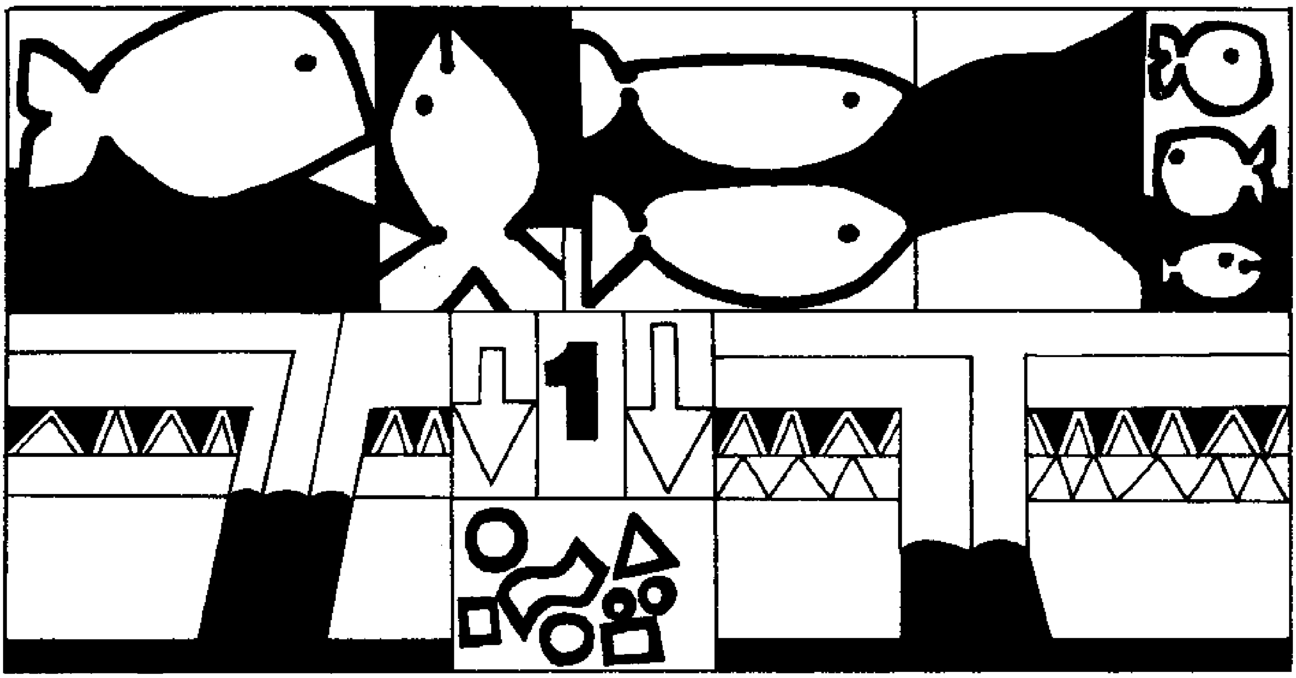
WASTE WATER TREATMENT IN COMMERCIAL FISH PROCESSING



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WASTE WATER TREATMENT IN COMMERCIAL FISH PROCESSING:

Reducing Stick Water Loadings

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Due to new federal, state and local regulations and the advent of strict enforcement of existing laws dealing with water pollution, some industries have been hard pressed to meet the effluent treatment requirements. Many smaller businesses have found themselves in a difficult position with little capital for improvements and no research capability with which to address their problems.

At the request of a commercial fish processor operating on Lake Michigan, Sea Grant Advisory Services personnel investigated a waste water disposal problem. It was found that large volumes of waste water resulting from the processing of alewives for fish meal were being inadequately treated in a lagoon system. Since the partially treated effluent then entered Green Bay, an abatement order had been issued by the State of Wisconsin.

The waste water problem was studied in two stages. First, in-plant practice was examined to determine whether process revisions could be made to reduce the amount of lipids, protein and other suspended solids in the discharge. While little progress could be made within the constraints of the existing process, a further processing step was developed to remove more solids and to increase product recovery. Secondly, the resulting waste water discharge was studied for purposes of improving treatment practice. Owing to the complexity of the material in the discharge, an anaerobic treatment stage was found to be required. Accordingly, design focused on combination anaerobic-aerobic systems (1).

Portions of the data presented in this paper resulted from cooperative studies conducted by students in the Department of Food Science and the Department of Civil and Environmental Engineering during the Spring Semester, 1971 (5). The cooperation of the Sanitary Engineering Laboratories and Professor W. C. Boyle in the preparation of this paper is also acknowledged.

