Wastewater Treatment Alternatives for a Vegetable and Seafood Cannery

by

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1.0 INTRODUCTION

Cannery wastewater characteristics, like all food processing effluents, vary with the type of raw product processed and the efficiency of the processing scheme. Wastewater treatment alternatives for sardine and green bean operations are likely to be different. Seasonal wastewater variations include not only wide fluctuations in volume but also drastic changes in wastewater characteristics due to canning completely different products at the same plant. Hence, the same plant packaging sardines this month may be packaging green beans next month. It would not be uncommon for the same plant to process these products at different times on the same day. This variability is one of the major challenges in treating a cannery wastewater.

The objective of the study presented herein was to analyze wastewater treatment alternatives for Lake Packing Company, Inc. (LAPCO), located in Lottsburg, Virginia. LAPCO has been in existence for about 80 years and employs approximately 100 people. Presently, there are three main production processes; the canning of whole-pack tomatoes, oysters, and herring roe. While each waste is amenable to biological treatment, organic content differs widely since raw tomatoes contain more carbonaceous material and oyster and herring roe contain more proteinaceous material. Suspended solids concentrations and settleability characteristics also differ considerably. Biochemical oxygen demand (BOD) levels vary by two orders of magnitude.

The Virginia State Water Control Board (VSWCB), in recent years, has been closely monitoring the land irrigation system presently used by LAPCO for wastewater disposal. The spray irrigation field is located over a ground water supply used for drinking water by a nearby residential area. Increasing sodium levels found in monitoring well samples have raised a flag to the VSWCB and indicate that an alternative treatment and disposal process may be necessary in the interest of public health. Sodium levels in the groundwater have steadily risen from 8 mg/l in 1985 to 220 mg/l in February of 1989. The Environmental Protection Agency (EPA) established that the safe drinking water level is 270 mg/l. High wastewater sodium concentrations have also caused soil in the irrigation field to become dispersed inhibiting percolation. In response, LAPCO recently applied for an extension of its non-discharge permit to spray irrigate on an additional 24 acres. In 1988 only 8 acres were used. This is only a temporary solution since, eventually, sodium will continue to leach into the groundwater. This approach will also cause more land with agricultural value to be subjected to the adverse effects of sodium; i.e., crop intolerance and ponding. The problem must be solved by either reducing the amount of sodium used in production processes or selection of an alternative wastewater treatment program.

The economic burden of wastewater treatment is, of course, a major concern for any company but may be especially burdensome for a small company like LAPCO. Production runs are more mechanized for companies such as Del-Monte and Campbell's Soup, which use state-of-the-art equipment and can afford higher capital investments. Care must be taken to ensure that a wastewater treatment process does not affect the company's ability to be competitive and that production costs are within the working capital limits of the company.

The magnitude of the economics problem cannot be underestimated. In 1968 there were 17 canneries processing whole-pack tomatoes in Virginia [3]. By 1974 only 7 processors remained [4]. At the present time (1989), LAPCO is the only remaining, whole-pack tomato cannery in Virginia [5]. Tomato production in Virginia has declined from 40,000 tons in 1978 to 25,200 tons in 1985. This pattern is evident throughout the country as well. Between 1982 and 1985, production for Delaware, Virginia and Maryland fell from 110,100 tons to 80,300 tons with a corresponding dollar value decrease from $9,165,000 to $6,037,000. Likewise, U.S. canned tomato packs for the entire eastern region have decreased from 2,093,000 cases in 1978 to 717,000 in 1986 [6]. A similar pattern of plant closures has occurred in Canada, as well. Although the above industry pattern may not be entirely due to the rising cost of wastewater treatment, it is certain that this has had a major impact. Often, canneries originally located in rural areas had towns develop around them. Due to high sulfide concentrations in tomato wastewater, odor problems resulted and operations were forced to close because of public comment.

If biological treatment was to be used by LAPCO, treated effluent would have to be discharged to a local waterway, the Coan River. This is an estuarine river system located about 10 miles upstream from the mouth of the Potomac River and the Chesapeake Bay. Effluent limitations would be defined by the National Pollutant Discharge Elimination System (NPDES) set forth by the 1972 Federal Water

Pollution Control Act Amendments. Through these amendments, interim effluent guidelines were set up which were supposed to have led to the goal of zero discharge by 1985.

The first set of interim guidelines represent the best practicable control technology currently available (BPT) and went into effect in 1977. The second, more stringent set of effluent guidelines represent the application of best available control technology economically achievable (BAT) and were supposed to go into effect 1 July, 1983. These levels were withdrawn in June of 1979, however, for the canned and preserved fruits subcategory, which includes tomatoes. BAT levels were deemed to be unreasonable and were replaced by more lenient levels designated best conventional pollutant control technology currently available (BCT). BCT limitations were set up to replace BAT values for other existing industries discharging conventional pollutants. The current BCT and BPT levels are identical for the whole-pack tomato processing industry. Effluent limitations are included for 5 day biochemical oxygen demand (BOD_5) total suspended solids (TSS) and pH. Current BCT levels governing LAPCO's tomato processing wastewater are shown in table 1.

Table 1. BCT/BPT Effluent Limitation for Canned Tomatoes per CFR, Part 407, Subpart F

	LB/1000 LB	
	BOD_5	TSS
Daily Maximum	1.21	2.15
30 Day Average	0.71	1.48
Annual Average	0.49	0.90

pH: At all times within the range 6.0 to 9.5

BCT effluent requirements for the Atlantic and Gulf Coast hand shucked oyster subcategory, which are likewise identical to the BPT values are shown in table 2. Note that there is no BOD limitation, but there is an oil and grease (O&G) limitation. LAPCO holds a permit to discharge this wastewater which places additional limitations on the quantity of pollutant discharged, irrespective of production values. These LB/day values are presented in table 2.

The effluent guidelines for herring roe wastewater were derived by the VSWCB. There are no proposed or established EPA guidelines. The VSWCB considered herring roe wastewater characteristics to be similar to wastewater generated by a herring filleting operation, for which there are established federal guidelines. Originally herring roe limits were designated BPJ (Best Professional Judgment) values and were relatively austere. In 1989, one year after BPJ values were proposed, LAPCO received its VPDES permit to discharge herring roe wastewater. These values are presented in table 3 and they are approximately 6 times higher than original BPJ values. LAPCO does not discharge this wastewater, however, since further testing is necessary to see if wastewater needs treatment prior to discharge.

TABLE 2. EFFLUENT DISCHARGE LIMITATIONS FOR LAPCO'S HAND SHUCKED OYSTER PROCESS

	LB/DAY[a]		LB/KLB[b]	
EFFLUENT CHARACTERISTIC	MONTHLY AVG.	DAILY MAX	MONTHLY AVG.	DAILY MAX
BOD_5	NL	NL	NL	NL
TSS	108.82	156.42	16.00	23.00
O&G	5.25	7.47	0.77	1.10

- pH BETWEEN 6.0 AND 9.0 AT ALL TIMES
- NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS
- NL = NO LIMIT

NOTES: a. VPDES PERMIT LIMITATIONS

b. 40 CFR, SUBPART Z, BCT LIMITATIONS

TABLE 3. HERRING ROE PROCESS DISCHARGE LIMITATIONS PER VPDES PERMIT

EFFLUENT CHARACTERISTIC	(LB/DAY) MONTHLY AVG.	(LB/DAY) DAILY MAX	(LB/KLB) MONTHLY AVG.	(LB/KLB) DAILY MAX
BOD_5	63.3	67.3	7.9	8.4
TSS	42.3	56.9	5.3	7.1
O&G	12.3	29.5	1.6	3.7

- pH BETWEEN 6.0 AND 9.0 AT ALL TIMES
- NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS

The purpose of this study was to investigate treatment alternatives for LAPCO's production processes. An analysis is presented which reveals whether or not treatment is necessary for LAPCO's herring roe and oyster wastewaters. An investigation into tomato peeling options is also presented.

2.0 LITERATURE REVIEW

This chapter will review literature on the canning and food processing industry. The emphasis will be placed on wastewater treatment. After an overview of the tomato processing industry is presented, a brief discussion of LAPCO's herring roe and oyster processes will follow. Literature will then be reviewed in three key areas, all pertaining to wastewater treatment of food processing effluents. First, land application will be discussed, particularly as it pertains to LAPCO's present disposal system. Anaerobic and aerobic biological treatment options for the canning industry will then be reviewed. Specific examples will be presented and advantages and disadvantages of each treatment alternative will be discussed.

2.1 TOMATO PROCESSING OVERVIEW

Tomatoes are the leading processed vegetable consumed in the United States and rank second to potatoes in dollar value among all processed vegetables [1]. Tomatoes have a long history and were popularly known in Europe during the 16th century as "love apples". Although the first U.S. cannery dates back to the year 1847, numerous operations sprouted up shortly thereafter. In 1907, American tomato canneries packed 12,918,206 cases of tomatoes [2]. By the year 1937, 61 tomato varieties had been developed [1].

Tomatoes are processed in numerous ways. The tomato packing industry includes whole-packed, stewed, italian, catsup, chili sauce, tomato paste, tomato puree, tomato sauce and tomato soup. The processing scheme for most tomato packing operations is presented in figure 1. Note that the term "whole-pack" represents peeled whole tomatoes.

LAPCO usually processes both whole-pack tomatoes and tomato juice. Tomato juice has not be processed for the past two years, however, because of very low profit margins relative to whole-pack. This situation is not expected to change in the near future. Our primary concern was then only the whole-pack tomato canning process.

LAPCO's whole-pack processing scheme is presented in detail in figure 2. Raw tomatoes are dumped by the crate into a receiving pit filled with water. This removes sand and mud and facilitates conveying tomatoes into the production

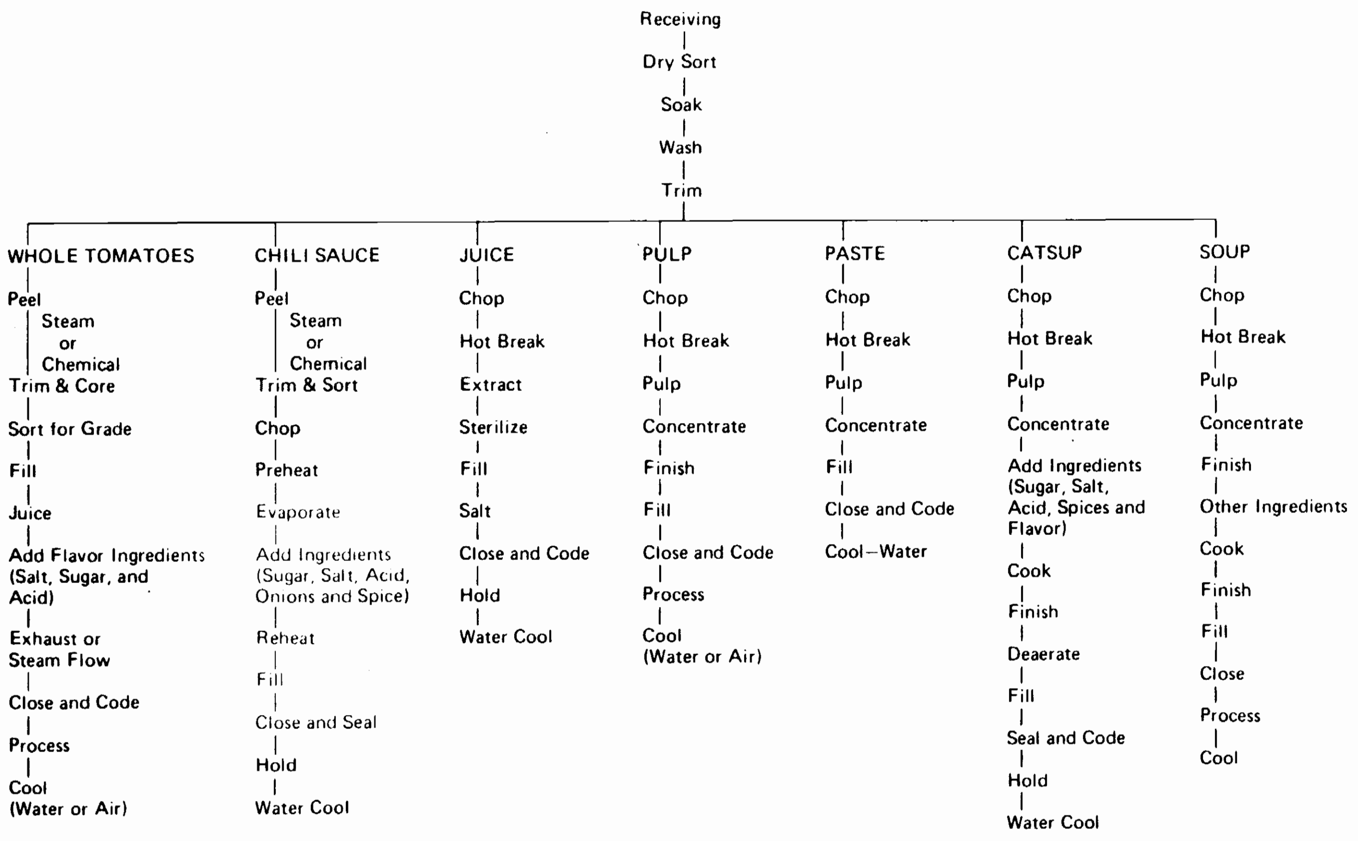


FIGURE 1. PROCESSING SCHEME FOR VARIOUS TOMATO PACKING OPERATIONS (AFTER GOULD [1])

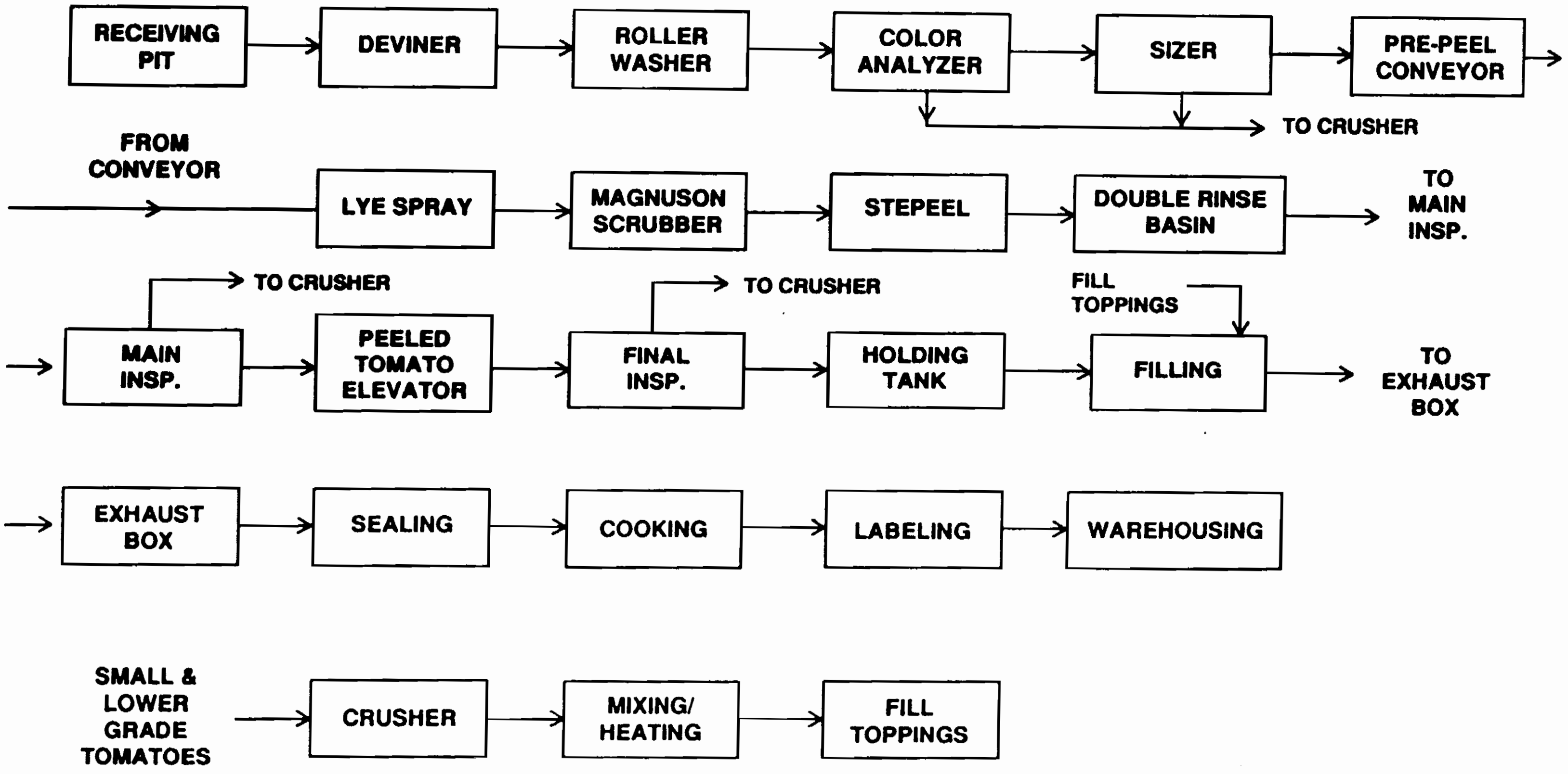


FIGURE 2. LAPCO'S WHOLE PACKED TOMATO PRODUCTION PROCESS

line. Since fruit is mechanically harvested, a deviner is necessary to remove any vines that may be collected. Tomatoes then pass over rollers and undergo a spray rinse. A color analyzer removes green tomatoes. Depending upon the amount of green color, these tomatoes are either discarded or sent to the crusher. The sizer separates small tomatoes and sends them to the crusher also. A conveyor carries tomatoes through a caustic (also called lye) or sodium hydroxide spray which is approximately 12-15% NaOH and kept at about 90°C. The detention time of tomatoes in the lye spray is about 30 seconds. A wetting agent called "Faspeel" is added to the caustic solution such that the concentration is approximately 0.3%. Faspeel, a trade name for an Emery Chemical Company Product called Emery 1210, is a mixture of short chain aliphatic fatty acids (pentanoic, hexanoic, heptanoic, octanoic and nonanoic). It is to be used at a concentration not-to-exceed 1%, per vendor specifications. The purpose of using a wetting agent is to achieve a good peel at a lower NaOH concentration. A 20% NaOH concentration would be needed without it. Note that Faspeel is also marketed by other chemical companies, but each Faspeel has a different chemical composition. For instance, Wyandotte Chemical Co. uses an anionic surfactant composed of sodium mono-and dimethylnaphthalene sulfonates [1].

Following caustic treatment, tomatoes then enter the Magnuson Scrubber. Manufactured by Magnuson Engineers of San Jose, California, this is a rotating cylinder containing bristles and spray rinses to remove loosened tomato peels from previous contact with NaOH. About 90% of the peel is removed here. Depending upon how easily tomatoes are peeled, spray rinses in the Magnuson Scrubber can be turned off and tomatoes then undergo a "dry" caustic peeling process. Continuing through the process, tomatoes go to the Stepeel (another trade name) where the final 10% of the peel is removed. This agitates tomatoes by vigorously passing them over rotating rubber rollers, under another spray rinse. There are two Magnuson Scrubbers and two Stepeels operating in parallel. Tomatoes are then rinsed twice to remove any sodium and wetting agent residual, per FDA regulation 21 CFR 121.0191.

Peeled tomatoes then go through two additional grading or inspection processes. Lower quality product goes to the crusher while unacceptable tomatoes are discarded. Tomatoes that get crushed are used to top off or fill to capacity, cans filled with peeled, whole tomatoes. Final graded tomatoes go to a holding tank filled with water. This allows production up to this point to continue for a while, should a mechanical failure occur downstream of this point. Tomatoes then go to one of three canning lines.

First, cans are filled with peeled tomatoes and then with crushed tomatoes from the mixing/heating tank. The exhaust box heats filled cans to allow a good vacuum seal. Sealed cans are then cooked in one of five, large, continuously rotating tanks kept at about 100°C. Note that most operations that are subject to interruption or to mechanical failure are located downstream of the holding tank. Note also that core removal is no longer a necessity since new tomato varieties have been developed which have little or no core [1].

As results will soon show, the caustic peeling operation causes high sodium levels in tomato wastewater. These levels may govern the method of wastewater treatment to be undertaken by LAPCO. Other tomato peeling methods have been investigated in order to avoid the resulting problems associated with caustic. Thomas <u>et al</u>. [7] compared results obtained from peeling tomatoes with caustic, steam blanching, and freeze-heat methods with $CaCl_2$ brine and liquid nitrogen. Tomatoes of the Floridel variety were used, and peeling ability as well as fruit damage was analyzed. Weight loss of peeled tomatoes and color retention were the damage factors.

Steam blanched tomatoes were exposed to 85 psi of live steam. Optimum exposure time was about 2.5 minutes to obtain good peeling characteristics on 90% of the fruit tested. The resulting weight loss of fruit was about 15%. Caustic peeling was performed with a one minute exposure to 18% NaOH at 90°C. Very good peelability was achieved in 100% of fruit, and weight loss was 14%. Caustic peeling was the fastest method and showed the best peeling characteristics. Brine peeling with $CaCl_2$ at -20°C (4°F) yielded good results for a 2.5-3.0 minute exposure time. Liquid nitrogen exposure for 20 seconds, followed by a 40°C (104°F) water rinse for 2.0 minutes, yielded good peeling characteristics on 100% of fruit with only a 9.3% weight loss. In the freeze-heat procedure, subsurface cells rupture from ice crystals formed during extreme low temperature exposure. Pectic enzymes are released in the ensuing high temperature soak which break down pectic material and loosen the tomato peel to facilitate removal [7]. This method of peel removal is obviously quite expensive and not likely to be a realistic option. No literature could be found describing follow-up studies or full-scale implementation.

A problem associated with caustic peeling is poor color retention. Spherical chromoplasts as well as a chromoplast sheath are located along the inside lining of cell walls within the pericarp or outer region of the tomato. The outer region includes the epicarp (outer skin) and mesocarp (fleshy region beneath the skin). These chromoplasts contain pigments which include lycopene, carotenes, and phytofluene (after Harris et al. [7]). Thomas et al. [7] have produced scanning electron micrographs showing extensive chromoplast destruction when lye was used as the peeling agent. They believe vitamin A may then be lacking. Chapter 4 will show that lye peeling produces a wastewater that is highly colored, presumably from chromoplast destruction. In an effort to abate the use and disposal of NaOH, potassium hydroxide (KOH) can be used as the active peeling agent. This report will show, however, that there is no advantage to using KOH with respect to wastewater disposal for the whole-pack tomato industry.

It has been reported that the Agricultural Research Service investigated peeling tomatoes using a heat/cool sequence with steam at approximately 316°C (600°F) [8]. Although tomato peel was successfully removed, heat losses could not be contained. A host of steam peelers came on the market in the late 1970s. Mostly used for potato peeling, only limited success has been reported with tomatoes [9]. The mechanism of peel removal is the sudden pressure drop to atmospheric conditions which causes the peel to become superheated, generating flash steam between the skin and the peel. Thomas [10] recently concluded that steam peeling could not be used by a cannery processing only whole-pack tomatoes. Steam peeling is not as efficient as peeling with caustic. Since so many unpeeled fruit remain, a steam peeling operation could only be used if a large quantity of a secondary tomato product; i.e., juice or sauce, were produced with poorly peeled fruit.

Special varieties or cultivars have been produced which are responsible for the success of mechanical harvesting and the accompanying high-speed automation. These varieties are firm, tough-skinned fruit that are able to withstand rough handling from the mechanical harvester. Although they are easily peeled with NaOH, their development stunted the use of steam peelers [8]. Hence, they have added to the burden of wastewater disposal.

