WASTEWATER TREATMENT

Options for Louisiana Seafood Processors

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I. INTRODUCTION

Rapid population growth and industrial development have caused a sharp increase in the level of pollutants that are emitted into Louisiana's coastal waters. The preservation of suitable water quality for the state's valuable commercial and sport fishery requires careful management of these discharges.

Most of Louisiana's economically important seafood processing industry operates in environmentally sensitive areas. The permits section of the Louisiana Department of Environmental Quality (LDEQ) has identified a need for technological support to develop treatment guidelines for this industry.

A multitude of small rural processing facilities support Louisiana's in-shore and near-shore fisheries for popular finfish, crustaceans, and mollusks. These processors generate the bulk of their problem wastewaters on a seasonal basis. The direct discharge of these partially treated or untreated wastewaters adversely affects coastal sport fisheries, commercial oyster beds, and local drinking water supplies.

Seafood processing wastewaters primarily consist of biodegradable materials that are free of toxic substances yet tend to contain high concentrations of soluble organics. These wastes are measured in terms of their biological oxygen demand (BOD_5), total suspended solids (TSS), and fecal coliform bacteria.

The United States Environmental Protection Agency (EPA) has developed national, technology-based treatment guidelines for the seafood processing industry.[1] These standards dictate the daily 30-day maximum allowable values for BOD_5, TSS, oil and grease, and pH for several categories of seafood processors.
Unfortunately, the state's unique environment and differing seafood processing technologies prevent EPA's guidelines from being useful in selecting appropriate treatment methods for Louisiana processing operations.

Future regulatory policies may dictate a move away from technology-based effluent limitations to more stringent limits based on water quality. These new ceilings doubtlessly will demand more advanced wastewater treatment methods. We must, therefore, identify practical treatment options and limitations that both are economically acceptable to the seafood processing industry and protect the natural environment.

This report has four specific objectives. These are to identify the major categories of Louisiana seafood processors by species, to define the environmental regulatory requirements that apply to seafood processors, to catalog available historical data for describing the wastewaters of major Louisiana seafood processors, and to develop treatment recommendations for the nontoxic biodegradable wastes produced by these facilities for each processing category.

II. SEAFOOD PROCESSING IN LOUISIANA

Commercial fishing is a major Louisiana industry. Records value the annual catch for 1982-87 at more than $257 million[2]. As Table 2.1 shows, shrimp, menhaden, yellowfin tuna, oysters, spotted trout, catfish/bullheads, blue crab, red drum, black drum, red snapper, freshwater crawfish, and black mullet each had a 1986 per-species dockside value of more than $1 million. Shrimp, menhaden, and oysters boasted 1986 dockside values of $206.4, $53.5, and $24.4 million, respectively[2].

Farm-raised crawfish and catfish also are important. Many processors handle these farmed species. Crawfish farmers produced 72 million pounds in 1987, while catfish farmers harvested 22 million pounds during the same year.

Authorities estimate the annual value of processed fish in Louisiana averaged about $254 million from 1981 to 1985. During that time, the state accounted for about 5% of the seafood products processed in the United States and about 20% of seafood products processed in the Gulf region.

Louisiana's share of the seafood processing industry had risen to about 25% of the Gulf total by 1986. Processors handled between 70,000 and 100,000 tons of Louisiana seafood that year. They imported an unknown additional quantity from out-of-state sources. Despite this growth, a recent survey of more than 200 seafood processors and wholesaling operations indicates the number of Louisiana processors did not show a dramatic increase from 1970 to 1985.[2]

The Louisiana Department of Health and Hospitals (LDHH) issues permits to food handling facilities. This agency dispensed more than 1,037 separate permits to seafood processors in 1986. This figure may be misleading, since each permit represents only a single operation within a facility and not the complete plant. There actually were some 690 Louisiana seafood processing establishments in operation that year. The typical processing operation seasonally employed about 25 workers per establishment.

Each seafood processor on the LDHH list can employ several processes and can handle numerous species of seafood. As presented in Table 2.2, more than 57% of the state's seafood processors are located in its 11 coastal parishes (counties). These are Cameron, Vermilion, Iberia, St. Mary, Terrebonne, Lafourche, Jefferson, Plaquemines, St. Bernard, Orleans, and St. Tammany.[3] Terrebonne and Lafourche host nearly 25% of the processors. No other specific data about seafood processors is available.

Table 2.1 Louisiana Commercial Landings of Major Seafood Species in 1986 (2).

Species	Volume (1,000 lb)	Value ($1,000)
Shrimp (heads off)	146,681	206,355
Menhaden	1,459,153	53,536
Oysters (meat)	12,653	24,384
Blue Crab (hard)	31,611	9,301
Freshwater Crawfish	16,680	7,070
Catfish and Bullheads	6,909	3,210
Spotted Seatrout	1,978	1,675
Red Drum	7,817	5,707
Black Drum	5,225	1,837
Black Mullet	2,277	1,192
Tuna	2,618	3,750
Red Snapper	1,358	3,007

Table 2.2 Number of Seafood Processors in Louisiana by Parish (3).

Parish	No. of Operations	No. of Processors
Acadia	5	4
Allen	6	1
Ascension	11	5
Assumption	26	14
Avoyelles	27	22
Bossier	2	1
Caddo	6	4
Calcasieu	22	11
Cameron	48	32
Catahoula	2	2
Concordia	2	2
DeSoto	1	1
East Baton Rouge	38	16
Evangeline	16	8
Franklin	5	4
Iberia	18	15
Iberville	24	13
Jefferson	71	50
Jefferson Davis	3	2
Lafayette	23	12
Lafourche	93	66
Livingston	6	4
Orleans	73	43
Ouachita	10	7
Plaquemines	52	40
Rapides	4	4
Richland	1	1
St. Bernard	43	35
St. Charles	21	12
St. James	9	7
St. John	7	4
St. Landry	35	23
St. Martin	63	40
St. Mary	35	24
St. Tammany	15	12
Tangipahoa	30	19
Terrebonne	140	104
Vermilion	33	17
Washington	6	5
Webster	2	1
West Baton Rouge	2	2
West Feliciana	1	1
Total	1,037	690

III. PERMITTING PROCESSES

Permits

State and federal agencies require Louisiana seafood processors to have four separate permits (Fig. 3.1), depending on facility location and type of operation. These permits include the

National Pollution Discharge Elimination System (NPDES) permit issued by the EPA,

Louisiana Water Discharge Permit System (LWDPS) issued by the LDEQ,

Sanitary permits issued by the LDHH through the Office of Preventive and Public Health Services, and

Transportation permits issued by the Louisiana Department of Transportation and Development (LDOTD).

EPA Permit

The EPA includes wastewater discharges and other waste emissions, such as non-process water, in its consolidated permits program. Specifically, the discharge of pollutants into the waters of the United States requires a National Pollutant Discharge Elimination System (NPDES) permit.[4] The requirement for this permit falls under the Clean Water Act of 1977 (33 USC 1251).

Processors seeking a NPDES permit must complete two application forms. The first is the General Information Form (EPA Form 3510-1), which must be completed by all applicants.[4] The second is Form 2--Discharge to Surface Waters. Depending on the type or status of the organization that requires permitting, NPDES provides five variations of Form 2:

Form 2A, Publicly Owned Treatment Works (EPA Form 3510-2A);

Form 2B, Concentrated Animal Feeding Operations and Aquatic Animal Production Facilities (EPA Form 3510-2B);

Form 2C, Existing Manufacturing, Commercial, Mining, and Silviculture Operations (EPA Form 3510-2C);

Form 2D,New Manufacturing, Commercial, Mining, and Silviculture Operations (EPA Form 3510-2D); and

Form 2E, Facilities Which Discharge Only Nonprocess Wastewater (EPA Form 3510-2E).[4]

A NPDES application requires the applicant to report data about the nature of the discharge. This information includes the anticipated start-up date (if the facility is not already in operation). It must list the location of each outfall by latitude and longitude, as well as the names of the receiving waters. Additional information required by the NPDES includes

A list of the operations contributing wastewater to the effluent that describes the average flow contributed by each and any treatment given to the wastewater;

A line drawing displaying the water flow through the facility;
A description of any intermittent flows; and

The level of production at the facility with the affected outfalls.[5,6]

In addition to the physical characteristics of the flow, the applicant must report pollutant data. He must provide the results of at least one analysis for the BOD_5, chemical oxygen demand (COD), total organic carbon (TOC), ammonia (as N), flow, winter and summer temperatures, and pH.

The application lists toxic pollutants and hazardous substances that require identification by the applicant, if he expects any discharge. The applicant must report all analytical data in his possession concerning any toxic pollutants and hazardous substances in his operation's discharge and explain why they might be present.

If the applicant either knows or suspects that a biological test for acute or chronic toxicity was made on any discharge, or the waters that received it, within three years of the application date, he must identify the test and describe its purpose. An applicant for a new facility must list the names of existing similar facilities that, to the best of his knowledge, resemble it.[6]

The deadline for filing a NPDES permit application is 180 days before a permit expires or 180 days prior to start-up for a new facility. Federal regulations stipulate that construction of a new effluent source under the NPDES program may not begin before the issuance of a permit.[4] EPA does not require a fee for permit applications. All information provided on Forms 1 through 2E is public.

LDEQ Permit System

The LDEQ issues a five-year Louisiana Water Discharge Permit System (LWDPS) license to dischargers who meet the required effluent limitations and monitoring requirements. The permit application and the draft permit suggest that applicants apply for permits with the LDHH, NPDES, and, if suitable, the LDOTD.[7]

The application directs applicants to report data about relevant raw materials and water supply sources. This information does not require certification by an expert. Applicants must furnish a water-flow diagram and a discharge identification based on daily averages for each discharge point.

LDEQ's permit parallels most of the information required in the EPA application. The state permit application, however, demands additional data concerning total solids (TS), total dissolved solids (TDS), turbidity, the means by which wastes reach state water, disposal methods and facilities, and operating treatment methods. The LDEQ also compels applicants to provide maps showing where wastes enter state waters.

The state environmental agency application tracks the EPA application for each significant wastewater source at the facility. This includes sources combined at a common discharge point but excludes the flow diagram, toxicity, and the way the waste reaches state water.

Factors LDEQ applicants must appraise include economic effects, environmental sensitivity, availability of raw materials, fuel and transportation, availability and economic impact of the potential site, and the plant's relationship to other facilities. Applicants must consider how they intend to avoid potential and actual adverse environmental effects. They have to weigh other projects, sites, and mitigating measures that might offer more environmental protection. They are required to submit cost-benefit analyses.

LDEQ issues a draft permit after it receives the application. The draft permit does not grant an authorization to discharge. This document only describes the requirements that must be met to receive the final permit.

The applicant must have a public notice published in one edition of the Baton Rouge State Times and in one or more specified local newspapers. This notification is made at the applicant's expense, who must send proof of publication to the LDEQ office before he can receive the final permit.

This notice is a standard form that includes the type of effluent and the name and location of the receiving stream. It implies that some change in the existing water quality may occur. The notice also states that the application and proposed limitations are public information and can be examined at the LDEQ office. Any comments or requests from the public may be submitted in writing to that agency within 30 days of the notice date. The applicant should introduce comments or propose requests for changes in the draft to the LDEQ during the 30-day period.

LDEQ's permit fee in 1988 was 20% of the annual maintenance and surveillance fee, but not less than $227.50.[7] Applicants must pay this fee before the LDEQ will issue the final permit. Under the terms of the final permit, an applicant must submit Discharge Monitoring Reports (DMR). The draft permit also defines such terms as "once-through, non-contact cooling water"; "daily average"; "daily minimum"; and "composite sample." These terms relate to acceptable DMR measurements.

The facility may be liable for damages to both private property and state waters. Limitations and monitoring requirements include such factors as flow, BOD_5, TSS, oil/grease, and pH.

LDHH Permit

The Office of Preventive and Public Health Services, a division of the Louisiana Department of Health and Hospitals (LDHH), regulates seafood processors under Chapter 9 of the state's sanitary code. The sanitary code specifically defines all aspects of seafood processing sanitation, and it gives precise instructions on the operating permit.[8]

A Louisiana plant's operations for cleaning, shucking, picking, peeling, or packing of any marine or freshwater animal food product must be inspected and approved by the state health officer before it can receive an operating permit. The owner/operator must make written application for this inspection.

The owner/operator receives a serial permit number and can begin processing, once his plant has been inspected and approved. This permit number must appear on every package, can, carton, or other container in which he packs shellfish for distribution and sale. The number or the packer's name and address must be identified by lithography, embossing, or imprinting on the container. The serial permit may be revoked for a violation of any provision of the sanitary code.

Under the sanitary code, shellfish cannot be harvested or sold in Louisiana as food unless they are taken from areas approved by the state health officer or imported into the state under supervision of the U.S. Food and Drug Administration Public Health Service.[8] Wholesalers must keep accurate daily records of the names and addresses of their seafood suppliers. They also must keep track of the locations where they caught the seafood, who bought the finished product, and where it was delivered. These records must be kept on file for 60 days and can be inspected during business hours by a state health officer.

Plant construction is another area of special concern of the sanitary code. Designs for new facilities must meet minimum requirements before construction can be approved. A new plant's lighting plan, for example, must provide no less than 40 foot-candles. Its building has to be properly ventilated. Construction materials must be easy to clean and nonporous. Floors have to drain water completely and rapidly. The plant must have abundant hot and cold water supplies as well as lavatories that do not open directly into exposed rooms holding seafood products. The code also regulates transportation, water storage, cleanliness of boats, sewage disposal on shellfish boats, sewage disposal near shellfish areas, contamination of shell stock, equipment, employee health, tags, and refrigeration.

LDOTD Permit

The Louisiana Department of Transportation and Development, acting under Louisiana R.S. 48:385, requires disposal of wastes into highway ditches or rights-of-way to be approved in writing by the assistant secretary of the LDOTD Office of Highways. These permits include serial, control, unit numbers, and a request to use and occupy the right-of-way of a state highway within a parish. The seafood processor must describe in detail how the right-of-way will be used and include a project description with his request.

The state agency will consider the application only if the processor has attempted all other possibilities for discharge.[9] The seafood processor must submit written permission from the LDHH secretary and the local parish health unit with his application.

Also, the applicant must include a plan describing the treatment plant and discharge line, its size and contruction materials, and its location on the property. Finally, he must submit a profile showing highway ditches and outfall canals where the effluent leaves the highway right-of-way, and the manufacturer's plant specifications.[10] The LDOTD requires a fee for using the right-of-way and retains the right to cancel this permit.

Applicable Effluent Standards

Several different effluent limits can apply to seafood processors. Influential factors in choosing one include the water body into which the facility discharges, whether the permit is for a new or old facility, and whether discharges will flow into a publicly owned treatment works (POTW) or directly into the environment.

The flow diagram in Figure 3.2 illustrates the LDEQ effluent limit assignation procedures applicable to seafood processors. Note that waste load allocation covers all dischargers and can supersede all other effluent regulations.

Wastewater that is free of toxic materials is still subject to various water quality and flow parameters so as to determine the strength of its wastes, frequency, and amount of flow. The most important water quality parameters for choosing waste treatment options include BOD_5, flow frequency and amount, TTS, pH, temperature, oil/grease, ammonia, and dissolved oxygen level.

Effluent limits may be expressed either as a loading in kilograms of BOD_5 or TSS per day or as a concentration such as 30 mg/l BOD_5/30 mg/l TSS. The specific waste standards have daily maximum and average limits for each waste component. Processors have violated their permits if they exceed the set loading levels for a certain waste component over a specific period.

The U.S. Toxic Pollutant Control Act outlines a list of 129 distinct toxic or priority pollutants. This list changes as researchers identify new toxic compounds. Table 3.1 displays the current list. If a processor suspects his wastewater may contain toxic compounds, he must monitor the discharge.

Effluent limitations for toxic compounds are established by procedures other than those used for point source dischargers. Effluent monitors usually apply an acute biomonitoring program using an LC_{50}. This methodology utilizes a test organism, such as the fathead minnow, to find toxic effects based on the animal's survivability when exposed to a wastewater. Results from these tests determine whether the wastewater requires treatment.

Waste Load Allocation

Streams in many parts of Louisiana suffer from poor water quality. Technology-based effluent standards may not adequately protect a stream from further degradation. This is because such standards assume certain treatment levels will be satisfactory without regard to the condition of a specific stream's water quality.

The waste load allocation (WLA) process determines effluent limitations for point source discharges. It is based on the water quality conditions of the receiving stream. This approach soon may supersede most existing technology-based effluent standards for all Louisiana waters.

Louisiana's method for setting effluent limitations divides stream systems into two different types. The first includes river systems that would not be affected significantly by a point source discharge because they have adequate assimilative capacity as a result of their rates-of-flow and water quality. The Atchafalaya, Red, and Mississippi rivers fall into this category. Technology-based effluent limits, however, may apply to seafood processors that discharge into these waters.

The second type includes stream systems that may not have adequate assimilative capacity. Such systems could be affected profoundly by a point source discharge and would require treatment. Most Louisiana surface waters fall into this category.

Point source discharge effluent limits can be based on results obtained from a mathematical water quality model of a stream. These models simulate the changes in dissolved oxygen (DO) concentration that can take place over a set number of river miles downstream from the introduction of point source pollution.

The BOD_5 from a pollution source consumes oxygen in the water column at a measurable rate. Researchers can use waste load, stream water geometry, and, sometimes, quality information, to develop a dissolved oxygen sag curve that projects an effluent's impact on a stream. A set of these curves (Fig. 3.3) exists for each possible effluent limitation or level of treatment.

According to established water quality standards, a stream's dissolved oxygen levels normally must not be allowed to fall below 5.0 mg/l (4.0 mg/l in coastal waters). These standards apply the least stringent effluent limit that will allow the in-stream DO to be maintained at this level so as to determine the degree of necessary treatment. Generally, the degree of treatment will range from at least equivalent to secondary effluent limits (30 mg/l BOD_5/ 30 mg/l TSS) to allowing no discharge of any pollutants. More stringent limitations that include additional parameters, such as ammonia content, also can be imposed.

Existing Point Source Performance Standards

The EPA's effluent limitation guidelines represent the reductions that could be attained by industrial wastewater treatment facilities through the application of the best conventional technology (BCT) and the best available practicable control technology (BPT). BCT standards apply to conventional pollutants. EPA employs these technology-based standards to develop effluent limits for existing point source discharges. The effluent standards applicable to seafood processors are TSS, oil/grease, and pH. These guidelines require primary treatment methods that focus on the removal of suspended and floating materials from the waste stream.

Existing Source Pretreatment Standards

The EPA effluent limitation guidelines apply to seafood processors that discharge into a publicly owned treatment works (POTW). Pretreatment is part of the total required remedial process. It must take place before wastewater can be discharged into a POTW. These standards use the same waste components as are applied to point source dischargers that empty directly into state waters (TSS, oil/grease, and pH).

Local parish authorities, in cooperation with the EPA, normally administer the program that regulates these dischargers. There are no requirements for pretreatment of the three regulated waste components, and there are no required treatment technologies for existing sources.

New Point Source Performance Standards

The EPA's New Point Source Performance Standards (NSPS) apply to new seafood processing facilities. The waste components covered by these standards are BOD_5, TSS, oil/grease, and pH. Floating and suspended solids and soluble organic materials, as measured by BOD_5, first must be removed to reach this level of treatment. This indicates that at least a secondary treatment methodology is required.

New Source Pretreatment Performance Standards

EPA's New Source Pretreatment Performance Standards apply to new facilities that discharge into a local POTW. They cover BOD_5, TSS, oil/grease, and pH. These standards have no effluent limitation requirements. Local parish or city authorities normally cooperate with EPA to administer the program that regulates these dischargers.

