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CHARACTERIZATION AND TREATMENT OF BRINE WASTEWATERS FROM THE CUCUMBER PICKLE INDUSTRY

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

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ABSTRACT

Pickling is one of the oldest means of food preservation. Currently, the U.S. cucumber pickle industry is a $500 million/year industry involving 39 states. Wastes from pickling operations are characterized by high chloride content, high oxygen demand, low pH, and high total and suspended solids. Waste treatment technology for removing suspended solids, reducing oxygen demand, and neutralizing pH is available, but no economical method for removing salt is available. The pickling industry is faced with the task of drastically reducing salt content of its effluents.

Industrial water and wastes surveys were conducted at two pickle companies. Water usage and waste characteristics were determined on major unit operations, including tankyard brining, desalting and processing, slicing and cutting operations, and pasteurization. Laboratory and pilot scale studies were performed to evaluate potential for recycling concentrated tankyard brines. Both a high pH coagulation-precipitation procedure and an ultrafiltration procedure were investigated. A "desk-top" evaluation of various brine treatment processes compared their cost-effectiveness.

The study indicated that in-plant water and salt usage could be substantially reduced by closer management and better housekeeping; that tankyard brines could be treated and reused at least once with no sacrifice of product quality; and that existing wastewater treatment facilities (aerated lagoons) could be upgraded to improve BOD and solids removal. Additionally, the results of the study provide a detailed characterization of the types and concentration of components of waste streams from unit operations in cucumber pickle production.

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

Appendix B

SUMMARY AND CONCLUSilONS

Pickling is one of the oldest means of food preservation. Currently, the U.S. cucumber pickle industry is a $500 million/year industry involving 39 states. Wastes from pickling operations are characterized by high chloride content, high oxygen demand, low pH, and high total and suspended solids. Waste treatment technology for removing suspended solids, reducing oxygen demand, and neutralizing pH is available, but no economical method for removing salt is available. The pickling industry is faced with the task of drastically reducing salt content of its effluents.

Industrial water and wastes surveys were conducted at two pickle companies. Water usage and waste characteristics were determined on major unit operations, including tankyard brining, desalting and processing, slicing and cutting operations, and pasteurization. Laboratory and pilot scale studies were performed to evaluate potential for recycling concentrated tankyard brines. Both a high pH coagulation-precipitation procedure and an ultrafiltration procedure were investigated. A "desk-top" evaluation of various brine treatment processes compared their cost-effectiveness.

Specific conclusions are as follows:

1. In general, wastewaters from cucumber pickling operations are characterized by high chloride content, high oxygen demand, low pH, and high total and suspended solids. Nutrient concentrations, especially Kjeldahl nitrogen, are also appreciable.

2. Approximately 40-50% of each year's cucumber crop is fresh-packed (canned) rather than brined, and fresh-pack operations generally predominate during the period from May-August. Nevertheless, plant wastewater continues to be characterized by high salt and organic carbon levels, since during this time 50-60% of the cucumbers are brined. The smaller cucumbers are drained and rebrined after 36 hours and the "36-hour drain," containing about 0.6 lb NaCl/gal and in addition organic carbon and other components leached from the cucumbers, is discharged.

3. Spent tankyard brines not only contain high concentrations of salt (l.O-1.6 lb NaCl/gal), but also, on the average, 3400 mg/l of organic carbon, 330 mg/l of suspended solids, 730 mg/l of total Kjeldahl nitrogen, 90 mg/l of phosphorus, and 2300 mg/l of acidity (as $CaC0_3$). In addition the pH falls between 3 and 4. These brines have a high pollutional potential and are much more concentrated than domestic sewage.

4. A major factor to consider in reuse of 36-hr and spent brines is their softening enzyme (pectinase) content. Pectinase activity can be eliminated in these brines by coagulation-precipitation at high pH or by ultrafiltration.

5. Regeneration by high pH treatment involves raising pH of the brines to 11 with lime and sodium hydroxide, followed by settling and neutralization with hydrochloric or acetic acid, Treatment of brines by this method not only eliminates pectinase activity but also removes phosphate and drastically reduces bacterial populations. However, it does not remove the majority of the organic component as measured by TOC or COD analysis.

6. Brinestock brined in high pH treated brine (one reuse cycle) compares favorably with that brined in new brine.

7. Pickles packed as sweet or dill after brining in high pH treated brine are not significantly different in quality from those brined in new brines.

8. Ultrafiltration of brines is another potential method of regeneration. In the laboratory, pectinase activity can be removed from 36-hr or spent tankyard brines by ultrafiltration through flat membranes with average molecular weight passthrough of 10,000 or less. Such treatment does not significantly reduce organics as measured by TOC or COD. Since the hollow-fiber membrane configuration is generally more efficient, it is possible that larger pore sizes could be used, with correspondingly greater flux rate, in a full-scale application.

9. In the studies herein described, brine was reused only once. There is some question as to buildup of metals, organic compounds, or other materials during repeated reuse. In the long run, costs of treating brine will be dependent on whether elimination of pectinase activity alone will suffice, or whether removal of all organic compounds is necessary. Ultrafiltration and high pH treatment appear to suffice for the former case; in the latter case, other methods would be required.

10. It is estimated that at least 30% of the salt used is wasted because of salt spillage, tank leakage, and tank overflow.

11. Water requirements per unit of cucumbers handled vary widely within each unit process. Part of the variation can be attributed to leakage, overflow, or failure to close valves during times when the unit is not in operation,

12. Desalting (processing) wastewaters are typically low pH and relatively high in chloride concentration. In the first desalting water chloride levels are about 40 gm Cl /l. Organic carbon levels are high and in general the more finely divided the product, the higher the TOC, as well as the Kjeldahl nitrogen and phosphorus levels, Apparently, the greater the surface area exposed to the processing water, the greater the loss of soluble components and fragments of cucumber tissue.

13, Pickle plant wastes, with the exception of the salt, respond to biological treatment provided sufficient detention time and sufficient oxygen are available. Neutralization of pH by addition of alkali appears to be unnecessary if sufficient aeration is provided to allow the aerobic degradation of the organic acids (such as lactic and acetic acids) in the wastewaters.

14. Observations on water use, salt handling, cucumber handling, and tank management were conveyed to management personnel at Plants A and B. At the request of management at Plant A two additional presentations were subsequently made to tankyard and line foremen and supervisors to acquaint them with the relationship of conservation of water, salt, cucumbers, and other materials to reduction of volume and strength of wastewater and to overall increase in net profits.

15. The work described herein has led to funding of a demonstration project by the Environmental Protection Agency. The project will be conducted at a North Carolina pickle plant by scientists from North Carolina A & T State University (Greensboro) and the University of North Carolina at Chapel Hill.

RECOMMENDATIONS

1. Due to the highly pollutional nature of tankyard brines the present widespread practices of discharging these brines untreated onto the tankyard or into a surface water should be discontinued. Instead, they should be reused or, if wasted, drained directly into a treatment facility rather than onto the ground where buildup is unsightly and causes odors, where they create a potential groundwater hazard, and where they are subject to being washed by rain as "slugs" into the treatment system or receiving stream.

2. The use of fiberglass or other non-leaking tanks should be encouraged. If wooden tanks are used, leaks should be repaired promptly.

3. Strict supervision of dry salt and brine handling should be instituted to avoid salt loss. If 33% of the salt is presently wasted at a typical plant using 10,000 tons/year, elimination of this wastage would result in a savings of $72,600 (@ $22/T).

4. Water meters should be installed on lines serving each major unit process. Readings should be made at least daily, and unusually large volume requirements per unit of product should be investigated. Leaks, overflows, breaks in the waterline, and other mishaps should be corrected promptly. Water use studies indicate that 40-90% of the water currently used is unnecessary. Assuming a plant discharging 200,000 gallons per day (73 million gallons per year) under present conditions cut water usage by 50% (a conservative value), the daily discharge would be cut to 100,000 gpd, effectively doubling the detention time in the wastewater treatment system and the annual water usage would be cut to 36.5 million gallons. In water costs alone, assuming a cost of $l/lOOO gallons, a savings of $36,500 could be achieved.

5. Treatment and reuse of spent brines should be tested on a larger scale. Assume a plant using 6700 T of salt per year (10,000 at present, minus 3.3 T saved by better housekeeping); assume 90 % of the 6 T remaining in the spent brines can be recovered by coagulation-precipitation or ultrafiltration. Reuse of this 5.4 T would eliminate that load on the receiving stream and in addition offer a potential savings in salt costs, depending on the cost of treatment. Costs of treatment can only be derived by further study on a larger scale.

6. Present treatment systems should be operated to conform to design capacity. Equipment for suspended solids removal is essential, and once in place should be closely monitored and maintained. Hydraulic loading should be reduced by water conservation. Most important, dissolved oxygen concen-

trations of at least 1 mg/l should be maintained in the aeration basins, Adequate oxygen is essential for BOD removal. In addition, if sufficient oxygen is available, neutralization of the influent by chemical addition is usually unnecessary, thus eliminating the costs, as well as the hazards, of strong alkalis such as sodium hydroxide or anhydrous ammonia. It is estimated that the cost of neutralizing 200,000 gallons per day of typical picklin wastewater with NaOH (@ $100 per ton as 50% strength) would exceed 55,000 per year.

7. The potential for reuse of pasteurizer water in cleanup or other areas should be investigated. Alternatively, to reduce loading on the waste treatment system the possibility of discharging the relatively clean pasteurizer water to the municipal system should be investigated (as is already the practice at some plants).

8. Since regeneration and reuse of brines is generally more feasible the more concentrated the brine, measures to reduce the volume of desalting water should be investigated. One approach to this problem is the countercurrent rinsing suggested by previous investigators.

9. Another alternative which would reduce the volume of desalting water, as well as overall salt use, is the adoption of lower salometer salt storage for brinestock.

10. Efforts should be made to avoid dropping cucumbers, brinestock, or parts thereof onto the tankyard, onto the floors, or into the wastewater drains. Once dropped, a valuable raw commodity becomes a waste, causing a Z-fold loss -- (1) of initial cost and (2) of cost to treat it as a waste.

11. The first and cheapest approach to wastewater control should be elimination of wastage of water, cucumbers, salt, and any other materials. Such improved "housekeeping" can be accomplished by continuing education of all plant personnel. Without improved housekeeping it is doubtful that any other more sophisticated approaches -- brine treatment and reuse, countercurrent rinsing, advanced waste treatment processes, et *cetera* -- can succeed in reducing the volume and loading of wastewaters sufficiently to meet proposed effluent guidelines.

INTRODUCTION

In 1972 representatives of the Mount Olive Pickle Company and the U. S. Food Fermentation Laboratory requested assistance of the Department of Environmental Sciences and Engineering in handling wastewater problems related to production of pickles, with the understanding that any useful information obtained would be made available to all interested pickle companies. With small grants from the University Research Council (University of North Carolina at Chapel Hill, URC Council Grant VC 334) and from Pickle Packers International, Inc. (PPI) work was begun on characterization and treatment of brine wastes from the cucumber pickle industry. The scope of this work was greatly expanded in 1973 with a $12,000 research grant from the UNC Water Resources Research Institute and $10,000 from PPI.

The scope of work undertaken included

I. Industrial water and waste surveys at two North Carolina pickle plants, including water usage and characterization of wastewaters

II. Economic evaluation of various treatment processes for brine wastewaters

III. Laboratory and pilot evaluation of recycling of tankyard brines, by high pH coagulation-precipitation and by ultrafiltration.

This report represents the information obtained during this study and includes recommendations for decreasing water usage; reducing waste loads of salt, BOD, and solids; and upgrading existing wastewater treatment facilities.

General Description of the Pickle Industry

The cultivation of cucumbers as a food crop and the preservation of foods by pickling are practices so old that their origins are unknown. The cucumber, ***Cucumis sativus***, a native of Southern Asia, has been in cultivation for more than 4000 years, being grown in Egypt in Old Testament times (King, 1941; Bush-Brown and Bush-Brown, 1958).

Pickling is one of the oldest methods of preserving food, used long before heat sterilization and freezing were available. The work pickle is derived from the Dutch ***pekel,*** "brine or pickle," and from the equivalent German *pökel*. Conventional pickling involves storage of food in salt brine, accompanied by natural fermentation mediated by indigenous micro-organisms and leading to the production of acidic endproducts. The salt serves to govern the extent and type of microbial growth, and the combination of high salt-low pH serves to preserve the food. Many vegetables can be preserved in brine, sauerkraut and cucumber pickles being the best-known examples. Others include okra, tomatoes, carrots, corn, and green beans.

Compared to canning or freezing, pickling is an energy-conserving method of food preservation, and during World War II fuel shortages there was a revival of brining both in the home and commercially (Etchells, Jones, and Bell, 1952).

In the last decade the term pickle has also been applied to cucumber products which have not been brined or fermented but have been packed directly in vinegar (fresh-pack process).

The practice of pickling cucumbers was brought to America by early Dutch settlers in the New York region (Binsted et al., 1962). Currently in the United States manufacture of cucumber pickles is a $500,000,000/yr industry involving some 39 states. Around 129,000 acres of pickling cucumbers are harvested each year, producing over 600,000 tons with a value to the farmer of over $60 million. In North Carolina, a major cucumber-producing state, over 27,000 acres are harvested, yielding over 85,000 tons of cucumbers with a value to the farmer of nearly $9 million (Tables 1 and 2). In North Carolina the usual field size is small, so that in this State cucumbers are produced by a relatively large number of farmers. Three large pickle processing plants are located in North Carolina: Mount Olive Pickle Company, Mount Olive; Perfect Packed Products Company, Inc., Henderson; and Cates Pickle Company, Faison.

TABLE 1. PRODUCTION OF CUCUMBERS FOR PICKLES IN 1972 (*Almanac*, 1974)

Area	Harvested Acreage (1000 acres)	Yield Tons/ Acre	Production (1000 T)	Value ($/T)	Total Value ($1000)
North Carolina	27.0	2.50	67.5	117	7,898
Southern States	71.5	3.10	227.3	98	21,667
Michigan	26.0	3.76	97.8	86	8,391
Northern States	46.0	5.10	234.4	92	21,478
California		12.05	67.5	93	6,284
Western States	11.4	10.11	115.5	91	10,515
Total processed	128.8	4.43	571.2	94	53,660
Total, fresh mkt.	49.2	-----	216.3	---	-m-D--
Total, U. S.	178.0		806.3		

TABLE 2. ECONOMIC ASPECTS OF CUCUMBER PRODUCTION AND PICKLING PROCESSING IN NORTH CAROLINA*

Acreage harvested: ~27,300 acres (ranks second in acreage)

Yield per acre: 3.05 tons (122 bushels)

Crop harvested: 83,250 tons (-3.33 million bushels)

Price per ton: $95-$98 (~$2.50/bushel)

Value of crop to N. C. Farmers: ~$8 million

Average field size: 1.5-5 acres (a large number of farmers benefit)

Value at manufacturer's level: ~$50 million

Value at retail level: ~$62.5 million

Amount of manufactured goods sold outside of State: -95%

*Information supplied by J.L. Etchells, Head, Southeastern Marketing and Nutrition Research Division, U.S. Food Fermentation Laboratory, Raleigh, N. C., 1972.

Growth Projections of the Pickle Industry

The U.S. pickle industry has grown at a rapid rate, in terms of both overall consumption and consumption per capita. A major factor in pickle consumption is the use of pickle slices in the fast-food industry. Table 3 shows growth trends in the industry since 1930 (USDA, 1973).

TABLE 3. PICKLE CONSUMPTION IN THE UNITED STATES

Year	CONSUMPTION	
	Cases of 24/303's	pounds/capita
1930	12,058,400	2.35
1935	11,629,400	2.20
1940	15,872,600	2.88
1945	20,747,300	3.73
1950	29,249,500	4.62
1951	25,730,000	4.01
1955	35,876,300	5.22
1960	38,933,400	5.20
1965	45,674,700	5.62
1970	64,265,600	7.60
1973	72,542,500	8.34

Partly because of the growth of the pickle industry currently many plants may find themselves with inadequate and overloaded waste treatment systems at a time when funds for capital improvements are hard to obtain.

Product Description, Styles, and Types of Packs

United States Standards for Grades of Pickles define pickles as follows:

> "Pickles means the product prepared entirely or predominantly from cucumbers *(Cucumis sativus L,)*. Clean, sound ingredients are used which may or may not have been previously subjected to fermentation and curing in a salt brine (solution of sodium chloride NaCl). The prepared pickles are packed in vinegar solution, to which may be added salt and other vegetable(s), nutritive sweetener(s), seasoning(s), flavoring(s), spice(s), and other ingredients permissible under the Federal Food, Drug, and Cosmetic Act. The product is packed in suitable containers and heat treated, or otherwise processed to assure preservation." *(Almanac*, 1974).

The term *style* refers to the shape of the product and includes the following categories: whole, crosscut, slice lengthwise, cut, and relish (finely cut).

There are two major *types* of pack -- cured and fresh-pack.

Cured type pickles are naturally fermented in NaCl brine to which may be added flavorings such as dill. During curing the internal salt concentration may reach levels too high for palatability, in which case the pickle then is partially desalted before packing in vinegar solution. Types of cured pickles include

(1) Natural or genuine dills - cured in salt brine with dill herb
(2) Processed dills - cured pickles packed in vinegar solution with dill flavoring
(3) Sour pickles - cured, packed in vinegar
(4) Sweet pickles and mild sweet pickles - cured, packed in vinegar with nutritive sweetening ingredient
(5) Sour mixed - cured, packed in vinegar, packed with onions and cauliflower and other ingredients
(6) Sweet mixed and mild sweet mixed - as in 5, but with nutritive sweeteners added
(7) Sour mustard pickles or sour chow-chow - as in 5, except packed in mustard sauce rather than in vinegar
(8) Sour pickle relish - cured, finely cut or chopped cucumbers, packed in vinegar solution, may contain other finely cut vegetables
(9) Sweet pickle relish - as in 8, but with nutritive sweetener added,

Fresh-pack type pickles are prepared from uncured unfermented cucumbers and packed in vinegar solutions of various types. They are processed by heat for preservation. The types include

(1) fresh-pack dill - packed in vinegar solution with dill flavoring
(2) fresh-pack sweet dill - as in 1, but with nutritive sweetener
(3) fresh-pack sweetened dill relish - finely cut or chopped, packed in vinegar, dill and nutritive sweetener added, may contain other finely cut or chopped vegetables
(4) fresh-pack sweet and fresh-pack mild sweet - packed in vinegar with nutritive sweetener
(5) fresh-pack sweet relish and fresh-pack mild sweet relish - as in 3, but without dill flavoring
(6) fresh-pack dietetic - may be prepared with or without addition of sweetener, salt, and other ingredients to meet requirements for special dietary uses.

Currently, of the annual crop about 40% is made directly into fresh-pack or pasteurized pickle products using the canning operation largely developed at the U.S. Food Fermentation Laboratory (Etchells and Moore, 1971).

Pickle Production and the Wastewaters Generated

Sources of wastewaters from pickle manufacture are readily apparent as one follows the progress of cucumbers from field to finished product (Figure 1). The three major divisions in production of brined-type pickles are (1) brining, (2) "processing" or freshening," and (3) finishing.

It must be noted that in the pickle industry brine strengths are expressed in terms of degrees salometer, measured with a hydrometer calibrated in percent saturation with respect to sodium chloride. A saturated solution of salt would read 100° salometer (see Table 4).

Green cucumbers trucked in from field weighing stations may be first graded (sorted according to size) or put directly into brining tanks (field run). As a rule, the cucumbers are not washed first.

In most plants green cucumbers are brined outdoors in large wooden tanks ranging in size from 1000-20,000 gallons and accommodating from 100-2000 bushels of cucumbers. These tanks are actually huge barrels constructed with staves and hoops; consequently, they must be kept wet to reduce their tendency to shrink and leak. During the winter months the tanks are filled with water containing lime (or in some instances, microbicides) to keep the wood wet and to "sweeten" the tanks. As tanks are needed in the spring and summer, the limewater (~10 lb hydrated lime per 1000 gal) is drained out onto the tankyard and the tanks are washed with freshwater. Care of empty tanks is reviewed by Veldhuis et al (1941).

Before cucumbers are added to the tank, a cushion (6"-8" deep) of 25° brine is placed in the bottom of the tank to prevent bruising the cucumbers as they are dumped in. After filling to within about a foot of the top of

FIGURE 1. FLOW CHART OF TYPICAL UNIT PROCESSES IN THE PRODUCTION OF FRESH-PACK AND PROCESSED CUCUMBER PICKLES.

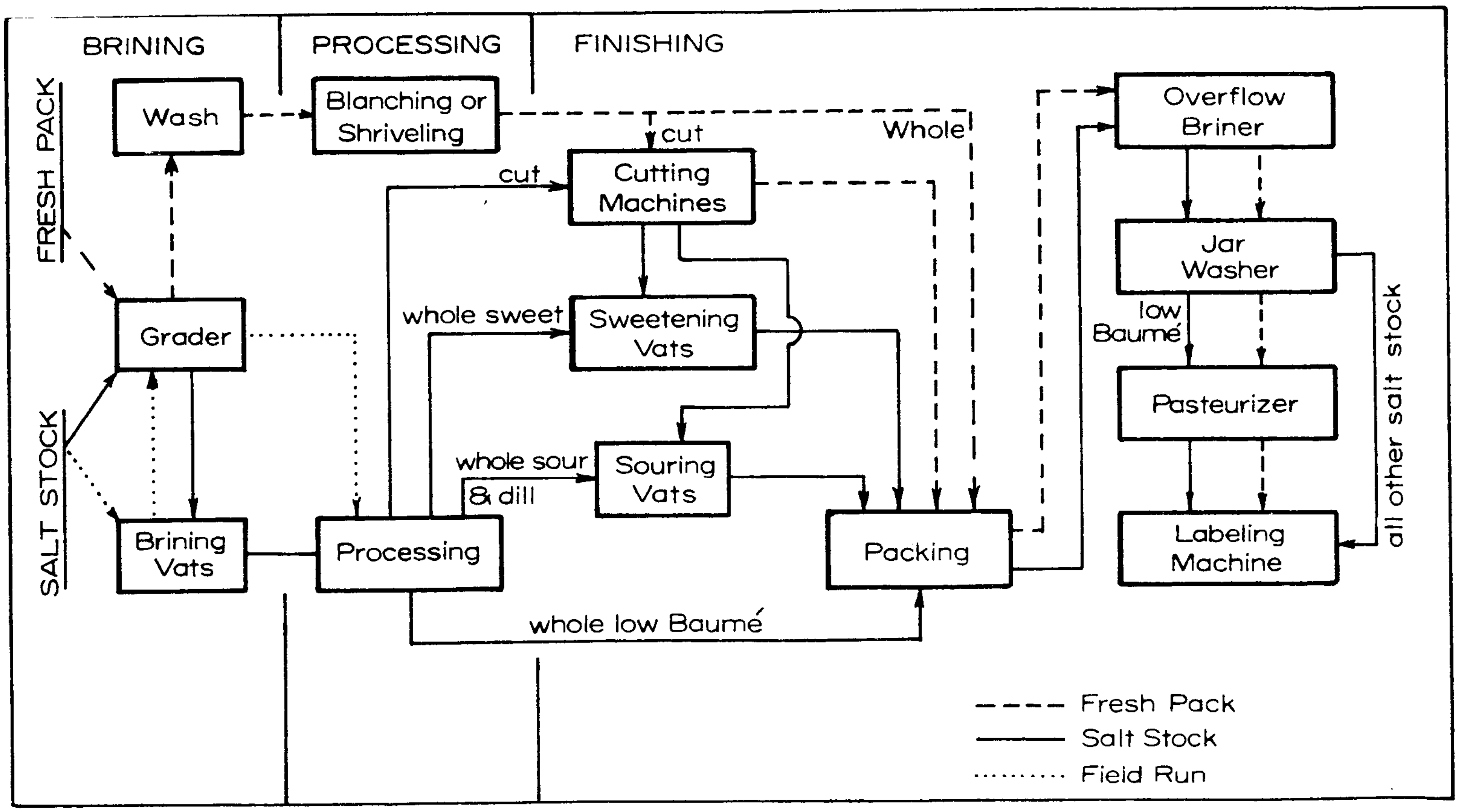

TABLE 4. SALT (NaCl) SOLUTION CONVERSION CHART*

Degrees Salometer	Percent salt by weight	Grams of salt per 100 cc. water by vol.	Grams of salt per 100 cc. of solution	Specific gravity 20°/4°	Ounces of salt per gallon of water	Pounds of salt per gallon of water	Ounces of salt per gallon of solution	Pounds of salt per gallon of solution
0	0.00	0.00	0.00	0.998	0.00	0.000	0.00	0.000
5	1.32	1.34	1.33	1.007	1.78	0.111	1.77	0.111
10	2.64	2.71	2.68	1.017	3.61	0.226	3.57	0.223
15	3.96	4.12	4.06	1.026	5.49	0.342	5.41	0.338
20	5.28	5.58	5.47	1.036	7.44	0.465	7.29	0.455
25	6.61	7.08	6.91	1.046	9.44	0.590	9.20	0.575
30	7.93	8.62	8.36	1.055	11.5	0.717	11.12	0.696
35	9.25	10.2	9.85	1.065	13.6	0.850	13.11	0.820
40	10.6	11.8	11.4	1.074	15.7	0.984	15.2	0.950
45	11.9	13.5	12.9	1.084	18.0	1.12	17.2	1.07
50	13.2	15.2	14.5	1.094	20.2	1.26	19.3	1.21
55	14.5	17.0	16.0	1.104	22.6	1.41	21.3	1.33
60	15.8	18.8	17.6	1.14	25.1	1.56	23.4	1.46
65	17.2	20.7	19.3	1.125	27.6	1.73	25.7	1.61
70	18.5	22.7	21.0	1.135	30.3	1.89	28.0	1.75
75	19.8	24.7	22.7	1.145	32.9	2.06	30.2	1.89
80	21.1	26.8	24.4	1.156	35.7	2.23	32.5	2.03
85	22.2	28.5	25.9	1.166	37.9	2.37	34.5	2.16
90	23.8	31.2	28.1	1.179	41.6	2.60	37.4	2.34
95	25.1	33.5	29.9	1.191	44.6	2.79	39.8	2.49
100	26.4	35.9	31.7	1.202	47.8	2.99	42.2	2.64

*From USDA Food Fermentation Laboratory

the tank, the tanks are "headed down" with a cover of wooden boards, loosely constructed to allow free movement of liquid while keeping the cucumbers submerged. The cover is fastened in place with heavy beams. Salt brine is added to about 4-6" above the head. Initially the cucumbers absorb brine and water diffuses out of the cucumbers, so dry salt is added periodically to maintain a brine strength of 20°-30°. Any leakage from the tanks will also necessitate addition of brine. Rain may dilute the brine and require addition of more salt.

In the case of small cucumbers up to 1 1/4" (diameter) an additional step may be necessary. Small cucumbers often have flowers still attached to the stems. Fungi associated with flowers have been shown to produce pectinases, enzymes which destroy the pectin in the cucumber cell walls, thus causing softening of the brinestock (Bell, Etchells, and Costilow, 1958). To combat this problem, it is common practice, especially in the South, to drain off the initial 25" brine after 36 hours, replacing it with fresh brine. The 36-hour drain is discharged as a waste. Thus, additional salt is required for small cucumbers and an additional waste stream is generated. For example, for a 500 bushel tank, 1500 lb of salt is required for the 25° brine, so small stock requires an extra 3/4 ton of salt, much of which is wasted onto the tankyard over a relatively short period of time (Etchells and Hontz, 1972).

During the first 4-6 weeks of brining at 20-30° salometer, a natural fermentation takes place. This fermentation is mediated by salt-tolerant microorganisms adhering to the cucumbers. Utilizing organics and nutrients diffusing from the cucumbers, these organisms produce lactic acid and the is depressed to -3.5. After sufficient acidity (~0.6%) is reached, the brine strength is increased by addition of dry salt to a final strength of 45-70° salometer. The combination of low pH and high salt serves to suppress the activity of many (but not all) undesirable organisms and to thus preserve the cucumbers.

When the brined cucumbers are needed for product, they are removed from the vats, processed or freshened, and packed (see below). The used or "spent" brine is commonly discharged to the ground as waste.

To control surface growths of yeast, tanks are commonly left open to sunlight. Despite the low pH and high salt conditions certain scum yeasts can thrive in the fermented brine. Scum yeasts, although not incriminated in salt-stock softening (Bell and Etchells, 1956), damage the appearance and overall quality of the stock. Species of yeast involved are *Debaryomyces* (the most widespread), *Zygosaccharomyces, Endomycopsis,* and *Candida* (Etchells and Bell, 1950). Scum growth is especially apt to occur when skies are overcast and when the weather is warm. Veldhuis et al (1941) recommend daily agitation of the liquid surface to retard growth of yeasts; they state that if scum is allowed to develop to the point at which it is visible irreparable damage can occur. Since few plants practice agitation, when scum accumulates it is removed by skimming or by overflowing. In either case, brine is lost to the ground.