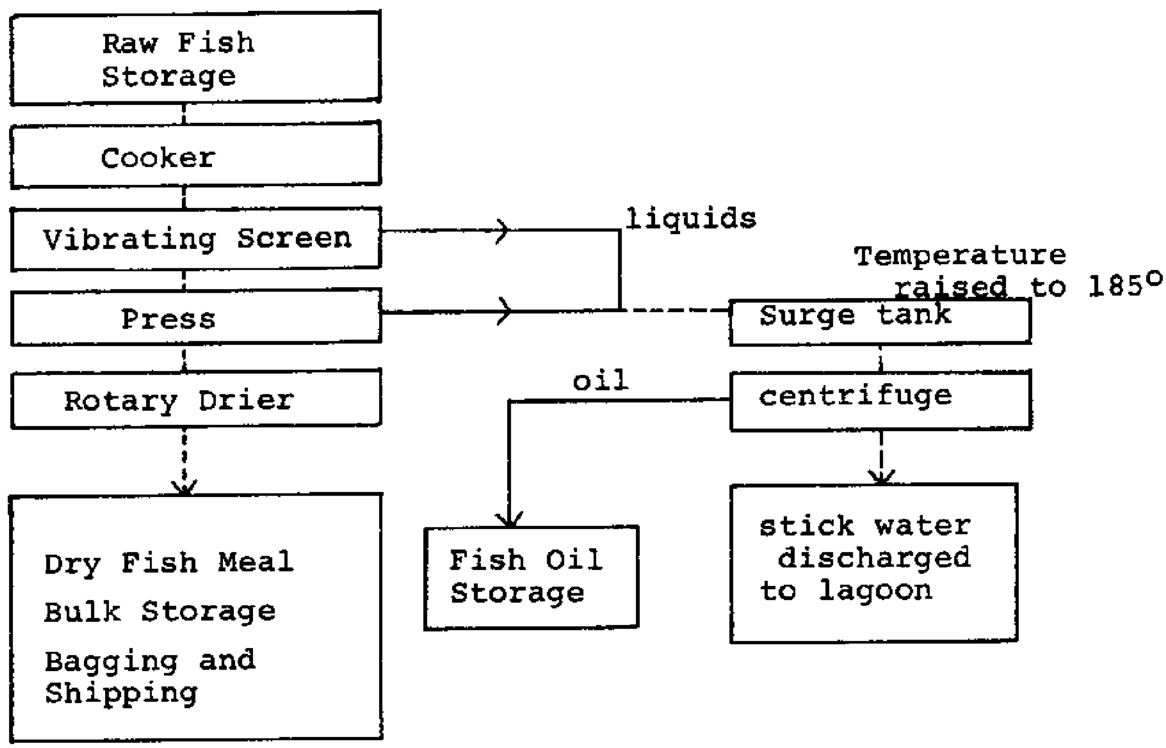


Figure 1. Process Flow Diagram Fish Reduction Plant (modified process of U.S. Fish and Wildlife Service Fish Reduction Plant)

PROCESS DESCRIPTION

The basic fish meal process in use at the time, which is similar to that described by Brody (2), was not changed. Figure 1 provides a schematic for "fish reduction." In this process, steam cooked raw fish are pressed and dried. Stick water or liquor resulting from the pressing operation is then heated to 185°F, centrifuged to remove oil and discharged.

Design Basis

In order to develop a design basis for the stick water treatment units, process operating values were assumed as noted in the following quote (3).

> "The firm operates during the months of May through September. May, August and September quota have averaged six hours per day processing time for a five-day week. June and July quota have averaged 20 hours per day for a seven-day week.
>
> The principal products from the process are fish meal and fish oil. The waste stream called "stick liquor" is an oily, sticky, yellowish colored liquid with a noxious fishy odor.
>
> Volume of Waste Water:
>
> Volume of waste water produced during one season of operation is calculated from the seasonal operating schedule.
>
> Process:
>
> At 7 tons of alewife per hour and 200 gallons of waste water per ton, the flow rate becomes: Q = 1400 gal/hr.
>
> Production Schedule:
>
> May, August and September: 5 days/week and 5 hr/day
> Time = 65 days x 6 hr/day = 450 hours.
>
> June and July: 7 days/week and 20 hr/day
> Time = 61 days x 20 hr/day = 1220 hours.
>
> Total hours per season = 1670 hours.
>
> Total volume of waste per season:
> Volume = 1670 hr/season x 1400 gal/hr = 2.338 million gallons
> = 314,000 cubic feet."
>
> (3)

Stick Water Characterization

A sample of the "raw" or unpretreated discharge from an alewife processing plant was analyzed and the data are reported in Table 1 below. It should be noted that for purposes of labortory study, it was necessary to prepare a stick water sample by steam cooking frozen alewife and straining the resulting "chowder." This surrogate was analyzed and these values are also shown below for comparison.

	Raw, percent water	Simulated Raw, percent water
TS	5.62	5.47
Ash	0.56	----
TVS	5.06	4.62
Protein	3.21	----
Lipid	1.85	----

Table 1. Stick Water Compositions

The Chemical Oxygen Demand was determined to be approximately 84,000 mg/l for the simulated raw stickwater. The Total Solids (TS) and the Total Volatile Solids were determined in accordance with procedures described in Standard Methods (4).