Table 3.1 Current EPA List of Priority Pollutants

Volatiles
acrolein
acrylonitrile
benzene
bromoform
carbon tetrachloride
chlorobenzene
chlorodibromemethane
chloroethane
2-chloroethylvinyl ether
chloroform
dichlorobromomethane
1,1-dichloroethane
1,2-dichloroethane
1,1-dichloroethylene
1,2-dichloropropane
1,2-dichloropropylene
ethylbenzene
methyl bromide
methyl chloride
methylene chloride
1,1,2,2-tetrachloroethane
tetrachloroethylene
toluene
1,2-trans-dichloroethylene
1,1,1-trichloroethane
1,1,2-trichloroethane
trichloroethylene
vinyl chloride

Acid Compounds
2-chlorophenol
2,4-dichlorophenol
2,4-dimethylphenol
4,6-dinitro-o-cresol
2,4-dinitrophenol
2-nitrophenol
4-nitrophenol
p-chloro-m-cresol
pentachlorophenol
phenol
2,4,6-trichlorophenol

Base-Neutral Compounds
acenaphthene
acenaphthylene
anthracene
benzidine
benzo(a)anthracene
benzo(a)pyrene
3,4-benzofluoranthene
benzo(ghi)perylene
benzo(k)fluoranthene
bis(2-chloroethox)methane
bix(2-chloroethyl)ether
bis(2-chloroisopropyl)ether
bix(2-ethylhexyl)phthalate
4-bromophenyl phenyl ether
butylbenzyl phthalate
2-chloronaphthalene
4-chlorophenyl phenyl ether
chrysene
dibenzo(a,h)anthracene
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
3,3'-dichlorobenzidine
diethyl phthalate
dimethyl phthalate
di-n-butyl phthalate
2,4-dinitrotoluene
2,6-dinitrotoluene
di-n-octyl phthalate
1,2-diphenylhydrazine
(as azobenzene)
fluoranthene
fluorene
hexachlorobenzene
hexachlorobutadiene
hexachlorocyclopentadiene
hexachloroethane
indeno(1,2,3-cd)pyrene
isophorone
naphthalene
nitrobenzene
N-nitrosodimethylamine
N-nitrosodi-n-propylamine
N-nitrosodiphenylamine
phenanthrene
pyrene
1,2,4-trichlorobenzene

Pesticides
aldrin
alpha-BHC
beta-BHC
gamma-BHC
delta-BHC
chlordane
4,4'-DDT
4,4'-DDE
4,4'-DDD
dieldrin
alpha-endosulfan
beta-endosulfan
endosulfan sulfate
endrin
endrin aldehyde
heptachlor
heptachlor epoxide
PCB-1242
PCB-1254
PCB-1221
PCB-1232
PCB-1248
PCB-1260
PCB-1016
toxaphene

Metals, Cyanide and Total Phenols
antimony, total
arsenic, total
beryllium, total
cadmium, total
chromium, total
copper, total
lead, total
mercury, total
nickel, total
selenium, total
silver, total
thallium, total
zinc, total
cyanide, total
phenols, total

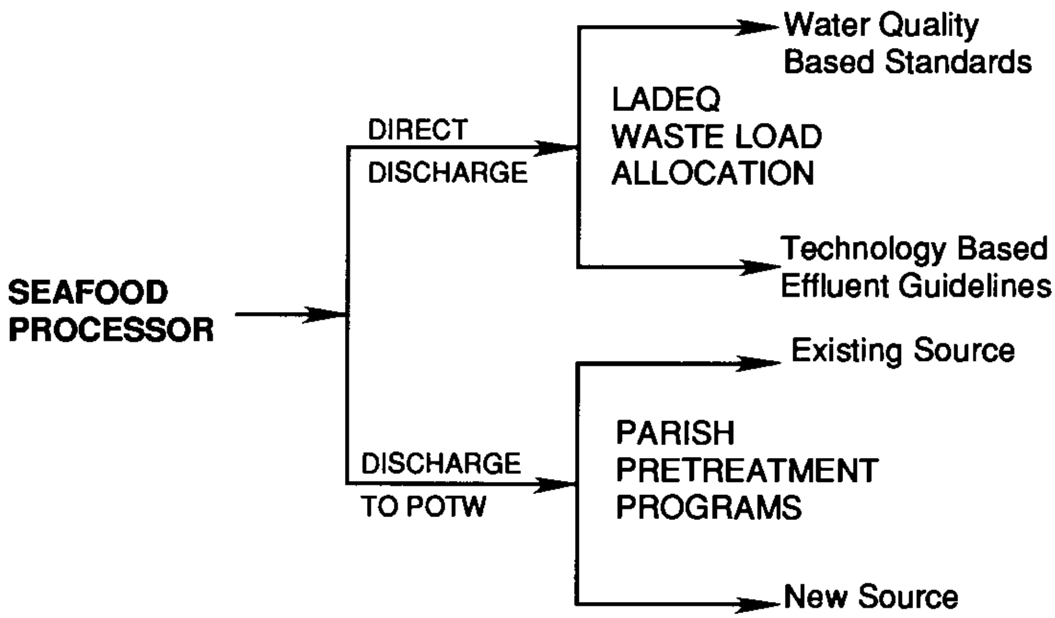

Figure 3.1 Permits Required for Seafood Processors

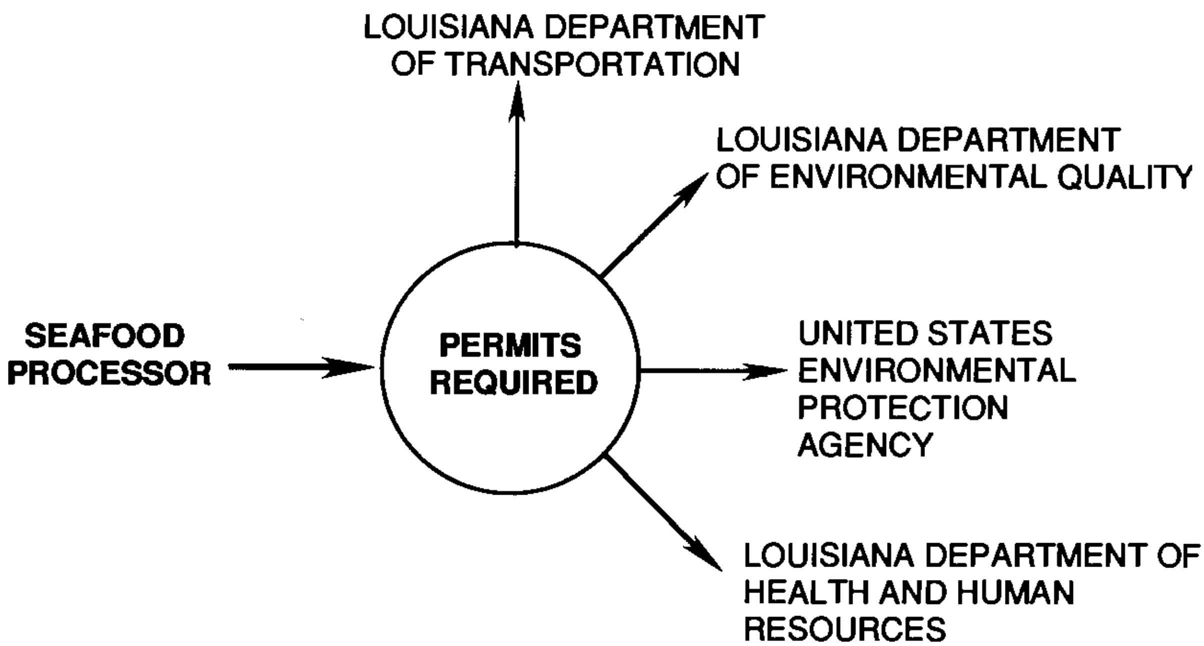

Figure 3.2 LADEQ Effluent Limitation Procedures Applicable to Seafood Processors.

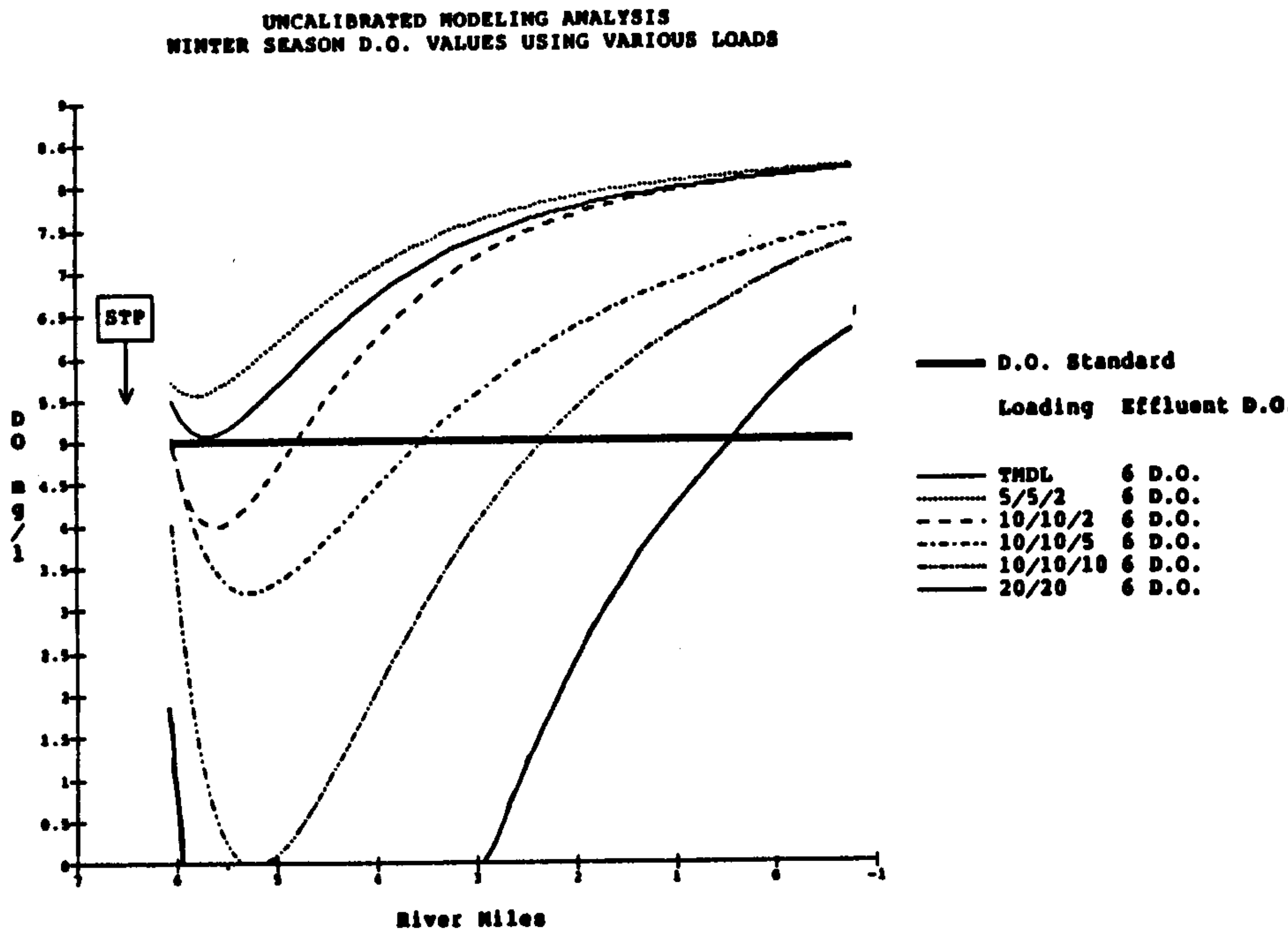

Figure 3.3 Typical Waste Load Allocation Analysis of a Point Source Discharge.

IV. TREATMENT METHODS

The purpose of wastewater treatment is to remove various components that would cause undesirable effects on receiving streams and bayous. Excessive amounts of BOD_5, suspended solids, and nutrients can lower dissolved oxygen concentrations in the immediate and downstream areas of the receiving waters. Low dissolved oxygen levels in a stream can kill fish, produce noxious odors, and reduce suitable fish and shellfish habitat for miles below the wastewater discharge.

Options available to seafood processors for controlling discharges vary considerably depending on the size and location of the facility. Costs associated with these treatment processes depend on site limitations and the ultimate degree of treatment required to protect the receiving water body. Traditional end-of-pipe technologies (i.e., activated sludge and trickling filters) can be used on most wastewater, but capital and operational costs may be high.

Waste Minimization

Waste minimization involves the implementation of management practices designed to reduce wastewater flow and strength. These in-plant water and solid waste reduction practices can offer more economical approaches to lowering total wastewater treatment costs. They should emphasize, wherever possible, conservation of plant water use and removal from the waste stream of waste solids such as shells, meat fragments, and viscera. Figure 4.1 shows the role of waste minimization practices for plant processes and wastewater treatment.

Wastewater treatment plants for seafood processors are sized hydraulically. This means larger plants are more costly. Substandard plant solids management and clean-up procedures can contribute to excessively high suspended solids and BOD_5 in the wastewater. This situation can result in requiring greater volumes of the treatment processes needed to deal with the wastewater adequately. In-plant separation of heavy solids and screening of lighter solids at the source of generation can help hold down the size of the processor's treatment plant.

Washwater Reduction

Washwater is a major controllable contributor to wastewater generation in a seafood processing plant. Processors use washwater for cleaning the incoming raw product, for cleaning the product between processing steps, and for general area and equipment clean up. They often can reduce the volume of washwater through in-plant management practices that emphasize turning off washwater to processes when not needed or by installing simple devices to regulate water use. Water control devices might include foot-operated pressure plates and automatic timers to turn water flow on and off and flowmeters to limit water volume.

Solids Separation

Solids in seafood processing result from various processes such as raw product washing, picking, filleting, cooking, and packaging. Large shell or body fragments separated during picking or filleting should not be reintroduced into the waste stream. These ought to be placed in proper disposal receptacles.

Seafood solids can be separated further in most operations by screening the discharge water at the source of generation and by using proper clean-up techniques. Small screens installed over drains or floor channels can eliminate many fine or heavy suspended solids. Processors can add the cleaning of these screens to their standard shift operations. Clean-up includes dry or wet floor sweeping before wash-down. Swept and screened materials should be treated as solid waste.

Water Reuse

The Federal Drug Administration (FDA) and the LDHH regulate the reuse of process water in the seafood industry. This area shows promise for reducing wastewater generation from some facilities, particularly mechanical shrimp peeling operations.

Reuse of washwater must meet coliform bacterial standards and be nearly free of solids to avoid clogging of equipment. The LDHH must approve any in-plant modifications on a case-by-case basis.

Wastewater Treatment Processes

The effluent limitations imposed on a seafood processing plant mandate which levels of treatment will be required for its wastewaters. Figure 4.2 defines these levels as primary, roughing, secondary treatment, and polishing. Table 4.1 compares the expected removal efficiency of these treatment processes. Wastewater characteristics can be estimated by combining the removal efficiencies of these levels.

Primary treatment is a physical or chemical process intended to remove medium-to-coarse suspended solids and some BOD_5 associated with wastewater solids. Secondary treatment refers to a physiochemical or a biological process that eliminates most of the BOD_5 and fine suspended solids. Polishing treatment takes out the remaining BOD_5 and suspended solids and can include removal of certain nutrients that may overload receiving water bodies. Roughing treatment can be either physiochemical or biological and reduces high-strength wastewaters to acceptable levels for further treatment by secondary treatment methods. Roughing can precede secondary treatment, if the wastewater has very high levels of suspended solids and BOD_5.

Table 4.2 shows the application of these methods to wastewater generated by a manual blue crab picking operation. The results show that for this wastewater, reductions of 99.5% of the BOD_5, 99.8% of the TSS, and 94% of wastewater ammonia are achievable. These estimates do not consider operation variability associated with specific site locations, seasonal fluctuations, operator expertise, or other similar factors.

The theoretical performance of most wastewater treatment methods is predictable. The impact of setting up the waste minimization techniques outlined in this report (water use, solids, and BOD_5 reductions) must be determined according to each case.

Primary Treatment

Primary treatment generally is a physical process that removes insoluble suspended materials. This treatment can be used alone to meet effluent standards for suspended solids. More commonly, however, primary treatment precedes biological treatment or other forms of secondary treatment. Solids and sludge collected from these processes must be disposed of properly as solid waste. Screening, sedimentation, and flow equalization are the major primary treatment methods used by seafood processors.

Screening intercepts larger solid particles from the flow of wastewater. The screen types used most frequently in the seafood processing industry are static, rotating, vibrating, tangential, and moving.[11] Figure 4.3 depicts a mechanical rotating screen. Screens have uniform openings for wastewater to flow through. The mesh size (number of openings per inch) directly corresponds to the minimum particle size the screen will remove. Flow may be inhibited when screens are not regularly cleaned to remove collected solids. Simple screens of the type shown in Figure 4.4 may be removed manually and cleaned, while more sophisticated screens are self-cleaning.

The EPA recommends a 20-mesh screen as the minimum treatment for most seafood processing effluents, but this mesh size clogs easily when used in static or tangential screens.[11] A single screen may remove up to 50% of the solids from a waste stream. A series of screens can remove more than 70% of wastewater solids.

Screens are relatively inexpensive, easy to maintain, and can be designed for automated operation. They can be retrofitted easily to sumps and discharge weirs at existing facilities. Screens are not, however, suitable for effectively removing very small particles or for providing sufficient support for secondary or polishing treatment technologies.

Sedimentation is the gravitational settling of suspended particles that are heavier than water.[12] Figure 4.5 shows a typical sedimentation basin pattern. Sedimentation tanks can be circular or square but customarily are rectangular.

Whatever their shape, sedimentation tanks have four zones. These include an inlet zone with baffles to minimize turbulence, a settling zone with low velocities to maximize particle sedimentation, a sludge-collecting zone, and an outlet zone divided by baffles.[11]

Other sedimentation tank features include a surface skimmer for removal of oil and grease, a chain-driven scraper for sludge removal, and a sludge hopper. The surface skimmer is mandatory. Oil and grease can clog secondary treatment operations and create environmental problems in the receiving waters.

Sedimentation processes may be enhanced by the addition of chemicals such as calcium carbonate, ferric chloride, polymers, or by creating other wastewater streams. These chemicals react with both dissolved and suspended compounds by creating heavier sludges for removing more suspended solids.

Sedimentation basins may require a high degree of maintenance and supervision to carry out their tasks reliably. Skimmers, sludge scrapers, and pumps all must be kept working. Excellent package units are available and can be placed at a site as a complete system.

Capital costs usually are greater for sedimentation units than for screens. On the other hand, removal of suspended solids by sedimentation can approach as high as 70%, and the effluent can be used in subsequent secondary treatment facilities.

Flow equalization, another primary treatment option, may be incorporated into the suspended solid removal process. The main features of a flow equalization system are a holding tank and pumping equipment. The system design reduces flow fluctuations and shock loadings and removes suspended solids through sedimentation. It maintains a constant effluent flow rate despite its inflow rate. The tank also may be used to divide the effluent and channel it in separate directions.

Secondary Treatment

The main objective of secondary treatment is to remove fine suspended solids and soluble BOD_5. Secondary treatment most often is biological, although it uses some physiochemical processes.

Complex mixtures of microorganisms remove waste stream BOD_5 to carry out the biological wastewater treatment process. As Figure 4.6 shows, bacteria (biological mass, biomass, or "bugs") use the complex organics (soluble BOD_5) in the wastewater as food. These bacteria consume oxygen and produce harmless carbon dioxide, water, and additional bacteria as they ingest wastewater organics.

In most treatment systems the bacteria are either suspended in the wastewater by mixing and aeration (activated sludge, stabilization lagoons) or are attached to media such as rocks (trickling filters), sand particles (fluidized beds), or plates (rotating biological contractors). The fine suspended solids not removed by prior treatment tend to adhere to the bacterial solids in the system and settle better. The biological system takes them out through integral sedimentation basins (activated sludge), in separate basins (trickling filters), or merely by allowing them to settle to the bottom (stabilization ponds).

Most biological processes used today are aerobic systems that require oxygen input from mechanical aeration devices such as surface aerators and blowers, or from trickling the wastewater over media. Sometimes other biological processes (algae) in the system (facultative stabilization lagoons) provide oxygen. The system is considered anaerobic or septic if oxygen is not readily available.

Besides carbon dioxide, the anaerobic process produces several intermediate waste products that require further biological degradation. Anaerobic treatment systems are used by some industries, although odors and lower treatment efficiencies can be problems. Many biological systems combine both anaerobic and aerobic processes. Wastewater stabilization lagoons are aerobic near the surface of the lagoon and gradually become anaerobic at the bottom.

Biological treatment systems can encounter various operational problems. Shock loading resulting from short flow duration or high-strength wastewater can cause serious impairment to treatment performance. General organic and hydraulic overloading of a system also can diminish treatment. Cold temperatures, power outages, temporary plant shutdowns, and seasonal operation all can have major effects on a biological treatment system. Despite these problems, biological treatment is cost effective and can produce excellent results.

Septic Tanks are the most widely used treatment system for small wastewater flows.[13] A well-designed septic tank system has two components. These are a tank and a soil absorption field (polishing treatment).

The tank is designed to settle and degrade suspended solids at the same time it retains floatable grease and scum. The soil absorption field further degrades soluble BOD_5 and removes suspended solids and nutrients. The soil absorption field is critical to the proper operation of these systems.

Using a septic tank alone is not an adequate treatment method. Septic tank treatment systems can be severely limited by shallow water tables or the inadequate availability of land for the soil adsorption components. This situation adversely affects many seafood processors located along bayous or streams.

Septic tanks are usually buried, water-tight vessels designed for wastewater with a small intermittent flow. These tanks are generally available as prefabricated concrete tanks, but they can be constructed on-site for any size flow or site requirement.

Figure 4.7 demonstrates a typical septic tank pattern. The vessel provides sedimentation for suspended solids, partial degradation of soluble BOD_5, storage, and slow degradation of collected solids, and separation of grease and scum. These systems discharge a somewhat clear effluent.

Various tank configurations are available with baffles and tees to reduce turbulence and separate tank compartments for scum and solids removal. The systems provide manholes for periodic cleaning and inspection. They also must furnish venting, since these systems are anaerobic and gases will accumulate. Designs usually require a 24-hour fluid retention time at maximum sludge depth and scum accumulation.

The polishing treatment or soil adsorption step built into the septic tank system is designed to increase removal of suspended solids, BOD_5, and nutrients in the wastewater to standards that protect receiving water bodies. These methods include intermittent sand filters, tile fields, rock/reed filters, chemical addition for nutrient removal, wastewater stabilization lagoons, and aerobic treatment methods. Seafood processors in most coastal areas should not use tile fields. Acceptable polishing methods are discussed in other sections of this manual.

Activated Sludge is a biological wastewater treatment process in which a mixture of wastewater and biological sludge is agitated and aerated.[12] The sludge is a complex mass of microorganisms that results from aerobically treated organic waste.[11]

Most activated sludge systems are continuous-flow, but some systems can be batch-operated. While the system is mixing, the microorganisms feed on the available organics. An additional or cell sludge mass forms as the microorganisms grow.

The effluent settles in a sedimentation unit to remove the biological solids produced in the aeration basin. A portion of the settled sludge is recycled to be recombined with influent raw wastewater. The remaining sludge is removed and disposed of as solid waste.

Figure 4.8 shows diffused air and mechanically mixed activated sludge systems. Air usually is supplied through a horizontal perforated pipe along one side of the tank.

There are several different types of activated sludge operations. These include conventional, complete-mix, extended aeration, and step aeration. Conventional activated sludge uses a primary clarifier or sedimentation basin followed by the aeration basin and a secondary clarifier. Bacterial biomass of sludge is produced in the aeration basin and separated in the secondary clarifier. Some of the sludge is recombined with the influent wastewater as activated sludge, and the rest is wasted.

The detention time of these systems is usually four to eight hours. Diffusers or mechanical mixers provide aeration and mixing. The expected removal of BOD_5 can range from 85-93%; and of TTS, from 80-90%.

Extended air-activated sludge is the most common process used in packaging plants. This process provides a detention time of 16-48 hours. Because of this long detention time, the amount of generated sludge that needs to be disposed of is less than the amount from conventional activated sludge.

Package units are available for a variety of flows. These come complete and ready-to-install. Both below- and above-ground units are available.

Wastewater Stabilization Lagoons are another option for secondary treatment. Of the five types of lagoons available, three are recommended for the treatment of seafood wastewater. These include facultative, aerated, and anaerobic.

Facultative lagoons, as shown in Fig. 4.9, treat wastewater through the interaction of sunlight, wind, algae, and oxygen.[13] The organic material breaks down in facultative lagoons through algae-bacterial symbiosis. Under aerobic conditions, this division produces water and carbon dioxide as by-products. Under anaerobic conditions, it creates carbon dioxide and methane. Algae uses the carbon dioxide to produce new cellular material. This means the carbon is recycled within the ponds, and little organic reduction will occur unless either the algae is removed or the carbon is taken away anaerobically by means of methane fermentation.[12]

As shown in Figure 4.10, facultative lagoons, are shallow and have three layers or zones. The upper layer is 100% aerobic because the wind provides mixing action that promotes oxygen transfer. Algae also releases oxygen through photosynthesis. The middle layer contains organisms known as facultative bacteria that can function in either aerobic or anaerobic conditions. The bottom layer is anaerobic and actively decomposes solids.

Depth limits the performance of facultative lagoons. If the lagoon is less than one meter in depth, it is impossible for an anaerobic layer to form. Conversely, if the depth exceeds two to three meters, the lagoon may become completely anaerobic.

The second lagoon type, shown in Figure 4.11, is the aerated lagoon. Aerated lagoons are 100-percent aerobic. Surface aerators or submerged diffused aeration supply the oxygen. This process is similar to the activated sludge process.