Since the tanks are open they receive not only sunlight, but also rainwater. Consequently, brine is lost by overflow to the ground, the remaining brine is diluted, and more salt is required. In addition loss of acidity may necessitate addition of acetic acid.

A final source of wastewater is the leakage of brine from improperly maintained tanks. To indicate the contribution of leakage to waste generation, the following calculation is illustrative:

> Assume a tank 12' in diameter with 65° brine. Leakdown of 1" of brine will result in a volume loss of 68 gallons containing 109 lb of salt. Leakdown of 1' of brine will result in a volume loss of 816 gallons containing 1306 lb of salt.

Loss of brine will necessitate its replacement and, thus, will require additional consumption of salt and water. In addition, loss of the acid end-products of fermentation will necessitate addition of acetic acid. Finally, the spilled brine will contribute oxygen-demanding materials to the wastewater draining from the tankyard.

Returning to the cucumbers, the brined cucumbers at this point are inedible because of their high salt content (~16%). In order to reduce the salt the cucumbers are soaked in 1-2 equivalent volumes of fresh water. Final desired salt content for dills is ~4.7%; for sweets, ~2.5%. During the second washing process the water generally contains alum, for texture improvement, and may also contain turmeric or Food Yellow No. 5 for coloring. During processing air is usually pumped into the solution to promote mixing and rapid diffusion of salt. The processing waters are discharged as wastewater.

Before and after processing, cucumbers may be regraded; pricked to promote inward diffusion of flavoring agents; or sliced into spears, cubes, slices, relish, and so on. Cutting and pricking operations generally involve fluming of the cucumbers through the system and may also involve jet washing at the point of cutting or pricking. Flume waters may be reused until too dirty; washwaters go directly to waste.

Depending on the product, the pickles may be soaked in various combinations of vinegar, sugar, and spices. The flavoring liquors are expensive and thus efforts are usually made to avoid spillage. Some losses occur during transfers and during dumping of leftover liquors when a particular product run is finished.

The pickles may be packed by hand or machine into jars or buckets. After packing the final cover brine is added, generally dispensed by an overflow briner into the containers as they pass by on a conveyer belt. Caps or covers are added by machine and the outside of the jars is washed. Wastewaters include the overflow brine, the washwater, and losses due to breakage or spillage.

The finished product may or may not be pasteurized, depending on its sugar and acid content. Large quantities of cooling water are generated by the pasteurizers.

Finally, the products are labelled and crated.

Additional wastewater is generated by washing the floors in the finishing and packing area. This wastewater will contain spilled brines, liquors, and pickles or parts thereof.

During the green season about 40% of the incoming cucumbers are made into fresh pack products. Cucumbers are graded, washed, and sent to the packing room, where they may be blanched or shriveled in weak brine, then packed whole or cut. All freshpack products are pasteurized. Since fermentation, storage in brine, and desalting are eliminated, much of the waste associated with brined products is eliminated. Since fresh cucumbers can be held no longer than 24 hours, the freshpack operation is limited to the green cucumber season. In order to pack as many as possible by freshpack, the cucumber season has been extended by planting both spring and fall crops and during this time it is not unusual for plants to operate 2-3 shifts per day for 6-7 days a week.

Summarizing, major sources of wastewater are as follows:

(1) 36-hour drain
(2) spent brine
(3) leakage and overflow of tanks
(4) lime water from sweetenting tanks
(5) processing waters
(6) wash waters from cutters, slicers, etc.
(7) transfer losses
(8) cooling water for pasteurization
(9) loss of cover liquors
(10) water used in cleanup.

Previous Studies on Reduction of Wastes from Pickle Packing

Two in-depth wastes surveys of the pickle industry have been published and while some of the findings have been put into widespread practice, others bear repetition and adoption. Barnes and Weinberger (1958) emphasized the value of inventorying sources and amounts of wastes and of reducing pollution at the source where possible. Their survey was primarily directed toward BOD reduction. Suggestions for reducing pollution included:

(1) double-netting when removing brined cucumbers from vats to transfer containers to reduce drippage
(2) saving of left-over concentrated cover liquors for later use
(3) reduction of in-plant spills
(4) segregation of high-strength liquors and storage for release at times of high stream flow
(5) metering of water usage
(6) automatic cornposited sampling of waste flows, their characterization, and record-keeping to aid in control of plant operation.

Nemerow (1963) surveyed a North Carolina pickle plant and evaluated effects of the raw wastes discharge to the receiving stream. As in the previous survey, Nemerow's attention was primarily on BOD reduction. Suggestions for reducing BOD and solids included:

(1) installation of screens over drains in syrup tanks to aid in retaining small pickles and peels
(2) avoiding overfill of desalting vats to eliminate loss of brinestock
(3) dry-sweep collection of pickles and pickle parts which are dropped onto floors and their disposal to garbage rather than to the wastewater system.

Mercer et al. (1970, 1971) were able to recondition olive storage and processing brines with pilot-scale activated carbon treatment. The treated brines were used to store olives with no detectable effect on product quality. The costs for a plant processing 5000 tons of olives per year, amortized over a 10-yr period, were estimated to be $2.76/ton or $27.60 per 1000 gal of reconditioned brine. On the average, activated carbon treatment removed 38 - 65 % of the COD in the olive brines. and 21 - 30 % of the suspended solids.

The authors estimated that cost could be reduced to around $1 per ton by reactivation and reuse of spent carbon if a centrally located reactivation facility could serve 10 canneries.

Lowe and Durkee (1971) also examined the reclamation of salt from olive brines, using the process of evaporation by submerged combustion. In this process spent brines are heated by passage of gaseous combustion products directly through the body of the liquid. The rapid heat transfer from the rising gas bubbles takes place under low partial pressure conductions so that boiling takes place at temperatures considerably less than the normal boiling point. Since there are no heat transfer surfaces there are no problems with fouling or corrosion, so that equipment cost can be lowered. The disadvantage of the process is its relatively low thermal efficiency. The slurry of crystals formed during submerged combusion is about 57.5% solids and contains in addition to the salt about 6% combustible organic material. The organics are destroyed and the water removed by incineration at 1200 F. The incinerated salt is stored dry. At time of reuse it is dissolved, filtered or settled to remove the ashed carbon residue, and made up into brine. In their studies the reconditioned brine contained 25 mg/l COD, compared to 34,700 in the spent brine.

Since cost of the submerged combustion process is dependent on the volume of water to be removed, the more concentrated brines are more economically treated.

Blizard (1973) reported work on submerged combustion by USDA-Western Laboratory and Selas Corporation. Based on 5500 T of cucumbers requiring 660,000 gal of 15% brine solution and considering costs of capital amortization (10 yr basis), labor, power, maintenance, filtration, balanced against value of recovered salt, he estimated the cost of the process to be $0.06 per ton of cucumbers.

Cranfield (1974) reported on a brine recycling program at Alaga-Whitfield Foods, Inc., in Montgomery, Alabama. Spent brine (60° salometer, pH 3.5) is collected in a storage tank, pumped through a heat exchanger where it is heated to 205 F, neutralized to pH 4.6 with lime, and settled. Salt is added to raise salometer to 100°, then the brine is pumped back to the tankyard. Control of salt concentration in the tanks is achieved not by addition of dry salt, but by draining off lower-salometer brine and replacing it with the 100° salometer brine.

Modification of In-Plant Procedures to Reduce Waste

Hoover (1974) poses the pertinent question to be answered in regard to preventing food-processing wastes: "Can we change existing processes so that less waste is produced, while maintaining or improving product quality"? Reviewing the pickling industry he describes past and on-going innovations developed at the USDA Food Fermentation Laboratory located at N. C. State University. The most widely-adopted innovation is the fresh-pack process by which 40% of the annual cucumber crop is now handled. The fresh pack process involves packing the fresh cucumbers directly in brine, vinegar, and seasonings, followed by pasteurization in the sealed jar. This process eliminates fermentation, storage in brines, and desalting and in addition produces a product of fresh texture and color.

Another approach developed at the USDA Laboratory is the controlled fermentation process (Etchells, Bell, and Costilow, 1966). Hontz (personal communication) estimates that currently 77.8% of the salt used in processed-type pickles is wasted, either as spent brine or desalting water. The controlled fermentation process was developed by USDA in cooperation with the North Carolina and Michigan Agricultural Experiment Stations. The first approach was in-the-jar fermentation, achieved b (1) pasteurization of the cucumbers to eliminate undesirable organisms, (2) aseptic addition of a pure culture of lactic acid organisms, and (3) aseptic addition of sterile brine solution in the jar. Controlled fermentation in the jar offers the following advantages: elimination of weeks of vat storage, reduced pickling time, consistently high quality, and reduction of spoilage losses. By elimination of vat storage, it would eliminate nearly all of the salt wastes. A disadvantage of the in-the-jar process is that fresh cucumbers would have to be handled shortly after arrival, placing a large demand on labor and equipment.

In-the-vat controlled bulk fermentation is now under consideration (Etchells et al., 1973). This process would offer most of the advantages of controlled fermentation without the time and equipment intensive aspects. Controlled bulk fermentation should result in drastic reductions in salt usage since the brinestock can be held at 25° salometer rather than at the 60-65" level commonly used. The following calculations indicate the potential salt savings :

At 65° salometer 16.25 lb of salt is required per bushel of cucumbers.

At 25° salometer only 6.18 lb/bushel is required, a reduction of 10.07 lb/bushel (62%).

Furthermore, the amount of desalting water, and consequently, the amount of processing wastewater, should be drastically reduced since the salt content of the cucumbers brined at 25° will be close to that required in the final. product.

Unfortunately (Etchells et al., 1973) the controlled bulk fermentation process will not eliminate the need for the 36-hr drain with small cucumbers (up to 1.25" in diameter), necessitated by the softening enzymes which diffuse from mold-laden blossoms.

Vaughn et al. (1969) have proposed another modification of in-plant procedure which would eliminate salt wastes. They propose that salt-storage be eliminated and that anaerobiosis and acidification to 1.2% total acid with lactic and acetic acids, supplemented with 0.3% sodium benzoate, be substituted. Pilot and tank experiments were conducted with olives; laboratory tests, with cauliflower, carrots, celery, cucumbers, onions, and chili peppers. Anaerobiosis was maintained in tanks by overlaying the liquid surface with white polyethylene sheets secured with slats. Pinholes provided for CO_2 escape during fermentation, and for storage the holes were covered with a wax sealant.

CHARACTERIZATION OF WASTEWATERS GENERATED IN PICKLE MANUFACTURE

Relatively little information is available in the literature on the pollutional characteristics of wastewaters from pickle manufacture, especially on the wastewaters from individual unit processes.

Results of previous studies are indicated in Tables 5 and 6. Overall, pickling wastewaters are characterized by high dissolved solids, low pH, high chloride content and high BOD.

Because of the relative lack of information on the character of pickling wastewaters, coupled with a pressing need by pickle manufacturers to upgrade their wastewater treatment facilities, the need for extensive survey was obvious.

Plant A was chosen for an extensive survey of water use, overall and in unit processes; wastewater generation, overall and for unit processes; characterization of wastewater components; handling of cucumbers, salt, and other ingredients. Cooperation of plant personnel made possible daily meter readings, production figures, and sampling. Samples were chilled and taken to the UNC Wastewater Research Center for analysis. Table 7 describes the analytical methods employed in the study.

Plant B was also extensively studied and an industrial waste survey was conducted by graduate students from UNC- Chapel Hill (see Appendix A).

Plant C was sampled occasionally, primarily for comparison with results obtained at Plants A and B.

Tankyard Wastes

At Plant A the average tank capacity is 6000 gallons, a size which accommodates 600 bushels of cucumbers. Each 6000-gal tank produces about 2400 gallons of spent brine. When the plant is running at peak capacity, 3-5 tanks are emptied each working day, i.e., 1800-3000 bushels of cucumbers are processed each working day. On a yearly basis, about 700 tanks are processed, and thus ~ 1.68 million gallons of spent brine are generated.

From the tankyard, samples of brine were taken from 23 vats of whole cucumbers representing both spring and fall crops and 5 sizes of cucumbers; from two tanks of relish; and from vats of cauliflower, pepper, and onion. These brine samples represent the spent brines which would be discharged to waste as the vegetables are processed.

TABLE 5. CHARACTERISTICS OF WASTEWATER FROM PICKLE MANUFACTURE

REFERENCE	pH	BOD_5 (mg/l)	Cl (mg/l)	TS (mg/l)	SS (mg/l)
Barnes and Weinberger (1958)	3.6-4.4	800-5400	2500-14000	------	---
Haseltine (1952)	4.0	2000	6500	13,600	200
Kimball (1960)	4.0-6.0	---	----	------	---
Nemerow (1963)	3.9-8.8	1070	3000	8,000-24,000	148
Ryan (1940)	4	3000	----	4,000	200

TABLE 6. CHARACTERISTICS OF WASTEWATER FLOWS FROM UNIT PROCESSES IN PICKLE MANUFACTURE

Source	Flow Description	pH	SS (mg/l)	BOD_5 (mg/l)
Barnes and Weinberger(1958)	Sweet liquor	2.9-3.1	----	$2\text{-}5 \times 10^5$
	Cleanup wash	3.9-7.0	----	0-800
Nemerow(1963)	Alum-tumeric wash			
	- whole pickles	4.1	1024	420
	- pickle chips	3.2	1185	1890
	Drainings from relish	3.2	7980	2500

TABLE 7. ANALYTICAL PROCEDURES

Parameter	Method	Source*
Acidity, Total (as $CaCO_3$)	Electrometric Titration - pH 8.3	2
Biochemical Oxygen Demand (BOD, 5 day, 20 °C)	YSI DO Analyzer (probe method) (modified blank depletion)	2
Carbon - Inorganic Organic (TOC)	Dow-Beckman Carbonaceous Analyzer Model No. 915 (Dual Channel)	1
Chemical Oxygen Demand (COD)	Dichromate reflux - 0.25 N (corrected for chlorides)	2
Chloride (Cl)	1) Mercuric Nitrate Titration 2) Specific Ion Probe (Orion)	2
Dissolved Oxygen (DO)	Winkler Azide or YSI DO Analyzer (probe method)	2
Metals, Total	Perkin-Elmer Model 303 Atomic Absorption Unit	1
Dissolved	Filtration through 0.45 μ membrane filter	
Nitrogen, Ammonia (NH_4-N)	Technicon AutoAnalyzer - Sodium Phenolate	1
Nitrogen, Kjeldahl, Total (Kjeld-N)	Technicon AutoAnalyzer - Digestion + Phenolate	1
Nitrogen, Nitrate (NO_3-N)	Technicon AutoAnalyzer - Hydrazine Reduction	1
Nitrogen, Nitrite (NO_2-N)	Technicon AutoAnalyzer - Diazotization	1
pH	Electrometric	2
Total Phosphorus (TP)	Persulfate Digestion + Technicon AutoAnalyzer Automated Stannous Chloride	1
Solids, Total (TS)	Gravimetric, 103 °C (Method 224 A)	2
Solids, Total Dissolved (TDS)	By subtraction (TS - SS)	
Solids, Total Suspended (SS)	Gooch Crucible Filtration, 103 °C (Method 224 C)	2

*[1]FWPCA. 1969. FWPCA METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES. U.S. Department of Interior, Federal Water Pollution Control Administration. Analytical Quality Control Laboratory, Cincinnati, Ohio.

[2]APHA, AWWA, WPCF. 1971. STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER, 13th edition. American Public Health Association, Inc., New York, New York.

TABLE 8. CHARACTERIZATION OF TANKYARD BRINES FROM CUCUMBERS

Type	Crop	Size	BOD mg/ℓ	TOC mg/ℓ	SS mg/ℓ	TS g/ℓ	NO_2-N + NO_3-N mg/ℓ	NH_4-N mg/ℓ	Kjeld-N mg/ℓ	TP mg/ℓ	pH	Acidity mg/ℓ	Specific Conductivity mmhos	Cl g/ℓ
Whole	Spring	1 A	1440	400	147	188	1.0	100	350	32	3.8	440	152	109
		1 A	1830	300	359	211	<1.0	105	400	32	4.1	420	90	120
		1 B	1560	300	181	228	1.5	55	625	24	3.2	600	192	134
		1 B	>2700	1300	189	220	2.0	125	450	48	3.3	1070	185	126
		2 A	>2600	3700	151	204	2.0	215	500	102	3.2	2620	174	120
		2 A	>2700	3800	212	227	2.0	245	950	115	3.1	2900	182	126
		3	420	<100	174	200	1.5	15	225	10	3.7	540	189	185
		3	>2700	3200	168	187	2.0	240	-	90	3.2	2440	169	106
		4	>2700	3500	199	193	3.0	245	1900	102	3.2	2590	162	104
		4	>2600	2900	186	226	7.0	200	500	72	3.3	2040	93	131
		Field run	>2700	5000	2137*	217	-	320	675	125	3.1	3480	180	130
		"	>2600	1300	174	208	3.0	145	300	58	3.3	1370	184	126
		"	>2600	4300	176	201	3.0	290	750	110	3.6	2340	174	122
	Fall	2 B	2550	5100	168	156	1.0	415	725	120	3.5	3240	151	88
		2 B	>2700	4400	329	187	6.0	310	1050	120	3.3	2620	166	104
		3	>2600	5300	249	173	12.0	385	925	106	3.5	2600	156	96
		3	>2700	4600	358	164	7.0	370	825	105	3.5	3100	152	91
		4	>2700	3400	231	198	3.0	330	750	82	3.3	2460	172	114
		4	>2700	3400	343	174	4.0	275	625	95	3.3	2330	162	100
		Field run	>2600	5800	392	148	12.0	335	675	95	3.2	3560	143	82
		"	>2600	6000	159	188	9.5	370	975	119	3.3	3840	164	103
		"	>2600	4300	521	114	9.5	255	850	128	4.0	2090	121	63
		"	>2700	6200	355	141	5.0	395	1075	122	3.3	3760	136	77
	Avg.			3417	329	189	4.4	249	732	87	3.4	2324	159	111
	Max.			6200	2137	228	12.0	415	1900	128	4.1	3840	192	185
	Min.			< 100	147	114	< 1.0	15	225	24	3.1	420	90	63
Relish	Spring		> 2700	1300	169	203	2.0	100	325	45	3.2	1110	179	118
	Fall		> 2700	4600	197	190	12.0	390	1075	110	3.2	3160	169	107

*Tank had just been emptied and sediment was stirred up

Brines from whole cucumbers (Table 8) are, as expected, extremely high in chlorides, reflecting the high salometer storage brine strengths used in Plant A and many other plants, Additionally, these brines are extremely high in organic carbon (averaging 3400 mg/l), suspended solids (averaging 329 mg/l), Kjeldahl nitrogen (averaging 732 mg/l) and phosphorus (averaging 87 mg/l). Because of the fermentation there is a low pH (around 3.4) and a high acidity (averaging 2324 mg/l). The discovery that spent brines contained not only salt but high levels of other pollutants was surprising to pickle plant personnel. However, one might anticipate that when cucumbers are placed in concentrated brines soluble components will diffuse out into the brine until an equilibrium is attained.

Values for relish brines were in the same ranges as those for whole cucumber brines (Table 8).

From the data shown in Table 8 it is obvious that spent brines from cucumbers have a very high pollutional potential. In Table 9 the spent brine characteristics are compared with ordinary domestic sewage, which seems weak in comparison (Brown et al., 1973).

TABLE 9. TANKYARD BRINE COMPARED TO TYPICAL DOMESTIC SEWAGE

Parameter	Brine	Sewage
TOC, mg/l	3400	124
SS, mg/l	330	170
Kjeld-N, mg/l	732	31
TP, mg/l	87	10
Cl, g/l	111	<1
pH	3.4	7.2

Table 10 shows the characteristics of the 36-hour drain brines from small cucumbers. Again, this brine is very high in BOD, TOC, chlorides, and acidity. Since all of this brine is discharged to waste (usually onto the ground) during the green season it constitutes a major wastewater load during a relatively short period.

Pepper and cauliflower brines are similar to cucumber brines (Table 11). Onion brines, however, are markedly different, with low organic carbon levels and low acidity. In relation to overall waste loads, the contribution of onion, pepper, and cauliflower brines is minimal, as only a few vats of each are used each year,

Wastewaters from Processing and from Other Operations

Characteristics of processing wastewaters from several products are shown in Table 12, Processing wastewaters are generated in the desalting step.

TABLE 10. CHARACTERISTICS OF 36-HOUR DRAIN, PLANT A, 1974

Date	BOD	TOC	SS	TDS	Kjeld-N	NH_4-N	TP	Cl	Acidity mg/l as $CaCO_3$	pH
	Parameter (mg/l)									
June 13 (1)		2320			188	35		11,500		
(2)		5399				10		11,000		
June 16	>9850	5494	235	111,000			60	44,500	1560	3.8
Aug. 30 (1)	13,800	7400	645	113,000				47,000		3.3
(2)	12,600	6520	1130	154,000				55,000		3.3

TABLE 11. CHARACTERIZATION OF TANKYARD BRINES FROM MISCELLANEOUS VEGETABLES, PLANT A, 1974

Item	BOD mg/l	TOC mg/l	SS mg/l	TS g/l	(NO_2+NO_3)-N mg/l	NH_4-N mg/l	Kjeld-N mg/l	TP mg/l	Cl g/l	Acidity mg/l	pH	Specific Conductivity mmhos
Cauliflower	>2700	6200	219	145	8.0	225		142	79	1850	4.0	138
"	>2700	8700	327	135	14.0	190	1625	162	70	2490	4.1	128
Pepper	>2700	6300	310	316	----	95	725	80	184	800	4.2	202
"	>2700	9500	289	208	----	165	1575	128	185	2230	3.6	197
Onion	630	<100	620	189	----	20	----	9.6	113	170	3.9	172

TABLE 12. CHARACTERIZATION OF WASTEWATER FLOWS FROM PROCESSING VARIOUS PICKLE PRODUCTS

Wash	Unit	Date	Time	BOD mg/l	TOC mg/l	SS mg/l	TS g/l	TDS g/l	$(NO_2+NO_3)N$ mg/l	NH_4-N mg/l	Kjeld-N mg/l	TP mg/l	pH	Acidity mg/l as $CaCO_3$	Spec. Cond. mmhos	Cl g/l
1st	Salad Cubes	3/20(1)	pm	>2220	1100	66	5.3	5.2	---	>50	182.0	26.2	3.6	686	89	46
	"	3/20(2)	pm	>2310	1100	71	84.8	84.7	---	>50	162.0	29.0	3.6	617	90	47
	"	3/21	am	5	<100	57	0.7	0.7	<0.2	1.0	4.0	1.2	6.4	21	1	0.4
	Relish	3/27	pm	>2460	1700	--	----	----	---	----	-----	----	3.6	514	90	----
	Sweet Chips	3/20(1)	pm	>770	600	230	65.7	65.5	---	----	-----	----	3.5	480	74	36
	"	3/20(2)	pm	>770	600	455	71.0	70.5	---	>50	100	22.2	3.5	523	80	39
	Dill Pickles	3/21	pm	>225	200	83	68.1	68.0	0.6	34.0	62.5	10.2	3.6	309	80	39
	Sweet Pickles	3/21	am	140	200	275	4.3	4.0	0.5	40.0	75.0	13.5	3.7	309	74	36
	"	3/28	pm	>830	300	---	----	----	---	----	-----	----	3.7	266	82	41
2nd	Sweet Chips	4/9	pm	>400	200	290	69.8	69.5	0.4	34.5	>100	8.3	3.5	557	53	30
	Dill Chips	4/11	pm	>400	<100	180	37.6	37.4	0.6	21.0	62.0	3.8	3.6	677	35	20
	"	4/12	pm	>400	<100	150	31.5	31.3	0.7	23.5	60.0	4.0	3.6	553	34	20
	Dill Pickles	4/17	pm	234	<100	140	----	----	---	----	-----	----	4.2	146	39	--
	"	4/18(1)	pm	>400	<100	220	----	----	---	----	-----	----	3.6	574	41	--
	"	4/18(2)	pm	>400	<100	215	----	----	---	----	-----	----	3.6	506	42	--
	Sweet Pickles	4/19	pm	105	<100	160	25.4	25.2	<0.3	7.5	44.0	2.6	4.0	454	30	12
	Sweet Mix	4/9	pm	>400	200	280	25.5	25.3	<0.3	14.5	63.0	4.9	3.5	591	30	17
	"	4/10	pm	>400	<100	350	35.2	34.8	<0.4	16.5	75.0	4.3	3.6	514	30	14
	"	4/19	pm	>400	<100	800	----	----	---	----	-----	----	3.6	514	36	--

TABLE 13. CHARACTERIZATION OF WASTEWATER FROM CHIP MACHINE, PLANT A, 1974

Date	Type of Pack	BOD	TOC	TS	TDS	SS	Kjeld-N	NH_4-N	(NO_2+NO_3)-N	TP	Cl	Acidity mg/l as $CaCO_3$	Spec. Cond. mmhos	pH
		PARAMETER (mg/l)												
Mar. 20	Processed	<2	0*		64	22	<1.0	<1.0	<0.2	0.3	41	17	1.0	6.7
Mar. 27	"	6	0*									26	0.3	5.8
Aug. 1	"	16	25	12,925				2.0		0.9	8200		20.5	6.0
Aug. 2	"	14	21	13,275						0.6	8200		20.5	6.0
July 16	Fresh	50	65		260			1.0	<0.3	1.0	90	17	0.3	6.7
Sept. 12	"	84	120		2770	67							4.1	4.8
Sept. 13	"	48	101		225									6.2

*Out of range of machine

TABLE 14. WASTEWATER CHARACTERISTICS - SALAD CUBES MACHINE, PLANT A, 1974

Date		BOD	TOC	TS	TDS	SS	Kjeld-N	NH_4-N	(NO_2+NO_3)-N	TP	Cl	Acidity mg/l as $CaCO_3$	Spec. Cond. mmhos	pH
		PARAMETER (mg/l)												
Mar. 20	(1)	1440	800		1,015	1694	94	> 50		17.3	34,600	394	70	3.7
	(2)	5	---		660	57	4	1	<0.2	1.2	375	21	1	6.4
	(3)	>2200	1100		5,200	66	182	> 50		26.2	46,400	686	89	3.6
	(4)	>2300	1100		84,710	71	162	> 50		29.0	47,000	617	90	3.6
Mar. 27		> 810	700								25,100	300	54	3.8
Aug. 1		540	530	26,170		1744		10		7.5	13,600		37	4.3
5		400	975	55,020		254		14		8.0	13,500		26	4.3

Desalting may be done before or after cutting, At the plant studied, cutting was generally done prior to washing. This evidently resulted in greater loss of soluble organics. As shown in Table 12, the more finely divided the product, the greater the TOC in the first wash water. While more dilute than spent brines, the processing waters are nevertheless high in chlorides, acidity, nitrogen, solids and organic carbon. Since a unit volume of cucumbers may require 2 to 3 times its volume in washwater, processing waters contribute a large volume of wastewater,

The wastewaters from cutting salad cubes from brinestock are high in chlorides, phosphorus, Kjeldahl nitrogen, organic carbon, and suspended solids (Table 13).

Wastewaters from the chipping unit (Table 14) were quite variable during the sampling periods, but on the whole were lower in TOC and BOD and higher in pH than those from relish and salad cubes operations. Wastewaters from the pricking machine were also quite variable (Table 15).

TABLE 15. CHARACTERIZATION OF WASTEWATERS FROM THE PRICKING MACHINE

	3/20	3127
BOD, mg/l	11	138
TOC, mg/l	<100	<100
SS, mg/l	13	---
TS, mg/l	2000	2000
$(NO_2 + NO_3)$-N, mg/l	<0.2	---
NH_4-N, mg/l	1.0	---
TP mg/l	0.3	---
P_H	6.1	4.3
Acidity, mg/l as $CaC0_3$	26	60
Specific conductivity, mmhos	3	38
Cl, mg/l	1100	16,200

Water Usage

Knowledge of the volumes of water used in different operations, especially in relation to the amount of product produced, is important in locating practices which waste water and which thus produce an unnecessarily large amount of wastewater to be treated. Meters were installed at a number of locations inside and outside the plant, and where possible, water usage was computed for unit of production. Water usage on the tankyard and in the restrooms is shown in Table 16. The seasonal nature of tankyard water requirements is readily apparent, the requirements reaching up to 150,000-200,000 gallons daily during the height of the green season, While the tank wash waters and the 36-hour drain brines will be released to waste during the green season, much of this water is used to prepare brines which may not be discharged for many months. Note from Table 16 that use of the meters during the study alerted personnel to leaks and broken water lines.

Tables 17-25 show the amounts of water used in various unit processes, both in terms of gallons used and in terms of volume per unit of product. The average, maximum, and minimum amounts of water required show, in some cases, wide variations. From observation of the operations, it appears that the overall water use, in each case, can be reduced to at least the average value. Excessive use of water can usually be traced to leaks, to leaving the water running while no product is being handled, or to overflow. The problem of excessive water use is especially obvious on days when large amounts of water are consumed when the unit is not in operation.

Table 26 summarizes the present water use at selected unit operations and indicates the potential reduction in water use if the water volume is cut to the minimum values observed. Reducing water consumption would of course reduce wastewater generation - in these operations, by 47-91%. Such drastic reduction would result in corresponding reduction in cost of water and in corresponding increased detention time in the hydraulically overloaded wastewater lagoons.