PROCESS ADDITIONS

Several pretreatments were applied to the simulated raw stick water with varying results. Of them, the glutaraldehyde coagulation process, reported in detail here, seemed to offer the best combination of reasonable cost versus potential recovery of marketable product. Coagulation with lime was also examined in some detail and these results are also summarized.

First, stick water samples were filtered cold at c. 120, 195 and c. 210°F through a Buchner funnel and No. 40 paper with only low solids removal and poor filterability. Two proprietary chemical coagulants were also evaluated together with ferric chloride, alone and in combination with hydrochloric acid additions.

When used alone, only the highest ferric chloride concentration of 1000 mg/l yielded a good solids removal. When used in combination with the hydrochloric acid at a pH of c. 4.5, a concentration of 500 mg/l ferric chloride was sufficient. However, these treatments appeared to be generally uneconomical when compared to glutaraldehyde or lime coagulation.

Glutaraldehyde Coagulation

Coagulation with glutaric dialdehyde at elevated temperatures appeared to be effective on a laboratory scale. In essence, a mixture of 0.1 percent gluteraldehyde, as supplied by the Aldrich Chemical Company, and stick water was found to coagulate at a pH of 5.0 when briefly heated close to the boiling point. Study of the proposed process shown in Figure 2 included the following steps and observation. The recommended processing steps are described below:

1) Addition of hydrochloric acid (HCL). The concentrated acid is added by a metering pump at a point which is followed by an appropriate mixing length of pipe.
2) Addition of gluteraldehyde $[OHC-[CH_2]_3-CHO]$. This is also added by a metering pump at a point which is followed by an appropriate mixing length of pipe.
3) Storage and heating to promote coagulation.
4) Filtration of the precipitate is accomplished in a sewage sludge-type filter. It consists of a rotating drum or reel which dips into the precipitated mixture. A partial vacuum on the inside of the drum draws the water through a fine mesh leaving the concentrated marine protein on the outside. When the concentrate rotates far enough, it is scraped off by a doctor blade and dropped into a conveyor.
5) Recirculation of the marine protein to the major fish concentrate kiln for dehydration.