The major advantage of aerated lagoons is connected to oxygen availability. They can treat higher volumes of wastewater daily than the other lagoon types, since the aeration provides large amounts of oxygen. Other advantages of aerated lagoons include their requirement of smaller land areas and costs of construction.

The third type of lagoon is the anaerobic. These pools contain no oxygen. Anaerobic bacteria degrade the organic wastes. Solids remain in the water until they decay. Since anaerobic degradation does not result in complete removal of organic waste, this treatment needs to be followed by an oxidation pond or aerated lagoon to "polish" the effluent.

Attached Growth Biological Contractors, as shown in Figure 4.6, have bacteria attached to such media flat plates, rocks, plastic shapes, or sand--depending on the process. The processes include trickling filters, rotating biological contractors, and fluidized beds.

A trickling filter is a bed of coarse material. Wastewater is applied over the bed in drops, films, or spray from moving or fixed nozzles. Wastewater flows through the filter bed to underdrains.[13] The system is completely aerobic, since the water level is below the filter media. Its bed material can be made of stones, slats, or plastic.

Trickling filters must be preceded by primary treatment or a high solids concentration will clog the bed. The filter media should be small enough to have a large surface area while large enough to prevent clogging and to provide enough area between media particles to maintain oxygen levels. Microorganisms that degrade the organic matter in the wastewater cover the media. As the bacteria grow, the biomass builds up on the rocks or media and eventually sloughs off the surfaces. A second clarifier must be provided to remove these solids from the effluent.

Low-rate trickling filters can be used for secondary treatment or as nitrification filters. High-rate trickling filters are used for roughing filters to reduce very high strength wastes.

Rotating biological contractors (RBCs) are practically rotating trickling filters. A series of rotating disks are placed equidistantly and partially submerged in a wastewater tank. The rotation provides the aeration, and the disks are the filter media. The organic material degrades as the wastewater trickles down the disks. RBCs require less space for operating trickling filters but also require a final clarifier.

Biological fluidized beds (Fig. 4.12) are a form of biological treatment where the microorganisms cling to a medium as described for trickling filters and RBCs. The medium is sand constantly suspended in an aerated flow of wastewater.

Fluidized beds look like a combination of trickling filters and activated sludge, but they differ greatly from both processes. The wastewater flows around the sand grains, the medium surfaces are exposed for microbial activity, and oxygen is uniformly available.

The media are not allowed to clump together and form dead spots--areas of low microbial growth rate in the system. Also, the friction of the sand grains bumping into other sand grains shears off biomass and keeps the microorganism in an accelerated growth stage. These factors make fluidized beds more efficient than trickling filters, activated sludge, or RBCs and usually requires less space.

Dissolved Air Flotation (DAF), as shown in Figure 4.13, is a physical treatment method to remove dissolved material, fat, oil, and grease from wastewater with the aid of very tiny air bubbles.[19] DAF is one of the few physical processes that can meet secondary wastewater treatment standards.

In the DAF process, air dissolves when the wastewater is put under pressure. A flotation tank holds the wastewater flow to allow the dissolved air to escape and attach to suspended particles. The specific gravity of the suspended particles and air is lighter than the water. This causes the particles to float to the surface where they can be skimmed off.

Chemical coagulants often are added to wastewater before it enters the flotation tank to create a surface that can easily entrap air bubbles. The purpose of this chemical addition is to increase the rate of removal by producing large masses of suspended particles called flocs. The rate of removal depends on particle size, since the larger the particle size the higher the percentage of efficiency in removal.

Roughing Treatment

Roughing treatment is designed to reduce excessive BOD_5 and suspended solids concentrations to levels treatable by secondary treatment methods. Secondary treatment normally can handle BOD_5 from about 50-500 mg/l. Treatment performance can be erratic above this level, and shock loading can cause plant upset. This process pretreats these high waste loads if necessary and minimizes the effect of shock loading.

Roughing treatment technologies use the same processes as does secondary treatment, but are intended to handle higher wastewater concentrations. Influent concentrations of BOD_5 into these treatment processes may range from more than 1,000 up to 2,000 mg/l. Effluent concentrations should remain below 500 mg/l with no shock loads.

Stabilization lagoons, RBCs, and trickling filters are the most common secondary treatment methods used in roughing. These systems respond well to shock loadings, resist clogging, minimize odors, and have low operating costs.

Polishing Treatment

Polishing treatment usually is a final step toward reducing suspended solids, nutrients, and BOD_5 so as to meet more stringent water quality standards. Any standard that requires treatment performance to meet effluent BOD_5 and TSS of less than 30 mg/l will require some form of polishing or tertiary treatment. Furthermore, any effluent nutrient restrictions also will require polishing treatment.

Polishing treatment technologies for BOD_5 and suspended solids removal include slow sand filters, rock-reed filters, and wetlands treatment. Polishing treatments for nutrient removal include fluidized beds, RBCs, and chemical precipitation.

BOD_5 and TSS Control require the use of a filtration process like microscreens and sand filters. A microscreen is a mechanical filter used in polishing that does not have to be backwashed. The microscreens are cylindrical drums mounted parallel to the ground. Their surfaces are made of a metallic filter fabric.

The polishing process calls for a partially submerged drum to rotate, while the wastewater moves in one side and out the other. A fine screen stops the solids, and water jets spray the total solids accumulation into a trough, where it is reprocessed.

Sand filters remove BOD_5 and suspended solids down to very stringent standards. Several types are available to seafood processors. These include rapid, upflow, and slow sand filters.

Rapid sand filters are usually rectangular with a filter bed about 18-24 inches deep underlain by larger rock or drain tile. Wastewater flows into the system and downward through the bed until it clogs and restricts the flow. At this point the wastewater either is diverted to another unit or is held in storage while the filter is cleaned by backwashing.

Backwashing uses clean water to reverse the filter's flow pattern. The rate of flow is high enough to expand the bed and break loose the collected debris and solids. The backwash water then must be discharged to a sewer or to a slow sand filter to collect the solids. The rapid sand filter is effective for high flowrate systems, although package units are available for most facilities.

Slow sand filters (Fig. 4.14) are passive filters that have a graded sand media 18-24 inches deep, but have no provision for backwashing. Wastewater flow is distributed over the bed and seeps downward in the media bed, where the solids collect in the upper two inches. When the filter begins to clog the flow is diverted and the wastewater is allowed to slowly seep into the bed until it is drained. The bed is cleaned by scraping the upper one to two inches of sand which should contain almost all the filtered suspended solids. This material should be disposed of as solid waste.

A third type of filter is the upflow sand filter (Fig. 4.15). Wastewater in the filter is pumped into the bottom of the filter and flows upward through the media. Particles are captured throughout the depth of the media, and thus a smaller volume of filter media can be used. Collection of enough suspended solids eventually reduces the flow through the filter, which then must be flushed. The flow is not reversed as in the rapid sand filter. It is merely increased enough through the media so as to expand the bed and lift out the suspended solids. Flushing takes about a minute, after which normal operation can resume. The flushed water must be sent either to the sewage system or treated by a slow sand filter.

Wetlands can remove suspended solids and BOD_5 naturally. Natural wetlands are marshy areas that remain saturated throughout the year with the resultant characteristic vegetation. Emergent plants such as rushes, reeds, and cattails characterize wetlands systems. Louisiana's freshwater wetlands also may boast cypress and willow trees and a variety of other floating and rooted plants.

Brackish and saltwater wetlands are common in Louisiana. These systems use a combination of mechanisms to bring about removal of suspended solids and BOD_5. Plants and bottom surfaces provide sites for microbial activity, and slow-moving water enhances sedimentation. Plant uptake can produce limited nutrient removal, while long hydraulic detention times and shallow water provide aerating conditions that will degrade soluble BOD_5.

The use of natural wetlands for wastewater treatment is experimental, and direct application for seafood processors is limited. Discharge regulations consider wetlands to be receiving water bodies and not treatment units. Further study is necessary before this approach becomes acceptable, but it shows promise as a low-cost treatment method for seafood processors on sites that could take advantage of nearby wetlands.

Constructed wetlands (rock-reed filters) are shown in Figure 4.16. These consist of shallow lined or unlined basins filled with two to three feet of rock media that support the growth of emergent plants and attached microorganisms.

Wastewater flows into the system via a submerged inlet. The plants take up some nutrients, and their roots provide additional sites for microbial degradation of wastes. Microorganisms attached to the rock media provide the bulk of the treatment. Simple entrapment in the rock and roots removes suspended solids.

Retention times in these systems vary between one and three days. Water levels are maintained just below the surface of the rock media to minimize odor and insect problems and to hinder the growth of algae. Rock-reed filters are very effective for treating low strength wastewaters with a BOD_5 of less than 150 mg/l.

Nutrient Control requires the use of special methods when water quality standards dictate that a water body must be protected from the discharge of nutrients in a processor's wastewater. Some of these methods may only be a retrofit to an existing facility, while others may require complex process additions.

Certain nutrients can be controlled by investigating their sources of generation in the plant and carrying out waste minimization management practices. Most nutrients evolve from the process and must be treated with an end-of-pipe technology.

Phosphorus can be removed most effectively by using chemical precipitation. Chemicals such as ferric chloride or alum will enhance the removal of suspended solids in sedimentation basins. These chemicals also will react with phosphorus and cause removal through sedimentation. Chemical addition can be used with package sedimentation plants and septic tanks.

Biological treatment or physiochemical methods can remove ammonia. Biological treatment (nitrification) could include fluidized beds, RBCs, and activated sludge systems. These processes have been adapted for nitrification of wastewaters containing up to 300 mg/l ammonia. Physiochemical methods for ammonia removal include selective ion-exchange and air-stripping.

Table 4.1 Comparison of Treatment Efficiencies for Various Treatment Methods (12).

Treatment	Waste Parameters Removed	Expected Removal Efficiency
Primary	TSS	50 - 65
	BOD_5	24 - 45
Roughing	TSS	40 - 60
	BOD_5	40 - 60
Secondary	TSS	85 - 95
	BOD_5	75 - 95
Polishing	TSS	80 - 99
	BOD_5	65 - 98
	Phosphorus	70 - 80
	Nitrogen	85 - 98

Table 4.2 Estimated Reduction Efficiencies for Seafood Processing Wastewater (Using A Manual Blue Crab Picking Operation).

Treatment	BOD_5 (mg/l)	TSS (mg/l)	Ammonia (mg/l)
Raw Wastewater Concentration	4400	620	50
Waste Minimization*			
Removal Efficiency	40%	50%	20%
Discharge Quality	2640	310	40
Primary Treatment**			
Removal Efficiency	35%	58%	0%
Discharge Quality	1716	130	40
Roughing Treatment**			
Removal Efficiency	50%	50%	0%
Discharge Quality	858	65	40
Secondary Treatment**			
Removal Efficiency	85%	90%	0%
Discharge Quality	129	7	40
Polishing Treatment**			
Removal Efficiency	85%	90%	92%
Discharge Quality	24	< 1	3

*Estimated removal efficiency.
**Removal efficiency take from Table 4.1.

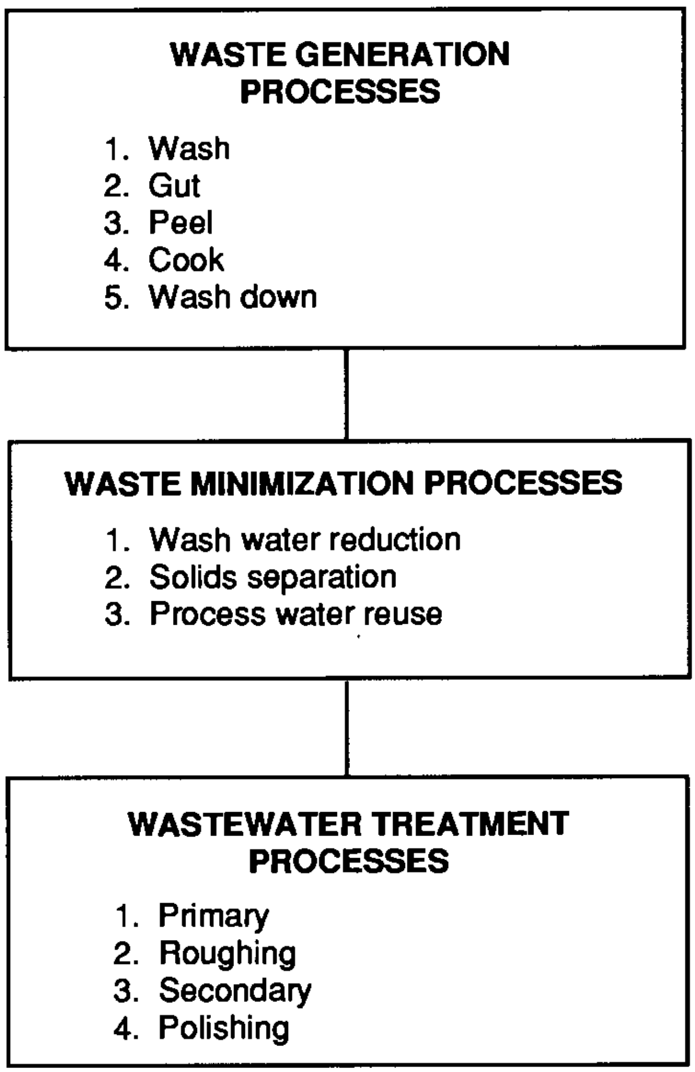

Figure 4.1 Relationship of In-Plant Waste Generation Processes to Waste Minimization and Wastewater Treatment Practices

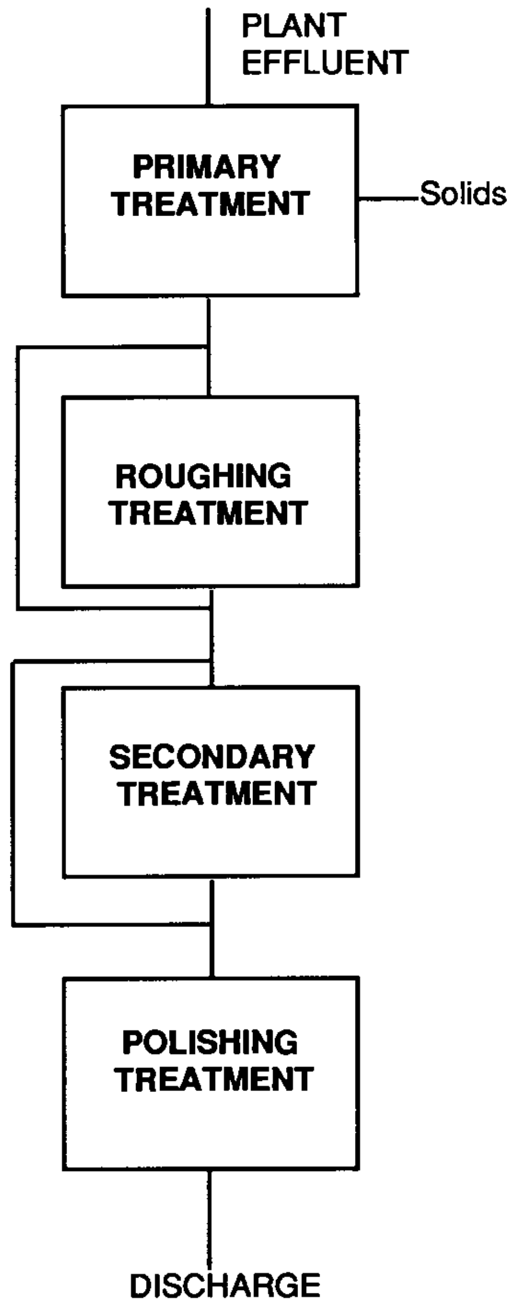

Figure 4.2 Sequence of Wastewater Treatment Practices for Seafood Processes

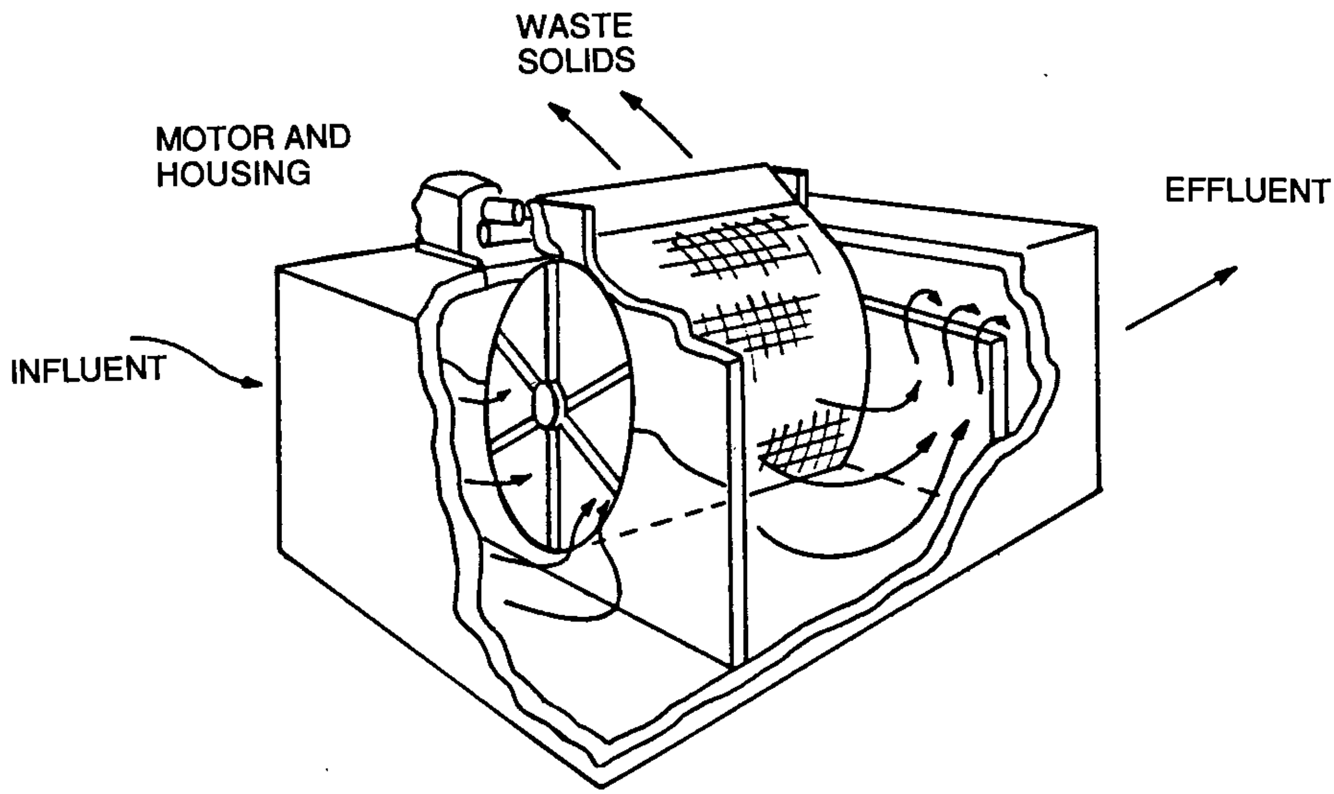

Figure 4.3 Mechanical Rotating Screen (11).

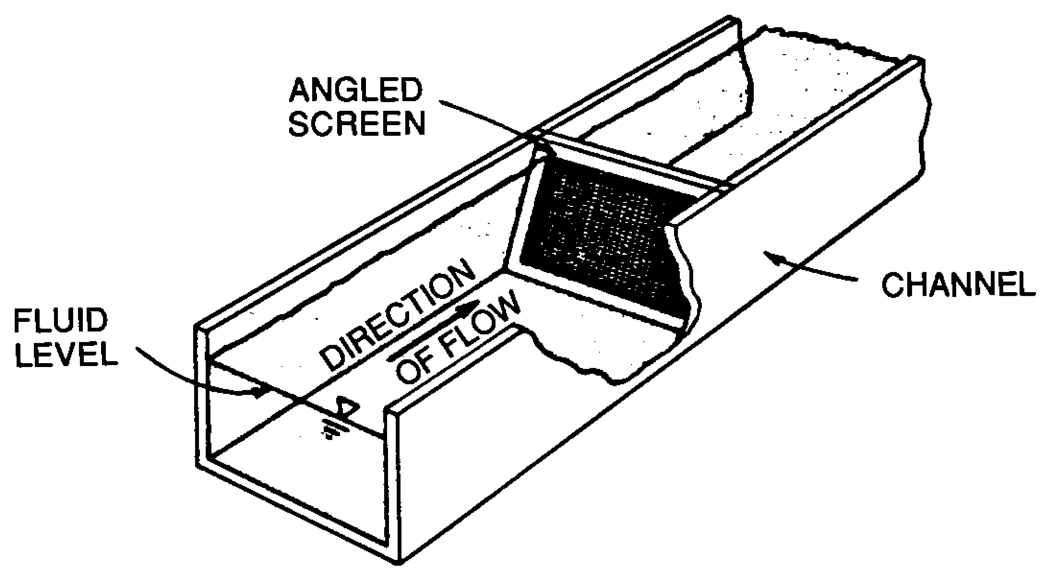

Figure 4.4 Simple Static Inclined Screen (11).

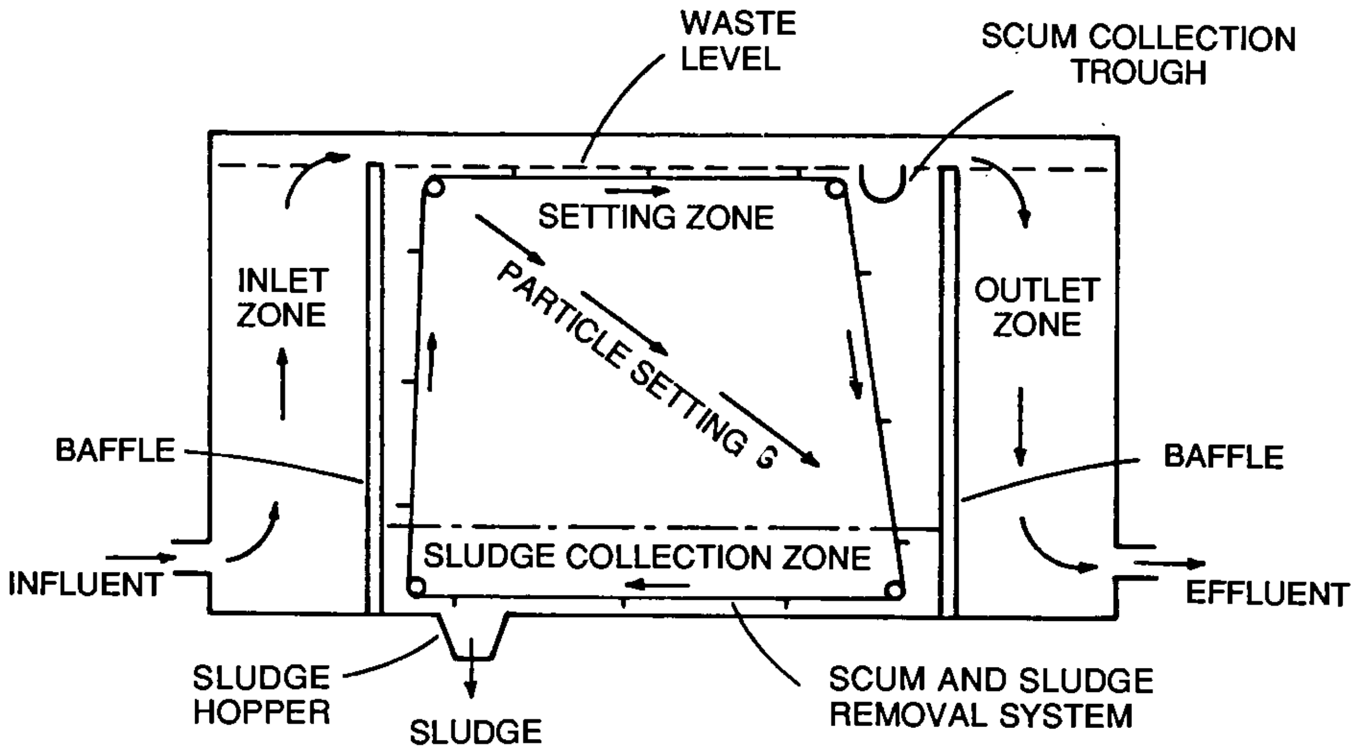

Figure 4.5 Typical Components of a Sedimentation Basin (12).