Table 25 shows water usage by pasteurizers. In this case, the data were converted to reflect gallons of water used per standard case - 24/303 (24 pints). Pasteurizer water is generally quite clean, being simply the cooling water. The BOD_5 is usually $\leq$ mg/l (Macon, personal communication). It can be, and often is, discharged directly to the municipal wastewater treatment system in order to reduce the volume of wastewater to be treated by the industry. Again wide variations, from 3.7 to 89.8 gallons per case, were seen. A consultation with plant personnel indicated that during portions of the study there were operational problems with the pasteurizers, leading to excessive water use. Since water use by the pasteurizers can run up to nearly 450,000 gallons per day, the importance of quick repairs is obvious. In the case of those plants which treat pasteurizer waters in their own wastewater treatment systems, elimination of excessive water consumption again saves on water costs and wastewater treatment. At the end of Table 25 a summary is shown of the average, maximum, and minimum volumes of waste used per standard case of product, showing the large variations and the potential for reduction.

Overall Plant Wastewaters

In Figure 2 is shown a layout of a typical North Carolina pickle plant with a perimeter drain system to collect tankyard and other runoff flows and with aerated lagoons for wastewater treatment. Tables 27-29 show the characteristics of the overall plant wastewaters at three plants. These wastewaters are the influent to the plant wastewater treatment systems and represent what is actually treated. At Plant A the wastewaters include tankyard runoff and all in-plant wastewaters except pasteurizer wastewaters; at Plant B, all wastewaters including pasteurizer wastewaters; at Plant C, all wastewaters except tankyard runoff.

TABLE 16. TANKYARD WATER USAGE, PLANT A, MARCH-AUGUST, 1974

Date	Day	Gallons	Activities*
Mar. 12	T	32,912	Grading yard; washdown
13	W	5,012	" "
14	T	15,484	Washdown, made 5,000 gal. brine
15	F	36,128	"
16	S	0	
17	S	0	
18	M	16,606	Brine made
19	T	10,397	Washed tanks
20	W	6,433	"
21	T	5,161	
22	F	7,256	Grading; washdown
23	S	0	
24	S	0	
25	M	55,277	2" line broken, ran all night
26	T	5,535	
27	W	23,263	Washed and filled tanks
28	T	16,232	" "
29	F	27,302	" "
30	S	0	
31	S	10,322	Broken water line
Apr. 1	M	46,750	Washed and filled tanks
2	T	20,046	" "
3	W	27,152	" "
4	T	27,826	" "
5	F	24,160	" "
6	S	0	
7	S	0	
8	M	95,669	Washed grading area, filled tanks, leak in restroom
9	T	23,637	Leak in restroom, Ajax machine; filled tanks
10	W	28,798	" " "
11	T	24,983	Filled tanks
12	F	53,632	Washed and filled tanks
13	S	0	Washed grading area
14	S	20,046	"
15	M	0	
16	T	64,253	Washed and filled tanks
17	W	98,736	Filled tanks
18	T	118,633	"
19	F	62,458	"
20	S	29,770	"

*All values include water used in restrooms

TABLE 16. TANKYARD WATER USAGE, PLANT A, MARCH-AUGUST, 1974 (continued)

Date		Day	Gallons	Activities*
Apr.	21	S	0	
	22	M	72,830	Filled tanks
	23	T	54,230	"
	24	W	22,515	"
	25	T	71,434	"
	26	F	75,249	"
	27	S	0	
	28	S	0	
	29	M	111,602	Filled tanks
	30	T	191,563	"
May	1	W	174,658	"
	2	T	152,368	"
	3	F	175,032	"
	4	S	2,244	"
	5	S	0	
	6	M	188,768	"
	7	T	123,420	"
	8	W	188,122	"
	9	T	162,989	"
	10	F	179,819	"
	11	S	61,336	"
	12	S	0	
	13	M	236,144	"
	14	T	223,727	"
	15	W	178,548	"
	16	T	186,476	"
	17	F	32,538	"
	18	S	21,542	"
	19	S	0	
	20	M	110,854	"
	21	T	87,292	"
	22	W	96,342	"
	23	T	95,071	"
	24	F	0	
	25	S	0	
	26	S	156,332	"
	27	M	41,364	"
	28	T	32,912	"
	29	W	39,195	"
	30	T	7,929	"
	31	F	24,534	"

*All values include water used in restrooms

TABLE 16. TANKYARD WATER USAGE, PLANT A, MARCH-AUGUST, 1974 (continued)

Date		Day	Gallons	Activities*
June	1	S	0	
	2	S	17,728	Filled tanks
	3	M	32,762	"
	4	T	16,980	"
	5	W	30,668	"
	6	T	20,196	"
	7	F	62,832	"
	8	S	0	
	9	S	15,484	Washed and filled tanks
	10	M	19,298	"
	11	T	33,361	"
	12	W	27,900	"
	13	T	55,202	"
	14	F	57,147	"
	15	S	67,769	"
	16	S	0	
	17	M	33,510	
	18	T	60,738	
	19	W	59,017	
	20	T	63,056	
	21	F	63,730	
	22	S	0	
	23	S	276,835	
	24	M	166,654	
	25	T	124,692	
	26	W	65,674	
	27	T	47,872	
	28	F	39,719	
	29	S	167,627	
	30	S	0	

* All values include water used in restrooms

TABLE 16. TANKYARD WATER USAGE, PLANT A, MARCH-AUGUST, 1974 (continued)

Date	Day	Gallons	Activities
July 1	M	76,446	Cleaning and washing tanks
2	T	54,754	"
3	W	77,119	"
4	T	76,894	"
5	F	90,134	"
6	S	155,210	"
7	S	0	"
8	M	106,889	"
9	T	137,632	"
10	W	76,296	"
11	T	126,487	"
12	F	76,894	"
13	S	128,955	"
14	S	0	
15	M	94,098	"
16	T	148,104	"
17	W	42,038	"
18	T	113,771	"
19	F	88,788	"
20	S	83,926	"
21	S	0	
22	M	109,956	"
23	T	82,804	"
24	W	113,098	"
25	T	76,894	"
26	F	83,552	"
27	S	152,517	"
28	S	0	
29	M	104,645	"
30	T	111,602	"
31	W	79,138	"
Aug. 1	T	101,504	Filled tanks, washed yard
2	F	87,890	Filled tanks
3	S	0	
4	S	89,685	"
5	M	50,789	"
6	T	77,343	"
7	W	88,488	"
8	T	76,670	"
9	F	60,588	"
10	S	0	
11	S	0	
12	M	0	
13	T	0	
14	W	0	
15	T	0	

TABLE 16. TANKYARD WATER USAGE, PLANT A, MARCH-AUGUST, 1974 (continued)

Date	Day	Gallons	Activities
Aug. 16	F	0	
17	S	0	
18	S	0	
19	M	87,591	"
20	T	97,090	"
21	W	92,453	"
22	T	89,835	"
23	F	54,754	"
24	S	104,870	"
25	S	0	
26	M	64,029	"
27	T	66,497	"
28	W	54,230	"
29	T	78,690	"
30	F	86,992	"
31	S	75,398	"

TABLE 17. WATER USAGE, WHOLE PICKLE MACHINE, PLANT A, JUNE-JULY, 1974

Date		Water Used Gal	Gal/bushel
June	1-24	0	
	25	3,000	0.31
	26	1,700	0.27
	27	400	0.10
	28	1,500	0.22
	29	3,100	0.32
	30	0	
	31	0	
July	1	1,700	0.37
	2	1,400	0.18
	3	7,200	1.02
	4	4,800	0.94
	5	3,400	2.06
	6	4,300	0.47
	7	-	-
	8	1,900	0.33
	9	1,400	0.21
	10	2,600	0.52
	11	1,800	0.34
	12	3,100	0.60
	13	4,600	1.32
	14	0	
	15	1,200	1.30
	16	500	0.56
	17	0	
	18	200	0.25
	19	1,000	3.70
	20-31	0	
		Av.	0.73
		Max.	3.70
		Min.	0.10

TABLE 18. WATER USAGE, STRIP MACHINE, PLANT A, JULY, 1974

Date	Water Used: Gal	Water Used: Gal/bushel
July 1	0	
2	5,800	10.8
3	10,400	13.4
4	6,300	7.7
5	5,000	1.4
6	24,400	27.7
7	0	-
8	7,100	8.2
9	12,000	9.7
10	2,200	1.7
11	14,000	13.7
12	9,700	9.0
13	32,500	37.8
14	0	-
15	700	1.1
16	12,600	11.9
17	21,400	18.4
18	10,800	9.3
19	3,100	5.6
20	9,700	16.2
21	0	-
22-29	No Production	
30	21,000	16.6
31	0	-
	Av.	12.4
	Max.	37.8
	Min.	1.1

TABLE 19. WATER USAGE FOR PROCESSING AND PACKAGING SALAD CUBES, PLANT A, MARCH-MAY, 1974

DATE	WATER USED (gal)	gal/bushel of product
March 12	3,000	4.6
13	1,000	1.4
14	2,200	2.2
15	800	0.7
16	0	
17	0	
18	2,500	3.6
19	2,400	2.3
20	2,400	2.0
21	2,300	4.2
22	1,300	1.9
23	0	
24	0	
25	0	
26	2,500	2.1
27	1,900	2.7
28	2,600	3.7
29	700	1.1
30	0	
31	0	
April 1	1,500	1.8
2	1,500	2.3
3	100	1.3
4	1,000	1.4
5	0	
6		
7		
8	2,200	3.1
9	400	1.3
10	1,200	1.1
11	800	1.1
12	0	
13	0	
14	0	
15	0	
16	800	no production
17	0	
18	0	
19	0	
20	0	

TABLE 19. WATER USAGE FOR PROCESSING AND PACKAGING SALAD CUBES, PLANT A, MARCH-MAY, 1974 (continued)

DATE		WATER USED (gal)	WATER USED gal/bushel of product
April	21	0	
	22	2,300	3.0
	23	22,000	28.4
	24	10,100	8.2
	25	2,000	1.0
	26	1,300	1.9
	27	0	
	28	0	
	29	0	
	30	0	
May	1	1,100	1.2
	2	3,900	2.4
	3	600	0.6
		Avg.	3.2
		Max.	28.4
		Min.	0.6

TABLE 20. WATER USAGE, CHIP MACHINE, PLANT A, PROCESSED CHIPS, SELECTED DATES

Instance	Water Usage Gal/day	Water Usage Gal/bu
1	1600	4.0
2	3100	4.4
3	3300	4.1
4	2000	2.9
5	1600	2.3
6	3400	4.8
7	3400	4.8
8	1900	2.7
9	5200	6.5
10	2600	3.7
11	2500	3.6
12	2000	5.3
13	1900	3.8
14	1900	2.7
15	800	1.4
	Ave.	3.8
	Max.	6.5
	Min.	1.4

TABLE 21. WATER USAGE FOR PRICKING MACHINE, PLANT A, MARCH-MAY, 1974

Date	Water Used (gal)	gal/bushel of product
March 12	6,000	12.0
13	2,500	7.4
14	2,700	3.8
15	2,800	4.0
16	0	-
17	0	-
18	2,000	2.8
19	2,200	4.6
20	3,200	21.3
21	1,400	no production
22	400	"
23	0	-
24	0	-
25	0	-
26	3,600	18.0
27	2,700	5.4
28	3,900	13.0
29	3,900	3.5
30	0	-
31	0	-
April 1	1,400	9.3
2	600	1.6
3	2,900	no production
4	3,600	"
5	0	-
6	0	-
7	0	-
8	3,900	no production
9	300	"
10	3,000	"
11	3,500	7.4
12	400	0.9
13	0	-
14	0	-
15	0	-
16	500	no production
17	4,300	"
18	3,500	"
19	3,200	"
20	0	-

TABLE 21. WATER USAGE FOR PRICKING MACHINE, PLANT A, MARCH-MAY, 1974 (continued)

Date		Water Used (gal)	gal/bushel of product
April	21	0	-
	22	0	-
	23	3,600	9.0
	24	400	no production
	25	2,400	6.0
	26	2,900	6.1
	27	0	-
	28	0	-
	29	2,900	4.0
	30	0	-
May	1	4,700	4.7
	2	1,000	no production
	3	2,900	"
	4	0	-
	5	0	-
	6	4,500	6.4
	7	2,800	11.2
	8	7,200	11.5
	9	2,200	9.8
	10	200	no production
	11	0	-
	12	0	-
	13	7,700	11.0
	14	4,300	10.8
	15	300	no production
	16	0	-
	17	1,700	3.8
	18	0	-
	19	0	-
	20	5,800	23.2
	21	5,100	34.0
	22	1,800	3.4
	23	0	-
	24	0	-
	25	0	-
	26	0	-
	27	2,000	20.0
	28	3,200	3.2
	29	2,300	3.3
	30	100	2.0
	31	0	-
		Avg.	8.8
		Max.	34.0
		Min.	0.9

TABLE 22. WATER USAGE, CHIPS MACHINE, PLANT A, FRESHPACK SEASON

	Water Use	
Date	gal	gal/bu
July 22	8100	9.5
23	5100	3.4
24	4400	8.8
25	3300	11.0
26	5000	5.9
27	2200	1.1
28	0	
29	0	
30	1900	No production
31	4200	4.9
August 1	1700	5.7
2	0	
3	2500	No production
4	0	
5	4300	3.9
6	3100	2.8
7-18	0	
19	2700	4.5
20	2300	3.3
21	3600	5.1
22	1600	2.3
23	0	
24	0	
25	0	
26	2800	4.3
	Ave.	5.1
	Max.	11.0
	Min.	1.1

TABLE 23. WATER USAGE FOR CHIP MACHINE, PLANT A, MARCH-MAY, 1974

DATE	WATER USED (gal)	WATER USED gal/bushel of product
March 12	20,000	25
13	12,500	31
14	0	
15	0	
16	0	
17	0	
18	0	
19	13,500	34
20	7,500	25
21	2,700	no production
22	15,000	22
23	0	
24	0	
25	0	
26	1,000	no production
27	13,400	27
28	18,100	90
29	8,400	17
30	0	
31	0	
April 1	0	
2	0	
3	0	
4	4,600	no production
5	0	
6	0	
7	0	
8	3,600	no production
9	16,100	32
10	14,900	21
11	0	
12	0	
13	0	
14	0	
15	0	
16	0	
17	0	
18	0	
19	0	
20	0	

TABLE 23. WATER USAGE FOR CHIP MACHINE, PLANT A, MARCH-MAY, 1974 (continued)

DATE		WATER USED	
		(gal)	gal/bushel of product
April	21	0	
	22	15,900	40
	23	10,900	36
	24	11,800	17
	25	17,800	37
	26	6,000	27
	27	0	
	28	0	
	29	0	
	30	0	
May	1	18,800	27
	2	19,700	28
	3	0	
	4	0	
	5	0	
	6	2,000	no production
	7	3,700	25
	8	15,500	48
	9	6,900	31
	10	0	
	11		
	12		
	13	400	no production
	14	10,700	24
	5	7,700	no production
	16	17,600	25
	17	0	
	18	0	
	19	0	
	20	400	no production
	21	2,900	no production
	22	800	no production
	23	16,600	30
	24	10,900	20
	25	0	
	26	0	
	27	9,600	24
	28	4,600	46
	29	16,600	55
	30	0	
	31	0	
			Avg. 32
			Max. 90
			Min. 17

TABLE 24. WATER USAGE FOR RELISH MACHINE, PLANT A, MAY-JUNE, 1974

DATE		WATER USED (gal)	WATER USED gal/bushel of product
May	1	0	
	2	0	
	3	0	
	4	0	
	5	0	
	6	2,900	4.1
	7	6,200	no production
	8	5,200	7.4
	9	4,000	5.0
	10	6,800	5.2
	11	0	
	12	0	
	13	7,600	8.4
	14	3,500	2.7
	15	3,800	6.1
	16	0	
	17	0	
	18	0	
	19	0	
	20	0	
	21	0	
	22	6,100	5.4
	23	4,700	4.2
	24	2,600	4.7
	25	0	
	26	0	
	27	3,400	4.9
	28	3,600	5.1
	29	0	
	30	0	
	31	0	
June	1	0	
	2	0	
	3	0	
	4	0	
	5	3,000	4.3
	6	0	
	7	0	
	8	0	
	9	0	
	10	0	
	11	0	
	12	0	
	13	0	
	14	4,600	7.1
			Avg. 5.3
			Max. 8.4
			Min. 2.7

TABLE 25 WATER USAGE, PASTEURIZERS, PLANT A, MARCH-AUGUST, 1974

Date	Production as equiv. 24/303 cases*	Water Consumption gal	Water Consumption gal/case
March 18	3046	46,376	15.23
19	5680	41,888	7.37
20	2520	47,124	18.70
21	3867	76,296	19.73
22	3243	25,432	7.84
26	6400 +	35,156	5.49
27	6000	41,888	6.98
28	4447	16,456	3.70
29	3460	26,928	7.78
Apr. 1	4732 +	49,368	10.43
2	5142	57,596	11.20
3		59,840	
4	3584	96,492	26.92
9	5447	104,720	19.23
10	1749	90,508	51.75
11	5753	85,272	14.82
12	1641	38,148	23.25
16	2402	116,688	48.58
17	4279	62,832	14.68
18	2494	60,588	24.29
19	5290	83,776	15.84
22	5384	80,036	14.87
23	2206	70,312	31.87
24	4058	69,564	17.14
25	3913	69,564	17.78
26	2481	151,096	60.90
29	3725	155,584	41.77
30	3300	85,272	25.84
May 1	6295	82,280	13.07
2	3991	91,256	22.87
3	4948	97,988	19.80
6	6158	62,832	10.20
7	6087	93,500	15.36
8	4334	81,532	18.81
9	6253	73,304	11.72
10	4447	83,776	18.84
13	2619	69,564	26.56
14	5306	100,980	19.03
15	3414	95,744	28.04

TABLE 25. WATER USAGE, PASTEURIZERS, PLANT A, MARCH-AUGUST, 1974 (continued)

Date		Production as equiv. 24/303 cases	Water Consumption gal	gal/case
May	16	7131	92,004	12.90
	17	2124	80,036	37.68
	20	3638	103,972	28.58
	21	3136	105,468	33.63
	22	1479	121,924	82.44
	23	3699	77,792	21.03
	24	4946	89,012	18.00
	27	2303	105,468	45.80
	28	4886	61,336	12.55
	29	3425	65,076	19.00
	30	4196	103,972	24.78
June	3	4221	50,116	11.87
	4	6895	180,268	26.14
	5	6745	371,008	55.00
	6	3723	201,212	54.05
	7	1942	106,216	54.69
	10	1965	157,828	80.32
	11	3147	205,700	65.36
	12	3367	302,192	89.75
July	1	8,605	172,040	20.0
	2	16,553	392,700	23.7
	3	16,838	418,880	24.9
	4	25,043	402,424	16.1
	5	11,747	349,316	29.7
	6	18,116	714,340	39.4
	8	15,271	314,160	20.6
	9	16,007	385,968	24.1
	10	15,879	311,168	19.6
	11	17,132	360,536	21.0
	12	11,942	364,276	30.5
	13	11,491	448,800	39.0
	14	0	0	-
	15	6,135	74,052	12.1
	16	6,269	358,292	57.2
	17	6,340	302,940	47.8
	18	6,560	192,236	29.3
	19	4,533	228,140	50.3
	20	0	112,948	-
	21	0	0	-
	22	0	748	-
	23	6,578	194,480	29.6
	24	5,462	114,444	21.0
	25	10,837	181,764	16.8
	26	5,840	123,420	21.1
	27	3,133	152,592	48.7
	28	0	0	-
	29	0	24,684	-
	30	7,688	117,436	15.3
	31	5,319	153,340	28.8

TABLE 25. WATER USAGE, PASTEURIZERS, PLANT A, MARCH-AUGUST, 1974 (continued)

Aug. 1	3,047	151,096	49.6
2	6,742	137,632	20.4
3	0	0	-
4	0	0	-
5	3,963	70,312	17.7
6	3,932	166,056	42.2
7	3,150	124,916	39.6
8	6,428	139,876	21.8
9	6,187	116,688	18.9
10	0	0	-
11	0	0	-
12	0	0	-
13	0	0	-
14	0	0	-
15	0	0	-
16	0	0	-
17	0	0	-
18	0	0	-
19	2,332	65,076	27.9
20	4,197	130,152	31.0
21	0	3,740	-
22	6,250	73,304	11.7
23	4,578	68,816	15.0
24	0	0	-
25	0	0	-
26	4,616	56,848	12.3
27	1,800	41,140	22.8
28		91,256	-
29	3,636	70,312	19.3
30	7,915	44,132	5.6
31	0	0	-

ummary:

Month	Water Used, gal/case		
	Ave	Max	Min
March	10.3	19.7	3.7
April	26.2	60.9	10.4
May	27.6	82.4	10.2
June	54.6	89.8	11.9
July	28.6	57.2	12.1
August	23.7	49.6	5.6

*Conversion factors used:
x = 24/303 = 24 pt ≈ 24 lb; 12/8 oz = 0.25 x; 12/12 oz = 0.33 x; 12/16 oz = 0.5 x; 12/22 oz = 0.7 x; 12/26 oz = 0.8 x; 12/32 oz = x; 6/48 oz = 0.75 x; 6/½ gal = x; 4/gal = 1.3 x; 6/#10 = 2 x.

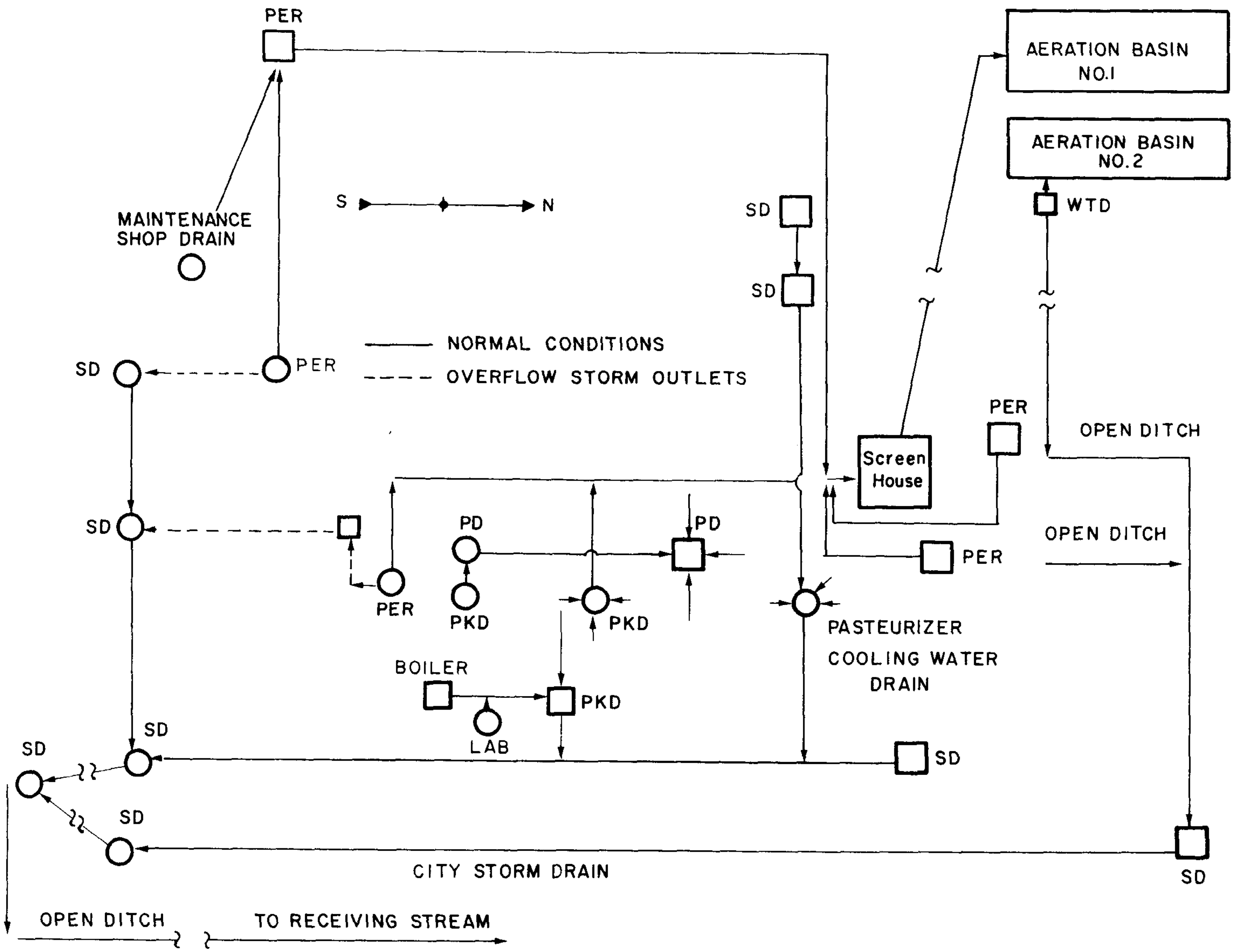

FIGURE 2. DIAGRAM OF LAYOUT OF PLANT A (not to scale). Key: SD - Storm Drains, PER - Tank Yard Perimeter Drains, PD - Process Room Drains, PKD - Packing Room Drains, WTD - Wastewater Treatment Drain

TABLE 26. SUMMARY OF PRESENT AND POTENTIAL WATER USAGE IN UNIT OPERATIONS

Unit	Water Usage, gal/bushel		
	Average	Minimum	Potential Reduction
Whole pickle machine	0.73	0.10	0.63 (86 %)
Strip machine	12.4	1.1	11.3 (91 %)
Salad cubes machine	8.8	0.9	7.9 (90 %)
Chips machine, fresh season	5.1	1.1	4.0 (78 %)
Chips machine, brine season	32	17	15 (47 %)
Relish machine	5.3	2.7	2.6 (49 %)

In general wastewater reflected type of input; in most cases, as expected, wastewater strength was greatest at Plant A.

In nearly all cases pH was low -3.6-4.9. BOD_5 levels ranged from 200 to nearly 4000 mg/l. TOC levels were correspondingly high. To plant officials Kjeldahl nitrogen levels were surprisingly high - up to 90 mg/l. One must consider, however, that many soluble components of the cucumbers leach out during brining and are discarded along with the spent brines and processing waters. Oxidized nitrogen (nitrite, nitrate) concentrations were very low, usually less than 1 mg/l. Phosphate-P levels were generally less than 10 and were lowest at Plant C. Some of the phosphorus can be attributed to leached cucumber components, some to detergents and lubricants.

Suspended solids values were high - up to 670 mg/l. In general they were highest at Plant A, reflecting the effect of tankyard runoff.

Likewise, chloride and total dissolved solids were highest at Plant A. It should be stressed that chlorides, along with many of the other dissolved solids, are unaffected by conventional primary and secondary treatment. Therefore, any chlorides entering the wastewater system will be discharged eventually to the receiving stream. The lagoon system does have the advantage of moderating the impact of concentrated "slugs."

Representative volumes of wastewater discharges at Plant A are shown in Table 30. Note that volumes are greater during the freshpack season when the plant operates at maximum capacity and when 24-hr operation for 6 days per week is common.