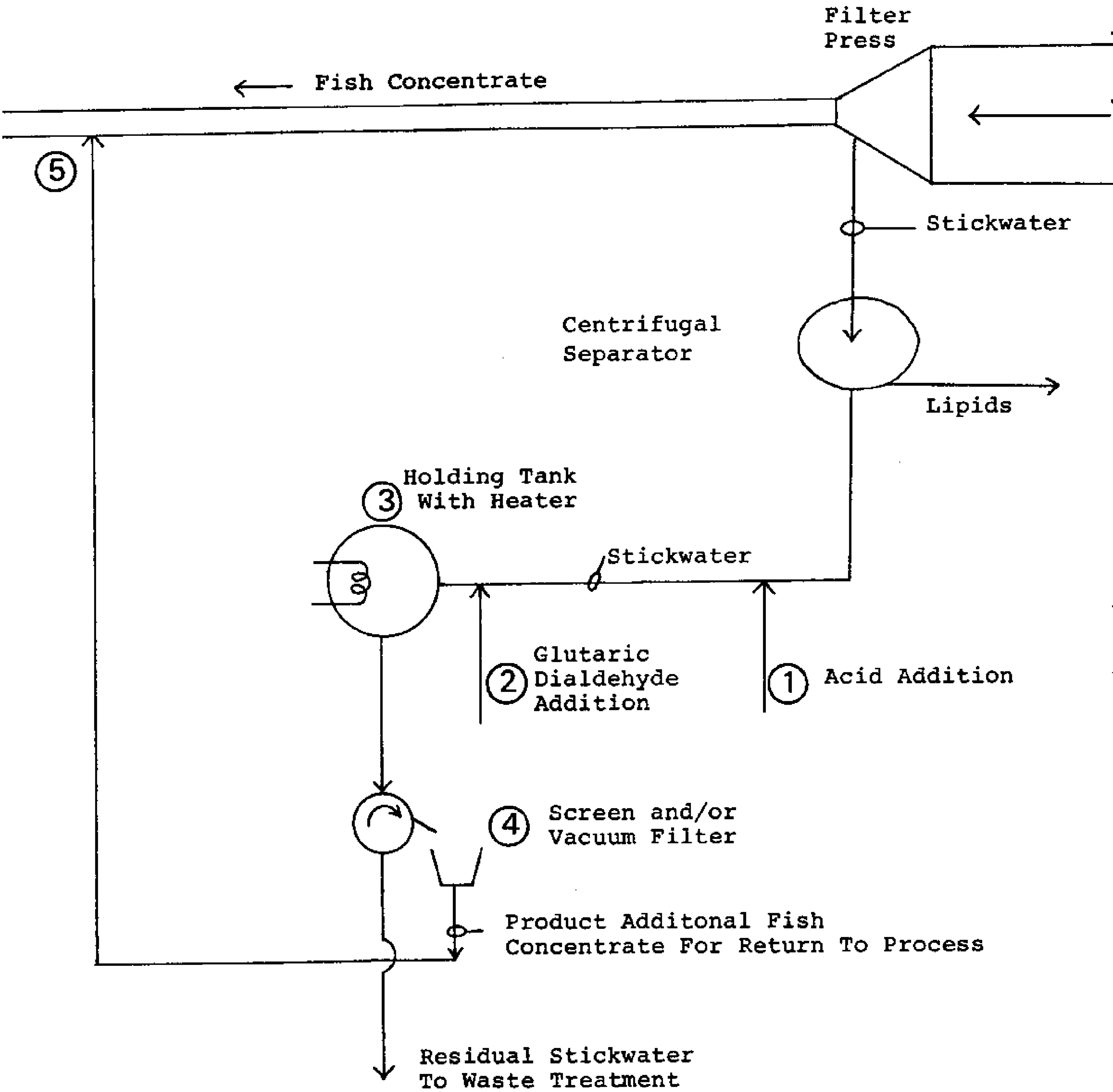


Figure 2. Process Flow Diagram - Glutaraldehyde Method

Lime Coagulation

Coagulation with lime was also studied on a laboratory scale and the results are summarized below for purposes of comparison with the glutaraldehyde process.

In essence, it was observed that raising the pH of the stick water into the range of 10-11 produced a settleable sludge. The sludge could be further conditioned for vacuum filtration by the addition of 250 mg/l of ferric chloride.

Figure 3 provides a flow diagram for the process as developed in the laboratory. The heated stick liquor would enter a mixing tank for pH adjustment to 10.5 with 6000 mg/l of lime.

> "The treated water would then be flocculated and introduced to the thickener. Concentrated sludge from the thickener (would be) conditioned with ferric chloride and filtered on a rotary drum-type vacuum filter. Filter cake (would be) mixed with the feed to the dryer. The filtrate and supernatant (would be) combined, recarbonated with flue gas from the dryer in order to reduce the pH to about 8.0. Effluent from the recovery process (would then be) ready for biological treatment." (3)

Finally, it should be noted that the lime treatment has the added advantage of precipitating substantially all of the phosphorous present.

Both processes were subjected to cost analysis with results that were generally comparable. The potential market value of the product resulting from the glutaraldehyde coagulation was felt to be the most reliable, owing to the high calcium content of the sludge resulting from coagulation with lime.

> "The (lime-thickening) process produced a filter cake with 41 percent solids content for feed to the dryer. To adjust the raw stick liquor pH to 10.5, it was necessary to add 6000 mg/l lime. At this dose, the concentration of calcium in the final fish meal product was calculated to be 1.14 percent by weight." (3)

The filter cake as recovered and before remixing with the main product stream was determined to be 41 percent by weight solids with an estimated 7.9 percent calcium content.