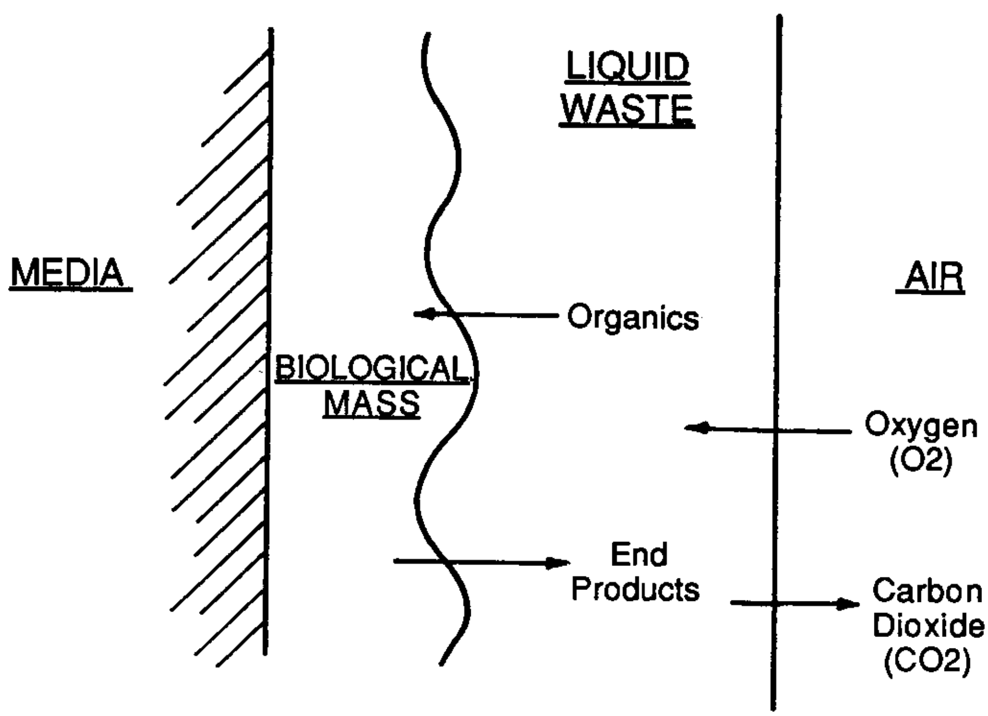

Figure 4.6 Process Details of the Biological Degradation of Organic Liquid Waste (12).

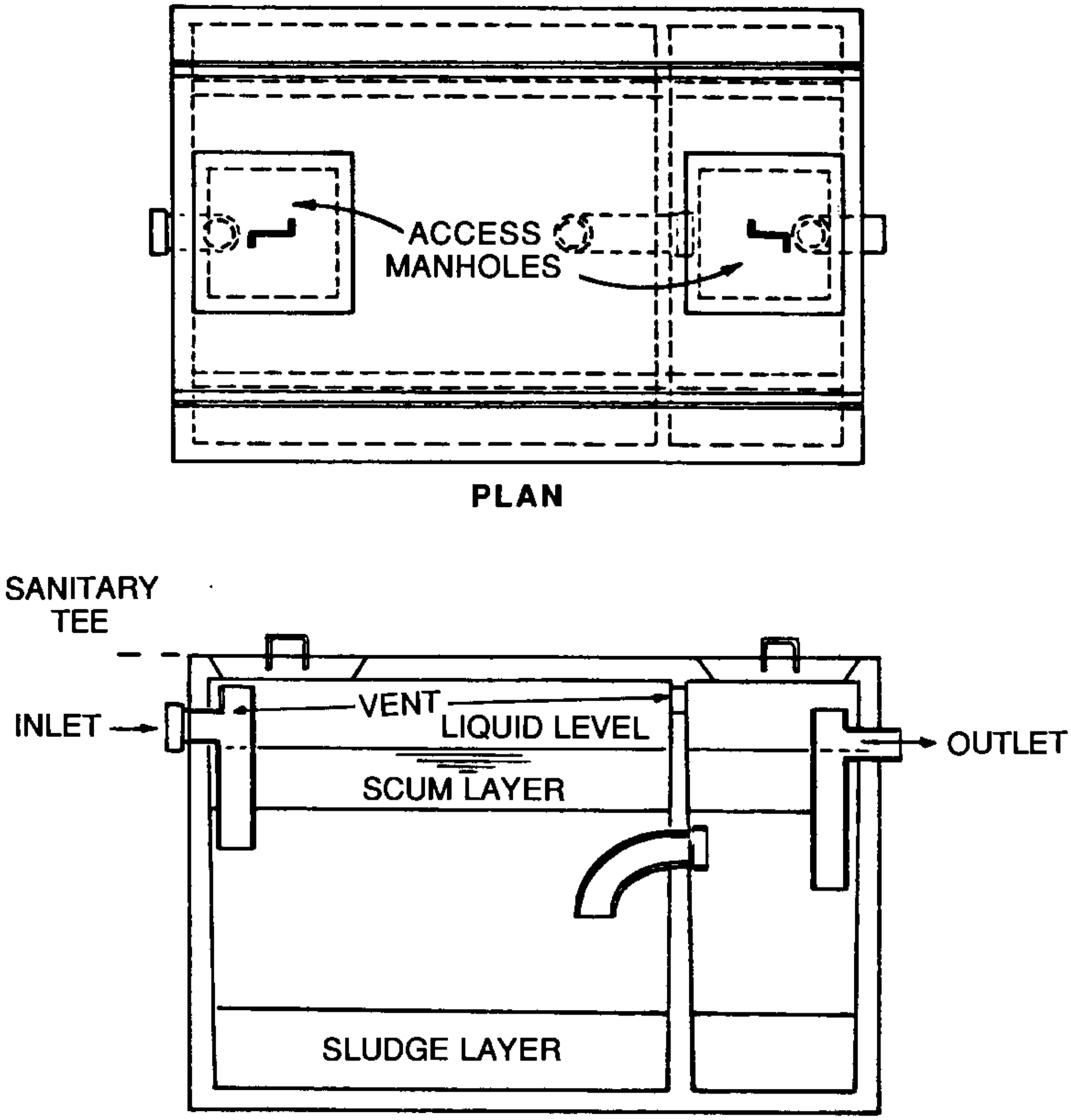

Figure 4.7 Plan and Side View of a Dual-Compartment Septic Tank (13).

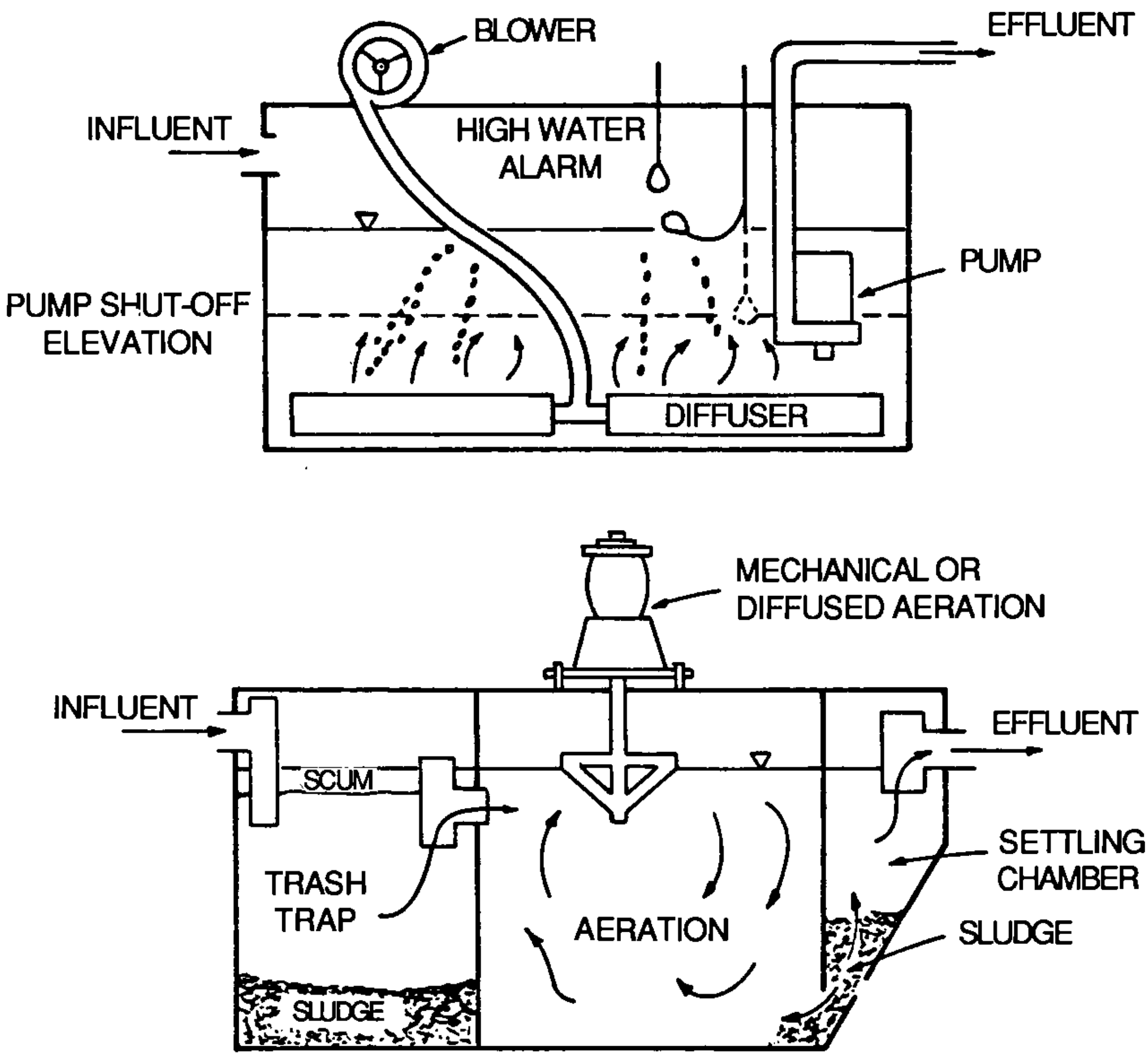

Figure 4.8 Two Types of Activated Sludge Systems:
(a) Diffused Air and (b) Mechanically Mixed (13).

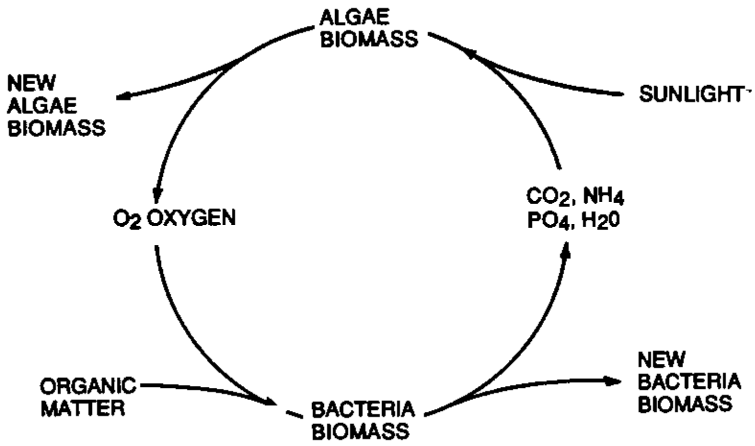

Figure 4.9 Interaction of Algae and Bacteria in a Facultative Wastewater Stabilization Lagoon (12).

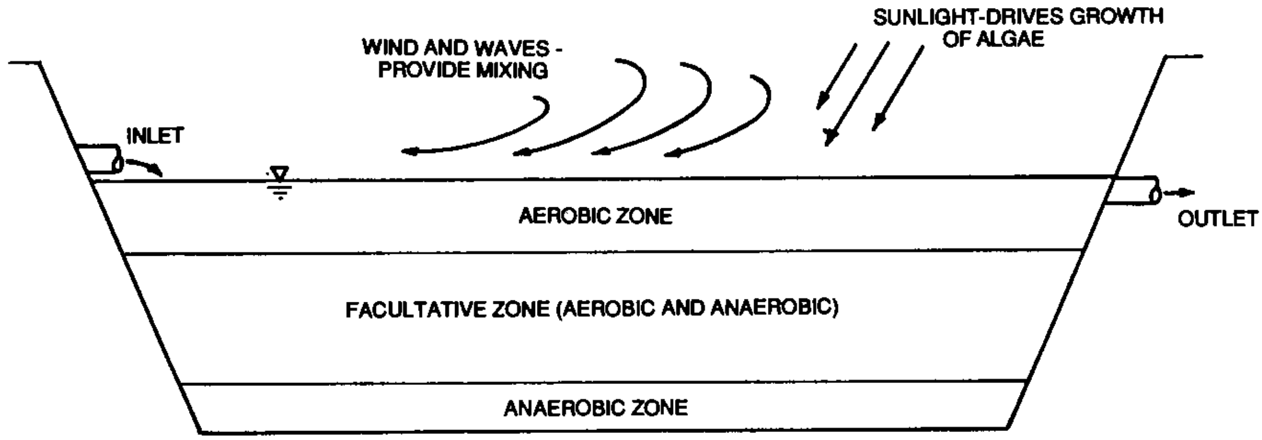

Figure 4.10 Process Diagram of a Facultative Wastewater Stabilization Lagoon.

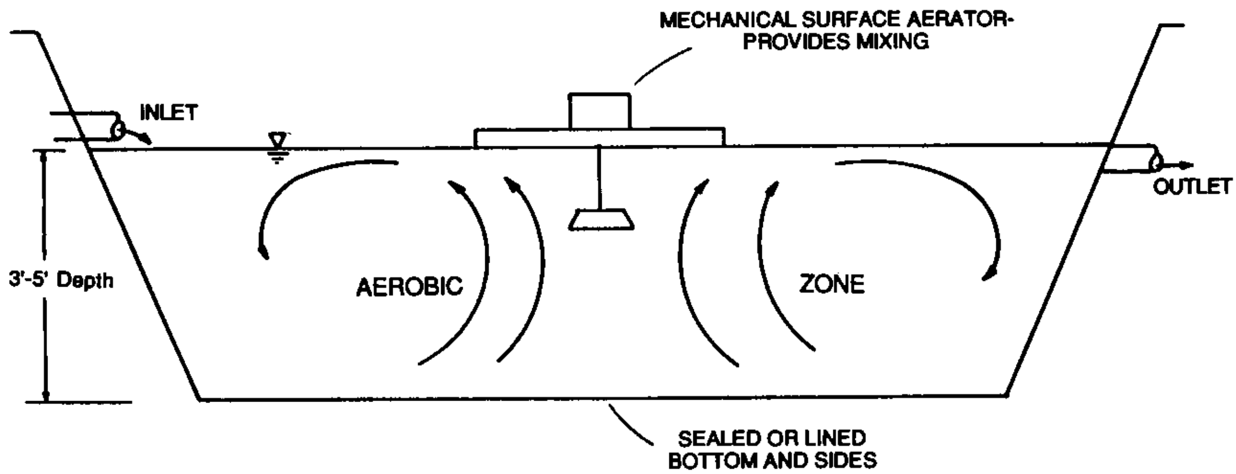

Figure 4.11 Process Diagram of an Aerated Wastewater Stabilization Lagoon.

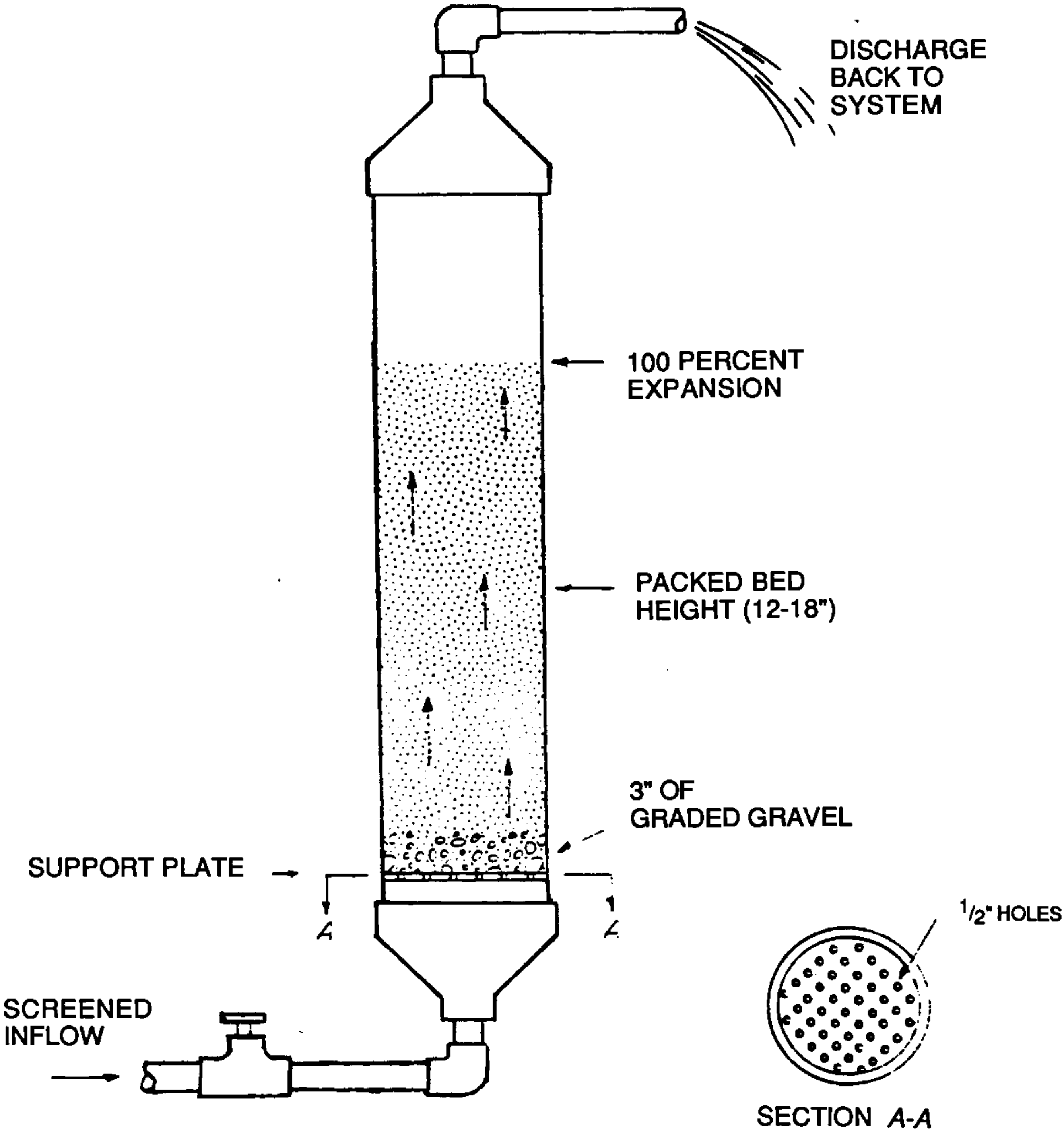

Figure 4.12 Biological Fluidized Bed.

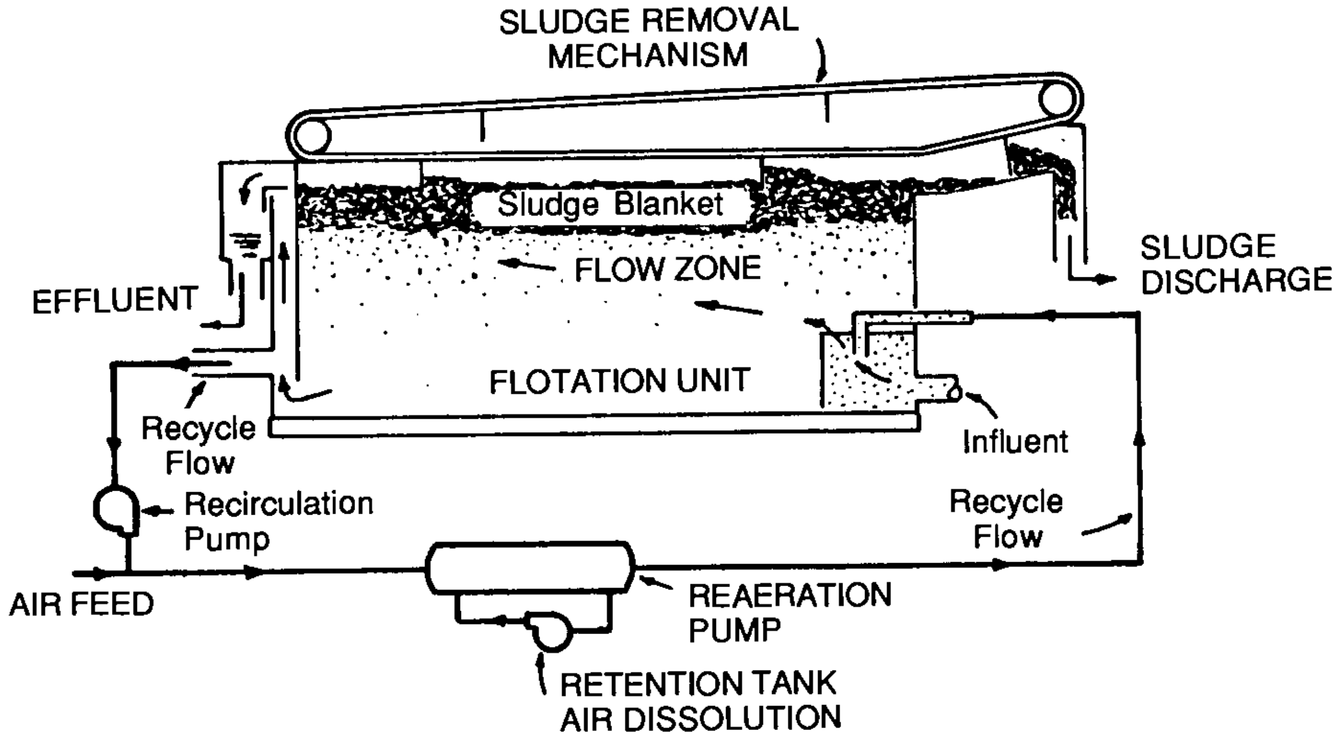

Figure 4.13 Process Diagram of a Dissolved Air Flotation (DAF) System (12).