TABLE 27. PLANT WASTE CHARACTERISTICS, PLANT A, 1974

DATE	BOD	TOC	TS	TDS	SS	Kjeld-N	NH_4-N	$(NO_2 + NO_3)$-N	TP	Cl	Acidity mg/l as $CaCO_3$	Specific Conductivity mmhos	pH
	mg/l												
May 9 day	1560	870					19.5	0.7	6.5	11,000			3.8
night	1020	910					9.0	0.3	7.8	16,600			3.9
21 day		405		20,170	175	37.0	17.5	0.4	4.5	11,300	154	25	4.3
night		629		44,400	320	77.0	27.5	0.3	4.4	20,200	180	41	4.3
22 day		375		19,330	210	41.0	19.0	0.3	4.4	11,000	163	25	4.3
night		579		32,400	310	59.0	26.5	0.4	6.1	18,800	171	39	4.4
23 day		360		19,180	220	36.0	16.0	0.3	4.5	10,600	171	23	4.3
night		677		34,740	390	58.0	26.5	0.3	6.4	19,500	171	39	4.4
28 day	2100	704	27,380	27,120	163	51.5	22.5	0.3	6.4	15,900	343	38	3.9
night	1620	563	25,745	25,615	134	80.0	32.0	0.4	10.6	14,700	369	34	3.9
29 day	780	495	23,525	23,420	104	48.5	24.5	0.3	7.7	16,300	317	31	3.9
night	1140	744	30,620	30,440	187	64.0	27.0	0.4	8.4	18,600	386	41	3.8
June 6 day			9,429			9.0				6,450		12	
7 night			7,295			13.5				4,350		7	
10 day	1200	694	21,610		313		18.0	0.8	4.1		377	26	4.1
11 night	600	319	19,690		98		9.0	0.6	2.9		189	23	4.2
13	240	116	14,220	14,000	226					26,000	9	18	7.7
July 16	1410	800		18,320	315		12.0	0.5	5.7	10,000	154	24	4.8
Aug. 2	1320	1650	29,900		290		27.0		6.7	11,700		30	4.4
5	1560	1790	23,470		166		14.0		5.8	10,200		29	4.0
6	2040	1107	21,200		77		8.0		3.8	5,800		18	4.0
7	1920	1159	23,950		157		25.0		5.6	9,100		25	4.6
28	2520	1520		36,545	156					22,000			3.7
29	2940	1660		42,711	428					25,000			3.6
Sept. 11	3840	2793		189,840	635							110	4.1
12	1980	1117		117,450	595							85	4.5

TABLE 28. PLANT WASTE CHARACTERISTICS, PLANT B, 1974

Date	PARAMETER TOC	TKN	NH_4-N	(NO_2+NO_3)-N	TP	Cl	TS	TDS	SS	pH	Acidity mg/l as $CaCO_3$	Specific Conductivity mmhos
	mg/l											
May 9	715	29.0	16.0	0.9	4.1	1,700						
24	490	44.0	19.0	1.1	4.2	11,300	37,980		191	4.0	240	25
June 29	490					3,600		4,690	128	4.6		9
July 11	520					11,500		17,520	535	4.9		17
12	230					4,000		5,810	105	4.9		9
15	1040				15.5		16,580			4.4	197	21
23	262				3.4		10,050			4.8	69	14
Aug. 7	490		9.5	0.5	3.9	3,150		725	19	3.9		
10	1720		6.5	0.5	5.4	4,450		1,253	49	4.0		
14	520		13.5	0.6	5.5	6,300		1,175	460	4.0		
20	730		23.5	0.5	10.0	8,400		1,603	670	4.0		
21	440		14.5	0.5	5.5	3,350		1,470	56	3.9		

TABLE 29. PLANT WASTE CHARACTERISTICS, PLANT C, 1974

Date		PARAMETER BOD (mg/l)	TOC	TKN	NH_4-N	(NO_2+NO_3)-N	TP	Cl	TS	TDS	SS	pH	Acidity mg/l as $CaCO_3$	Specific Conductivity mmhos	Comments
May	16	1740	890	16.5	6.0	0.3	2.8	4,200	7660		98			6.6	Hamburger dill chips
	21	-	1040	70.0	21.5	0.5	5.0	8,100		17,340	126	3.6	686	22.0	2 lines, processed, hamburger dill chips/sweet relish
	24	-	750	89.0	42.0	1.4	4.2	19,800		35,880	305	3.8	240	39.0	Processed, hamburger dills
	29	360	378	39.5	18.0	0.3	5.7			16,489	42	3.4	240	26	
June	8	360	240	-	<2.0	0.3	1.5	8,250	1843		162	4.5	51	1.9	Fresh pack whole and spears; processed relish.
	16		75	<3.0	<3.0		0.8	740		940	36			1.6	3 lines, all dill
	21	1650	950					405			61	4.5		1.2	2 lines; 1 sweet chips, the other, whole dills
Aug.	8	216	231		2.0		1.9	1,750	3468		161	4.6		5.7	

TABLE 30. EFFLUENT DISCHARGE VOLUMES, PLANT A, 1974

Dates	Daily Volume, gallons/day* Maximum	Average
Jan. 21-Feb. 15	240,000	200,000
Mar. 18-Apr, 12	250,000	215,000
Apr. 16-May 10	325,000	248,000
May 13-May 31	290,000	230,000
June 10-June 22	350,000	260,000
July 1-July 19	320,000	250,000
July 19-Aug. 19	260,000	205,000

*Information provided by plant personnel. Volumes do not necessarily represent total volume of wastewater since during heavy rainfall excessive flow from the tankyard can be bypassed around the treatment system.

Potential for Ground Water Contamination

Although spent tankyard brines are often discharged directly onto the ground and although unlined ponds or lagoons are frequently used for treatment of pickle wastewaters, there appears to be no published information on the potential for groundwater contamination by chlorides in these wastes. Investigations of chloride contamination of groundwater by chlorides from other sources seem to indicate that chlorides move readily through some soils, especially clay soils, and that the negative adsorption of [Cl]- by clay particles results in movement of chloride ahead of the water front (Wierenga, O'Connor, and Dregne, 1972).

The vertical movement and the degree of spread under various conditions of salt concentration and soil type is somewhat unpredictable (Brunotte et al, 1971). As the brine moves through the soil, ionic composition changes due to ion exchanges with soil components and leaching of previously accumulated salts (Hornsby, 1973).

Fryberger (1972) described the pollution of a freshwater aquifer by oil field brines, resulting from disposal of these brines in an unlined pit. He estimated that flushing of the aquifer would take more than 250 years and recommended extreme caution in discharge of brines to unlined pits.

Discussion and Conclusions

In general, as expected, wastewaters from cucumber pickling operations are characterized by high chloride content, high oxygen demand, low pH, and high total and suspended solids. Nutrient concentrations, especially Kjeld-N, are also appreciable. The 36-hour drain from small cucumbers contains about 0.6 lb NaCl/gal and also contains appreciable organic carbon and other components leached from the cucumbers. The spent tankyard brines contain high concentrations of salt (1.0-1.6 lb NaCl/gal) and also, on the average, 3400 mg/l of organic carbon, 330 mg/l of suspended solids, 730 mg/l of total Kjeld-N, 90 mg/l of phosphorus, and 2300 mg/l of acidity (as $CaCO_3$). The pH falls between 3 and 4. These brines have a high pollutional potential and are much more concentrated than domestic sewage.

Desalting (processing) wastewaters are also typically of low pH and relatively high chloride concentrations. In the first desalting water chloride levels are about 40 gm Cl/l. Organic carbon levels are high and in general the more finely divided the product, the higher the TOC as well as the Kjeld-N and phosphorus levels. Apparently, the greater the surface area exposed to the processing water, the greater the loss of soluble components and fragments of cucumber tissue.

Water requirements per unit of cucumbers handled vary widely within each unit process. Part of the variation can be attributed to leakage, overflow, or failure to close valves during times when the unit is not in operation. The water use studies indicate that 40-90 % of the water currently used is unnecessary. Reduction of unnecessary water use would lower the hydraulic loading on the wastewater treatment system, increasing the detention time, and would also reduce cost of water.

The potential for reuse of pasteurizer water in cleanup or other areas should be investigated. Alternatively, to reduce loading on the wastewater treatment system the possibility of discharging the relatively clean pasteurizer water to the municipal system should be investigated by plants not currently doing so.

Approximately 40-50 % of each year's cucumber crop is fresh-packed rather than brined, and fresh-pack operations generally predominate during the period from May-August. However, the plant wastewater continues to be characterized by high salt and organic carbon levels, since during this time 50-60 % of the cucumbers are brined. Brining is associated with intensive tankyard activity, including drainage of 36-hour brines from the smaller cucumbers. Salt spillage is also most apt to occur at this time. Loss of brines by overflow during rainfall and by leakage also occurs. With perimeter drainage systems, all wastewaters from the tankyard area will be discharged to become a part of the overall plant wastewater. Therefore, it is not surprising that highsolids and chloride levels are found year-round at plants with perimeter systems.

Because of the highly pollutional nature of tankyard brines the present widespread practices of discharging these brines untreated onto the tankyard should be questioned. In addition, the potential of chloride contamination of groundwater by tankyard runoff or by seepage from unlined wastewater treatment ponds should be investigated.

LABORATORY EVALUATION OF COAGULATION-PRECIPITATION AND ULTRAFILTRATION FOR REGENERATION OF STORAGE BRINES

One approach to reduction of salt in pickle wastewater-s is regeneration and reuse of salt brines within the manufacturing process. As previously noted there are two major sources of high salt wastes: (1) the used (spent) brine from tanking and storage, and (2) the processing waters resulting from washing and firming the salt stock prior to packing. Tankyard brines, which are currently discharged into the ground in most plants, are of two strengths (1) the "36-hr drain" of -7% salt from the smaller cucumbers, and (2) the storage brine of -16% salt.

Coagulation-Precipitation

Coagulation-precipitation as a means of brine regeneration has been investigated by Geisman and Henne (1973). These investigators, basing their work on earlier work by Popper et al. (1967), used chemical precipitation followed by clarification (filtration) and activated carbon treatment. Of the chemicals tested, NaOH was found to be the most economical and effective. Brines of 50° and 70° salometer were treated by adding NaOH to a pH of 11.0, then filtered through cotton precoated with diatomaceous earth. Filter effluent was passed through an activated carbon bed, then neutralized with HCl. Geisman and Henne reported COD reductions of 50-97%, but since COD data are not included in the tabulated data, it is not possible to determine volumes used or the step in the process responsible for the reduction. When the process was tested on commercial scale, the high costs of filtering and activated carbon treatment resulted in omission of these steps. Settling for 48 hr, followed by removal and neutralization of the clear supernatant, was substituted.

Pickles made with brine regenerated by this method were found to be comparable in quality to those made with freshly made brine.

Geisman and Henne estimated the cost for treating brines by this method at $1450 for brine for 100,000 bushels of cucumbers. This cost would be counterbalanced by a savings of $3100 for salt needed for that amount of brine.

Palnitkar and McFeeters (1974) treated spent brines with alkali, using the method of Geisman and Henne. Their results were similar to those found in our work, i.e., little or no organic material was removed and only small amounts of Kjeldahl nitrogen were removed. They fermented cucumbers (size 3B) in untreated brine, fresh brine, base treated brine, and heat treated brine, and found that there was no difference in color, odor, and texture.

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Repetitive recycling experiments indicated that brine could be recycled at least 5 times with no effect on product quality, even though there was some buildup of organics. Their work also indicated a significant reduction in bloater content in pickles fermented in spent brine.

Laboratory studies conducted by Bell (personal communication, 1972) indicated that coagulation-precipitation of brine with lime and NaOH at pH 11 essentially eliminated softening enzyme activity, either by irreversible denaturation of the enzyme or by its physical removal with the sludge.

Since high pH coagulation-precipitation appeared to eliminate the softening enzyme, laboratory studies were conducted on-site at Plant A and at the UNC Wastewater Research Center to estimate amount of chemicals required for regeneration of brines by this method. A variety of storage brines from different sizes of cucumbers, as well as from other vegetables, was examined to determine if the brines differed significantly in their requirements.

A list of tanks, contents, and dates of filling was obtained from the yard foreman, and representative tanks were chosen for sampling. Samples were removed from a vertical sampling channel located in each tank which allows sampling at all depths.

To 1-L aliquots of each brine, 0.1% (1 gm) of hydrated lime [$Ca(OH)_2$; purified grade] was added during rapid mixing with a magnetic stirrer. pH was monitored with a pH meter (Leeds and Northrup, 7400-A 2 Series).

pH was recorded after lime addition. pH was then raised toll by addition of 5% NaOH solution (prepared by diluting commercial NaOH solution, 50% concentration, commonly purchased by pickle plants). After 5 min mixing during which floc formed, the brine was transferred to a 1-L graduate cylinder and allowed to settle for 30 min. Then, sludge volume was noted and a portion (300 ml)of supernatant was decanted to a 500 ml beaker (Pyrex) and titrated with acetic acid, 6.5% (prepared by diluting commercial grade acetic acid , 13% concentration) to pH 7.0. Alkali and acid requirements for different brines are indicated in Table 31.

Samples of untreated and treated brine were analyzed for TOC, solids, N forms, total phosphorus, and Cl . Results are shown in Table 32. As expected, phosphorus content was decreased and chloride content was unaffected. No appreciable amount of organic carbon was removed, indicating that the organic carbon is primarily in soluble form. While a visible improvement in overall clarity of the brine was achieved, there was no significant change in suspended solids levels. Apparently there was only a qualitative difference, possibly due to substitution for some of the solids initially present by a fine light chemical floc.

The results show a wide variation in buffer capacity among the various types of storage brines. Extremes generally were found in vegetables *was* other than cucumbers. Onion brine was especially low in buffer capacity, and the addition of the lime was sufficient to raise pH to 11.6 and effect good coagulation. Of course, little sludge was produced. At the other

TABLE 31. BASE OR ACID REQUIRED FOR SPENT BRINE COAGULATION-PRECIPITATION

STOCK	pH		5% NaOH to pH 11.5 (ml/l or gal/1,000 gal)	Sludge (% volume)	6.5% Acetic Acid to (pH) (ml/l or gal/1,000 gal)
	Initial	After 0.1% Lime Addition			
Cucumbers, field run, fall	3.25	3.70	53.4	38%	43.6 (6.8)
Cucumbers, field run, spring	3.60	4.70	29.7	50%	37.6 (6.8)
Cucumbers, 1B, spring	3.40	8.90	14.6	26%	27.3 (5.8)
Cucumbers, 2A, spring	3.40	4.35	24.8	33%	27.3 (6.7)
Cucumbers, 3, fall	3.55	3.95	43.3	46.5%	41.6 (5.9)
Cucumbers, 4, fall	3.50	4.20	20.8	no data	28.3 (6.8)
Cucumber relish, spring	3.30	5.10	19.8	47.5%	20.3 (6.3)
Cucumber relish, fall	3.30	3.90	46.4	49%	39.6 (6.8)
Cauliflower	3.90	6.10	51.9	30%	77.9 (6.95)
Pepper	4.00	8.80	59.7	no precipitation after 20 min.	- - - -
Onion	4.10	11.60	----	5%	35.5 (4.6)

TABLE 32. TANK-YARD BRINE SAMPLES BEFORE AND AFTER COAGULATION-PRECIPITATION

PRODUCT	TANK * NO.	TOC	SS	NH_4-N	Kjeld-N	TP	PH
		mg/l					
Cucumbers, field run, fall	18-l i	5800	388	275	500	87.5	3.3
	f	5500	437	250	400	10.1	11.8
Cucumbers, field run, spring	30-4 i	3700	451	200	300	85.0	3.7
	f	3300	342	175	275	5.6	11.9
Cucumbers, 1B spring	45-14i	1400	460	200	225	38.5	3.5
	f	1400	482	113	163	4.5	11.7
Cucumbers, 2A, spring	24-121	2800	288	175	250	56.5	3.4
	f	2800	530	150	225	7.8	11.6
Cucumbers, 3, fall	23-16i	4700	260	300	425	83.5	3.6
	f	4800	340	275	425	6.6	11.7
Cucumbers, 4, fall	16-18i	3500	343	225	363	152	3.5
	f	3400	348	213	338	6.0	11.4
Cucumber relish, spring	l0-13i	1300	259	100	150	28.0	3.2
	f	1200	408	88	138	4.9	11.5
Cucumber relish, fall	24-14i	5000	337	325	500	93.0	3.5
	f	4700	321	275	450	6.2	11 8
Cauliflower	28-17i	7700	447	350	950	155	4.1
	f	6900	434	375	825	5-3	11.7
Pepper	25-7 i	6900	262	125	350	80.0	4.3
	f						
Onion	l-1Oi	0	131	40	45	8.9	4.1
	f	0	444	20	30	1.5	11.9

* i= initial, untreated sample; f= final, treated sample -

extreme, pepper brine had a high buffer capacity and exhibited little or no settling after 30 min settling time,

Cucumber brines exhibited a range of buffer capacities, and there was no apparent correlation of buffer capacity with size or season. On the average, approximately 0.3% (vol/vol) of caustic soda solution (50% NaOH) was required to raise the pH to 11.5. To neutralize the supernatant, approximately 1.7% (vol/vol) of acetic acid solution(l3%) was required.

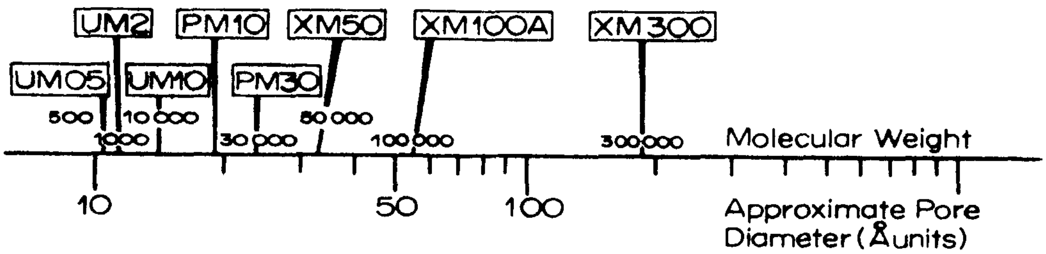

FIGURE 3. RETENTION OF ULTRAFILTERS
Retention depends on molecular size and configuration. MW cut-off shown applies to protein. (From Amicon Corp., 1972)

Ultrafiltration

Molecular filtration (ultrafiltration) is a relatively new process for removing large molecular weight (MW) compounds from aqueous solutions. By selection of a membrane of suitable pore-size, compounds of a specific MW range can be retained. While ultrafiltration has been used to recover valuable components from milk and other wastes, no information has been published on the possibility of treating pickle brines by this method. Since enzymes are large macromolecules, generally with molecular weights of 100,000 or more, it was anticipated that softening enzyme would be easily removed with a relatively large pore size. The bulk of the soluble organic material in pickle brines has not been identified. It was hoped, however, that with suitable membranes substantial amounts of this organic carbon could be removed.

A. Materials and Methods

1. Membranes

a. Type

Amicon Diaflo[R] ultrafilters were employed. This type of filter consists of an anisotropic polymeric membrane on a porous substructure. Characteristics of different ultrafilters and microporous filters are shown in Figure 3. For these studies the following membrane sizes were employed: XM 300, XM lOOA, XM 50, PM 30, PM 10, and UM 2. The number of each type of filter indicates its porosity in terms of molecular weight, i.e., XM 300 has a mean pore size of 300,000 MW; XM, of 50,000 MW. As noted in Amicon literature, since indicated pore size is a mean value, for maximal retention a cut-off size well below MW of the solute to be retained is generally chosen.

b. Membrane Preparation and Storage

Ultrafilters of the XM series are supplied ready for use. Filters in the PM and UM series have a glycerin film to prevent drying out; these filters were prepared by rinsing in distilled water for 1 hr with one change of water prior to use. Filters could be stored by refrigeration in 10% ethanol. In most instances, however, new filters were used to make results more comparable.

C. Flux

During serial filtration experiments rate of ultrafiltration was determined for each of the membranes. This was done by collecting filtrate in 10 ml graduate cylinders using a stopwatch to measure time required for production of 5 ml aliquots. By use of two stopwatches, flow rate over time could be determined.

2. Cell

For ultrafiltration studies a stirred cell (Amicon) was employed. Cell capacity is 50 ml of feed solution, but larger volumes can be filtered continuously by coupling a feed reservoir between the cell and the pressurized gas tank. Magnetic stirring in the cell minimizes concentration polarization. To prevent heating of cell contents, air from a laboratory air line was used to cool the magnetic stirrer.

3. Pretreatment of Sample

Preliminary experiments indicated that unless gross suspended solids were removed from the feed, ultrafiltration rates were extremely slow. Therefore, feed samples were pretreated by vacuum filtration through a membrane filter (5.0 um pore size, Metricel GA-l, Gelman).

4. Temperature

All filtrations were performed in a constant temperature room maintained at 21 C. Samples stored by refrigeration were allowed to reach room temperature before filtration.

5. Pressure

Pressure for the cell was provided with pressurized nitrogen gas and regulated by the pressure valve on the tank. A pressure of 30 psi was used for XM 300, XM lOOA, and XM 50 membranes; 60 psi, for smaller pore-sized membranes.

6. Experimental Approach

Experiments involved two approaches to ultrafiltration: parallel and serial. In the former, the feed sample was subdivided into identical aliquots, each of which was passed through a different size of filter. In the latter, the feed was passed through a large-pore filter, the filtrate serving as feed for the next finer filter, and so on. In the second procedure it was difficult to filter enough through the initial membranes to provide sufficient volume for feed and analyses throughout the filter series.

7. Analytical Procedures

Pickle brine samples present difficulties in analysis due to corrosiveness and to interference of Cl in many analytical procedures. In many cases analytical methods required modification to compensate for these characteristics.

a. Chloride

Chloride concentrations were measured chemically or electrometrically. In earlier work and in all of the coagulation-precipitation and ultrafiltration studies Cl was determined using the high concentration modification of the mercuric nitrate method (standard Methods,1971). Even with this modification, the high salinity of spent brines required considerable (x 50) dilution of samples.

b. COD

Chemical oxygen demand (COD) was measured using the procedure recommended for wastewaters (Standard Methods, 1971.). To compensate for Cl interference, mercuric sulfate was added in the proportions indicated.

C. TOC

Total organic carbon (TOC) analysis generally offers a rapid means of measuring organic carbon in wastewater. However, problems were encountered with brine samples due to their high Cl content. With the instrument available (Model 915 TOC Analyzer, Beckman Instruments), brine caused corrosion of the combustion chamber and the adjacent stainless steel tubing. Discussions with Beckman personnel indicated that there was no way to modify the instrument so that it could handle undiluted spent brines: Therefore, samples were diluted sufficiently to lower Cl concentration to <l000 mg/l. This resulted in unavoidable loss of some accuracy, especially in instances in which Cl concentration was high in proportion to organic carbon concentration.

d. Pectinase Activity

To assure high levels of enzyme activity in the untreated brine, commercial pectinase was added prior to filtration. These high levels made it possible to magnify any reductions in enzyme activity. Pectinase was obtained from the USDA Food Fermentation Laboratory in Raleigh.

All analyses of pectinase activity were performed by Ms. Horney at the USDA Laboratory under the direction of T. A. Bell who developed the analytical method (Bell et al, 1955). In brief, the method is based on the ability of pectinase to break down sodium polypectate and thus reduce its viscosity. Since salt interferes with the test, the sample must be dialyzed prior to analysis.

B. Results

Preliminary tests were conducted by filtering 50 ml aliquots of 36-hr brine through the largest filters (XM 300, XM lOOA, and XM 50). Chloride and COD concentrations were determined on the untreated brine and the filtrate. Pectinase activity was measured in untreated brine, filtrate, and concentrate. Results of these tests are shown in Table 33.

That pectinase was being removed by ultrafiltration is indicated by a decrease in filtrate activity along with increased concentrate activity. As anticipated, salt concentrations remained constant, within expected experimental error. Note that the amount of COD removed was approximately the same regardless of filter size. This removal was due primarily to removal of suspended solids rather than to removal of soluble organics.

Results from a serial filtration of 36-hr brine through the XM 300, XM lOOA, and XM 50 filters are shown in Table 34. Again, the salt concentrations were found to remain nearly constant throughout and there were no marked changes in COD although some removal was observed as indicated primarily by increased values in concentrate samples. The low pectinase activities throughout were due to enzyme breakdown during storage of the stock solution. For subsequent tests fresh solutions were made. However, the problem of whether decreases in enzyme activities could be attributed to effects of ultrafiltration or were merely a function of time needed to be resolved.

To resolve this problem, a fresh batch of brine with added pectinase was allowed to stand at room temperature with no preservative (toluene)

TABLE 33. EFFECT OF PARALLEL ULTRAFILTRATION ON 36-HR BRINE

Sample	Parameter: Cl mg/l	COD mg/l	Pectinase Activity (units)
Untreated	54,300	3,700	856
XM 300, filtrate	53,000	2,400	{570 516
XM 100A, filtrate	54,800	2,400	{516 338
XM 100A, concentrate	------	-----	1158
XM 50, filtrate	52,400	2,300	{161 246
XM 50, concentrate	------	-----	1393

TABLE 34. EFFECT OF SERIAL ULTRAFILTRATION (XM 300 → XM 50) ON 36-HOUR BRINE

	Filtrate			Concentrate		
Sample	Cl mg/l	COD mg/l	Pectinase units	Cl mg/l	COD mg/l	Pectinase units
Untreated	25,700	16,200	39			
XM 300	26,100	15,700	34	---	18,800	110
	26,100	16,100	7			
	26,300	16,000	14			
XM 100 A	25,600	15,100	11	25,500	16,100	11
	25,400	15,400	14			
	25,000	15,500	13			
	25,500	15,600	9			
XM 50	25,600	15,100	5	24,700	15,400	37
	24,500	15,000	8			

added. At intervals samples were taken, preserved with toluene, and refrigerated. Enzyme activity levels are shown in Table 35.

TABLE 35. EFFECT OF STANDING ON PECTINASE ACTIVITY

Time,hr	Pectinase Activity, units
0.0	650
2.5	957
4.0	800
6.0	1140
12.0	828

The reason for the low level of activity in the fresh sample is not known. More important are the relatively constant levels at the later times, indicating that the enzyme does not break down within a few hours. It also points out the relatively wide variation that may occur within one enzyme test. Therefore, actual reduction would be indicated by larger differences than those observed above.

Serial filtration was repeated with smaller pore-sized ultrafilters. Results are shown in Table 36 and in Figure 4. Again, the COD was affected very little by ultrafiltration. Enzyme activity was substantially reduced by ultrafilters smaller than XM 50.

Since serial filtration necessitates filtering larger amounts of brine through the larger-sized filters, the different filter types could better be compared by filtering equal amounts of untreated brine. Again, pectinase was added and the sample was pretreated by filtration through a 5.0 u membrane filter. Results of such tests are shown in Table 37 and in Figure 5. Only enzyme activity was monitored since it had been demonstrated repeatedly that no significant removal of COD could be achieved. It is apparent that pectinase is removed significantly by ultrafilters PM 30 and smaller.

Flux of filtrate through the various sized ultrafilters during serial filtration is shown in Figure 6. Originally experiments were designed to use the same pressure (30 psi) for each filter, but filtration rates became so slow that higher pressure was used (60 psi). It should also be noted that solute concentrations in the feed solutions of the smaller pore-sized ultrafilters would be decreasing continually. While this does not make the flux performance for each filter as comparable as if the same feed solutions were used, common operating procedures may use 20 or more different sizes of filters in series. These results should show optimum flux rates for brine solutions at the pressures shown.