2.2 HERRING ROE PROCESSING

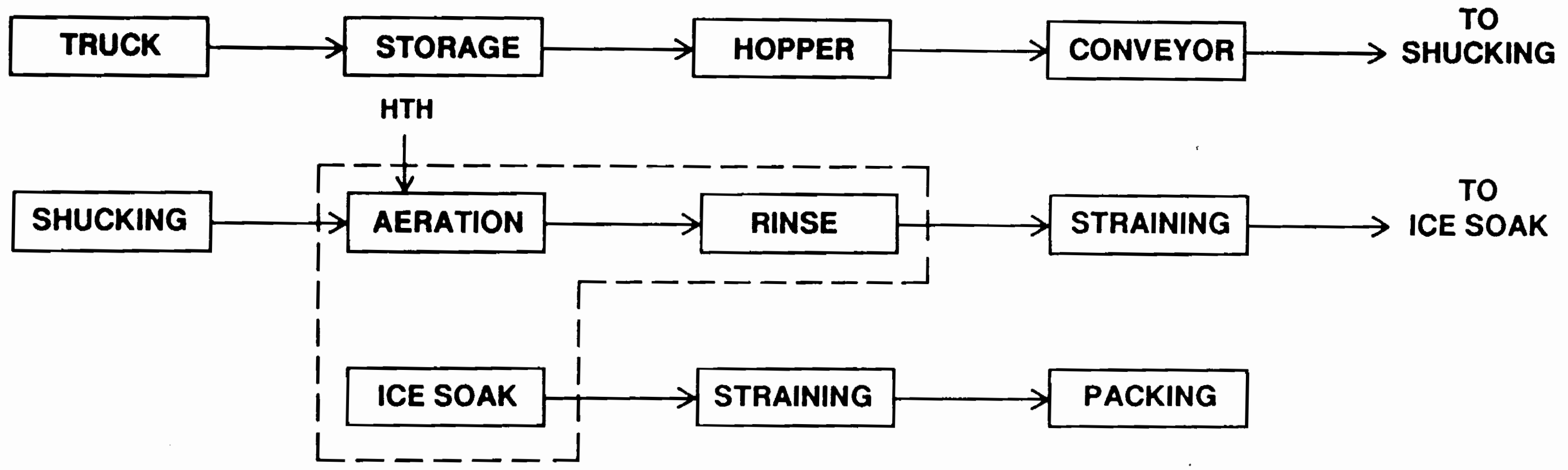
The canning of herring roe is a fairly simple operation. This product is processed from March through May by LAPCO. Roe is received from local herring filleting processors. It is first washed to remove residual blood and scales. This is accomplished with water from 18 spray rinse nozzles while the roe moves along a conveyor belt. Cans are filled with roe in a semi-automated process. They are then filled to capacity with a brine solution, sealed and cleaned with additional spray rinsing. Cans are cooked, labeled and finally warehoused on the premises.

Depending upon product availability, processing may be intermittent. Both the numbers of hours per day and days per week for this operation can vary widely. The specie of herring roe packed may also change. In the past, Atlantic Menhaden roe has also been packed. Wastewater characteristics will probably be very similar regardless of the type of roe processed.

2.3. OYSTER PROCESSING

LAPCO packs oysters from October through April. Note that oyster and herring roe canning both occur during the months of March and April. Atlantic oysters are hand-shucked in a process shown by figure 3. Oysters were at one time seeded and harvested by LAPCO, but disease and desalinization of local waterways made this unprofitable. Oysters are now delivered by truck, put into a storage area, and fed to a hopper which automatically feeds baskets conveyed to the shucking area. After shucking, they are sorted into standard and select oysters, depending upon size. Both grades of oysters undergo the same processing. Shells are put into a waste pit and are moved by a front-end loader to an on-site disposal location at the end of the day.

Although raw oysters have a considerable amount of mud on their exterior, they are not prewashed. On very cold days,



NOTE: a) DOTTED LINE SURROUNDS PROCESSES WHICH OCCUR IN THE SAME TANK.

FIGURE 3. LAPCO'S HAND-SHUCKED OYSTER PROCESS FLOW DIAGRAM

however, when oysters are delivered frozen, water is run through the hopper to thaw them. This causes additional mud to enter the disposal flume. Because of different bottom soil types in the Chesapeake Bay, the extent of sediment on the oysters may vary daily. However, hand shucking plants do not generally wash shell stock since the only benefit is to make hand shucking more pleasant [11].

Oyster meat gets processed in batches of approximately 20 gallons. Meat is put into a water-filled basin that is 3 ft. 4 in. in diameter and 2 ft. deep (131 gallons including oyster meat). Chlorine is added as a disinfectant in the form of high test hypochlorite (HTH). Roughly 3 to 4 oz. of HTH powder (which is 65% calcium hypochlorite) are added per batch processed. The basin is vigorously aerated for approximately 10 minutes. This allows adequate contact with the disinfectant for a reasonable detention time. Oyster meat also begins to absorb water and swell during this process. Aeration is turned off and rinse water then enters the bottom of the basin. Since the basin is filled to capacity prior to the aeration cycle, this rinse water causes overflow around the perimeter. The rinsing process lasts approximately 10 minutes and thoroughly removes any unwanted residue and residual chlorine. Because of the upward flow of water and the swelling, meat will rise to the top of the tank. When the rinse cycle is complete, meat is strained through a colander. Approximately half the water volume of the basin remains. Meat is then returned to the basin and put on ice for about 20 minutes. By this time the meat is at a temperature of 4°C and has swelled to its maximum volume. It then gets strained once again before being packed. The dotted line in figure 3 surrounds three key processes that occur in the same tank. There are six separate tanks, each operating intermittently up to four times per day.

2.4 LAND APPLICATION

Applying wastewater to land has been the favored method of waste disposal within the fruit and vegetable industry. Land disposal is often well-suited to this industry since the wastewater usually contains high levels of soluble organic matter, and is discharged during the dry season when local water surface streams are at lowest levels and evapotranspiration rates are highest [12]. There are two modes of operation for land disposal, surface irrigation and spray irrigation [13]. Surface irrigation includes ridge and furrow, overland flow, and flood irrigation. Spray irrigation, the most common method of land disposal, uses a sprinkler system to discharge wastewater on relatively flat, dry land with adequate percolation and evapotranspiration.

Design of a spray irrigation system must be based on cover crop and soil assimilative capacities and on a land limiting constituent (LLC) analysis. Land area requirements are based on the LLC. Any wastewater constituent could be determined to be the LLC, resulting in the greatest land area requirement for disposal. Water, COD, nutrients, metals, organics, and others all need to be considered. Approximately 200 lbs. BOD/acre/day would be an upper loading limit for a readily degradable wastewater and a loomy, well drained soil, although for soluble wastes, higher loadings could be tolerated for short periods of time. Optimum resting periods also need to be considered [12].

The objective of land treatment is not only the degradation of organic constituents, but also the immobilization of inorganic constituents. In this manner, a land treatment site is a biological-physical-chemical reactor. A successful design will prevent surface and ground water pollution and not irreversibly remove land from a defined use; i.e., a condition suitable for crop production, forest, open space or parks [14].

LAPCO's main spray irrigation concern (the LLC) is sodium. To understand the adverse effects of high sodium concentrations, three parameters need to be defined.

First, the cation exchange capacity (CEC), is the sum of all exchangeable cations adsorbed per 100 grams (g) of dry soil when the exchange capacity is completely utilized. CEC is measured as milliequivalents per 100 g (meq/100g) [14]. As long as the CEC is not depleted, soil will continue to adsorb or immobilize metal cations. Second, exchangeable sodium percentage (ESP) represents the proportion of the CEC occupied by sodium [14]. Soil damage due to sodium uptake increases in direct proportion to the ESP. The third definition is more of an operational parameter and is called the sodium adsorption ratio (SAR). It is an empirical measure of the sodium imbalance of a wastewater (14). The empirical definition is:

$$\mathrm{SAR} = \frac{\mathrm{Na}}{[(\mathrm{Ca} + \mathrm{Mg})/2]^{\frac{1}{2}}}$$

where all concentrations are expressed as meq/l.

The ESP and SAR are directly related and in fact if one is known the other can be found through an empirical relationship (after Richards [13]). The CEC and SAR are indirectly related since a high CEC value could temporarily mask the effects of a high SAR. Loehr and Overcash [14] recommend maintaining an SAR of less than 10, unless special precautions are taken. Exceeding this value for extended periods of time will cause the clay present in soil to swell and deflocculate, ruining soil structure

[14]. A soil with poor structure will pack, cake, crack, and harden; therefore, it will be poorly drained. A good soil has structured openings or pores, leaving the soil loose and crumbly [15].

Although sodium can adversely affect vegetative cover because of osmotic relationships, ionic interferences, and toxicity [13], these concerns are of lesser importance to LAPCO. Since tomatoes are moderately sensitive to sodium [16] and LAPCOs tomato wastewater has an SAR of near 30, it is not possible to get any yield from a tomato crop on land in the disposal area. LAPCO has been able to produce a growth of Bermuda grass, an extremely salt tolerant species [13]. This allows for a substantial quantity of sodium to be removed from the land area during the harvesting of the grass, which has assimilated sodium. However, the only way LAPCO has been able to maintain adequate soil structure to grow even hearty Bermuda grass, has been through yearly application of as much as 2,000 lbs./acre of gypsum on the surface of the disposal area. This was also necessary to prevent ponding. Gypsum or $CaSO_4$ application is a corrective measure whereby Ca ions eventually percolate through the soil and displace Na ions, maintaining a favorable SAR.

Overcash [13] has stated that if a soil structure has been severely deteriorated, corrective action could take months or even several years, and only partial restoration will occur. Widner [17] feels that a strict use of SAR values in northern Virginia has limited justification, since rain will cause a leaching effect on sodium in the soil. The SAR is thus more important in arid areas. Widner also believes adjusting pH to neutral before irrigating will prevent degradation of soil structure, even with LAPCO's high SAR wastewater.

It is unlikely that soil percolation rates are beyond recovery since LAPCO has had such good success with the application of gypsum. On the other hand, remobilizing bound sodium, which has been a necessity to be able to spray irrigate, has contributed to high sodium concentrations in groundwater beneath the disposal area. Since the underlying aquifer is used as potable water for a local residential area, LAPCO and the SWCB are concerned. The EPA has established that the safe drinking water level for sodium is 270 mg/l. A monitoring well in the disposal area revealed a sodium concentration of 221 mg/l in February, 1989. There is a definite trend showing that this level will continue to rise. Results from the same monitoring well in November, 1984 showed a sodium concentration of only 1.0 mg/l. Hence, even if adequate hydraulic conductivity is maintained, land disposal of tomato wastewater may no longer be an option for LAPCO.

2.5 ANAEROBIC TREATMENT

Review of literature pertaining to the treatment of strong food processing wastewaters would not be complete without some discussion of anaerobic treatment. Anaerobic treatment alternatives for strong food wastes are cheaper than equivalent aerobic treatment. Lower energy requirements and lower sludge handling costs are the basis of this economic advantage (after Smith _et al_. [18]). Tomato peeling wastewater is unique, however, and this investigation will instead show that this waste does not lend itself to efficient anaerobic treatment. The focus of this investigation is on the limitations and disadvantages of anaerobic treatment, particularly as they apply to LAPCO's tomato wastewater.

High sodium concentrations in tomato processing wastewater severely hamper the use of anaerobic treatment. McCarty and McKinney [19] found about 3,800 mg/l of sodium to be toxic during an acclimation study. While this level caused significant inhibition, sodium levels as high as 6,500 mg/l could be "tolerated" with strict pH control near 7.0. Such strict pH control would be a difficult task if tomato peel wastewater, with a pH near 12.0, had to be carefully adjusted to neutral with concentrated acid. Stevens and van den Berg [20] treated tomato peel wastewater from a "dry" caustic peeling process similar to that used by LAPCO. The COD value of near 75,000 mg/l and total solids value of about 88,000 mg/l are nearly identical to LAPCO's Magnuson Scrubber wastewater when operated in a "dry" mode. This wastewater had a higher sodium concentration of 11,000 mg/l, as compared to a LAPCO value of about 7,500 mg/l. A fixed-film, downward flow reactor was used and a COD reduction of only about 58% was achieved at a volatile solids loading rate of approximately 12 kg/m³/day. Wastewater used in this study was diluted 5:1, presumably to lower the sodium content to near 2,000 mg/l. In another study van den Berg and Lentz [21] used an anaerobic contact process to degrade dry-caustic-peeled potato wastewater. Here the waste was diluted to reduce the sodium content from about 6,000-8,000 mg/l to about 3,000 mg/l. Influent COD levels of about 38,000 mg/l were reduced by 70% with the following operational parameters:

Volatile solids loading rate (VSLR) = 3.0 kg/m³/day

Hydraulic Retention Time (HRT) = 20 days

Solids retention time (SRT) = 27 days

The authors found that the relationship between chemical oxygen demand (COD), nitrogen (N), and phosphorus affects sodium toxicity. Raising the nitrogen content of the waste from a COD:N:P ratio of 300:5:1 to 300:10:1 proved beneficial, presumably because nitrogen (added as an ammonium salt) antagonized sodium. This study showed that sodium inhibition can occur at 3,000 mg/l, whereas Stevens and van den Berg [20] imply that inhibition may be occurring even below this value. Since LAPCO's Magnuson Scrubber wastewater typically has a sodium concentration in excess of 5,000 mg/l, sodium inhibition would be a serious concern for anaerobic treatment.

Neutralization of strong caustic alkalinity present in the Magnuson Scrubber wastewater requires the addition of a considerable amount of strong acid. This may lead to toxicity due to high concentrations of certain anions. Sulfuric acid, which was used for neutralization purposes during the aerobic treatability study presented herein, could not be used for anaerobic treatment without significant inhibition due to sulfate. In this study, about 10,000 mg of sulfate was added per liter of wastewater feed when lowering the pH from about 12.5 to 8.5. Higher additions would result during anaerobic treatment since pH would be lowered to 7.0. Lettinga _et al_. [22] found that sulfate inhibits methanogenesis to a notable extent at concentrations exceeding 5,000 mg/l.

Sulfide formed as a result of microbial sulfate reduction will cause an even more serious inhibition problem. H_2S inhibition is a function of the influent COD/SO_4^{2-} ratio. The basis of this ratio is that at COD/SO_4^{2-} values greater than 10g/g, H_2S-Sulfur (H_2S-S) can be kept below 100 mg/l because of the stripping capacity of the biogas [22]. H_2S-S concentrations of 100 mg/l are known to inhibit anaerobic digestion (after EPA [23]). The value of COD/SO_4^{2-} for LAPCO's neutralized Magnuson Scrubber wastewater is roughly 5.0.

Even if sulfides were not formed due to sulfate addition, odor problems would surely be a concern because of the presence of naturally occurring sulfur compounds in tomato peel wastewater. A brief review of the chemistry of tomatoes shows that eight volatile sulfur compounds have been isolated which contribute to tomato flavor. They are formed as a result of cooling cooked tomatoes, and dimethyl sulfide is included in the list of volatiles formed [1]. Methyl sulfide is formed upon heating and up to 7.9 ppm of methyl sulfide and 0.15 ppm of hydrogen sulfide have been found in processed tomatoes (after Miers [24]). One other sulfur compound important to tomato flavor is 2-isobutylthiazole [1]. Although no literature was found on the total sulfur content of tomatoes, results presented in this study show high total sulfur and sulfate concentrations (approximately 300 mg/l and 500 mg/l, respectively) in LAPCO's Magnuson Scrubber effluent.

Should KOH be used as the active peeling agent instead of NaOH, it would be important to consider the toxic affects of potassium. Since potassium inhibits anaerobic processes at 2,500 mg/l [23], anaerobic treatment would not be a practical alternative. Potassium levels would far exceed this value if KOH peeling were to be used. One additional concern is total dissolved solids (TDS), which can inhibit any biological process in excess of 16,000 mg/l [23].

2.6 AEROBIC TREATMENT

Through conversations with numerous companies canning tomatoes and pickled vegetables, it is evident that aerobic lagooning is a popular treatment method in the industry. Stabilized lagoon effluent is often discharged to a waterway or spray irrigated on land the following season, after a one year retention time. Indeed, it has been stated that aerated lagoons with a long retention offer the best advantages for treatment of wastewater from the fruits and vegetables processing industry [25]. Aerobic algal ponds and facultative aerobic lagoons have also been used by the canning industry. Maulding (after Dickson [12]) reported a 96% BOD removal treating pea processing waste at a loading of 70 lbs/acre/day for an algal pond and (after Eckenfelder [12]) a 68% removal of BOD when treating tomato waste at a 5 day HRT with a facultative aerobic lagoon. Combined anaerobic-aerobic ponds have been used in the canning industry, achieving 91% BOD removal at a loading rate of 617 lbs/acre/day and HRT of 22 days [23].

One of the biggest concerns in combining anaerobic-aerobic or facultative treatment is odor problems. Lepper and Lacey [26], however, were able to use an anerobic-aerobic lagoon system to treat tomato wastewater without generating objectionable odors. Nitrate salts were added to the anaerobic cell and prevented sulfate reduction by raising the oxidation-reduction potential [23]. Approximately 98% BOD removal resulted, but the BOD concentration was only 1,356 mg/l (compared to LAPCO's 21,400 mg/l) and tomatoes were not peeled with caustic.

LAPCO has adequate land available to use an aerobic lagoon but is concerned about the possibility of generating offensive odors. Although an investigation into siting a proper location for an aerobic lagoon was performed for LAPCO by the soil conservation service in 1982, the president of LAPCO felt that the cost of installing a liner would be prohibitive. He also stated that public opinion in the neighboring residential area would not allow construction of a lagoon due to the concern of generating offensive odors. Because of these concerns, the president of LAPCO directed Virginia Tech to exclude the use of lagooning as a treatment alternative. As discussed in Chapter 1.0, odor problems have been a contributing factor in closing tomato processing plants in the past.

The second aerobic treatment option investigated was the sequencing batch reactor (SBR). The SBR offers significant advantages over conventional activated sludge for small intermittent wastewater flows and seems to be a viable approach to treat LAPCO's seasonal effluents. The following section reviews literature pertaining to SBRs.

2.6.1 SEQUENCING BATCH REACTORS

The SBR operates in a periodic fill-and-draw mode. It operates in a batch rather than a continuous process. The SBR provides in time what the continuous-flow system provides in space [27]. An SBR has thus been called a fill-and-draw, activated sludge system [28].

SBR performance is based on a repeating cycle composed of five discrete periods: fill, react, settle, draw and idle [29]. The purpose of each period of operation is shown in figure 4. Wastewater is fed to the SBR during the fill

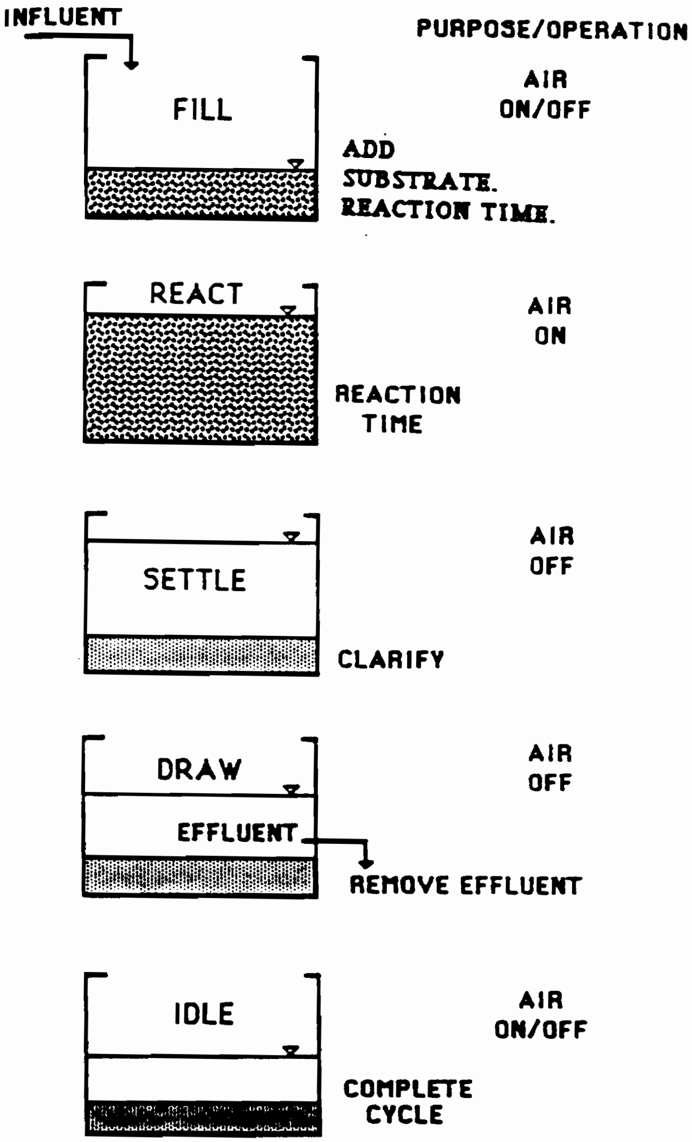


FIGURE 4. THE FIVE OPERATING PERIODS OF AN SBR CYCLE [After Ref. 29]

period. Aeration can be supplied continuously or only during the latter portion of this period. The react phase starts when the fill is complete, or nearly so, by aerating the tank until sufficient biooxidation has occurred. At the completion of react, aeration is turned off and quiescent settling ensues, leaving a layer of stabilized supernatant. This supernatant is drawn off in such a way as to not disturb settled biomass or subnatant. The SBR remains in the idle mode until it is time for the cycle to repeat itself. Low level aeration can be applied during the idle phase to prevent extended anaerobic conditions.

Although multiple SBRs can be placed in series, a single tank system is applicable to noncontinuous-flow situations, such as those that occur in the food processing industry [27]. There are many advantages to using an SBR, the major advantage being flexibility. Each period of operation can be regulated to produce the desired effluent quality. Capital costs are lower for SBRs than continuous-flow systems since flow equalization, treatment, and settling are achieved in the same reactor [30]. Batch systems also have an intrinsic kinetic advantage over continuous-flow operations [31]. This causes a considerable reduction in reactor volume when compared to conventional continuous-flow systems (after Irvine and Richter [32]).

Mandt [33] has used the term "high substrate tension" to describe the high organic concentration and zero or near zero dissolved oxygen (D.O.) level initially present during the fill period. This high substrate tension causes an anoxic period to occur which favors floc forming organisms and helps to prevent growth of filamentous organisms. Filamentous organisms decrease the density of biological solids in a reactor and hamper settling. This is a key operational concern, since the success or failure of an SBR is dependent on the development of a bacterial population that will settle well and leave a clear supernatant [31]. In addition, active biomass will store organic substrate for use once oxygen is again introduced into the system, following the anoxic fill stage. This enhances oxygen transfer by producing a driving gradient which inherently makes an SBR 10 to 20% more energy efficient than a conventional continuous flow system [33].

Nitrate nitrogen entering in the wastewater or formed during the previous react period is denitrified during an anoxic fill period. This further minimizes oxygen requirements, in addition to removing nitrogen from the wastewater [33]. Mechanical mixing may or may not be required during an anoxic phase. One potential problem with an anoxic feed, however, is an odor that could make anoxic conditions in the full-scale impractical [34].

Another advantage to using an SBR over a continuous process is that no return activated sludge pumping is required [28]. As a result, sludge return rates will not limit mixed liquor suspended solids (MLSS) concentrations [35]. Therefore, an SBR can operate at much higher MLSS values than a continuous-flow, activated sludge system. Goronszy [35] explains that a poor settling sludge for a continuous system may settle very well in an SBR of equivalent hydraulic load, since the SBR has a larger settling area.

While provisions must be made to remove settled subnatant and remove biological solids that are generated, Irvine _et al_. [36] have shown that if a reactor is loaded low enough, wasting can occur less than once a month. This can reduce the cost of solids handling. For this to occur, a reactor would have to be oversized because of the low loading rate. This would increase energy requirements due to aerating and mixing a larger liquid volume. On the other hand, Irvine _et al_. [32] have pointed out that for a reactor that is undersized or operating at too high a MLSS value, the maximum oxygen uptake rate required may not be readily achievable by standard aeration equipment. Hence, careful consideration must be given to the size of an SBR and to choose the proper operating MLSS value. This is a necessity if the dissolved oxygen demand is to be met.

