S, DAF, IP	8.1	20	3.0	7.5	0.76	1.9

S = screen; GT = simple grease trap; Al = aerated lagoon; IP = in-plant change;
DAF = dissolved air flotation

The new source performance standards are presented in Table 119.

Pretreatment

No constituents of the effluents discharged from plants within the farm-raised catfish, crab, shrimp and tuna industries have been found which would (in concentrations found in the effluent) interfere with, pass through (to the detriment of the environment) or otherwise be incompatible with a well-designed and operated publicly owned activated sludge or trickling filter waste water treatment plant. The effluent, however, should have passed through the equivalent of "primary treatment" in the plant to remove settleable solids and a large portion of the greases and oils. Furthermore, in a few cases, it should have been mixed with sufficient wastewater flows from other sources to dilute out the inhibitory effect of any sodium chloride concentrations which may have been released from the seafood processing plant. The concentration of pollutants acceptable to the treatment plant is dependent on the relative sizes of the treatment facility and the processing plant and must be established by the treatment facility.

SECTION XII

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SECTION XIII

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SECTION XIV

GLOSSARY

Activated Sludge Process: Removes organic matter from sewage 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.

Ammonia Stripping: Ammonia removal from a liquid, usually by intimate contacting with an ammonia-free gas such as air.

Anaerobic: Living or active in the absence of free oxygen.

Anexuviant: With reference to crab, meaning without the backs (after "backing").

Bacteria: The smallest living organisms which comprise, along with fungi, the decomposer category of the food chain.

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.

Bifurcation: A site where a single structure divides into two branches.

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 th net energy level of 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.

Blood Water (Serum): Liquid remaining after coagulation of the blood.

Blowdown: A discharge of water from a system to prevent a buildup of dissolved solids in a boiler or clarifier.

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.

Breaded Shrimp: Peeled shrimp coated with breading. The product may be identified as fantail (butterfly) and round, with or without tail fins and last shell segment; and as portions, sticks, steaks, etc., when prepared from a composite unit of two or more shrimp pieces, whole shrimp, or a combination of both without fins or shells.

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 solution which remains liquid down to 5°F; used in freezing 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, shellfish, 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.

Chemical Precipitation: A waste treatment process whereby substances dissolved in the waste water 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 waste water.

Cluster Sampling: A method that is useful for increasing sampling efficiency and reducing error when the universe can be partitioned into groups such that the objects in a group are more heterogeneous within than between.

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.

COD (Chemical Oxygen Demand): A measure of the oxygen required to stabilize that portion of organic matter in a sample that can be oxidized by a strong chemical oxidizing agent.

Coefficient of Variation: A measure used in describing the amount of variation in a population. An estimate of this value is S/X where "S" equals the standard deviation and X equals the sample mean.

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.

Cook: May be referred to as the second cook of a two cook operation.

Crustacea: Mostly aquatic animals with rigid outer coverings, jointed appendages, and gills. Examples are crayfish, crabs, barnacles, water fleas, and sow bugs.

Dentrification: 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.

Ecology: The science of the interrelations 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.

Environment: The physical environment of the world consisting of the atmosphere, the 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 intentional or unintentional enrichment of 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 aerobe can grow in the presence of free oxygen.

Facultative Anaerobe: An organism that although fundamentally an anaerobe 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 "stick water") 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 form clumps of solids in sewage.

Floc Skimmings: The flocculent mass formed on a quieted liquid surface and removed for use, treatment, or disposal.

Grab Sample: A sample taken at a random place in space and time.

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 undergound 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.

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 in waste water.

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 or wood tank with circulating seawater for the purpose of keeping a crab alive until processed.

M: Meter, metric unit of length.

Mm: Millimeter = 0.001 meter.

Mg/l: Milligrams per liter; approximately equals parts per million; a term used to indicate concentration of materials in water.

MGD: Million gallons per day.

Merus: Largest section of crab leg closest to crab body.

Microstrainer/microscreen: A mechanical filter consisting of a cylindrical surface of metal filter fabric with openings of 20-60 micrometers in size.

Mixed Liquor: The name given the effluent that comes from the aeration tank after the sewage has been mixed with activated sludge and air. Mortality The ratio of the total number of deaths to the total population, or the ratio of the number of deaths from a given disease to the total number of people having the disease.

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.

Organoleptic: Involving the employment of the sense organs.

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.

Peeler: Removes the greatest portion of the shell from shrimp.

Percolation: The movement of water through the soil profile.

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 alkalies.

Plankton (Plankter): Organisms of relatively small size mostly microscopic, that have either relatively small powers of locomotion or that drift in that water with waves, currents, and other water motion.