TABLE 36. EFFECT OF SERIAL FILTRATION (5.0 μ → UM 2) ON 36 HOUR BRINE

Filter	Filtrate		Concentrate	
	COD mg/l	Pectinase Activity	COD mg/l	Pectinase Activity
Untreated	3350	1,446		
5.0 μ	3330	1,510		
XM 300	3270	1,350	3330	too high to measure
XM 100A	2800	1,330	3000	1,730
XM 50	2700	950	2800	3,100
PM 30	2800	236		
PM 10	2700	65	2900	310
UM 2	2500	10	3200	150

TABLE 37. EFFECT OF ULTRAFILTRATION (2000-10,000 MW PORES) ON PECTINASE ACTIVITY OF BRINE

	Pectinase Activity (Units)	
Filter	Filtrate	Concentrate
Untreated	3028 2927	
5.0 μ	2800 2560 2509	
XM 100A	2625 1936	3229 3257
XM 50	990	4793
PM 30	28	4393
PM 10	16	4742
UM 2	0	4997

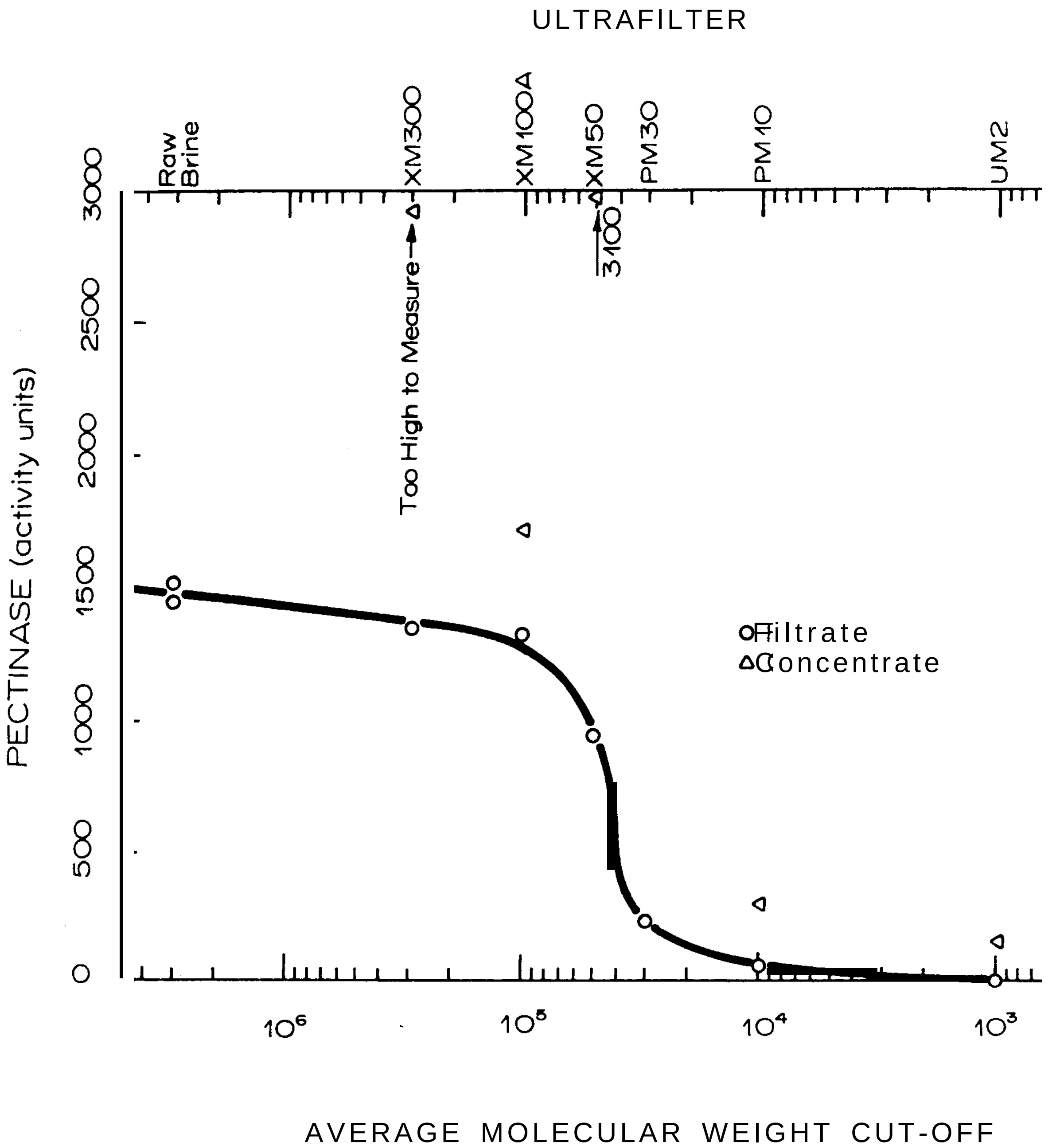

FIGURE 4. EFFECT OF SERIAL ULTRAFILTRATION ON PECTINASE ACTIVITY IN 36-HR BRINE

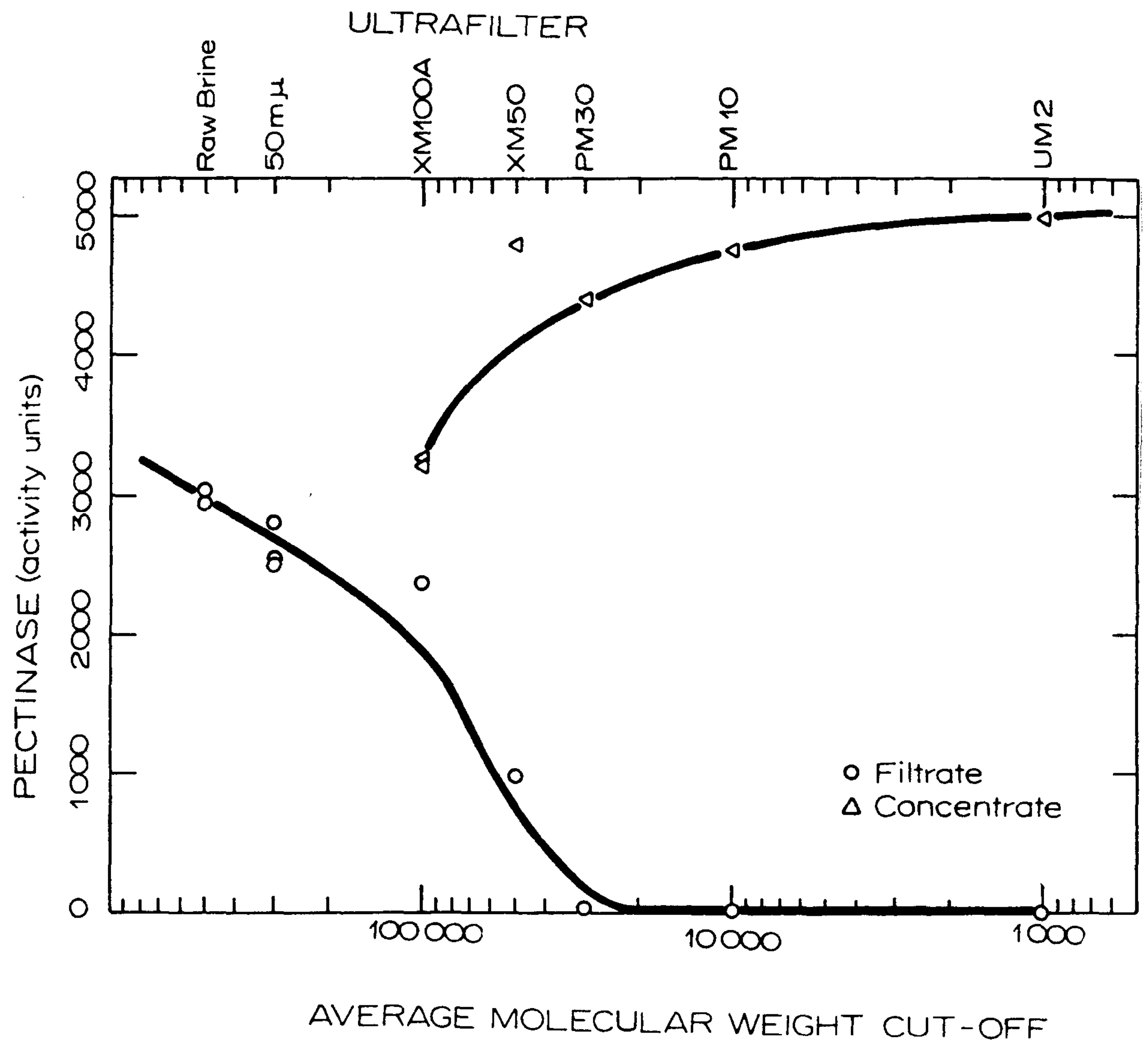

FIGURE 5. EFFECT OF ULTRAFILTRATION ON PECTINASE ACTIVITY IN SPENT BRINE

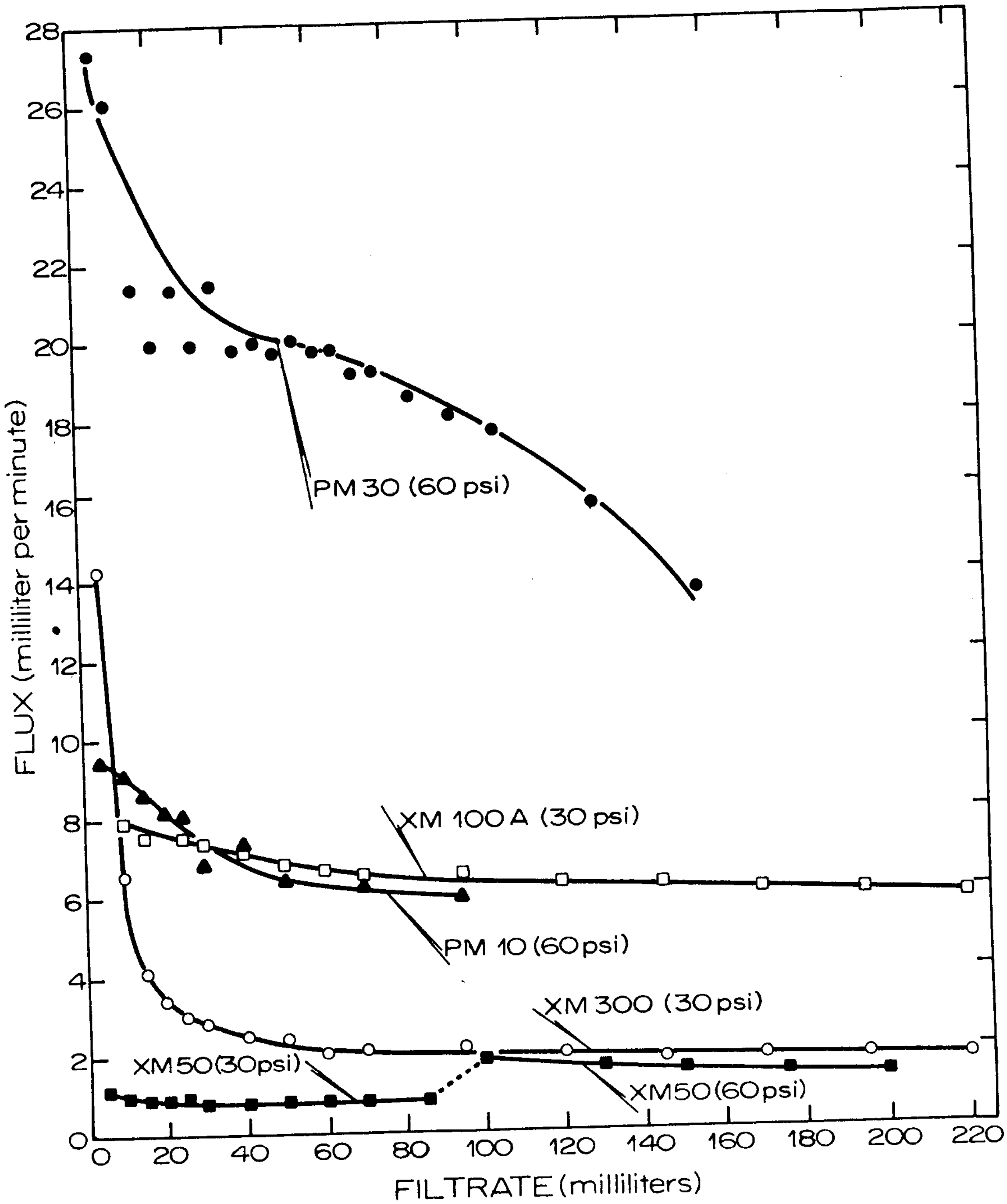

FIGURE 6. FLUX DURING SERIAL ULTRAFILTRATION

Discussion and Conclusions

Previous studies by Bell had shown that coagulation-precipitation is an effective means of removing pectinase activity from spent brines. Ultrafiltration results from this study show that it too is an effective means of removing pectinase activity. Neither treatment substantially reduces the COD of the brine,

Further comparison of the two methods should be made in terms of economics. Economic considerations were foremost in Geisman's (1973) recommendation of coagulation-precipitation over other methods of brine regeneration. Inflation and fuel shortages of the past few years have rendered cost estimates made in previous studies outdated. While the scope of this study does not allow detailed cost comparisons, factors to be considered for both types of treatment can be discussed.

Treatment by coagulation-precipitation requires large quantities of caustic soda and glacial acetic acid, both of which have become more expensive and at some times unavailable immediately upon request. Chemical costs depend on quantities purchased and are cheapest by tank loads of 20-23 tons. Prices given by local chemical supply companies range from $145-160 per ton for caustic soda; for acetic acid, from $300-340 per ton. In both cases, costs were based on tank load purchases. Cost of storage would have to be compared with increased purchase costs for lower volumes per order. Freight and handling would also require consideration.

Costs of actual treatment (assuming batch type reactors) would include a mixing chamber and settling tank, pH monitoring equipment, and chemical feed equipment. The large quantities of sludge generated would require additional handling; possibly the sludge could be discharged into the aerated lagoon wastewater treatment system currently used at most plants.

Ultrafiltration eliminates the expense of chemical purchase, transport, and storage, and also does not present the occupational hazards associated with handling strong acids and caustics, However, the initial costs of ultrafiltration units are high, as are the costs of replacing membrane components when they become damaged or become fouled beyond regeneration. Most waste treatment-operations utilizing ultrafiltration use thin channel or hollow fiber systems rather than plate-type membranes. These systems are reportedly more efficient and present less problems with clogging. Power costs are associated with ultrafiltration since a pressure gradient must be maintained across the membrane. The pressure to be maintained depends on the flux desired and on the membrane surface area. Often it is more economical to increase surface area than to increase pressure, but this would have to be studied to determine the optimum area and pressure for the optimum membrane pore size. From the results of this study, PM 10 size membranes appear to be the largest feasible.

Both types of brine treatment require storage facilities for spent brine after removal from brining vats prior to treatment, as well as storage of treated brine until reuse.

The question arises as to how well treated brine can be stored before reuse. Since COD remains high in the treated brines, unless the brines are stored aseptically there is a likelihood of bacterial or fungal growth and the possibility of causing off-flavors in cucumbers brined in the regenerated brine, Some companies have been reusing heat-treated brines and they report no deterioration in quality of product, but the possible build-up of small molecular weight organics over a period of years cannot be dismissed. If spent brine were stored and then treated before reuse, excessive microbial growth might cause problems in sanitation. On the other hand, if stored after treatment some microbial growth might necessitate re-treatment before reuse. One plant stores all salt as 100% saturated brine and uses no dry salt. Treated brine is recycled into the 100^0 salometer holding tank and this high salt concentration evidently prevents any problems of microbial growth.

Recycling of brines does seem feasible for cucumber pickling operations. From the point of view of this study, ultrafiltration appears more favorable as it is simpler in terms of handling and personnel required, but it would be necessary for each plant to determine the most cost-effective method based on its own situation,

PILOT-SCALE EVALUATION OF COAGULATION-PRECIPITATION FOR REGENERATION OF 36-HOUR AND SPENT BRINES

Two large-scale pilot studies were conducted at Mount Olive Pickle Plant. In the first study, 36-40 hour brine from small cucumbers was used; in the second study, spent brine. Objective of the experiments was to evaluate the feasibility of reuse of brine after treatment with lime and sodium hydroxide.

REGENERATION OF 36-40 HOUR BRINE

Brine (36-40 hr) was collected from a commercial vat of No. 1 size cucumbers brined at 25" salometer (6.6% salt). This brine was used to re-pack cucumbers from the same commercial vat. For the pilot testing 60 gal plastic-lined metal drums with plastic "heads" were used.

Four types of treatment were employed, and control with new brine was included. Each test was run in duplicate, giving a total of 10 drums. The test drums were set up as shown in Table 38.

TABLE 38. EXPERIMENTAL DESIGN FOR EVALUATION OF COAGULATION-PRECIPITATION FOR REGENERATION OF 36-40 HOUR BRINE

Drum No,	Brine Treatment
A-l, A-Z	New brine, 25" salometer
B-l, B-Z	Untreated 36-40 hr brine
C-l, c-z	Brine treated by high pH procedure, no pH adjustment
D-l, D-Z	Brine treated by high pH procedure, pH adjusted to 5.5 with acetic acid
E-l, E-Z	Brine treated by high pH procedure, pH adjusted to 5.5 with HCl

Brines C, D, and E were prepared by the following procedures:

(1) Addition of 0.10% Ca(OH)2 while stirring
(2) Addition of 50% NaOH to a final pH of 11.9
(3) Quiescent settling for 2 hours
(4) Decanting of 45 gallons of clear brine to each of 6 test drums.

For C tanks, no further treatment was done. For D tanks, the pH was adjusted down to 5.5 with acetic acid; and for E tanks, the pH was adjusted down to 5.5 with HCl.

The test and control brines were used to repack the same cucumbers from which the 36-40 hr brine was drained. About 250 lbs of cucumbers were placed in each test drum. These cucumbers were at a low pH (around 5.3) and were still carrying a high level of bacterial flora.

Table 39 shows effect of the lime-NaOH treatment on the brine. Note that there was little or no effect on COD, indicating that most of the oxygen demand was associated with soluble components. An increase in Kjeldahl nitrogen was noted. This could possibly be due to solubilization of some of the nitrogen-containing organic materials. The major accomplishments of the procedure were (1) decrease in pectinase activity and, (2) decrease in total bacteria.

TABLE 39. TREATMENT OF 36-HOUR BRINE BY LIME-NaOH ADDITION

Parameter	Before Treatment	After Treatment
Suspended Solids, mg/l	390	289
Total Solids, mg/l	77,011	63,645
COD, mg/l	7,900	7,300
Cl , mg/l	39,500	31,500
Kjeld-N, mg/l	250	325
NH_4-N, mg/l	155	130
Pectinase, units/ml	16	0
Cellulases, units/ml	220	----
Total Bacterial Count, no./ml	6.8×10^6	9.6×10^4
Acid Formers, no./ml	5.0×10^6	<10

The drums were then headed down and subjected to the usual salting schedule. Table 40 shows the progress of fermentation in the five sets of test drums. Note that within 3 days the pH in the "C" drums was almost as low as that in the control (A) drums. After 6 days the brines in the

TABLE 40. PROGRESS OF FERMENTATION IN NEW BRINES AND IN TREATED AND UNT
36-HOUR BRINES

PARAMETER	TREATMENT		ELAPSED TIME 3 hr	3 days	6 days
pH	A-1	New	5.2	3.8	3.7
	2		5.3	3.7	3.7
	B-1	Untreated	5.3	3.8	3.7
	2		5.4	3.8	3.8
	C-1	Treated, pH 11	9.1	4.2	4.1
	2		9.2	4.3	4.3
	D-1	Treated, pH 5.5	5.4	4.1	4.1
	2	with CH_3COOH	5.4	4.1	4.2
	E-1	Treated, pH 5.5	5.4	3.7	3.7
	2	with HCl	5.7	3.8	3.8
Sugar, %	A-1		0.46	0.00	0.08
	2		0.48	0.08	0.08
	B-1		0.61	0.08	0.08
	2		0.65	0.08	0.08
	C-1		0.64	0.12	0.08
	2		0.66	0.00	0.08
	D-1		0.64	0.08	0.08
	2		0.63	0.08	0.08
	E-1		0.69	0.08	0.08
	2		0.63	0.00	0.08
Pectinase, units/ml	A-1		3	0	0
	2		0	0	0
	B-1		13	0	0
	2		12	4	0
	C-1		0	1	0
	2		0	0	0
	D-1		3	4	0
	2		6	0	0
	E-1		7	0	0
	2		11	0	0
Kjeld-N, mg/l	A-1		-	725	825
	2		-	800	900
	B-1		-	950	1050
	2		-	900	850
	C-1		-	875	1000
	2		-	950	1025
	D-1		-	975	1125
	2		-	1000	1100
	E-1		-	975	1075
	2		-	800	800

TABLE 40 (continued)

PARAMETER	TREATMENT	ELAPSED TIME		
		3 hr	3 days	6 days
COD, g/l	A-1	-	15.5	12.7
	2	-	16.2	12.4
	B-1	-	17.9	14.9
	2	-	18.2	14.6
	C-1	-	19.3	15.7
	2	-	18.3	15.9
	D-1	-	20.2	17.3
	2	-	19.3	18.0
	E-1	-	15.2	16.8
	2	-	14.0	17.5

TABLE 41. QUALITY OF BRINESTOCK FERMENTED IN NEW, TREATED, AND UNTREATED 36-HOUR BRINES

Treatment		Pressure Test, Units (av. of 10 cucumbers)*	Presence of Bloaters (40 cucumbers tested)
A-1	New brine	16.7	0
2		16.7	0
B-1	Untreated	16.0	0
2		15.8	0
C-1	Treated, pH 11	16.7	5
2		17.1	0
D-1	Treated, pH 5.5	17.1	0
2	with CH_3COOH	17.3	0
E-1	Treated, pH 5.5	16.2	0
2	with HCl	17.7	0

*Cucumber size: $\frac{15}{16}$"; 36-hr cucumbers drained and brine replaced as indicated; stock tested after 18 days.

TABLE 42. EVALUATION OF CUCUMBER PICKLES BRINED IN NEW, UNTREATED, AND RECYCLED BRINES.

Type		Type of Brine	Appearance	Flavor		Texture	Overall
				Odor	Taste		Acceptability
Sweet	A	New brine, 25°	7.4	7.5	7.1	7.8	7.3
	B	Untreated brine	7.5	7.4	7.3	7.9	7.4
	C	Floc, pH 11.5	7.2	7.2	7.2	7.2	6.8
	D	Floc pH 5, acetic	7.0	6.7	6.2	6.4	6.3
	E	Floc, pH 5, HCl	6.8	6.9	6.4	7.1	6.8
Dill	A	New brine, 25°	7.5	7.0	6.7	6.7	6.6
	B	Untreated brine	7.2	6.7	6.2	6.1	6.6
	C	Floc, pH 11.5	7.0	6.4	5.2	6.0	5.3
	D	Floc, pH 5, acetic	7.3	7.3	7.3	7.4	7.2
	E	Floc, pH 5, HCl	7.8	7.3	7.6	6.8	7.2

Rating: 10, 9 = Excellent; 8, 7 = Good; 6, 5 = Fair; 4, 3 = Poor;
2, 1 = Barely or Not Acceptable

(Rating criteria devised by USDA Food Fermentation Laboratory) drums were similar in pH, sugar, pectinase content, and Kjeldahl nitrogen. The COD in all of the recycled brines was somewhat higher than in the control brine.

After 18 days the quality of the brinestock was evaluated (Table 41). There was little or no difference in quality as indicated by pressure tests. Bloater content was low in all drums with one exception, one of the "C" drums.

After storage, the brinestock was processed into dill or sweet pickles and a taste panel evaluated the quality of the pickles. As shown in Table 42, all the pickles were evaluated as fair to good in overall acceptability. The least acceptable overall rating was given to dill pickles which had been brined in recycled brine without pH adjustment.

REGENERATION OF SPENT BRINE

In the second pilot study spent brine was regenerated by the lime-NaOH procedure and used to brine fresh cucumbers. Again, several types of treatment were employed and controls with new brine were included. The experimental design is shown in Table 43.

After the indicated treatments, the test brines were distributed to 10 drums, each containing 260 lb of #2 size fresh cucumbers. In Table 44 effect of lime-NaOH treatment on spent brine is shown. There was no significant difference in treated and untreated brine with the exception of the suspended solids, which decreased by almost 65% after treatment.

TABLE 43. EXPERIMENTAL DESIGN, EVALUATION OF COAGULATION-PRECIPITATION FOR REGENERATION OF SPENT BRINE

Drum No.	Brine Treatment
F-l, F-2	New brine, 30" Salometer
G-l, G-2	Brine treated by high pH procedure, neutra--1ized to pH 6.0 with acetic acid, and diluted to 30" salometer
H-l, H-2	New brine, 45" salometer
J-l, J-2	Brine treated by high pH procedure, neutralized to pH 6.0 with acetic acid, and diluted to 45" salometer
K-l, K-2	Brine treated by high pH procedure, no neutralization, diluted to 45" salometer

TABLE 44. TREATMENT OF SPENT BRINE BY LIME-NaOH ADDITION

Parameter	Before Treatment	After Treatment
Suspended Solids, mg/l	599	209
Total Solids, mg/l	241,490	210,500
COD, mg/l	8,100	8,400
Cl, g/l	140	139
Kjeld-N, mg/l	300	275
NH_4-N, mg/l	250	220
pH	3.5	11.0

Brinestock quality was evaluated after 101 days (3 l/2 months). Results are shown in Table 45. In this experiment, quality of the cucumbers brined in recycled brine was equal to or better than those brined in new brines.

TABLE 45. QUALITY OF BRINESTOCK FERMENTED TN NEW BRINES AND IN TREATED SPENT BRINES

Drums	Pressure Test, Units (av. of 10 cucumbers)	Presence of Bloaters % of 40
F-l, F-2	14.6	23
G-l, G-2	17.2	16
H-l, H-2	15.7	14
J-l, J-2	17.9	13

The progress of fermentation was also monitored, as shown in Table 47. As shown in Table 47, the pH in the recycled high pH brine dropped within 6 days to the level in the controls. Kjeldahl and ammonia N values were much higher initially in the recycled brines but after 6 days there were no consistent differences among treatments in content of these nitrogen forms.

TABLE 46. POTASSIUM CONTENT OF BRINES DURING FERMENTATION OF FRESH CUCUMBERS (2B and 3)

Days Elapsed	Potassium, mg/l 30" Brine	Potassium, mg/l 45" Brine
0	110	78
6	1250	1450
	1300	1550
22	1400	1440
	1600	1200

TABLE 47. PROGRESS OF FERMENTATION OF FRESH CUCUMBERS IN NEW BRINES AND IN TREATED SPENT BRINES

Parameter	Treatment		Elapsed Time 0 days	6 days	22 days
pH	F-1	New brine, 30°	6.8	3.5	3.3
	2			3.5	3.3
	G-1	Treated brine,	5.8	3.6	3.4
	2	30°, pH 6 with CH_3COOH		3.5	3.3
	H-1	New brine, 45°	5.6	3.6	3.3
	2			3.5	3.3
	J-1	Treated brine, 45°	5.7	3.6	3.4
	2	pH 6 with CH_3COOH		3.5	3.4
	K-1	Treated brine, 45°,	10.9	3.7	3.4
	2	pH 11		3.7	3.4
Susp. Solids, mg/l	F-1		105	7930	860
	2			5630	1310
	G-1		84	8720	900
	2			4650	630
	H-1		129	2230	2450
	2			3490	730
	J-1		119	14,160	1080
	2			13,740	1470
	K-1		119	21,870	790
	2			5,020	1450
Sugar, gr/100 ml	F-1		-	0.60	0.05
	2		-	0.48	0.02
	G-1		-	0.25	0.01
	2		-	0.50	0.04
	H-1		-	0.50	0.03
	2		-	0.62	0.08
	J-1		-	0.52	0.02
	2		-	0.62	0.03
	K-1		-	0.62	0.03
	2		-	0.74	0.03
COD, g/l	F-1		0.18	17.5	17.0
	2			17.3	16.5
	G-1		3.90	20.9	18.0
	2			18.7	18.4
	H-1		0.19	20.5	17.7
	2			22.4	14.1
	J-1		5.80	24.6	16.2
	2			23.6	18.2
	K-1		4.90	23.3	18.1
	2			23.9	17.7

TABLE 43 (continued)

Parameter	Treatment	Elapsed Time 0 days	6 days	22 days
Kjeld-N, mg/l	F-1	10	700	-
	2		825	-
	G-1	125	1000	-
	2		825	-
	H-1	8	875	-
	2		1050	-
	J-1	195	1100	-
	2		1150	-
	K-1	190	1075	-
	2		1075	-
NH_4-N, mg/l	F-1	2	195	-
	2		185	-
	G-1	90	275	-
	2		235	-
	H-1	2	225	-
	2		230	-
	J-1	140	315	-
	2		280	-
	K-1	130	265	-
	2		260	

Discussion and Conclusions

A major factor to consider in reuse of 36-hr and spent brines is their softening enzyme (pectinase) content. Pectinase activity can be eliminated in these brines by coagulation-precipitation at high pH. Treatment of brines by this method also removes phosphate and drastically reduces bacterial populations. However, it does not remove the majority of the organic component as measured by TOC or COD analysis. Brinestock brined in high pH treated brine (one reuse cycle) compares favorably with that brined in new brine. Pickles packed as sweet or dill after brining in reused brine are not significantly different in quality from those brined in new brines.

In these studies brine was reused only once. There is some question as to buildup of metals, organic compounds, or other materials during repeated reuse. In the long run, feasibility of treating brine for reuse will be dependent on whether removal of pectinase activity alone will suffice, or whether removal of all organic compounds and/or metals will be necessary. In the latter instance, the coagulation-precipitation method described here would be inadequate.

Treatment and reuse of spent brines on a large-scale basis offers potential for greatly reducing the salt load on the wastewater treatment system and on the receiving stream, as well as for greatly reducing salt costs. Assume a plant

using 6,700 tons of salt per year (10,000 tons at present, minus 3,300 tons saved by better housekeeping); assume 90% of the 6,000 tons remaining in the spent brines can be recovered by coagulation-precipitation or ultra-filtration. Reuse of this 5,400 tons would eliminate that load on the receiving stream and in addition, offer a potential savings in salt costs, depending on the cost of treatment.

BIOLOGICAL TREATMENT OF WASTEWATERS FROM CUCUMBER PICKLING

Introduction

The only rational basis for undertaking wastewater treatment is correction of deficiencies in quality which could cause harmful environmental impact. Wastewaters from the pickle industry contain several types of constituents which potentially could cause such difficulties, including suspended matter, biodegradable organics, and chlorides. Technology is available for removal of any or all of them to any extent desired, subject only to financial limitations.

Biological treatment, which includes the types of systems most commonly installed today, is concerned principally with destruction and removal of biodegradable organics and, to a lesser degree, suspended matter. It must be recognized that biological treatment has no impact on chloride contents of wastewaters. Removal of chlorides would require application of entirely different technology.

Goals of Biological Treatment

Biodegradable organic chemicals are those which can be utilized by bacteria and other microorganisms as sources of energy and elements required by them to form additional cell material (growth). Biochemical utilization of the organics leads to their breakdown into simpler chemicals and, perhaps, ultimately to inorganic ash and gases.

Although biodegradable organics in wastewater discharges may be objectionable for many reasons, the concern most often encountered is based on their impact on dissolved oxygen resources in receiving streams. This can be attributed to the fact that processes involved in biochemical transformation of carbon in organic compounds include utilization of oxygen and production of carbon dioxide. The oxygen required is obtained by the organisms from dissolved oxygen in the receiving water, thereby imposing a "biochemical oxygen demand" (BOD) on the limited supply of that gas in the stream. The total amount of BOD exerted depends upon the amount of organic chemical discharged and the extent to which it is biodegradable. The rate at which exertion occurs is influenced by many other variables, as well, including the numbers and types of organisms present and several environmental factors, including temperature and pH.

If dissolved oxygen in the stream is used more rapidly than it can be replaced from the atmosphere, and through photosynthesis by algae, its concentration will decrease. As more organics are added to a stream, dissolved oxygen concentration is reduced to progressively lower levels until, eventually, adverse effects are observed on survival of various types of fish and fish food organisms. Addition of sufficient organics to exhaust completely the supply of this essential element can render the water unsuitable for supporting any fish life. Further, under those circumstances, other types of biochemical reactions may lead to production of foul odors in the vicinity of the stream.

