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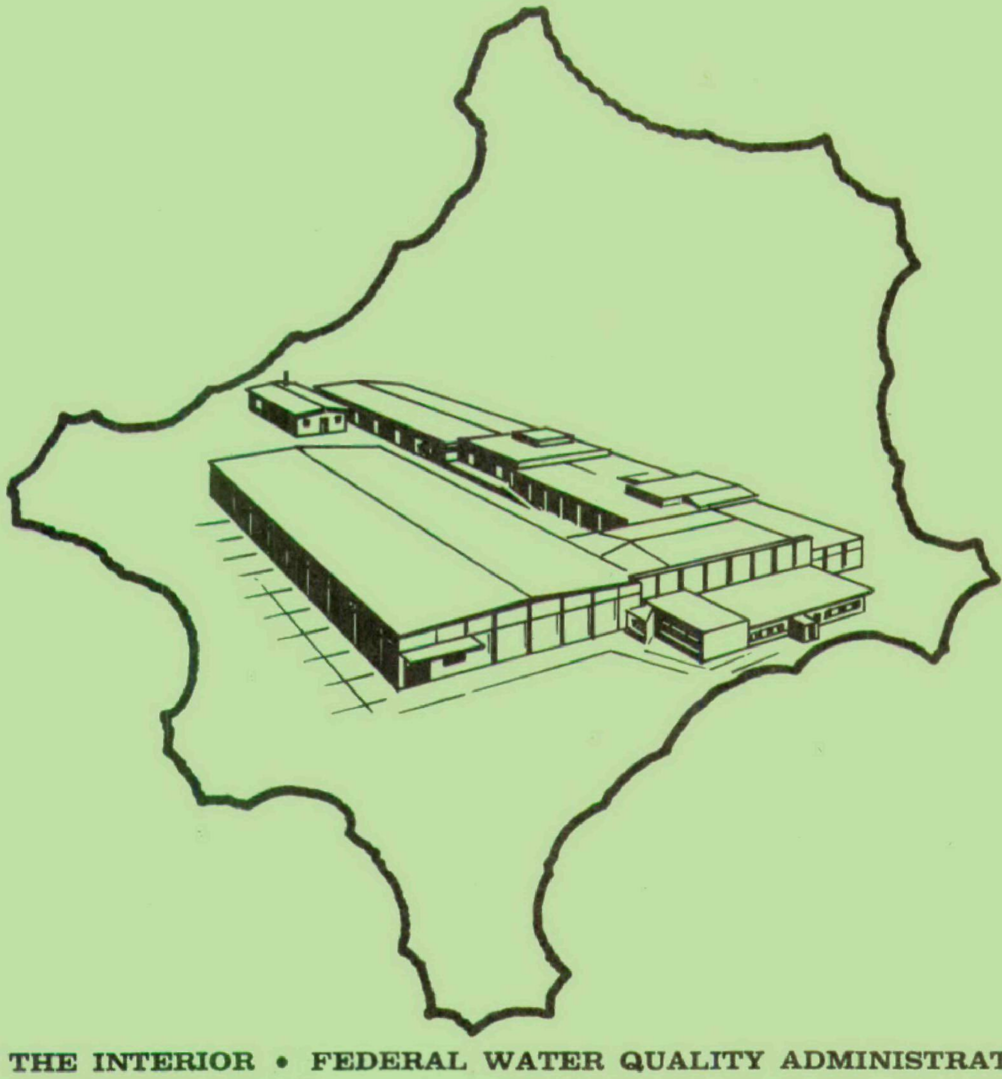
Treatment of Sole Leather Vegetable Tannery Wastes



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"TREATMENT OF SOLE LEATHER VEGETABLE TANNERY WASTES"

SEPARATION, PRETREATMENT, AND BLENDING OF THE WASTE FRACTIONS FROM A SOLE LEATHER TANNERY FOR FINAL TREATMENT IN A STRATIFIED ANAEROBIC-AEROBIC LAGOON SYSTEM

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEPARTMENT OF INTERIOR

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Abstract

Four major studies, two pilot scale and two full scale, were carried out during the period of this investigation. The basic objective of the studies was to find a technically feasible and economical procedure for treating the wastes from a sole leather vegetable tannery. A detailed identification of the sources of all wastes as well as a comprehensive characterization of each waste fraction was made for the International Shoe Company Tannery located at Marlinton, West Virginia.

It was found that a large percentage of the pollutants initially were contained in a relatively small fraction of the total waste volume. The treatment scheme consisted of separation and pretreatment of the individual waste streams followed by mixing all waste streams for additional treatment in an anaerobic-aerobic lagoon system.

The lime bearing wastes from the beamhouse were screened, treated with polyelectrolytes, and then clarified. The lime sludge was used for landfill. The system was designed to treat one million gallons of waste per week. BOD was reduced 85-95 percent and the suspended solids reduction was in excess of 95 percent. Installed cost of the total system was approximately $40,000 and it is estimated that the operating cost will be about $15,000 per year or 7 cents per hide processed.

This report was submitted in fulfillment of Research and Development Grant Number WPD-185 between the Federal Water Pollution Control Administration and the University of Cincinnati.

Key Words:

Tannery
Pilot Plants
Prototype Plants
Waste Treatment
Industrial Wastes
Clarification
Anaerobic-Aerobic Lagoons

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Section 1

Conclusions and Recommendations:

The investigation described in this report was conducted for the express purpose of developing and evaluating a procedure for treating the wastes from a sole leather tannery. The study plan included the characterization, separation, and pretreatment of the various waste fractions followed by a blending of all waste streams for final purification. Pilot plant scale studies were used to provide design and operational data for a full-scale waste treatment system which was constructed and operated as a part of the demonstration grant.

The lime-bearing wastes from the beamhouse were screened, treated with an anionic polyelectrolyte and clarified prior to being mixed with the other beamhouse waste fractions (also screened). The pretreated beamhouse wastes then were subjected to biological treatment in stratified anaerobic-aerobic lagoons equipped with floating aerators. After the lagoons had been operated for several months on beamhouse wastes, the spent vegetable tan liquors were added and the total wastes treated biologically.

The data derived from the pilot plant and full scale treatment procedure over a period of approximately three years lead to the following specific conclusions and recommendations:

1. A detailed study of the total tanning operations is a required first step in formulating a feasible waste treatment procedure. Specifically the sources of all wastes must be identified and each waste stream must be completely characterized. The volume, discharge pattern and constituents of each waste fraction must be determined accurately and related to specific tanning operations.

2. A waste reduction program through conservation, reuse, and process changes is feasible for a sole leather tannery. Such a program can be effective only if the plant operating personnel are fully informed of the objectives to be achieved and the role that they play in the total plan.

3. About 70 percent of the total pollutional load discharged from a sole leather tannery initially is contained in three or four waste streams which comprise only about 30 percent of the total volume of wastes discharged. Segregation and pretreatment of the individual waste fractions, therefore, is necessary if an economical waste treatment procedure is to be achieved.

4. Separation of waste streams can be facilitated by use of self-priming and submersible pumps coupled to plastic piping run overhead rather than underground. It is important that segregation procedures not interfere unduly with normal tanning operations or require undue maintenance.

5. Excess hair, fleshings and grease should be removed from the waste streams at an early point in the waste management procedure as these materials clog pumps and generally interfere with any mechanical handling of the wastes. Mechanically cleaned screens with openings as small as 20 mesh provide excellent control of coarse suspended solids and require little maintenance.

6. Feasible pretreatment methods for the individual waste streams can be determined by laboratory and pilot plant studies. For example it was found that the lime-bearing waste fractions from the beamhouse containing a considerable quantity of suspended lime could be clarified readily by use of an anionic polyelectrolyte followed by quiescent settling. By contrast, without polyelectrolyte, little clarification was achieved. It was noted also that the suspended lime could not be removed effectively when all of the beamhouse waste streams were mixed prior to adding the polyelectrolyte. The data obtained from the laboratory and pilot plant studies were used for designing the full-scale separation, pretreatment and clarification system.

7. In the full scale system an anionic polyelectrolyte at a dosage of 10 mg/l provided optimum removal of the suspended lime particles from the lime waters. Removal efficiencies in excess of 90 percent were achieved routinely at clarifier overflow rates of 1600 gallons per day per squarefoot of clarifier surface area. Even at overflow rates of 2,000 - 2,500 gpd/ft^2, removal efficiencies of 80-90 percent were quite common.

8. The sludge obtained from the lime-water clarification operation was pumped from the bottom of the clarifier and used for land-fill. The solids content of the sludge as pumped from the clarifier ranged from 8 to 30 percent with an average of 15 percent. The volume of sludge produced averaged about 3 percent of the total volume of lime-water clarified.

The lime sludge when placed on porous drying beds could be dried sufficiently in three days to permit it to be handled as a dry solid.

9. After pretreatment all of the waste streams from the beamhouse were blended and pumped to a lagoon system for biological treatment. The pH of the blended beamhouse wastes ranged from 11.5-12.5. Neutralization of the excess alkalinity and reduction of the pH to a suitable range for biological treatment was accomplished by adding spent bleach acid to the lagoons.

10. The combination of spent bleach acid and beamhouse wastes produced an extremely voluminous precipitate which reduced the effective capacity of the lagoons significantly. It was found, however, that once the lagoons became operative sufficient carbon dioxide and organic acids were formed to automatically control the pH of the system. Further neutralization, therefore, was unnecessary.

11. Severe odor problems were encountered when operating the anaerobic-aerobic lagoons on beamhouse wastes only. The addition of the spent vegetable tan liquors eliminated the odors completely.

12. Foaming of the aerated lagoons occurred periodically and was severe enough to prohibit the location of such a system near residential or commercial areas. High pressure water jets were effective in controlling the foam when air temperatures were above freezing but could not be used during the winter months.

13. Loading intensities as high as 20-25 pounds of BOD per day per 1,000 cubic feet of lagoon capacity were employed in the pilot plant studies. The loading intensity for the full-scale system ranged from 2 to 20 pounds per day per 1000 ft^3. The reduction in BOD through both the pilot and full scale units normally ranged from 80-95 percent. During cold weather when the water temperature in the full-scale lagoon dropped to 33-34°F. for an extended period of time BOD reductions of 65 to 75 percent were obtained.

14. Little reduction in color of the spent tan liquors was achieved in the biological system. It was found that the color could be precipitated either before or after biological treatment by raising the pH of the wastes to 11.5 or greater with lime. The resulting precipitates, however, were voluminous and settled poorly. In some cases settling was improved by use of polyelectrolytes.

15. The final effluent from the full scale lagoon system contained from 100-200 mg/l of suspended solids. The settleable solids level, however, was near zero through-

out the period of study.

16. Large numbers of bacteria were present in the final effluent. Adequate disinfection was achieved with chlorine at a dosage of about 30 mg/l and a 15-minute contact period. The treated waste exerted an extremely high chlorine demand but the reaction was sufficiently slow to permit high bacterial kills before the chlorine disappeared.

17. The installed cost of the Marlinton system was approximately $40,000. The operating costs are estimated at about $15,000 per year or $0.07/hide processed based on a production level of 800 hides per day.

18. Further research is needed to provide additional operational and performance data for the anaerobic-aerobic lagoons during the winter months.

19. A further definition of the bacteriological characteristics of tannery wastes is needed along with more refined studies on disinfection requirements and procedures.

20. Studies on the combined treatment of domestic sewage and sole leather tannery wastes in anaerobic-aerobic lagoons are needed. Most of the sole leather tanneries remaining in operation are located near communities where joint treatment would be physically possible.

21. More research work is needed on the removal of the color from spent vegetable tan liquors. It is likely that such information would be of value in the treatment of other types of wastes containing vegetable extracts.

Section 2

Introduction

The tanning industry long has been recognized as a major contributor to water pollution because of the high concentrations of organic and inorganic substances present in untreated tannery effluents. The overall volume of tannery wastes in the United States, however, amounts to only about 16 billion gallons per year with the sole leather tanneries contributing approximately 10 percent of this volume. On a national basis, therefore, the wastes from sole leather tanneries are relatively insignificant whereas on a local or regional basis they often are of a major concern.

It is of interest to note that some of the earliest work on industrial waste treatment in the United States was devoted to finding acceptable means for treating tannery wastes. The annual reports of the Massachusetts State Board of Health describe laboratory and pilot plant studies on tannery waste treatment from 1850 to about 1910. The Public Health Service performed extensive waste treatment studies at various tanneries in the period from 1912-1914 (1). Following the Public Health Service work, investigators for the tanning industry, both in the United States and abroad, conducted many studies on the treatment of tannery wastes alone and in combination with domestic wastes (2,3,4,5,6,7,8,9,10,11 and 12).

While the research effort has been extensive, few full scale treatment plants have been built for handling tannery wastes. A detailed investigation of the tanning industry in the United States in 1965-66 revealed that while a number of tanneries were served by various treatment procedures no tannery had acquired a treatment system that was completely satisfactory. Operational data gathered during the survey indicated that most of the systems had been improperly designed from the standpoint of the effects of specific constituents of tannery wastes on conventional waste treatment processes.

The tanning industry, however, recognized the need for finding acceptable means of waste treatment which might be employed throughout the industry. In 1965 the Tanners' Council of America retained the Author as a consultant on waste management. During 1966 a laboratory-pilot plant study on the treatment of beamhouse wastes from a sole leather tannery was carried out at the International Shoe Company Tannery located at Marlinton, West Virginia. This study was sponsored jointly by the Tanners Council of America, the Water Resources Commission of West Virginia and the University of Cincinnati. The data derived from the pilot plant study formed the basis for the Demonstration Project described in this report. This Demonstration Project supported by the Federal Water Pollution Control Administration also was conducted at the Marlinton Tannery.

Approximately 160 persons are employed at the Tannery and about 800 heavy steer hides are processed into sole leather on each of the five working days per week. While many individual steps are required for converting the hides into leather they can be grouped under two major operations, beamhouse and tan yard. In the beamhouse operations the hides are prepared for tanning and in the tan yard the skins are converted into sole leather. Salt cured hides are used.

In the beamhouse operations, the hides are initially washed and soaked to remove curing salt, extraneous dirt, blood, and manure and to soften the hides. After the hides are washed and soaked, they are immersed in a lime-sulfide solution in still vats or pits. The lime and sulfides dissolve the unwanted hide substance and loosen the hair. After the hides are removed from the lime vats, they are rinsed to remove excess chemicals, unhaired, fleshed, and sent on to the bating process. Bating consists of washing the hides in a solution containing wetting agents, enzymes, and ammonium salts to remove excess lime and to further prepare the hides for tanning.

In the tanning operation the hides are gently rocked for a period of several weeks in a solution made from vegetable extracts. The vegetable extracts react with the collagen fibers to produce leather. Following the tanning step, the leather is run through a bleaching process to remove excess tannin and to give the desired color control. Final finishing operations for sole leather are mainly mechanical in nature and are designed to impart specific characteristics to the leather.

The major parameters used for characterizing sole leather tannery wastes are pH, chlorides, BOD, COD, chlorine demand, total solids, suspended solids, ammonia, organic nitrogen, alkalinity, sulfides, and color. Most of the pollutants stemming from sole leather tanning processes are found in the initial wash and soak waters, the spent lime liquors and the spent vegetable tanning solutions.

The beamhouse wastes have a high concentration of BOD, COD, suspended solids, ammonia, organic nitrogen, sulfides, chlorides, and alkalinity. The pH of the total beamhouse wastes ranges from 11.5 - 12.5. The major pollutants found in the beamhouse wastes initially are contained in relatively small batch volumes of waste.

The spent tan liquors are extremely high in color and COD and moderately high in BOD. The pH averages about 4.5 and the acidity is sufficient to reduce the pH of the total tannery wastes to about 9.5 when all waste streams are mixed.

The major waste fractions stemming from the tanning operations are illustrated in Figure 1. Some of the more important characteristics of the individual waste streams are tabulated in Table 1.

Table 1: Characteristics of Tannery Waste Fractions

Waste Fraction	Flow (tgpd)	COD (mg/l)	Suspended Solids (mg/l)	pH
Wash Water	25	2100	1300	6.8
Soak Water	10	2200	1000	7.8
Lime Water	10	11900	30300	12.3
Rinse Water	20	2500	4900	12.3
Hair Water	15	2500	3100	12.3
Fleshing Water	5	3600	4900	12.3
Bate Water	55	1700	1000	9.0
Spent Tan Liquors	60	10000	500	4.5

Note: 1 tgpd = 3785 liters per day tgpd - 1,000 gal/day

As shown in Table 1, the lime vat, rinse vat, and hair washer waters contain moderate to high concentrations of COD and suspended solids (mostly $Ca(OH)_2$) and have a high pH; yet they make up only 32 percent of the beamhouse waste water volume. The wash, soak, and bating waters represent 64 percent of the waste volume, but are moderate to low in COD and suspended solids and near neutral in pH.