Returning to the idea of SBR flexibility, Arora et al. [28] have explained a key advantage to the use of an SBR when flowrates are seasonal. When flow is lower than design capacity (for example, when LAPCO production turns from tomatoes to oysters), liquid level sensors can be set at a lower level so that only a fraction of the SBR tank capacity is used. The treatment cycle duration then could remain the same and aeration requirements would be reduced.

The major disadvantage to using an SBR is that special hardware is needed to control its operation. A microprocessor is required to automatically control cycle times and aeration strategies. Operation can also be manually controlled by timers and level sensors with some sacrifice of flexibility. Manual adjustment of timers would be required if wastewater flows change and if it becomes necessary to change the duration of any period [29]. This is an important consideration since LAPCO's production day can be anywhere from three to nine hours long. Whether using sophisticated control technology or manual control, however, SBRs often require close supervision [36].

An important operational parameter for an SBR is the food to microorganism (F/M) ratio. This is a measure of organic loading on a reactor, expressed as lb BOD/lb MLSS·d. The

F/M value can also be based on mixed liquor volatile suspended solids (MLVSS).

Aeration requirements, sludge production, and treatment efficiency are all directly related to the F/M value. Reactor size can be reduced by using a high F/M value. Irvine _et al_. [37] performed a full-scale loading study on SBRs treating municipal wastewater. Loadings of 0.16 and 0.42 lb BOD_5/lb MLVSS·d were investigated. BOD_5 and TSS were each reduced to below 10 mg/l. There was a tendency, however, for the higher loaded reactor to be underaerated. Although the authors of that investigation felt higher loadings could be tolerated, they maintain that organic loadings greater than 0.5 LB BOD_5/LB MLVSS·d should be considered cautiously. The F/M values used by these authors were based on an aeration time-adjusted basis. This means that the true F/M value was divided by the fraction of time per day that reactors were aerated, yielding a higher time-adjusted value.

3.0 METHODS AND MATERIALS

Methods and materials used to perform treatability studies are presented in this chapter as well as analytical procedures used for the determination of wastewater parameters. The procedure used to perform a tomato peeling study is also presented.

3.1.0 TREATABILITY STUDIES

Treatability studies included gravity settling, screening, coagulation with pH and temperature adjustment, biological treatment with a sequencing batch reactor, and application to a sludge drying bed.

3.1.1. SETTLING

Settleability was determined by the settleable solids test, method 209 E of standard methods [38]. This test was performed for herring roe and tomato wastewater in accordance with procedure 3a, the volumetric method.

3.1.2 SCREENING

Screening was performed on herring roe wastewater by passing samples through a size 20 mesh screen. For tomato wastewater, samples were passed through a number 3.5 or a number 10 sieve. Wastewater parameters were analyzed before and after screening to determine the extent of removal. Due to the amount of large solids present in tomato wastewater, it was necessary to determine the quantity of solids removed during the screening procedure as well as the remaining filtrate volume. A dimensionless yield parameter was used for this purpose which was equal to the volume of filtrate divided by initial sample volume.

3.1.3 COAGULATION WITH pH AND TEMPERATURE ADJUSTMENT

This test was performed only on tomato wastewater. Since it is known that heating used to process tomato juice has a great affect on its consistency, an attempt was made to coagulate solids by altering temperature and pH. Wastewater was collected after the shaker screen for this purpose. Six samples were used: (1) control, (2) 4°C, (3) 50°C, (4) pH 7, (5) pH 4, (6) pH 2.2 and 4°C. A seventh sample was included to see the effect of a 1,000 mg/l addition of lime as $Ca(OH)_2$. The initial temperature and pH of all samples was 25°C and 11.5, respectively. The duration of all applied conditions was 30 minutes.

3.1.4 BIOLOGICAL TREATMENT

Biological treatability studies were performed only on tomato wastewater. A detailed wastewater characterization of LAPCO's whole-pack tomato operation isolated Magnuson Scrubber wastewater for separate treatment. Therefore, all biological treatability studies were performed on this one segregated wastewater contribution. Although LAPCO's tomato process generates the most wastewater and the highest pollutant concentrations, the biological treatment method selected had to also be applicable to herring roe and oyster wastewater. Because of the low volume of wastewater generated, the variable nature of flow and pollutant concentrations, and the advantages presented in chapter 2, the SBR was determined to be the most reasonable method of biological treatment.

Three SBRs were set up and designated reactors A, B and C. Each SBR had a volume of eight liters and was initially seeded with three liters of mixed liquor activated sludge from the Blacksburg VPI Sewage Authority. Magnuson Scrubber wastewater was screened through a #10 sieve and pH adjusted to 8.5 ± 0.1 standard units. Each reactor used a separate container of feed which was placed upon a Fisher Scientific Thermix Stirrer (model 120 M). Vigorous stirring was necessary since pH adjustment caused noticeable density or settling zones to form in the feed containers. For pH measurement, a Cole Parmer hand held probe (model 5941-00) was used. A Fisher Accument Selective Ion Analyzer (model 750) was initially used for pH measurement but stabilization problems resulted, possibly because of the high dissolved solids content.

Feed was delivered to reactors A and B by a common peristaltic pump at identical flow rates using a Cole Parmer Masterflex Pump Controller (model 7553-60). Feed was delivered to reactor C by an FMI lab pump (model RP-D). During the react phase, each reactor was aerated with lab supplied air through a 6 inch long diffuser stone. Air was filtered to remove any oil residue. A second air supply was later added to each reactor using fish tank air pumps (Second Nature Whisper 500), which also supplied air through a 6 inch diffuser stone. A second air supply was found to be necessary to maintain aerobic conditions in the reactors. At the completion of the settling period, a valve was manually adjusted to allow gravity decanting (or draw) of treated supernatant. To maintain desired mixed liquor suspended solids concentrations (MLSS), either mixed liquor or settled subnatant was wasted periodically. A mass balance on MLSS was used to determine the volume to be wasted, considering suspended solids present in reactor treated effluent.

Different organic loadings, expressed as an F/M ratio, were applied to each reactor to try and determine the maximum loading rate achievable, while still meeting effluent limitations and maintaining aerobic conditions. Units for F/M values were lb BOD_5/lb MLSS·d. The cycle times and organic loadings imposed on each reactor are discussed in conjunction with experimental results in the following chapter. All three reactors concurrently underwent three operating conditions which will now be briefly overviewed.

Initially the goal was to feed 0.4 L, 0.8 L and 5.0 L to reactors A, B and C, respectively, at a 50% wastewater dilution. Poor settling characteristics and anaerobic conditions, however, quickly occurred in reactors B and C. In fact, reactor C exhibited little or no settling after only one loading cycle. Reactor C was then broken down and restarted with 1.6 L of daily feed, but failure again ensued after only 3 days of operation. At this point, on 13 September, 1989 a decision was made to feed 0.4 L of screened Magnuson Scrubber wastewater to each reactor to allow slower acclimation and to see the effects of this low volume loading on reactor operation. This 0.4 L daily feeding continued until 25 September 1989.

A daily feed of 0.4 L corresponded to a 20 day HRT and a F/M of approximately 0.2. Another goal of these low volume feedings was to see how many days of operation could occur without wasting MLSS. Up to this point, all SBR experiments were collectively called acclimation trials.

Following acclimation operation, the second phase of operation was initiated. This was a high loading study, and the goal was to operate each reactor at F/M values near 1.0 by controlling feed volume and MLSS. The third phase of experiments involved tracking SBR operation at F/M values of 0.22 to 1.11. By periodically measuring or "tracking" soluble COD decrease during a complete SBR cycle, it is possible to optimize the loading rate and aeration period. The details of all three SBR experiments, i.e., acclimation, high load, and tracking are discussed in chapter 4.

3.1.5 SLUDGE DRYING BED

To simulate a sludge drying or evaporation bed, raw Magnuson Scrubber wastewater was placed in two plastic bins with dimensions of 1.0 ft. by 1.0 ft. by 4 3/8 in. deep.

Each "bed" was filled to a depth of 4.0 ± 1/16 in. to allow approximately 3/8 in. of freeboard. They were placed outside in a full-sun location and covered with a clear tarp kept 2 ft. above the beds. The tarp, designed to keep out precipitation, was positioned parallel to the beds so that the sides were kept open to allow wind currents to enhance evaporation. One bed remained undisturbed while the other was agitated every day to prevent a thick surface cake from forming. This test was performed from 29 August 1989 until 17 September 1989. The volume reduction of Magnuson Scrubber wastewater was recorded during this period.

3.2.0 ANALYTICAL PROCEDURES

During characterization studies wastewaters were analyzed for 5-day biochemical oxygen demand (BOD_5), ultimate biochemical oxygen demand (BOD_{ult}), chemical oxygen demand (COD), oil and grease (O&G), total suspended solids (TSS), volatile suspended solids (VSS), total solids (TS), total dissolved solids (TDS), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), total phosphorus (TP), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), pH, total sodium, potassium (and 12 other trace metals) chloride (Cl), sulfate (SO_4) and total organic carbon (TOC). Biologically treated wastewater was analyzed for many of the same parameters in addition to mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), dissolved oxygen (D.O.), soluble chemical oxygen demand (SCOD), and color (as platinum cobalt units, PCU).

All tests were performed in accordance with Standard Methods for the Examination of Water and Wastewater [38] with the following exceptions and notations:

- BOD_5 samples were seeded, after dilution, with mixed liquor from activated sludge treating municipal wastewater. For BOD_5 tests on SBR feed, samples were seeded with acclimated activated sludge from the SBRs. Reactor effluents were not seeded. Dilutions as high as 1:6,000 were necessary for raw, Magnuson Scrubber wastewater. Although seeded blanks were used, quality control samples made of standard glucose solution were not included.

- BOD_{ult} was calculated using a K value determined by the log-difference method of Eckenfelder [23].

- Following distillation, TKN and NH_3-N were determined titrimetrically.

- TP analysis used the ascorbic acid method with persulfate digestion. TP values were determined using a Beckman DU-6 spectrophotometer at a wavelength of 880 nm. A standard curve was generated for each set of TP samples tested.

- Cl, SO_4, NO_2-N and NO_3-N were determined by ion chromatography using a Dionex model 2010i ion chromatograph with a cross-linked polystyrene/ divinyl benzene column, flow rate of 2 ml/min and pressure of 1,000 psi.

- Sodium and potassium were determined by a Perkin-Elmer Flame Atomic Absorption Spectrometer after sample digestion with nitric acid. Dry ashing was used at times in place of digestion for the determination of sodium.

- VPI & SU's soil testing and plant analysis laboratory performed a simultaneous 12 element inductively coupled plasma (ICP) analysis on tomato and herring roe wastewaters.

- TOC analyses were performed using a Dohrmann DC-80 total organic carbon analyzer with the sludge/sediment sampler.

- Color analysis was performed on raw Magnuson Scrubber wastewater following centrifugation at 2,000 Gs for 10 minutes and then filtering through a glass microfibre filter. The visual comparison method was used (method 204 A).

3.3.0 TOMATO PEELING STUDY

Since characterization studies and literature reviews have shown sodium to be a major wastewater treatment and disposal concern, it would be beneficial to develop a tomato peeling method to eliminate the use of sodium hydroxide. A considerable effort has been put forth to eliminate the use of caustic in the citrus industry by peeling grapefruit with vacuum infused pectinase [39, 40]. Enzyme digestion as a means of peeling and sectioning grapefruit has proven to be quite successful. The following describes the methods and materials used to perform an enzyme peeling study of tomatoes using pectinase as the active peeling agent.

This study was performed in two parts. First, different activity levels of a commercially available pectinase solution were evaluated for tomato peeling ability. Then a comparison of enzyme peeled and caustic peeled tomatoes was made by performing these methods side-by-side.

The pectinase used was a Sigma chemical product, catalog No. P-5146, derived from Aspergillus niger, in a 40% glycerol solution. The stock solution had an activity of 10,000 units, 13.4 mg of protein per ml, and 120.6 units per ml. Store bought tomatoes were used for this test.

For the first experiment, 6 slits approximately 0.010 in. deep were made around the perimeter of each tomato. Two tomatoes were placed in each of three beakers filled with 0.5 liter of pectinase solution having activity levels of 10, 100 and 1,000 units, respectively. This corresponded to concentrations of 166, 1,660, and 16,600 mg/l. Solution pH was initially adjusted to 4.0 with 0.5 N NaOH, based on enzyme activity studies of Bruemmer and Griffin [39]. Pectinase solutions were kept at 60°C to accelerate activity [1]. Tomatoes were initially at room temperature and then soaked in the pectinase solutions for 30 minutes before being rinsed and then inspected for peel removal.

The second test used seven samples in duplicate, as follows:

(1) Enzyme blank (0 unit activity), tomatoes not scored.
(2) Enzyme blank, tomatoes with slits.
(3) 1,500 unit activity, tomatoes not scored.

(4) 1,500 unit activity, tomatoes with 30 poked holes approximately 0.010 in. deep.

(5) 1,500 unit activity, tomatoes with slits.

(6) 15% caustic solution at 90°C for 45 seconds, followed by a cold rinse for 30 seconds, tomatoes not scored.

(7) Same as (6), tomatoes with slits.

Tomatoes in enzyme and enzyme blanks (samples 1 - 5) underwent a 15 minute soak at their respective pectinase activities, followed by a 95°C water soak for 30 seconds to cause enzyme deactivation based on data from Gould [1]. It was hoped that this procedure would prevent tomatoes from becoming soft due to continued digestion of pectic material after the enzyme soak was complete. These samples then underwent a cold rinse (20°C) for 30 seconds before being inspected for ease of peel removal. Peeling ability was qualitatively determined by hand rubbing each tomato to loosen the peel. Tomatoes were also inspected for any internal damage and firmness.

4.0 RESULTS AND DISCUSSION

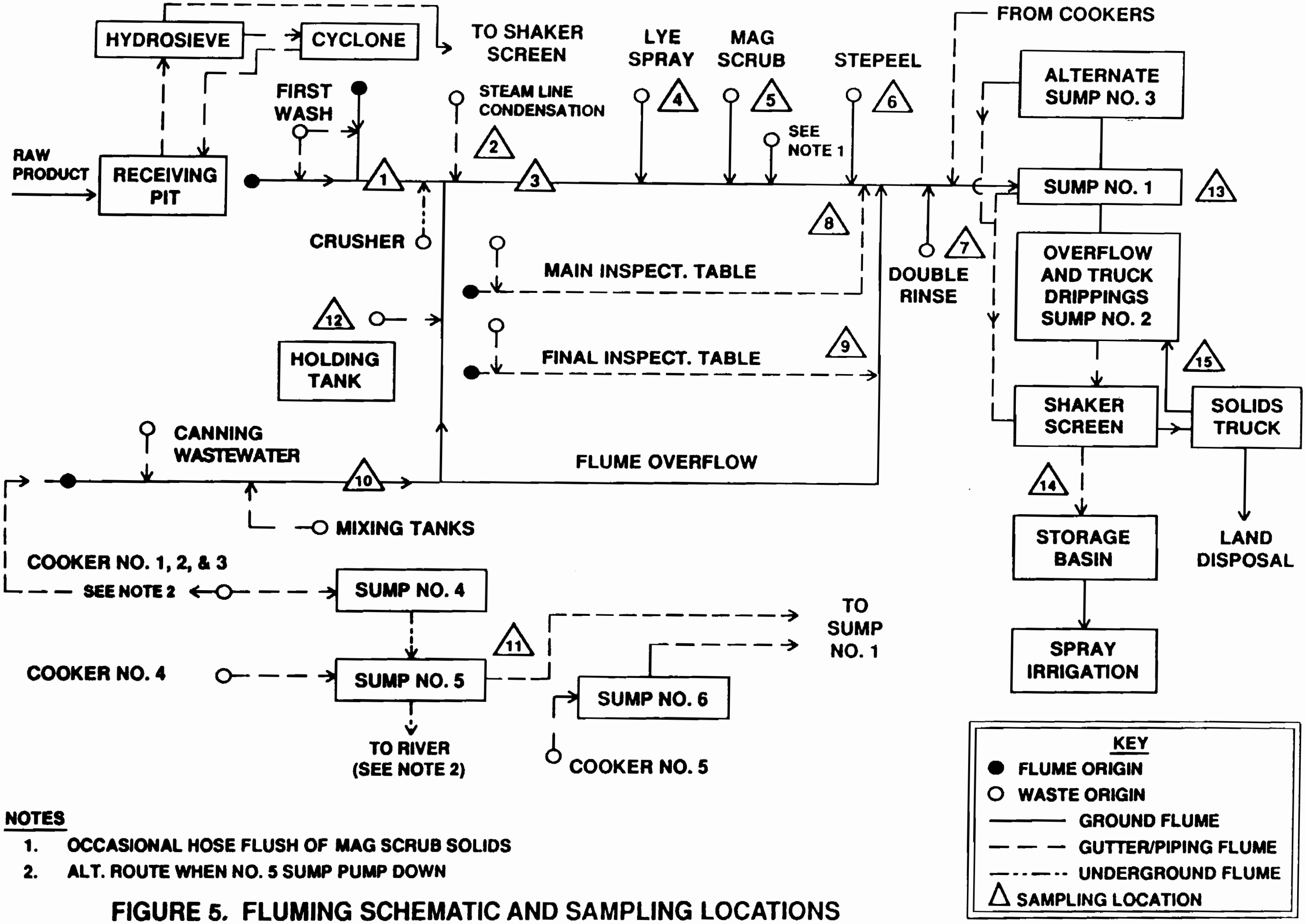
The results of wastewater characterizations for each of LAPCO's food processing effluents are presented in this chapter along with the results of treatability studies. Treatment alternatives investigated include gravity settling, coagulation, screening and biological treatment of tomato processing wastewater and also the use of sludge drying beds. Gravity settling of herring roe wastewater was also analyzed. Treatability data was mainly gathered on tomato processing wastewater since effluent produced by this product will govern the selected manner of treatment. However, proper design of a treatment scheme for the tomato process should be successful in treating both herring roe and oyster processing wastewater to discharge requirements.

4.1.0 WASTEWATER CHARACTERIZATION

Results of wastewater characterizations for tomato, herring roe and oyster processing wastewaters are presented in this section.

4.1.1 WHOLE-PACK TOMATO PROCESSING

The week before the scheduled production starting date (17 July 1989) a visit was made to the LAPCO plant to discuss their process and determine important sampling locations. Through this discussion and from later observation of daily production runs, sampling points were chosen as shown in figure 5. Because of heavy rainfall conditions during the early part of the growing season, raw tomatoes were not available and production start-up was delayed one week. Production began 24 July 1989. Since production is usually unsteady during the first couple of days due to mechanical problems and limited product availability, sampling began on 27 July 1989. Hourly flowrates for sampling point locations were measured and are shown in table 4. Total daily flow was determined by summing component flows since the water supply well meter was not working. Individual flowrates were determined either by measuring the time required to fill a one liter bucket or by measuring the time required for a ping-pong ball to traverse a certain distance in a flume. Each flowrate was measured hourly and each hourly measurement included no less than 5 trials so well defined values could be obtained. Daily flow contributions are based on a 9 hour production day. However, on 27 July 1989 production was hampered by mechanical problems and for a combined



NOTES
1. OCCASIONAL HOSE FLUSH OF MAG SCRUB SOLIDS
2. ALT. ROUTE WHEN NO. 5 SUMP PUMP DOWN

FIGURE 5. FLUMING SCHEMATIC AND SAMPLING LOCATIONS

Table 4. Sampling Point Flow Contributions for 7/27/89 Operation

Sampling Point Number	Flow (GPD)
1	17,532
2	200
3	22,743
4	200
5	13,560
6	14,076
7	7,002
8	6,609
9	2,139
10	4,947
11	1,714
12	215
13 (Σ3-12)	73,002

Note:

- **SP2 and SP4 are estimated values**
- **SP1, SP2, and crusher flows contributed to SP3 (See Figure 5).**

intermittent time of possibly 2 hours, at least one canning line was down. For a one-half hour period, production halted completely. Production also ended 15 minutes early on this day. Certain minor flow contributions had to be estimated since there was no possible means of obtaining these flow measurements; i.e., at sampling point (SP) 2 and 4.

The most important conventional wastewater parameters are presented in table 5 for the 27 July 1989 operation. Sampling point 10, the canning wastewater flume, deserves close attention. While other sampling locations yielded typical values, the SP10 COD, BOD and TSS values for this day were very atypical. This was due to breaks in the process train discussed earlier. If there was a brief period of down-time for a cannery machine such as the lid applicator there was enough "slack" in the production process to recirculate and hold some of the peeled tomatoes and crushed tomato topping product for distribution to the remaining two canning lines. However, depending upon the length of down-time, the number of lines down, the delay in notifying key people earlier in the process train of downstream production bottlenecking, and the final decision to halt production, some amount of finished product often ended up in the canning flume. If a few hundred tomatoes needed to be discarded, the bulk of this was caught by the

Table 5. Sampling Point Contributions and Cummulative Pollutant Load for 7/27/89 Tomato Wastewater Composites.

	Flow	COD			BOD$_5$[a]			TSS[c]			VSS[c]				Temp
SP #	(GPD)	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	pH	(°C)
5	13,560	49,346	5581	28.5	17,016	1924	9.8	48,640	5501	28.1	19,467	2202	11.3	11.7	--
10	4,947	26,281	1084	5.5	15,459	638	3.3	4,100	169	0.9	3,987	164	0.8	4.7	--
13[b]	73,002	12,526	7626	39.0	5,077	3091	15.8	3,536	2153	11.0	2,170	1321	6.8	--	--
LT[d]	1,765	2,878	42.4	0.2	1,308	19.3	0.1	--	--	--	--	--	--	7.2	25
SU[e]	4,000	119	4.0	0.02	73	2.4	0.01	--	10 Est	--	--	3 Est	--	8.3	23
WU[f]	14,000	2,146	251	1.3	1,388	162	0.8	--	500 Est.	--	--	60 Est.	--	--	--
14	73,002	9,277	5648	28.9	5,393	3283	16.8	3,073	1871	9.6	1,913	1165	6.0	10.8	31
Σ	92,767	7,684	5945	30.4	4,481	3467	17.7	3,078	2381	12.2	1,587	1228	6.3	--	--

NOTES:

a. SP 5 and 10 from COD/BOD$_5$ ratios of 8/9/89
b. Sum of SP 2-12 using remaining values of 8/9/89
c. SP 5 solids values are total solids and volatile solids. TSS found to be 25% of TS, 90% of which are volatile (VSS)
d. LT = lunch time
e. SU = start-up. Flow is approximate
f. WU = day end wash-up. Flow is approximate
g. Est = Estimated

shaker screen. On a few occasions however, crushed tomatoes from the mixing tanks needed to be discarded in the canning flume. This liquified product substantially raised organic content and solids content of sampling point 10. It must be emphasized that this situation is avoided to the greatest extent possible since it represents serious profit reduction due to loss of finished product. Raw product packed on 27 July 1989 was also extremely low, only 97.75 tons (195.5 KLBS). This is well below LAPCO's target production value of 150 tons per day. For these reasons, data acquired on 27 July 1989, while important in representing possible fluctuations in wastewater quality, will not be considered as representative of a typical daily wastewater. Note that except for sampling point 10, values presented in mg/l and lb/day for other sampling points are characteristic of everyday values. SP 5, the Magnuson Scrubber, was quickly highlighted as the major pollutant contributor with both a COD and total solids (TS) content of near 50,000 mg/l. The summation of all parameters in table 5 includes SP 14 production, start-up, lunch time, and wash-up contributions.

Nutrient levels in the wastewater on 27 July 1989 were also determined. The TKN level at SP 14 was determined to be 193 mg/l (118 lb/day or 0.6 lb/Klb), while the resulting NH_3-N level was 11.1 mg/l (6.8 lb/day or 0.03 lb/Klb).

Total phosphorus levels were determined at selected sampling point locations and are shown in table 6. The resulting C:N:P ratio for SP 14, represented as BOD_5:TKN:TP, was 91:3.2:1. Additionally, selected sampling points, including the final effluent and processing water supply well underwent a gamut ICP analysis for the determination of metal cations. These results are presented in table 7. Of particular interest are the high phosphorus, potassium, sodium and sulfur values for the Magnuson Scrubber wastewater (SP 5). These values were 265, 2,465, 4,357, and 296 mg/l, respectively.