For many years, depletion of dissolved oxygen has been the stream pollution problem receiving greatest attention in the U.S.A. One should recognize that this concern about dissolved oxygen levels in streams and lakes is not based on concern about human health because it never has been demonstrated that any relationship exists between dissolved oxygen content of the water and health of the population consuming that water. Accordingly, stream pollution problems relating to dissolved oxygen, and treatment processes directed towards removal of constituents causing BOD, are based primarily on maintenance of water quality adequate for support of aquatic life, protection of recreation uses, and prevention of local nuisances.

One way in which these problems can be minimized or eliminated is through removing biodegradable organics from the wastewater prior to discharge. The origin and basic rationale for biological treatment is based on the concept of providing facilities in which environmental conditions are maintained to encourage completion of the biochemical reactions before discharge of the wastewater. Thus, biological wastewater treatment processes only cause those reactions to occur in the treatment plant before discharge which otherwise would occur subsequently in the receiving stream anyway. The difference, of course, is that by causing the reactions to occur before discharge the impact on dissolved oxygen in the stream is minimized.

This goal generally is accomplished simply by accelerating reactions in the treatment facilities to reduce necessary holding time and required land areas. That is done through providing optimum environmental conditions and increasing the numbers of microorganisms coming in contact with the organics during treatment.

Types of Biological Treatment Systems

Of all biological treatment systems, the oxidation pond is the one which most closely approximates what happens in receiving streams and this unit has a deceiving appearance of simplicity. The physical facility consists simply of a basin providing a holding time of weeks or months, depending upon character of the waste, during which bacteria and other organisms can degrade organics in the wastewater. The reactions are the same as those which would occur over a period of many days in the receiving stream if the wastewater were discharged without treatment. Oxygen required to satisfy needs of the process and to avoid nuisances is furnished principally through photosynthesis by algae growing in the pond. Algae are microscopic green plants having capability for utilizing carbon dioxide and producing oxygen in the presence of sunlight. Because energy required for the process is derived from sunlight, the rate of oxygen supply is controlled by the amount of sunlight intercepted and, therefore, pond area becomes the controlling design parameter. The high concentrations of biodegradable organics, and the corresponding oxygen demand exerted, in wastewaters from even a moderate size pickle processing plant would require many acres of oxidation ponds, even under the best of conditions.

Frequently, it is more economical to provide biological treatment through using aerated lagoons. Again, the basic reactions which occur in these units are the same as those in oxidation ponds or receiving streams. However, required land areas are smaller because oxygen is supplied through man-made aeration systems which enhance transfer from the air to pond contents. The aeration can be accomplished by introducing compressed air into the basin, resulting in transfer of oxygen from bubbles into the liquid, or by surface aerators which cause violent agitation and enhance transfer of oxygen through the pond surface or into liquid droplets. Adoption of this type of system *removes* the constraint of having to provide large surface area to intercept adequate sunlight and leaves as primary design parameter the retention time of the wastewater in the pond. In practice, the time provided depends upon strength of the waste, its characteristics, pH, temperature and other eqvironmental factors, as well as required quality of effluent from the system. Frequently, aerated lagoons are constructed by industries with retention times of 5-100 days. The high concentrations of organics in wastewaters from pickle processing have led to construction of facilities of 15-60 days.

The types of organisms which develop during biological treatment of most wastewaters have specific gravity slightly in excess of water and tend to agglomerate into particles large enough to settle at reasonable rates. Effluent from an aerated lagoon, for example, can be passed through a settling tank of approximately two hours retention, causing separation of most of the organisms from the liquid under the influence of gravity. Liquid from the bottom of this unit contains substantially higher concentrations of microorganisms and can be returned to the aeration basin to increase their population in that unit.

The rate of attack on organic constituents of wastewaters entering the aeration basin increases in proportion to population of viable organisms, resulting in increased treatment capacity in systems based on aeration, final settling, and return of the settled sludge. This approach is termed the "activated sludge" process. Although there are many different versions, all of them accomplish the same purpose - they accelerate the rate of biological destruction of organics by increasing the supply of organisms in contact with the wastewater. This allows more extensive treatment in a given facility, or permits construction of a substantially smaller plant to accomplish a specified degree of treatment of a given wastewater. Still, the biochemical reactions which occur in this type of system are basically the same as those which would occur in receiving streams, oxidation ponds, or aerated lagoons.

Applications in Pickle Industry

Although several other biological treatment processes are available, and there are many modifications of ones already outlined, the types of facilities most commonly provided for treatment of wastewaters from pickle processing are aerated lagoons or activated sludge systems. Where adequate land is available at reasonable cost, the aerated lagoon usually is simpler and more economical. Where space is at a premium, activated sludge represents a more reasonable approach. Several aspects of these processes, combined with certain characteristics of wastewaters from the pickle industry, deserve at least brief attention.

It was pointed out earlier that biological treatment does not have significant impact on chloride content. On the other hand, it is possible that chlorides can have adverse effects on biological treatment because at sufficiently high concentration, growth of organisms may be inhibited. However, this effect usually is observed only at very high concentrations of chlorides and it appears at least doubtful that their inhibiting effects would be important at the levels commonly encountered in total wastewater flow from pickle processing.

A different adverse effect of chlorides on the activated sludge process can result from increased specific gravity of wastewater with rise in chloride concentration. That sometimes could interfere with settling of organisms, which typically have specific gravity very close to that of water. Of course, any thing which impedes separation of organisms in the final settling tank can preclude adequate concentration for attainment of levels in the aeration tank which produce acceptable treatment rates. The exact magnitude of chloride effects in treating pickle processing wastewaters in practice is not known currently.

A further consideration is that potentially harmful effects of chlorides may be magnified considerably in situations where they swing rapidly through wide ranges of concentration. These changes can be more harmful to aquatic life than sustained operation at either low or high concentration. This question deserves serious consideration and should be explored carefully, especially in any treatment system in which it is planned to use short retention activated sludge, where chloride concentrations may vary quickly.

A factor which sometimes is given too little consideration in planning and design of treatment facilities is production, handling and disposal of sludge. In any biological treatment system, the biochemical reactions result in partial destruction of biodegradable organics and utilization of some of the remaining wastewater constituents to produce new biological cells (growth). The proportions destroyed and converted into cells vary considerably depending on character of the chemical, environmental conditions, and period of retention in the system. Generally, aerated lagoon and activated sludge systems similar to those employed for treating wastewaters from the pickle industry produce net microbiological growth in the range of 0.1-0.5 pounds of suspended solids for each pound of BOD removed from the wastewater. Failure to remove these solids from the system in amounts corresponding to their net production must result in accumulation in the treatment plant. There, they either settle and reduce effective volume of the aeration tank or escape from the plant, which often is unacceptable because of limitations on effluent suspended solids and because those suspended solids themselves exert a BOD.

The present trend in requirements for effluent quality suggests that very soon it will be necessary for virtually all plants to provide facilities for sludge handling. Some alternatives which can be considered include providing very large sludge holding lagoons, land disposal, or sludge dewatering on drying beds, vacuum filters or sludge centrifuges followed by disposal in sanitary landfills, application to land or incineration. Usually, it is impossible for a biological treatment facility to meet standards imposed upon it by EPA and State agencies without careful management of suspended solids. Sludge handling problems undoubtedly will cause serious difficulties and major expense to most pickle processors and, often, may cost more to solve than construction of the biological wastewater treatment plant.

Operating problems occur sometimes *in* treating pickle processing wastewaters because of pH variations. Organic acids in the wastewater and production of even more organic acids during biological treatment can cause sharp decrease in pH in the aeration tank, even though the wastewater being treated is initially about neutral in pH. Successful biological treatment requires maintenance of reasonably uniform pH, usually in the range of 6-8. Rapid variations and departures substantially outside of that range usually are harmful to the process and result in lower treatment efficiency.

Activated sludge and aerated lagoon systems are basically aerobic processes, requiring presence of excess dissolved oxygen to attain optimum treatment and avoid odorous conditions. Inadequate oxygen supply can permit dissolved oxygen concentration in the aeration tank to drop below 1 mg/l and, perhaps, exert significant adverse impact on treatment. Wastewaters from the pickle industry may suffer unusually serious impact from inadequate aeration because resulting increases in concentrations of organic acids also can cause drop in pH, interfering with biological treatment because of low pH and low dissolved oxygen. This makes it especially important in treating wastewaters from the pickle industry to insure that dissolved oxygen in the aeration basin always is maintained at least above 1 mg/l. This requires provision of more conservative air supply, including standby equipment to cover failtures, and emergency neutralization equipment for addition of alkali to the aeration tank to prevent pH drop.

Biological treatment has been applied to pickle and olive wastes with good results if critical operating parameters are controlled. Barnes and Weinburger (1958) reported the use of trickling filters, activated sludge, and oxidation ponds for pickle wastes, but no details were given. Hazeltine (1952) conducted pilot studies on trickling filtration of sauerkraut and pickle wastes and concluded that with proper pH control and loading 85% or more reduction of BOD could be achieved. He found that chloride concentrations of up to 5000-6000 mg/l had little effect on treatment efficiency. Burnett (1974) reviewed effect of salinity variations on the activated sludge system; high salinity could be tolerated if sharp variations were avoided.

Ail North Carolina plants currently use aerated lagoons for waste treatment. In some cases plant growth has outstripped treatment facilities, as is exemplified by Plant A. Plant A has two aerated lagoons, each with a capacity of close to '2 MGD. These ponds were designed tc accommodate 100,000 gpd of wastewater, giving a total detention time of 40 days. However, the average hydraulic load consistently exceeds the design load by a factor of 2 or more (Table 30). A similar situation exists at Plant B. Personal observations and observations by plant personnel indicate that the dissolved oxygen level is frequently below that required for aerobic degradation of wastes. The low DO, coupled with shortened detention time, low pH, and high chloride levels, has resulted in marginal biological treatment efficiency.

Discharge of pickle wastes to municipal biological treatment systems has resulted in problems in a number of cases. Kimball (1960) reported the effect on a municipal system in Crosswell, Michigan when increased demand *for* sweet pickles and relish caused a tripling of the BOD load from a local pickle plant. Not only did the efficiency of the Imhoff tank - trickling filter system drop from 85 to 56%, but odor and corrosion problems developed. In a North Carolina town some years ago the municipal Imhoff tank system had to be abandoned when wastes from the local pickle plant rusted out the system.

Effects of Treated Effluent on Receiving Streams

As pointed out previously, biological treatment does not affect chloride concentration of pickle plant wastewaters. Discharge of high concentrations of salt can cause numerous undesirable effects of receiving streams. Such effects have been reviewed and summarized by Field et al. (1973) and McKee and Wolfe (1963) and include the following:

(1) density stratification in receiving streams

(2) release of mercury from sediments due to exchange of mercury with sodium and calcium
(3) groundwater pollution
(4) increased corrosion rates
(5) toxicity to freshwater fish
(6) interference with use of water for stock and wildlife watering if salt exceeds 1500 mg/l
(7) interference with use of water for irrigation

Salt-tolerance varies with different crops. Crop species especially sensitive to salt include green and field beans, celery, radish, citrus fruits, pear, apple, plum, peach, and avocado (Field et al., 1973) and tobacco (personal communication, P. Benton, N. C. Water and Air Resources, Industrial Wastes Section). The overall amount of acreage irrigated in North Carolina is -105,000 acres; in Michigan, 139,000; and in Delaware, 15,000 (Skogerboe , 1971) .

McKee and Wolfe (1963) cited the following recommended chloride limits: domestic water supply, 250 mg/l; industrial water, 50 mg/l; irrigation, 100 mg/l; stock and wildlife, 1500 mg/l.

Conclusions

Biological treatment is designed to remove biodegradable organics from wastewater prior to discharge. It has no impact on chloride content. However, high chloride levels may interfere with biological treatment, especially if there are sharp variations in concentration.

The organic component of pickling wastewater is readily treated biologically if sufficient detention time and sufficient dissolved oxygen are available(see Appendix A). Since much of the acidity is due to organic acids, aerobic biological treatment will also reduce or eliminate the need for pH adjustment with alkali.

There are numerous adverse effects of chlorides on receiving streams. The level of chloride considered "adverse" is highly dependent on the intended use of the stream.

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GLOSSARY

Abbreviations, Units

hr	-	hour
gal	-	gallon
gpd	-	gallons per day
l	-	liter
ml	-	milliliter
mg/l	-	milligrams per liter
mmhos	-	millimhos
MW	-	molecular weight
	-	micron (+ nannometer

Abbreviations, Terms

BOD	-	biochemical oxygen demand
Cl	-	chloride
COD	-	chemical oxygen demand
DO	-	dissolved oxygen
Kjeld-N	-	total Kjeldahl nitrogen
NH_4-N	-	ammonia nitrogen
NO_2-N	-	nitrite nitrogen
NO_3-N	-	nitrate nitrogen
spec. cond.	-	specific conductivity
SS	-	suspended solids
TDS	-	total dissolved solids
TOC	-	total organic carbon
TP	-	total phosphorus
TS	-	total solids

APPENDIX A

INDUSTRIAL WASTEWATER SURVEY OF A CUCUMBER PICKLE PLANT

by

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C. L. Hagger, Water Resources Engineering
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A Report

from

Department of Environmental Sciences and Engineering
School of Public Health
The University of North Carolina at Chapel Hill

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ABSTRACT

Manufacture of pickles results in large quantities of wastewater that are not easily treated. The pickle plant studied in this project presently is under pressure from *the State Board of Water and Air Resources to implement more adequate treatment of its wastewater discharges. The combination of present treatment facilities and operating procedures are judged to be inadequate to achieve proper treatment of the low pH, high organics and high salt content of effluents generated.*

This investigation was undertaken to examine some areas of concern in production and treatment of the wastewater to provide a basis for improving *procedures and facilities to reduce present treatment difficulties.*

An inventory was conducted to determine the volume and character of wastewaters generated within the plant. Further, the contribution of wastes from each plant manufacturing area was studied to determine where changes would be most effective. Flow measurements and wastewater sampling and analyses were *employed to yield desired information, summarized in the report.*

Neutralization of plant wastewater with three common alkalis was studied to compare their relative effectiveness. Small quantities of effluent were titrated with aqueous ammonium hydroxide and sodium hydroxide and with calcium hydroxide. A comparison of the neutralizing capacity of these alkalis for this particular waste was obtained. Large quantities of alkali may be required to raise the pH of the lagoon before biological treatment can be effective. Continued smaller additions may be needed to maintain proper pH within the system. Sodium hydroxide appears to be the chemical of choice.

Pilot treatability studies were conducted at bench scale to evaluate biological treatability by aerated lagoons and effects of variations in pH and salinity on biological treatment of wastes from the Henderson plant. Treatment facilities at the plant were simulated in each laboratory pilot unit through use of a series of three aerated columns. Daily plant effluent additions and transfers were made. Three conditions were studied: 1) neutralization to pH 7.0; 2) neutralization to pH 7.0 along with increased salinity and 3) neutralization to pH 5.5. Results indicated extensive removals of organics and revealed only slight differences in treatment provided for the wastes of different pH. Most of the organics removal is accomplished in 15-30 days detention.

Finally, a respiration study was carried out to demonstrate the effect of shock loads on the treatability of plant wastes. By measurement of dissolved oxygen uptake by treatment organisms, it was possible to examine the effects of large differences in salt content and acidity on treatability. These were less than had been anticipated.

INTRODUCTION

The plant surveyed produces pickles from cucumbers and other vegetables and discharges wastes which are high in organic content (BOD), suspended solids, chlorides and organic acids, causing a low pH. They are treated in aerated lagoons before discharge into a small creek, a small tributary of a reservoir. The treatment facilities consists of 6.7 million gallon aerated lagoon, partitioned by baffles to provide continuous flow in series through four equally sized basins. A Hinde Air-Aqua system provides submerged aeration throughout the entire lagoon. The lagoon originally was designed with a detention time of sixty days for an effluent flow estimated at 100,000 gal/day.

Effluent from the lagoon has had an adverse effect on stream water quality in the receiving creek according to the North Carolina State Board Water and Air Resources, which has ordered the plant to correct the deleterious effect on the tributary. Specific areas of concern include BOD, suspended solids and chloride loadings, in addition to pH.

This preliminary study of the problem was undertaken as a special project by a class studying "Industrial Water Quality Management," a course in the Department of Environmental Sciences and Engineering, the University of North Carolina at Chapel Hill.

EXISTING TREATMENT FACILITIES

All industrial wastewater flows from the plant, including those related directly to preparation of product, cooling waters, cleanup flows and storm runoff, are collected in a single sewerage system for treatment and disposal. The combined flow is screened for removal of some of the large suspended matter and currently is subjected to treatment in an aerated lagoon before discharge.

The screening operation is manual and has been observed during plant visits to be sufficiently clogged to permit overflow of unscreened wastewater into the aerated lagoon. Flow passing through the screen is discharged into the lagoon near one end of the first "bay."

The aerated lagoon is approximately 270 ft wide by 330 ft long, with 10 ft water depth. It is divided into 4 bays by 3 longitudinal timber baffles, with openings at alternate ends which permit passage of flow through them in series. Condition of the facility suggests that some of the flow may short-circuit through leaks in the baffle walls, but that is not viewed as a serious problem in view of the long detention period.

Total volume of the aerated lagoon is about 6.7 million gallons, providing detention of 67 days at the design flow of 100,000 gal/day. Actual flows through the plant are substantially higher than the design value, however, especially during the fresh pack season and when there is runoff during rainfall. This results in actual detention periods substantially lower than the design value.

Air supply is provided by two 40 hp blowers, rated at 595 cfm each. The air diffusion system is based on use of perforated plastic pipe (Hinde Air-Aqua system). Because some of the tubes are submerged in bottom deposits and have clogged orifices, the air diffusion pattern throughout the basins is somewhat irregular and the rate of air application appears to be too low, at least by visual estimate.

Recently an additional facility was installed to permit metering of flow entering the aerated lagoon, neutralization with sodium hydroxide or ammonium hydroxide, and addition of nutrients. The Parshall flume, pH control equipment and nutrient addition facilities were not in operation during these visits. The low elevation at which the facilities were installed, apparently, will require lowering the water level in the aerated lagoon and reduce effective volume of that unit when operation of the new facility is initiated later.

A 1970 report of the North Carolina Department of Water and Air Resources indicated influent BOD values ranging from 700-5,000 mg/l, with effluent BOD of 3100 mg/l. pH of the influent waste was 3.6-4.2 and pH in various sections of the aerated lagoon varied from 3.4-4.1, leading to a recommendation that the waste be neutralized with sodium hydroxide or ammonium hydroxide. Analyses for nutrients indicated presence of about one-half the recommended levels of nitrogen and phosphorus and addition of both nutrients on a regularly scheduled basis was recommended. The report indicated that the treatment facilities were not performing as designed (14% BOD removal instead of 90%) because of low pH, nutrient deficiencies, high chloride content, and inaccurate selection of design BOD load.

PURPOSE AND SCOPE

The class undertook a limited in-plant study of processes and practices, and investigated biological treatability of process wastes by aerated lagoon. The period of study was March-April, 1974. During this "off season" major plant activities are repair and maintenance of brine tanks, the firming process, processing and packing of sweet and sour pickles, and relish-making operations, all using pickles stored in brine (brine stock). The volume and nature of wastewaters produced and the range of activities are substantially lower than in the "green season."

Four operating processes within the plant were identified as major sources of wastewater. Grab samples were collected and analyzed to determine waste constituents and attempts were made to measure flows generated by each process. Plant practices were observed and suggestions offered for their modification to reduce waste materials reaching the lagoon.

The treatability studies focused on determination of whether wastes with these characterists can and should be treated biologically and, to a limited extent, under what conditions. Also, laboratory studies were conducted to determine which alkali would be most effective in neutralizing the low pH plant effluent. Shock effects of low pH and changes in chloride levels on biological activity of the organisms were examined through respiration rate studies. Of necessity, all of these studies were conducted within a limited time frame.

IN-PLANT SURVEY

Objective

The objective of this phase was identification of the many chemical and organic constituents of the wastewater and measurement of the volume of wastewater contributed to the lagoon by each of four plant operating areas: 1) the processing room where cucumbers are colored and finned, where sweet pickling is accomplished and where relish is chopped and prepared; 2) the manufacturing and packing area where pickles are sliced and where products are packed into jars and capped; 3) the pasteurizing area where the sealed jars are pasteurized, labeled and packed for shipment; and 4) the tankyard,

Procedure

Since a limited study had been done previously by a company engineer, a decision was made to utilize the same sampling points so that data might be compared. A sketch of the drainage system is shown in Figure 1. The processing room sample point was a large, shallow, open manhole (Drain 15B) on the hill overlooking the lagoon. Three tankyard drains also emptied into this manhole but the wastes could be distinguished one from another due to three separate and easily sampled discharge pipes within the manhole.

Two sampling points were identified in the manufacturing area. The waste collection box at the end of the drain under Line 6 served as one sample point, collecting wastes from the capping lines and the pickles being packed on Line 6. The second sampling point was the waste collection box approximately 15 feet below the confluence of the drains serving Lines 3 and 5 and the sorting and cutting area. In the pasteurization area, samples were collected from the drain two feet upstream from its discharge to the waste collection box.

Flow measurements were made with a four-gallon bucket and stop watch. This method was not satisfactory for in-plant sampling due to the condition of the drains which did not permit a free flow into the bucket. The large volumes of water discharged from the pasteurizing room at Drain 15B also made measurement difficult.

One night was spent observing the cleanup crew.

A few simple experiments were also carried out on a pilot size screening device (hydrasieve) to determine its applicability for screening solids from the lagoon influent.

All chemical tests on the samples collected were performed in accordance with the procedures outlined in Standard Methods' for the Examination of Water and Wastewater. The laboratory analyses were conducted by the UNC Wastewater Research Center.

Results

From a survey of the wastewater flows it was found that the drainage system from the pasteurizing area also collected wastes from the concentrated brine and pickling liquor preparation area. The processing room drains directly to the lagoon through a pipeline which also collects storm runoff from the railroad yard and salt storage area. The manufacturing-packing area and the pasteurizing area drain to a sewer running in front of the building, which also collect wastes from the boilers and tankyard before emptying into the lagoon.

Silt observed in all tankyard drains and during periods of heavy rainfall is carried to the lagoon. Several tankyard drains were completely clogged and had apparently been so for some time since storm runoff and tank drainage had worn deep rivulets in the hillside around and alongside the drains. The steep hillsides around the lagoon are essentially barren permitting sediment to be carried to the lagoon. Siltation in the lagoon contributes to the clogging of the air bubbling system and to the need for dredging.

Screens were used on several of the inside drains in an attempt to prevent large pickles and pieces of pickle from reaching the lagoon. These screens were generally in poor condition and often did not fit properly. The basket screen at the end of Lines 3 and 5 functions only during periods of high flow. During periods of low flow the deteriorated condition of the drain lip allows wastes to run under the basket and directly to the sewer. The screens were generally observed to need cleaning. Several times employees were observed removing the screens and flushing screened materials into the sewers.

The influent screen at the lagoon was clogged with screened materials on every visit. On several occasions the effluent poured over the clogged screen into the lagoon carrying large pieces of material with it. Solids removed from the screen were piled on the ground to one side where rainfall overflow washed them directly into the lagoon.

From observing the night shift cleanup crew, it was noted that the poor condition of the flooring in the packing area hindered attempts to sweep the floor clean and necessitated the use of additional hosing to remove food particles trapped between the bricks in the floor. These food particles were hosed to the drains and subsequently into the sewers. Attempts to encourage plant personnel to measure the volumes of water used in evening cleanup by reading the water meters were unsuccessful. Accordingly, no data was collected on this activity.

The analytical data and flow measurements are summarized in Tables l-5. All of the wastes were acidic, with pH generally less than 4.0. The most acidic wastes were generated in the processing area and Line 6 of the manufacturing-packing area.

Examination of the combined pasteurizing, manufacturing-packing and boiler room effluents collected at a manhole outside the building show lower BOD, total solids, organic carbon and acidity presumably due to dilution. Chlorides and pH, however, remained substantially unchanged, for which there currently is no explanation.

Extremely simple preliminary tests on plant wastes indicate a strong potential for the reduction of organic loading through the use of a Hydrasieve as seen from the reduction in DOD and solids given in Table 6.

Discussion

Experience during this limited study indicated that the wastes do not lend themselves to grab-sampling or unsophisticated flow measurements. There was high variability in both volume and nature of the wastes during this two-month period of the off-season. Reliance on averages and extrapolation of data collected during the off-season to the "green season" is both unrealistic and unreliable. A well-planned, organized study over an entire year of the manufacturing process and of the wastes it generates is needed to provide a comprehensive and realistic analysis of the volume and nature of the wastewater involved and to determine those areas of the plant where in-plant process changes and water conservation will substantially reduce waste effluent. This study must be backed up by competent and full laboratory analyses of wastes so that the best treatment methods may be determined. Short cut solutions will only result in capital expenditures which offer little or no improvement. The age and operation of this processing plant together with variable nature of its wastes necessitates the services of a consulting engineer to develop a satisfactory solution.