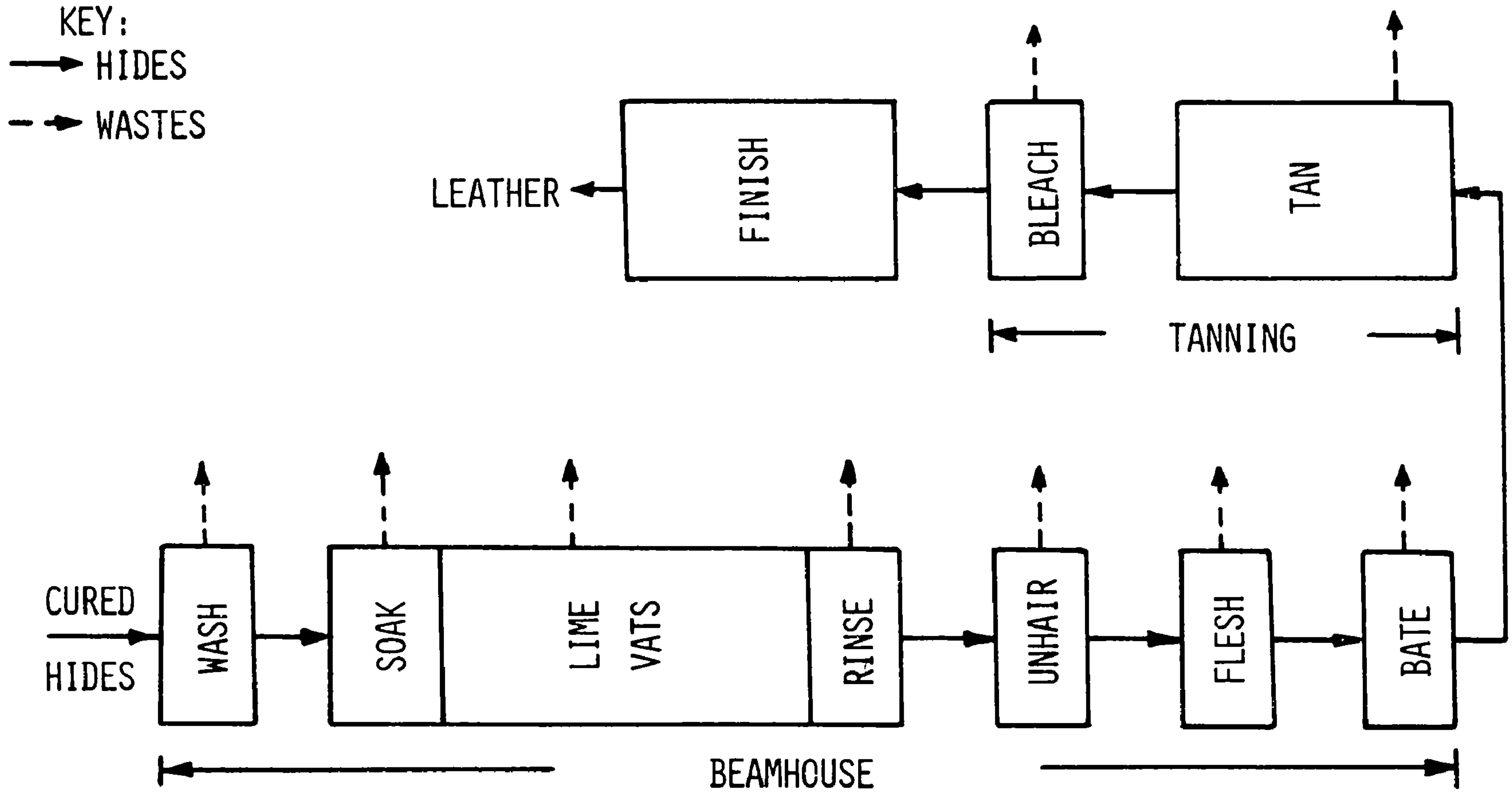


FIGURE 1. SOURCES OF MAJOR WASTES

When the concentrated waste fractions are mixed with the large volumes of wash waters and other less concentrated wastes, the resulting or final beamhouse waste stream is large in volume and still grossly polluted. For example, lime while soluble to a rather limited extent in water will continue to dissolve as the liquors containing high concentrations of suspended lime are mixed with non-lime bearing wastes thereby increasing the hardness, alkalinity, and pH of the combined waste streams.

The spent tan liquors when mixed with the beamhouse waste streams containing lime yield a voluminous precipitate which is difficult to separate from the liquid phase. In addition the colored compounds present in the spent tan liquors are sufficiently concentrated to impart an extremely intense color to the total tannery wastes.

In general, small volumes of concentrated wastes are easier and more economical to treat than large volumes of a more dilute waste. Also in many cases it is easier to remove the pollutants from the individual waste streams than from the combined wastes.

It was determined, therefore, that the basic approach to be used for the Marlinton project would be that of removing the pollutants from the individual waste streams when feasible. Waste streams were to be mixed only after pretreatment or when such mixing could be justified in terms of economy or ease of treatment.

Section 3

Experimental and Operational Findings

Research Plan:

The basic plan utilized in this investigation consisted of separating the beamhouse waste streams, removing the excess suspended lime, and blending all waste streams for final treatment by biological means. Pilot plant studies were used to provide design data for the full scale system. In general, each unit or treatment process was constructed and evaluated before the next downstream unit was constructed. This "step-by-step" procedure provided a desired degree of flexibility to the design of the total system and allowed for easy modification when changes had to be made in the basic plan.

Removal of Suspended Lime:

A review of the literature showed that many investigators believe that the excess suspended lime is the major complicating factor in the treatment of beamhouse wastes because of its tendency to form calcium carbonate scale on the surfaces of conduits, containers and mechanical equipment. The high pH resulting from the lime also precludes any form of biological treatment for reduction of the BOD of the wastes unless the waste is partially neutralized. Neutralization of the excess lime with acid is costly and leaves the waste with a high calcium content. Also neutralization with acid must be controlled carefully because of the danger of liberating hydrogen sulfide from the sulfides contained in the waste. Flue gas sometimes is used to neutralize the excess alkalinity.

Ceamis (13), Jansky (14), Rosenthal (15), Guerree (16) and Eye and Graef (17) have shown that the combined tannery wastes are ameanable to biological treatment if the suspended lime is removed as a pretreatment measure. Ceamis (13), Jansky (14) and Domanski (18) investigated the use of iron salts as coagulants for the lime-bearing waste fractions. Sproul (19), Scholz (20) and Eye and Graef (17) have reported on the use of polyelectrolytes in tannery waste treatment.

A laboratory study was conducted to determine the effectiveness of polyelectrolytes as a flocculant for the lime-bearing beamhouse effluents. From correspondence with several manufacturers it was learned that the beamhouse waste water characteristics, i.e. high pH, colloidal lime and soluble protein, dictated the use of anionic, rather than cationic or non-ionic polyelectrolytes. This information was substantiated later in the study.

Jar tests, performed to determine which waste fractions could be flocculated by an anionic polyelectrolyte, showed that the lime-bearing waters (i.e. lime vat, rinse vat, and hair washer waters) could be treated readily. Table 2 contains the jar test data.

Table 2: Flocculation of Beamhouse Waste Fractions by an Anionic Polyelectrolyte

Waste Fraction	Results	Dosage
Wash Water	NF	-
Soak Water	NF	-
Lime Water	EF	6 mg/l
Rinse Water	EF	6 mg/l
Hair Water	EF	10 mg/l
Fleshing Water	NF	-
Bate Water	NF	-

Note: NF = No flocculation
EF = Excellent flocculation

Jar tests were performed to determine the optimum dosage of anionic polyelectrolytes. Dosages of 0-60 mg/l of polymer were evaluated using rapidity in settling, density of floc and clarity of supernatant as criteria. Dosages of 8-60 mg/l gave satisfactory removal of the suspended lime, but there was only minor improvement in removals at dosages above 20 mg/l.

A small pilot plant was constructed and operated on a batch basis to further define the settling characteristics of the suspended lime particles. Polyelectrolyte dosages from 0 to 50 mg/l were investigated. Little improvement in the rate or degree of clarification was noted at dosages above 10 mg/l. It also was found that 5 mg/l gave approximately the same removal of suspended solids as 10 mg/l. The rate of settling at the 10 mg/l dosage, however, was twice as great as for 5 mg/l and a dosage of 10 mg/l was used for design purposes.

Typical results obtained from the pilot plant studies at a polyelectrolyte dosage of 10 mg/l are presented in Table 3 and illustrated in Figure 2.

Table 3. Results of Pilot Plant Clarification

Waste	Suspended Solids mg/l	Suspended Solids %Reduction	COD mg/l	COD %Reduction	Alkalinity %Reduction
Lime	6,000	-	-	-	-
Clar. Lime	1,650	72.5	-	-	66.7
Lime	9,700	-	-	-	-
Clar. Lime	2,400	75.3	-	-	-
Lime	4,900	-	-	-	-
Clar. Lime	1,550	68.4	-	-	60.0
Lime	11,200	-	4,100	-	-
Clar. Lime	1,650	85.1	2,750	33.0	77.4
Lime	18,500	-	4,200	-	-
Clar. Lime	3,500	81.1	2,650	37.0	85.6
Lime	15,400	-	4,600	-	-
Clar. Lime	4,000	74.1	2,150	53.0	84.3
Lime	16,700	-	2,850	-	-
Clar. Lime	2,100	87.4	1,750	38.5	81.7
Lime	12,350	-	3,140	-	-
Clar. Lime	3,400	72.5	2,320	26.0	80.5
Lime	12,750	-	3,040	-	-
Clar. Lime	1,950	84.7	1,890	38.0	87.2

The data derived from the small scale pilot unit were used to design a larger pilot plant which was constructed adjacent to the beamhouse and operated on a continuous flow-through basis. The results obtained from the larger pilot unit verified the optimum polyelectrolyte dosage of 10 mg/l as well as the necessity of separating the lime-bearing wastes from the other beamhouse waste fractions. From the data obtained from the pilot plant clarifier it was concluded that suspended solids removals of 90 percent and 70 percent could be achieved at overflow rates of 2,000 gpd/ft^2,

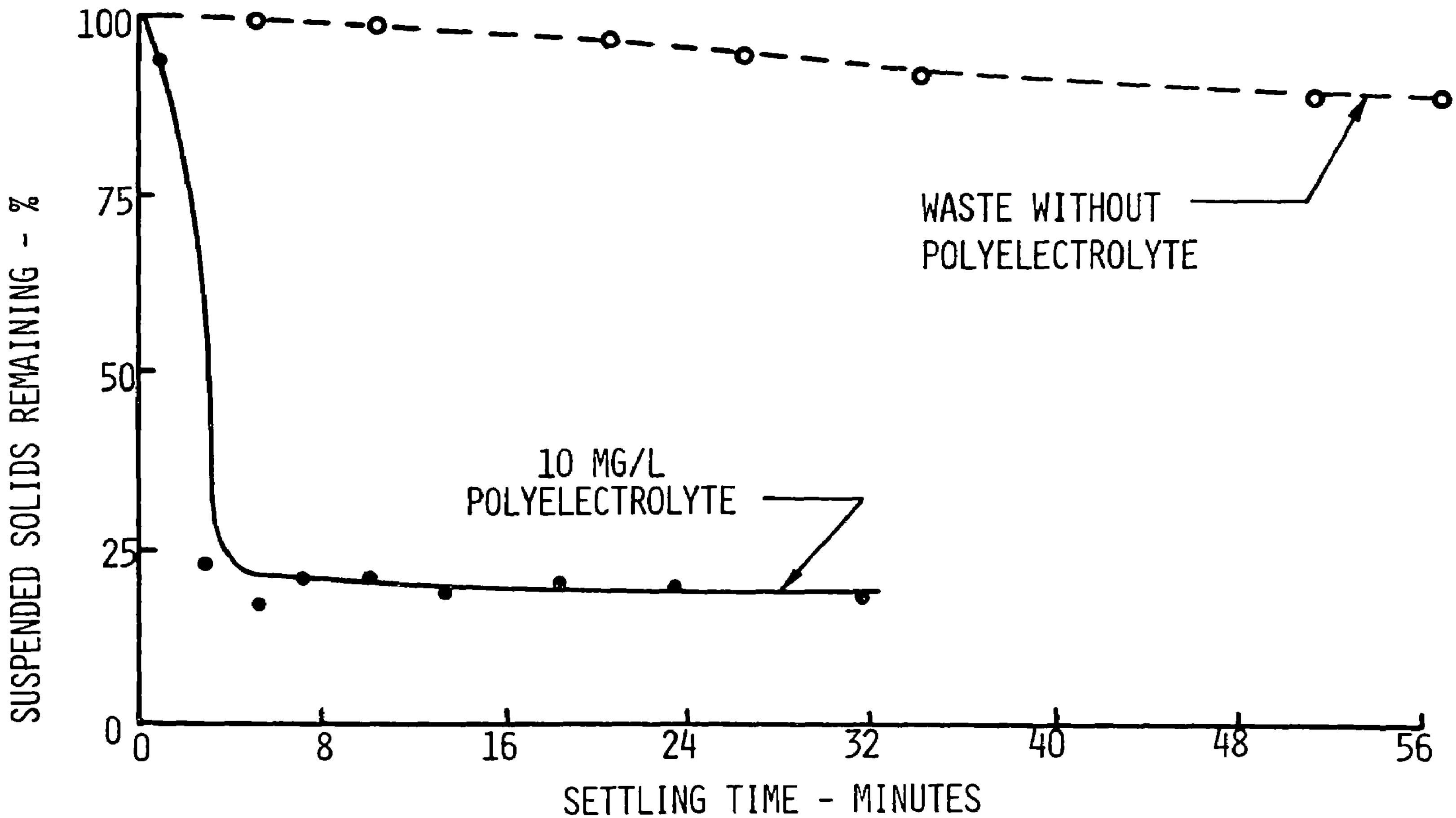


FIGURE 2. SETTLING CURVES FOR LIME BEARING WASTES

and 3,000 gpd/ft^2 respectively.

Settling tests conducted in a settling cylinder revealed that the polyelectrolyte treated lime waters exhibited flocculent settling for a short period of time followed by hindered settling. Settling curves for two concentrations of suspended solids are shown in Figure 3. Analysis of the settling curve data indicated that for quiescent settling overflow rates as high as 3500 gpd/ft^2 could be utilized. By contrast without polyelectrolytes the maximum calculated overflow rate was less than 100 gpd/ft^2.

The success achieved in the pilot plant studies prompted a decision to design and construct a full-scale system to clarify the total lime-bearing wastes discharged from the beamhouse. A preliminary plan for separating the waste fractions was developed and the clarification unit complete with polyelectrolyte feeding equipment was designed.

Design and Construction of the Full-Scale Clarification System:

The layout of the process units and the sewer system at the start of the project is illustrated in Figure 4. The wastes discharged from the 10 initial soak vats and the 30 lime-sulfide and rinse vats were carried in a common sewer located beneath the battery of vats. Construction of an auxiliary sewer underground to serve the soak vats independently of the lime vats would have been extremely difficult and expensive. It was decided, therefore, to empty the soak vats by use of a pump and an overhead piping system.

A self-priming non-clog pump was connected to a main header pipe which in turn was connected to a riser pipe in each of the ten soak vats. Each riser pipe was equipped with a fast acting, manually operated valve. When a vat is to be drained, the pump is started and the appropriate valve is opened. The pump switch is controlled by an adjustable timer which automatically stops the pump after a predetermined time interval which is just sufficient to allow a vat to be emptied. This arrangement was inexpensive, easy to construct, and has presented few operational problems.