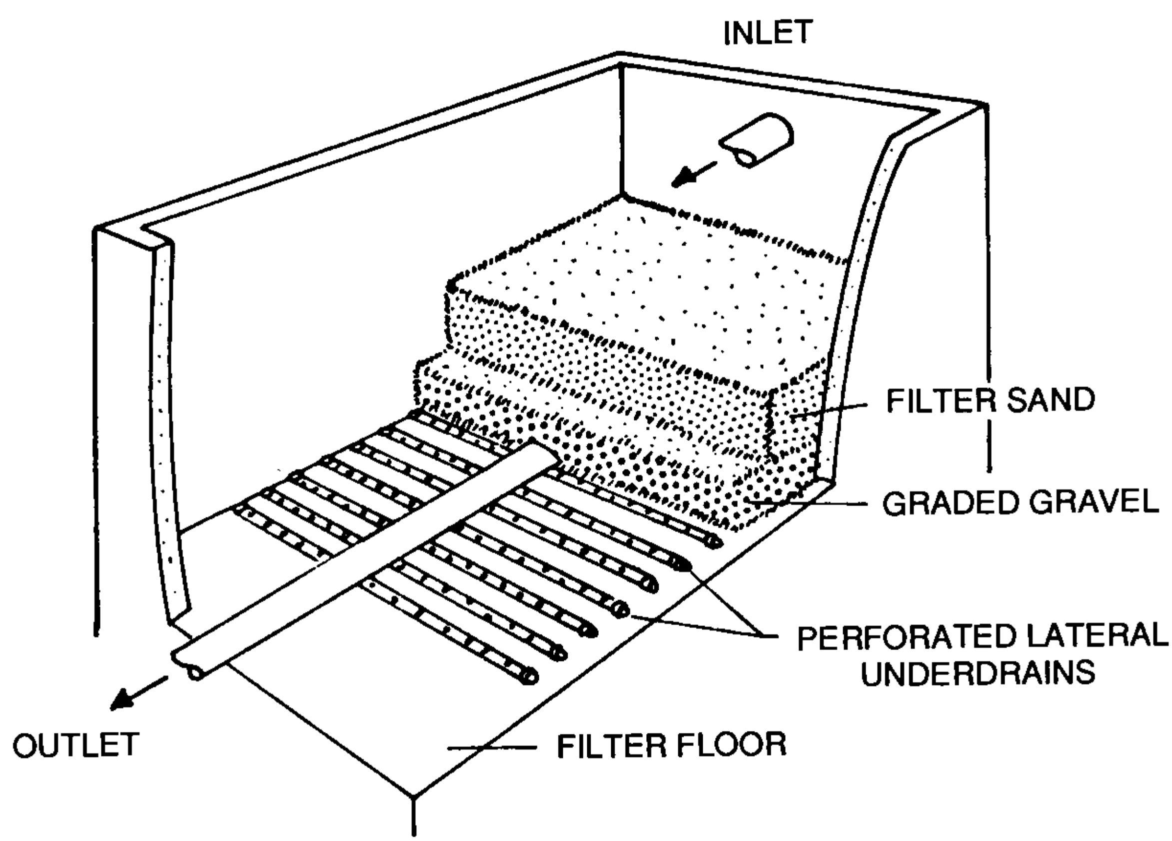

Figure 4.14. Process Flow Diagram of a Slow Sand Filter (12).

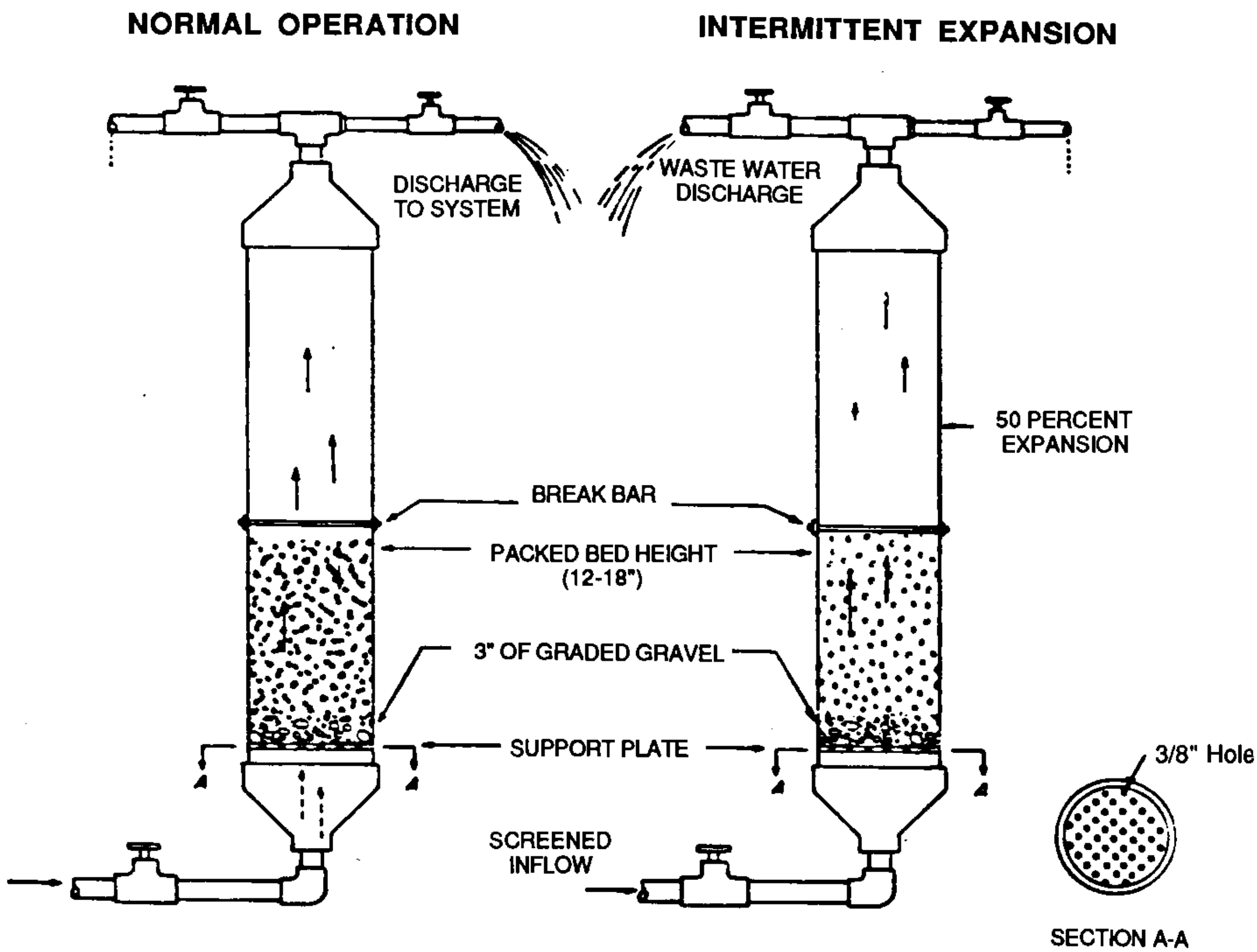

Figure 4.15 The Two Modes of Operation for a Pressurized Upflow Sand Filter Constructed from Common PVC Pipe and Fittings.

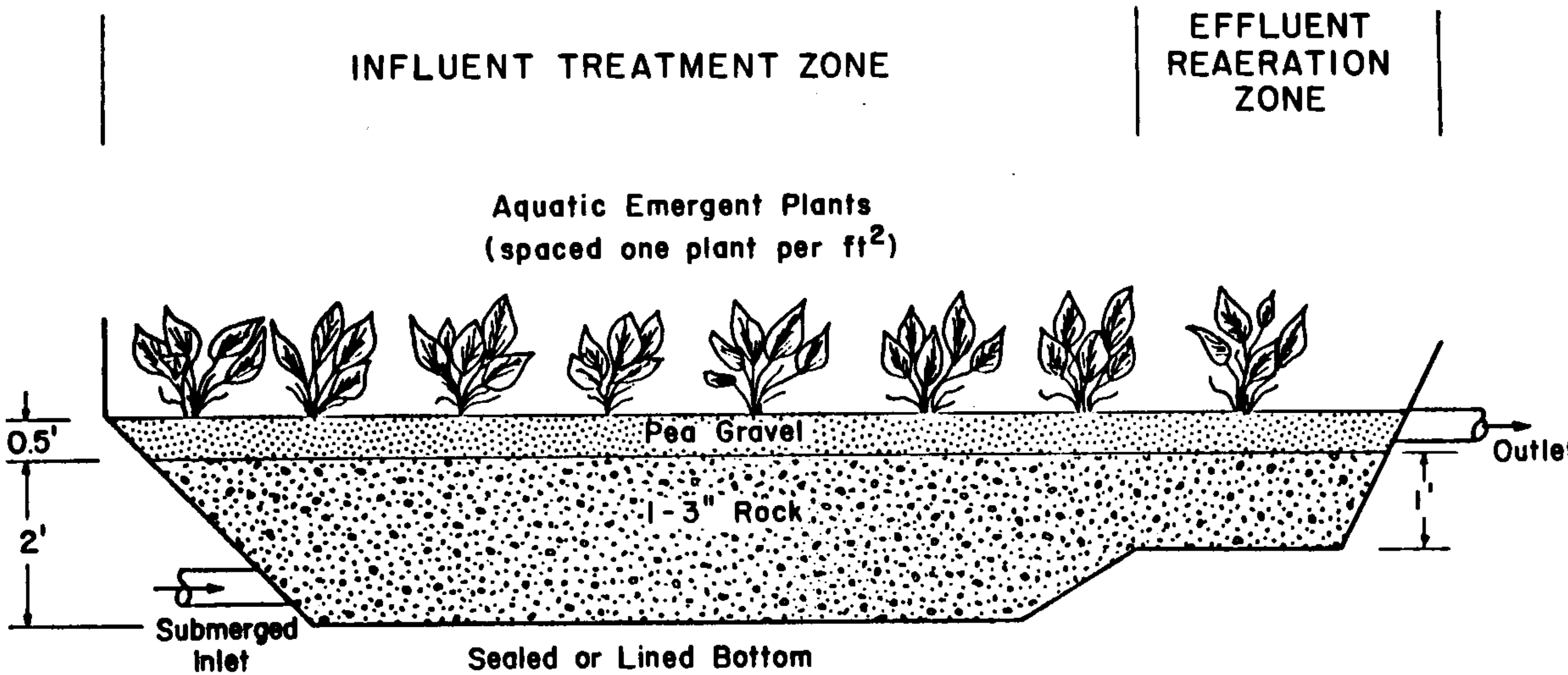

Figure 4.16 Process Flow Diagram of Constructed Wetlands System.

V. SHRIMP PROCESSORS

Processing

Shrimp are one of the major catches for Louisiana commercial fishermen. These shellfish are marketed in a variety of ways including fresh in the shell, frozen (raw or cooked), breaded, canned, cured, and as a specialty product.[11]

Shrimpers load their catches in the holds of their boats and pack them in ice. Once they have been brought ashore, shrimp should be put in a flotation tank to remove the packing ice. Afterward, they are sent through a rotary drum to remove excess water and debris.

The future of the shrimp is decided after they are weighed. Some are taken to be sold at markets and on the roadsides, some remain to be headed, and the rest go to the processing plant.

Heading

Shrimp are headed either manually or mechanically. Fishermen, if they are far enough from shore, may manually remove the heads from shrimp at sea and throw them overboard. To head a shrimp manually, one squeezes the shellfish just ahead of the tail with one hand, while twisting and pulling the head from the body with the other.

Mechanical headers use knives to cut off shrimp heads. These devices require the shrimp to be positioned correctly on a conveyance system, whereon a rotating knife or a guillotine-type cutter separates the head from the tail. This step is often part of the peeling process.

Peeling

Peeling means the removal of the shell from the shrimp. Most shrimp are mechanically peeled, although some are peeled manually in limited volume markets or in under-developed countries.[11] Machine-peeled shrimp are normally used for canning because they are more pale than hand-peeled shrimp and also have an inferior flavor and texture.

Typical peeling machines receive headed shrimp and singulate them, separate them into a one-at-a-time stream, before cutting the shells along the dorsal side next to the vein. The shrimp then pass over a bed of rollers that rotates or oscillates so that adjacent rollers rotate opposite one another. The meat is too thick to pass between the rollers which grip the shells and strip them away from the shrimp bodies. The meat continues on along the downward-sloped axes of the roller bed, where it is ready for the next process.

Deveining

The deveining process is usually the next step. This may be carried out by a separate machine or part of the peeler, depending on the size and species of shrimp and the machine manufacturer.[11]

One process removes the vein by washing it out after a cut has been made along the shrimp's back. Another process takes it out by passing a shrimp through a cylinder that rotates in water. The vein is removed as it passes through the drum where indentations on the side of the drum catch it and pull it out.

After peeling and deveining, the shrimp are washed and inspected. Once inspected, the shrimp are blanched in a salt solution for approximately 10 minutes and then dried and blown to remove excess water and shell particles.

Grading

Grading is the separation of items according to some established criteria. These standards may include size, weight, and quality. Quality can be broken down further into measures such as freshness, odor, firmness, physical damage, and deterioration. Shrimp are graded after they have been shelled, washed, and inspected.

Size grading is an automatic process that uses a screening principle. The shrimp are placed on top of a screen on which they remain, unless they are small enough to fall through. The devices may be stationary or vibrating horizontal screens, tumblers or other mechanisms. Sizing devices based on shrimp weight are also available, but a constant relationship between size and weight must be present and known.

Automatic weighing systems are readily available and widely used in the seafood industry. These systems are generally more accurate and require less labor than manual processes. This means automated weight grading systems operate are less expensive to operate. Manual systems, however, are used more frequently than automated systems when the weight of an item must be adjusted for a purpose such as packaging.

Quality is a grading criterium that cannot be tested easily by mechanical means. This means quality grading is primarily a manual activity. Although there are some instruments that will measure characteristics of quality, a worker must read the gauge and make the final decision. Quality selection is probably the most important criteria in the process to the consumer. It is one of the most costly and time-consuming aspects of the grading system.

Packing

After grading, the shrimp are ready to be packed for freezing or canning. Shrimp to be frozen are treated with an acid solution, usually citric. This treatment preserves the color of the shrimp which improves its appearance throughout its shelf-life. The acid treatment also reduces spoilage and may destroy viral and bacterial organisms on the meat's surface. It requires the shrimp to be dipped into an acid solution for 15-30 seconds at a temperature of 2-4 °C.[11]

Shrimp are among the most perishable food items. Care must be taken when freezing and storing the product. Shrimp should be frozen at -40 °C and maintained at -18 °C.[11] This practice will result in a shelf-life of up to 12 months after freezing.

The freezing process involves immersing the shrimp in a low temperature medium such as a brine solution, liquid nitrogen, or freon. The processor must be careful to make sure the package has a good moisture-vapor barrier. Shrimp that lose moisture during storage develop a disagreeable odor and flavor and are tough after cooking. Some shrimp are breaded before freezing.

Batter and Breading

Shrimp are battered with a viscous coating to prepare them for breading. A good batter should coat the product with a uniform thickness. It should not distract from the meat's flavor, and must be capable of holding the breading.

Specialized companies prepare most batter mixes. Batters usually consist of base materials like corn flour, cornmeal, and non-fat dry milk solids. The dry batter ingredients must meet the requirements of the product manufacturer before they are bagged and shipped to the breading plant, where they are mixed with water to form the batter.

Most of the batter application process is automated. The shrimp are spaced manually or automatically on a conveyor chain to provide a large amount of open area. The conveyor passes over a plate that contains a pool of batter to coat the bottoms of the meats.

Next, the shrimp pass under a falling film of batter to coat their tops and sides. They travel on for a short time to drain off the excess batter. The excess batter recirculates to the pool. Recirculation keeps the batter solids suspended and the viscosity constant.

Breading is the addition of a dry granular or particulate compound to the batter-coated raw product. The breading provides taste, texture, and (after cooking) color. Breading shrimp helps provide a more competitive price by reducing the amount of meat required to reach the fixed weight of the final product.

The breading cascades over the battered shrimp or is rolled or pressed on to guarantee adherence. The conveyor vibrates to remove the excess. In some plants, the shrimp fall a few centimeters to a second conveyor to free loose breading.

The type of breading used depends on the flavor, texture, color, and taste desired. Cornmeal-based breading is golden yellow in color after cooking; bread-crumb-based is reddish brown; and wheat-cereal-based is a golden brown. Particle size and porosity are also factors since they influence oil-absorption and texture. The battered and breaded shrimp are packed and frozen for shipping.

Canning

After peeling and deveining, canned shrimp are peeled and deveined before they are boiled in hot brine for about four minutes. The shrimp are inspected and graded according to size. Most canned shrimp products are marketed according to size. Common size grades include tiny, small, medium, large, jumbo, and colossal.

The processor removes broken shrimp for separate sale and either wet- or dry-packs the intact shrimp. A hot saline solution both preserves and enhances the flavor of wet-packed shrimp. The cans are automatically vacuum-sealed and retorted (pasteurized). The cans must be retorted under conditions at least equivalent to 4 minutes at 120 °C or 10 minutes at 115 °C. The cans are cooled and washed before labelling, boxing, and shipping to market.

Waste Generation

Mechanical peeling and handpicking shrimp are two very different processes in terms of water use and the amounts and strength of wastewater generated. The LDEQ recognizes separate standards of performance regulations for these operations.

Mechanical Peeler

Figure 5.1 displays a process flow diagram for waste generation. This diagram does not show heading, although it is a common process in many peeling operations. Shrimp heads take up to 45% by weight of the whole raw shrimp. On-site heading can add significant waste loading and flow to the waste stream.

Wastes generated by mechanical shrimp peeling operations contain
initial wash water with fine sand, grit, rocks, bacterial solids, shrimp heads, shrimp meat, shells and shrimp heads; peeling, deveining, and heading process water with viscera, shells, shrimp heads, and bacterial solids; and final wash water with shells and waste meat.

Other miscellaneous shrimp plant processes include grading, packing, chemical treatment, retorting, cooling, wash down, and breading. Most of these use water for conveyance of the product and wastes.

The peeling machine accounts for a least 70% of the water used in the peeling facility.[17] The Latrium Model A peeling machine (manufactured by the Latrium Machine Company of New Orleans) requires a water supply of about 7.6-10.1 l/sec (120-160 gpm). Separators, heading machines, chemical treatments, cooking, and raw washing all require additional water use.

One Mississippi peeling operation with in-plant raw wash, cooking, packaging, and three operating peelers can produce nearly 37.9-56.8 l/sec (600-900 gpm) of wastewater.[15] If this plant operated two shifts of nine-hours per day, it would put out an estimated wastewater flow of 2,453-3,679 m^3/d (648,000-972,000 gpd).

Since the automatic peeling process does not recycle water, the raw water use is about the same as the wastewater generated. The estimated flow of waste created from a typical Gulf Coast peeling machine (Latrium Model A) processing 498.3 kg (1,100 lbs) heads-on shrimp/hr for eight hours is 286.5 m^3/d (75,680 gpd).[18] Other, more indirect, estimates of the wastewater flow rates generated by a single peeling machine show a much lower flow of only 61.3 m^3/d (16,200 gpd).[16]

Peeling machines contribute the significant waste load to the final discharges of shrimp processing plants. Mechanical peeling wastes approximately 78-85% (by weight) of the whole shrimp.[19] A peeling machine produces about 72% of the BOD_5 and 68% of the total suspended solids (TSS) load in a plant's waste stream.[17]

The chemical composition of mechanically-peeled shrimp waste is about 22% protein, 42.3% chitin, and 35.7% calcium carbonate. Peeling machine effluent has concentrations of BOD_5, total organic nitrogen (TON), and percent-recoverable net solids of 2050 mg/l, 229 mg/l, and 1.55%, respectively.[18] BOD_5 and TSS measured for the whole facility flow have ranged from 1000-1800 mg/l and 400-800 mg/l, respectively.[17]

Analysis of individual waste flows from peeling facilities shows that peeling, deveining, blanching, receiving, raw washing, and miscellaneous flows contribute 72%, 7%, 2%, 10% and 9%, respectively, of the BOD_5. The same factors also respectively contribute 68%, 12%, 5%, 6%, and 9% of TSS.[17]

Handpicking

Handpicking is by far the most common Louisiana shrimp processing operation. These facilities can be large, processing about 1,000 pounds daily; or they can be small, producing less than 500 pounds of peeled shrimp daily.

Estimates indicate that handpicking wastes about 77-84% of shrimp by weight.[19] Shrimp waste from handpicking operations reportedly is composed of 27.2% protein, 57.5% chitin, and 15.3% $CaCO_3$. Actual wastewater characteristic data is difficult to use because of the great variability of operations.

Figure 5.2 displays a typical flow diagram for a handpicking shrimp processor. This diagram does not indicate any initial washing or heading that may take place on the boat. For whole shrimp processors, heading and rough washing can produce large quantities of water that contains shrimp heads, shells, dead animals, viscera, and fragments.

Handpicking yields shells and related fragments, and it uses much less water than does mechanical peeling. Blower operation generates separated solids from the picked tail meat, and the brine operation produces some wash water. Final cleaning and wash-down after packing, freezing, and casing is the only other source of waste created by this process. Wastewater produced from these operations can be highly variable in strength and quality, but its impact still is considerably less than that of a mechanical peeling operation.

Treatment Options

Mechanical Peelers

Table 5.1 shows the possible effluent limits and treatment train options available to Louisiana mechanical shrimp processors. A mechanical shrimp peeling operation generates high-flow, high-strength wastewater. This type of wastewater is the most difficult and expensive to treat because of its large hydraulic volumes and the high oxygen demand exerted by its BOD[5].