The second sampling trip occurred on 8 August 1989. Individual flowrates and pollutant contributions were again determined. They were found to be similar to flowrates from 27 July 1989. Although the water supply well meter remained inoperable, a final combined effluent flowrate was determined by measuring the time required for the storage basin (SP 14) wastewater level to increase a measurable value. A float switch on the storage basin was set to a 2 ft. 4 in. (0.71 m) fill. Since the area of the basin was 12.0 ft. (3.7 m) by 8 ft. 1 in. (2.5 m), this corresponded to a fill volume of 1,686 gallons (6,382 L). After the basin was filled to the specified level, the float switch turned on an irrigation pump which discharged the same 1,686 gallons (6,382 L) to an irrigation field about a

Table 6. Total Phosphorus Levels from 7/27/89 Wastewater Samples

Sp. #	Total Phosphorus Mg/L	 Lbs/Day	 Lb/KLb
5	370	41.8	0.21
8	12.6	0.69	0.004
9	12.6	0.22	0.001
10	86.0	3.55	0.02
14	59.5	36.2	0.19

Table 7. ICP Elemental Analysis at Selected Wastewater Sampling Points and Process Supply Water for 7/27/89.

	mg/L											
Location	P	K	Ca	Mg	Mn	Zn	Fe	Al	Cu	B	Na	S
Mag. Scrub (SP 5)	265	2465	111	109	0.67	ND	8.86	7.06	ND	0.70	4357	296
Double Rinse Basin (Sp 7)	15.0	216	4.3	0.4	ND	ND	0.48	0.030	ND	0.45	175	131
Final Effl (SP 14)	48.1	507	27.7	22.7	0.45	ND	19.83	12.97	ND	0.52	844	27.2
Potable Supply Water	0.22	9.6	6.4	3.2	ND	ND	0.099	0.030	ND	0.44	109	3.13

Detection Limits: Mn = 0.001
Zn = 0.004
Cu = 0.002

quarter mile (0.4 kilometer) away. By knowing the fill volume and measuring the time to complete the specified fill, an accurate flowrate could be determined. This measurement was taken at least hourly throughout the day. The result is that a very accurate combined effluent flowrate was obtained which was also used in mass balance calculations as a check for the summation of individual sampling point flowrates and pollutant contributions. Individually determined flowrates and pollutant parameters at each contributing sampling point are shown in table 8, while independently determined values of the same parameters for the combined final effluent (SP 14) are shown in table 9. Notice that a total of approximately 90,000 gallons per day (GPD) of water are used with approximately 70,000 GPD used during actual production.

Wastewater flowrate fluctuations were monitored throughout the day during start-up, production, lunch time, and wash-up operations. Major changes in hourly flowrates can easily be visualized in figure 6. Start-up occurred from hours 5 (5 AM) to 7. Production ran from hour 7 through hour 17 with an hour lunch break between hours 12 and 13. Wash-up commenced at hour 17. Hourly flowrates remained fairly constant at approximately 7,500 GPH during actual production. Start-up and lunch time water usage was low while day end wash-up water usage exceeded production usage

Table 8. Sampling Point Pollutant Contributions from 9 hr Production Composites of 8/9/89.

	Flow	COD			BOD_5			TSS[a]			VSS				Temp
SP #	(GPD)	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	pH	(°C)
1	13,545	790	89.2	0.36	451	51.0	0.18	500	56.5	0.20	67	7.6	0.03	7.0	25
2	200*	1,012	1.7	0.01	660	1.1	0.00	480	0.80	0.00	85	0.14	0.00	--	--
3	23,040	1,350	258.4	1.04	628	120.7	0.48	947	182.0	0.73	437	84.0	0.34	--	--
4	200*	3,829	6.4	0.03	2,188	3.6	0.01	500	0.8	0.00	200	0.3	0.00	12.0	48
5	10,089	46,694	3929	15.8	16,315	1373	5.5	52,211	4393	17.7	25,086	2111	8.5	11.8	48
6	12,033	4,084	410	1.6	2,417	243	0.98	3,200	321	1.3	2,892	290	1.2	7.5	25
7	8,721	339	24.7	0.1	194	14.1	0.06	312	22.7	0.1	280	20.4	0.1	7.0	25
8	5,643	2,946	139	0.56	1,683	79.2	0.32	1,000*	47.1	0.2	900*	42.4	0.2	7.0	25
9	2,376	2,946	58.4	0.23	1,683	33.4	0.13	1,000*	19.8	0.1	900*	17.8	0.1	7.0	25
10	4,887	6,984	285	1.1	4,125	168	0.68	837	34.1	0.1	763	31.1	0.1	4.7	43
11	1,350	474	5.3	0.02	124	1.4	0.01	75	0.8	0.00	50	0.6	0.00	--	95
12	215	31,196	55.9	0.22	17,826	32.0	0.13	7,800	14.0	0.1	7,733	13.9	0.1	--	--
13[b]	68,754	9,025	5175	20.7	3,610	2070	8.3	3,036	1741	7.0	1,831	1050	4.2	--	--

*Estimated

NOTES:

a. SP 5 solids values are total and volatile solids. TSS found to be 25% of TS, 90% of which are VSS.

b. Sum of SP 2-12. measured value for COD = 8,982 mg/L

Table 9. Pollutant Parameters for SP 14 (Final Effluent) Obtained from Composite Sampling on 8/9/89

	Flow	COD			BOD_5			TSS			VSS				Temp
	(GPD)	mg/L	Lb/day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	pH	(°C)
Production[b]:															
	70,542	7,802	4590	18.4	4,288	2523	10.1	2,073	1220	4.9	1,173	690	2.8	10.5	30
Start-up[a]:															
	3,698	558	17.2	0.07	307	9.5	0.04	265	8.2	0.03	106	3.3	0.01	8.3	23
Wash-Up[a]:															
	15,895	2,165	287	1.2	1,190	158	0.6	4,281	568	2.3	448	59.4	0.2	7.4	23
TOTAL	90,135	6,510	4894	19.7	3,316	2493	10.7	2,389	1796	7.2	1,002	753	3.0	--	29

NOTES:

a. Values obtained by weighted average hourly grab samples. BOD_5 values attained from production COD/BOD_5 ratio.
b. Production composite includes lunchtime flow (1701 gal.)

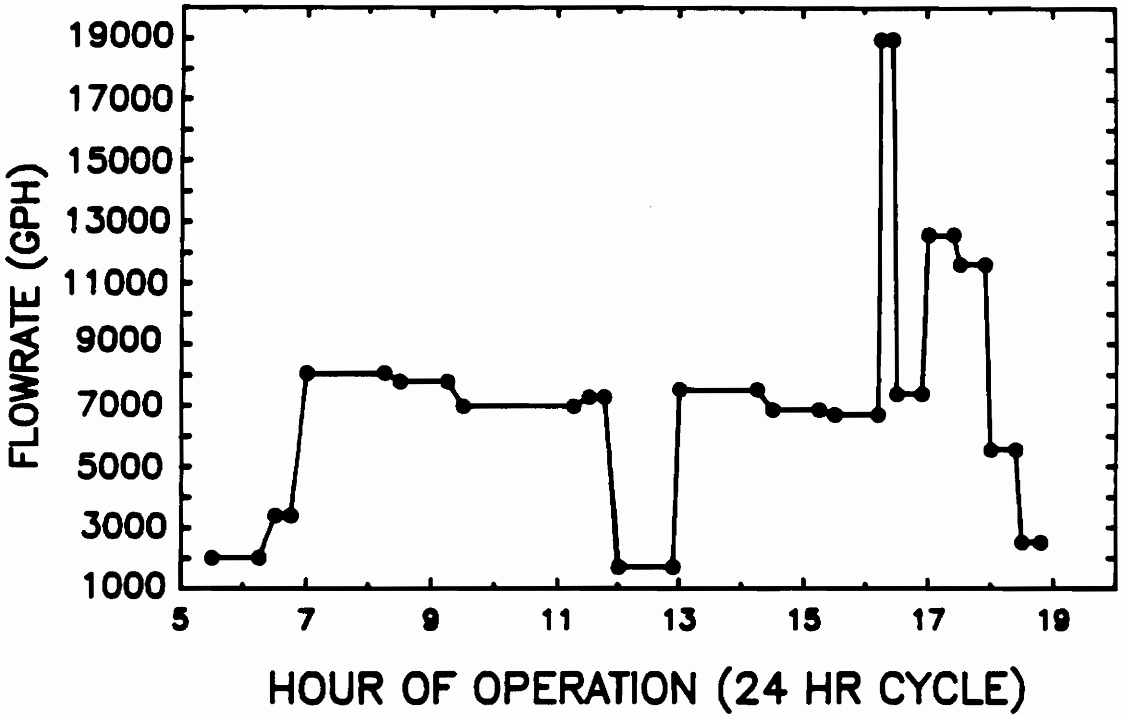


FIGURE 6. WASTEWATER FLOWRATE FLUCTUATIONS FOR 8/9/89

through the first hour of cleanup operation. The high spike at hour 16 resulted from draining the receiving pit.

Hourly COD variations which occurred throughout the day are shown in figure 7. Concentrations of start-up and wash-up values were low in comparison with production values. TSS fluctuations are shown in figure 8. The large spike at hour 16 was again due to draining the receiving pit. Since it only took about 15 minutes to drain the receiving pit, the representative peak in figure 8 is too wide. Average values for TSS in table 9, however, weighted this peak as only 15 minutes wide. Although it is obvious that TSS concentrations in wash-up wastewater were greater than production values, VSS concentrations decreased sharply when production ceased as shown in figure 9. Since production comes to virtually a complete halt during lunch, a similar sharp VSS decrease was seen at hour 12 of figure 9.

From the results of table 7 it is obvious that most of the sodium emanates from the Magnuson Scrubber. A complete mass balance of sodium contributions from each sampling point was necessary to completely quantify all sodium sources since this is one of LAPCO's and the SWCB's primary concerns. Hence, results of a sodium balance on wastewater from 8 August 1989 are shown in table 10. This table

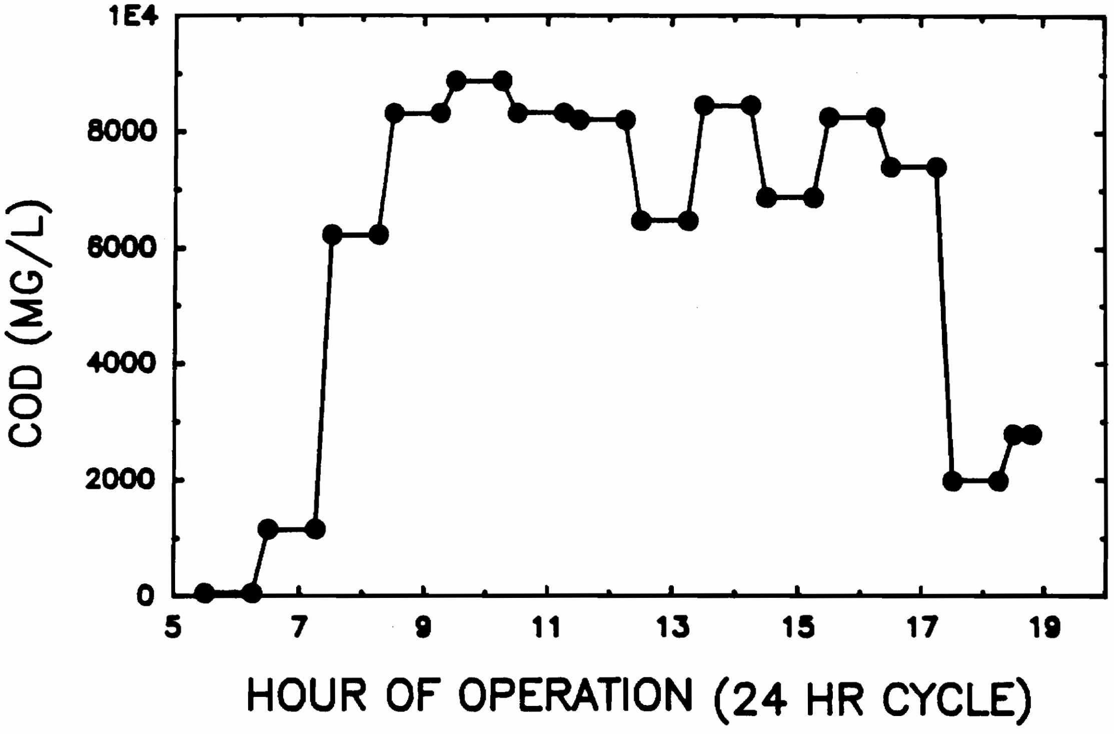


FIGURE 7. HOURLY VARIATION OF WASTEWATER COD

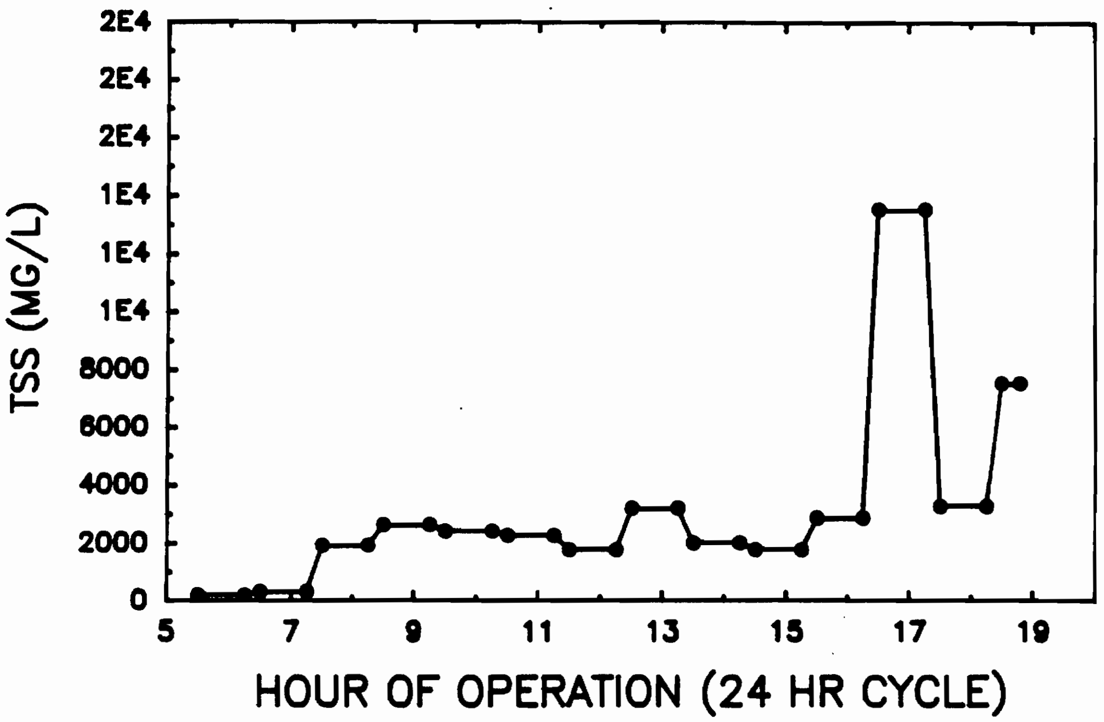


FIGURE 8. HOURLY VARIATION OF WASTEWATER TSS FOR 8/9/89

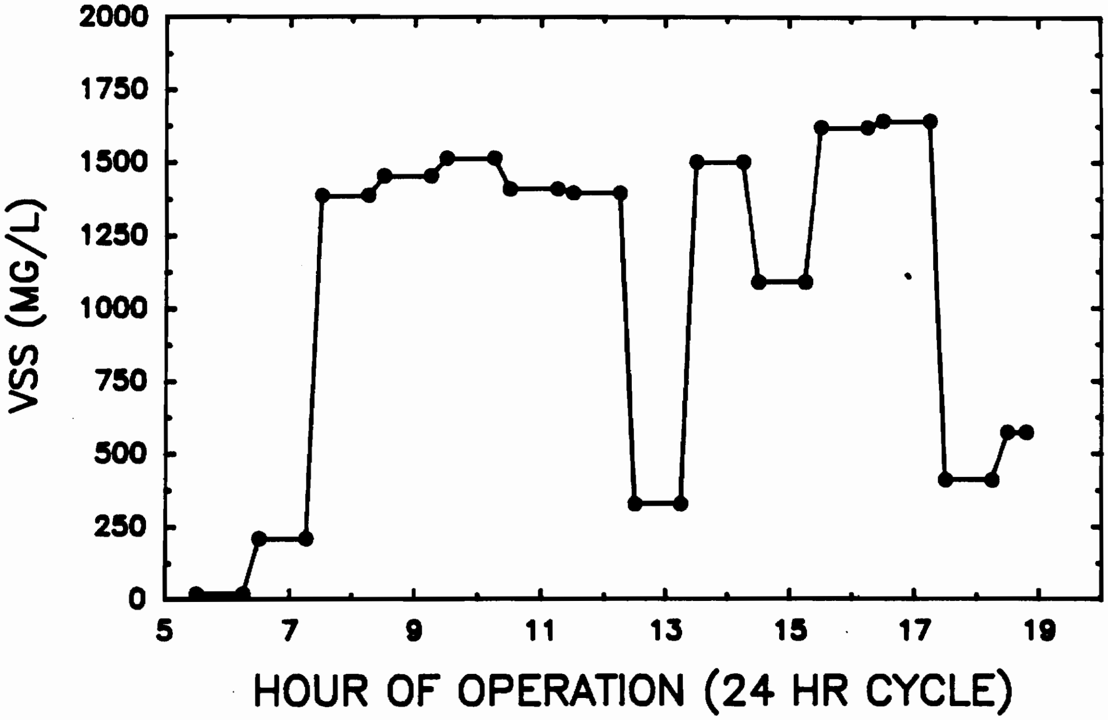


FIGURE 9. HOURLY VARIATION OF WASTEWATER VSS FOR 8/9/89

TABLE 10. SODIUM MASS BALANCE FOR WASTEWATER GENERATED 8/9/89

SP #	FLOW (GPD)	MG/L	LB/DAY	LB/KLB	% OF TOTAL	CORRECTED[a] %
1	13,545	116	13.1	0.05	2.6	0
3	23,040	122	23.4	0.09	4.7	0
4	200	10,000	16.7	0.07	3.4	3.9
5	10,089	5,000	421	1.7	84.5	96
6	12,033	205	20.6	0.08	4.1	1.9
7	8,721	163	11.9	0.05	2.4	0.7
8	5,643	123	5.79	0.02	1.2	0
9	2,376	123	2.44	0.01	0.5	0
10	4,887	122	4.97	0.02	1.0	0
11	1,350	122	1.37	0.006	0.3	0
14	70,542	846	498	2.0	100	100% = 426 LBS.

NOTES:

- SP 3, 10, and 11 ESTIMATED TO BE BACKGROUND VALUES
- SP 4 ESTIMATED BASED ON DILUTION OF CAUSTIC BATH CONVEYOR DRIPPINGS BY SPRAY RINSE
- SP 5 DETERMINED BY MASS BALANCE AND SP 6 AS 4.1% OF SP 5 BASED ON COMMONWEALTH LAB DATA
- MASS BALANCE ERROR = 2.5% DUE TO ROUNDING OFF AND DUE TO ASSUMPTIONS

[a] BASED ON SUPPLY WATER Na = 122 MG/L (72 LB)

shows 96% of all sodium in the wastewater is discharged through the Magnuson Scrubber. For 8/9/89 production, this amounted to about 409 lbs/day from a total of 426 lb/day of added sodium found in the combined wastewater stream (SP 14). Since supply water from a well used for processing and rinsing contained a high sodium concentration (122 mg/l), an additional 72 lbs/day was added because of this "background" level. The actual sodium load was therefore 498 lbs/day.

Listed in table 11 are the results of ion chromatographic determinations of specific anions in the well water and final effluent. These results show a high quality supply water with respect to these parameters. It was important to determine the chloride level in the wastewater to see if it was high enough to interfere with COD results. If we assume 90% of final effluent chlorides come from the Magnuson Scrubber, then approximately 900 mg/l Cl were present at SP5. With the high dilutions used to determine Magnuson Scrubber CODs (500 to one), this level of Cl will not cause any interference. Also note that a large fraction of the phosphorus in the wastewater was orthophosphate. This can be seen by comparing the phosphorus level shown for SP 14 in table 11 which was not digested, with the table 7 value, which was digested. The SP 14 sample was filtered through a Whatman No. 1

TABLE 11. SELECTED ANIONS FROM PROCESS SUPPLY WATER AND FILTERED SP 14 ON 8/9/89 SAMPLES

	CONC., MG/L	
ANION	SUPPLY	SP 14
Cl^-	3.25	89.5
NO_2-N	ND	ND
NO_3-N	0.22	1.03
PO_4-P	1.14	25.3
SO_4	13.6	74.4

qualitative filter before ion analysis. One of the most important aspects of the tabulated 8 August 1989 data is that pollutant loads based on production are representative of expected values. This is because production ran smoothly and 124.42 tons of raw tomatoes were processed on that day.

Wastewater sampling continued on 25 August 1989 and results from samples collected that day are presented in table 12. Results were comparable to previous test results except that the Stepeel (SP 6) values were unusually high. Although the amount of raw tomatoes processed was 152.07 tons on that day, only half-day composite samples were taken. Values for SP 14 were derived from a grab sample. Still most values were comparable to previous test results. An additional sampling point was added and designated SP 15. This represented juice dripping from the truck containing discarded solids, located below the shaker screen. As the truck became more full, discarded tomatoes were crushed. The drippings trickled down over a large area and ended up in sump No. 2. This flow contributed to SP 14 and not SP 13 and helps explain why the screened wastewater BOD_5 was greater than the combined unscreened value. Tables 8 and 9 show unscreened and screened BOD_5 values of 3,610 mg/l and 4,288 mg/l, respectively. This was unexpected since screening removes about 4 TPD of

Table 12. Sampling Point Pollutant Contributions for 8/25/89
9 Hour Production Based on AM Composites

	Flow	COD			BOD_5			TSS			VSS			
SP #	(GPD)	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	pH
5	--	48,886	4113	13.5	17,093	1438	4.7	61,347	5162	16.7	30,327	2552	8.4	12.2
6	--	9,820	985	3.2	5,812	583	1.9	12,433	1248	4.1	9,813	985	3.2	8.3
10	--	8,980	366	1.2	7,580	309	1.0	740	30	0.1	740	30	0.1	5.0
13	--	11,856	6798	22.4	4,742	2719	8.9	--	--	--	--	--	--	--
14	66,762	11,472	6388	21.0	6,305	3511	11.5	3,847	2142	7.0	2,071	1153	3.8	--
15	2,900	17,964	434	1.4	--	--	--	237	5.7	0.02	157	3.8	0.01	--

NOTES:

- Flow measurements for 8/9/89 used for SP 5, 6, 10 & 13
- SP 14 = Grab Sample. Composite value may be lower.
- BOD_5 determined from 8/9/89 COD/BOD_5 ratios.
- SP 5 solids values are total solids and volatile solids. TSS found to be approx. 25% of TS, and VSS approx. 90% of TSS. See Table 20 for actual SP 5 TSS values.
- Additional T.S. values
  SP 13 = 15,720 mg/L
  SP 14 = 16, 320 mg/L
- SP 4 pH = 12.5

solids. This difference may then be because peeled skin particles removed by the screen are not as readily biodegradable as the soluble organic compounds that are present. Also, the vast majority of BOD$_5$ present is soluble and passes through the screen. This is evident since soluble and total COD values for SP 5 were determined to be approximately 30,000 and 50,000 mg/l, respectively. Even after filtering an SP 14 sample through a 40 micron filter, TOC values were reduced less than 20%, from 3,200 mg/l to 2,600 mg/l. A likely reason for the COD discrepancy between SP 13 and SP 14 on 8/25/89 is that only a grab sample at SP14 was taken on this date so values cannot be accurately compared to SP 13.