Pollutant: a substance which taints, fouls, or otherwise renders impure or unclean.

Pollution: Results when something--animal, vegetable, or mineral--reaches water, making it more difficult or dangerous to use for drinking, recreation, agriculture, industry, or wildlife.

Polishing: Final treatment stage before discharge of effluent to a water course, carried out in a 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 waste waters in a confined space with evaporation and percolation the primary mechanisms operating to dispose of the water.

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 Liquor: Stick water resulting from the compaction of recovered fish waste 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 that 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, pastuerizing, 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 organic 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 waste waters.

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 waste water 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 248°F with steam under pressure.

Reuse: Water reuse, 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 Contractor: A waste treatment device involving closely spaced light-weight disks which are rotated through the waste water allowing aerobic microflora to accumulate on each disk and thereby achieving a reduction in the waste content.

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 waste water is trickled over the 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.

Sanitary Sewers: In a separate system, are pipes in a city that carry only domestic waste water. The storm water runoff is taken care of by a separate system of pipes.

Secondary Treatment: The second step is 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 waste water 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 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 waste water to treatment plants or receiving streams.

Shaker Blower: Dries and sucks the shell off with a vacuum, leaving the shrimp meat.

Shock Load: A quantity of waste water or pollutant that greatly exceeds the normal discharged into a treatment system, usually occuring 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.

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 hybridizing.

Stationary: Process with statistics which are independent of a time translation.

Stick Water: Water which has been in close contact with the fish and has large amounts of organics entrained in it.

Stoichiometric Amount: The amount of a substance involved in a specific chemical reaction, either as a reactant or as a reaction product. 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.

Suspended Solids: The wastes that will not sink or settle 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.

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".

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.

Universe: The collection of objects or a region of time or space of which it is desired to determine the collective properties or attributes.

Viscus (pl. Viscera): Any internal organ within a body cavity.

Washer: Shrimp are vigorously agitated to loosen the remaining shell and wash the shrimp meat.

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
Selected Biblography

Air Flotation Use Within the Seafood Industry

1. Atwell, J.S., R.E. Reed and B. A. Patrie. 1972 "Water Pollution Control Problems and Programs of the Maine Sardine Council." Proceedings of the 27th Industrial Waste Conference. Lafayette: Purdue University, 1972

2. Baker, D.W. and C. J. Carlson. 1972. "Dissolved Air Flotation Treatment of Menhaden Bail Water." Proceedings of the 17th Annual Atlantic Fisheries Technology Conference (AFTC). Annapolis, Maryland.

3. Claggett, F.G., and Wong, J., Salmon Canning Wastewater Clarification, Part I. Vancouver: Fisheries Research Board of Canada, Laboratory, 1968

4. Claggett, F. G., and Wong, J., Salmon Canning Wastewater Clarification, Part II. Vancouver: Fisheries Research Board of Canada, Laboratory, February 1969.

5. Claggett, F. G., A Proposed Demonstration Waste Water Treatment Unit. Technical Report No. 1970. Vancouver: Fisheries Research Board of Canada, Vancouver Laboratory, 1970

6. Claggett, F. G., Demonstration Waste Water Treatment Unit, Interim Report 1971 Salmon Season. Technical Report No. 286 Vancouver: Fisheries Research Board of Canada. 1972

7. Claggett, F. G., The Use of Chemical Treatment and Air Flotation for the Clarification of Fish Processing Plant Waste Water. Fisheries Research Board of Canada, Vancouver Laboratory, Vancouver, British Columbia, 1972.

8. Claggett, F. G., Treatment Technology in Canada, Seattle, Environmental Protection Agency, Technology Transfer Program, Upgrading Seafood Processing Facilities to Reduce Pollution, 1974

9. Jacobs Engineering Co. Pollution Abatement Study for the Tuna Research Foundation, Inc. 120 pp. May 1971.

10. Jacobs Engineering Co. Plant Flotation Tests for Waste Treatment Program for the Van Camp Seafood Co. 27 pp. June 1972.

11. Mauldin, A. Frank. Treatment of Gulf Shrimp Processing and Canning Waste, Seattle, Environmental Protection Agency, Technology Transfer Program, Upgrading Seafood Processing Facilities to Reduce Pollution, 1974

12. Mauldin, Frank A., Szabo, A. J. Unpublished Draft Report-Shrimp Canning Waste Treatment Study, EPA Project No. S 800 90 4, Office of Research and Development, U.S. Environmental Protection Agency, February 1974.