The initial wash waters were re-routed to a sump along with the initial soak waters. A float actuated pump

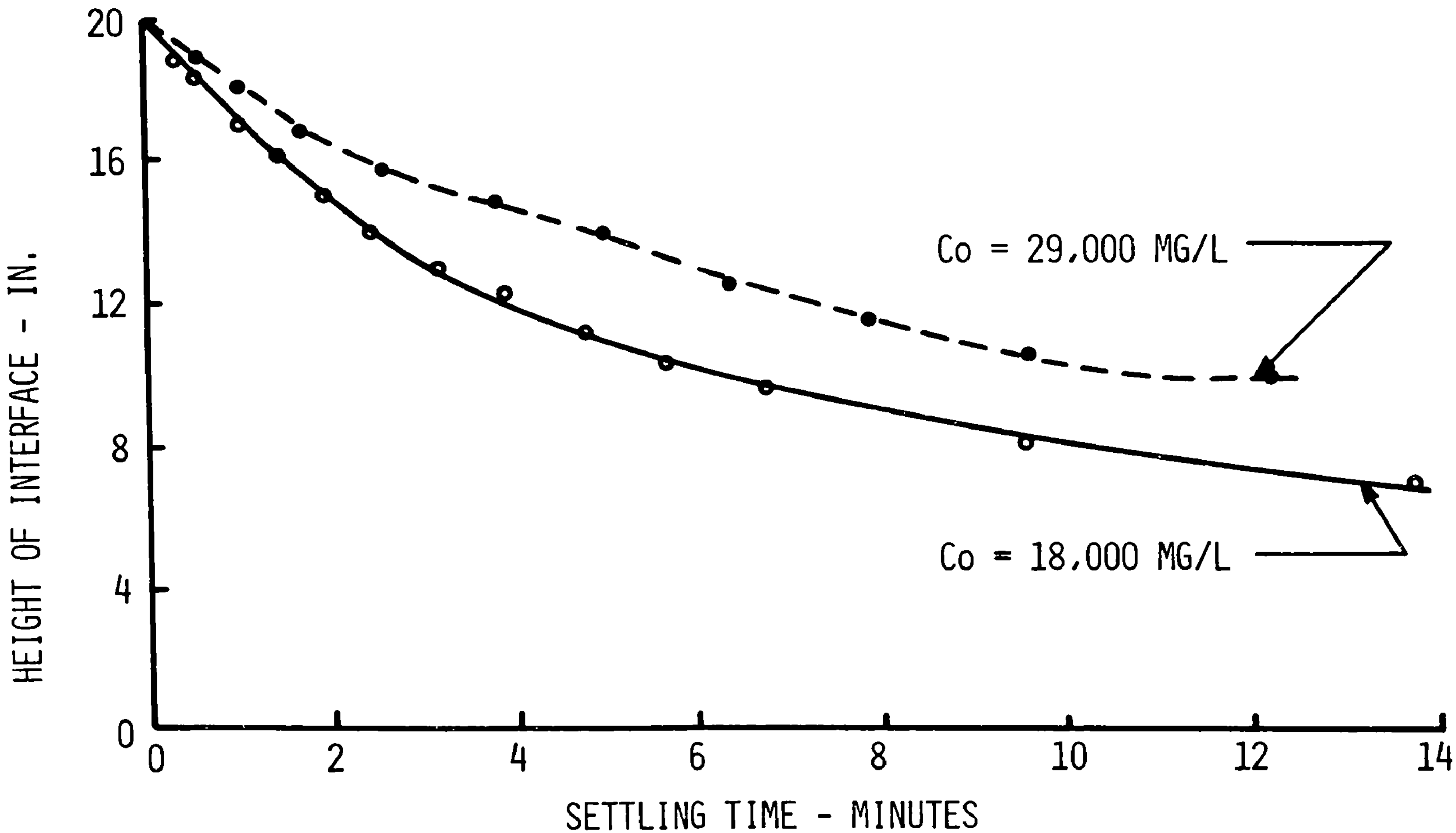


FIGURE 3. SETTLING RATES FOR LIME SLUDGE

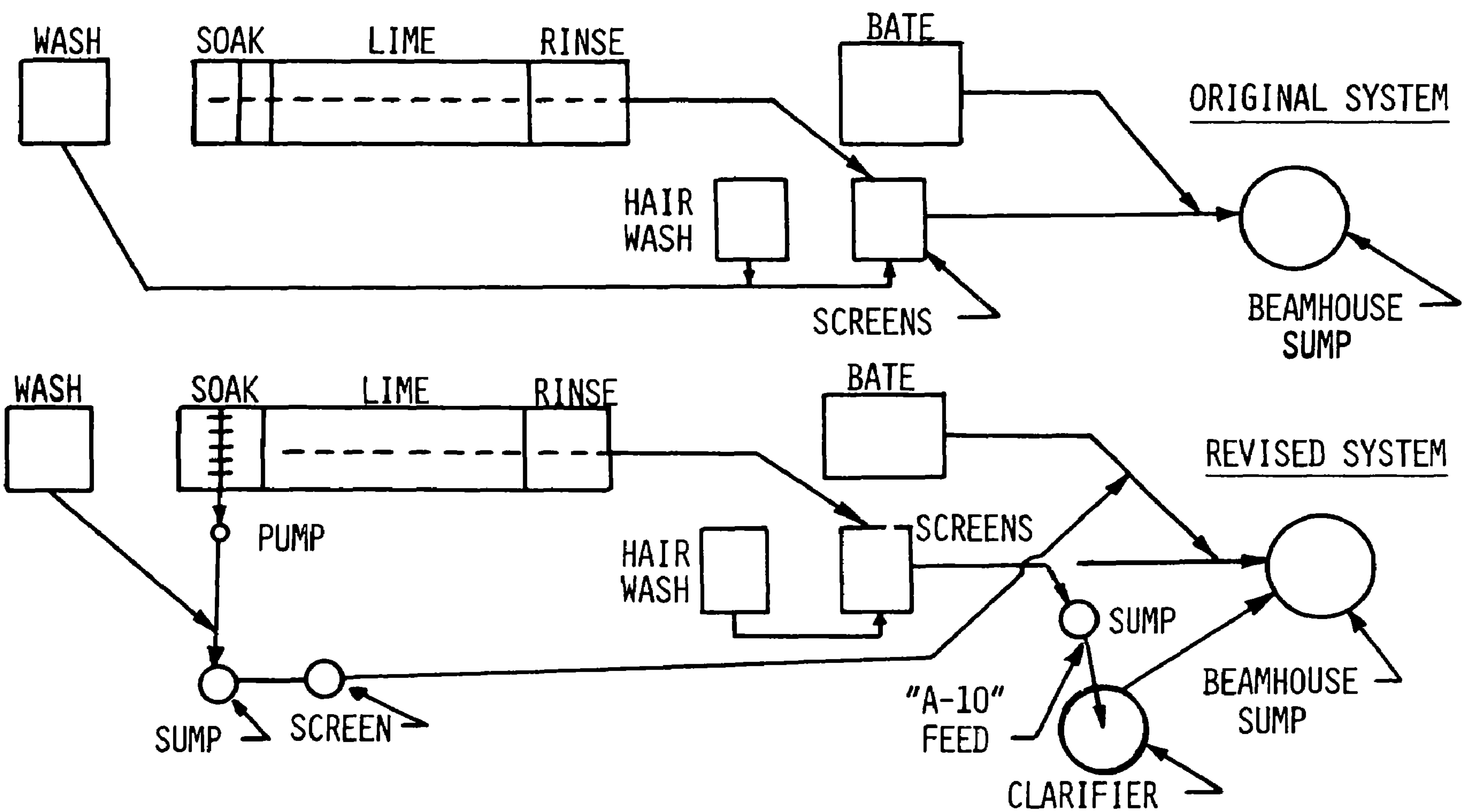


FIGURE 4. SEWERAGE SYSTEM SERVING BEAMHOUSE

delivers the wash and soak waters to a 20 mesh, 30 inch diameter vibratory screen for removal of hair and other extraneous matter derived from the initial processing of the hides. After screening this waste stream is discharged into the main sump serving the entire beamhouse.

The revised flow diagram for the beamhouse sewerage system also is illustrated in Figure 4. Since the lime-bearing wastes are discharged intermittently over an eight hour period on each working day, it was determined that a holding sump would be advantageous from the standpoint of clarifier operation. A sump with a capacity of about 2,000 gallons was constructed near the end of the lime liquor discharge channel and the lime liquors diverted to the sump. A float actuated pump was installed in the sump to pump the lime bearing wastes to the clarifier. Provision was made to inject the polyelectrolyte solution into the discharge line from the sump pump by means of a small gear pump which operates only when the main pump is running. The discharges of the sump pump and the chemical feed pump can be adjusted to accomodate flows in excess of 100,000 gallons in an eight hour period.

The clarifier was designed to provide a detention time of 30 minutes and an overflow rate of 2,000 gpd/ft^2 at a feed rate of 150 gpm. A cylindrical steel tank 12 feet in diameter and 11 feet deep was selected. These dimensions met the design requirements and more importantly permitted the tank to be fabricated at the factory and transported to the site by truck. The cost of factory fabrication was approximately 50 percent less than for field construction of a similar unit.

Mixing and flocculation of the lime-liquor polyelectrolyte mixture was accomplished by constructing a baffled inclined feed trough leading to the center feed column which also was equipped with baffles. The feed trough and center feed column were fabricated from steel barrels welded together end to end. The clarifier, therefore, was constructed to function as an upflow unit. Sludge is withdrawn through a perforated steel pipe placed on the bottom of the clarifier and connected to a sludge pump. The details of the clarification system are shown in Figure 5.

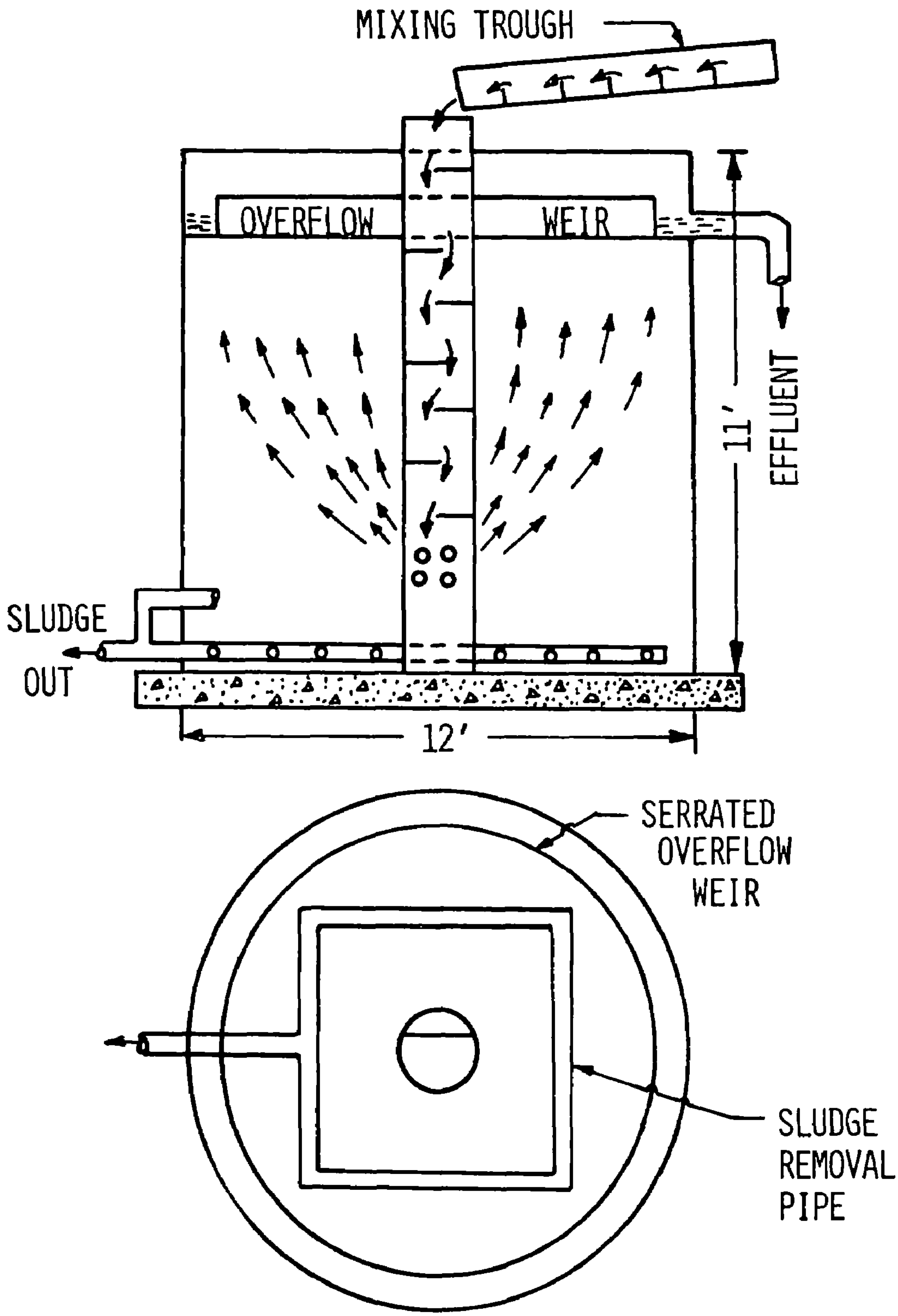


FIGURE 5. UPFLOW CLARIFIER DETAILS

Performance of the Clarifier:

The performance of the clarifier was evaluated during the early part of the study period by measuring the reduction in suspended solids, alkalinity, and chemical oxygen demand through the unit, Table A-1 and Figure 6. The data show that wide variations in removal efficiency occurred even at relatively low overflow rates. Factors found to be contributing to the poor removals included: 1) the total suspended solids removals were adversely affected by the volatile solids composed of grease and hair which did not settle; 2) the influent samples were not reflecting the actual suspended solids concentration present because of clogging of the sampling device by grease and hair; 3) there was evidence of solids washout from the clarifier resulting from too great an accumulation of sludge in the unit and 4) the soluble portion of the total alkalinity showed considerable variation from day to day.

A revision in the sampling and operational schedule for the clarifier during March, 1968 improved the percent removals of suspended solids. The chemical oxygen demand data accumulated during this period indicated that some reduction in organics was being achieved in the clarifier although the percent reduction varied widely from day to day. The data for the month of May, Table 4, show that increasing the dosage of polyelectrolyte to 15 mg/l had little effect on the clarifier performance. During June and July even closer attention was given to maintaining a constant overflow rate as well as to preventing too great an accumulation of sludge in the clarifier.

The data presented in Table A-2 show the pronounced effect of close operational control of the clarifier on the performance. The data likewise show that the fixed suspended solids were being removed about as predicted by the pilot plant studies. Subsequent experiments on prolonged operation of the clarifier at overflow rates generally in excess of 2000 gpd/ft^2 and at polyelectrolyte dosages below 10 mg/l indicated that reasonable removals of fixed suspended solids can be achieved, Table A-2.

The data shown in Figure 7 illustrate the effectiveness of removal of suspended solids at two overflow rates for a polyelectrolyte dosage of about 10 mg/l. In general

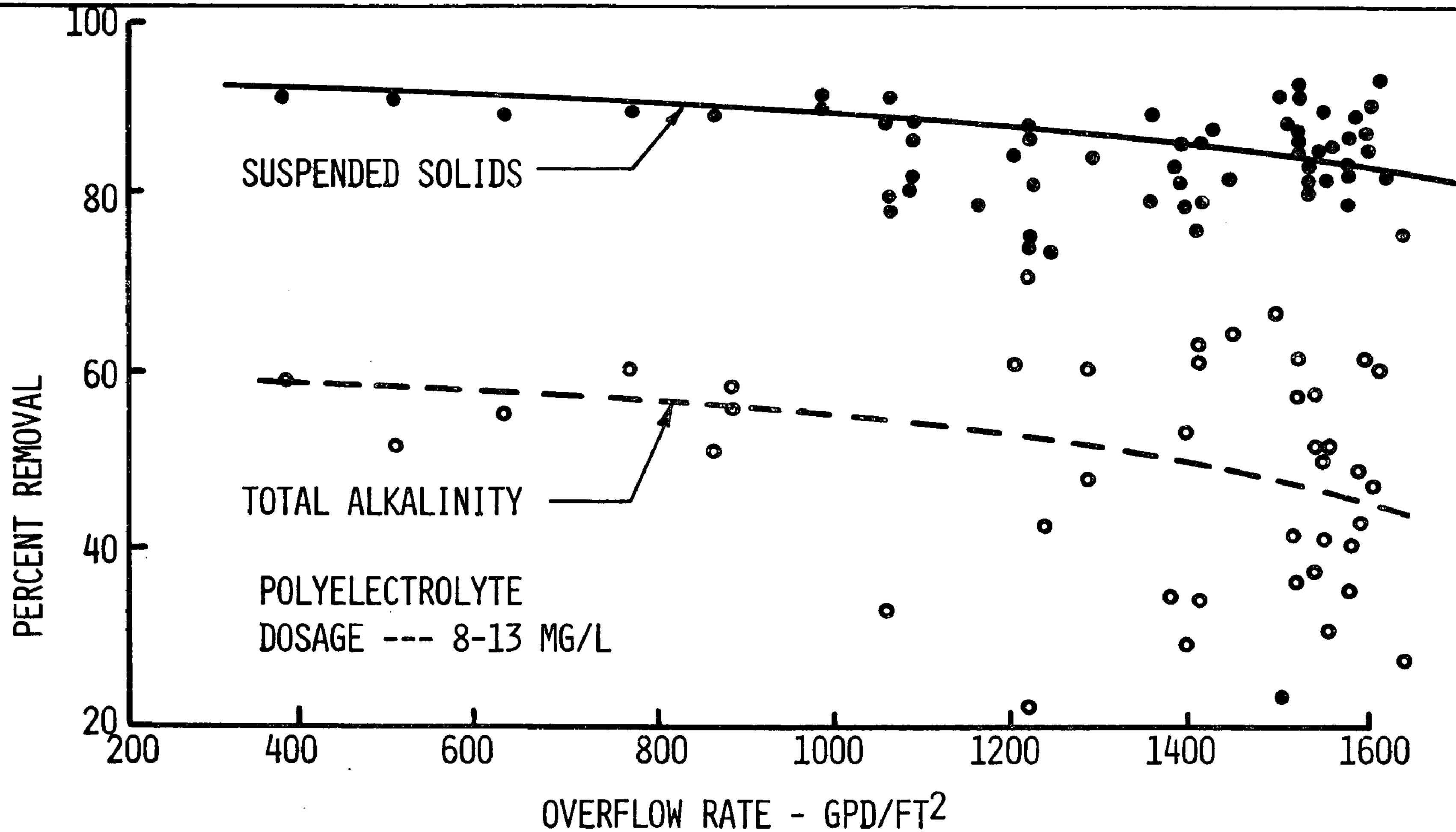


FIGURE 6. CLARIFIER PERFORMANCE

Table 4: Performance of Clarification System

Date	Suspended Solids Inf. mg/l	Suspended Solids Eff. mg/l	Suspended Solids Removal %	COD Inf.	COD Eff.	COD Removal %	Dosage A-10* mg/l	Overflow Rate gpd/ft^2
4/8/68	2920	520	82.2	5158	2253	56.8	11.3	1610
9	2900	540	81.4	4012	2247	44.0	10.4	1610
10	3480	240	93.1	4086	1835	55.2	10.4	1610
11	3040	440	85.5	3898	1965	49.6	9.6	1610
12	2720	420	84.6	3271	2775	15.2	9.9	1610
4/15/68	3960	520	86.9	3444	2084	39.5	10.9	1560
16	3960	620	84.3	4488	2947	34.4	10.2	1580
17	6000	560	90.7	4972	2591	47.7	9.9	1610
18	4120	560	86.4	4582	2609	43.2	9.8	1590
19	4800	1020	79.8	5524	3039	45.0	9.9	1590
22	6180	700	88.7	5530	2974	46.2	10.0	1590
4/23/68	3620	660	81.8	4820	3150	34.6	10.0	1590
24	3420	160	95.3	4428	2767	37.5	10.0	1590
25	5600	620	88.9	4968	2863	42.4	10.9	1590
26	5480	800	85.4	4253	2405	43.3	16.6	1590
29	4720	200	95.8	3479	2578	25.9	16.6	1590
5/13/68	3920	840	78.6	4806	2607	45.7	15.3	1590
14	3520	560	84.1	2654	1669	37.1	15.1	1590
15	3740	460	87.7	2815	1743	38.2	15.8	1590
16	4260	220	94.8	3616	1800	50.2	14.4	1590
17	5200	500	90.4	4913	2085	57.6	14.1	1590
5/20/68	3840	400	89.6	3334	2168	35.0	15.3	1590
21	3620	340	90.6	4008	1494	62.6	14.5	1590