As sampling data accumulated, it became increasingly evident that the Magnuson Scrubber wastewater, SP 5, needed to be segregated from the remaining wastewater for a treatment scheme to be developed in an economical fashion. Further sampling efforts were made to better characterize only Magnuson Scrubber wastewater.

Additional samples were collected on 5 September 1989 and a test was performed which shows how the Magnuson scrubber wastewater operation can vary. Depending upon the quality of the raw product, the concentration of caustic used in the peeling operation, and the ease of peeling on a particular day, the Magnuson scrubber could be run dry. If the water is not needed to aid in the peeling process, approximately 3,000 GPD can be saved. This is shown by the increase in total solids in table 13 for the Magnuson Scrubber while running dry. The dry operation TS value was about 87,000 mg/l while wet operation yielded a TS value of about 61,500 mg/l. The corresponding increases in COD and BOD_5 are also shown as well as the decreased COD, BOD_5, and TS values for screened wastewater. Dry operation yielded a COD increase from 51,000 mg/l to 67,000 mg/l and a BOD_5 increase of 18,000 mg/l to 23,500 mg/l.

On 21 September 1989 a final sampling trip was made to characterize the Magnuson Scrubber wastewater when potassium hydroxide was used as the active peeling agent instead of sodium hydroxide. The results are shown in table 14, where it can be seen that the COD and total solids values of 47,000 mg/l and 65,500 mg/l were very similar to those resulting from the use of NaOH (51,000 mg/l and 61,500 mg/l, respectively). This is to be expected if the same peeling efficiency is achieved. Although essentially all sodium is eliminated from the wastewater by this peeling option, a disproportional amount of potassium is added. This high potassium concentration is due to two reasons. First, fresh tomatoes contain a high concentration of potassium, 224 mg/100 g, compared to

TABLE 13. MAGNUSON SCRUBBER WASTEWATER CHARACTERISTICS FOR 9/5/89 GRAB SAMPLES

	CONCENTRATION, MG/L		
	COD	BOD_5[a]	TS
MAG. SCRUBBER RUN WET	50,962	17,806	61,470
MAG SCRUBBER RUN DRY	67,359	23,535	87,387
MAG SCRUBBER #10 SIEVE RUN WET	46,755	16,336	52,970

NOTE: a. DETERMINED FROM COD/BOD_5 RATIO OF 8/9/89

TABLE 14. MAGNUSON SCRUBBER WASTEWATER FROM POTASSIUM HYDROXIDE PEELING ON 9/21/89

	CONCENTRATION, MG/L		
	COD	T S	K
KOH PEELED SP 5 WASTEWATER	47,232	65,540	8,567

only 3 mg/100 g for sodium [1]. This is also evident from table 7 which shows 2,465 mg/l of potassium present in the Magnuson Scrubber wastewater when NaOH was used as the peeling agent. Second, more KOH is necessary to provide the same peeling ability as NaOH. Approximately 1.4 times as much KOH is needed, based on a comparison of the molecular weights of KOH and NaOH. This is in addition to the potassium already present in the wastewater. The resulting concentration of potassium in the final effluent wastewater (SP 14) was 1,379 mg/l for the 70,000 gallons of water used for production, corresponding to 805 lbs of potassium per day. This is far more than the resulting sodium concentration at SP 14 of approximately 850 mg/l or 500 lbs per day when using NaOH as the peeling agent.

Any further analysis on the characterization of tomato processing wastewater was performed only on the Magnuson Scrubber and was in combination with treatability studies. This additional data is covered under section 4.2.0.

4.1.2 HERRING ROE PROCESSING

This section summarizes the results of VPI & SU testing on LAPCO's herring roe process wastewater. Since this research project began near the end of the roe processing season, the characterization study presented was based on one day of production. Samples were taken on 18 April 1989. Although this was one of the last days of herring roe packing, the quantity of roe canned was the highest of the season (3,356 lbs.). Therefore, all daily wastewater parameters determined were considered maximum values. On the date of sampling the production day lasted only 3.5 hours. Because the length of processing time may increase, depending upon product availability, all pollutant parameters will be reported in lb/hr. If production time increases in the future, values in lb/day could be modified accordingly.

Raw wastewater characteristics are shown in table 15. Processing values in lb/day are based on 3.5 hours of packing. Wash-up and start-up durations were 65 minutes and 45 minutes, respectively. The total volume of wastewater generated was 7,245 gallons, which is only a fraction of the 90,000 GPD generated by tomato processing.

A wastewater and process flow diagram is shown in figure 10. There were three packing operations generating wastewater. The percentage of production wastewater generated in each operation is also shown in figure 10. About 90% or 4,371 gallons were used for washing roe prior to canning. All samples were taken at the influent to the storage basin and before the shaker screen. Test results

Table 15. Lapco Herring Roe Process Wastewater Characterization (cont'd)

	FLOW		BOD$_5$				COD				TSS			
	GPD	Gal/ 1000 lb	mg/L	Lb/hr	Lb/Day	Lb/Klb	mg/L	Lb/hr	Lb/Day	Lb/KLB	mg/L	Lb/hr	Lb/Day	Lb/Klb
Processing[a]	4857	1447	3170	36.7	128.4	38.14	5960	69.0	241.5	72.0	1140	13.2	46.2	13.77
Wash Water	1569	468	184	2.2	2.4	0.72	274	3.3	3.6	1.1	50	0.61	0.65	0.19
Startup Water	819	244	92	0.84	0.63	0.19	137	1.2	0.94	0.28	50	0.46	0.34	0.10
TOTAL	7245	2159	2168	39.7	131.0	39.1	4071	73.5	246.0	73.4	781	14.3	47.2	14.1

NOTES: a. Temp. = 20°C, pH = 7.5

Table 15. Lapco Herring Roe Process Wastewater Characterization (Cont'd)

	Settleable Solids	TKN				AMMONIA-N				SODIUM			
	mg/L	mg/L	Lb/hr	Lb/Day	Lb/Klb	mg/L	Lb/hr	Lb/Day	Lb/KLB	mg/L	Lb/hr	Lb/Day	Lb/Klb
Processing	50	363	4.2	14.7	4.38	4.4	0.051	0.18	0.054	219	2.54	8.87	2.64
Wash Water	--	18	0.22	0.24	0.072	2	0.024	0.026	0.008	200	2.42	2.61	0.78
Start-up Water	--	4	0.036	0.027	0.008	1	0.009	0.007	0.002	93	0.085	0.064	0.019
TOTAL	45	248	4.5	15.0	4.5	3.5	0.084	0.21	0.064	190	5.0	11.5	3.4

Table **15.** Lapco Herring Roe Process Wastewater Characterization (Cont'd)

	OIL AND GREASE				TOTAL PHOSPHORUS				TOTAL SULFUR				POTASSIUM			
	mg/L	Lb/hr	Lb/Day	Lb/ Klb	mg/L	Lb/hr	Lb/Day	Lb/ Klb	mg/L	Lb/hr	Lb/Day	Lb/ KLB	mg/L	Lb/hr	Lb/Day	Lb/ Klb
Processing	6.3	0.73	0.26	0.077	41.6	0.48	1.69	0.50	34.6	0.40	1.40	0.42	42.89	0.50	1.74	0.52
Wash Water	3	0.036	0.039	0.012	3.0	0.036	0.039	0.012	8	0.097	0.10	0.03	11	0.13	0.14	0.04
Start-up Water	0	0	0	0	0.5	0.0046	0.0034	0.0010	6	0.055	0.0041	0.0012	9	0.082	0.061	0.018
TOTAL	5.0	0.77	0.3	0.09	28.6	0.52	1.73	0.51	24.8	0.55	1.50	0.45	32.1	0.71	1.94	0.58

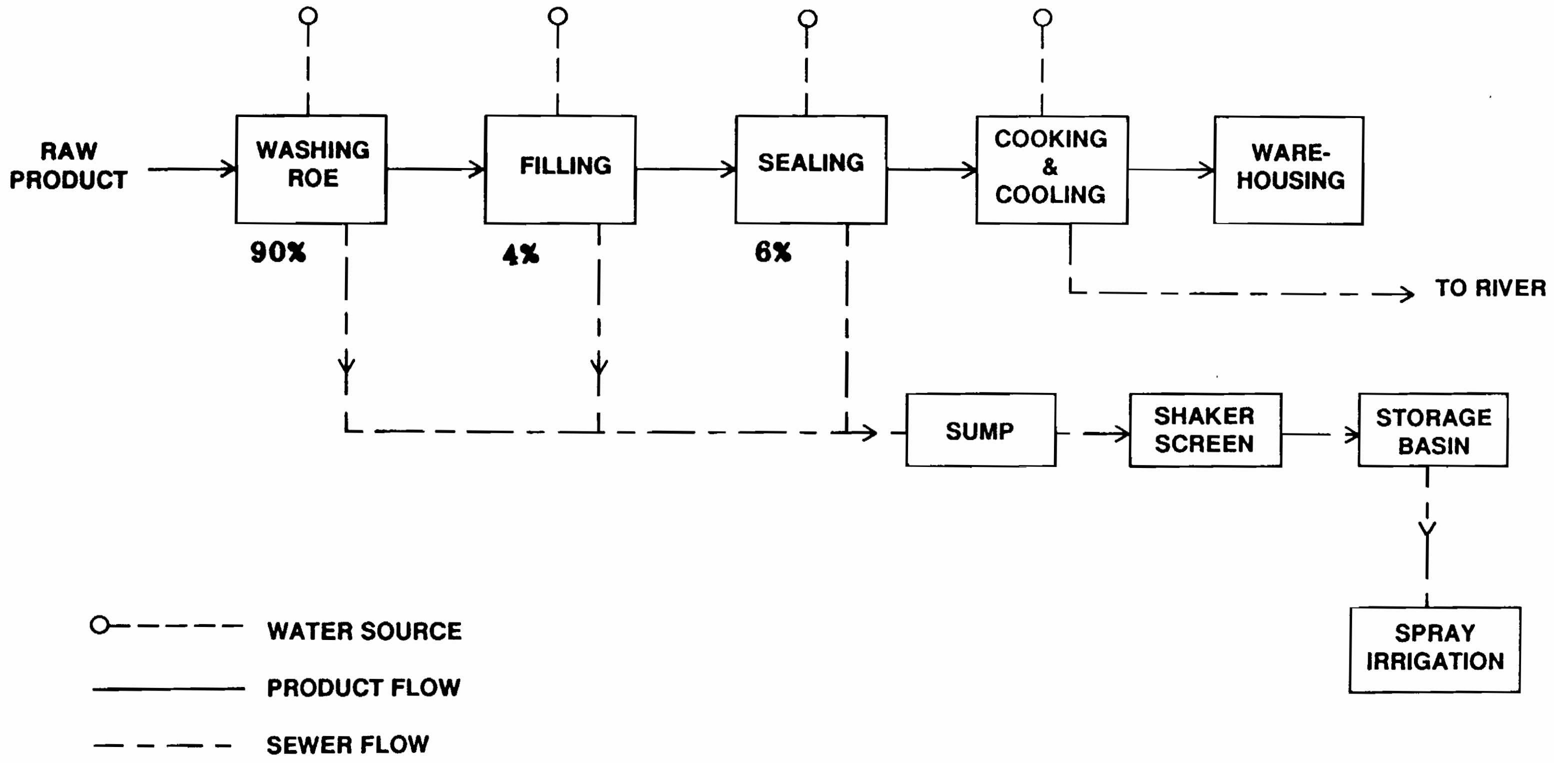


FIGURE 10. LAPCO HERRING ROE WASTE AND PROCESS FLOW DIAGRAM

showed no measurable BOD_5 or TSS was removed by the large mesh screen (about size 10) in place on the date of sampling. Herring roe is small enough to go through a screen of that size.

Total BOD_5, TSS, and sodium quantities generated were 131, 47, and 11.5 lb/day. Corresponding tomato wastewater values were roughly 2,500, 1,800 and 500 lb/day, respectively. Note that cooking and cooling water were previously found to be clean enough for discharge to the Coan River.

Supply water was found to have a sodium level of 93 mg/l. Recall that during the tomato season this level was 122 mg/l. The filling operation involves topping off each can with a brine solution after it has been filled with roe. This is where sodium enters the herring roe wastewater.

4.1.3 OYSTER PROCESSING

Wastewater was characterized on two separate days. First, LAPCO's hand-shucked oyster process was studied in detail and characterized on 29 November 1989. Results are shown in table 16. Most of this wastewater was generated from the rinsing process described in Chapter 2. Before the aeration period, a tank was filled with water from a

Table **16.** Hand-Shucked Oyster Wastewater Sampling Results of 11/29/89

Discharge Description	Flow (GPD)	COD mg/L	COD Lb/Day	COD Lb/Klb	BOD_5 mg/L	BOD_5 Lb/Day	BOD_5 Lb/Klb	TSS mg/L	TSS Lb/Day	TSS Lb/Klb	VSS mg/L	VSS Lb/Day	VSS Lb/Klb
Prod.	8,177	852	58.10	16.62	384	26.19	7.49	121	8.25	2.36	73	4.98	1.42
Wash-up	1,800	565	8.48	2.43	231	3.47	0.99	193	2.90	0.83	70	1.05	0.30
TOTAL	9,977	800	66.58	18.05	356	29.66	8.48	134	11.15	3.19	73	6.03	1.72

NOTE: ● Quantity of shucked product processed = 3496.14 lbs.

spigot. This flowrate was measured for all six tanks during two separate fill periods. Each tank underwent four cycles on that day. Following aeration, water was again delivered to each tank, but a value was turned which caused rinse water to enter the bottom of each tank. Measurements of tank fill rates were therefore used for rinse water overflow rates.

Since the average rinse cycle lasted 11 minutes and the average flowrate was 20 gpm, a total of 5,280 gallons were used on 11/29/89. By putting 20 gallons of oysters into a completely filled tank, the same volume of water became displaced and overflowed the tank. This amounted to about 480 gallons for the day. Approximately half the volume of each tank was put through the strainer, adding 1,440 gallons to the total. An average background flowrate of 67 gph was measured throughout the day which was due to sink drains, hose rinsing and steam condensate. This accounted for an additional 737 gallons, considering 11 hours of operation from 4:00 A.M. until 3:00 P.M. Wastewater generated from the actual packing process was estimated at 10 gallons per cycle per tank or 240 gallons. All five of the above sources were combined in table 16 to yield a total production flow of 8,177 gpd. Wash-up water was estimated as 3 hoses operating for one hour at 10 gpm or 1,800 gpd. It was not possible to distinguish production water usage from wash-up water since at times these processes overlapped.

The production COD level of 852 mg/l is the average of 5 samples taken between 7:00 A.M. and 2:00 P.M. The range was 200 mg/l - 2,271 mg/l and the standard deviation was 761 mg/l. Care was taken to collect a wash-up sample when no other production operations were occurring except for a background contribution. The total BOD_5 generated was about 30 lb/day while TSS was 11 lb/day, roughly half of which were volatile. This amounted to BOD_5 and TSS contributions that were roughly 1% of tomato wastewater values. TKN, NH_3-N, and TP values for a daily composite sample were 34.7 mg/l, 0.7 mg/l and 2.6 mg/l, respectively.

A second oyster wastewater sampling trip was made on 21 December 1989. Wastewater had unusual characteristics on this day because outside temperatures were well below freezing. Product delivered to LAPCO was frozen so hose water was continually flushed through the hopper to thaw the oysters. Much of the sediment which typically got discarded with spent shells was then flushed into the wastewater flume. A suspended solids level of 514 mg/l resulted, which was roughly four times greater than the previous level (134 mg/l) determined on 29 November 1989.

Table **17**. Hand-Shucked Oyster Wastewater Sampling Results of 12/21/89

Discharge Description	Flow (GPD)	COD			BOD_5			TSS			VSS		
		mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	Lb/Klb	mg/L	Lb/Day	lb/Klb	mg/L	Lb/Day	Lb/Klb
Composite	7,200	443	26.6	13.6	140	8.41	4.29	514	30.9	15.7	103	6.18	3.16

NOTES:

- TS = 1413 mg/L
  TVS = 488 mg/L
  TDS = 899 mg/L
- Quantity of shucked product processed = 1955 lbs.
- Composite included half-hourly samples from 6:00a.m. to 12:00p.m.
  From 12:00a.m. to 6:00a.m., flow was estimated to be 200 gph.

Results of the second characterization are shown in table 17. This table represents the results on a composite sample taken every half hour from 6:00 A.M. to 12:00 P.M. and includes production and wash-up contributions. Flowrates were determined half-hourly at the point of discharge to the river. Water usage based on production was much higher on this date than in November (3,682 gal/Klb vs 2,854 gal/Klb). This increase was a result of the need to thaw the shell stock. An oil and grease test was not performed since annual test results for the past five years have shown the O & G level to be less than 10 mg/l. Considering the above flowrates, the O & G load is only a fraction of the discharge limitation.

4.2.0 TREATMENT ALTERNATIVES FOR HERRING ROE WASTEWATER

It would be difficult to use a screen to remove roe particles because their diameter is only about 0.020 in. (0.50 mm). Such a fine mesh screen would likely clog with crushed roe particles as well as sand. As shown in table 16, the settleable solids value of 50 ml/L represents good settling wastewater, so plain sedimentation will remove a significant level of the solids and BOD.

Herring roe wastewater characteristics following primary settling are shown in table 18. Based on full-scale

Table **18.** Herring Roe Wastewater Characteristics Following Primary Settling (cont'd)

	BOD_5				COD				TSS			
	mg/L	Lb/Hr	Lb/Day	Lb/Klb	mg/L	Lb/Hr	Lb/Day	Lb/Klb	mg/L	Lb/Hr	Lb/Day	Lb/Klb
Processing	874	10.1	35.4	10.55	1644	19.0	66.5	19.8	124	1.44	5.0	1.49
Wash Water[a]	125	1.51	1.64	0.49	184	2.23	2.41	0.72	40	0,48	0.52	0.15
Start-up Water[a]	62	0.56	0.42	0.13	92	0.84	0.63	0.19	40	0.36	0.27	0.08
TOTAL	621	12.2	37.5	11.2	1150	22.1	69.5	20.7	96	2.3	5.8	1.72

Table 18. Herring Roe Wastewater Characteristics Following Primary Settling (Cont'd)

	TKN				AMMONIA-N				TOTAL PHOSPHORUS			
	mg/L	Lb/Hr	Lb/Day	Lb/Klb	mg/L	Lb/Hr	Lb/Day	Lb/Klb	mg/L	Lb/Hr	Lb/Day	Lb/Klb
Processing	273	3.2	11.1	3.31	8.7	0.10	0.35	0.10	11.0	0.13	0.45	0.13
Wash Water[a]	16	0.19	0.21	0.063	1	0.012	0.013	0.004	2.5	0.030	0.033	0.010
Start-up Water[a]	4	0.036	0.027	0.008	1	0.009	0.007	0.002	0.5	0.005	0.003	0.001
TOTAL	188	3.43	11.34	3.38	6.6	0.1	0.4	0.1	8.1	0.17	0.49	0.14

Table 18. Herring Roe Wastewater Characteristics Following Primary Settling (Cont'd)

	TOTAL SULFUR				POTASSIUM			
	mg/L	Lb/Hr	Lb/Day	Lb/Klb	mg/L	Lb/Hr	Lb/Day	Lb/Klb
Processing	14.4	0.17	0.58	0.17	34.93	0.40	1.41	0.42
Wash Water[a]	8.0	0.097	0.10	0.03	11	0.13	0.14	0.042
Start-up Water[a]	6.0	0.055	0.0041	0.0012	9	0.082	0.061	0.018
TOTAL	11.2	0.32	0.68	0.20	26.6	0.612	1.611	0.48

NOTES:

a. Estimated based on raw values, settled processing, and composite screened wastewater values.

application, the BOD_5 of the waste is reduced from 131 lb/day (59.3 kg/day) to 37.5 lb/day (17.0 kg/day) by settling alone. This represents a reduction of 71% and is well below the SWCB daily maximum limit of 67.3 lb/day (30.5 kg/day). However, the limit based on production, 8.4 lb/1,000 lb, is still exceeded. The LAPCO value here is 11.2 lb/1,000 lb. This is based on raw product, as stated in permit No. VA0077780. Maximum daily limits for TSS, again using 4/18/89 values as maximum, of both 57 lb/day (25.8 kg/day) and 7.1 lb/1,000 lb are easily met by settling as demonstrated by the LAPCO values of 5.8 lb/day and 1.72 lb/1,000 lb. The oil and grease requirement for the herring roe processes is easily met without treatment.

The above results shown no benefit to operating the shaker screen during the roe season. Fish scales and other large particles (some of which can damage pumps), of course, still need to be removed. If the volume of these large particles is small, perhaps the screen could be operated in a stationary mode yielding lower electrical power requirements.

Solids generated from the roe process may be composted and the mulch used as fertilizer. Little sodium appears to be associated with the roe solids, so soil should not be adversely affected by the compost. There may also be a market for herring roe waste as a feed to a local catfish or eel farm.

Table 19 is included to show the concentration of additional trace elements in the raw wastewater, settled wastewater, and the supply water. These results are not particularly significant except that they show levels which are not inhibitory to biological treatment.

Brine waste could be segregated, thereby excluding most of the sodium from the remaining wastewater. While fourteen 40 gallon tanks or 560 gallons of brine were used on 4/18/89, at most, only a few hundred gallons of brine overflows the cans or is poured directly into the brine waste holding tank. Brine that is not recycled from this 200 gallon holding tank could be directed to an evaporation bed. This would be an economical method of eliminating sodium from land applied wastewater.

4.3.0 TREATMENT ALTERNATIVES FOR OYSTER WASTEWATER

As previously discussed, wastewater generated on 12/21/89 was unusually high in TSS and will therefore be considered a maximum seasonal value. Frozen shell-stock occurs only about 10 days out of the year so the maximum pollutant assumption should be valid. By comparing the effluent

Table 19. Herring Roe Wastewater Trace Elements

Element	Concentration, mg/L Raw Wastewater	 Settled Wastewater	 Well Water
Aluminum	0.079	0.11	0.061
Copper	0.0064	0.0086	0.012
Boron	0.37	0.43	0.51
Calcium	1.69	2.29	1.60
Magnesium	3.51	2.15	0.93
Manganese	0.017	0.013	0.0043
Zinc	0.36	0.31	0.022
Iron	0.61	0.24	0.021

discharge limitations in table 2 with the results of table 17, it can be seen that no treatment is required to meet the stated guidelines. TSS results showed that 15.7 lb/Klb were generated. The daily maximum limit is 23.0 lb/Klb. The margin of safety here is high since even the monthly average limitation of 16.0 lb/Klb is met without treatment. Results shown in table 16 are more typical of everyday operation. This shows only 3.19 lb/Klb of TSS were produced on 11/29/89.

4.4.0 TREATMENT ALTERNATIVES FOR TOMATO WASTEWATER

The results of subjecting tomato wastewater samples (SP 14) to different environmental conditions showed a small reduction in COD and TOC. A control with no pH or temperature adjustment and only quiescent settling yielded a COD decrease of 18% from 8,200 mg/l. There was no advantage to pH or temperature adjustment. COD reductions for samples 2 through 6 showed values ranging from 2% to 32%. Sample 4 (pH adjusted to 7.0) showed the lowest reduction while sample 6 (pH adjusted to 2.2, temperature lowered to 4°C) showed the highest removal. Addition of 1,000 mg/l of $Ca(OH)_2$ yielded only a 23% COD reduction.

The characterization of the tomato processing wastewater led to targeting the Magnuson Scrubber wastewater for separate treatment. The rationale is that the remaining 80,000 gallons of wastewater could be land applied without harm to the soil from elevated sodium levels. The sodium adsorption ratio (SAR) would correspondingly decrease from 28.9 to 8.15. Furthermore, the lye conveyor spray rinse wastewater (SP4) should also be included for treatment with the Magnuson Scrubber wastewater. The proximity of these two wastewater flumes along with only a slight contribution from SP4 would result in a minimal cost increase to include this additional flow. This would remove greater than 98% of the added sodium.