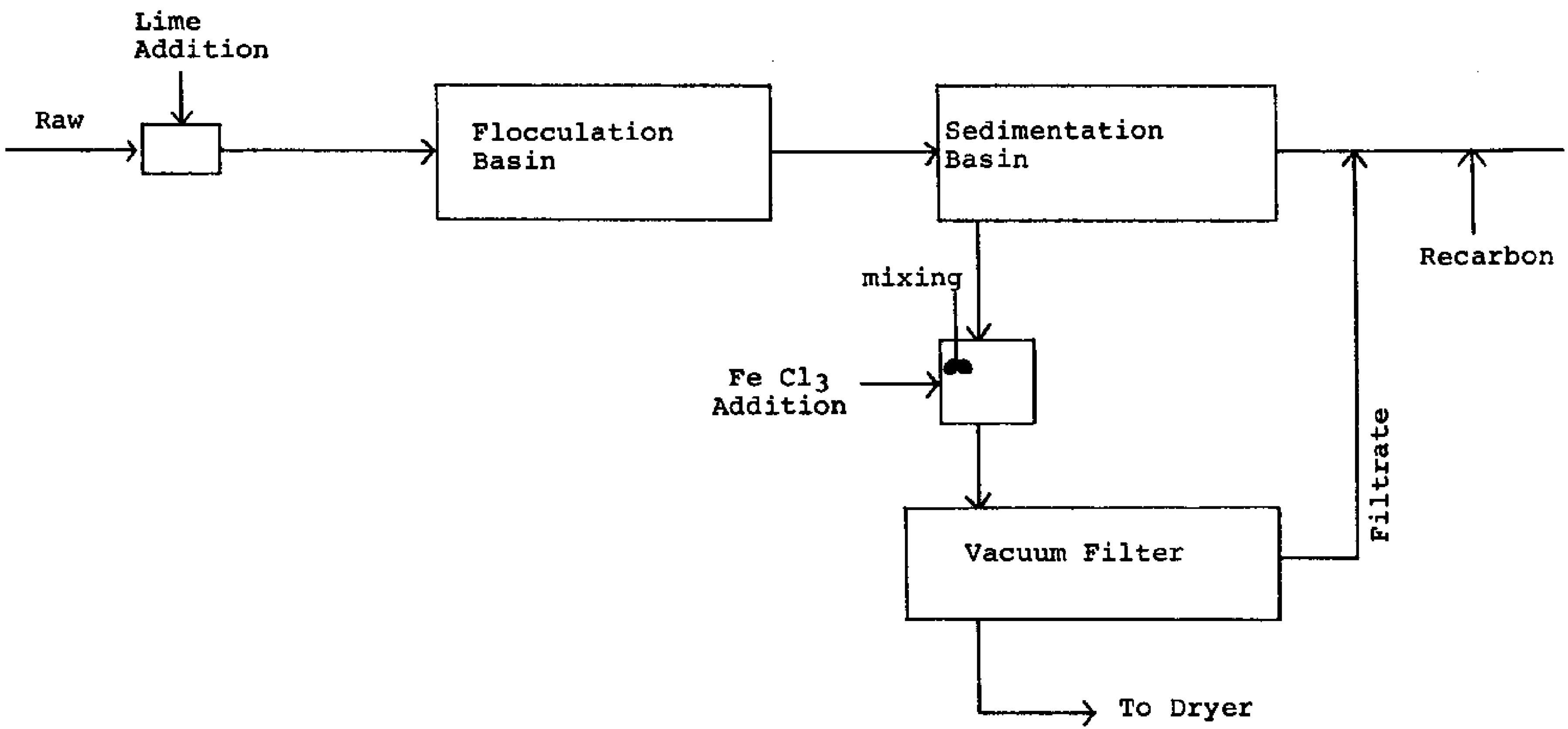


Figure 3. Process Flow Diagram, Lime Coagulation

Cost Analysis of Process Additions

A partial cost analysis was developed based upon the glutaraldehyde coagulation. The calculations shown below are intended only as an indication of the potential cost reductions to be realized by an additional process step. Several cost factors are noted below that should be considered in any detailed estimate of income potential, but were not included here.

First, in the case studied, equipment costs were estimated at $30,000, which included an addition to the present building. Depreciation and other deductions were not considered in the cost estimate. Labor costs were not estimated. The cost to complete dehydration in a rotary dryer were not estimated. Finally, the gluteraldehyde costs were taken at $1.25 per pound and should be reduced when purchased in lots of more than two thousand pounds.

The resulting marine protein concentrate is used mainly as animal food. The contained protein is a complete source of the eight essential amino acids and holds promise for the future as a human food source.

The income estimate was based upon the sale of concentrated solids exclusive of fat in the stick water (SW) which is sold as whole meal for $165.00 per ton. The following calculations were based upon 1000 pounds of stick water with an estimated recovery of 35.6 pounds of protein worth roughly $0.08 per pound.

Income

$$\frac{\text{Income}}{1000\ \text{lbs. SW}} = \frac{\text{Solids (not fat)}}{1000\ \text{lbs}} \times \frac{\text{Price Received}}{1000\ \text{lbs}}$$

$$= (0.0356)\ (\$165/\text{ton})\ (1/2)$$

$$= \$2.937/1000\ \text{lbs SW}$$

Expenses

1) Hydrochloric Acid (HCL) required per 1000 lbs of stick water based upon an additional rate of 0.2 mls/100 mls. stickwater [SW]

$$\text{Weight of HCL} = \text{Ratio}\ \frac{\text{HCL}}{\text{SW}} \times 1000\ \text{lbs SW} \times \frac{\text{Wt HCL}}{\text{Wt SW}}$$

$$= (0.002)\ (1000\ \text{lbs})\ (1.268)$$
$$= 2.536\ \text{lbs HCl}/1000\ \text{lbs SW}$$

$$\text{Cost of HCl} = \frac{\text{Cost}}{\text{ton}} \times \frac{\text{ton}}{\text{lbs}} \times \text{lbs HCl used}$$

$$= \frac{\$18}{\text{ton}} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} \times 2.536 \text{ lbs HCl}$$

$$= \$0.0228/1000 \text{ lbs SW}$$

2. <u>Glutaraldehyde (GA) required per 1000 lbs SW based upon rate of addition @ 0.1 mls GA/100 mls SW.</u> (Price based upon purchase of 25 percent weight GA in 2000 lb lots.)

$$\text{Cost GA} = \text{lbs SW} \times \text{ratio} \quad \frac{\text{Wt GA}}{\text{Wt SW}} \times \frac{\text{Cost}}{\text{lb GA}}$$

$$= (1000 \text{ lbs SW})\ (.001)\ (\$1.25/\text{lb GA})$$

$$= \$1.25/1000 \text{ lbs SW}$$

Chemical total cost
per 1000 lbs of SW = Cost GA + Cost SW

= $1.25 + $0.0228

= $1.2728

Net income per
1000 lbs of SW = Income - Expense

= $1.662/1000 lbs SW

(or) NI = $3.32/ton of SW

The recovery of approximately 72 pounds of solids per ton of stick water indicated a gain of some $3.30 as noted under "Net Income [NI]."