13. Peterson, P.L. Treatment of Shellfish Processing Wastewater by Dissolved Air Flotation. Unpublished report. Seattle: National Marine Fisheries Service, U.S.D.C. 1973

14. Snider, Irvin F. "Application of Dissolved Air Flotation in the Seafood Industry." Proceedings of the 17th Annual Atlantic Fisheries Technology Conference (AFTC). Annapolis, Maryland, 1972.

15. Kato, K., Ishikawa, S. "Fish Oil and Protein Recovered From Fish Processing Effluent" S. Wat. Sewage Wks. 1969.

"At a fish processing plant in Shimonoseki City, Japan, two flow lines (for horse mackerel, scabbard fish, and yellow croaker) produce waste waters amounting to 1800 tons daily from which purified oil and protein are recovered. Oil, first separated by gravitational flotation, passes through a heater and is then purified by two centrifugal operations. Underflow from the oil separator is coagulated and transferred to pressure flotation tanks to separate proteins which are finally dewatered by vacuum filtration. Data on the characteristics of the effluent, results of tests, and design specifications are described fully. The process removes about 86 percent of the suspended solids and about 77 percent of the BOD." ("Water Pollution Abstracts" 1970, (43), Abstract No. 787, London: Her Majesty's Stationery Office).

16. Vuuren, L.R.J., Stander, G.J., Henzen, M.R., Blerk, S.H.V., Hamman, P.F. "Dispersed Air Flocculation/Flotation for Stripping of Organic Pollutants from Effluent" Wat. Res. 1968.

"The principles of the dispersed air flotation system which is widely used in industry are discussed. A laboratory scale unit was developed to provide a compact portable system for use in field investigations, and tabulated results are given of its use in the treatment of sewage-works effluents and waste waters from fish factories, pulp and paper mills, and abattoirs showing that their polluting load was greatly reduced." ("Water Pollution Abstracts, 1968 (41)).

17. E.S. Hopkins, Einarsson, J. "Water Supply and Waste Disposal At a Foot Processing Plant. J. Industrial Water and Wastes. 1961

"The water supply system and waste treatment facilities serving the Coldwater Seafood Corporation plant at Nanticoke, Md., are described. Waste waters from washing equipment and floors, containing fish oil, grease and dough pass to a grease flotation tank, equipped with an "Aer-o-Mix" aeration unit. The advantages of the facilities are discussed." ("Water Pollution Abstracts," 1961 (34), London: Her Majesty's Stationery Office).

18. Shifrin, S.M. et al., "Mechanical Cleaning of Waste Waters From Fish Canneries" Chemical Abstracts 76 1972

"Shifrin et al presented the results of studies on fish cannery waste treatment in the U.S.S.R. using impeller-type flotators. With a waste containing 603 mg/l of fats, 603 mg/l of ss, and 2,560 mg/l of COD, mechanical flotation reduced these values by 99.8, 86.5 and 59.8 percent, respectively. The flotators were claimed to be more effective than settlers operating with or without aeration. ("Journal Water Pollution Control Federation," 1973, (45), No. 6, p. 1117.)

APPENDIX B

Selected Bibliography

Air Flotation Use Within the Meat and Poultry Industry

1. Wilkinson, B.H..P. "Acid coagulation and dissolved air flotation." Proc. 13th Meat Ind. Res. Conf., Hamilton, N.Z., 1971, M.I.R.I.N.Z. No. 225,

"A process developed by the Meat Industry Research Institute of New Zealand for removal of colloidal proteins from meat trade waste waters comprises cogulation with acid followed by air flotation. Pilot-plant trials have achieved removals of 85-95 percent suspended solids, 70-80 percent BOD and COD, and 99 percent coliform organisms." ("Water Pollution Abstracts" 1972, (45), Abstract No. 478, London: Her Majesty's Stationery Office).

2. Woodard, F.E., Sproul, O.J., Hall, M.W., and Glosh, M.M. "Abatement of pollution from a poultry processing plant." J. Wat. Pollut. Control Fed., 1972, (44), 1909-1915.

"Details are given of the development of waste treatment scheme for a poultry processing plant, including studies on the characteristics of the waste waters, in-plant changes to reduce the volume and strength of the wastes, and evaluation of alternative treatment methods. Dissolved air flotation was selected as the best method, after coagulation with soda ash and alum, and the treated effluent is chlorinated before discharge; some results of operation of the plant are tabulated and discussed." Typical operating data from a full-scale plant show removals of 74-98 percent BOD, 87-99 percent suspended solids, and 97-99 percent grease. ("Water Pollution Abstracts" 1972, (45), Abstract No. 1788, London: Her Majesty's Stationery Office).