*Rohm and Haas

Table 4: Performance of Clarification System

Date	Suspended Solids Inf. mg/l	Suspended Solids Eff. mg/l	Suspended Solids Removal %	COD Inf.	COD Eff.	COD Removal %	Dosage A-10 mg/l	Overflow Rate gpd/ft^2
5/22/68	3600	540	85.0	3414	1870	45.6	14.8	1590
23	5060	380	92.5	4001	1924	51.7	15.4	1590
24	3400	520	84.7	3574	1989	44.4	14.4	1590
27	5000	500	90.0	4760	2483	47.7	15.1	1590
28	4480	280	93.8	3508	1912	45.5	15.1	1590
29	4140	560	86.5	3388	1686	50.1	16.0	1590
31	3460	180	94.8	3266	1856	43.1	15.7	1590
6/3/68	4080	400	90.2	4282	2164	49.3	15.0	1590

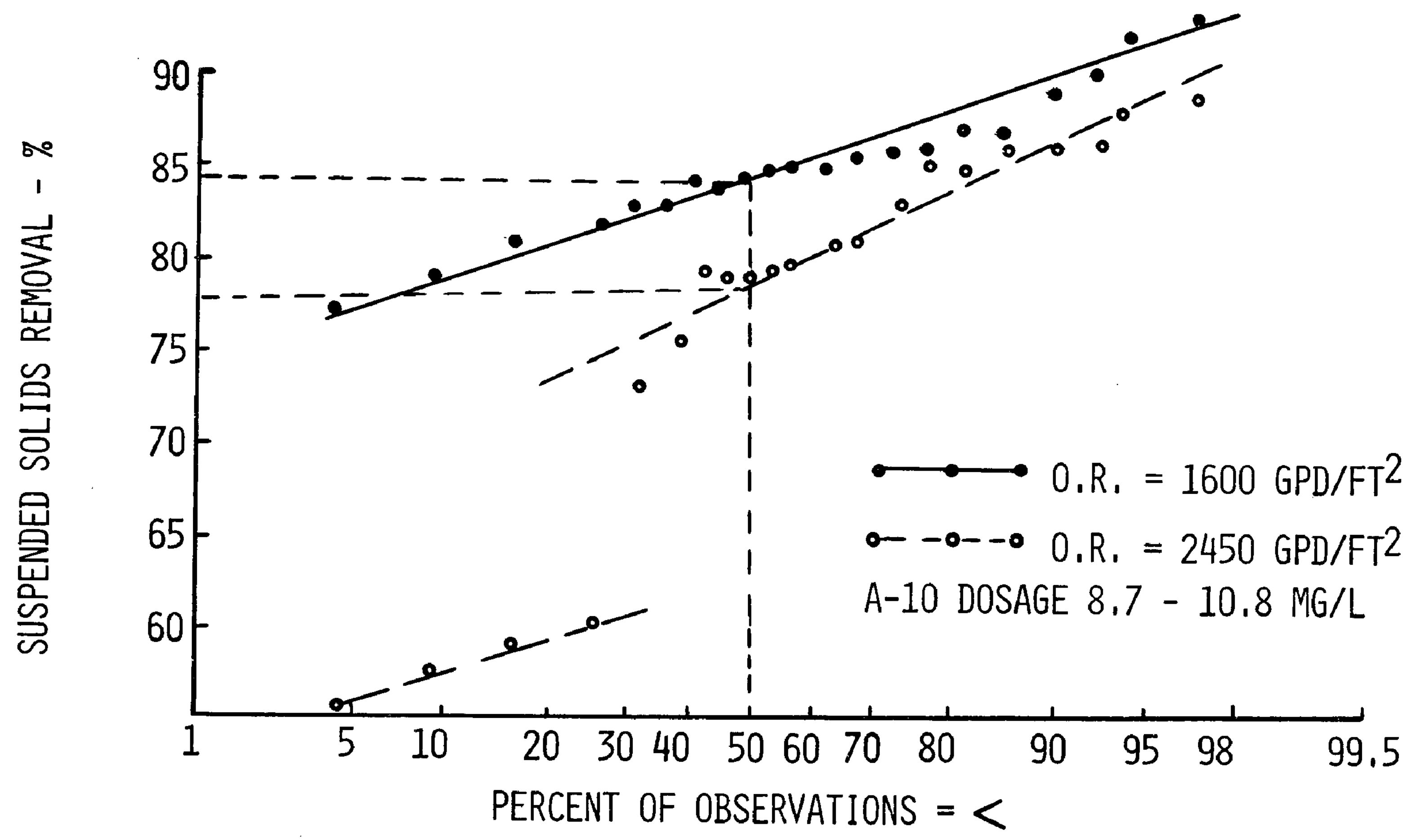


FIGURE 7. OVERFLOW RATE VS SUSPENDED SOLIDS REMOVAL

the removal of suspended solids exceeded 80 percent even at the higher overflow rates. The effect of polyelectrolyte dosage on fixed suspended solids removal is illustrated in Figure 8. The average removal was about 8 percent greater at polyelectrolyte dosages of 7-11 mg/l than at 4-7 mg/l for the same range of overflow rates.

The dosage of polyelectrolyte used in this system was higher than normally considered economical in water and waste treatment. Only the lime bearing waste fractions which represented about 30 percent of the beamhouse flow, however, required treatment and the actual weight of polyelectrolyte used each day was relatively small.

The annual operating costs for the separation and clarification system are estimated to be:

Electrical power ---------	$ 200
Truck for sludge ---------	500
Polyelectrolyte ----------	800
Repair and Maintenance ---	500
Labor --------------------	3,000
	$5,000

Characteristics of the Lime Sludge:

The sludge was withdrawn from the clarifier through a perforated pipe on the bottom of the unit and pumped to a 1000 gallon tank mounted on a truck chassis. The sludge was used for landfill without further dewatering. The average volume of sludge produced per week (5-working days) was about 10,000 gallons or about 3 percent of the volume of lime-bearing wastes clarified. The solids content of the sludge as removed from the clarifier ranged from a low of 7.2 percent to a high of 29.8 percent. The average solids content of the sludge was 14.1 percent. Only ten loads out of a total of 237 had a solids content less than 10 percent and eleven loads exceeded 20 percent. The usual variation in solids content, therefore, was relatively small.

The sludge exhibited excellent drying characteristics. A number of experiments on dewatering the sludge on beds of flyash revealed that the sludge drained readily even during periods of cold, wet weather. In general the sludge cracked and could be removed from the drying beds in two to three days. The dried sludge was flaky and did not exhibit any tendency to accumulate additional water from rain or melting snow.

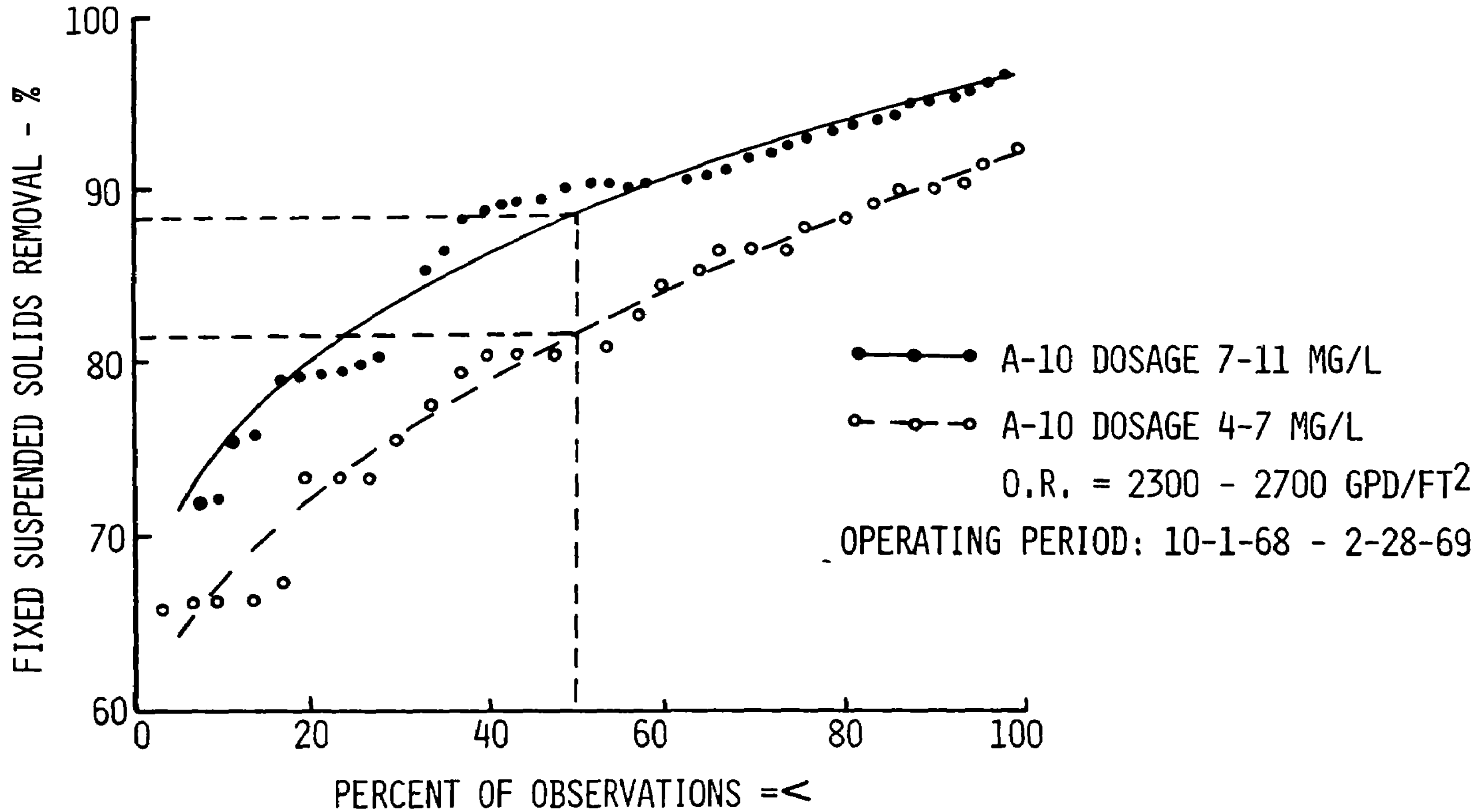


FIGURE 8. POLYELECTROLYTE DOSE VS FIXED SUSPENDED SOLIDS REMOVAL

The results of one drying experiment in which the sludge was placed on flyash beds four feet square are presented in Table 5.

Table 5: Sludge Drying Characteristics

Time					Weather	
Days	#1	#2	#3	#4	Type	Temp.
0	2"	4"	6"	8"	Clear	25°F.
1	1/4"	1/2"	1-1/4"	2"	Cloudy	28°F.
2	1/4"	1/2"	1-1/4"	2"	Snow	22°F.

This aspect of the study is of particular importance because lime sludge normally is difficult to dewater effectively. The dried lime sludge can be used for landfill or for certain agricultural purposes.

Biological Treatment:

Separation and pretreatment of the various waste fractions while effective in removing the inert suspended solids effected only a limited reduction in the total organics contained in the wastes. The BOD (5-day, 20°C) of the pretreated and blended waste streams from the beamhouse ranged from 1000 - 1500 mg/l and the COD from 2000 - 3000 mg/l. The total tannery wastes after pretreatment and blending had a BOD of 1500 - 3000 mg/l and a COD of 4000 - 8000 mg/l. The total Kjeldahl nitrogen concentrations in the beamhouse wastes and the total tannery waste averaged about 200 and 150 mg/l respectively.

It was decided that the use of a biological system for removing organics would be investigated. The economic position of the sole leather industry dictated that the treatment system selected for reducing the organics have a low capital and maintenance cost and be relatively easy to operate and maintain. Another important consideration in the selection of a system for removing the organics was that the production of sludge be minimal so that extensive drying facilities would not be required.

A combination of anaerobic and aerobic biological units appeared to meet the basic requirements established for the system, particularly if they could be combined in a lagoon or series of lagoons. Ivanof (21) and Toyoda (22) reported on the successful treatment of sole leather tannery wastes by anaerobic means. Gates and Lin (23) conducted laboratory and pilot plant studies on a stratified anaerobic-aerobic lagoon process and found it applicable to treating tannery wastes.

A decision was made to explore the feasibility of combining an anaerobic and an aerobic biological process in a deep lagoon to achieve the desired removal of organics. A deep lagoon equipped with a floating aerator arranged to aerate only the upper zone of the wastes being treated offered the potential advantages of: 1) low construction cost where soil conditions were favorable; 2) small land area requirements; 3) low volume of sludge accumulated; 4) reduced air requirements for the aerobic system since some organics would be eliminated in the anaerobic zone; and 5) heat conservation during winter operation. The large volume of wastes undergoing biological breakdown also would tend to protect the biological system against shock loads which are always possible from batch operations in a sole leather tannery. This concept was evaluated in pilot plant and full scale studies.

Pilot Plant Studies on Beamhouse Wastes:

Samples of pretreated beamhouse waste fractions were blended in proportion to their respective volumes discharged from the tanning operations. The mixed wastes with the pH adjusted to about 8.5 were used as the feed to the anaerobic unit. The anaerobic feed volume was five liters per day, five days per week. The five liters were introduced continuously over a period of 15-30 minutes, while simultaneously five liters were withdrawn and dosed to the aerobic unit. An overflow siphon was attached to the aerobic tank in such a manner that a volume of ten liters was always maintained. Therefore, as five liters were added to the unit five liters were discharged as effluent.

The anaerobic unit was acclimated to the pretreated tannery waste water initially by adding one liter of partially digested primary sludge from a domestic sewage treatment plant and one liter of composted beamhouse sludge to the 35-liter anaerobic unit. The container was then filled to the 35-liter mark with raw sewage from a municipal outfall. On the second or following day one liter of the neutralized, blended tannery waste water and four liters of raw domestic sewage were added to the tank. The five liters added caused the displacement of five liters of the previous contents of the tank. On the third day, two liters of tannery waste water and three liters of raw domestic sewage were added to the unit. On each subsequent day the tannery sewage addition was increased by one liter, while the raw domestic sewage addition was decreased one liter. After six days the unit was considered acclimated. The anaerobic unit was then fed with five liters of the neutralized "blend" on five days per week. The operational data for the anaerobic unit are listed below:

Volume	=	1.2 cubic feet
Influent COD	=	1000-2500 mg/l Avg. 1550 mg/l
Effluent COD	=	500-1500 mg/l Avg. 780 mg/l
% Removal	=	50%
Loading Intensity	=	15 lb COD/1000 cu.ft./day
Detention Time	=	1.4 weeks = 9.8 days
Temperature Range	=	25-38°C. Avg. 30°C.