The volume of wastes generated in those processes having the greatest brine concentration, the highest oxygen demand and the lowest pH determine

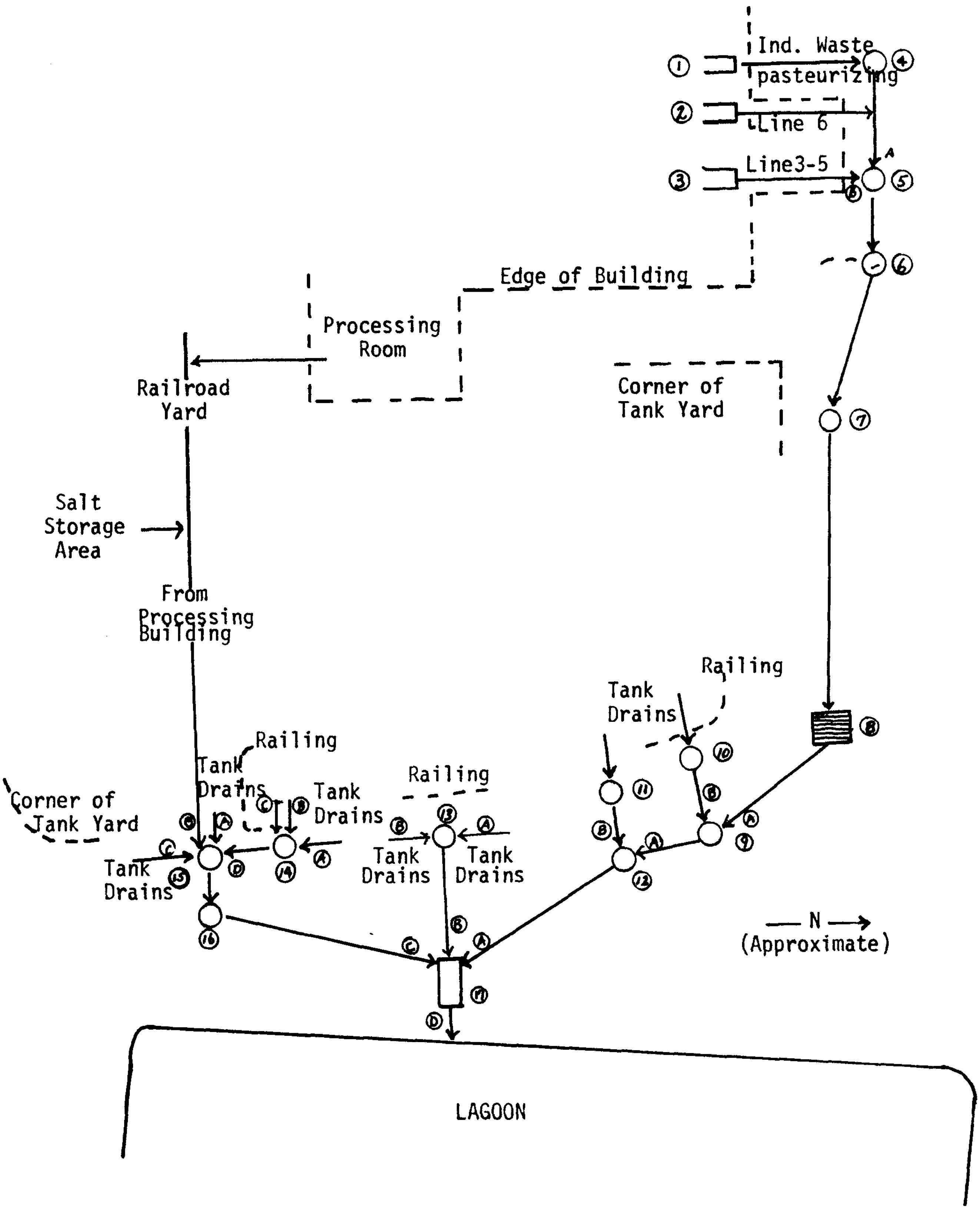


FIGURE 1. SKETCH OF SEWER SYSTEM AT PLANT

TABLE 1. PROCESSING ROOM GRAB SAMPLES COLLECTED AT DRAIN 15B

	March 27, 1974*				April 3, 1974				April 11, 1974	
Date Time Analysis	1540-1605 Composite	1540-1605 Imhoff Cone Super-natant	1540-1605 Imhoff Cone Super-natant	1735	1445-1500 Composite	1607*	1645-1700* Composite	1705* a	939 a	951 b
Organic Carbon	11,800	16,200	16,200	10,400	1,050	7,800	1,400	1,150	850	1,100
BOD (mg/l)	21,600	>24,000	>24,000	21,900	1,050	>9,480	2,400	2,040	1,800	>2,490
Total Solids (mg/l)	33,665	49,303	49,565	26,187	30,805				15,077	70,334
Suspended Solids (mg/l)	283	89	120	99	511	1,025	111	175	28	
Settleable Solids (mg/l)		25.5	20		142.5				1.5	
pH	3.7	3.4	3.4	3.8	3.7	3.6	3.8	3.8	3.7	3.
Acidity	1,149	3,000	2,811	900	429	969	566	471	506	549
Specific Conductance (mmhos)	18	15	15	8.4	.41	42	34	30	18	52
Chlorides	7,400	6,500	6,500	3,300	16,810	18,542	14,518	11,869	8,500	28,300
PO_4 as P (mg/l)	5.5	4.7	6.5	2.2	9.0	10.8	3.3	2.6	0.9	18.
NO_2 and NO_3 as N (mg/l)					1.0			.7	1.0	
NH_3 as N (mg/l)					21.5		12.5	12.5	1.0	
Kjeldahl N as N (mg/l)					82.5	>50	62	50	24.5	

*Relish operation shut down

[a]Drain off the corner of the building near railroad track

[b]Waste well in the drainline between the waste well in the railroad yard and Drain 15 B

TABLE 2. PROCESSING ROOM DATA (DRAIN 15B)

DATE	TIME	FLOW (GPM)	AVERAGE FLOW (GPM)	COMMENTS
March 27, 1974	1540	16.67		
	1545	25.00		No relish operation
	1555	32.69	24.84	
	1605	25.00		
	1715	50.00		
	1720	16.67	22.05	
	1725	11.54		
	1730	10.00		
April 3, 1974	1445	160.00		
	1447	160.00	162.86	
	1450	171.43		
	1455	160.00		
	1500	240.00		
	1602	28.24		
	1605	13.52	23.06	
	1611	27.43		Drain above 15 B
	1649	160.00		
	1650	171.43	163.81	
	1651	160.00		
April 11, 1974	935	40.00		
		46.10		
		46.10	44.76	
	939	43.6		
		48.0		
	951	48.0		Well in drain between railyard and 15 B
		46.1		
		46.1		
	955	43.6		
		40.0		
		38.7	39.9	
	1000	38.7		
	1001	38.7		

TABLE 3. CHARACTERISTICS OF WASTEWATER FLOWS FROM MANUFACTURING-PACKING AREA AND FROM PASTEURIZING ROOM

	Manufacturing-Packing Area						Pasteurizing Room		
Date	April 3, 1974			April 11, 1974			April 3, 1974		April 11, 1974
Analysis / Time	*1535	1547	1551(a)	909	915(b)	930(a)	1620(c)	1630(a)	850(c)
	Line 3 and 5	Line 6		*Lines 3 and 5		Line 6			
Organic Carbon	2,320	3,440	880	980	2,600	26,100	870	990	276
BOD (mg/l)	>2,340	>4,740	1,290	>1,800	>4,980	24,900	1,380	1,530	>498
Total Solids (mg/l)	13,706	11,519	4,387	412	66,544	62,329	-	-	883
Suspended Solids (mg/l)	70	53	300	-	-	-	737	6	-
Settleable Solids (mg/l)	1.5			1.0	26.0		-	-	-
pH	3.5	4.2	5.1	3.7	4.0	3.2	4.9	4.8	4.7
Acidity	831	291	86	154	386	2,108	146	86	60
Specific Conductance (mmhos)	13	5.2	4.1	2.9	49	5.1	2.10	746 µmmhos	89
Chlorides	4,839	1,783	1,274	1,200	29,700	2,500	635	188	312
PO_4 as P (mg/l)	1.9	3.0	5.7	0.5	0.9	4.2	1.3	1.0	.5
NO_2 and NO_3 as N (mg/l)		-	1.1	0.9	-	-	0.7	0.8	0.7
NH_3 as N (mg/l)	6.0	3.5	4.0	1.0			8.5	5.0	1.0
Kjeldahl N as N (mg/l)	>50.0	>50.0	>50.0	15.5			>50.0	24.5	

*Composite drain serving lines 3 and 5 just prior to waste well
(a) Collected from waste well serving line 6 and the capping machines
(b) Hot pepper pickling liquid dumped into drain from transport vat
(c) Floor drain just prior to waste well

TABLE 4. CHARACTERISTICS OF WASTEWATER FLOW FROM DRAINS

	Tankyard Drains		Manhole Immediately Outside Boiler Room	
Date	April 11, 1974		April 11, 1974	
Time	1002(a)	1005(b)	1020(c)	1030
Organic Carbon	1,500	1,500	1,130	930
BOD (mg/l)	2,490	2,490	1,350	1,770
Total Solids (mg/l)	49,150	71,430	3,711	3,496
Suspended Solids (mg/l)	-	-	-	-
pH	4.0	3.3	3.7	3.9
Acidity	300	883	300	197
Specific Conductance (mmhos)	52	74	2.8	2.6
Chlorides	28,700	38,900	1,100	1,100
PO_4 as P (mg/l)	7.4	38.0	0.9	0.5
NO_2 and NO_3 as N (mg/l)			1.1	1.0
NH_3 as N (mg/l)			2.0	2.0
Kjeldahl N as N (mg/l)			18.0	13.5

(a) Drain from that portion of tankyard lying to left as one stands facing lagoon (under Drain 15 B)

(b) Drain from that portion of tankyard lying to the right as one stands facing the lagoon (drain to right of 15 B)

(c) Manhole immediately outside boiler room

TABLE 5. FLOWS FROM MANUFACTURING ROOM - LINE 6

Date	Time	Flow (GPM)	Average Flow (GPM)	Comments
4/3/74	1545	7.27		
	1547	6.15	6.33	Line closing for the day
	1549	5.58		
	1550	20.00	20.00	Machine washdown
4/11/74	930	Flow too small to measure; primarily from two capping units (condensed steam)		

TABLE 6. DATA FROM PRELIMINARY HYDRASIEVE TRIAL

Using Coarse Screen	
Influent Suspended Solids, mg/l	113
Effluent Suspended Solids, mg/l	110
Suspended Solids after settling, mg/l	66
Influent Settleable Solids, ml/l	10
Effluent Settleable Solids, ml/l	7
Using Fine Screen	
Influent Suspended Solids, mg/l	130
Effluent Suspended Solids, mg/l	55
Suspended Solids after settling without screening, mg/l	49

impact of the wastes on the lagoon. Therefore, it is imperative to acquire a close approximation of the contribution of each process to the total lagoon capacity over the different "manufacturing seasons" of the year. Monitoring of water lines to each individual process would provide information on how, where and when water is used and, teamed with good laboratory analyses of wastes generated, would permit determining the impact of each process on the lagoon. Times of potential shock loading in the lagoon could become apparent. Furthermore, this information would be useful in determining those plant areas where water conservation could make substantial contributions to waste reduction.

Organic suspended solids reaching the lagoon cause excessive oxygen demand and create accumulations of sludge which clog the air diffusion system and may necessitate occasional draining and dredging of the lagoon. High solids concentrations in the wastewater from the manufacturing-packing area apparently originated with draining of the coloring and firming vats, the wastewater from relish washings, the practice of dumping syrups left in vats after packing the products and poor cleaning practices in the manufacturing-packing area. Control of these wastes alone would greatly reduce the volume of organic materials reaching the lagoon.

From a standpoint of oxygen depletion, all of these wastes are important. The syru wastes are especially significant due to their excessively high oxygen demand.

The installation of a Hydrasieve on the lagoon influent would prevent many organic solids not trapped by in-plant screening from reaching the lagoon. Organic wastes too fine to be screened by plant floor drains and pickles and other vegetable products carried by tankyard drains to the lagoon could be effectively trapped thereby reducing the oxygen-demand on the lagoon.

Recommendations

1. Retain a consulting engineer.
2. Meter the water flow to each process to obtain accurate data on the wastewater generated.
3. Reduce the solids reaching the lagoon in plant wastes.
   a) Initiate equipment and floor cleaning by dry sweep whenever possible. This may require closing manufacturing lines 15 minutes before the end of the shift and all factory line workers sweeping the machines with hand brushes and pans.
   b) Eliminate hosing of organic materials to the floor drains whenever possible. If hosing is required for final cleanup, utilize high-pressure, low flow hoses to reduce volume of wastewater generated, but only after dry sweep.
   c) Repair flooring in the sorting and packing area so that wastes may be swept up easily and not trapped between bricks requiring use of high-power hoses for flushing and cleaning floors.

d) Repair floor drains so that screens fit tightly.
e) Establish a program for routine maintenance of all floor drains, screens and waste collection boxes. Provide adequate disposal for screenings and discourage practice of flushing screened materials to sewer.
f) Evaluate the possibility of screening wastewater from the relish operation to remove fine pieces and their recovery.
g) Pickles on the floor or platforms should be swept up and placed in garbage barrels -- not flushed or swept into sewers or into the cracks around vats.
h) Exercise greater care in removing by netting the cut pickles from the alum process into the transport vats.
i) Establish routine maintenance for the influent screen at the lagoon and provide regular and adequate removal of screened wastes.

4. Install a Hydrasieve for the screening of lagoon influent.
5. Control tankyard erosion.
6. Establish clear communication between the decision-making offices, the laboratory and engineering and maintenance regarding policies and implementation of these recommendations.
7. Instruct plant personnel on the importance of all of these measures and why they must be accomplished.

BIOLOGICAL TREATABILITY STUDY

In attempting to determine the treatability of wastes from this plant, many variables should be examined thoroughly. The fact that time available to this group for the study was rather limited required that some assumptions be made and that the group of factors studied be limited to a few of the most important ones.

It was assumed that before substantial improvement in the treatment system can be made, three conditions must be corrected. These include 1) removal, prior to discharge into the lagoon, of large organic solids in the plant effluent, 2) substantial increase in the volume of air supplied for aeration, and 3) possible addition of certain nutrients required by the microbial population of the treatment system but not available naturally in this wastewater in optimum quantities. These changes are considered prerequisite to proper treatment and were therefore incorporated into our study.

Once these conditions were eliminated or corrected, the two most important variables remaining and the ones which distinguish pickle wastes from practically all other food processing wastes are the low pH and the high chloride content. It was felt that knowledge of the effect of these factors on treatability would be most valuable in improving future treatment.

Therefore, three specific conditions were studied. They were (1) neutralization of plant effluent to pH 7.0, (2) neutralization to pH 7.0 plus slight increase in chloride content, (3) neutralization to pH 5.5. Comparison of 1 with 3 indicates the degree of neutralization necessary while comparison of 1 with 2 shows the effect of increased chloride content. Should large scale water conservation measures be practiced in the future without similar decreases in usage of salt, the chloride concentration of the lagoon could be expected to rise significantly above its present level.

The treatability study was designed to simulate treatment received in the lagoon. This was accomplished by daily batch additions of plant effluent, obtained from this plant and stored under refrigeration, to a series of aerated columns.

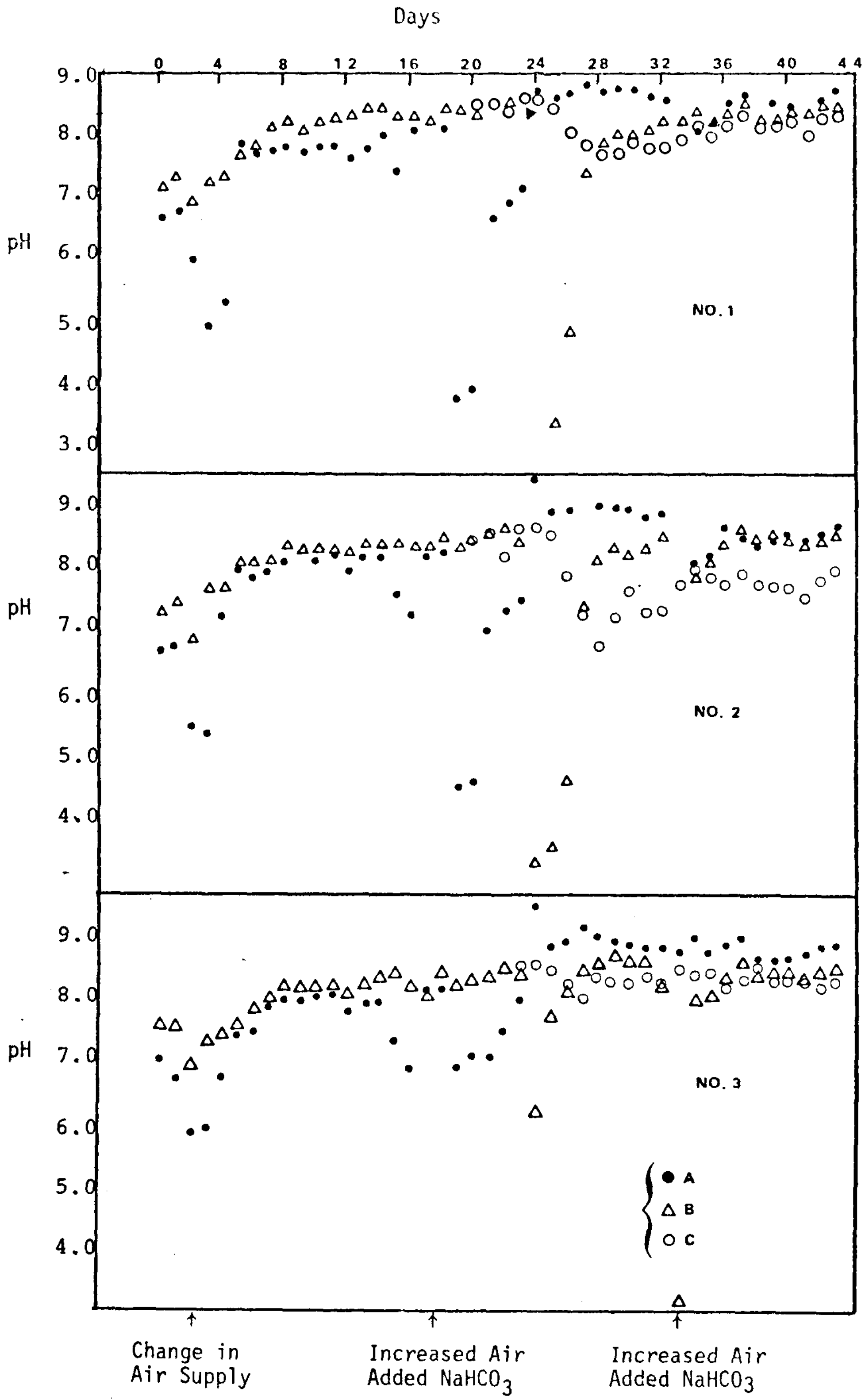
The cylinders simulated the first three stages of this plant's aerated lagoon. The nine columns ranged in height from 26-35 inches and in diameter from 3 3/4-4 l/4 inches. Several of these had conical bottoms while the remainder were flat bottomed. These minor variations in contour and dimensions should not have influenced the experiment. Each column had a tap on the side for removal of samples for transfer and analysis. No attempt was made to sinulate existing air supply conditions or to determine optimum air requirements. Instead we attempted only to maintain the air supply at a level such that there would be no concern for its adequacy. Air supply to individual columns was from a common manifold. Originally, diffusers were used for aeration. After several days these were replaced with large opening pipettes since the air flow was inadequate. Air supply was regulated by screw clamps.

The units were arranged in three numbered sets, each of which had three columns in series ("A," "B," and "C"). Each column contained 3 liters. The "A" (first unit of each set of three) columns were begun with a seed mixture of plant pond effluent, effluent from the trickling filter at the Mason Farm Sewage Treatment\Plant and Morgan Creek water. The other columns were empty. Each day, 200 ml (l/15 of the column volume) were removed from the "A" columns and added to the "B" columns until the "B" columns reached 3 liters. After that 200 ml were removed from "B" and added to "C" and from "A" to "B". Columns "A" were fed each day from a composite sample of lagoon influent collected 3 times a day at the plant. Several days' samples were mixed together for the feed. Since it was assumed that coarse screening would necessarily be provided, the sample was passed through coarse weave gauze which removed the large pieces of pickle but none of the smaller solids.

Losses due to evaporation were made up daily. Transfers and feeding of the columns were made daily. The pH of the columns was recorded daily as a simple monitoring test. More extensive analyses were done less frequently.

Each set of columns was operated under different conditions. Group 1 was closest to common treatment procedure in that the sample was neutral-

FIGURE 2. DAILY pH MONITORING OF LAGOON SIMULATION UNITS



ized to pH 7 with sodium hydroxide. Group 2 was also neutralized to pH 7, but salt was added to increase salinity by about 15%, thereby simulating possible conditions resulting from a water conservation program. Group 3 was fed fed with sample neutralized to pH 5.5.

All feed was supplemented with nitrogen and phosphorus. For an initial BOD of 2500 mg/l, total P of 4.6 mg/l and total N or 46.1 mg/l, a BOD:N:P ratio to 100:50:1 was obtained by an addition of 20 mg/l as P and 80 mg/l as N to the samples.

Results of the treatability study show that adequate aeration is essential to achieve biological treatment. As indicated in Figure 2 the pH was highly dependent on the air supply. When the experiment was begun using diffuser to disperse air in the column the pH dropped because of inadequate dissolved oxygen. After the diffusers were replaced with pipettes, allowing an increase in air supply, the pH increased above neutrality, During the course of the experiment whenever the air supply decreased for any reason the pH fell drastically, illustrating the need for an adequate, dependable air supply to support aerobic biological attack on organic acids in the wastes. Increase in aeration soon led to improved pH in the system, sometimes assisted in the initial recovery by addition of sodium bicarbonate.

Our original hypothesis was that there would be a significant difference between treatability at pH 5.5 and at 7.0. This was not observed. In fact, the system increased in alkalinity after biological activity began. Thus despite the different initial pH, all cylinders stabilized around a pH of 8.0. This also is shown in Figure 2.

As shown by averages in Table 7 the BOD removal beyond 30 days was not substantial. Thus, '-he existing lagoon should be able to handle hydraulic beyond its design capacity. Another implication is that in future study shorter time periods should be adequate. To obtain effluent BOD values lower than those indicated probably will require addition of settling and perhaps other processes in addition to the aerated lagoons.

A 15% increase in salinity did not adversely affect treatment as shown by comparing results of unit 1 and unit 2. Therefore, a substantial water conservation program could be instituted without altering waste treatment. It should be noted that the influent salinity values used in this experiment (12,000 mg/l chloride) should be well above the yearly average.

Conclusions

1) This pickle plant waste can be treated biologically.
2) Extensive neutralization of the influent may not be necessary to maintain an acceptable pH in the lagoon. Possibly after initial neutralization and stabilization of the biological activity, no neutralization of the influent will be needed. In order to achieve this end, a pH monitor in the first basin would be highly desirable.

TABLE 7A. DATA FROM TREATABILITY STUDIES

Characteristic	Date 1974	Pond Influent	Unit No. 1 15 Days	Unit No. 1 30 Days	Unit No. 1 45 Days	Unit No. 2 15 Days	Unit No. 2 30 Days	Unit No. 2 45 Days	Unit No. 3 15 Days	Unit No. 3 30 Days	Unit No. 3 45 Days
BOD_5, mg/l	4/4	>2,250	120	<10	<10	50	<10	<10	90	<10	30
	4/18		186	111	57	165	93	114	198	72	45
Total Org. C., mg/l	2/2	1,400									
	2/14	1,400									
	2/18	1,199									
	2/19	1,110									
	2/26	1,270									
	3/20	2,700	200	200	-	<100	<100	-	-	<100	-
	3/28		<100	<100	-	200	<100	-	<100	<100	-
	4/18		<100	<100	<100	<100	<100	<100	200	<100	<100
Susp. Solids, mg/l	2/2	235			-						
	2/14	237			-						
	3/20	345	2,340	488	-	2,667	753	-	2,550	1,020	-
	3/28		1,095	2,721	-	2,990	570	-	3,690	940	-
	4/18		703	333	418	1,060	530	560	1,350	775	305
Total Solids, mg/l	2/2	23,600									
	2/14	23,970									
	3/20	28,240	14,380	10,670	-	15,840	13,000	-	9,130	7,310	-
	4/18		22,560	17,150	15,480	34,430	26,930	26,410	24,530	15,770	
Ammonia, mg/l as N	2/2	9.0									
	2/14	8.0									
	2/18	8.5									
	2/19	7.5									
	2/26	6.0									
Kjeldahl N, mg/l	2/2	29.0									
	2/14	32.0									
	2/18	26.5									
	2/17	26.5									
	2/26	45.0									
Nitrite & Nitrate, mg/l	2/18	1.6									
mg/l as N	2/19	1.5									
	2/26	1.1									
Total Phos., mg/l as P	2/26	4.6									
Vol. Susp. Solids, mg/l	4/18		229	193	222	390	225	80	420	300	195
Chlorides, mg/l	4/18		14,200	11,000	10,600	17,700	13,100	12,700	15,600	10,600	9,200
Conductivity, mmhos	4/18		29	21	20	31	28	28	28	22	20

TABLE 7B. SUMMARY OF TREATABILITY STUDIES

Unit 1. Initial pH = 7.0, Chloride = 12,000 mg/l

Analysis	0 Day	15 Day	30 Day	45 Day
Avg. TOC (mg/l)	1,970	<150	<150	<100
Avg. BOD (mg/l)	>2,250	153	50	33
Avg. Susp. Solids (mg/l)	270	1,450	1,180	420
Avg. [Cl⁻] (mg/l)	12,000	14,200	11,000	10,600

Unit 2. Initial pH - 7.0, Chloride = 13,500 mg/l

Analysis	0 Day	15 Day	30 Day	45 Day
Avg. TOC	1,970	<150	<100	<100
Avg. BOD	>2,250	110	50	60
Avg. Susp. Solids	270	2,240	620	560
Avg. [Cl⁻]	13,500	17,700	13,100	12,700

Unit 3. Initial pH = 5.5, Chloride = 12,000 mg/l

Analysis	0 Day	15 Day	30 Day	45 Day
Avg. TOC	1,970	<150	<100	<100
Avg. BOD	>2,250	150	40	38
Avg. Susp. Solids	270	2,530	910	300
Avg. [Cl⁻]	12,000	15,600	10,600	9,200

3) A water conservation program that increases salt concentration will not adversely affect treatment.
4) Unless further studies show differently, screening and nutrient addition should be practiced.
5) The existing lagoon has sufficient detention time for flows significantly greater than the design flow of 100,000 gals/day.
5) Adequate aeration is crucial to treatment.

WASTEWATER NEUTRALIZATION

Three alkalis were compared for neutralization of the plant wastewater. The purpose of the experiment was to provide a basis for determining the most economical and effective alkali for wastewater neutralization should large quantities be needed in the future, either for initial raising of the lagoon pH or for maintenance of the proper pH once biological treatment has begun.

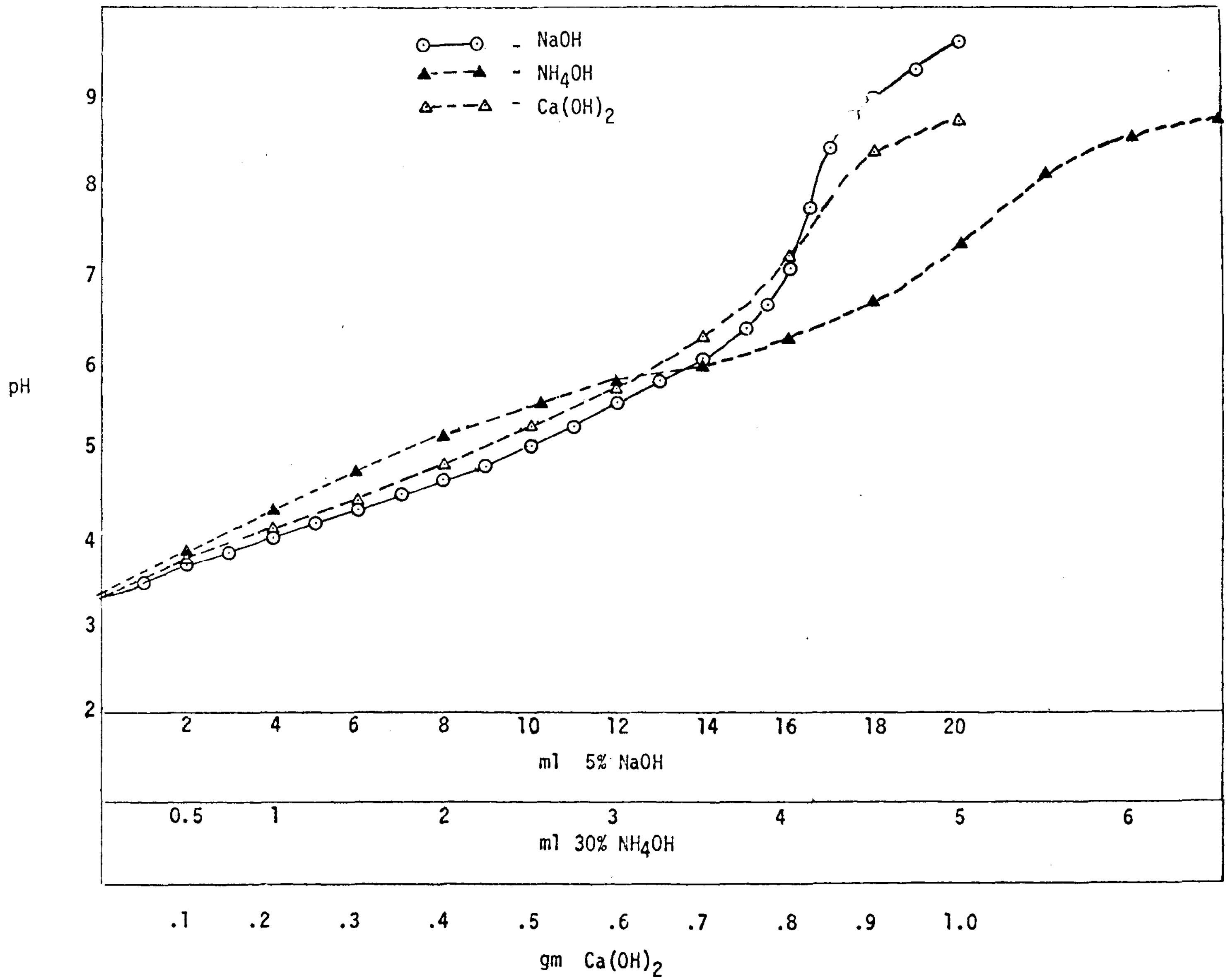
Composite samples (1 liter) of plant effluent were titrated with 5% sodium hydroxide, 30% ammonium hydroxide, or solid calcium hydroxide, which was weighed out in 0.1 gm aliquots that were slurried with distilled water just prior to use. The resulting pH of the plant wastewater was recorded after each addition of alkali.

The titration curves for these bases are shown in Figure 3. Table 8 summarizes the quantities of bases required to neutralize plant wastewater to pH 5.5 and to pH 7.0.

TABLE 8. CHEMICAL REQUIREMENTS FOR NEUTRALIZATION

pH	NaOH (gals/1000 gals.)		NH_4OH (gals/1000 gals.)		$Ca(OH)_2$ (lbs./1000 gals.)
	5%	50%	5%	50%	
5.5	12.0	1.2	15.6	1.56	4.7
7.0	16.0	1.6	28.8	2.88	6.6

FIGURE 3. TITRATION CURVES FOR UNTREATED WASTEWATER



It should be noted that the above figures are in gals/1000 gals for sodium and ammonium hydroxide, but are in lbs /l000 gals for calcium hydroxide. Availability and cost, in addition to other factors, should be considered before selecting the alkali to use. For example, the possible eutrophic effects of ammonium on the receiving stream, and even the reservoir, must be evaluated carefully before using that base for neutralization.

Conclusions and Recommendations

1. If available locally at a competitive price, sodium hydroxide appears to be the chemical of choice because of availability of storage and feed facilities at the site, ease of handling, and minimum precipitate production.
2. Ammonium hydroxide should not be added in excess of nutrient requirements, if any, because of potential downstream eutrophication problems.
3. pH should be monitored in the aeration basin, rather than only in untreated influent waste, to insure adequate control for the biological treatment process.

RESPIRATION RATE STUDY

Because of the great variability in flows and wastes characteristics, it was important to consider the effects of shock loads upon the biological system. Two types of shocks were considered in this study: low pH and changing salt concentrations.