These unit figures can be placed on a seasonal basis by assuming the typical five-month operating season noted above for alewife processing. With a facility designed to handle seven tons of alewife per hour producing approximately 1500 pounds or 200 gallons of waste water per ton of fish process, it was estimated that the process change to glutaric dialdehyde coagulation could potentially increase the solids yield by up to 550,000 pounds per year, which, at $0.08 per pound, was valued at $44,000.00. These production figures were expected to yield roughly 6000 tons of stick liquor annually. The chemical costs were estimated to be $24,000.00 per year. As noted above, the other costs for coagulation and equipment were not estimated.

WASTE WATER TREATMENT

The following preliminary analysis was conducted on waste water effluent from the lime coagulation described above. Regardless of pretreatment, the removal efficiencies and the resulting effluents had the comparable Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand after five days (BOD_5) values noted in Table 2 below. The glutaraldehyde coagulated waste could not be readily analyzed for suspended solids owing to its gelatinous nature. The close agreement in COD and BOD_5 values was felt to provide a sufficient basis for suggesting that the overall waste water treatment results should be quite similar. For that reason, the following studies are reported as probably typical of stick water effluents following glutaraldehyde coagulation. The Total Suspended Solids (TSS), the Volatile Suspended Solids (VSS) and the other determinations were made in accordance with procedures described in the Standard Method (4).

	After Glutaraldehyde Coagulation	After Lime Coagulation
COD, mg/l	29,500	27,000.0
BOD_5, mg/l	23,950	21,600.0
TSS	------	10,500.0
VSS	------	8,000.0
$N\text{-}NH_3$	------	1,130.0
pH	------	8.0*
		*Following neutralization or recarbonation

Table 2. Waste Water Compositions

The waste water treatment studies considered many alternatives. Among these processes were both anaerobic and aerobic biological treatment, direct evaporation and chemical coagulation. The possibility of combined treatment with municipal waste was also considered with and without pretreatment at the source. The effluent produced by chemical coagulation appeared to offer the greatest potential economy in overall waste water treatment costs.

The laboratory investigations were begun with reference to those of Borchardt and Pohland (1). Both anaerobic and anaerobic-aerobic reactor studies were conducted over a wide range of potential operating conditions. Those results used in design are presented in Table 3 below.

	After Anaerobic	After Aerobic
Influent BOD_5, mg/l	21,600	4,000
Reduction BOD_5,%	c.80	--
Effluent BOD_5, mg/l	4,000	--
COD, mg/l	5,000	250
TSS, mg/l	650	50
Vss, mg/l	500	--

Table 3. Treated Stick Water Compositions and Reductions

The two-stage anaerobic-aerobic waste water treatment facility design had the general values notes in Table 4 below.

	Anaerobic	Aerobic
Throughput, gpd	16,000	16,000
Detention time, days	88	62
Volume*, cf	188,000	134,000
*Loading rate 0.01 lb. VSS/cf/day.		

Table 4. Treatment Facility Design Values

It should be noted that the design to be described below provides for future growth. On a seasonal basis, the total volume of current waste water production was estimated on Page above at 314,000 cf. When converted to a weight basis, the gross stick water tonnage can be calculated as shown below:

$$\text{Gross Stick Water Tonnage} = \frac{314{,}000 \text{ cf } (62.4 \text{ lb/cf}}{2{,}000 \text{ lb/ton}}$$

$$= (157) \quad (62.4)$$

$$= 9{,}800 \text{ tons } \underline{\text{per year}}$$

It should be noted that this compared with current production estimates corresponding to c. 6,000 tons per year. The waste water treatment facility then was designed to handle 150 percent of the current production.

Anaerobic Treatment Unit

Figure 4 shows the general plan view for a two-cell design with these properties.

> "Each cell is 15 feet deep and has the dimensions of 100 by 100 feet at the water surface elevation. Side slopes are 2:1. The ten-day detention pond has a depth of 15 feet to water level, [and] surface dimensions of 70 by 70 feet at the water surface elevation and side slopes of 2:1." (3)

It was speculated that the high odor level that is generally associated with anaerobic treatment units might be suppressed here by a surface scum. This expectation was attributed to the high grease content on the order of two percent weight before coagulation of the raw waste. It was also suggested that the high grease content might help to seal the lagoon bottom. Inflow turbulence and gas production were relied upon to produce a completely stirred condition.

An estimate of the annual operating cost for an anaerobic lagooning facility was arrived at by assuming a ten-year life with financing at seven percent per annum. Capital costs were estimated for the design in Figure 4 at c. $21,000 exclusive of land and pumping facilities. Ammortization of this expense together with an estimated $1,000 per year of operating costs resulted in a total facility cost of c. of $4,000 per year.

Aerobic Final Treatment Unit

The general characteristics of the anaerobic influent to the final treatment unit were noted in Table 3. Design of the aerobic units was based upon a warm weather operation from May to November at a flow of 16,000 gpd. In addition to the mechanically aerated lagoons, a quiescent pond with a 30-day detention time was provided as a post treatment.