A mechanical peeler contributes more than 80% to wastewater flow and strength. This means in-plant water conservation efforts to separate solids and decrease washwater use will have a limited impact on wastewater generation in such an operation.

We will consider here two scenarios for possible treatment trains. The first is a low-tech, low-energy, high-land-area train, and the second is a high-tech, high-energy, low-land-area requirement train.

A low-tech approach might make use of an aerated lagoon to provide roughing of the high-strength wastewater. It could provide further treatment through facultative lagoons with sufficient detention time to collect and degrade solids and remove soluble BOD_5. Polishing would have to be performed by means of a rock-reed filter or sand filter for this method to meet even a 30/30 effluent limitation.

A more compact high-tech approach could incorporate solids separation and washwater reduction in the plant followed by a treatment train. This train would include mechanical screens, sedimentation, trickling filters, extended air activated sludge, rapid sand filtration, and biological nitrification.

We have examined several wastewater methods in regard to their applications to seafood processing wastewater. Most of these procedures have focused on the removal of TSS through the use of simple sedimentation, hydrocyclones, simple screens, and enhanced settling done by means of polymers or chitsan additives.[19,20,21] They have been demonstrated to remove up to 85-90% of the TSS concentrations. This research concentrated on the combined mixed wastewater and did not address either the effect treatment or reuse of individual waste streams.

Other methods of wastewater treatment, such as activated sludge and waste stabilization lagoons, have proven effective also for crab processing wastewaters, which are similar to shrimp peeling wastes.[23] Apparently these systems are not in wide use because of the seasonal nature of shrimp peeling operations, the high flow and strength of the wastewater, and the high costs for land and operation of these systems.

A 1987 EPA study shows modified marsh or wetlands treatment systems can be effective in removing BOD_5 and TSS from shrimp processing wastewater. Other studies advocate carrying out dry clean-up techniques in combination with screening to reduce TSS and BOD_5 concentrations in mixed shrimp processing wastewater.[22] Most of these methods involve radical changes in processing technique or are not directly applicable to mechanical shrimp peeling operations. Simple in-house process modifications apparently hold the most promise for reductions of water use and wastewater generation.

Handpicking

Wastewater generated from handpicked shrimp operations is typically low-flow and moderate-strength. In-plant modifications to reduce washwater use and separate solids can reduce discharge characteristics significantly. These wastewaters often are treated by means of technologies with lower energy requirements.
Table 5.2 suggests some possible treatment trains that can be used to meet various effluent limitations. It presents both a low-tech, low-energy plan and a high-energy, high-tech approach.

Table 5.1 Possible Wastewater Treatment Trains for Mechanical Shrimp Peeling Processors Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	None	None	Aerated lagoon	Facultative lagoon	Rock-reed filter
	Solids separation	Sedimentation	Trickling filter	Extended air activated sludge	None
20/20	Solids separation washwater reduction	Mechanical screens	Aerobic lagoons	Facultative lagoons	Rock-reed filters
	Solids separation washwater reduction	Mechanical screens and sedimentation	Trickling filters	Extended air activated sludge	Sand filter
10/10/5	Solids separation washwater reduction	Mechanical screens	Aerobic lagoons	Facultative lagoons	Rock-reed filters slow sand filters
	Solids separation, washwater reduction	Mechanical screens and sedimentation	Trickling filters	Extended air activated sludge	Rapid sand filters and nitrification
5/5/2	Solids separation, washwater reduction	Mechanical screens	Aerobic lagoons	Facultative lagoons	Rock-reed, slow sand filters and nitrification
	Solids separation, washwater reduction	Mechanical screens and sedimentation	Trickling filters	Extended air activated sludge	Rapid sand filters and nitrification

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

Table 5.2 Possible Wastewater Treatment Trains for Hand Pick Shrimp Processors Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	Solids separation	Simple screens	None	Septic tank	Rock-reed filter
	None	None	None	Facultative lagoons	Rock-reed filter
	None	Sedimentation	None	Extended air activated sludge	None
20/20	Solids separation	Simple screens	None	Facultative lagoons	Rock-reed filters
	Solids separation washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed filter
10/10/5	Solids separation washwater reduction	None	None	Facultative lagoons	Rock-reed filters, slow sand and nitrification
	Solids separation, washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Sand filters and selective ion exchange
5/5/2	Solids separation, washwater reduction	None	None	Facultative lagoons	Rock-reed filters, slow sand and nitrification
	Solids separation, washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed and sand filters, and selective ion exchange

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

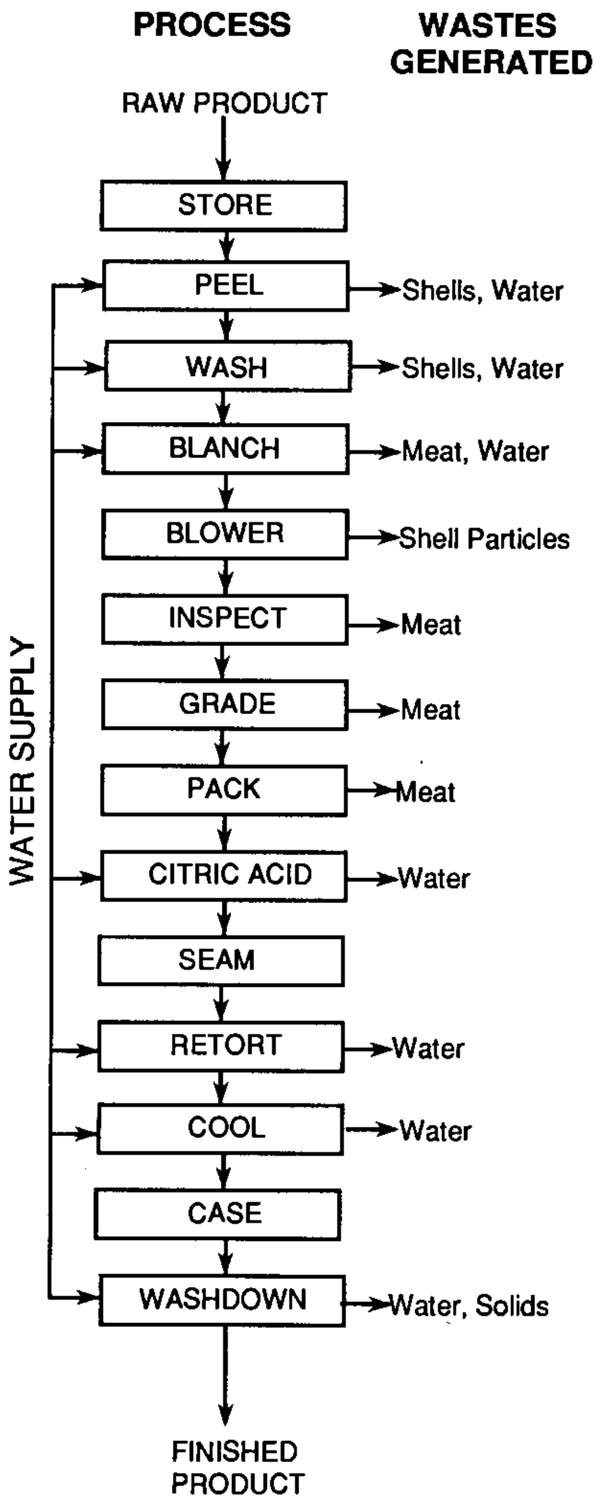

Figure 5.1 Process Flow of Waste Generated from a Mechanical Shrimp Peeling Operation (19).

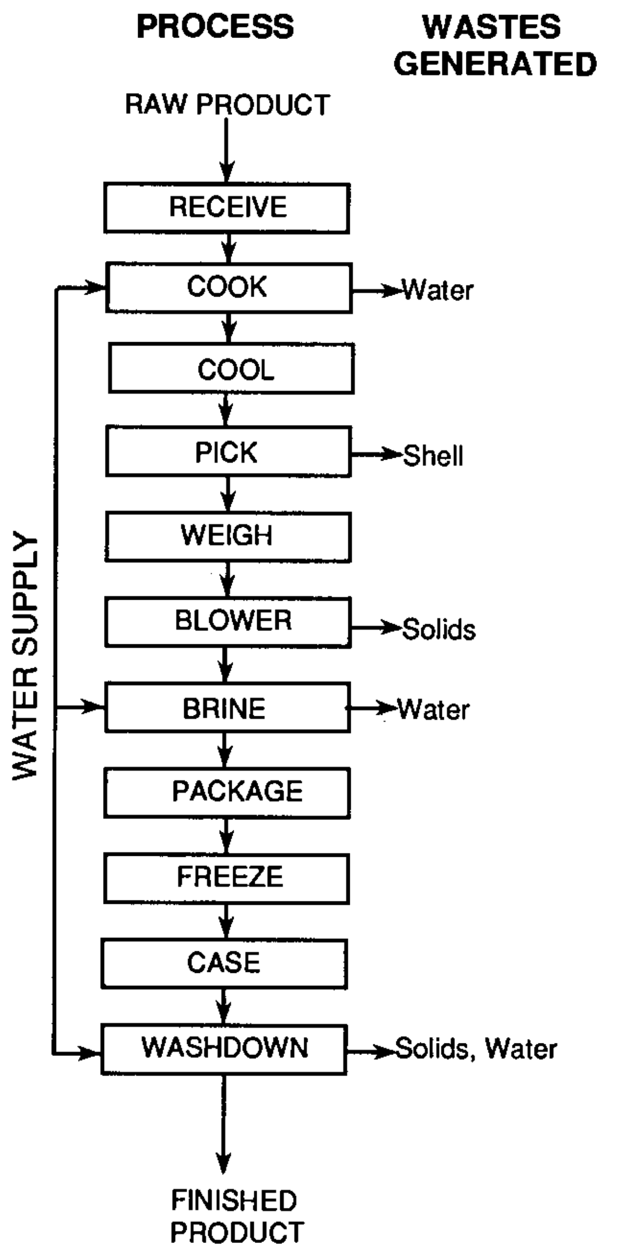

Figure 5.2 Process Flow of Waste Generated from a Hand Pick Shrimp Processing Plant (19).

VI. OYSTER PROCESSORS

Processing

Louisiana oysters typically are sold either shucked or in-the-shell. Shucked oysters can be processed further into canned or breaded and frozen products. No matter how the oysters are sold, the processing steps are similar and sequential. Figure 6.1 shows a generalized process flowsheet.

Washing

Unshucked oysters undergo very little processing. They are washed to remove slime, accumulated surface bacteria, dirt and fouling organisms. After washing, oysters to be sold unshucked are packed and chilled. They are sent to wholesalers or directly to retailers and restaurants.

Oyster cleaning operations use potable water. Rotary washing systems and a strong water current circulating tank can be used. Three common types of oyster washers are the tumbler, the pressurized spray, and the brush.

A tumbler washer is a standard type of rotary washer[11]. It has a cylindrical drum of expanded metal that rotates while either completely or partially submerged in water. The interiors of these washers are generally smooth with baffles. The operator must be careful that the oysters are tumbled and not dropped where the shell and meat can be damaged.

Of the other oyster washers used in Louisiana, the pressurized spray washer requires the unshucked oysters to be placed on a conveyor belt and sprayed from above and below. The brush washer has a bed of brushes supporting the oysters. Water is sprayed down on the oysters, and the brushes provide a scrubbing surface.

Shucking

Shucking is the separation of the oyster's meat from its shell. Shucked oysters are graded by hand according to such criteria as size, weight, quality, freshness, firmness, color, odor, physical damage, and deterioration. Oysters are shucked once they have been graded.

Shucking is usually a manual task. An experienced shucker averages one oyster every 7.8 seconds, making it a high cost operation[11].

Manual shucking techniques vary according to species, geographical location, and shucker preference. The general procedure begins with the shucker picking up a single shellfish in one hand and holding it down on a shucking block or table.
He forces a special knife between the shell halves with the other hand and severs the muscle attachment carefully so as not to damage the meat. Next, he severs the hinge and discards the loosened top shell. After cutting the remaining muscle attachment, the shucker removes the meat and discards the shell.

Automatic shuckers are used to prepare oysters as cooked or partially cooked products. There is no automatic shucker that can produce raw oyster meats. Cooking the oysters reduces the meat volume and weakens or severs the shell-meat bond.

Heating the oysters through the steam-and-shake process is more common than either cooking or shucking, since it will produce a cooked product in fewer steps. The oysters are retorted for about 15 minutes at 120 °C. During this step the oysters lose 65% of their weight in water loss. Then the meats are removed from their shells in the tumbler. The tumbler exterior contains holes to allow the meats to drop out while retaining the shells. The shells are removed through the end of the cylinder. Oyster shells, as a by-product, are used as road building materials or as beds for oyster spat setting.

Blowing

After shucking, the oysters are cleaned of debris through a blowing process. The meats are placed in a tank of water suspended on a perforated plate. Compressed air is blown from below providing rapid circulation to remove shell chips, sand, and other debris. Since this process uses fresh water, the oysters absorb some water. This adds to their weight and reduces salinity. Legal limits are set on blowing time[11].

The oysters are sized and graded after blowing. This is usually done manually. Most oysters are packed at this point in tins or glass jars, but others are battered and breaded. The process for battering and breading oysters is the same process described in Chapter 5 for shrimp processing.

Wastewater Generation

Figure 6.1 shows wastewater generated by oyster processors. About 75% of an oyster's weight (including the shell) is waste.[19] The major sources of waste are shells and washwater. The shell material is a valuable by-product. It is used for road building material and as spat habitat for managed oyster culture beds. The washwater is the main source of wastewater and contains grit, suspended solids, viscera, and shell fragments. Table 6.1 illustrates typical wastewater characteristics.

Wastewater Treatment Options

Table 6.2 shows the wastewater treatment options available to oyster processors for meeting various effluent limitations. The data in Table 6.1 makes the point that a great deal of variability exists for oyster wastewater characterization data. This wastewater usually is considered a moderate-flow, low-strength waste.

In-plant washwater reduction and solids separation techniques would be very effective means for reducing wastewater flow and strength. Table 6.2 illustrates possible wastewater treatment trains for oyster processors.

The low-tech approach for wastewater treatment includes facultative lagoons and rock-reed filters. The high-tech approach uses simple screens, sedimentation, and conventional activated sludge. For more stringent effluent limitations, the low-tech approach recommends aerobic lagoons followed by rock-reed filters. The high-tech approach employs extended air activated sludge and polishing by rock-reed filters, slow sand filters, and nitrification.

Table 6.1 Raw Wastewater Characteristics for Oysters Processors (17).

Flow m^3/day	BOD_5 mg/l	COD mg/l	TSS mg/l	Oil/Grease mg/l
53 - 1215	250 - 800	500 - 2000	200 - 2000	10 - 30

Table 6.2 Possible Wastewater Treatment Trains for Oyster Processors Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	Solids separation	None	None	Facultative lagoon	Rock-reed filters
	Solids separation	Sedimentation	None	Conventional activated sludge	None
20/20	Solids separation and washwater reduction	None	None	Facultative lagoon	Rock-reed filters
	Solids separation and washwater reduction	Simple screens and sedimentation	None	Conventional activated sludge	Rock-reed filters
10/10/5	Solids separation, washwater reduction	None	None	Aerobic lagoon	Rock-reed, slow sand filters and nitrification
	Solids separation, washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed, slow sand filters and nitrification
5/5/2	Solids separation, washwater reduction	Simple screens and sedimentation	None	Aerobic lagoon	Rock-reed, slow sand filters and nitrification
	Solids separation, washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed, slow sand filters and nitrification

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

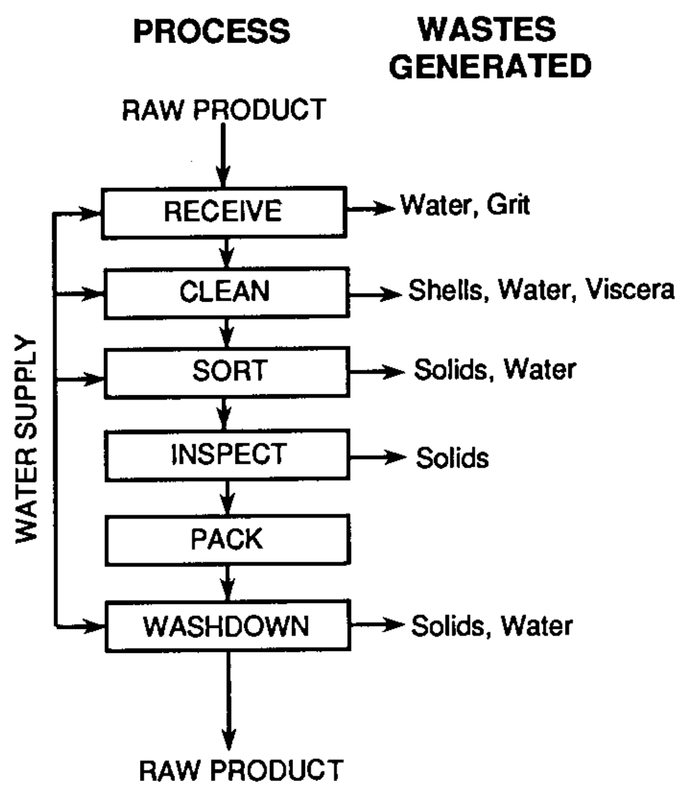

Figure 6.1 Process Flow of an Oyster Packing Operations (19).

VII. BLUE CRAB PROCESSORS

Processing

All blue crabs go through some degree of processing since they never are eaten raw. Raw crab meat may carry bacteria harmful to humans when consumed.

Crabs are sold in five forms. These include uncooked hard crabs, cooked hard crabs, picked fresh meat, picked pasteurized meat, and soft-shelled crabs. Uncooked hard crabs generally are sold by the pound either before or after washing.

Most crabs are processed by hand instead of by mechanical means. Crabs usually are washed with potable water and then sold live to prevent bacteria produced by dead and decaying animals. A generalized flowsheet for crab processing appears in Figure 7.1.

Cooking

The crabs are cooked in a retort. The retort, a pressure vessel, is filled with water or steam for 20-30 minutes. When cooking live crabs, the temperature must be high enough to cook the product in a moist environment. The standard pressure for cooking blue crabs is generally between 30-140 kPa.[11] The product either may be sold after cooking or submitted to further processing.

Picking

Crabs are picked after they are cooked. Picking involves the removal of the meat from the crab body (picking also pertains to shrimp heading and peeling). Most commercial operations pick their crabs by hand.

The cooked crabs are placed in a cold room overnight and before going to the picking table. The picker's first step is to break off the crab's appendages and throw away all but the claws. He removes the shell and discards the viscera.

The picker slices the body in half from front to rear and makes a second cut to expose the lump meat. The lump meat comes from the large muscle area where the swim fins meet the body. It is the most valuable part of the crab, and pickers take care to remove it without breaking it apart. A third cut exposes the flake meat and the muscle tissue of the legs other than the swim fins. The picking knife tip removes the flake meat which goes directly into containers to be packed. The processor then discards the remainder of the crab's body. The pincher claws are cracked open last, and the meat is removed. Claw meat is less valuable than lump meat because it is darker.

Mechanical pickers generally require removal of the crab's viscera and legs before processing. The picker cuts the crab body and removes the center shell membrane.

The core halves are placed manually in the picking machine head, which holds each in place. The machine head is loaded into the picker where it rotates. Centrifugal force throws the lump crab meat out. A wiper inside the picker then scrapes the meat into a pan under the chute. Once the lump meat is out of the shell, the picker automatically shifts to a higher rotating speed to pull the remaining flake meat from the crab core. The machine automatically changes the pan that collects the crab meat.

Processors also use two less-common automated pickers. One applies a controlled vacuum and pressurized water to force the meat out of the body. The second, and newest method, uses cooked crab cores from which the viscera, legs, and back shells have been removed. This machine vibrates at a speed of 3,000-4,000 cycles per minute with an amplitude of approximately 2.5 cm.[11] The meat falls from the shell and goes into packing containers.

If the crab pincher claws are mechanically picked, a Harris Crab Picker is used.[11] The Harris Crab Picker can handle cooked, whole eviscerated crabs or crab cores. The claws pass through a hammer mill that grinds them. The grinds go into a brine tank, where the crabmeat floats, and the shells sink. The meat is skimmed off the top, and the shells are removed from the bottom. Although this device can process crab cores, its disadvantage is that the lump meat will be broken up.

Packing

After picking, crabmeat is stored in retail containers, usually parchment-lined cans or "C" enamel cans. The meat then is either sold or pasteurized to extend its shelf life. Pasteurization takes place in the retort. At atmospheric pressure, 85-87 °C water brings the internal temperature up to 85 °C for at least one minute to kill bacteria.[11] The cans cool after pasteurization in a water bath for two or three minutes. They are reduced to a temperature of 37.8 °C within 45 minutes. The product then may be packed in shipping cartons and distributed within 24 hours.

Cans of crabmeat ought to be turned over every two weeks to prevent drying and flavor loss. A disadvantage of canning is that additives or a pH change must be administered prior to the process or the meat eventually will discolor.

Soft-Shelled Crabs

The Louisiana soft-shelled crab industry recently has begun to develop into a major player in the national market. This sector continues to grow and is expected to become an important part of Louisiana's overall seafood processing industry. The success of soft-shell processing in Louisiana is attributable in part to the development of closed recirculating shedding systems that are economically, environmentally, and technically sound.[24]

Crabs shed their shells when they outgrow the old ones. The new shell is soft for a brief period, when most of the animal is edible. The Louisiana soft-shelled crab business, basically a cottage industry, depends on harvesting the animals before their shells harden.

When crabs are ready to molt their shells they are called peelers.[25] The coloration of the line inside the last two segments of the paddle fins identify peelers. This area normally is white but turns pink about a week before shedding. The fins turn bright red two or three days prior to shedding. Peeler crabs instinctively move to shallow water. Since molting crabs lose most of their strength, they are easy to catch.

Processors grade soft-shelled crabs by size (point to point). The crabs are wrapped individually and frozen. Most soft-shelled crabs are sold frozen, since fresh shells quickly harden.

Wastewater Generation

Figure 7.1 shows the sources of wastes for a typical crab canning operation. About 86% by weight of the blue crab is considered waste in processing.[19] Although this waste includes viscera, gills, meat and grit, it is made up mostly of shell fragments.

Wastewater generates from the large volumes of process water, retort water, wash-down water, and non-separated solid wastes. Table 7.1 describes the characteristic wastewater of a typical conventional (manual) blue crab picking plant.

Wastewater Treatment Options

The wastewater generated by a handpicked crab operation is typically low-flow and high-strength with high levels of oil and grease, ammonia, and TSS. Its low flow inhibits low-tech approaches for treating this wastewater to aerobic lagoons.

Reduction can greatly affect all waste parameters in plant separation of solids and washwater. Segregation of cooking water would help reduce oil/grease and BOD_5.