It would also be expected that background sodium levels would decrease in the supply water since sodium concentrations in the irrigation field soil would decrease, and less sodium would then percolate to the underlying aquifer. Although the process of flushing out most of the remaining salt in the irrigation field may take a few years, the situation will improve. For instance, if the sodium concentration in the water supply decreased by half its present value, the final effluent (without a Magnuson Scrubber or SP4 contribution) sodium concentration would be about 65 mg/l with a resulting SAR of 3.7. In this case the 32 acres used for wastewater spray irrigation could become productive land for additional tomato harvesting, assuming adequate soil recovery due to the many years of high salt application. Furthermore, the wastewater could be applied to additional land should a shortage of irrigation water occur in the future.

Of course, the most obvious advantage of treating the two waste streams separately is reduced cost due to treating only roughly 11% of the total wastewater, while still treating 80% of the COD and 30% of the TSS. These underlying facts have led to the following alternatives for treatment of SP4 and SP5: 1) Biological treatment with pretreatment screening and pH adjustment. 2) Sludge drying beds. Experiments of treatment alternatives performed in this analysis, however, used wastewater solely from SP 5.

4.4.1.0 BIOLOGICAL TREATMENT OF ISOLATED SP 5 WASTEWATER

If biological treatment is used, pretreatment is necessary. Therefore, this discussion precedes reactor treatability studies.

4.4.1.1 PRETREATMENT

Pretreatment options investigated included settling, screening, and the use of a belt filter press. The results of a settling study on 1,000 mls of Magnuson Scrubber wastewater showed 1,000 mls/L; i.e., no settling. The test was repeated with a cylindrical container instead of an Imhoff flask. This test also showed no settleability. The test was also performed on SP 14 and SP 6 with results yielding 500 mls/L and 140 mls/L, respectively. These are presented for comparison purposes only. Results from this test show that the use of a settling basin for tomato peel wastewaters would not be effective.

A lab-scale, belt filter press study was only crudely simulated to see what range of pressure would be needed to develop a reasonable solids cake. These results showed that a pressure of approximately 15 psi for a duration of 10 seconds would develop a handleable solids cake. A belt which was coarse enough to filter this waste was not available. The extent of belt clogging from a coarse woven belt was not determined, nor was chemical conditioning considered. If a belt filter press were utilized it would contain a gravity dewatering zone, preceded by a mixing zone if chemical conditioning were required, and only a low pressure roller zone. Adjustment of pH before the belt filter press may be necessary. Further investigation would be needed to determine all necessary design and operating parameters. An in-depth polymer study may show that only a gravity thickening table would be needed.

Screening of the Magnuson Scrubber wastewater may be the best alternative. The effects of screening are presented in table 20. Here it can be seen that only about 10% of the total COD was removed by either a size 3.5 or size 10 sieve. Furthermore, less than 25% COD removal occurred when nearly all TSS had been removed. Since the TSS value after filtration through a Whatman filter was low in comparison with the COD value, table 20 shows that approximately 75 percent (or 37,700 mg/l) of total COD was soluble. Greater than 90% or approximately 15,000 mg/l of suspended solids were volatile (VSS). Since 20% more TSS was removed by using a size 10 instead of a size 3.5 sieve, its use is recommended. Using a finer mesh would probably lead to clogging and using a wider mesh screen may allow large skin particles to wrap around screen openings, also causing poor performance. Note that although 50 percent of TSS was removed by a size 10 mesh, tables 13 and 20 show that COD was lowered by only 10 percent.

The most important aspect of the screening will be the percent solids of the captured skin particles. This can also be represented as a yield factor, determined as the ratio of filtrate volume divided by volume of wastewater screened. The results of determined yield values are shown in table 21. The yield increased from 0.62 L/L to 0.84 L/L by applying light pressure (10 psi). When the Magnuson

TABLE 20. EFFECT OF SCREENING AND FILTERING ON MAGNUSON SCRUBBER WASTEWATER OF 8/25/89

	CONCENTRATION, MG/L		
	COD	TSS	VSS
RAW MAG SCRUB[a]	48,886	15,954	14,951
SIZE 3.5 SIEVE	44,442	11,533	9,300
SIZE 10 SIEVE	44,045	8,567	7,233
WHATMAN #1 QUALITATIVE	37,776	233	200

NOTE: a. TDS= 45,393 MG/L

TABLE 21. FILTRATE VOLUME EXPRESSED AS YIELD VALUES FROM SCREENING MAGNUSON SCRUBBER WASTEWATER THROUGH A #10 SIEVE

SAMPLE DESCRIPTION	YIELD (L/L)
RUN DRY	0.40
RUN WET	0.62
ACIDIFIED, pH 3.5	0.68
APPLIED PRESSURE, APPROX. 10 PSI	0.84

Scrubber was run dry, the yield was very low (0.40 L/L). Since acidification made the wastewater less viscous, a screening test was also performed on acidified wastewater. The results showed, however, that acidification did not substantially increase yield. The results of table 21 are important since they show a high water content of the solids unless pressure is applied to the screen. This will substantially affect the volume of solids to be disposed. If a higher pressure were applied, the yield could be increased further. However, a value of 0.80 or greater may possibly be achieved by the vigorous agitation that occurs through hitting a vibrating screen at a high velocity, the vibration of the screen itself, and the relatively long residence time of the solids on the screen. It is expected that a vibrating screen will give the best performance and, thus, it is the recommended pretreatment operation if biological treatment is used.

Pre-Treatment Solids Considerations

Reactors were fed screened Magnuson Scrubber wastewater (#10 sieve, with approximately 10 psi applied pressure). Usually one 20 liter carboy was screened at a time, which generated enough feed to last between one and two weeks of reactor operation. This was used also to determine the amount of pretreatment solids generated per day.

After screening 20 liters (5.28 gallons) of wastewater, the weight of solids residue was 1.86 kg (4.11 lbs.). The unit weight of solids per volume of wastewater screened was 0.093 kg/l (0.778 lb/gal). Therefore, for roughly 10,000 gallons of Magnuson Scrubber wastewater, 7,780 lbs or about 4 tons of solids would need to be disposed of daily from pretreatment screening. Approximately 5 to 20 tons per day of solids are presently disposed of at an on-site location. This includes vines and graded tomatoes in addition to screened wastewater solids. High range values of disposal tonnage result from a low quality tomato crop when a large amount of green and rotten tomatoes are discarded after grading. With segregation the total amount of solids to be disposed will be the same as that currently produced. However, the pH and sodium content of the 4 tons of solids from the screened Magnuson Scrubber wastewater will be quite high.

While the pH of SP 5 is below 12.5 (mean value = 12.0, standard deviation = 0.3, range 11.1 - 12.4) which prevents the solids being labeled as a hazardous waste, it would prevent biodegradation and plant growth in the disposal area. This could be overcome by pH adjustment before screening. Note that the pH of SP 4 is always 0.2 to 0.4 units higher than SP 5. It remains to be seen if combining SP 4 and SP 5 will cause the pH to exceed 12.5. The salt content alone, however, could necessitate disposal off-site to a local sanitary landfill that would have a liner in place and be able to tolerate high sodium waste contributions. This would cause disposal costs to dramatically increase and may not be a viable option depending upon the hauling distance or proximity of a landfill to the LAPCO plant. Although it is hoped that on-site disposal of this waste is a viable alternative, this matter warrants further investigation.

pH Adjustment

Biological activity is optimum for most organic wastes when pH is between 6.5 and 8.5 [23]. For the biological reactor study presented herein, pH of feed wastewater was reduced to 8.5 ± 0.1 units. The amount of acid, in the form of concentrated H_2SO_4, required for proper neutralization was determined by recording mls of acid utilized to neutralize 2.5 L of screened Magnuson Scrubber wastewater. The result was that 8.5 mls were required to reduce the pH from 12.3 to 8.5. For a full-scale production loading of roughly 10,000 gallons, the amount of concentrated H_2SO_4 required would be 34 gallons per day. For a maximum of 50 full days of production, assuming 10 weeks at 5 days per week, a total of 1,700 gallons of H_2SO_4 would be used for the tomato processing season.

Caution must be exercised when adding concentrated acid to a strong caustic waste such as the Magnuson Scrubber wastewater. Drastic pH changes can occur from improper addition of acid and therefore direct addition of acid to the Magnuson Scrubber flume just prior to the reactor basin is not recommended. This means an equalization basin is needed to adequately control pH without undue fluctuation which could impair biological treatment. In addition, pH control must be achieved by an automated controller. An emergency relay must be included as part of the controller to either stop production or have the Magnuson Scrubber wastewater flow to an emergency storage basin. Either of these situations must occur if the pH of the reactor feed drops below 6.5 or increases above about 8.7. Operation should be targeted between pH 8.0 and pH 8.5 to keep acid utilization costs as low as possible. Note that jar tests showed only 3% more acid is necessary to reduce pH from 8.5 to 8.1.

The equalization basin needs to be well-mixed to equally distribute the acid throughout the very viscous wastewater. To reduce mixing power requirements, the acid addition could occur in a flume prior to the equalization basin. Mixing would then occur by currents naturally present in a small equalization basin with a short detention time.

From a safety standpoint, large uncontrolled additions of H_2SO_4 need to be avoided. The ensuing reaction is exothermic and generates a large amount of heat. Equally important, due to the high sulfide content of the wastewater, a bulk addition of H_2SO_4 decreases the pH of the wastewater or local regions thereof, below the pKa of hydrogen sulfide. H_2S is then released as a gas, causing odor and possibly toxicity problems. Release of these fumes was noticeable in the lab since neutralization was often achieved too quickly. Attempts to measure sulfide levels using method 427 D of Standard Methods [38] were unsuccessful.

4.4.1.2 Sequencing Batch Reactor Results

Results and discussion of each phase of the SBR treatability study are presented below.

Acclimation

The results of early acclimation SBR cycles for reactor A are shown in table 22. Note the steady increase in effluent COD because of the combined effects of residual COD and overcoming dilution due to the use of a 20 day HRT. One of the goals of this acclimation study was to see how feasible it would be to operate the reactor at a long

HRT, similar to a lagoon, and not have any wastage of settled solids. Table 22 shows that even at a 20 day HRT, MLSS increase was substantial. Over two weeks of operation, the operating MLSS increased from 1,000 mg/l to 6,000 mg/l. This was due to the very high organics concentration which resulted in a rather conventional F/M value of approximately 0.2, even though only 0.4 L were fed daily to an 8 L reactor. COD levels were lowered by roughly 95% to 2,300 mg/l. After two weeks of operation, it became necessary to waste mixed liquor. This table realistically represents the type of performance that would occur in full scale treatment during the first two weeks of the tomato processing season, if a design was based on a 20 day HRT.

The results of acclimation SBR cycles for reactor B are shown in table 23. Here the HRT was decreased to 8 days but, inevitably, increased organic loading caused the MLSS to increase from approximately 1,000 mg/l to almost 5,000 mg/l in only the first four days of operation. Loading was then decreased by half to 400 mls of feed to decrease solids production and still allow acclimation. Effluent COD values were below 3,000 mg/l.

A similar table showing acclimation operation for reactor C is shown in table 24. Originally, it was desired to use a

TABLE 22. REACTOR "A" ACCLIMATION OPERATION -

DATE	FEED (MLS)	DILUTION (%)	COD (MG/L) FEED	COD (MG/L) EFFL	MLSS (MG/L)	MLVSS (MG/L)	SETTLED SOLIDS (L)	pH EFFL
9/8	400	50%	23,377	---	1,013	844	1.0	7.9
9/9	↓	50%	22,479	---	---	---	1.0	---
9/10	↓	50%	22,479	665	2,153	1,967	1.5	8.5
9/12	↓	NONE	44,957	757	3,565	3,318	2.5	---
9/13	↓	↓	↓	937	---	---	3.0	---
9/14	↓	↓	↓	1,230	---	---	2.5	8.7
9/15	↓	↓	↓	1,300	---	---	3.0	8.7
9/16	↓	↓	↓	1,441	4,250	---	3.4	---
9/18	↓	↓	↓	---	---	---	4.0	---
9/19	↓	↓	↓	1,653	---	---	3.5	---
9/20	↓	↓	↓	1,870	4,687	---	3.6	---
9/22	↓	↓	44,957	---	---	---	4.5	---
9/23	↓	↓	44,370	2,225	---	---	5.5	---
9/24	↓	↓	44,370	---	5,380	---	---	---
9/25	400	NONE	44,370	2,373	5,920	---	---	---

NOTES:

- NO WASTING OF MLSS OCCURRED
- CYCLE = 24 HRS (1/2 HR FILL, 22 HRS REACT, 1/2 HR SETTLE, 1/2 HR DRAW, 1/2 HR IDLE)
- SECOND AIR STONE ADDED FOLLOWING 9/13 CYCLE
- MLSS & MLVSS MEASURED AT END OF CYCLE EXCEPT 9/8 INITIAL VALUES

TABLE 23. REACTOR "B" ACCLIMATION OPERATION

DATE	FEED (MLS)	DILUTION (%)	COD (MG/L) FEED	COD (MG/L) EFFL	MLSS (MG/L)	MLVSS (MG/L)	SETTLED SOLIDS (L)	pH EFF
9/8	800	50%	23,377	---	1,013	844	1.0	7.7
9/9	800	50%	22,479	---	---	---	1.5	7.9
9/10	800	50%	22,479	1,406	3,112	2,947	3.8	8.6
9/12	800	NONE	44,957	1,569	4,794	4,444	2.2	---
9/13	400	↓	↓	1,618	---	---	3.0	8.7
9/14	↓	↓	↓	1,945	---	---	2.8	---
9/15	↓	↓	↓	1,937	---	---	6.0	8.9
9/16	↓	↓	↓	2,180	4,325	---	6.4	9.2
9/18	↓	↓	↓	---	---	---	6.4	---
9/19	↓	↓	↓	2,283	---	---	5.5	---
9/20	↓	↓	↓	2,508	5,942	---	5.0	8.9
9/22	↓	↓	44,957	---	---	---	4.5	8.9
9/23	↓	↓	44,370	2,674	---	---	5.5	---
9/24	↓	↓	44,370	---	6,280	---	---	---
9/25	400	NONE	44,370	2,840	7,040	---	---	---

NOTES:

- 500 MLS MIXED LIQUOR WASTED AT COMPLETION OF 9/12 CYCLE TO ACHIEVE 4,500 MG/L MLSS
- CYCLE = 24 HRS (1/2 HR FILL, 22 HRS REACT, 1/2 HR SETTLE, 1/2 HR DRAW, 1/2 HR IDLE)
- SECOND AIR STONE ADDED FOLLOWING 9/13 CYCLE
- MLSS & MLVSS MEASURED AT END OF CYCLE EXCEPT 9/8 INITIAL VALUES

TABLE 24. REACTOR "C" ACCLIMATION OPERATION

DATE	FEED (MLS)	DILUTION (%)	COD (MG/L) FEED	COD (MG/L) EFFL	MLSS (MG/L)	MLVSS (MG/L)	SETTLED SOLIDS (L)	pH EFF
9/7	5,000	50%	23,377	---	1,013	844	7.5	8.3
9/9	1,600	50%	22,479	---	---	---	1.2	8.3
9/10	1,600	50%	22,479	1,898	2,725	2,508	4.0	8.3
9/12	1,600	NONE	44,957	---	6,183	5,667	8.0	8.3
9/13	400	↓	↓	---	---	---	4.5	9.2
9/14	↓	NONE	↓	2,204	4,900	---	2.8	---
9/15	↓	↓	↓	2,189	---	---	2.8	9.1
9/16	↓	↓	↓	2,300	3,850	---	2.7	9.3
9/18	↓	↓	↓	---	---	---	2.7	---
9/19	↓	↓	↓	2,692	---	---	2.2	---
9/20	↓	↓	↓	2,826	5,625	---	2.2	9.1
9/22	↓	↓	44,957	---	---	---	2.0	9.1
9/23	↓	↓	44,370	3,171	---	---	2.0	9.1
9/24	↓	↓	44,370	---	4,240	---	---	---
9/25	400	NONE	44,370	3,367	4,480	---	---	---

NOTES:

- REACTOR BROKEN DOWN & RESTARTED AFTER 9/7 OPERATION
- 2L MIXED LIQUOR WASTED AFTER 9/12 CYCLE
0.4L MIXED LIQUOR WASTED AFTER 9/13 CYCLE
- CYCLE = 24 HRS (1/2 HR FILL, 22 HRS REACT, 1/2 HR SETTLE, 1/2 HR DRAW, 1/2 HR IDLE)
- SECOND AIR STONE ADDED FOLLOWING 9/13 CYCLE
- pH OF 9/13 FEED NOT ADJUSTED

1.6 day HRT, but after the first loading on 9/7/89, MLSS increased to such a large extent that almost no settling occurred. Unsure that a high solids concentration caused this problem, the reactor was broken down and restarted with new seed on the following day. While it was desired to keep this reactor more heavily loaded with an F:M of 1.0 and a 5 day HRT, the same problem of excessive MLSS increase occurred. Loading to this reactor was eventually also decreased to 400 mls per day due to poor settling. It is likely that the high MLSS value of 5,625 mg/l, which occurred on 9/20/89, is a spurious result. Such a large increase in MLSS should have resulted in an increase in settled solids. This did not occur. Note also how effluent pH was found to stabilize at a value of 9.1 increasing from a feed value of 8.5. The tendency of this wastewater to buffer pH near 9.1 indicated that deamination of organic nitrogen was prevalent. This was also an indication that the rate of nitrification was low in comparison with ammonification.

BOD_5 and suspended solids removal during acclimation operation of all three SBRs were also investigated, and these results are presented in table 25. While BOD_5 removal was in excess of 98% and TSS removal in excess of 95%, these results include a small amount of dilution from the use of a 20 day HRT. Since these results were only for

TABLE 25. BOD$_5$ AND SOLIDS REMOVAL DURING ACCLIMATION EXPERIMENTS

REACTOR A

	BOD$_5$		TS		TSS		TDS	
DATE	INFL	EFFL	INFL	EFFL	INFL	EFFL	INFL	EFFL
9/20	---	---	52,970	10,430	13,243	91	39,728	10,344
9/23	16,374	100	---	---	---	---	---	---
9/25	---	---	51,570	12,050	12,893	337	---	---

* BOD$_5$ OF RAW (UNSCREENED) MAG. SCRUB = 16,814 MG/L

REACTOR B

	BOD$_5$		TS		TSS		TDS	
DATE	INFL	EFFL	INFL	EFFL	INFL	EFFL	INFL	EFFL
9/14	17,000	422	---	---	---	---	---	---
9/20	---	---	52,970	13,020	13,243	180	39,728	12,840
9/23	16,374	175	---	---	---	---	---	---
9/25	---	---	51,570	14,180	12,893	520	---	---

REACTOR C

	BOD$_5$		TS		TSS		TDS	
DATE	INFL	EFFL	INFL	EFFL	INFL	EFFL	INFL	EFFL
9/20	---	---	52,970	14,340	13,243	277	39,728	14,064
9/23	16,374	234	---	---	---	---	---	---
9/25	---	---	51,570	15,130	12,893	607	---	---

NOTE: ALL DATA VALUES ARE MG/L

acclimation experiments, they will not be expanded upon. BOD_5 and TSS results were very promising, however, and correspond to excellent treatment below discharge limitation levels. Based on annual average effluent guidelines presented in table 1, target production levels of 150 TPD, and 10,000 GPD of Magnuson Scrubber wastewater, effluent BOD_5 and TSS values must be below 1,760 mg/l and 3,230 mg/l, respectively. Of particular interest are effluent TDS values presented in table 25.

Fixed dissolved solids (FDS) levels in Magnuson Scrubber wastewater were approximately 13,000 mg/l, so a considerable fraction of effluent TDS was due to conservative substances. A significant fraction may have been due to dissolved organics which were present as residual carotenoid pigments. It is these dissolved organics which are responsible for the resulting highly colored effluent. The most abundant carotenoid of tomatoes is lycopene. Carotenoids (chemical formula $C_{40}H_{56}$) are chemically much more stable than other plant and animal pigments such as chlorophyll and hemoglobin [1]. Their presence in treated reactor effluents showed that they were not readily biodegradable.

The color level of Magnuson Scrubber wastewater was determined to be between 8,000 and 10,000 platinum cobalt units (determined as true color). Although a color analysis was not performed on reactor effluents, no color removal could be visually detected. A TOC analysis was performed on 9/16 reactor effluents. Reactors A, B, and C TOC values were 660, 880, and 1,100 mg/l, respectively. BOD_5 values were low in comparison with TOC values as further evidence of residual organic matter which was not readily biodegradable.

Nutrient removal was investigated for reactor A during acclimation. Results are presented in table 26. While nitrogen and phosphorus levels were reduced by approximately 97% and 85%, respectively, the mode of reduction is biological assimilation into settleable solids. It was later determined that nitrification did not occur. The mode and frequency of solids disposal will then determine the fate of nutrient reduction during full-scale operation. The BOD_5:TKN:TP ratio of Magnuson Scrubber wastewater determined on 14 September was 76:4.4:1, indicating an excess of both N and P. Excess N and P were found in all effluents analyzed as further proof that nutrients were not limiting. This excess was less apparent when the ratio was based on BOD_{ult}. The BOD_{ult}:TKN:TP value was 115:4.4:1.

TABLE 26. NUTRIENT REMOVAL IN REACTOR "A" DURING ACCLIMATION

	CONCENTRATION, MG/L			
	TKN		T.P.	
DATE	FEED	EFFL	FEED	EFFL
9/14	993	30.3	225	33.8
9/15	---	---	225	26.7

High Load SBR Operation

Following completion of acclimation studies, the SBRs were heavily loaded to see the effect of using an HRT of 3.2 days with a corresponding F/M value near 1.0. The operating conditions and cycle times were as shown in tables 27 and 28. Since no settling occurred at completion of the 24 hour cycles, the react period durations were increased to approximately 37 hours to simulate 48 hour cycling. This did not improve settleability. At the completion of 37 hours of react, MLSS values for reactors A, B and C were found to be 9,467 mg/l, 10,222 mg/l, and 11,022 mg/l, respectively. Although no treatability data could be derived from this study, some very important operational problems were noted.

A foaming condition existed during acclimation studies, where an inch or two of foam was always present. For more highly loaded reactors, this was found to be a more serious concern. Sometime before the completion of 12 hours of aeration, a thick foam around 6 inches high formed in reactor C. This level was high enough to clear reactor freeboard, causing spillage onto the lab floor. Approximately 25% of reactor volume was lost. Reactors A and B did not foam over. This wastewater initially acted as a defoaming agent, immediately dispersing any foam

TABLE 27. HIGH LOAD OPERATING CONDITIONS PERFORMED 9/27/89

	F:M[a]	HRT(DAYS)	MLSS(MG/L)	FEED(L)
REACTOR A	1.0	3.2	5,000	2.5
REACTOR B	0.9	3.2	5,500	2.5
REACTOR C	1.2	3.2	4,200	2.5

NOTE: a. F:M BASED ON LB BOD_5/LB MLSS.
BOD_5 = 16,374 MG/L

TABLE 28. CYCLE TIMES USED FOR HIGH LOAD OPERATION

	TIME, HOURS					
	FILL		REACT	SETTLE	DRAW	IDLE
	TOTAL	AERATED				
REACTOR A	6	3	13.5	2	1.5	1
REACTOR B	6	3	13.5	2	1.5	1
REACTOR C	3	0	16.5	2	1.5	1

present at the beginning of a fill cycle. After a period of react cycle, however, compound(s) responsible for this chemical de-foaming were degraded and foaming ensued. SBR application would require either the use of a defoaming agent or a tapered aeration cycle.

The second problem noticed was the difficulty in maintaining aerobic conditions in each reactor. Even after 13 hours of vigorous aeration using two, 6 inch, air stones per reactor, dissolved oxygen (D.O.) levels were less than 0.5 mg/l in reactors A and B. Reactor C had the highest D.O. level of 4.5 mg/l. After 42 hours of aeration, D.O. levels for reactors A, B and C measured 0.5 mg/l, 3.5 mg/l, and 5.5 mg/l respectively. The visibly lower aeration applied to reactor A was not adequate to maintain aerobic conditions conducive to biological activity. This was also apparent through soluble COD (SCOD) measurements taken after 42 hours. SCOD values were 6,771, 3,787, and 3,522 mg/l, respectively. Note also that an odor problem occurred in the lab during this time of high loadings.