A facility with the design values noted in Table 4 and with a

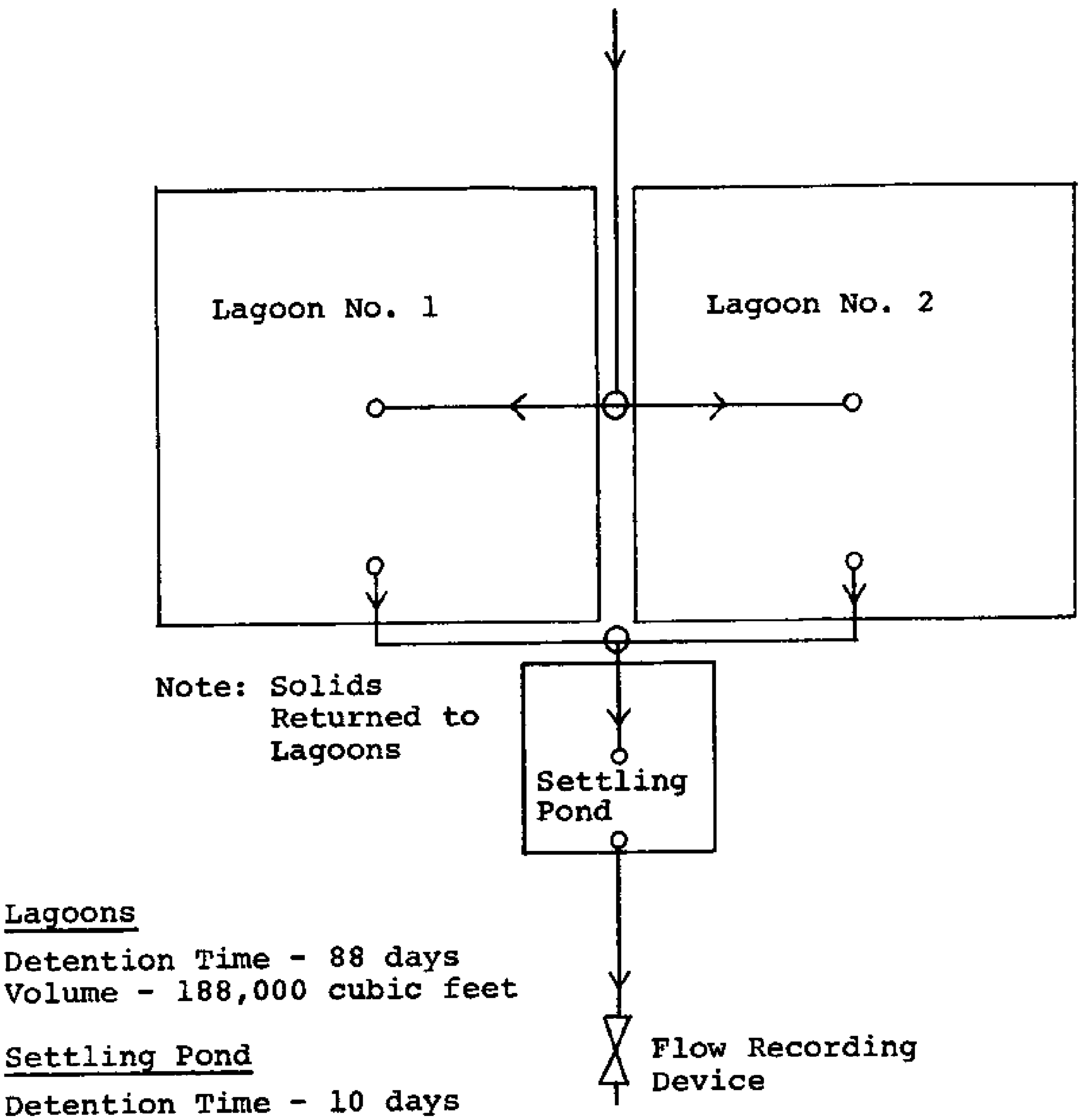
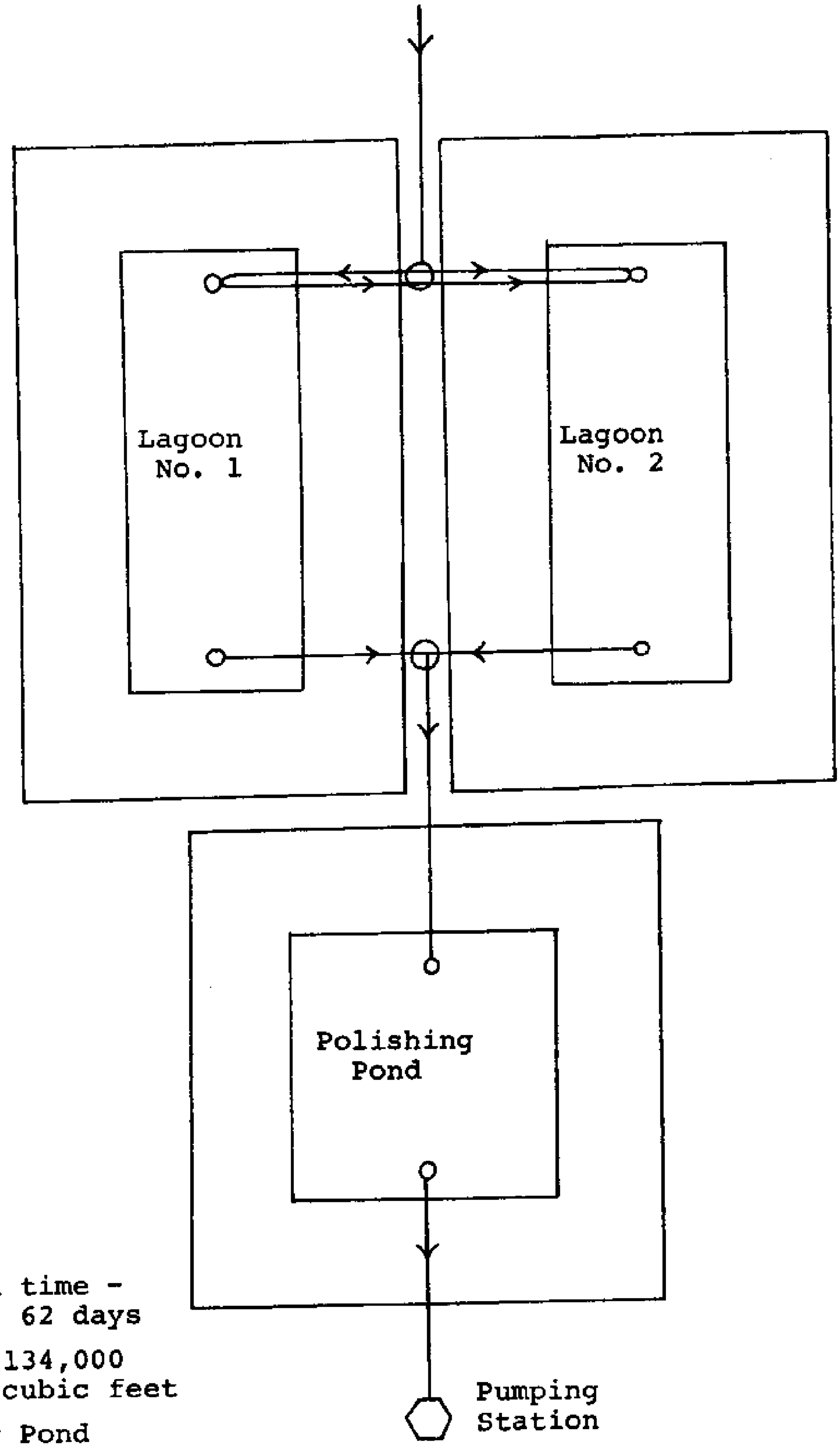