Table 7.2 presents possible treatment trains for manual crab processors. Three approaches are offered. The first is a low-tech approach that uses aerobic lagoons and rock-reed filters to meet the 30/30 limitations. For more stringent standards, sand filtration and nitrification are added to remove BOD_5, TSS, and ammonia.

The other two techniques are both more high-tech and compact than the low-tech method. One approach involves sedimentation followed by application of extended air, activated sludge, and rock-reed filtration. More stringent standards for this method require sand filters and nitrification to be used for polishing. The third approach uses sedimentation followed by or combined with dissolved air flotation and rock-reed filters. Again, more stringent standards require polishing steps to be included. The recommended polishing steps are rapid sand filtration and selective ion exchange.

Table 7.1 Raw Wastewater Characteristics from a Manual Blue Crab Picking Plant (12).

Flow m^3/day	BOD_5 mg/l	Ammonia mg/l	TSS mg/l	Oil/Grease mg/l
2.52	4400	50	620	220

Table 7.2 Possible Wastewater Treatment Trains for Hand Pick Crab Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	Solids separation	Simple screens	None	Aerobic lagoon	Rock-reed filters
	Solids separation	Sedimentation	None	Extended air activated sludge	Rock-reed filters
	Solids separation	Sedimentation	None	Dissolved air flotation	Rock-reed filters
20/20	Solids separation and washwater reduction	None	None	Aerobic lagoon	Rock-reed and sand filters
	Solids separation and washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed and sand filters
	Solids separation and washwater reduction	Simple screens and sedimentation	None	Dissolved air flotation	Rapid sand filters
10/10/5	Solids separation, washwater reduction, water reuse	None	None	Aerobic lagoon	Rock-reed and slow sand filter and nitrification
	Solids separation, washwater reduction, water reuse	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed and slow sand filter and nitrification
	Solids separation, washwater reduction, water reuse	Simple screens and sedimentation	None	Dissolved air flotation	Rapid sand filters and selective ion exchange
5/5/2	Solids separation, washwater reduction	Simple screens sedimentation	None	Aerobic lagoon	Rock-reed, slow sand filter and nitrification
	Solids separation, washwater reduction	Simple screens sedimentation	None	Extended air activated sludge	Rock-reed and slow sand filter and nitrification
	Solids separation, washwater reduction	Simple screens sedimentation	None	Dissolved air flotation	Rapid sand filter and selective ion exchange

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

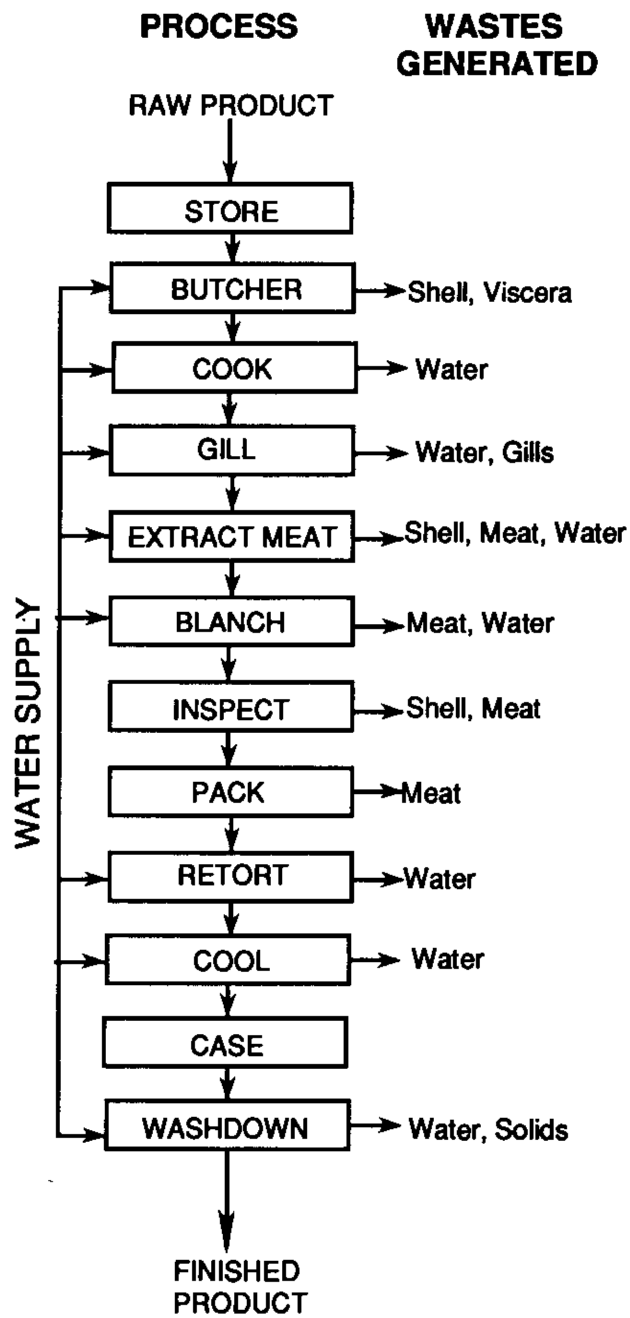

Figure 7.1 Process Flow of a Crab Canning Operation (19).

VIII. CRAWFISH PROCESSORS

Processing

Louisiana crawfish are marketed in a variety of ways. The most overwhelmingly popular method is live, unpurged crawfish. The other marketable forms include boiled, frozen whole, frozen tail meat in the shell, shelled frozen tail meat, vacuum-packed meat, and soft-shelled crawfish. The fat can be sold separately.

Live crawfish most often are sold in onion sacks. They can live up to five days in sacks stored in a cooler, although there will be a considerable depletion of their body weight. Some processors are experimenting with different containers for live crawfish.

Family farms sell some 15 million pounds or 56% of crawfish directly without any processing.[26] A generalized process flowsheet for crawfish is shown in Figure 8.1.

Purging

The bulk of the remainder of the crawfish are purged. This process entails holding crawfish in salted water for 24-36 hours.[11] Purging cleans out the crawfish's alimentary canal--the so-called black vein--for mostly aesthetic reasons. The crawfish either can be packaged at this point or frozen.

Cooking

Processors cook crawfish either by boiling or steaming. The most common treatment before further processing is freezing. Crawfish tails may be sold with or without the shell after the heads and thoraxes have been removed. Cooked crawfish sold in the shell are always frozen, while those sold without the shell may be either chilled fresh or frozen. Some 30% of the crawfish marketed in Louisiana are sold as fresh tail meat.

Picking and Packing

Most crawfish are picked manually by a procedure that snaps off the upper body and then squeezes out the tail meat. The tails are graded by size. All the fat must be removed from the cooked crawfish meat before it is frozen Crawfish tailmeat turns rancid within a few weeks if it is not washed before freezing.

The producer must be careful about the freezing procedure because the meat may turn black or blue if frozen incorrectly. It is best to dip the tails in citric acid (lemon juice) prior to freezing to preserve proper coloration. The recommended freezing method is quick freezing at 18°C.[11] The tails may be kept one year at this temperature. The frozen meat may be stored in typically consumer-sized containers, in institutional-sized packages, or vacuum packed.

The crawfish are edible after they are defrosted. They may be used in dishes prepared at home or commercially such as gumbo, crawfish bisque, jambalaya, or fried crawfish tails.

Soft-Shelled Crawfish

Crawfish, like blue crabs, molt their shells when they outgrow them. Molting produces soft-shelled crawfish that are served simply fried or with a sauce.

Soft-shelled crawfish have been available on a limited basis at restaurants in South Louisiana since about the mid-1980s. Production was about 6,000 pounds in 1986 and increased to an estimated 27,000 pounds in 1987.[26]

The 1987 price for soft-shelled crawfish was $8.00/lb, and the market is expected to increase dramatically. Industrial innovations, such as automated separators and water quality management, could give an additional boost to production over the next several years.

There are two ways soft-shelled crawfish are marketed. The majority of both products are sold frozen, since the molting stage is not permanent. One way to market the soft-shelled crawfish is to remove only the head section of the crawfish leaving the body and tail to be eaten. The second is to use only the tail meat. The first method is the more efficient, since it uses more of the crawfish.

Wastewater Generation

Figure 8.1 shows the waste generation from crawfish processing. About 60% by weight of the processed crawfish is considered waste. Crawfish processing wastes consist of shell fragments, viscera, and fat. The wastewater is composed mostly of wash-down water from picking tables and floors, initial washwater, pre-retort washwater, and retort water. There is a very limited data base for crawfish processing wastewater characteristics, but data established on a single plant operation is presented in Table 8.1.

Wastewater Treatment Options

Crawfish wastewater characteristics data suggest the typical handpicked crawfish operation generates a high-flow, low-strength waste with high TSS and oil/grease content. Table 8.2 illustrates the treatment trains that would be appropriate for treating these wastewaters. In-plant washwater reduction and solids separation would have a great impact on reducing BOD_5, TSS, and flow. In addition, segregation of cooking water would reduce oil/grease content.

Two basic approaches are presented for treating these wastewaters. The first employs low-energy facultative lagoons in combination with rock-reed filters. More stringent effluent limitations require use of aerobic lagoons and slow sand filters, with the addition of nitrification for polishing.

The second approach uses sedimentation and conventional activated sludge and adds rock-reed filters, slow sand filters, and nitrification to meet more exacting standards. The most stringent effluent standard replaces conventional activated sludge with extended air activated sludge.

Table 8.1 Raw Wastewater Characteristics from a Crawfish Picking Plant (11).

Flow m^3/day	BOD_5 mg/l	TSS mg/l	Oil/Grease mg/l
5142	86	372	272

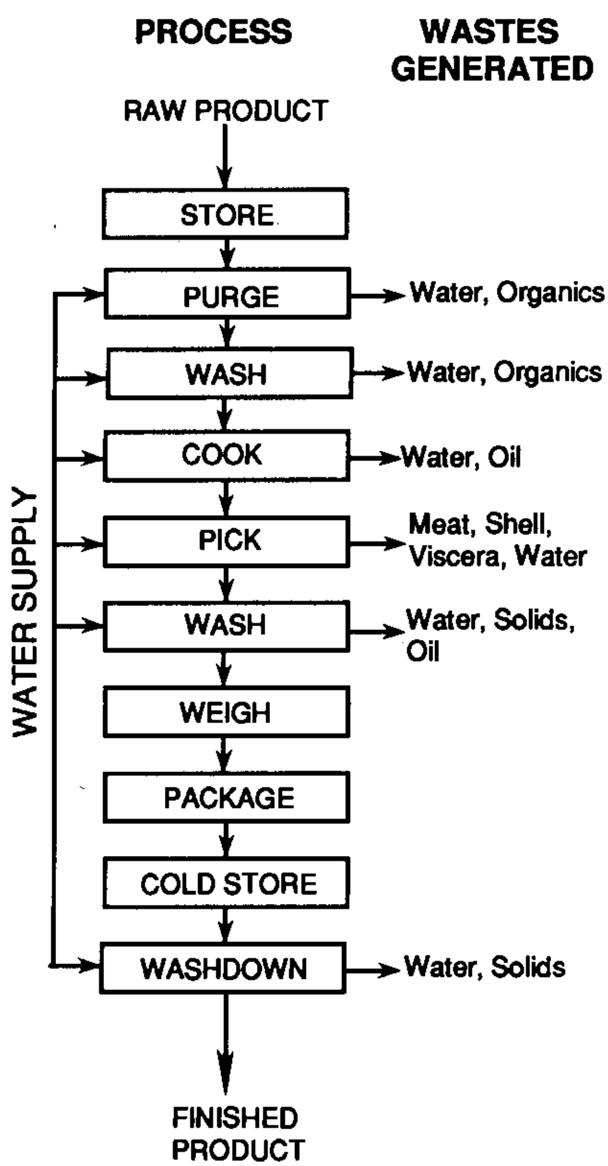

Figure 8.1 Process Flow of a Crawfish Processing Operation (11).

Table 8.2 Possible Wastewater Treatment Trains for Crawfish Processors Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	None	None	None	Facultative lagoons	Rock-reed filters
	Solids separation	Sedimentation	None	Conventional activated sludge	None
20/20	Solids separation and washwater reduction	None	None	Facultative lagoons	Rock-reed filters
	Solids separation and washwater reduction	Simple screens and sedimentation	None	Conventional activated sludge	Rock-reed filter
10/10/5	Solids separation and washwater reduction	None	Aerobic lagoon	Facultative lagoons	Rock-reed, slow sand filters and nitrification
	Solids separation and washwater reduction	Simple screens and sedimentation	None	Conventional activated sludge	Rock-reed, slow sand filters and nitrification
5/5/2	Solids separation and washwater reduction	Simple screens and sedimentation	Aerobic lagoon	Aerobic lagoon	Rock-reed, slow sand filters and nitrification
	Solids separation and washwater reduction	Simple screens and sedimentation	None	Extended air activated sludge	Rock-reed, slow sand filters and nitrification

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

IX. EDIBLE FINFISH PROCESSORS

Processing

Processing finfish, by far, has more steps than most other seafood products. In the United States market, 30% of the fish by weight are sold fresh, 20% are canned, 10% are frozen, and 1% are cured.[11] Figure 9.1 shows a generalized process flowsheet for edible finfish.

Washing

Washing standards for fresh fish vary by species and according to operational needs. Processors wash their fish after unloading to remove surface bacteria, dirt, and slime. They usually carry out this activity in tumbler washers filled with potable water. Operators are careful not to allow fish to drop from the interior baffles and to make sure the fish are turned to prevent bruising.

Sorting

The next step the fish undergo is sorting. Sorting means separating fish into similar groups. Although fish may be sorted manually by species and size on the harvesting vessel, this process usually takes place ashore after the washing process. There, fish can be separated mechanically with tumblers capable of separating 1,200 kg of mixed species per minute.

Processors also sort fish by hand, according to their quality. No commercial mechanical equipment that can duplicate this task.

Grading

Grading is the next step in the processing chain for fish. Processors may carry out this task according to such criteria as weight, quality, and size.

Weight and quality grading generally are carried out manually. Manual grading by weight requires the product to be placed on a scale and weighed. Automatic weighing systems are less accurate, but more economical than the manual technique. Quality grading takes many factors into consideration including freshness, firmness, odor, damage, and deterioration. Size grading usually applies a mechanical screening principle. The fish must be small enough to pass through a separating device such as a screen or a tumbler.

Singulation

Singulation, the separation of a single fish from a bin of fish, must be performed prior to most other unit operations. Singulation usually is a manual task that is carried out in combination with another operation, particularly orientation.

Orientation

Orientation most often is a manual operation, since it is easy for humans to recognize a shape and turn a fish in the proper direction if it is not correctly placed. Automated orientation requires an advanced sensing system to recognize the allometric relationship of the head and tail of a fish, including contour, physical dimensions, shape, color, and surface features.

Processors can orientate fish species with long narrow bodies easily by means of a simple automated device without a sensory mechanism. The fish can be dropped on top of a sloping, flat slide. The fish will go down head first if the slide has the proper surface characteristics and angle. Should a fish slide down tail first, its scales catch in the surface to stop it. The slide should narrow to a point small enough for only one fish to pass at a time to keep the fish orientated.

Scaling

Processed fish next are scaled. Manual scaling requires that a rough surface be rubbed on the exterior of the fish hard enough to remove the scales. Power-assisted scalers and fully automatic scalers apply the same principle. Power-assisted scalers use a rotary scaling tool driven by a power source (generally an electric drill). The scaler, a hand tool, must be moved over the fish's body. Automatic scalers use contoured, fixed scaling blades and contoured rotary scaler wheels to strip off the scales.

Heading

After scaling, the fish are headed. The two commercial methods used to head fish are the straight-cut and the V-cut.

The straight-cut method uses a circular saw, a guillotine cutter, or a band saw to cut perpendicular to the fish's backbone. The band saw is the only one of these tools that is manual.

The V-cut method produces a higher yield than the straight-cut but is more expensive. Two rotary blades make the cuts from behind the gills moving toward the head.

A very important factor in mechanical heading is the length of the fish.[11] The sorting must be precise, since the machines automatically measure and cut at a standard distance, once the fish have been orientated. If a fish is too short, excess meat could be lost.

Removal of the head occurs as it hangs over the edge of the conveyor. The head is carried away to be used in the manufacture of such by-products as oil and meal.

Evisceration

Evisceration is the process of removing the internal organs from the fish. Evisceration is an important unit, since it reduces the finfish's rate of decomposition in two ways. It removes bacteria present in the digestive system, and it takes out enzymes that break down muscle tissue.

Manual evisceration usually requires three cuts--opening the belly, severing the internal organs, and removing the anus. The entrails are pulled from the carcass. The main arteries should be severed to improve bleeding, since a well-bled carcass will produce whiter fillets. It is also important to try not to cut the digestive tract. A cut digestive tract can increase the rate of decomposition and decrease the shelf life as a result of body cavity contamination.[11]

Feeder system/gutting machines feature a conveyer with a series of special retainers that hold the fish after orientation. Manual orientation is often necessary. A circular saw with a slitting blade splits the body cavity from behind the head to in front of the tail. Rotary blades next cut the body cavity completely open to sever the major arteries and assure complete bleeding. An inverted V-shaped slide holds the body open to make the viscera accessible to the eviscerating machine.

The eviscerating machine is usually a rotary device, possibly a cylindrical wheel with drilled holes or rotating toothed wheels. Some machines can eject a slitting knife to catch and pull the entrails from the body cavity. The body cavity then is washed with potable water to remove any unwanted materials. Automatic evisceration can gut 20-120 fish a minute.[11]

Filleting

Filleting is the next unit processing operation the fish encounter. It involves removal of large slabs of meat from each side of the fish in one piece. Filleting removes most, if not all, of the fish's bones. In many operations aimed at producing only fillets, there is a considerable amount of wasted edible fish.

Commercial processors use manual filleting, but they set minimum fish sizes for the operation to make it worth the effort and expense. Processors also consider bone structure when they decide whether a fish is suitable for filleting.

The manual filleting process begins with piercing the fish behind the gills with a knife. The knife cuts along the spine leaving the dorsal fins and a narrow strip of skin on the bones. The head of the fish faces the filleter. He uses his knife's tip to lift and separate the meat from the spine by slicing toward the head. The filleter lifts the meat and makes a final cut toward the tail to free it. If skinning is the next step, the skin afterward remains attached to the tail. It gives the filleter a grip when he cuts the other side.

Automated filleting requires highly specialized machines for addressing such criteria as species, size and end use of the fillet. Some machines will accept fish with no prior processing, while others require such prior procedures as heading and gutting.

Finfish may be subdivided into four groups according to bone structure. These groups are herrings (i.e., sardines, pilchards, sprats and small mackerel), whitefish (i.e., ling, whiting, cod haddock, pollack and hake), redfish (i.e., (ocean perch, sea bream and rockfish), and flatfish (i.e., plaice, sole and flounder).[11]

Louisiana processors generally prepare members of the redfish family for human consumption. The bone structures of the members of each group bear enough similarity so that any filleting machine can be used on all of its fish.

Fish must be orientated either manually or automatically for the filleting machine. Many automatic machines use an inverted V-shaped guide to hold open the body cavities of headed and gutted fish. The machine pushes the fish as far forward as possible and holds them in place. It guides the fish past rotary filleting blades set at fixed angles and distances. The skeletal and body contours of the fish determine the angles. The distances are calibrated according to the thickness between body cavity and the exterior surfaces of the fish's bones.

Even though the machine cuts close to the bone, a highly skilled filleter often can produce less waste of meat. Despite their degree of inefficiency, filleting machines are much more cost effective than a human cutter. The machine can fillet 20-40 fish per minute while a skilled worker can produce only 1 or 2 per minute.[11]

Skinning

The next unit process, skinning, removes the skin from either all or part of a fish. Species of fish like catfish must be skinned because they have no scales. As with most unit operations, skinning may be either manual or automatic.

To manually skin a whole catfish, the skinner hangs the fish by its head on a hook. Then he removes the dorsal and pectoral fins. He cuts the skin all around the fish just behind the operculum. The operculum is the flap covering the gills. The skinner takes off the skin by grasping it with pliers and pulling downward. He cuts out the dorsal fin while removing the back strip of skin. Finally, he strips the ventricle side in the same manner. Skinners usually carry out this step last because they can remove the anal fin at the same time as they split the belly for evisceration. Catfish are skinned before evisceration only when they are to be processed whole.

The manual method of removing skin from the fillets requires resting the fish on a cutting board or table. While holding the fish in place with the left hand, the skinner runs a sharp knife between the skin and the meat.

Skinning may either pull or cut off the skin. Cutting the skin off is known as deep skinning. Deep skinning is not always preferable since pulling the skin allows the membranes below the skin to remain intact. These membranes protect the flesh from quick quality deterioration and also retain moisture. On the other hand, some fish species have a darker layer below the membrane. Removal of this layer improves fillet appearance and helps maintain its quality when frozen.[11] An obvious drawback to deep skinning is that the layer removal reduces fillet yield. Processors must consider species, product, economic trade-offs, shelf life, and consumer preferences when deciding the type of skinning to use on a fish.

The three major automated systems for skinning fish are oscillating knife, fixed knife, and band knife. The oscillating knife system is similar to the manual operation. It uses mechanical means to grasp both fillet and skin, while the knife moves back and forth at the point of separation. In the fixed knife system, the fillet moves, while the knife remains stationary. The band knife constantly moves at a right angle to the fillet.

Other skinning methods may be used on catfish species, but they are not common in commercial operations. A horizontal rotating cylinder with a stationary rough surface that the catfish pass over is one option. Another is a two-minute bath of 9% sodium hydroxide at 100 °C followed by a water dip. The rinsed fish should be exposed immediately for two minutes to a 2% acetic acid bath to restore the pH to its original status.[11]

Candling

Candling involves passing light through a substance to allow an observer to find any flaws or impurities. Candling locates parasites in fish fillets. The inspector views the fish on top of an intense light diffused by a frosted glass. Parasites or defects show up as dark spots, lines, or irregularities. The inspector then removes them with a knife.

Cutting

While cutting is part of most unit operations, it is used also to form fish sticks and portions from blocks and steaks. By seafood industry definition, cutting means severing muscle, bone, and other components to divide a single piece of meat.

Cutting tools range from an ordinary butcher knife to band and circular saws. Saws are used often to head and cut fresh and frozen fish. Fish sawdust forms when they are used. Heading results in a sawdust mixture of flesh and bone, while the sawdust is all flesh when frozen fish blocks are cut. The undesirable grittiness of frozen fish sawdust results in the loss of significant amounts of edible fish.

Frozen fish blocks may be sheared before they are cut. Shearing eliminates any loss caused by sawdust. To shear frozen fish the temperature must be raised to between -12 °C and -5 °C. This temperature range reduces the force required to cut and prevents the fish blocks from cracking.[11]

Some heading operations use guillotine-type shearing. Poor design of such equipment may cause vertebra to shatter resulting in bone slivers in the meat near the cut. Such slivers make the product less desirable to consumers.