A sample of mixed liquor from reactor C was taken after 13 hours of aeration, centrifuged at 1,300 x g for 10 minutes and filtered through a Whatman glass microfibre filter (Part No. 934-AH). Note that even after centrifuging, it was impossible to filter the sample through a 0.45 micron filter. A significant fraction of solids were therefore between approximately 0.45 and 1.5 microns. The sample then underwent an ion chromatograph analysis for the determination of specific anions, including fluoride, chloride, nitrite, nitrate, phosphate and sulfate. These results are presented in table 29. Values shown for NO_2-N, NO_3-N, and SO_4 are particularly notable. Nitrite and nitrate levels were not detected indicating that nitrification did not occur. High sulfate levels resulted from the addition of a large quantity of concentrated sulfuric acid that was necessary for neutralization. Calculations showed that greater than 90% of the sulfate present was due to acid addition.

Microscopic analysis on the mixed liquor from each reactor, which was performed weekly, showed a noticeable shift in population dynamics. Most noticeable was the decrease in large protozoa in reactor A following the high loading conditions of 27 September 1989. A noticeable increase in the population of filamentous organisms was found in all reactors, although settling problems resulted chiefly from excessive MLSS values.

TABLE 29. SELECTED ANION CONCENTRATIONS IN REACTOR C AFTER 13 HOURS OF AERATION DURING HIGH LOAD OPERATION PERFORMED 9/27/89

ANION	CONCENTRATION (MG/L)
F	53.7
Cl	374.7
NO_2-N	N.D.
NO_3-N	N.D.
PO_4-P	36.7
SO_4	3246

Detailed SBR Tracking Analysis

The goal of this study was to analyze reasonable loading cycles in more detail and extrapolate these results to full scale SBR operation. After the heavy loading of 27 September 1989, it was determined that a recovery period was necessary before a detailed analysis could continue. Hence, from 1 October, 1989 until 11 October, 1989 reactors B and C were fed 400 mls per day with cycling as described in table 22. Wasting occurred periodically to maintain MLSS concentrations near 5,000 mg/l. Reactor A was no longer fed in an effort to conserve Magnuson Scrubber wastewater as supplies began to run low and LAPCO's tomato season production had ended. Also, reactor A was heavily upset from the high load study. Reactor A was then configured as an aerobic digester and any wasted mixed liquor from reactors B and C was then fed to "Digester A".

Cycling times for detailed tracking analyses were as shown in table 30. Important operating parameters during these SBR runs are shown in table 31. Note the drastic increases in MLSS for any individual cycle, particularly for F/M values of 0.44 and 1.11. The greater the F/M value, the greater the daily increase in MLSS. Following 10/12 operation, with a F/M value of 0.44, MLSS had increased from 5,000 to 7,240 mg/l. When the F/M value was 1.11,

TABLE 30. CYCLING TIMES FOR 10/12, 10/16 AND 10/21 SBR OPERATION

		TIME, HOURS				
DATE	REACTOR	FILL	REACT	SETTLE	DRAW	IDLE
10/12	B	2	19	2	0.5	0.5
10/12	C	1	20	2	0.5	0.5
10/16	B	2	19	2	0.5	0.5
10/16	C	2	19	2	0.5	0.5
10/21	B	2	19	2	---	---
10/21	C	2	19	2	0.5	0.5

NOTE: FILL COMPLETELY AERATED DURING 10/21 CYCLES. 10/12 and 10/16 CYCLES HAD ANOXIC FILL

Table 31. Major Operating Parameters and COD Removals for 10/12, 10/16, and 10/21/89 Cycles.

Date	Reactor	Feed (MLS)	MLSS (mg/L)		F/M	HRT (Days)	Settled Solids (L)	COD (mg/L)		% COD Removal
			Initial	Final	Lb BOD_5/ lb MLSS			Infl.	Effl.	
10/12	B	1000	5000	7243	0.44	8	4.0	50,092	4121	92
10/12	C	500	5000	5707	0.22	16	4.5	50,092	3333	93
10/16	B	1000	5000	6500	0.44	8	4.4	50,092	5418	89
10/16	C	500	5000	5489	0.22	16	3.0	50,092	3600	93
10/21	B	2000	4000	7289	1.11	4	7.0	50,092	--	--
10/21	C	500	4000	4667	0.28	16	3.5	50,092	4846	90

NOTE: Reactor C, 10/21, included 18 mg/L phosphorus spike.

MLSS increased from 4,000 to 7,290 mg/l. This presented a quandary in the wasting procedure used to maintain specified MLSS values. Since the BOD of this waste was so high it became unrealistic to waste mixed liquor to provide lower MLSS values. The combination of high microorganism growth rate and high TSS level of reactor feed caused MLSS values to increase in a disproportionally large quantity in relation to the volume of feed. Hence, a greater volume of mixed liquor would have had to be wasted than wastewater volume originally fed to the reactor. Furthermore, due to operation at high MLSS values, reactor underflow (settled subnatant) suspended solids concentrations were typically between 10,000 and 13,000 mg/l. At these concentrations, the volume of subnatant wasted was between 75 to 100 percent of the feed volume. This means, for the conventional loading rates analyzed, that solids handling facilities (ex. thickener, filter press, etc.) will be large in relation to influent feed volume. This supports the use of an aerobic digester to decrease the amount of solids to be disposed.

COD removals are also presented in table 31. While these results indicate reasonable treatment, there are no COD effluent guidelines for tomato processing wastewater. Note that a relatively higher F/M value was analyzed on 21 October 1989 for reactor B. Expecting heavy solids production, the MLSS concentration was reduced to 4,000 mg/l. This was to no avail as MLSS concentrations still increased enough to inhibit settling.

The BOD_{ult}:TKN:TP value of untreated wastewater was 122:5:1. To insure that a utilizable phosphorus deficiency was not inhibiting COD removal, reactor C was spiked with 18 mg/l PO_4-P during the 21 October 1989 feeding cycle. The result showed no decrease in COD removal with the additional phosphorus. On the contrary, effluent COD increased, but this was due to a buildup of residual COD. It must be mentioned that reactors B and C were fed 1,000 mls and 500 mls of wastewater, respectively, every day from 16 October through 21 October to simulate uninterrupted treatment.

Soluble COD was recorded periodically for each reactor to track removal that was occurring throughout each cycle. This was done specifically to determine an optimum length of time for the react cycles. Tracking analysis results are presented in figures 11, 12 and 13 for reactor cycles performed on 12 October, 16 October, and 21 October 1989, respectively. SCOD values were found to increase linearly during the fill period and to decrease sharply after the start of the react period. As the react phase continued, SCOD removal rates decreased and eventually a residual SCOD

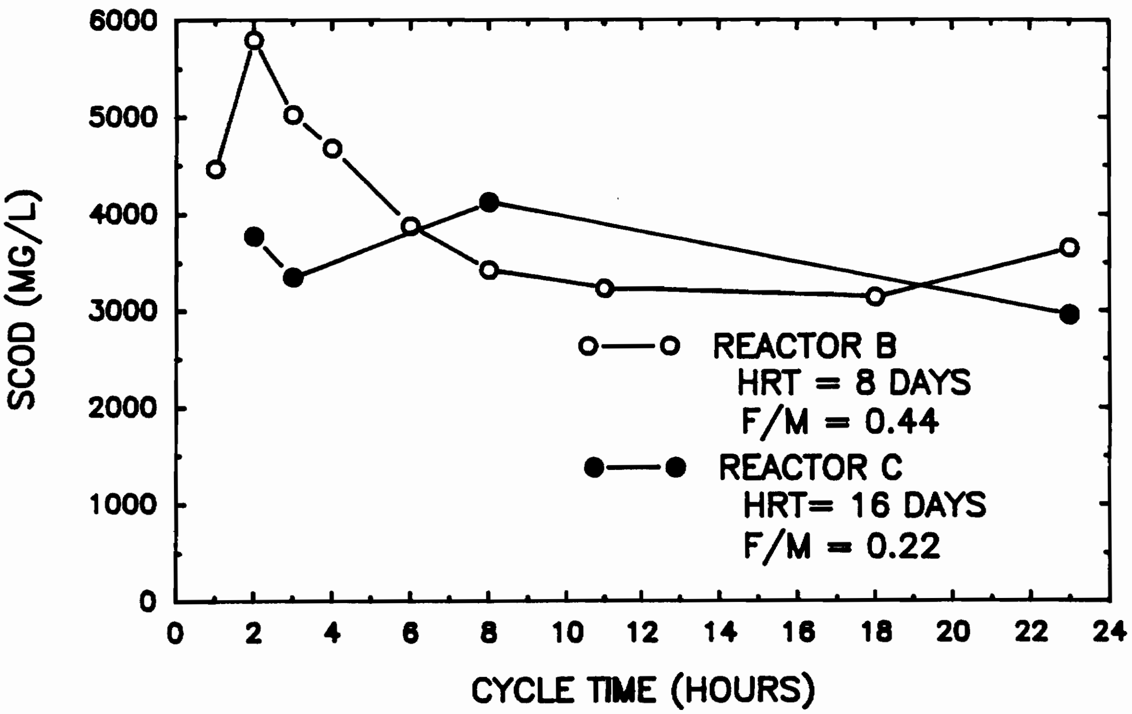


FIGURE 11. SCOD VS TIME FOR 10/12/89 CYCLES

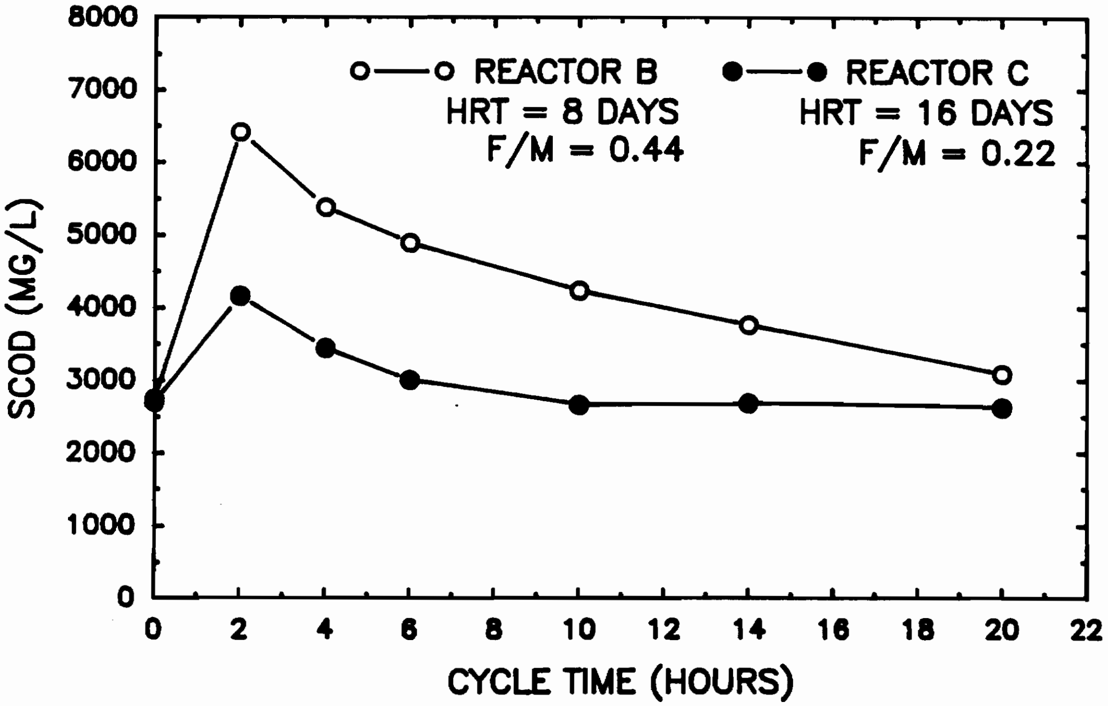


FIGURE 12. SCOD VS TIME FOR 10/16/89 CYCLES

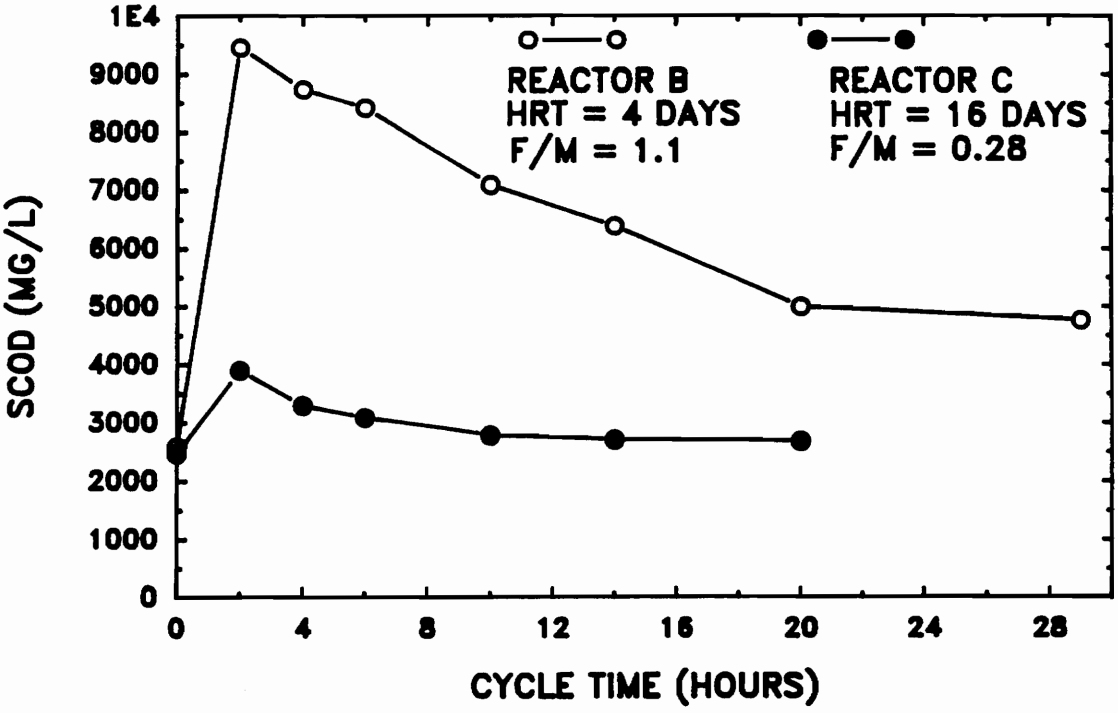


FIGURE 13. SCOD VS TIME FOR 10/21/89 CYCLES

remained. The SCOD value shown in figure 11 for reactor C at hour 8 was likely a spurious data point. This rise in SCOD was not evident in either figure 12 or 13. Effectively, all bio-oxidation was complete after 10 to 12 hours of react cycle time for F/M values of approximately 0.22 to 0.44. While COD decrease in reactor B during the 16 October cycle was not essentially complete until 20 hours of react time, it is believed this slower removal rate was due to throttling less air to reactor diffusers. This occurred since air delivery rates were not accurately gauged and manual adjustment of air supply values was necessary for each cycle.

Final effluent results for the tracked cycles are shown in table 32. Percent removals of BOD_{ult} and TSS are presented as well as the pH of treated effluents. Note that pH values were again found to stabilize near 9.1. Excellent removal of BOD_{ult} and TSS occurred. BOD_{ult} removals were between 92 and 97 percent and TSS removals were between 94 and 97 percent. These results were extrapolated to represent full scale production final effluents by assuming a target production level of 150 tons of raw product per day.

Treated effluent BOD and TSS levels based on full-scale production are shown to meet the most stringent federal

Table 32. Lab Scale Treatability Results and Extrapolation to Full-Scale Production

		BOD_{ULT}					TSS					
		mg/L		%	Full-Scale		mg/L		%	Full-Scale		Effl.
Date	Reactor	Infl.	Effl.	Removal	Lb/Day	Lab/1000 Lb.	Infl.	Effl.	Removal	Lb/Day	Lb/Klb	pH
10/12	B	21,401	946	96	79	0.26	14,066	699	95	58	0.19	9.1
	C	21,401	765	96	64	0.21	14,066	382	97	32	0.11	9.1
10/16	B	21,401	1628	92	136	0.45	14,066	860	94	72	0.24	9.0
	C	21,401	677	97	56	0.19	14,066	834	94	70	0.23	9.0
10/21	B	21,401	--	--	--	--	14,066	--	--	--	--	9.1
	C	21,401	1113	95	93	0.31	14,066	858	94	72	0.24	9.1

NOTES:

- $BOD_5 = COD/2.82$ and $BOD_{ULT} = BOD_5/0.83$ for untreated wastewater.
- $K_{10} = 0.15\ day^{-1}$ for untreated wastewater
- $BOD_5 = COD/6.7$ for treated wastewater unless directly determined
- $BOD_{ULT} = BOD_5/0.65$ for treated wastewater based on assumed $K_{10} = 0.08\ day^{-1}$
- Full-scale effluent based on 10,000 gal/day and 150 TPD target production.

discharge limitations presented in table 1. Reactor B effluent for 16 October, 1989 operation, however, showed a BOD_{ult} of 0.45 lb/Klb which is near the federal limitation of 0.49 lb/Klb. Effluent pH levels were consistently below the required maximum value of 9.5.

The results of these SBR cycles indicate that operation at F/M values of 0.22 or 0.28 would not be economical since SBR's were underloaded, especially using a 20 hour react period. Also, poor settleability would prevent operation at F/M values greater than 1.0. SBR operation at an F/M of 0.44 would be justifiable since effluent limitations were achieved, reactor solids settled well, and D.O. requirements were met.

Nutrient levels were also analyzed in reactor influent and effluent for selected cycles. Results are shown in table 33. TKN removal was approximately 75% and phosphorus removal approximately 60%. The high effluent TP value for reactor C on 21 October 1989 is most likely a spurious value although an extended anaerobic period during settling could have caused release of stored phosphorus from settled microorganisms. It must be emphasized again that any nutrient removal that occurred was due only to bacterial assimilation. As further evidence that nitrification did not occur, nitrite-N and nitrate-N were measured in

TABLE 33. INFLUENT AND EFFLUENT NUTRIENT ANALYSIS FROM 10/16 AND 10/21 CYCLES

		CONCENTRATION, MG/L			
		TKN		TP	
DATE	REACTOR	FEED	EFFL	FEED	EFFL
10/16	B	877	238	175	67.0
10/16	C	---	---	175	70.0
10/21	C	877	224	175	222

effluent from reactor B's 16 October 1989 cycle. No measurable NO_2-N level was detected and the NO_3-N level was found to be barely detectable at around 0.1 mg/l. Other anion concentrations determined from this effluent are shown in table 34. The Cl level in reactor feed was 957 mg/l, and in reactor C effluent it was 992 mg/l. This showed that the effect of dilution was overcome during 21 October operation for reactor C.

4.5.0 TOMATO PEELING STUDY

The results of the first enzyme peeling study using 10, 100, and 1,000 activity units of pectinase showed that peeling ability was enhanced. Slits made in the tomato samples became deeper, however, noticeably damaging the fruit. The peelability of the 1,000 activity unit samples was best. No distinction could be made between the other two activity levels.

The second test compared enzyme peeling (1,500 activity units) to caustic peeling (15% NaOH). While results were not quantitative, tomato skins peeled away noticeably easier when subjected to caustic. Samples subjected to 1,500 activity units of pectinase peeled easier than the enzyme blanks. Enzyme peeled tomatoes that had holes poked through their skins to facilitate enzyme penetration became

TABLE 34. SELECTED ANION CONCENTRATIONS IN REACTOR EFFLUENTS

		CONCENTRATION, MG/L				
DATE	REACTOR	NO_2-N	NO_3-N	PO_4-P	Cl	SO_4
10/16	B	ND	0.1	31.3	379	3308
10/21	C	---	---	---	992	---

NOTE: Cl IN FEED = 957 MG/L

softer. Tomatoes which were unmarked (no slits or holes) before enzyme treatment remained intact at the completion of the enzyme soak. The enzyme did not attack the epicarp (or outer skin), but there was an effect on the mesocarp beneath the outer skin. This is not surprising since pectic material is located between the fleshy red cells of the mesocarp. Once the tough skins were broken, they rubbed off easily. It may be that pectinase was able to penetrate the outer skin and attack pectic material beneath it. On the other hand, pectinous materials are broken down by enzymes naturally present within the fruit. This includes pectinase, pectinesterase, and protopectinase [1]. It is not known if environmental conditions activated enzymes naturally present within the tomatoes to further facilitate peel removal.

The caustic solution was highly colored after peeling only two tomatoes. This was not the case with enzyme solutions. Recall that the caustic soak lasted 45 seconds while the enzyme soak lasted 15 minutes. This demonstrates the harsh environment that makes caustic peeling so effective. This also demonstrates the release of carotenoid pigments, which can lower vitamin A content when caustic is used.

A more in-depth enzyme peeling study should be conducted. Tomatoes used in this analysis were of an unknown variety. Peelability of cultivars processed by LAPCO should be analyzed and results need to be quantitized. Enzyme peeling may prove to be a successful peeling innovation. Owing to the wastewater problems resulting from caustic peeling, other options need to be considered. New cultivars are being developed with superior peelability [45]. They would allow other peeling methods to be competitive with caustic. As Shultz and Green [45] have stated, the reduction of problems associated with tomato peeling waste was initiated by regulation, but the solution will be through innovations.

4.6.0 FULL-SCALE TREATMENT OPTIONS

The following discussion will present the designs of two treatment options for LAPCO's tomato process. Option 1 utilizes biological treatment via sequencing batch reactor. Option 2 involves the use of a sludge drying bed.

4.6.1 DESIGN OF OPTION 1 (BIOLOGICAL TREATMENT)

Based on data from characterization and treatability studies presented earlier and the following discussion, a full-scale treatment process using a sequencing batch reactor would conform to that shown in figure 14. Only SP4 and SP5 need to be treated biologically and the remaining wastewater may continue to be land applied by spray irrigation. The design is based on a daily combined Magnuson Scrubber/lye conveyor rinse flowrate of 12,500 gpd, a BOD_{ult} of 21,000 mg/l, and a TSS of 14,000 mg/l. Each operation of the design is discussed separately.