The aerobic unit was acclimated by starting with ten liters of raw domestic sewage and then adding five liters of anaerobic effluent each day thereafter. The operating characteristics of the aerobic unit are tabulated below:

Volume	=	0.34 cubic feet
Influent COD	=	500-1500 mg/l Avg. 780 mg/l
Effluent COD	=	150-500 mg/l Avg. 275 mg/l
Removal, %	=	65
Loading Intensity	=	25 lb COD/1000 cu.ft./day
Detention Time	=	0.4 week - 2.8 days
Temperature Range	=	20-38°C. Avg. 30°C.

A summary of the performance of the biological system is shown in Table 6 on the following page.

In the anaerobic zone the pH was reduced and the total sulfide concentration was increased. The pH reduction can be attributed to the organic acids and carbon dioxide liberated by the anaerobic bacteria. The increase in total sulfides was a result of the conversion of the

Table 6: Influent and Effluent Characteristics of the Pilot Biological Units

Waste Parameter	Anaerobic Influent	Anaerobic Effluent	Aerobic Effluent
COD	1,550 mg/l	780 mg/l	275 mg/l
Total solids	12,500 mg/l	10,900 mg/l	10,300 mg/l
Dissolved solids	10,800 mg/l	10,000 mg/l	9,500 mg/l
Suspended solids	1,700 mg/l	900 mg/l	800 mg/l
Total sulfides	75 mg/l	300 mg/l	5 mg/l
pH	8.5-9.0	7.8	8.0

sulfate and organic sulfur to sulfide by anaerobic organisms. The net reduction of COD, therefore, is not indicative of the total stabilization achieved in the anaerobic unit because the sulfates reduced to sulfides would register as additional COD in the effluent.

Considerable reductions in COD and sulfides were achieved through aerobic treatment of the anaerobic effluent. The solids levels, however, remained relatively unchanged. The data obtained from the pilot unit proved conclusively that the pretreated beamhouse wastes were ameanable to biological treatment. It was shown also that a stratified anaerobic-aerobic unit would meet the conditions specified for an acceptable system for reducing the organic components of the waste to an acceptable level.

Design of Stratified Anaerobic-Aerobic Lagoons:

The data obtained from the pilot plant study indicated that a full scale lagoon providing a detention time of 8-10 days would yield satisfactory reduction in the organics of the beamhouse wastes as measured by the COD. The criteria used to design a unit capable of treating the total beamhouse flow are listed in Table 7 on the following page.

The capacity of the aeration equipment needed to meet the oxygen requirements of the wastes in the aerobic zone of the lagoons was difficult to predict. Laboratory studies indicated that the solubility of oxygen in untreated beamhouse wastes was considerably lower than in ordinary tap water. Furthermore, no reliable data on oxygen transfer capability of floating aerators operating in

Table 7: Design Criteria for Stratified Lagoons

Flow: ------- 150,000 gpd --------	750,000 gals/week
COD: -------- 2,500 lb/day -----	12,500 lb/week
BOD: -------- 1,200 lb/day -----	6,000 lb/week
Det. Time (Theoretical)	
Anaerobic zone: -------------	5 days
Aerobic zone: --------------	3 days
Number of units: ----------------	2
Dimensions of each unit: ---------	100x100x12' deep
Effective volume: ----------------	160,000 cu.ft.
Loading intensity: --------------	16 lb/COD/1000 cu.ft./day

tannery wastes were available. In addition considerable BOD would be contributed by the spent tan liquors if and when they were mixed with the beamhouse wastes for biological treatment.

The design of the aerators to accomodate the total wastes was based on the following assumptions:

Oxygen required per week -------------- 10,000 lb.
Oxygen transferred per hour per H.P. -- 2 lb.
Total horsepower required ------------- 30

<u>Operating and Performance Characteristics of Lagoons</u>:

The lagoons were constructed late in 1967 but were not placed in operation until the summer of 1968. Three floating aerators, a 5 H.P., a 10 H.P., and a 15 H.P. were purchased and installed in the lagoons. The 5 H.P. unit was operated continuously for about five months while the pH of the lagoon was maintained at 12.0 or greater to evaluate the possibility of foaming and scaling problems. The layout of the lagoon system is illustrated in Figure 9.

During the late spring and early summer of 1968, spent bleach acid was mixed with the clarified beamhouse wastes to give partial neutralization of the residual caustic alkalinity. In July, 1968 sufficient concentrated sulfuric acid was added to the lagoons to reduce the pH to approximately 9.0. The aerators were started and almost immediately there was evidence of biological activity.

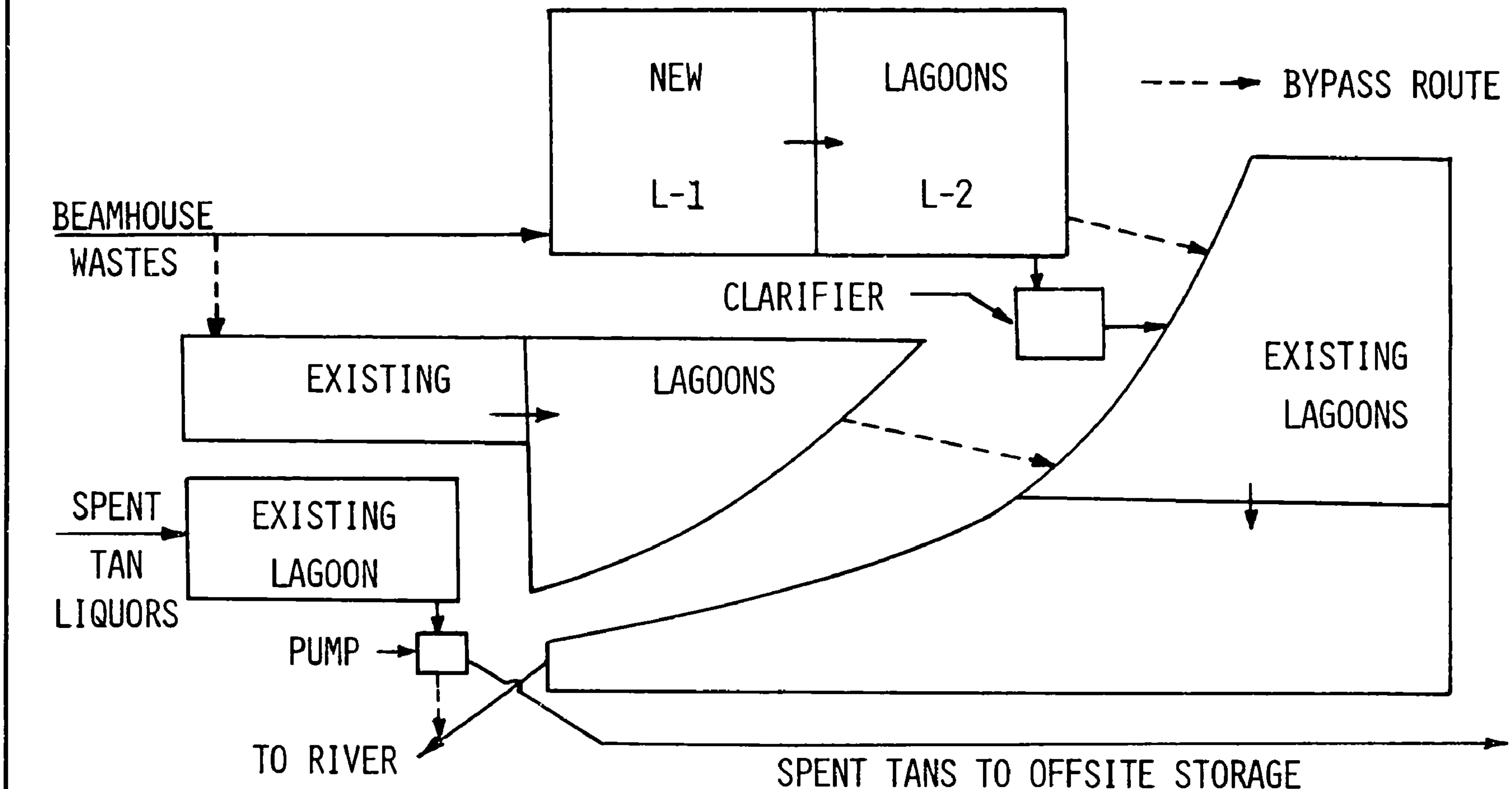


FIGURE 9. LAGOON SYSTEM AT PLANT SITE

The pH of the lagoons started dropping and it became apparent that continued neutralization of the caustic alkalinity with spent bleach acid was unnecessary. The COD of the effluent from the secondary lagoon (L-2) which was already on the decline following the reduction in pH dropped rapidly. After approximately one week, the COD of the primary lagoon (L-1) also showed a marked decline. The dissolved oxygen content of both lagoons was only about one mg/l at the surface and near zero at a depth of four feet.

Pronounced odors emanated from the lagoon system and efforts to control the odors by use of odor counteractants were unsuccessful. The odors were particularly critical as the lagoons were located in close proximity to a number of residences. At no time, however, was there any evidence of hydrogen sulfide being released from the operating lagoons.

The effluent from L-2 was passed through a small earthen clarifier equipped with vacuum sludge return lines. While the amount of settleable solids in the effluent was negligible 20-40 percent of the flow was re-cycled through L-2 for the purpose of adding an acclimated bacterial population to the incoming wastes. The effluent from the clarifier was discharged into two existing lagoons which contained a heavy accumulation of lime sludge. Soon after startup of the biological system, a heavy growth of algae was observed in the old lagoons which were receiving the effluent from L-2. Microscopic examination revealed the presence of a single species of motile algae plus many types of protozoa. The treatment achieved in the lagoon system, therefore, rendered the wastes suitable for supporting a variety of microscopic organisms.

Over a period of several weeks the algae became so dense that the dissolved oxygen was completely depleted during night time and hydrogen sulfide was released from the bottom deposits. Thus, while hydrogen sulfide was no problem in the operating lagoon, it became a serious problem in the lagoon which received the treated effluent. Some ten houses adjacent to the old lagoon showed severe darkening of the paint and reimbursement of the owners by the insurance company was necessary.

A survey of the operating lagoons revealed a sludge blanket approximately six feet in thickness in L-1 and from a few inches up to two feet in L-2. The sludge resulted from the precipitates that formed upon neutralization of the clarified lime liquors with the spent bleach acid. After operating both lagoons for about three weeks it became apparent that the rate of oxygen utilization exceeded the capacity for re-aeration with the 30 H.P. of available aeration equipment.

It also was found that large quantities of lime and soda ash were needed to keep the pH above 8.0 which was deemed to be the lowest permissible level because of the soluble sodium sulfide in the wastes. Consequently after about one month of operation, L-1 was rendered inactive by increasing the pH to about 12.0. All of the aerators were transferred to L-2 which had a volumetric capacity of about 0.6 million gallons.

The COD of the effluent from L-2 continued to decrease until it reached a value of about 900 mg/l, Figure 10. At this time a mixture of domestic sewage and river water was added to L-2 so as to achieve a more balanced biological population. Low D.O. values continued as did the odors although the odors could be controlled by the addition of ammonium nitrate. The control of pH was extremely difficult requiring the addition of several hundred pounds of soda ash each day. Much of the lime sludge removed from the clarifier also was added to L-2. This extra alkalinity coupled with a caustic alkalinity of 300-800 mg/l in the influent to L-2 maintained the pH at about 8.0-8.2.

Dissolved oxygen values observed for L-2 are listed in Table 8. The data listed in Table 9 show the alkalinity and hardness relationship between the influent and effluent from L-2.

The data indicate that little bicarbonate alkalinity existed in the influent whereas the total alkalinity of the effluent was in bicarbonate form. The decrease in the hardness values in L-2 probably resulted from the precipitation of calcium carbonate.

About mid-September auxilliary pumps were installed so that the feed rate to L-2 could be maintained at a constant rate. Prior to this time the feed rate fluctuated widely because all of the beamhouse wastes (about 150,000 gallons per day) were discharged over a 10-12 hour period. By reducing the flow rate to L-2 to about 75,000 gallons/day and increasing the detention time, the dissolved oxygen levels improved, Table 10. The remainder of the beamhouse waste was bypassed through an existing settling pond and then discharged to the receiving stream.

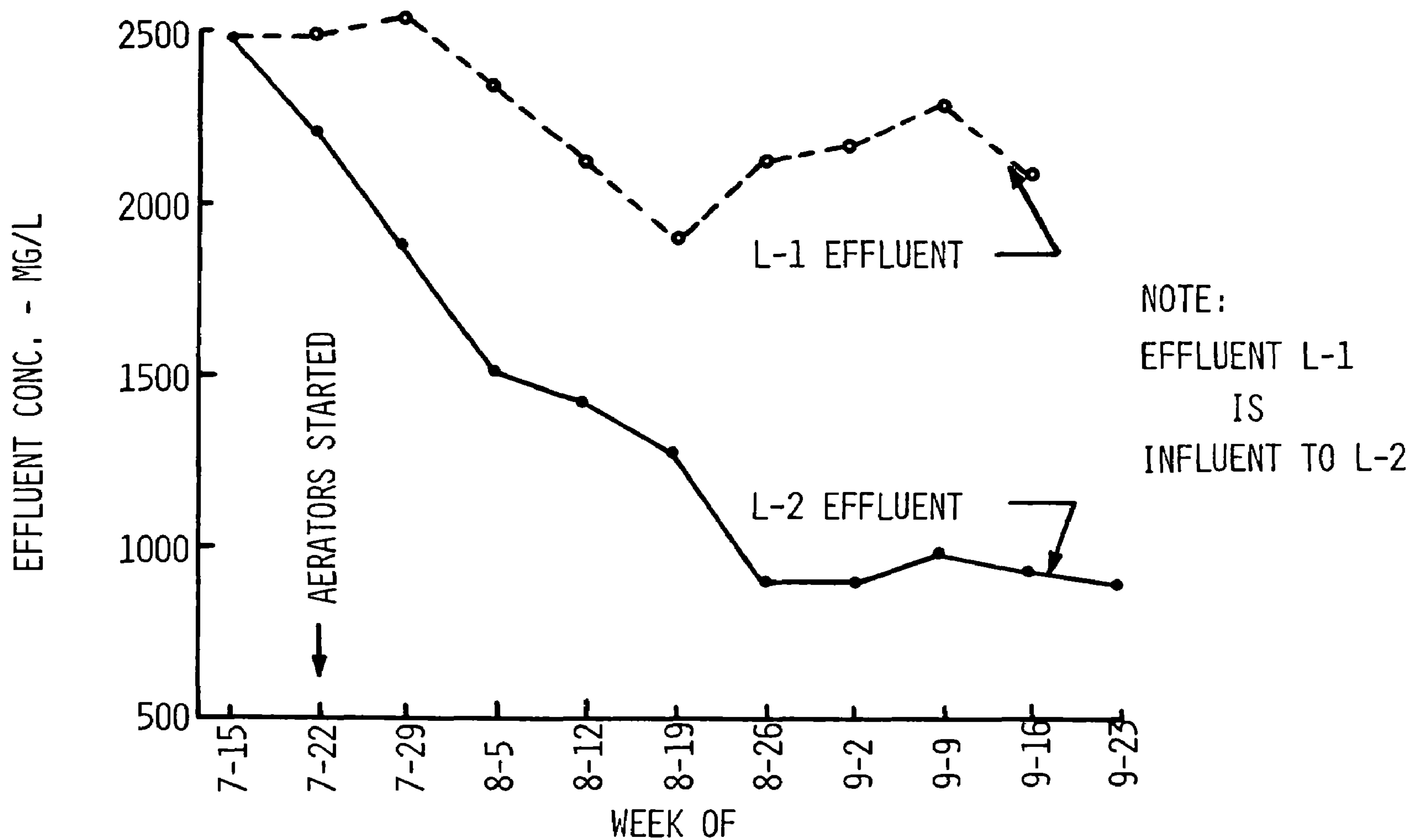
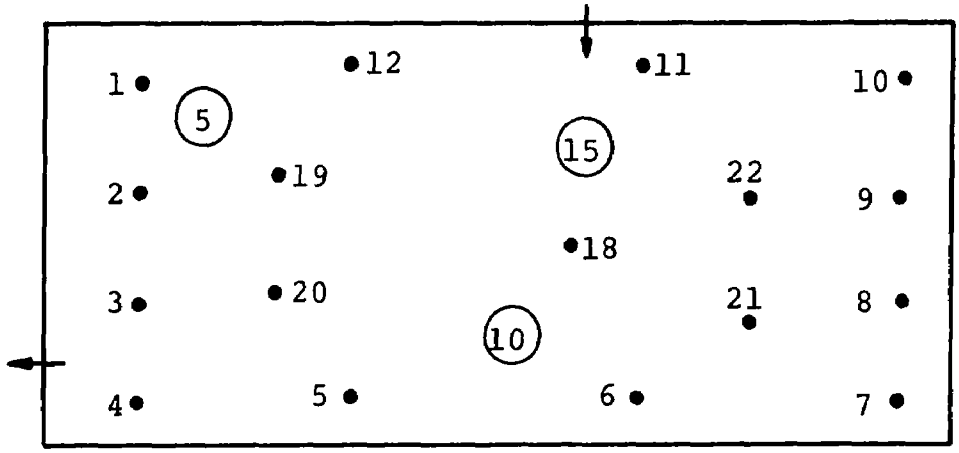