Block Formation

Edible fish may be further processed at the block formation stage. Fish blocks consist of boneless fillets compressed slightly in a frame and frozen to form a solid fish block of standard dimensions. Fish blocks are easily stored, shipped, and handled until their eventual division into fish sticks or portions. Fish sticks and portions are convenient, since they have long storage lives.

Processors form fish blocks by placing a one-piece cardboard box lined with waxed paper in a wood or aluminum frame of equal dimensions. They place the square fillets in the bottom corners of the box with their long axes perpendicular or parallel to the longer sides of the box and their thick edges on the outside. The filled box is closed, smoothed, and frozen at -38 °C for up to three hours.

The fish are frozen in a multiplate freezer adjusted so that the spacers keep pressure on the unfrozen blades. The pressure causes the fillets to fuse. Since the dimensions of the blocks are fixed, and the density is to be uniform, well-formed blocks rarely deviate more than 3mm from specified dimensions.

After cutting, fishsticks are battered, breaded, packed, and refrozen. The battering and breading application is the same as the application for shrimp and oysters. The packages may be of either consumer or institutional quantity.

Wastewater Generation

Waste generation from an edible finfish filleting operation is shown in Figure 9.1. Processors consider about 30-60% of processed finfish by weight to be waste. The generated wastes include solids, viscera, slime, and skins. Wastewater composition depends on the type of fish processed, but consists mostly of wash-down water from initial washing, filleting, skinning, freezing, and miscellaneous wash-down water.

Wastewater characteristics from a typical mechanical bottom fish filleting operation are presented in Table 9.1. Many filleting processors in Louisiana cut by hand. No data is available on these manual processing operations. Catfish processing is similar to bottom fish processing. These wastewater characteristics are presented in Table 9.2.

Wastewater Treatment Options

Wastewater characterization data shows that edible finfish wastewater is either moderate-strength, and high-flow or low-flow high-strength. Implementation of washwater control strategies apparently would make the latter wastewater more typical.

The treatment trains presented in Table 9.3 assume that both washwater and solids separation techniques are employed. The treatment of low-flow, high-strength wastewaters normally can be achieved by more compact (but higher energy-requiring) processes thân are more dilute wastewaters.

Table 9.3 presents two approaches. First is the low-tech approach. This method involves the use of aerobic lagoons and rock-reed filters. More stringent standards require the addition of a multicell aerobic lagoon for roughing and secondary treatment and rock-reed, slow sand filter nitrification for polishing.

Second is the high-tech approach using sedimentation and extended air activated sludge. Again, more stringent standards require rock-reed filters for polishing, but lower standards need rapid sand filtration and selective ion exchange for polishing.

Table 9.1 Raw Wastewater Characteristics from a Mechanized Bottom Fish Processing Operation (17).

Flow 1/sec	BOD_5 mg/l	TSS mg/l
6.6	640	300
20 - 25.9	192 - 640	---
8.3	1726	---
28.4	---	750

Table 9.2 Raw Wastewater Characteristics from a Mechanized Catfish Processing Operation (11).

Flow m^3/day	BOD_5 mg/l	TSS mg/l	Ammonia mg/l
79 - 170	340	400	0.96

Table 9.3 Possible Wastewater Treatment Trains for Edible Finfish Processors Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	Solids separation and washwater reduction	None	None	Aerobic lagoons	Rock-reed filters
	Solids separation and washwater reduction	Sedimentation	None	Extended air activated sludge	None
20/20	Solids separation and washwater reduction	Mechanical screens	Aerobic lagoons	Aerobic lagoons	Rock-reed and slow sand filters
	Solids separation washwater reduction	Sedimentation	None	Extended air activated sludge	Rock-reed filters
10/10/5	Solids separation and washwater reduction	Mechanical screens	Aerobic lagoons	Aerobic lagoons	Rock-reed and slow sand filter and nitrification
	Solids separation and washwater reduction	Sedimentation	None	Extended air activated sludge	Rock-reed and slow sand filter and nitrification
5/5/2	Solids separation and washwater reduction	Mechanical screens and sedimentation	Aerobic	Aerobic lagoons	Rock-reed, slow sand filter and nitrification
	Solids separation and washwater reduction	Mechanical screens and sedimentation	None	Extended air activated sludge	Rapid sand filter and selective ion exchange

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

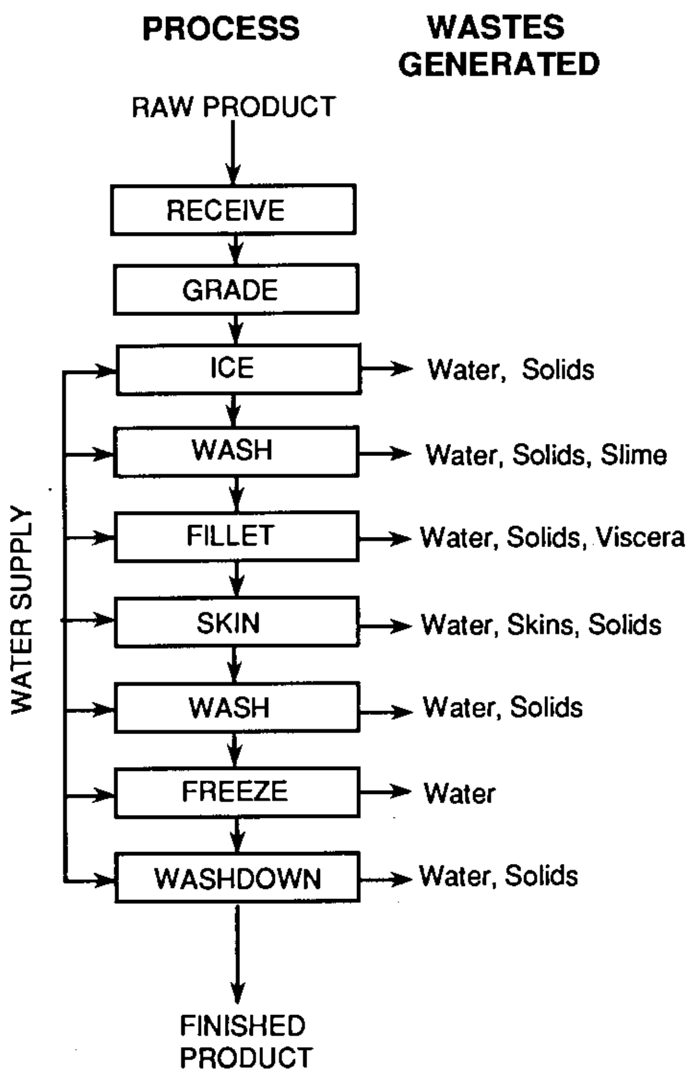

Figure 9.1 Process Flow of a Finfish Filleting Operation (19).

X. NON-EDIBLE FINFISH PROCESSORS

Processing

Non-edible (industrial) finfish are pelagic species. Pelagic fish are open-water fish (do not live in waters near land) such as menhaden, herrings, alewives, anchovies, and pilchards. Menhaden is the primary species processed in the Louisiana seafood industry.

Rendering accounts for the highest percentage of fish processed in the United States (35%).[11] Menhaden rendering produces fish meals, fish oils, and fish solubles. Fish meals and solubles primarily are used to make feeds for poultry, swine, cats, mink, and farmed fish. Scientists believe fish meal can increase an animal's growth rate as a result of the presence of trace elements not found in other feeds. They also are used to produce fertilizers.

Fish oils have a more diversified market. European countries use fish oils to produce margarine and cooking oils. These oils are common ingredients in cosmetics, quick dry primers, aerosol and aluminum paints, enamels, floor and wood sealers, drum and chassis coatings, house paints, industrial coatings, and lubricants.

Hydrogenated fish oils may be used to produce raw materials for stearic acid, glycerine, soap, candles, and rubber including methyl- or ethylesters. They are high in unsaturated fats that have a tendency to lower blood cholesterol and contain large amounts of vitamins A and D. Figure 10.1 shows a process flowsheet for menhaden rendering.

Unloading

Menhaden are always unloaded mechanically. Unloading equipment includes chain conveyors and vacuum or liquid pumping systems.

Pumping is the most common commercial method for unloading menhaden. The vacuum pump applies suction to move the fish out of the holding tank to a platform for separation. Liquid pumping systems flood the vessel's hold and then suck the menhaden out with the water. Screens on the pressure side of the pump separate the fish and the water. Either system can pump several tons of fish per hour. After unloading the fish, processors store them in temporary tanks until cooking.

Cooking

Stunning is the most humane method to prepare the fish for cooking. Most operations use electric stunners, since this method provides almost instant death. Menhaden are steamed in retorts for 20 minutes. The cooking coagulates the protein and ruptures the cell walls to release the stored oils and water.

Pressing

The cooked fish are pressed to release their oils. The menhaden are loaded into a continuous screw press. This machine operates with a double screw system that constantly increases the pressure applied to the fish solids. Liquids are released through perforations in the press. The remaining solids, called press cakes, are about 50-55% moisture and 3-4% oils.[11]

Separation

The liquid separated from the press cake is called press liquor. The composition of the press liquor is 6% solids, 16% oils, and 78% water. A centrifuge or deslugger removes the suspended solids from the press liquor. The centrifuged solids dry with the press cake. A conical scroll type, also called a decanter, is the most popular centrifuge.

The rest of the press liquor is polished to remove all other impurities and to separate the oil from the water. Hot water often is added to purify the oil-water separation. The water remaining is stick water. Stick water is a sticky mixture of solids (5.6%), oils (.4%), and water (94%).

The stick water, approximately 50% of the original fish weight, is evaporated down to a concentration between 30-50%.[11] The evaporation step is profitable, since the solids recovered make up about 20% of the solids in the final fish meal. The extracted fish oil is shipped to other plants to be processed into marketable products.

Drying

The press cake, concentrated stick water, and centrifuged solids are mixed and fed into a dryer. Combining these products means there is almost no waste produced from the fish. Whatever the type of dryer, control of the meal particle temperature is critical in maintaining the press cake's nutritional value.

The two types of commercial dryers used today are the direct and indirect. A direct dryer consists of a slowly rotating cylinder heated by an open flame blown through a parallel current mode. The meal travels through the dryer on a conveyor. The dryer has the capacity to dry 1,000 tons of raw material within a 24-hour period. The temperature may rise to 600 °C without causing damage. Evaporation from the wet meal particles cools the meal to prevent nutritional loss. The moisture content reduces to 9 or 10% within 15-20 minutes.

The other commercial dryer is the indirect type. An indirect dryer is made of fixed cylindrical drums with internally rotating flights. The flights stir the meal. They are heated internally, usually by steam. The meal does not come into primary contact with the steam as it does in the direct dryer. Air is blown through the dryer to evaporate the moisture.

The type of dryer does not affect the nutritional value. It does influence fuel costs and availability, required capacity, available space, and odor reduction problems.

Grinding

The processor separates the meal and screens it to remove trash before grinding. The hammer mill is the most common commercial grinder for fish meal. Its swing hammers grind the meal until the particle size is small enough to pass through the screen.

Bagging

The next operation is bagging. An important consideration is that the meal must not be bagged while hot, since nutritional damage may occur. Permeable bags work, but must be stored in a manner to allow for air circulation. Plastic-lined heat-sealed bags also may be used. An advantage of plastic bags is their odor-retention factor. After bagging, the processor ships the meal either to wholesalers or directly to buyers who manufacture products from the meals.

The drying and stick water evaporation processes are the primary odor sources. Good plant management that includes the use of strictly fresh raw products, high quality plant hygiene and ventilation, and negative air pressure in the plant will curb escaping odors. Some applicable odor-control principles include masking, water scrubbing, chemical treatment, and incineration. Incineration is the most reliable of the four.

Wastewater Generation

Waste generation from an inedible finfish rendering operation is shown in Figure 10.1. Properly managed rendering plants should produce only small volumes of waste, since the fish are completely cooked down.

The two basic categories of wastewaters generated from these operations are high-volume, low-strength wastes; and low-volume, high-strength wastes. The high-volume, low-strength wastes result from unloading, fluming, handling, transporting, and wash-down water.

Processors estimate the fluming or pumping flow is about 830 liters per metric ton of fish with a TSS concentration of 5,000 mg/l. Other estimates put the fluming water TSS as high as 30,000 mg/l.[17]

The low-volume, high-strength wastewaters are stick waters that have BOD_5 concentrations as high as 56,000-112,000 mg/l. The TSS content of these wastewaters can be as high as 6%. Increased use of by-product recovery equipment, such as stick water evaporators, to produce condensed fish solubles, and water reuse should eliminate the source of these wastewaters.

Wastewater Treatment Options

Possible treatment trains to meet the various effluent limitations are presented in Table 10.1. These recommend in-plant modifications to reduce all wastewater flows. Further BOD_5 reductions can be gained through improved by-product recovery.

Two possible wastewater treatment trains are recommended for non-edible finfish processors. The first is a low-tech approach that uses multi-cell aerobic lagoons for roughing and secondary treatment. Rock-reed filters provide the polishing. Slow sand filters and nitrification can be added to meet more stringent standards.

The second treatment technique uses screens and sedimentation followed by high-rate trickling filters for roughing. It uses conventional activated sludge for secondary treatment. Again, more stringent standards require the addition of mechanical screens, slow sand filters, and nitrification.

Table 10.1 Possible Wastewater Treatment Trains for Non-Edible Finfish Processors Based on Effluent Limitations.

Effluent Limit*	Recommended Treatment Sequence				
	Waste Minimization	Primary	Roughing	Secondary	Polishing
30/30	Solids separation and washwater reduction	None	Aerobic lagoons	Aerobic lagoons	Rock-reed filters
	Solids separation and washwater reduction	Simple screens and sedimentation	High rate trickling filters	Conventional activated sludge	None
20/20	Solids separation and washwater reduction	Mechanical screens	Aerobic lagoons	Aerobic lagoons	Rock-reed and slow sand filters
	Solids separation washwater reduction	Mechanical screens and sedimentation	High rate trickling filters	Conventional activated sludge	Rock-reed and slow sand filters
10/10/5	Solids separation and washwater reduction	Mechanical screens	Aerobic lagoons	Aerobic lagoons	Rock-reed and slow sand filter and nitrification
	Solids separation and washwater reduction	Mechanical screens and sedimentation	High rate trickling filters	Aerobic lagoons	Rock-reed and slow sand filter and nitrification
5/5/2	Solids separation and washwater reduction	Mechanical screens and sedimentation	Aerobic	Aerobic lagoons	Rock-reed, slow sand filter and nitrification
	Solids separation and washwater reduction	Mechanical screens and sedimentation	High rate trickling filters	Aerobic lagoons	Rapid sand filter and selective ion exchange

*(mg/1 BOD_5)/(mg/1 TSS)/(mg/1 NH_3-N)

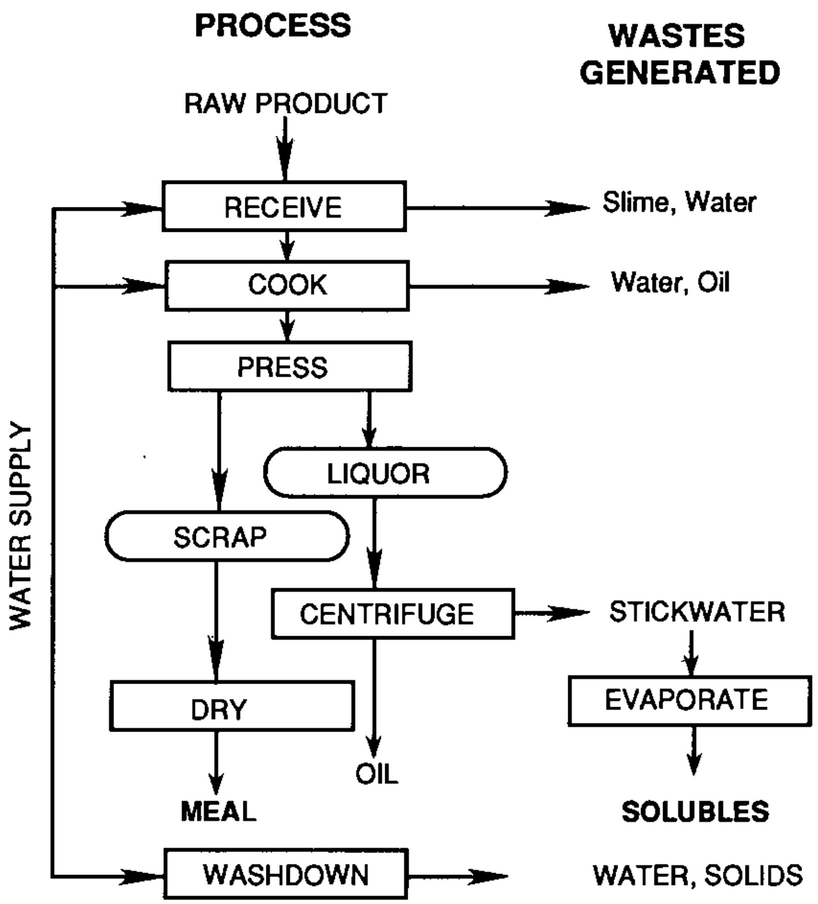

Figure 10.1 Process Flow of Menhaden Rendering Operation (19).

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GLOSSARY

Activated sludge: a wastewater treatment process that mixes and aerates water to stabilize the waste.

Aerobic: biological treatment processes that occur only in the presence of oxygen.

Allometric: the relative growth of a part in relationship to the whole organism, i.e., the length of the tail in relation to the whole fish.

Anaerobic: biological treatment processes that occur only in the absence of oxygen.

Batter: a formula designed to coat a raw seafood product to trap breading.

BCT: best conventional technology standards.

Biological: having to do with life and living processes.

Blowing: a process by which oyster meats, through osmosis, absorb fresh water to increase their weight and reduce their salinity.

BOD: biological oxygen demand; quantity of oxygen used in the aerobic stabilization of wastewater and polluted water.

BOD_5: standard 5-day BOD value used to define the strength of municipal wastewaters, to evaluate the efficiency of treatment by measuring oxygen demand remaining in the effluent, and to determine the amount of organic pollution in surface water.

BPT: best practicable control technology available.

Breading: addition of a dry granular or particulate compound to the batter coated raw product.

Candling: passing light through a substance to detect any flaws or impurities.

Carbon adsorption: process that removes refractory organics and colors from effluent waters.

Chemical precipitation: chemical addition to wastewater to alter the state of solids and to facilitate their removal.

COD: chemical oxygen demand; used in wastewater or polluted water as a measure of the oxygen equivalent of the organic matter susceptible to oxidation by a strong chemical oxidant.

Deep skinning: cutting the skin away from the fish rather than pulling it.

Deveining: removal of the alimentary canal from crustaceans mainly for aesthetic purposes.

Dissolved air flotation: treatment where air dissolved in pressurized wastewater escapes and attaches to suspended particles.

Effluent: waste material discharged into the environment.

Electrodialysis: use of an electric current to cause anions and cations to move toward their corresponding electrodes.

Evisceration: process of removing the internal organs or entrails from the body cavity.

Filleting: removing large pieces of meat from the backbone on each side of the fish.

Fish blocks: boneless fillets compressed in a frame and frozen to form a solid block of fish.

Floc: masses of microorganisms clinging together.

Flow equalization: a treatment process that stabilizes outgoing flow rates to overcome operational problems associated with the variations in incoming flow rates.

Grading: separating of items according to some established criteria, i.e., size, weight, quality, physical damage, etc.

Heading: manual or mechanical removal of heads from fish or shrimp.

Influent: waters flowing into a system.

Inorganic: matter other than plant or animal; not arising from natural growth.

Insoluble: incapable of being dissolved in a liquid.

Ion exchange: treatment process that uses resins to soften water, remove impurities, and recover chemicals by replacing calcium and magnesium with sodium.

Lagoon: a large shallow pond designed to treat wastewater through interaction of sunlight, wind, algae, and oxygen.

Microscreen: treatment process where a drum catches solids as the wastewater flows through the system.

Molting: the process in which crustaceans shed their exoskeltons and expand their new soft exoskeltons to allow for growth.

Operculum: skin flap covering the fish's gills.

Organic: relating to or containing carbon compounds.

Osmosis: movement of water through a membrane without the assistance of an external force.

Ozone oxidation: treatment process that removes discoloration and odors.

Peeling: removing of the shell from the shrimp, crab or crawfish.

Peelers: crabs ready to molt; after molting there is a lag time before the shells reharden.

Pelagic: living in open waters, not adjacent to land.

Permeable: having pores or openings that permit liquids or gases to pass through.

pH: the measure of the intensity of the acid or alkaline condition of a solution by determining the concentration of its hydrogen ions.

Press cake: solids remaining after nonedible finfish have been pressed.

Press liquor: liquid separated during pressing consisting of 6% solids, 16% oils, and 78% water.

Pressing: removing of the liquid from nonedible finfish through pressure.

Pretreatment: degree of wastewater treatment required before the wastewater can be discharged into a sewer.

Primary treatment: process that removes wastewater pollutants that will either settle or float by physical or chemical measures.

POTW: publicly owned treatment works.

RBC: rotating biological contractor; a partially submerged trickling filter.

Retort: a pressure vessel filled with water or steam which cooks or sterilizes by the application of heat.

Reverse osmosis: use of an external force to push water against the natural direction through a membrane to purify the water.

Sand filtration: treatment process that removes suspended or colloidal solids when wastewater is passed through fine sand media.

Sawdust: tiny slivers of flesh and/or bone that are produced when fish are cut.

Scaling: removing the layer of scales from the exterior of the fish.

Screening: a technique that removes larger solid particles from wastewater.

Sedimentation: gravitational settling of suspended particles that are heavier than water.

Shuck: to remove oyster meat from the shell.

Singulate: separation of a single fish from a bin of fish before proceeding to other unit operations.

Skinning: removing the skin from part of a fish or a whole fish that does not have scales.

Sludge hopper: a V-shaped tank used to collect sludge.

Sorting: the separation of fish into categories of fish with similar characteristics.

Specific gravity: the ratio of the density of a substance to the density of a substance (as pure water or hydrogen) taken as a standard when both densities are obtained by weighing in air.

Stick water: mixture remaining from press liquor after the oil has been removed.

Tertiary treatment: polishes primary and secondary treatment processes and removes minerals and ions.

TOC: total organic carbon; includes all dissolved particles of organic carbon.

Trickling filter: a bed of coarse material over which water flows and the organic materials in the wastewater are adsorbed and oxidized by the bacterial growth on the media.

TS: total solids; residue left in a drying dish after evaporation of a sample of water or wastewater and subsequent drying in an oven to remove all moisture.

TSS: total suspended solids; nonfilterable residue that is retained on a glass-fiber disk after filtration of a sample of water or wastewater.