<u>Vibrating Screen</u> - A number 10 shaker screen should perform well angled at approximately 30 degrees. Approximately 4 TPD of solids will have to be disposed, captured by a container beneath the screen. The characteristics of this solid waste will vary considerably with the quality of tomatoes processed. About 85% of the volume of wastewater

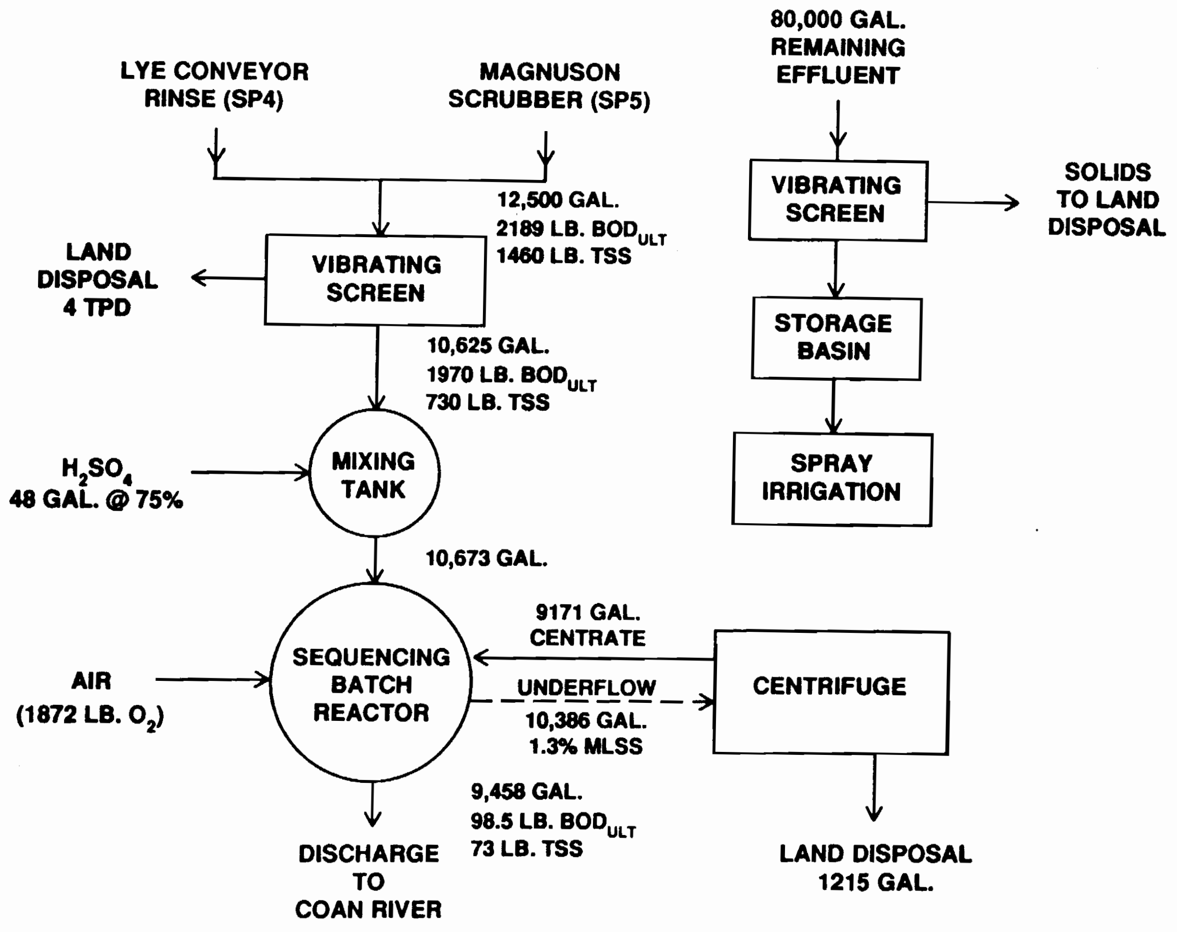


FIGURE 14. LAPCO TREATMENT OPTION NO. 1

will pass through the screen as filtrate. Results from table 25 show only about 3% of BOD_5 was removed through screening. Since these large skin particles are not readily biodegraded, it is assumed that a more significant fraction of BOD_{ult} would be removed by screening out large skin particles. Assuming 10% BOD removal, 50% TSS removal and 85% filtrate yield, resulting values entering the neutralization basin (mixing tank) are presented in figure 14.

Neutralization Basin - Based on an influent flow of 10,625 gpd, the amount of concentrated H_2SO_4 required for neutralization was determined through jar testing to be approximately 36 gallons. H_2SO_4 can be purchased as spent H_2SO_4 at an approximate 75% concentration. Therefore, approximately 48 gallons would be required. A tank size of 500 gallons would allow a residence time of 25 minutes and provide a buffer period should pH control fail. This residence time is short enough so natural mixing will occur and mechanical mixing will not be required. A controller will be necessary to regulate pH. The controller should activate an audio alarm and shut down Magnuson Scrubber operation in the event pH of reactor feed rises above 9.5. A backup controller will not be necessary; manual adjustment of acid feed can be used for emergency pH control. A cylindrical tank could be used.

Tank size would be 5.3 ft. (1.6 m) deep with a diameter of 4 ft. (1.2 m).

SBR - The reactor should be operated at a F/M value of 0.44 based on treatability data. Adjusting the F/M value on a BOD_{ult} basis, it would be 0.54. MLSS should be maintained at 5,000 mg/l and the HRT should be approximately 8 days. The required tank volume is then 90,000 gallons. An additional 95% removal of remaining BOD and an additional 90% removal of remaining TSS can be expected.

The tank would have a volume of 12,000 FT^3 (342 m^3), a depth of 15 FT (4.6 m), a length of 20 FT (6.1 m), and a width of 40 FT (12.2 m).

Aeration should be supplied by turbine or jet aerators. It would probably be difficult to provide adequate mixing with diffused aeration due to the high operating MLSS. Mechanical surface aeration may not be able to provide adequate mixing because of surfactant properties of the wastewater, along with the presence of a high density fraction of raw wastewater (settleability tests showed noticeable zones of different densities).

Lacking oxygen utilization data, an oxygen requirement of 1.0 LB O_2 per LB BOD removal will be assumed. Metcalf and Eddy [41] cite a typical oxygen transfer rate for jet aeration of 1.1 kg O_2/KW-h (1.8 LB O_2/HP-h). This was for wastewater conditions of: $T = 15°C$, $\alpha = 0.85$, $\beta = 0.9$, operating D.O. = 2.0 mg/l. However, high dissolved solids, along with a higher operating temperature, will lower this value substantially. A value of 0.83 Kg O_2/KW-h (1.4 LB O_2/HP-h) will then be used for design purposes. Approximately 1,872 LB O_2/day are required, resulting in a daily energy requirement of 1,337 HP-h or 997 KW-h. Approximately 56 horsepower would be required in the SBR to provide adequate aeration based on stated assumptions. Two 50 HP jet aerators should be used at approximately half capacity, which would still allow sufficient aeration in the event one aerator becomes out of service. There are other design parameters that need to be considered, but the above information should allow a reasonable cost estimation to be made for comparison purposes.

Aerobic Digester - Treatability data showed a daily MLSS increase of approximately 1,500 mg/l when operating at an F/M of 0.44 (BOD_5 basis) and an initial MLSS of 5,000 mg/l. Therefore, 1,126 lbs. of solids need to be wasted daily from the SBR and fed to the digester. At an optimistic underflow solids concentration of 13,000 mg/l, 10,386 gallons of subnatant must be wasted from the SBR, i.e., virtually the entire feed volume. While aerobic digestion is an option for solids reduction the volume of settled solids to be wasted daily is small enough that mechanical sludge concentration with a centrifuge may be a simpler, more economical approach.

Centrifuge - A centrifuge was recently purchased by LAPCO to remove sand from receiving pit water. Heavy rains this year made its use a necessity to minimize the amount of sand buildup at this location and ensure a cleaner product entering the cannery. This centrifuge is presently used only during production, so during off hours it may be used to concentrate SBR sludge. Assuming a 90% solids recovery and a concentrated sludge cake solids level of 10% (based on suspended solids alone), about 1,215 gallons of solids will remain. This would have to be landfilled. Approximately, 9,171 gallons of centrate would be returned to the SBR or discharged. Underflow from SBR to centrifuge should occur at the completion of the settling cycle at a rate of about 80 GPM. If centrate was not of discharge quality for TSS and BOD, it would then need to be returned to the SBR. A return flowrate of 80 GPM would not adversely affect supernatant quality by disturbing the settling layer, if this flow were properly baffled. A resulting discharge of about 9,500 gal/day of treated effluent from the SBR would enter the Coan River.

4.6.2 DESIGN OF OPTION 2: (SLUDGE DRYING BED)

A combined (SP4 and SP5) daily wastewater flowrate of 12,500 gallons will again be considered for a total of 40 days of production annually. The goal is to evaporate enough water and concentrate solids to allow thickened sludge to be easily disposed of in a landfill. Temperature, relative humidity, wind velocity, and the nature of the tomato peel sludge affect the evaporation rate. In the absence of accurate evaporation data, 20 inches per year are assumed to evaporate per year from water surfaces. This is a true value for northeastern U.S. locations [42]. Evaporation from a mud-like substance such as tomato peel wastewater is expected to be less. Since evaporation from land is one-third to one-half that of water surfaces [42], a conservative value of 10 inches per year will be used. This is extremely conservative since an evapotranspiration rate of 0.08 GPD per square ft of bed is a substantiated design value in the Chesapeake bay area [43], and the proposed evaporation rate presented here is only 0.017 GPD per square ft.

Based on 10 in. of evaporation per year, wastewater can be applied to a sludge drying bed to a depth of 12 inches. Since a remaining solids content of 10% based on suspended solids would normally be adequate to allow handling, then approximately 1,750 gpd or 70,000 gallons annually would need to be disposed. This represents roughly an 85% volume reduction by evaporation. However, due to a high dissolved solids content of the wastewater, it may be difficult to achieve this high volume reduction. Dissolved salts will become insoluble as evaporation progresses. In other words, total solids concentration and not suspended solids concentration will eventually govern volume reduction. A lab-scale, evaporation bed showed that a 63% volume reduction, achieved in 20 days, resulted in a handleable sludge. Realistically, the largest volume reduction expected is estimated to be about 70% for this wastewater. Therefore, 3,750 gpd or 150,000 gallons annually would have to be landfilled.

At an application depth of 1 foot the required land area is 20,050 sq. ft. (0.46 acres) per year, if an entire season were to be applied before any removal and final disposal. If each bed were 210 ft. long by 12 ft. wide, a total of eight beds would be required. With a side wall thickness of 4 in. and 2 ft. clearance between each bed and around the outer perimeter of the sludge drying bed area, the total land area required to construct LAPCO's sludge drying bed disposal system is:

$$A = 25,189\ FT^2\ (2,324\ m^2)$$

$$= 0.58\ Acres$$

Residual solids should be hauled away when the sludge depth decreases to 3-4 inches. If a dried cake layer forms on the surface and inhibits evaporation, the desired solids content may not be achieved. A sludge drying bed study performed as described in Chapter 3.0 showed minor inhibition, but conservative evaporation rates used in this study should account for this. The uncertainty arises since a 4 inch depth of application was used in this study.

The bed foundation must be firm and level so storage capacity is not reduced. Corrosion control will be very important. Safe limits of chlorides for concrete have been given as 0.1% to 0.4% total chloride ions by mass of binder. Salt concentrations tend to build up due to a combination of wetting, drying and capillary movement through the concrete. With significant chloride levels present, corrosion can occur even when the pH is in excess of 12. The concrete may then have to be coated with a tar epoxy or urethane coating [44]. Sulfates can also attack concrete, although prevention of corrosion due to chloride will also prevent adverse sulfate affects. As alluded to above, high pH will not adversely affect a concrete sludge drying bed structure. Care must be taken, however, to use a corrosion coating which will not be degraded by high pH wastewater.

Obviously the sludge drying beds must be covered to prevent precipitation from entering and hampering the drying process. This is not an easy task for such a large area. Options include a cover which is a load bearing structure or using a series of tarps securely held in place. If the tarp approach were used, it must be secured low to the ground, directly over the beds, before precipitation occurs. This means the use of a tarp is an "on-off" approach which requires manned observation and operation. When the evaporation process is complete, sludge must be removed with a front-end loader, trucked away and put in a final disposal area, i.e., a landfill. This landfill needs to be lined because of the possibility of salts leaching from the sludge. At this point it should again be noted that operating the Magnuson Scrubber dry will substantially reduce the amount of wastewater applied to the sludge drying bed; the land area requirement can be reduced by 20 to 30 percent. This would not decrease the final dried sludge residual to be disposed of, however.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This study presented an in-depth wastewater characterization for each of LAPCO's food processing effluents. The required level of treatment needed to meet federal and state discharge limitations was determined, and treatability studies were performed with these guidelines in mind. Tomato wastewater was treated biologically with an SBR. Magnuson Scrubber wastewater from the tomato process was isolated for separate treatment, and BOD_{ult} removals were between 92 and 97%. This corresponded to an effluent BOD_{ult} of roughly 1,000 mg/l. TSS removals were between 94 and 97% with effluent levels of about 800 mg/l. An innovative tomato peeling study was performed in an effort to eliminate sodium from LAPCO's wastewater.

The following conclusions can be made regarding treatment of LAPCO's herring roe wastewater:

- o Gravity settling can be used to treat herring roe wastewater. Treatability studies with this wastewater demonstrated that BOD_5 and TSS were reduced by 71% and 97%, respectively.

- If spray irrigation is no longer a treatment option and if wastewater is to be discharged to the Coan River, further treatment will be necessary in order to meet BOD requirements based on production.

The following conclusion can be made regarding oyster wastewater:

- Oyster wastewater characterizations have shown that this effluent can continue to be discharged without treatment; raw wastewater values for TSS and O&G are below effluent guidelines.

It is recommended that these additional studies be performed with oyster wastewater to eliminate future regulatory concerns:

- Chloride content of discharged wastewater.
- Free residual chlorine concentration in discharged wastewater.

The results presented in this thesis warrant the following conclusions for LAPCO's tomato wastewater:

- An SBR can be used to treat LAPCO's tomato wastewater.
- Operational parameters for SBR operation should be as follows: F/M of 0.4 lb BOD_5/lb MLSS·d, HRT of 8 days, MLSS of 5,000 mg/l, and a react period of 19 hours.

- Magnuson Scrubber wastewater should be screened through a size 10 mesh before biological treatment.
- Sludge drying beds can be used as an alternative method of treating and disposing of Magnuson Scrubber wastewater.
- As performed in this study, tomato peeling with pectinase as the active peeling agent is not as effective as peeling with caustic.
- Segregating Magnuson Scrubber and lye conveyor spray rinse wastewater for separate treatment removes 98% of the sodium from LAPCO's waste stream. The remaining wastewater may be land applied.

The following recommendations can be made:

- A detailed cost analysis comparing an SBR to a sludge drying bed must be performed.
- If an SBR is the treatment alternative selected, a pilot-scale study should be performed to obtain more accurate design information. This would ensure a more successful and economical design.
- Further investigation should be considered to develop innovative tomato peeling methods to abate or eliminate the use of caustic.

6.0 REFERENCES

1. Tomato Production, Processing, and Quality Evaluation, W.A. Gould, AVI Publishing Co., Inc., Westport, CT, 445 P. (1983).

2. The Canning Clan, Earl Chapin May, The Macmillan Co., NY, 292 P. (1937).

3. The Directory of the Canning, Freezing, and Preserving Industries, Second Ed., E.E. Judge & Sons, Inc., Westminister, M.D., 1968-69.

4. The Directory of the Canning, Freezing, and Preserving Industries, Fifth Biennial Ed., E.E. Judge & Sons, Inc., Westminister, M.D., 1974-75.

5. The Directory of the Canning, Freezing, and Preserving Industries, Twelfth Biennial Ed., E.E. Judge & Sons, Inc., Westminister, M.D., 1988-89.

6. The Almanac of the Canning, Freezing and Preserving Industries, 73rd Ed., E.E. Judge & Sons, Inc., Westminister, M.D., 1988.

7. Thomas, W.M., Stanley, D.W., Arnott, D.R., "An Evaluation of Blanch, Lye, and Freeze-Heat Methods for Tomato Peel Removal", Canadian Inst. Food Sci. Technol. J., Vol. 9, No. 3, 118-124 (1976).

8. Anon, "Heat/Cool Sequence Peels Tomato, Eliminates Caustic", Canner/Packer, Vol. 149, No. 9 (1977).

9. Lemaire, W.H., Havighorst, C.R., "A New Generation of Peelers", Food Engineering, August, 90-92 (1978).

10. Thomas, W.M., Personal Communication, Dec. 1989.

11. Chang, S., Wheaton, F.W., Design, Evaluation and Effluent Water Quality Analysis of Three Oyster Shellstock Washers", American Society of Agricultural Engineers 1979 Summer Meeting, Univ. of Manitoba, Winnipeg Manitoba, Canada (1979).

12. Mauldin, Water Pollution Abatement Technology, Costs and Capabilities, Canned and Preserved Fruits and Vegetables, National Commission on Water Quality, Ch. 4, PP. 62-64 (1975).

13. Overcash, M.R., and Pal, D., Design of Land Treatment Systems for Industrial Wastes - Theory and Practice, Ann Arbor Science, Ann Arbor, Mich., 684 P. (1981).

14. Loehr, R.C., Overcash, M.R. "Land Treatment of Wastes: Concepts and General Design", Journal of Environmental Engineering, Vol. 111, No. 2, 141-160 (1985).

15. Wallace, A., "Conditionerigation: New Process Proves Sucessful", Irrigation Journal, May/June, 12-15 (1987).

16. Wichelns, D., Howitt, R.E., Horner, G.L., and Nelson, D., "The Economic Effects of Salinity and Drainage Problems", Irrigation Journal, Jan/Feb, 36-41 (1988).

17. Widner, W., U.S. Dept. of Agriculture, Soil Conservation Service, Report Prepared for LAPCO, May 10, 1989.

18. Wheatley, A.D., Johnson K.A., Winstanley C.I., "The Reliability of Anaerobic Digestion for the Treatment of Food Processing Effluents", Anaerobic Digestion 1988: Proceedings of the 5th International Symposium on Anaerobic Digestion, Bologna, Italy, P. 136-146 (1988).

19. McCarty, P.L. and McKinney, R.E., "Salt Toxicity in Anaerobic Digestion", Journal Water Pollution Control Federation, Vol. 33, No. 4, 399-415 (1961).

20. T.G. Stevens and L. van den Berg, "Anaerobic Treatment of Food Processing Wastes Using a Fixed-Film Reactor", Proceedings 36th Purdue Industrial Waste Conference, Purdue University, W. Lafayette, In, 224-232 (1981).

21. L. van den Berg, C.P. Lentz, "Food Processing Waste Treatment by Anaerobic Digestion". Proceedings 32nd Purdue Industrial Waste Conference, Purdue University, W. Lafayette, IN., 252-258 (1977).

22. G. Lettinga, W.de Zeeuw, L.H. Pol, W. Wiegant, A. Rinzema, "Anaerobic Wastewater Treatment Based on Biomass Retention with Emphasis on the UASB-Process", Proceedings Fourth International Symposium on Anaerobic Digestion, Guangzhou, China, PP. 279-301 (1985).

23. Eckendfelder, W.W., Principles of Water Quality Management, CBI Publishing Co., Inc. 717 P. (1980).

24. P.E. Nelson and J.E. Hoff, :"Tomato Volatiles: Effects of Variety, Processing and Storage Time". Journal of Food Science, Vol. 34, 53-57 (1969).

25. Schmidt, C.J., Clements, E.V., Laconde, K., "Treatment Alternatives for the Fruits and Vegetables Processing Industry". Proceedings 30th Purdue Industrial Waste Conference, Purdue University, W. Lafayette, IN 318-332 (1975).

26. Lepper, L.L., and Lacey, H.R., "Progress Report on Brooks Foods Anaerobic-Aerobic Lagoon System For Tomato Waste". Proceedings 28th Purdue Industrial Waste Conference, Purdue University, W. Lafayette, IN 770-777 (1973).

27. Irvine, R.L., and Bush, A.W., "Sequencing Batch Biological Reactors - An Overview". Journal WPCF, Vol. 51, No. 2, 235-243 (1979).

28. Arora, M.L., Barth, E.F., and Umphres, M.B., "Technology Evaluation of Sequencing Batch Reactors". Journal WPCF, Vol. 57, No. 8, 867-875 (1985).

29. Irvine, R.L., Murthy, D.V.S., Arora, M.L., Copeman, J.L., and Heidman, J.A., "Analysis of a Full-Scale SBR Operation At Grundy Center, Iowa". Journal WPCF, Vol. 59, No. 3, 132-138 (1987).

30. Abufayed, A.A., and Schroeder, E.D., "Performance of SBR/Dentrification With A Primary Sludge Carbon Source". Journal WPCF, Vol. 58, No. 5, 387-397 (1986).

31. Dennis, R.W., and Irvine, R.L., "Effect Of Fill:React Ratio On Sequencing Batch Biological Reactors". Journal WPCF, Vol. 51, No. 2, 255-263 (1979).

32. Irvine, R.L., Fox, T.P., and Richter, R.O., "Investigaton of Fill and Batch Periods of Sequencing Batch Biological Reactors", Water Research, Vol. 11, 713-717 (1977).

33. Mandt, M.G., "The Innovative Technology Of Sequencing Batch Reactors". Pollution Engineering, July, 26-28 (1985).

34. Herzbrun, P.A., Irvine, R.L., and Malinowski, K.C., "Biological Treatment Of Hazardous Waste In Sequencing Batch Reactors". Journal WPCF, Vol. 57, No. 12, 1163-1167 (1985).

35. Goronszy, M.C., "Intermittent Operation Of Extended Aeration Process For Small Systems". Journal WPCF, Vol. 51, No. 2, 274-287 (1979).

36. Dennis R.W., and Irvine, R.L., "Laboratory Investigation Of Fill-And-Draw Biological Reactors For The Treatment Of High Strength Wastes". Proceedings 32nd Purdue Industrial Waste Conference, Purdue University, W. Lafayette, IN 776-785 (1977).

37. Irvine, R.L., Ketchum, L.H., Arora, M.L., and Barth, E.F., "An Organic Loading Study Of Full-Scale Sequencing Batch Reactors". Journal WPCF, Vol. 57, No. 8, 847-853 (1985).

38. Standard Methods For The Examination Of Water And Wastewater, 16th Ed., APHA AWWA WPCF, American Public Health Assn., Washington D.C. (1985).

39. J.H. Bruemmer, A.W. Griffin, O. Onayemi, "Sectionizing Grapefruit By Enzyme Digestion". Proc. Fla. State Hort. Soc., 91, 112-114 (1978).

40. R.A. Baker and J.H. Bruemmer, "Quality and Stability of Enzymically Peeled and Sectioned Citrus Fruit". ACS Symposium Series 405, PP 140-148 (1989).

41. Metcalf and Eddy, Inc., Wastewater Engineering Treatment/Disposal/Reuse, Metcalf and Eddy, Inc., McGraw Hill Book Co. (1979).

42. Phelps, Earle B., Public Health Engineering, Vol. 1, John Wiley & Sons, New York (1948).

43. Lomax, K.M., "Evapotranspiration Method Works For Wastewater Disposal Along The Chesapeake Bay". J. Env. Health, May/June, 324-328 (1979).

44. H. Roper, J.L. Heimann, D. Baweja, "Site And Laboratory Evaluation Of Repairs To Marine Concrete Structures And Maintenance Methodologies - Two Case Studies", Concrete In Marine Environment Proceedings, Second International Conference, St. Andrews By The Sea, Canada 1988.

45. Schultz, W.G., and Green, J.H., "Dry Caustic Peeling Technology". Food Processing Waste Management, Green and Kramer, AVI Publishing Co., Inc. (1979)

VITA

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ABSTRACT

WASTEWATER TREATMENT ALTERNATIVES FOR A VEGETABLE AND SEAFOOD CANNERY

by:

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Peeled or whole-pack tomatoes, herring roe and oysters are processed at a Virginia Cannery. Wastewater from each food processing effluent was characterized. Treatment alternatives were investigated for tomato and herring roe wastewaters. For herring roe processing wastewater, the discharge requirement for BOD was nearly met through plain settling, while the TSS limitation was easily achieved by settling out the roe particles. Oyster processing wastewater was found to meet effluent guidelines without treatment.

Bench-scale treatability studies were performed using sequencing batch reactors (SBRs) to treat the segregated wastewater from the caustic tomato peeling operation. This isolated 98% of sodium present in the wastewater.

Previously, all wastewater was land applied and the high sodium content damaged soil structure. Sodium levels in

monitoring wells below the irrigation field have risen, approaching regulated values. Results indicated that SBRs can be effective in reducing BOD and TSS to discharge requirements. BOD and TSS removals were well in excess of 90%. Initial values for BOD and TSS were 21,400 mg/l and 14,000 mg/l, respectively. Although conventional food to microorganism ratios were used, relatively long hydraulic retention times of 8 to 20 days were required to accomplish adequate BOD removal. Screening was found to be an effective form of pretreatment to remove large quantities of TSS.

It appears practical to treat the tomato peeling wastewater by means of sludge drying beds. Approximately 0.5 acre of land would be required for bed construction. Final disposal costs associated with landfilling the dried sludge may govern whether sludge drying beds or an SBR should be used.

In an effort to eliminate wastewater problems associated with the caustic peeling operation, an enzyme peeling study was performed using pectinase. Peeling ability of the enzyme was not as good as that of caustic, however, further investigation into alternative peeling operations is warranted due to the adverse effects of caustic materials on wastewater treatment alternatives.