FIGURE 10. COD OF EFFLUENTS FROM L-1 AND L-2

Table 8: Dissolved Oxygen Concentration in Lagoon 2



Date	Station Sketch	Depth ft.	Temperature °C	D.O. mg/l
8/16/68	1	0	23.2	1.2
	4	0	24.8	0.5
	18	0	23.2	4.8
	18	4	23.2	0.1
	18	8	23.2	0.1
8/19/68	1	0	25.0	1.2
	4	0	25.0	2.6
	7	0	25.1	1.2
	8	0	25.0	1.1
	10	0	25.0	0.6
	12	0	25.0	1.0
	18	0	25.0	0.7
	18	4	25.0	0.5
8/21/68	1	0	25.4	1.4
	4	0	25.5	1.9
	5	0	25.4	1.5
	7	0	25.4	1.7
	8	0	25.4	2.4
	10	0	25.3	1.4
	11	0	25.4	2.4
	18	0	25.5	3.2
	18	4	25.1	0.9
8/22/68	4	0	26.2	1.5
	4	4	26.2	0.6
	6	0	26.2	1.4
	7	0	26.2	1.3
	9	0	26.2	1.4
	10	0	26.2	1.1

Table 8: Dissolved Oxygen Concentration in Lagoon 2

Date	Station Sketch	Depth ft.	Temperature °C	D.O. mg/l
8/22/68	12	0	26.2	3.0
	18	0	26.2	2.2
	18	4	26.2	0.1
8/24/68	1	0	25.2	1.5
	3	0	25.1	1.4
	4	0	25.1	1.2
	6	0	25.1	1.2
	7	0	25.0	1.1
	9	0	25.1	1.5
	10	0	25.0	1.3
	12	0	25.2	1.5
	18	0	25.1	0.6
	18	4	25.0	0.4
	18	8	25.0	0.4
	20	0	25.0	0.7
	20	4	25.0	0.4
	20	8	25.0	0.2
	22	0	25.0	0.7
	29	4	25.0	0.3
	22	8	25.0	0.1
8/29/68	4	0	19.9	2.5
	4	4	19.2	1.6
	8	0	19.2	1.1
	8	4	19.1	0.6
	8	8	19.1	0.5
	12	0	20.0	0.6
	12	4	19.1	0.2
	12	8	19.1	0.1
	18	0	19.1	0.8
	18	4	19.1	0.5
	18	8	19.1	0.2
	20	8	19.2	0.8
	21	0	19.2	1.0
	21	4	19.1	0.9
	21	8	19.1	0.7

Table 9: Alkalinity and Hardness of Influent and Effluent of Lagoon 2

Date	Alkalinity				Hardness	
	Influent		Effluent		Influent	Effluent
	Total mg/l	Phth mg/l	Total mg/l	Phth mg/l	mg/l	mg/l
8/20/68	696	296	624	0	-	-
21	612	264	596	0	-	-
22	672	324	632	0	-	-
23	568	300	756	0	-	-
26	604	220	1140	0	844	240
27	798	560	544	0	1048	1048
28	544	160	612	0	588	492
29	914	600	592	0	914	512
30	876	544	548	0	1162	518
31	808	496	552	0	1172	488
9/1/68	940	564	600	0	1137	538
2	824	476	612	0	1202	526
3	872	434	654	0	1192	500
4	1028	716	510	0	1209	781
9	1200	880	536	0	1440	438
10	1560	1220	518	0	1469	439
11	1612	1316	424	0	1830	460
15	716	348	604	0	716	582
16	720	382	546	0	1062	648
20	906	600	630	0	1220	748
23	832	544	672	0	1220	712
24	-	-	496	0	-	624
25	-	-	472	0	-	542

Note: All values as mg/l $CaCO_3$

The odors disappeared completely and the pH remained at about 8.0 without addition of extra lime or soda ash.

Only limited BOD data were gathered during the "start-up" phase of the biological system because of limitations in laboratory facilities. A few BOD determinations made during September and October indicated that the BOD was being reduced by 80-85% as measured by the change from the influent to the effluent values, Table 11.

The BOD reduction probably is somewhat misleading because of the unknown contribution of biodegradable materials from the anaerobic sludge zone. The increase in

Table 10: Dissolved Oxygen Concentration in Lagoon 2

Date	Station Sketch	Depth ft.	Temperature °C	D.O. mg/l
9/23/68	1	0	17.5	3.0
	2	0	17.5	2.5
	3	0	17.5	2.5
	4	0	17.0	2.7
	6	0	17.1	3.0
	8	0	17.2	1.8
	10	0	17.2	1.5
9/24/68	1	0	18.2	3.0
	2	0	18.0	4.0
	3	0	18.2	3.7
	4	0	18.2	4.7
	5	0	18.0	4.1
	7	0	18.0	4.4
	8	0	18.0	4.7
	9	0	18.1	4.8
	11	0	18.1	2.0
	12	0	18.1	3.6

Table 11: BOD and COD Removals in Lagoon 2

Date	BOD-mg/l		COD	
	Influent	Effluent	Influent	Effluent
9/17/68	1084	191	2016	861
18	1059	198	2377	934
20	905	-	2011	873
23	-	114	1978	952
24	-	195	-	808
24	-	270 (10-day)	-	-
30	960	272	1951	934
10/2/68	900	221	2067	1419
7	1060	273	2107	1036
9	1310	190	1992	1063
14	690	110	2034	747
16	-	-	1878	686

the effluent values for L-2 at the end of September and the first few days of October probably can be attributed to reduced biological activity with decreasing temperatures in the lagoon. Laboratory studies on the effluent from L-2 indicated an oxygen uptake rate of 10-30 mg/l/hr.

The total Kjeldahl nitrogen level of the waste which averaged about 200 mg/l for the entire period was reduced by about 50 percent. No reduction in sulfides was observed and no measurable settleable solids ever appeared in the effluent although the suspended solids averaged about 200 mg/l. Bacterial studies on the effluent from L-2 showed a very high bacterial population although at no time was there any tendency toward agglomeration or flocculation of the bacteria. The sludge in L-2 decreased in thickness and had the appearance of well digested sludge indicating that anaerobic decomposition was reducing the sludge at a greater rate than it was being added to the unit.

Foaming was another severe problem encountered in operating the lagoon. At times a layer of foam 5-6 feet thick would accumulate over the entire surface of the lagoon. High pressure water jets were partially effective in controlling the foam but presented difficult operational problems when the air temperature was below freezing.

The combination of the odor and foam problems prompted a decision to construct new lagoons on a more isolated site. The study, however, did prove conclusively that the pretreated beamhouse wastes were ameanable to biological treatment without adjustment of the pH or without addition of extra nutrients. These studies also provided more explicit design values for the new system, namely that a detention time of at least 16 days would be required and that the loading intensity should not exceed about 10 lb. of COD/day/1000 cu.ft.

Another important characteristic of tannery wastes demonstrated in this study was the fact that tannery wastes even after treatment exhibited a rapid loss in dissolved oxygen, Figure 11. It could not be determined if this particular characteristic was caused by a chemical oxygen demand or reflected a lower saturation value for the tannery wastes. Wastes that had been sterilized tended to lose oxygen more slowly than non-sterilized waste.

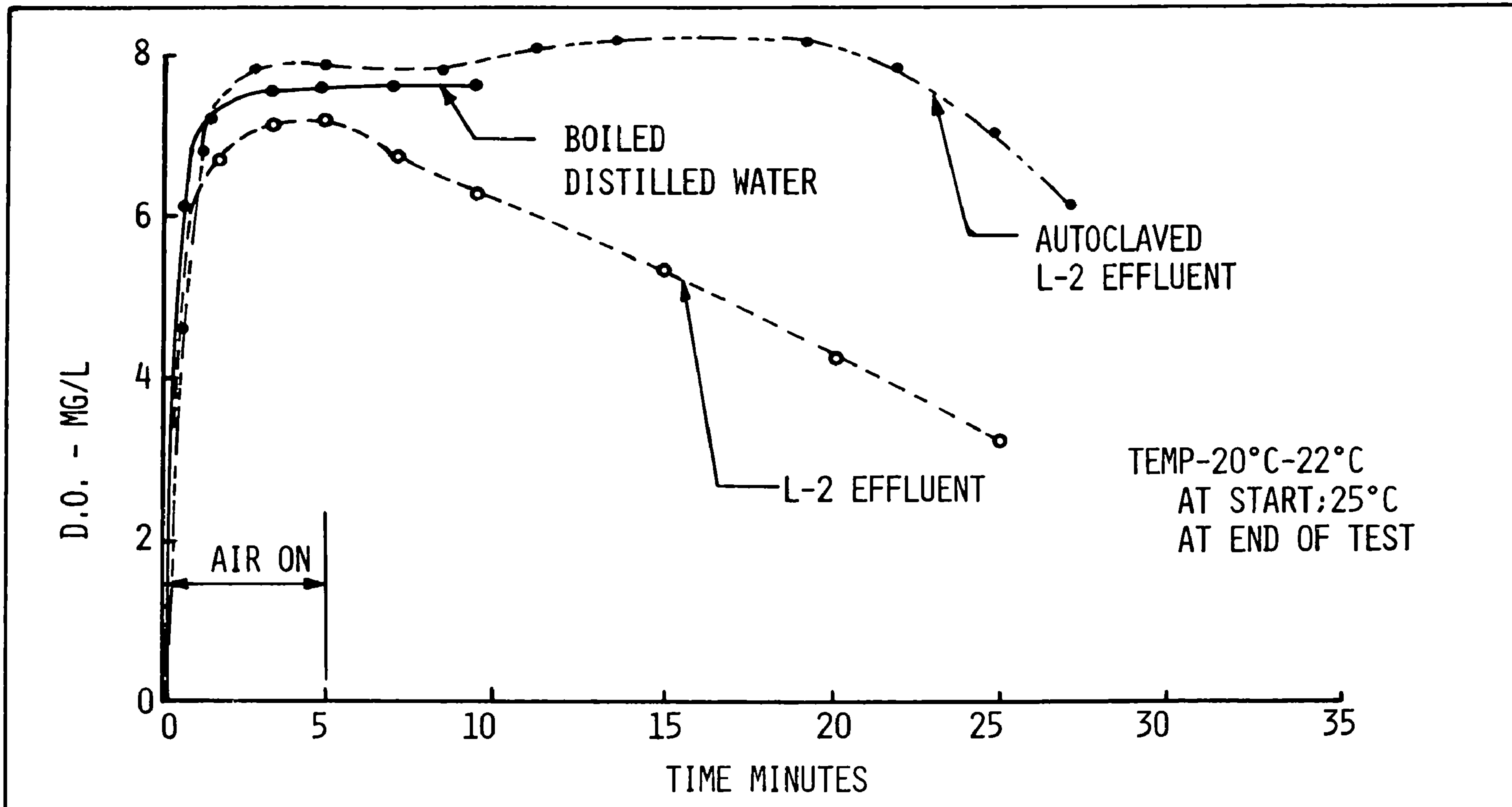


FIGURE 11. OXYGEN BUILDUP AND UPTAKE

Pilot Plant Treatment of the Total Tannery Wastes:

The construction of the new lagoon system was started in late autumn 1968 but was not completed until April, 1969. During this period of time pilot plant studies were conducted to obtain operational data which would be applicable to the system for treating the combined tannery wastes.

The data presented in Table A-3 indicate that the total tannery wastes (beamhouse plus spent vegetable tan liquors) are ameanable to biological treatment. The pH of the system remained remarkably constant even though the pH of the feed varied considerably. The CO_2 and organic acids produced in the anaerobic unit effectively neutralized the excess lime carried in the beamhouse waste fraction. The effluent from the aerobic unit contained only bicarbonate alkalinity throughout the entire study. Significant reductions in the COD and suspended solids were achieved.

The total Kjeldahl nitrogen levels were reduced 30-50%, but the ammonia content of the effluent remained high throughout the study, Table A-4. Determinations for the other forms of nitrogen could not be made because of the intense color imparted to the total wastes by the spent tan liquors. No reduction in total sulfides was observed.

The BOD of the total tannery wastes was reduced by 80-90 percent, Table 12. The effluent BOD values were in the same general range as observed for the full-scale lagoon system which had been operated on beamhouse wastes. A few BOD values and rate constants for the total wastes are shown in Table 13.

Table 13: BOD Values and Rate Constants

Date	Sample	1-Day	2-Days	3-Days	4-Days	5-Days
3/18/69	Inf.	1008	1568	1882	2150	2442
	K_1	.18	.17	.14	.13	-
"	Eff.	76	128	165	199	232
	K_1	.13	.11	.08	.07	-
3/19/69	Inf.	694	1120	1568	1680	1770
	K_1	.18	.17	.29	.24	-
	Eff.	75	119	147	170	191
	K	.18	.17	.14	.12	-

Table 12: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	5-Day, 20°C BOD Inf.	5-Day, 20°C BOD Eff.
Feed: Beamhouse Wastes Only Det. Time - 10 Days		
10/7/68	1060	273
8	1181	687
9	1212	196
10	1172	95
Feed: 3 Parts Beamhouse Waste 1 Part Spent Tan Liquors Det. Time - 10 Days		
14	690	110
15	-	37
22	1267	118
24	1525	167
29	915	117
31	1980	130
11/4/68	1470	134
5	2135	186
7	2957	259
12	2010	236
14	2127	250
19	2395	213
20	2220	180
21	2215	181

Date	5-Day, 20°C BOD Inf.	5-Day, 20°C BOD Eff.
Feed: 3 Parts Beamhouse Waste 1 Part Spent Tan Liquors-Det. Time - 10 Days		
11/26/68	1775	233
27	2140	225
Feed: 3 Parts Beamhouse Waste 1 Part Spent Tan Liquors - 1 L Sewage Det. Time 15 Days		
12/2/68	1472	285
3	2232	188
9	1520	144
10	1270	139
11	1475	81
12	1215	79
16	1205	157
17	1335	195
18	2030	245
19	2195	243
24	2032	170
26	1510	160
Feed: Beamhouse Wastes Only Det. Time - 10 Days		
1/6/69	1580	459
7	1632	244

Table 12: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	5-Day, 20°C BOD Inf.	5-Day, 20°C BOD Eff.	Date	5-Day, 20°C BOD Inf.	5-Day, 20°C BOD Eff.
Feed: Beamhouse Wastes Only Det. Time - 10 Days			Feed: 2 Parts Beamhouse Waste 1 Part Spent Tan Liquors - 0.9 L Sewage		
1/8/69	1547	138	2/6/69	1177	163
9	2018	128	3/6/69	1042	129
13	1250	334	7	863	168
14	1267	363	10	1075	158
15	1590	117	11	1915	168
16	1160	99	12	1215	161
Feed: 2 Parts Beamhouse Waste			17	1330	291
1 Part Spent Tan Liquors			18	2315	248
0.9 L Sewage: Det.Time-20 Days			19	1645	180
1/20/69	1460	176	3/25/69	1781	113
21	1340	179	26	2195	138
23	1740	143	4/1/69	1702	170
24	1530	155	2	1232	178
27	2260	301	8	1973	258
28	2240	194	9	2242	207
29	2285	191	15	1977	183
30	1470	210	16	2071	181
2/3/69	1155	184			
4	1435	220			
5	1422	162			

While the BOD data plot as smooth curves, Figure 12, the K_1 values show considerable variation from day to day. There was little evidence of an initial lag phase in the BOD reaction.

Domestic sewage was added to the feed to the pilot unit during a portion of the study. In general the performance was improved somewhat when sewage was added. Bacteriological and microscopic examination of the contents of the aerobic zone revealed a relatively low bacterial population and large numbers of protozoa. In all probability, the sewage served to reseed the system more effectively than recirculated effluent from the aerobic zone which had a relatively low bacterial population.

Studies on the oxygen buildup and uptake rates of the wastes from both the anaerobic and aerobic zones of the pilot unit were made. The data presented in Figures 13 and 14 indicate that the saturation value for oxygen in the tannery wastes is appreciably less than that of pure water. As shown in Figure 13 the waste in the anaerobic zone exerted a rapid oxygen uptake. The waste from the aerobic zone by contrast exhibited a low uptake rate indicating that the wastes were well stabilized.