Effects upon biological activity were noted by changes in the respiration rate of the microorganisms. The procedure followed was in accordance with a technique developed earlier, which has been reproduced in the Appendix. A brief outline of the procedure follows.

Mixed liquor (ML) from several of the pilot lagoon units was mixed and aerated for two days without feeding to allow sufficient time for complete utilization of readily oxidized material. At that point, the endogenous phase of microbial growth had been reached and oxygen uptake was at a minimum (endogenous rate). When material that can be utilized by the organisms is added to a biological system in that condition, an increased rate of oxygen uptake (respiration) is observed. No increase in respiration indicates that the material added is not utilized. A decrease in the respiration rate indicates a toxic effect.

The dissolved oxygen (DO) was measured with a Weston-Stack DO meter using a probe tapered to fit into a BOD bottle. A stop watch was used to measure 1 minute intervals at which time DO was recorded. When DO was plotted against time, a straight line was obtained, the slope of which gave the respiration rate which was compared with the endogenous rate. Since the rate of oxygen uptake depends upon the number of organisms present, the respiration rate was calculated as mg/l of oxygen used per minute per gram of suspended solids. The suspended solids indicated the relative number of organisms present. In this way, rates can be comparable between runs, in spite of different suspended solids values.

The BOD bottle held 300 ml. Twenty ml of feed (a composite sample as in the treatability study) was added and then the bottle was filled with the aerated mixed liquor, To examine pH effects, the pH of the feed solution was reduced by addition of HCl and respiration rate measured at each value. Initial and final pH values were measured for each run, hut no change was observed during the rate measurements.

The mixed liquor plus the feed had a Cl' content of 13,O0O mg/l. To increase salinity, NaCl was dissolved in the feed prior to addition of the ML. To see whether decreased salinity would have a beneficial effect, a 1:2 dilution was made of both ML and feed, This also decreased the suspended solids by half. Nevertheless, data comparison and interpretation were feasible because of calculating respiration rates as mg/l DO per gram of suspended solids, or as percent of endogenous rate.

The mixed liquor had been acclimated to a pH of 6.9 and Cl- concentration of 13,000 mg/l. Figure 4 shows the changes in respiration rate when fed samples of other pH. It is seen that the respiration rate decreases with decreasing pH of the shock load. However, it should be noted that even at the lowest pH (1.5), the respiration rate still was higher than the shocks of low pH. That is not to say that such pH levels could be sustained indefinitely without detrimental effects. pH levels near neutrality allowed maximum utilization of oragnic material, which is most desirable in waste treatment.

Figure 4 also shows effects of changing the salinity. While increasing the salt concentration did reduce the respiration rate, it remained above the endogenous rate. Decreasing the salinity by half had neither a harmful nor beneficial effect upon biological activity. Again, it is important to note that this study shows acute effects due to shock loads and not long term effects, which may be either more or less serious under various circumstances.

Conclusions

1. The microorganisms are very resistant to low pH shock loads. Wastes should be neutralized to maintain generally desirable pH throughout the system and acceptable effluent pH, without major concern about shock loadings of short duration.
2. Increased salinity does not have a greatly detrimental effect initially. Although further study on long term effects is necessary, water conservation programs should not be delayed for fear of harmful effects to the aerated lagoon by the resulting increased salinity.

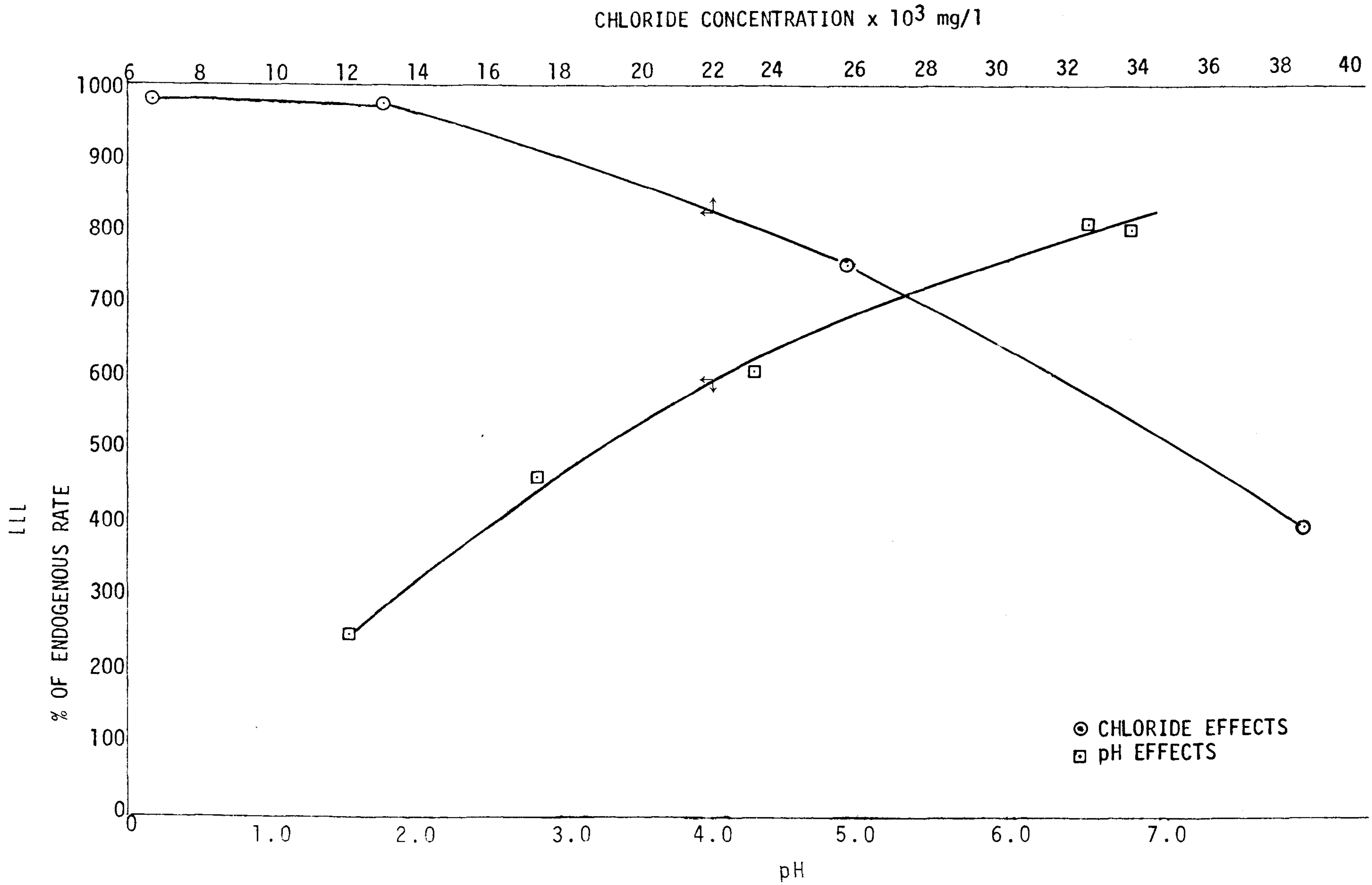


FIGURE 4. EFFECTS OF LOW pH AND HIGH SALT SHOCK LOADING UPON RESPIRATION

Conclusions

1. The microorganisms are very resistant to low pH shock loads. Wastes should be neutralized to maintain generally desirable pH throughout the system and acceptable effluent pH, without major concern about shock loadings of short duration.
2. Increased salinity does not have a greatly detrimental effect initially. Although further study on long term effects is necessary, water conservatior programs should not be delayed for fear of harmful effects to the aerated lagoon by the resulting increased salinity.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. A consulting engineer should be retained and detailed studies continued.
2. Water flows to each manufacturing process should be metered.
3. Suspended solids should be reduced by repairing floors and otherwise improving dry cleanup procedures, improving maintenance of screens, and removing or recovering suspended matter from the relish operation.
4. Improved screens should be installed at the lagoon influent and better maintenance, routines established.
5. Erosion from the tankyard area should be reduced.
6. Effluent from the manufacturing plant can be treated biologically.
7. pH should be monitored in the first bay of the aerated lagoon.
8. After establishing satisfactory biological activity it may not be necessary to add alkali continuously.
9. Subject to further studies, nutrients (nitrogen and phosphorus) should be added to insure BOD:N:P ratios of 100:5:1.
10. Adequate aeration is essential for successful biological treatment.
11. The existing 1agoon has sufficient detention to provide a high degree of BOD removal for “lows significantly greater than 100,000 gal/day.
12. Microorganisms involved in treatment of this wastewater appear to be resistant to low pH and variable chloride shock loads.
13. Water conservation can be undertaken without fear of significant harmful effects to biological treatment through increased salinity within the range which probably will be encountered in practice.
14. Communications with plant personnel concerning company policies and implementation of wastewater control procedures should be enhanced.

APPENDIX B

COST OF PICKLE BRINE RECOVERY

by

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Based upon a conceptual model of pickle manufacture that delineates waste streams, their rates, and their concentrations, *costs have been estimated for several processes for salt concentration and* for *organic removal.*

Based upon these estimates, reverse osmosis, butane freezing, distillation, and submerged combustion evaporation are most economical for salt concentration; biological oxidation is more economical for organic removal.

OUTLINE

1.0 A CONCEPTUAL MODEL OF PICKLE MANUFACTURE

In the manufacture of cucumber pickles, a large portion of the cucumber harvest must be preserved for processing at a later time. This preservation is normally accomplished by diffusing salt into the cucumbers. To accomplish this, the cucumbers are normally soaked in strong brine solutions, with periodic replacement of salt to maintain sufficient driving force for diffusion. A reasonable goal is to introduce salt into the cucumbers to the level of 15 percent or so, approximately 0.188 lb salt/lb of cucumbers.

Subsequently, most of this salt must be removed from the cucumbers by processing room: prior to packing.

1.1 TANK-YARD PROCEDURES

It is assured that salt is introduced into the pickles in the following staged process. First, pickles are soaked in saturated brine until equilibration; second, a small amount of depleted brine is withdrawn to make room for saturated brine addition; third, equilibration proceeds; and fourth, the process is repeated.

At stage by immediately following brine addition, there are

c_n lb salt/lb cucumbers within the cucumbers, and w_n lb salt/lb water in

the brine. Then denoting the n-plus-first stage as that resulting after equilibration, the salt concentration in the cucumbers will equal that in the brine, thus,

$$c_{n+1} = W_{n+1} = \frac{c_n + w_n}{2}$$

(The voidage within the cucumbers is taken as 50 percent so that there exists, in normal processing, approximately 1 pound water/lb cucumbers).

At this point d_{n+1} lb of water are withdrawn to make room in the tank for the addition of another d_n+1 lb of water containing salt near the saturation point. Then $w_{n+1}\,d_{n+1}$ lb of salt are withdrawn from the vessel, and Bd_{n+1} lb of salt are added to the vessel as nearly saturated brine, where B is the replacement brine concentration in lb salt/lb water.

After the addition of concentrated brine, the salt content within the tank is $w_{n+1} - w_{n+1}\,d_{n+1} + Bd_{n+1}$. This expression is to be set equal to s, the interstage concentration to which the salt solution must be adjusted for effective pickle processing. Solving for d_{n+1}, there results

$$d_{n+1} = \frac{s - w_{n+1}}{B - w_{n+1}}$$

These formulas can be used to calculate step-wise through the pickle salting procedure. Assume $d_0 = 0$, $w_0 = 0.194$ lb salt/lb water,

s = 0.194 lb salt/lb water, and B = 0.33 lb salt/lb water (0.194 lb salt/lb water corresponds to 16.25 per cent salt, and 0.33 lb salt/lb water corresponds to 25 percent salt). Stage-wise concentrations are the following:

$C_0 = 0$	$S = 0.194$
$W_0 = 0.194$	$B = 0.333$
$C_1 = W_1 = 0.097$	$D_1 = 0.411$
$C_2 = 0.097$	
$W_2 = 0.194$	
$C_3 = W_3 = 0.1455$	$D_3 = 0.259$
$C_4 = 0.1455$	
$W_4 = 0.194$	
$C_5 = W_5 = 0.170$	$D_5 = 0.147$
$C_6 = 0.170$	
$W_6 = 0.194$	
$C_7 = W_7 = 0.182$	$D_7 = 0.079$
$C_8 = 0.182$	
$W_8 = W_9 = 0.188$	Assume STOP

Since 0.188 lb salt/lb cucumber is the target salt concentration within the cucumbers, the cucumber salting process is halted at this point.

Per pound of salt stock, the spent brine withdrawals from the processing tanks at the various stages are the following, with totals as shown.

Per pound of salt stock, get the following:

	0.411 lb H_20	0.0399 lb salt
	0.259 lb H_20	0.0377 lb salt
	0.147 lb H_20	0.0250 lb salt
	0.079 lb H_20	0.0144 lb salt
With Totals	0.896 lb H_20	0.177 lb salt
+	1.00 lb stock	0.188 lb salt
		0.493 lb salt

Thus, per pound of cucumbers, the draw-down from the tanks is 0.896 lb water containing 0.177 lb salt or 0.131 lb salt/lb water. In addition, there is l-lb water remaining in the tank containing 0.188 lb salt.

Assuming that 500,000 bushels of cucumbers are processed in 100 days during the salting down season, and assuming furthermore 9 gal/bushel cucumbers and 4 lb/gal, the estimated weight of cucumbers is 18 x 106 lbs. At 0.896 lb water/lb cucumber, the water rate is then 16.1 million lb/l00 days or approximately 19.4 thousand gal/day.

The initial concentration is 0.131 lb salt/lb water, which corresponds 7.63 lb water/lb salt. This stream is to be concentrated to 0.33 lb salt/ lb water, or 3.0 lb water/lb salt. Consequently, the fraction $\frac{4.63}{7.63}$ = 60.7 percent of the water must be removed in effecting this separation. Thus the water removal rate in processing the tank yard brines is 1.21×10^6 gal/100 day season, or 12,000 gal/day.

The final brine solution from which the cucumbers are withdrawn for processing contains 0.188 lb salt/lb water. This brine is sufficiently concentrated that it needs no further processing and can be saved as is until the next season. It is assumed that this brine is stored in the tanks until the following season at which time it is reconcentrated with saturated brine to begin processing the new crop.

1.2 PROCESSING ROOM PROCEDURES

It is assumed that in salt removal, each lb of cucumbers containing 0.188 lb salt is contacted with 2-lb of water and allowed to equilibrate. After equilibration there results l-lb of cucumbers containing 0.0626 lb salt and 2-lb water containing 0.125 lb salt. This dilute brine stream constitutes the first processing waste.

The lb of cucumbers is washed a second time with l-lb of water. Sufficient time for equilibration is not allowed, however; the washing process is stopped at the point at which the cucumbers contain 0.038 lb salt/lb cucumbers. The dilute water stream from this washing containing 0.025 lb salt/lb of water is the second processing waste. [The figure 0.038 lb salt/lb cucumbers represents an average salt concentration weighted according to the relative production of dills and sweets. We have assumed 60 percent dills (4.7 percent salt) and 40 percent sweets (2.5 percent salt). The weighted average gives 3.82 percent salt remaining in the pickles or 0.038 lb salt/lb cucumbers.]

The rate of first processing waste, based upon an assumed 200 days of operation, is 21,600 gal/day containing 0.0626 lb water/lb salt. In brine recovery, the stream must be concentrated to 3 lb water/lb salt, or 17,500 gal/day of water must be removed, leaving 4,100 gal/day of brine at a salt level of 0.33 lb salt/lb water.

Similarly, the rate of second processing waste is 10,800 gal/day containing 40 lb water/lb salt. This stream must be concentrated to 3 lb water/lb salt; thus, approximately 10,000 gal/day of salt free water must be removed to leave 800 gal/day of brine with concentration 0.33 lb salt/lb water.

A schematic diagram of these streams along with the flow rates and compositions is given in Figure 1.

1.3 BRINE CONCENTRATING REQUIREMENTS

Comparing water removal rates, i.e., 12,000 gal/day from the tank yard brines versus a total of 27,500 gal/day from processing room waste, indicates that equipment sized to handle the latter could easily handle the former. Thus, attention is given to the design of equipment to handle mixed processing room wastes delivered at a rate of 32,400 gal/day containing 0.092 lb salt /lb water. Separating equipment must be sized to remove 27,500 gal/day of water leaving 4,900 gal/day of saturated brine to be used in subsequent processing.

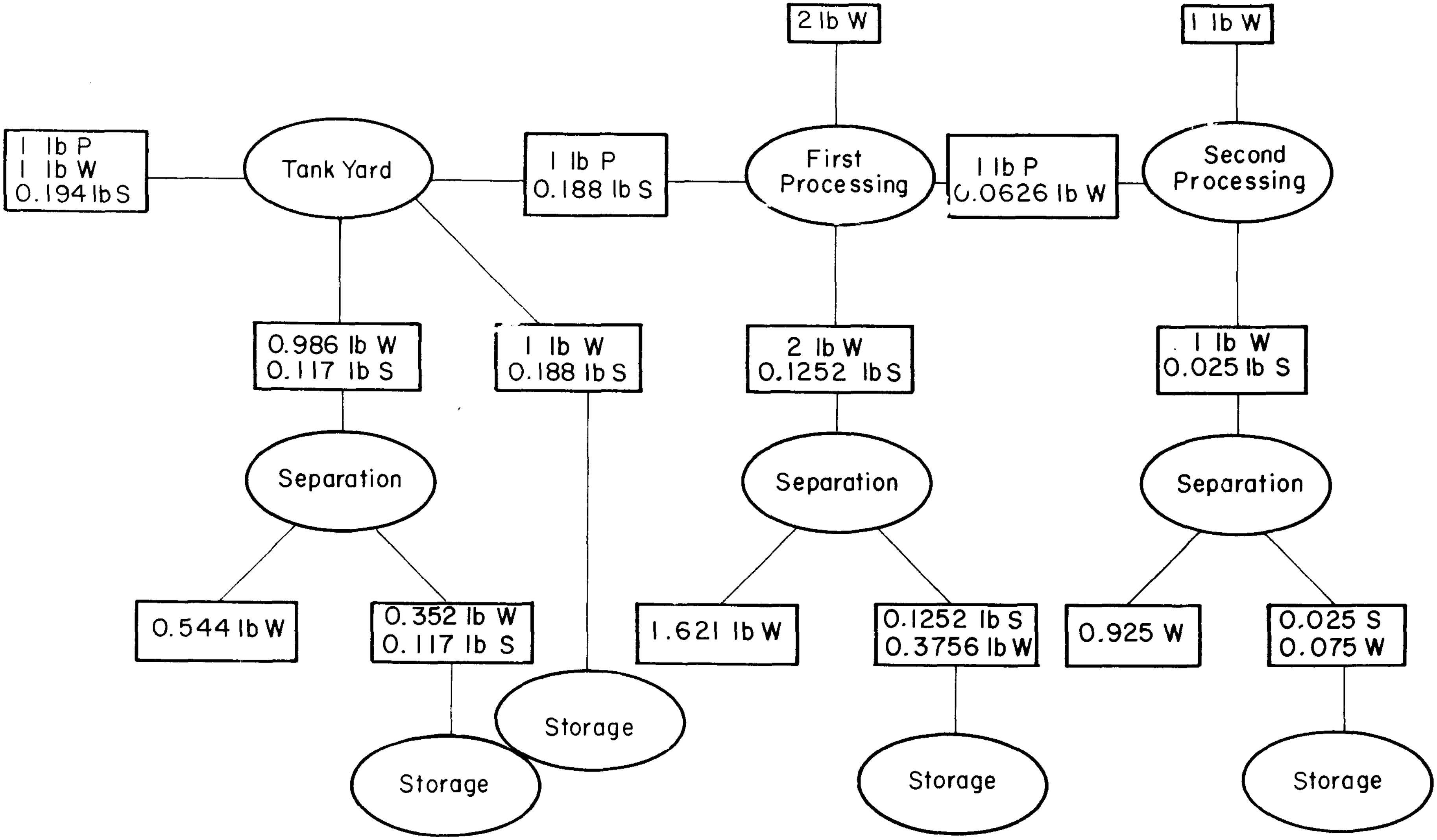

FIGURE 1. Schematic of Stream Flows in Pickle Processing. Basis: 1 lb Pickles

2.0 METHOD OF COST ESTIMATION

Costs have been estimated using a slight modification of a method developed by the Office of Saline Water[1] in which overall process costs are based on the costs of the major pieces of equipment. The cost of the major pieces of equipment must be estimated from vendor quotes, from the literature, or from other means of determination, and costs other than those for major equipment are taken as fixed percentages of the major equipment costs.

Total annual operating costs of a plant are comprised of

1) Capital costs, including major equipment, other materials, construction labor, indirect labor, taxes, insurance, engineering, and interest on construction capital, and
2) Annual operating costs, including the amortized capital cost, interim replacement, taxes, insurance, operating labor, and overhead. The total annual operating costs can, if desired, be expressed as the total cost per unit of production. In the case of pickle brine processing, significant bases for report cost/unit of production might be total cost per ton of pickles or total cost per ton of salt recovered.

2.1 CAPITAL COST ESTIMATION

Capital costs are estimated as follows:

Assuming that a process schematic has been drawn and that major items of equipment have been specified and their size determined, costs are estimated for these major items of equipment; these costs are designated as E.

In the construction of-the plant, other materials must also be purchased, piping, electrical wiring, small pumps, instrumentation, etc. These costs are referred to as other materials costs, M, and are taken as 40 percent of E.

Labor must be provided for construction of the plant. Construction labor, L, is taken as 60 percent of E.

[1]Jenkins, David S. et al., "A Standardized Procedure for Estimating Costs of Saline Water Conversion", Office of Saline Water, March 1956.

Labor indirect charges, including payroll burden, supervision, and construction equipment, is 43 percent of the labor charges, or has 25.8 percent of the major equipment charges.

The sum of these four costs is designated as the basic plant cost (BASC) and is equal to 2.258 times the major equipment cost.

To the basic cost must be added engineering cost, (12 percent of the basic plant cost), and tax and overhead (12 percent of the sum of the basic plant cost plus engineering charges) to get the fixed capital investment (FCI).

Working capital and startup funds at 11 percent of the fixed capital investment must also be included as must interest on the construction capital at 5 percent of the fixed capital investment.

The total of all these charges gives the total capital investment. A sumnary of the factors entering into the total capital investment is given in Table 1.

2.2 OPERATING COST ESTIMATION

Annual operating costs are based, by and large, on the total capital investment. First, the fixed costs (capital recovery, replacements, taxes, and insurance) as a fraction of the total capital investment are calculated. Assuming 8 percent for 15 years, the capital recovery factor is 0.117, or 11.7 percent of the total capital investment must be set aside each year for capital recovery. To this must be added insurance at 0.3 percent, state and local taxes at 6 percent and a fund for replacements at 0.4 percent. Summing these items gives the total fixed cost at 0.184 times the total capital investment. To these fixed costs must be added direct operating costs consisting of operating labor plus maintenance labor and supplies. For pickle processing it is assumed that no supplementary charges must be taken for labor, in other words, that labor requirements can be met by existing staff. Maintenance labor and supplies are taken to be 4 percent of the total capital investment.

Adding plant overhead at 2 percent of the total capital investment gives the total annual cost as 0.244 times the total capital investment.

To these costs must be added annual cost for energy, but credit can also be taken for the value of salt recovered.

The total annual cost so estimated should include all cost centers and should reasonably form the basis for initial estimates of process feasibility and of process economic attractiveness.

A sumnary of factors entering into annual operating costs is given in Table 2.

TABLE 1. CAPITAL COST ESTIMATION

Major Equipment Cost, E				
Other Materials Cost, M		0.4 E		
Construction Labor, L		0.6 E		
Labor Indirect		0.43 L	=	0.258 E
	=	BASC	=	2.258 E
Engineering: 0.12 BASC = BARC			=	0.2710 E
Tax (2% BARC, OH 10% BARC)			=	0.0325 E
	=	FCI	=	2.562 E
Working Capital and Startup: 11% FCI			=	0.282 E
Interest on Construction Capital = 0.5 FCI			=	0.141 E
		TOTAL		2.985 E
		TOTAL (FCI) =		3.0 E

3.0 COST ESTIMATES FOR BRINE CONCENTRATION

Costs have been estimated for the following processes for recovering salt from pickle brines: reverse osmosis, electrodialysis, two freezing processes - vapor compression and butane, solar humidification, solar distillation, the following methods of distillation; multi-stage flash, long-tube vertical, vapor reheat, and vapor compression; and submerged combustion evaporation.

TABLE 2. ANNUAL OPERATING COSTS

Fixed Costs		Fraction of TCI
Capital Recovery		0.117
Insurance		0.003
Taxes		0.060
Replacements		0.004
	TOTAL	0.184 FCI
Direct Costs		**Fraction of TCI**
Labor - assume existing staff		0.04 TCI
Maintenance labor and supplies		
Indirect Costs		**Fraction of TCI**
Plant Overhead (Total Indirect)		0.02 TCI
	TOTAL ANNUAL COST	0.244 TCI

Costs for major items of equipment for these processes have been estimated in a previously published study[2] for relatively large-scale plants. These major equipment costs were scaled to the problem in question, first, by using the exponential rule $C_1/C_2 = S_1/S_20^{0.7}$ to correct for the smaller scale associated with pickle manufacture, and second, by multiplication by the Marshall Stevens Construction Cost Index Ratio, to convert 1965 construction dollars into 1973 dollars.

[2]De La Rue, R. E., and Jones, J. M., "Comparative Engineering Analysis of Alternative Processes for Saline Conversion", Prepared for Office of Saline Water, U. S. Dept. of the Interior, Washington, D. C., under Contract No. 14-01-0001-412, May 1966.

These estimates have been validated by selected cross-checking. Selected types of equipment, especially evaporators, are the subject of independent cost correlations. These evaporators costs are calculated for processing and compared with evaporator contributions to the total cost as calculated using the OSW method, These results were in substantial agreement.

Cost estimates are summarized in Table 3. Reverse osmosis, butane freezing, distillation, and submerged combustion evaporation seem to warrant further consideration.

4.0 COST ESTIMATES FOR ORGANIC REMOVAL

Estimates have been made of the cost of two processes for the removal of organic materials from pickle brine: submerged combustion evaporation followed by kiln drying, and biological oxidation.

For the submerged combustion process, it has been assumed that submerged combustion would also be used for salt concentration, consequently the evaporator cost has been estimated as an increment to the evaporator cost for salt concentration.

Costs of biological oxidation have been estimated from published information,[3] assuming that BOD removal proceeds by first order kinetics and that the costs would be identical to those for municipal waste treatment providing the residence time is increased to account for the higher BOD in pickle brines. Under these assumptions, the time required for oxidation of BOD at a concentration of 4000 mg/liter is 2.3 times the time required for oxidation of 200 mg/liter, taken as representative of municipal sewage. Thus, the plant size should be 2.3 times 25,000 gal/day or about 63,000 gal/day. Total capital investment estimates were based on this size plant.

Cost estimates for organic removal are summarized in Table 4.

[3]Smith, R., "A Compilation of Cost Information for Conventional and Advanced Wastewater Treatment Plants and Processes, Prepared for Federal Water Pollution Control Administration, Cincinnati, Ohio, 1967.

TABLE 3. COST ESTIMATES FOR CONCENTRATING PICKLE BRINE

	Major Equipment Capital Cost for Brine Processing		Total Capital Investment in 1973 Dollars $ x 10^3	Total Annual Cost $ x 10^3	Estimated Annual Power Cost $ x 10^3	Estimated Annual Fuel Cost $ x 10^3	Total Annual Cost Including Fuel and Power $ x 10^3
	1965 Dollars $ x 10^3	1973 Dollars $ x 10^3					
Reverse Osmosis	56	80	240	59	1.7	--	61
Electrodialysis	360	514	1,542	554	16.1	--	550
Freezing							
Vapor Compression	78	111	333	81	8.8	--	90
Butane	70	100	300	73	1.8	--	75
Solar							
Humidification	143	204	612	149	2.0	--	151
Distillation	129	184	552	135	0.05	--	135
Distillation							
Multistage Flash	57	82	246	60	0.1	3.4	64
Long Tube Vertical	57	82	246	60	0.2	3.9	64
Vapor Reheat	76	109	327	80	0.1	3.0	83
Vapor Compression	130	186	558	136	0.4	2.7	139
Submerged Combustion Evaporation	--	65*	195	48	--	23	71

*Vendors quote

TABLE 4. COST ESTIMATES FOR ORGANIC REMOVAL FROM PICKLE BRINE

	Equipment Cost $\$ \times 10^3$	Total Capital Investment $\$ \times 10^3$	Total Annual Cost $\$ \times 10^3$	Fuel Cost $\$ \times 10^3$	Total Annual Cost $\$ \times 10^3$
Submerged combustion and incineration	35[4]	105	25	7	32
Biological oxidation (activated sludge)		60[5]	15		15

[4]Chilton, C. H., Cost Engineering in the Process Industries, McGraw-Hill Book Co., New York, 1960.

[5]Smith, R., "A Compilation of Cost Information for Conventional and Advanced Wastewater Treatment Plants and Processes", Prepared for Federal Water Pollution Control Administration, Cincinnati, Ohio, 1967.