Figure 4. Anaerobic Lagoon System



Lagoons

Detention time - 62 days

Volume - 134,000 cubic feet

Polishing Pond

Detention Time - 30 days

Figure 5. Schematic of Aerobic Lagoon System

basin arrangement similar to those shown in Figure 5 was developed.

> "Each cell is 10 feet deep and has dimensions of 80 by 140 feet at the water surface. Side slopes are 2:1. The quiescent polishing pond has a detention time of 30 days, (with a) depth of 10 feet to (the) water level, surface dimensions of 100 by 100 (feet) and side slopes of 2:1. The polishing pond is designed to reduce the effluent suspended solids from 500 to 50 mg/l. The effluent from the aerobic process will be characterized by a COD of approximately 250 mg/l and a suspended solids concentration of about 50 mg/l. Some nitrogen and phosphorus removal can also be expected." (3)

An annual cost was estimated using the same assumptions noted above for the anaerobic unit. When reduced to allow for a gravity flow discharge basis, the combined amortization and operative costs total c. $8,000 for the aerobic treatment facility.

The two-stage total treatment cost then becomes $12,000 per year.

CONCLUSIONS AND RECOMMENDATIONS

The gross income estimate shown on Page of up to $20,000 could serve to offset the cumulative cost estimates of $12,000 per year for the two-stage treatment process and provide a reserve against coagulation process and treatment costs that were not estimated. While further pilot-scale study would be required to confirm these bench-scale findings, the potential of this approach to waste water treatment with additional product recovery was certainly apparent.

Some further observations have come to light. For example, heated anaerobic digestion tanks might work better. Also, it must be noted that both treatment processes would have to be used together. Even then, the predicted final effluent from the aerobic unit would still have a COD of some 250 mg/l and a suspended solids of 50 mg/l. Special permits would be required before such a waste could be discharged.

References

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2. Brody, J., "Fishery By-products Technology", AVI Publishing Company, Westport, Connecticut (1955).

3. Unpublished Student Paper, Civil Engineering 760, Spring Semester 1971.

4. Standard Methods for the Examination of Water and Waste Water, APHA (1965)

5. Our thanks to the following students who participated in this project:

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