<u>Treatment of Total Tannery Wastes</u>:

In the initial phases of the investigation it was assumed that the entire waste treatment system could be constructed and operated on the tannery site (see Figure 9). Problems of odor and foaming of the anaerobic-aerobic lagoons dictated that a new site be selected for the biological treatment units. The company owned land about 7,000 feet from the tannery which was suitable for the new units. The land had been used for storing spent vegetable tan liquors during periods of low stream flow. The tan liquor was pumped through a 3-inch diameter plastic pipeline from the tannery to the holding basins. The rate at which waste water could be pumped through the pipeline was limited to about 55 gpm (whereas the total tannery waste flow amounted to about 120 gpm) because the maximum pressure that the pipe could withstand was about 40 psi.

Detailed hydraulic studies showed that the rate of pressure drop varied considerably for the various sections of the pipeline under constant flow conditions. It was determined that the installation of two pumps in

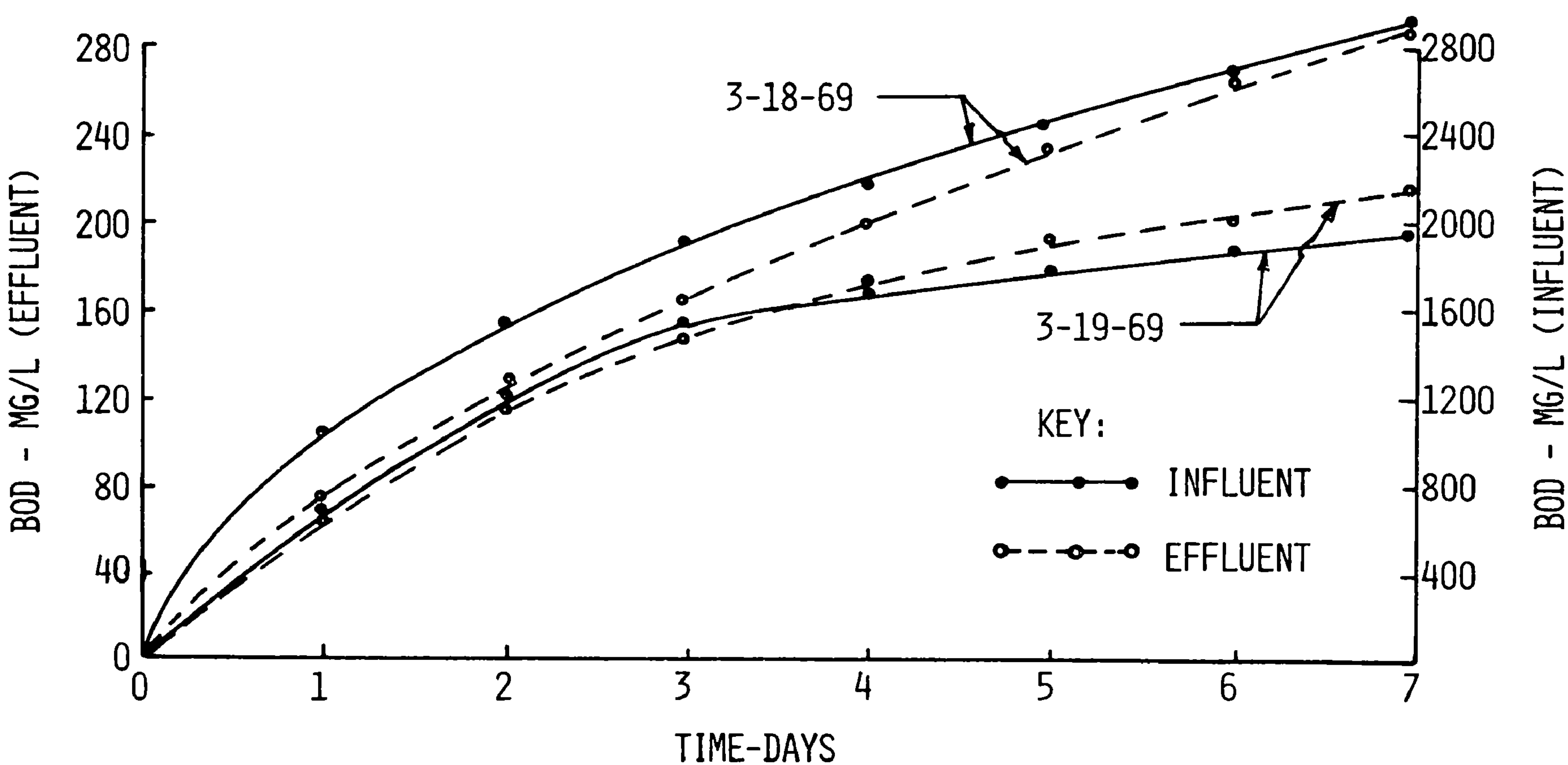


FIGURE 12. BOD VS TIME

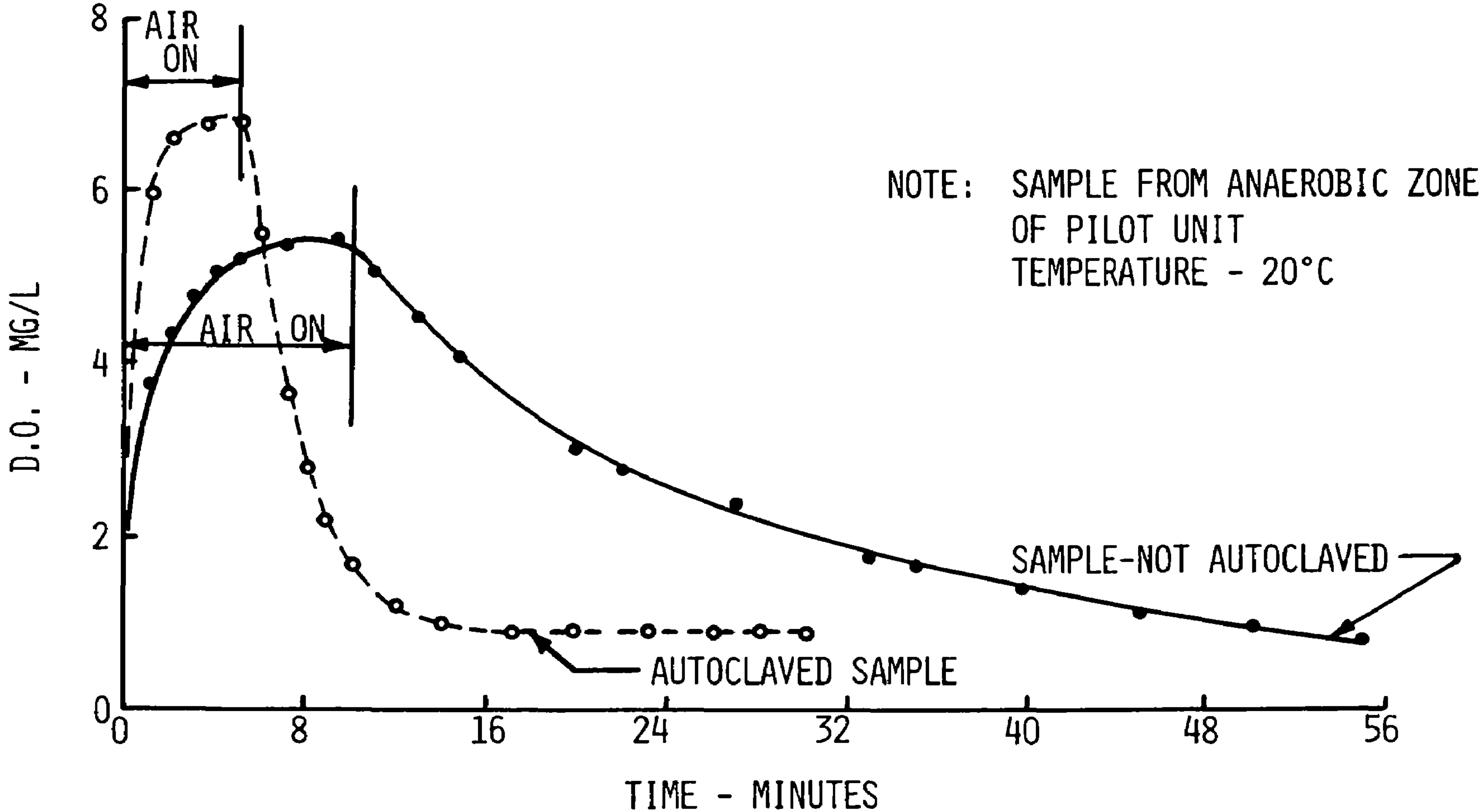


FIGURE 13. OXYGEN BUILDUP AND UPTAKE

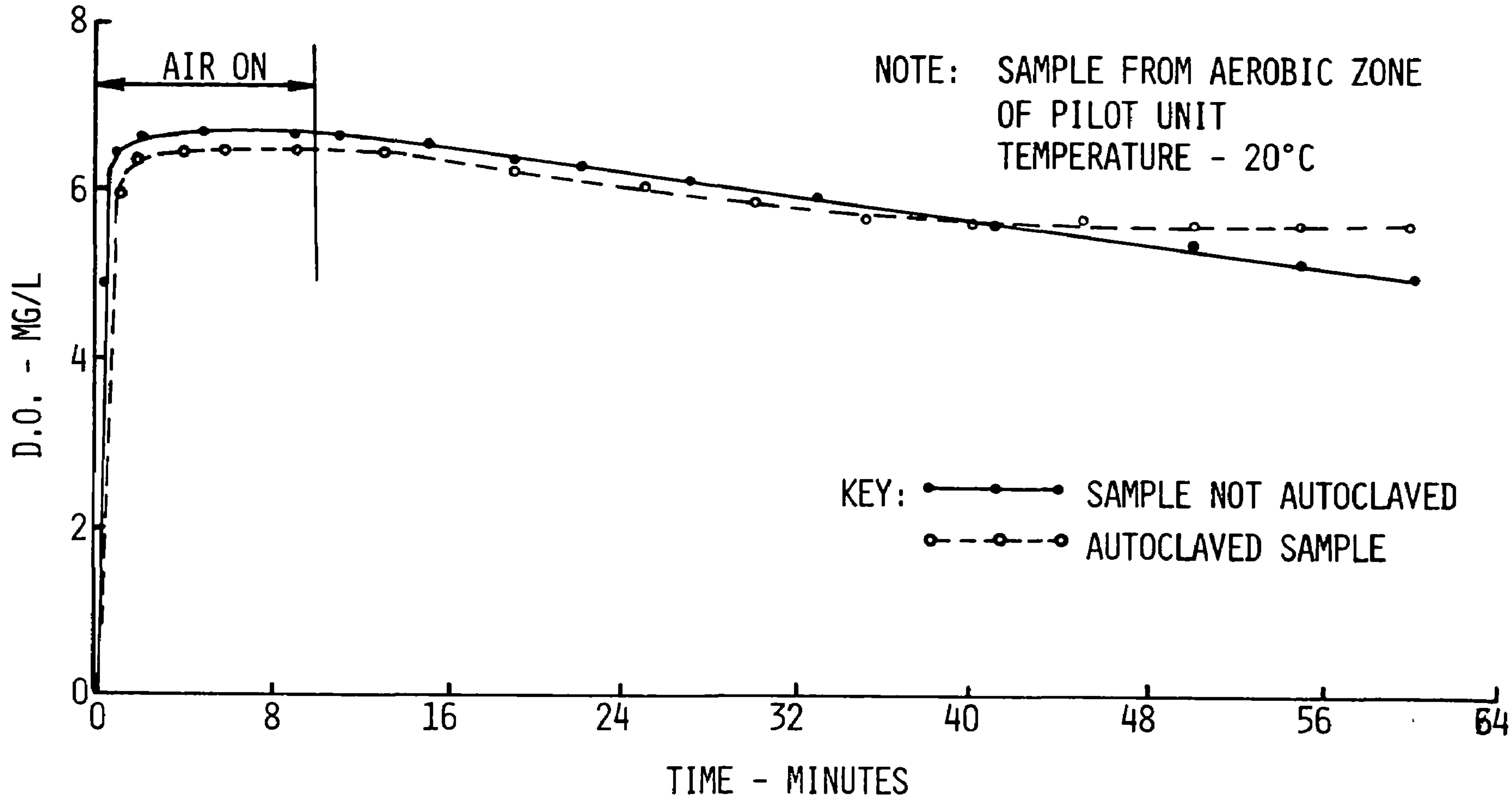


FIGURE 14. OXYGEN BUILDUP AND UPTAKE

series in the pipeline would boost the flow to the desired range without exceeding the pressure limitation on the pipeline. Two 5-HP close coupled pumps were installed at distances of 2500 feet and 4000 feet from the plant site. The pumps actuated by pressure switches delivered 115 gpm which was sufficient to pump the total tannery wastes to the new treatment site.

The decision to construct the new anaerobic-aerobic lagoons at a site about one mile from the tannery allowed the lagoons at the tannery site to be used for clarification of the lime-bearing wastes. The clarifier was taken out of operation at the beginning of March to ascertain if the suspended lime could be removed effectively by plain settling in the existing lagoon system. It was found that with the detention time of about three weeks provided in the lagoons the suspended solids concentration in the effluent as discharged to the receiving stream was essentially the same as when the lime bearing wastes were treated with polyelectrolyte and passed through the clarifier. The separation and pretreatment procedures other than mechanical screening for the beamhouse wastes were discontinued in March, 1969.

Construction of the new anaerobic-aerobic lagoons was completed in May, 1969. The new lagoons, Figure 15, provided a surface area of about 60,000 ft^2 and a volumetric capacity of about 2.3 million gallons. The new lagoons had a depth of only six feet and provided a detention time of about 16 days for the total flow. A deeper lagoon would have been preferred but construction difficulties limited the depth to about six feet.

In May, 1969 the lagoons were filled with clarified beamhouse wastes and the aerators were started. No effort was made to reduce the pH of the wastes prior to startup of the biological system and the wastes were not "seeded" with domestic sewage. Within two days the pH had fallen to about 9.5 and it was apparent that biological activity was underway.

The units were operated for approximately two months on beamhouse wastes. Odors were apparent in the vicinity of the lagoons and severe foaming occured intermittently. On July 12 and 13 , 500,000 gallons of spent tan liquor were added to the system. An immediate increase in the effluent BOD was noted. The odors disappeared completely and foaming was not nearly so severe. Small amounts of tan liquors were added intermittently from July 13 through

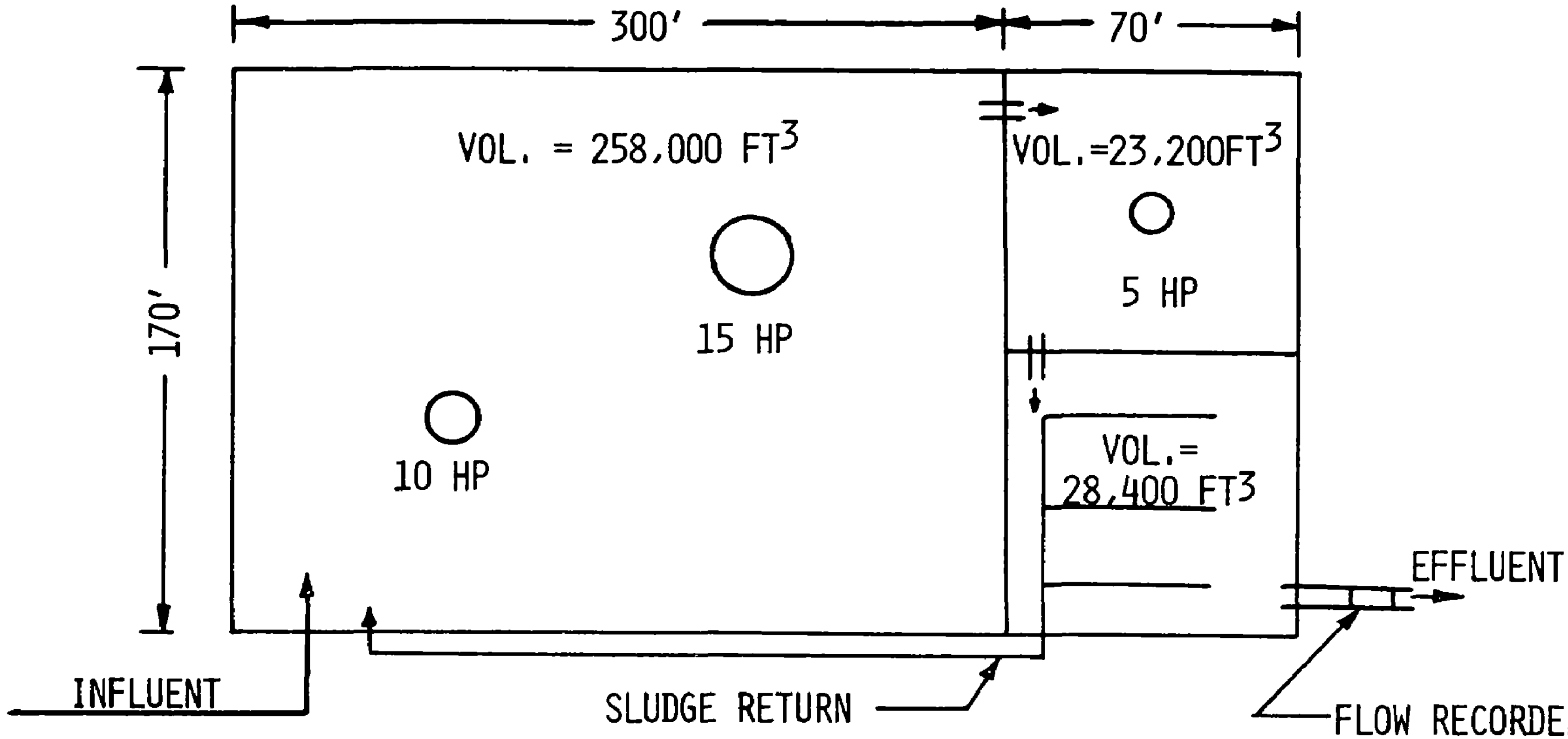


FIGURE 15. LAYOUT AND APPROXIMATE DIMENSIONS OF LAGOON SYSTEM

August 20 with little apparent effect on the performance of the lagoons as measured by the COD and BOD of the effluent.