3. Steffen, A.J. "The new and old in slaughter house waste treatment processes." Wastes Engng., 1957, (28).

"Methods of treating slaughterhosue waste waters by screening, sedimentation, the use of septic tanks, intermittent sand filtration, biological filtration and chemical treatment are discussed. Brief descriptions of the newer methods of treatment including the removal of solids and grease by flotation, anaerobic digestion, and irrigation are given." ("Water Pollution Abstracts," 1957, (30), Abstract No. 2414, London: Her Majesty's Stationery Office).

4. Meyers, G.A. "Meat packer tucks wastes unit in abandoned wine cellar." Wastes Engng., 1955, (26)

"At a plant of the H.H. Meyer Packing Co. at Cincinnati, Ohio, processing pork products treatment of the waste waters by dissolved air flotation reduces the amount of grease in the waste waters by about 80 percent and the concentration of suspended solids by 90 percent." ("Water Pollution Abstracts," 1955, (28), Abstract No. 1123, London: Her Majesty's Stationery Office).

5. Farrell, L.S. "The why and how of treating rendering plant wastes." Wat. & Sewage Wks., 2953, (100).

"In a paper on the treatment of waste waters from plants rendering meat wastes, preliminary treatment by fine screening, sedimentation, and pressure flotation is considered. Screening is economical if recovery of fats is not required. Pressure flotation, which is described fully, is the most efficient method of treatment as judged by the recovery of by-products and conservation of water. Air and coagulants are added to the waste waters in a tank maintained under pressure for solution of air and the waste waters then pass to the flotation unit at atmospheric pressure where dissolved air is liberated carrying solids to the surface. In a typical plant, a removal of 93 percent of the BOD and 93-99 percent of the total fat is achieved. If sedimentation is combined with flotation 93 percent of suspended solids is removed." ("Water Pollution Abstracts" 1953, (26), London: Her Majesty's Stationery Office).

6. Hopkins, E.S., Dutterer, G.M. "Liquid Waste Disposal from a Slaughterhouse." Water and Sew. Works, 117, 7, (July 1970).

"Hopkins and Dutterer reported the results of treating liquid slaughterhouse wastes in a system consisting of screening, grease separation by air flotation and skimming, fat emulsion breaking with aluminum sulfate (26 mg/l) and agitation, oxidation in a mechanical surface oxidation unit provided with extended aeration (24-hr detention time), overflow and recycle of activated sludge, and a final discharge to a chlorination pond (30-min contact). For an average discharge of 23,499 gpd (88.9 cu m/day), the BOD of the waste was reduced from 1,700 to 10.1 mg/l, and most probable number (MPN) coiform counts averaged 220/100 ml." ("Journal Water Pollution Control Federation," 1971, (43), No. 6, p. 949).

7. Dirasian, H.A. "A Study of Meat Packing and Rendering Wastes." Water & Wastes Eng, 7, 5, (May 1970). sides and quarters delivered from slaughterhosues, Dirasiar found that pressure flotation assisted by aluminum sulfate as a flocculation aid removed grease effectively.

"In a study of a plant that processes finished beef and pork from A recirculation ratio of 4:1 and a flotation period of 20 min were used in these studies. The final effluent showed a 98.5 percent removal of suspended solids (SS) (including grease) with the exception of influent samples containing less than 140 mg/l of SS. In all cases the SS in the effluent was less than 35 mg/l. ("Journal Water Pollution Control Federation," 1971, (43), No.6, p. 949.)

APPENDIX C

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 Cortlant 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 Boulevard, 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 North 4th Street, Columbus, Ohio 43216

Dorr-Oliver, Inc., Havemeyer Lane, Stamford, Connecticut 06904

Hendricks Manufacturing Company, Carbondale, Pennsylvania 18407

Peobody Welles, Roscoe, Illinois 61073

Clawson, F. J. and Associates, 6956 Highway 100, Nashville, Tennessee 37205

Allis-Chalmers Manufacturing Company, 1126 South 70th Street, Milwaukee, Wisconsin 53214

DeLaval Separator Company, Poughkeepsie, New York 12600

Envirex, Inc., 1901 South Prairie, Waukesha, Wisocnsin 53186

Liak Belt Enviornmental Equipment, FMC Corporation, Prudential Plaza, Chicago, Illinois 60612

Productive Equipment Corporation, 2924 West Lake Street, Chicago, Illinois 60612

Simplicity Engineering Company, Durand, Michigan 48429

Waste Water 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 North 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, Wisocnsin 53186

Environmental Systems, Division of Litton Industries, Inc., 354 Dawson Drive, Camarillo, California 93010

Infilco Division, Westinghouse Electric Company, 901 South 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

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)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

* Actual conversion, not a multiplier