From August 22 through September 22 all of the tan liquors were added to the system. The spent tan liquors, however, were not mixed with the beamhouse wastes prior to introduction to the biological system. Each waste fraction was pumped separately to the treatment site through the same pipeline. After September 22, the spent tan liquors and beamhouse wastes were mixed prior to being pumped to the treatment system.

The performance data for the anaerobic-aerobic lagoon system in terms of the pH, alkalinity, COD and suspended solids for the period from May 22 through October 24 are listed in Table 14. The pH of the effluent remained remarkably stable even though the influent values varied considerably. The reduction in total alkalinity during the period when only beamhouse wastes were added indicates that calcium carbonate was being precipitated. Near the end of the observation period there was little reduction in alkalinity. The spent tan liquors effected a slight reduction in the pH of the influent but did not change the total alkalinity significantly.

The reduction in COD ranged from about 30-80 percent. The spent tan liquors when added without prior mixing with beamhouse wastes greatly increased the COD and volatile suspended solids of the total influent. By contrast, the mixing of the two waste streams followed by settling, effected a significant reduction in the organic load imposed on the biological system. A large volume of sludge resulted from the blending of the two waste streams. It is probable, therefore, that the cost of handling the excess sludge would more than offset the gains made in reducing the organic load to the biological units.

When the spent tan liquors were pumped to the treatment site separately and added to the lagoons which had a pH below 9.0, no marked precipitation occurred. A detailed survey of sludge deposits in the anaerobic-aerobic lagoons after about five months of operation showed only a small accumulation of sludge, Table 15. The deposited sludge appeared to be decomposing readily hence it is believed that sludge accumulation will not be a problem in operating the system. The suspended solids in the effluent from the final lagoon ranged from 20 to as high as 400 mg/l while the settleable solids remained

Table 14: Performance of Full-Scale Biological System

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
5/22/69	12.0	7.7	848	368	2450	814	240	0	140	20
23	11.9	7.7	940	380	2470	822	380	0	240	20
26	12.0	7.6	1216	400	2582	645	340	0	500	10
27	12.1	7.5	1220	424	2218	683	120	0	140	10
28	11.5	7.8	748	436	2038	609	240	0	280	10
29	11.0	7.5	556	456	2133	663	120	25	120	95
6/2/69	11.7	7.7	632	516	1623	472	160	20	200	85
3	11.5	7.9	600	484	1535	386	200	0	220	40
4	11.6	7.9	536	484	1666	495	160	15	100	25
5	11.7	7.9	764	476	1738	377	80	10	120	40
6	11.7	7.8	784	464	1770	361	80	25	30	35
9	11.5	7.9	728	412	1786	413	200	40	400	90
10	11.1	7.9	516	496	1627	409	240	30	260	120
11	10.7	7.8	676	472	1596	400	130	15	370	95
12	11.7	7.8	704	440	1800	384	160	10	240	60
13	11.8	7.8	900	436	1497	370	110	30	210	30
16	11.8	7.8	784	496	1610	390	60	10	130	40
17	11.8	7.8	768	504	1537	369	120	40	280	80
18	11.7	7.8	624	444	1576	341	180	10	140	15
19	11.7	7.7	756	436	1631	361	190	10	190	25
20	11.4	7.8	624	484	1631	381	200	10	160	0
23	11.5	8.0	860	552	1550	402	170	10	190	90
24	11.4	8.0	844	600	1581	421	150	20	160	115

Table 14: Performance of Full-Scale Biological System

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
6/25/69	11.2	7.9	844	532	2195	416	160	30	240	75
26	11.6	7.8	836	564	1952	512	100	16	280	124
27	11.5	7.9	796	556	2113	399	26	26	194	45
30	11.0	7.9	796	420	1963	517	120	25	40	85
7/1/69	10.8	7.8	708	504	2113	611(427)	230	15	170	45
2	10.9	7.9	824	584	2307	620	110	30	100	15
3	11.2	7.9	844	556	2433	687(432)	110	40	180	30
7	10.9	7.9	822	586	1925	545	100	20	80	20
8	11.0	7.9	696	544	2113	552(496)	150	15	170	10
9	11.1	8.0	636	520	1954	503	160	20	60	0
10	11.2	8.0	728	488	2088	594(446)	210	35	140	0
11	11.1	8.0	766	524	1865	564	280	35	140	0
14	11.0	7.8	920	504	1967	1231	220	40	170	40
15	11.1	7.8	844	524	1604	1238(987)	180	40	20	55
16	11.0	7.7	776	504	2442	1542	260	74	220	46
17	11.1	7.7	808	528	2096	1561(1398)	250	90	260	40
18	11.1	7.7	816	528	1956	1522	290	110	180	40
7/21/69	11.2	7.7	884	536	1788	1201	225	25	275	70
22	11.2	7.7	596	616	1642	922(881)	215	35	265	75
23	11.4	7.9	720	612	1941	953	270	30	50	70
24	11.4	7.7	652	608	1809	894(797)	180	40	210	20
25	11.4	7.8	852	624	1798	818	250	30	30	50

COD values in ( ) are for filtered samples.

Table 14: Performance of Full-Scale Biological System

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
7/28/69	11.4	7.8	804	536	2046	885(719)	180	40	220	30
29	11.5	7.8	950	584	2160	711	140	30	20	30
30	11.4	7.8	784	568	1951	704(634)	200	20	130	10
31	11.3	7.8	772	572	1902	617	120	10	40	50
8/1/69	11.3	7.8	884	556	1933	660(578)	300	25	100	25
4	11.8	8.0	940	576	1969	690	220	20	360	60
5	11.6	7.9	884	488	1820	490(459)	400	25	110	35
6	11.5	7.9	856	504	1816	518	260	35	240	45
7	11.0	7.9	836	476	1863	483(410)	250	10	310	65
8	11.3	7.9	812	568	1880	441	240	20	260	50
11	11.6	8.0	836	664	1917	437	230	30	180	35
12	11.4	8.0	816	672	2019	383(343)	230	20	90	50
13	11.4	7.9	648	484	1781	475	250	15	250	55
14	11.5	7.9	676	464	1879	494(438)	360	20	190	60
15	11.4	7.9	736	492	1752	339	230	20	290	70
18	11.4	7.9	580	456	1874	339(290)	280	20	60	80
19	11.8	8.0	676	396	1851	304	160	15	220	50
20	11.6	7.9	644	464	1691	335	200	40	260	50
21	11.8	8.0	688	444	1582	320	280	20	200	50
22	11.6	8.0	744	468	2930	316(313)	330	30	260	25
25	10.2	8.0	760	424	1487	512	260	25	220	30
26	10.1	7.9	640	464	2822	602	290	20	330	40

COD values in (   ) are for filtered samples.

Table 14: Performance of Full-Scale Biological System

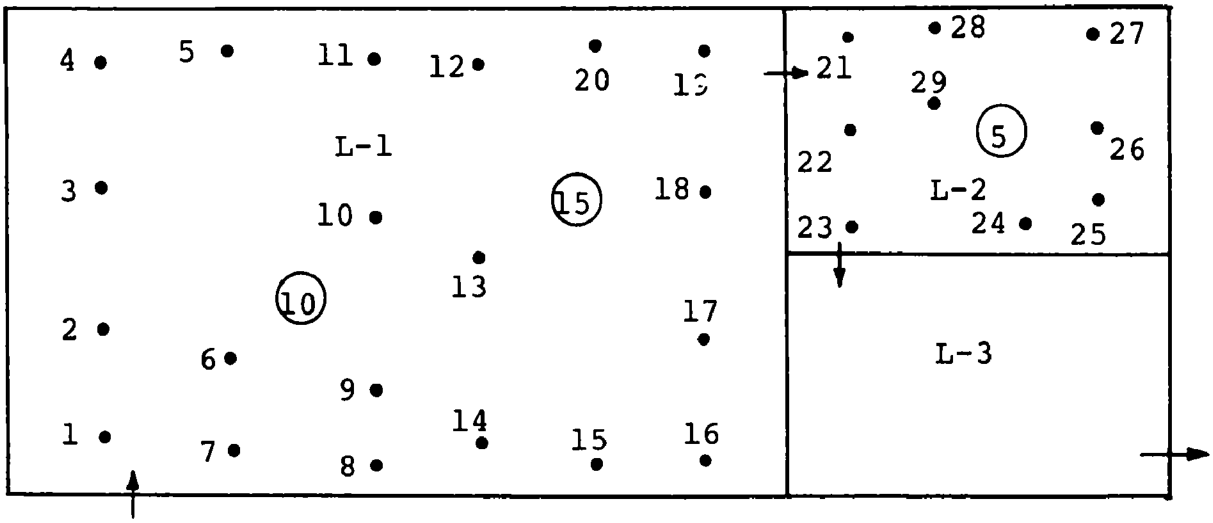
Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
8/27/69	8.5	7.9	484	460	3138	510	220	15	560	55
28	8.9	7.9	496	444	2844	525(400)	220	30	410	64
29	9.3	7.8	520	456	2760	555(508)	300	40	90	60
9/2/69	9.7	7.9	510	496	3050	820	260	30	420	70
3	8.9	7.9	532	504	3754	838(570)	220	25	440	70
4	8.3	7.9	556	496	2780	780	195	30	585	90
5	9.5	7.8	596	544	-	-	260	40	460	50
8	-	-	592	568	4344	706	-	-	-	-
9	-	-	616	536	3759	709	-	-	-	-
10	-	7.9	944	580	3363	817	-	-	-	-
11	-	7.9	596	532	2571	674	-	-	-	-
12	-	-	644	552	3693	801	-	-	-	-
15	7.8	7.9	556	504	6185	1187	300	75	720	315
16	-	-	576	560	6382	1119	-	-	-	-
17	9.1	7.9	644	556	5140	1720	350	82	710	353
18	-	-	572	528	5100	1728	-	-	-	-
22	7.8	7.9	724	404	1797	1293	310	90	380	260
23	11.5	8.0	836	624	1759	1224	270	70	370	370
24	11.5	7.9	792	598	1769	1046	240	100	240	260
25	11.4	7.9	812	572	2038	1085	220	80	210	270
26	11.5	7.9	800	568	1908	1033	230	90	340	270
29	11.3	8.0	916	600	2262	882	240	50	130	110
30	11.4	8.0	932	620	2376	806	250	80	430	130
10/1/69	-	-	-	-	2168	778	-	-	-	-
2	11.4	7.9	924	604	2093	733	190	40	190	120
3	11.4	7.9	896	576	2218	732	240	40	110	160

COD values in ( ) are for filtered samples.

Table 14: Performance of Full-Scale Biological System

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
10/6/69	10.0	7.9	656	644	2274	725	180	40	300	100
7	10.0	7.9	660	644	2004	816	190	70	410	90
8	9.8	7.9	736	656	1930	831	160	30	150	100
9	9.8	7.9	712	636	1918	816	130	40	70	120
10	9.8	7.9	696	648	1996	857	140	40	60	80
13	9.5	7.9	620	684	1999	951	150	30	90	70
14	9.6	7.9	592	692	1992	925	100	80	70	80
15	9.4	7.9	604	700	1935	944	110	40	50	60
16	9.4	7.9	724	696	2073	937	100	60	20	20
17	9.7	7.9	720	684	1943	892	120	60	80	40
20	9.8	7.9	704	700	1915	850	100	50	40	70
21	10.0	8.0	712	692	1830	913	100	70	60	90
22	10.1	7.9	736	656	1862	916	90	50	50	50
23	10.6	7.9	718	632	1949	938	60	40	60	40
24	10.8	7.9	-	-	1927	934	50	30	90	30

Table 15: Sludge Accumulation in Lagoons



Station No.	Water Depth Inches	Sludge Depth Inches	Station No.	Water Depth Inches	Sludge Depth Inches
1	66	0	16	75	5
2	66	4	17	72	3
3	63	6	18	73	0
4	69	3	19	72	0
5	66	4	20	69	0
6	72	0	21	66	0
7	66	1	22	69	0
8	60	6	23	66	2
9	66	5	24	66	0
10	72	2	25	48	1
11	66	4	26	63	0
12	69	0	27	69	3
13	69	2	28	60	0
14	69	3	29	78	0
15	66	5			

essentially zero for the entire period of study.

The nitrogen data presented in Table 16 show extensive reductions in the organic nitrogen content of the tannery wastes. The ammonia content of the effluent remained high throughout the period of observation. Laboratory determinations for nitrites and nitrates could not be made because of the high color of the treated effluent. It is not known, therefore, if any denitrification was achieved. The change in nitrogen levels observed in the anaerobic-aerobic lagoon was substantially the same as observed in the pilot plant operation.

The data on total sulfides indicate that the sulfides were unchanged in passage through the anaerobic-aerobic lagoons. This same characteristic was observed in the pilot plant studies. At no time was there evidence of hydrogen sulfide evolution from the operating system even though the pH of the effluent remained in the range of 7.7 to 8.0. Also when the spent tan liquors which had a pH of about 4.5 were mixed with the sulfide bearing wastes no hydrogen sulfide could be detected from an odor standpoint or by chemical means.

It is possible that the high dissolved salt content of tannery wastes prevents the formation and liberation of hydrogen sulfide at pH values above about 7.5. The sulfide concentration, however, does increase the chemical oxygen demand and will interfere with disinfection of the effluent.

The BOD data that were obtained* for the lagoon system show that reductions of 75-95 percent were obtained as measured by the influent and effluent values, Table 17 and Figure 16. Because of the long detention time, the variability of the BOD in the influent, and the mixing caused by the aerators, only approximate values for BOD removal can be given. The total removal of BOD obtained through the clarification and biological treatment steps, however, exceeded 90 percent. The limited number of BOD determinations made on filtered effluent samples indicates that most of the residual BOD was in dissolved form. Thus while the effluent at times contained appreciable volatile suspended solids these apparently were of little significance in terms of oxygen utilization.

While the 5-day, 20°C BOD values are used in most waste characterization and treatment studies, long term

*All BOD determinations made with a Manometric Analyzer manufactured by the Hach Chemical Company, Ames, Iowa.

Table 16: Performance of Biological System

Date	TKN		Ammonia Nitrogen		Organic Nitrogen		Total Sulfides	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
5/26/69	206	92	85	48	122	45	16	8
28	171	97	37	55	135	42	17	10
6/2/69	-	-	-	-	-	-	15	9
4	216	108	116	71	99	38	15	7
6	176	110	59	72	116	38	14	9
9	202	113	73	77	129	36	11	10
11	272	109	41	75	231	34	13	8
13	158	103	39	72	119	31	12	8
16	162	105	46	75	115	30	15	8
18	147	110	29	78	118	30	19	9
20	131	113	18	80	113	32	13	9
23	145	109	34	79	111	29	10	9
25	144	109	38	80	106	30	16	11
27	148	114	35	82	113	32	15	10
30	147	118	28	85	119	33	16	10
7/2/69	135	116	27	88	108	28	-	-
7	132	112	24	84	108	28	18	14
9	137	113	27	88	112	25	17	11
11	149	108	39	83	110	25	13	13
14	188	109	76	80	112	29	25	17
15	153	113	35	80	118	33	19	16
18	142	111	29	77	113	34	20	18
21	114	104	46	71	68	33	17	15
23	158	109	48	76	110	33	20	12
25	153	114	38	77	115	37	17	8
28	148	106	31	67	117	39	14	13
30	144	98	28	60	116	38		
8/1/69	161	102	52	71	109	31	15	16
4	148	96	40	71	108	25	19	16
6	149	95	47	68	102	27	11	15
8	137	87	29	67	108	20	14	13
11	156	86	52	68	104	18	15	14
13	161	104	55	83	106	21	17	14
15	154	88	48	70	106	18	-	-

*TKN -- Total Kjeldahl Nitrogen

Table 16: Performance of Biological System

Date	TKN		Ammonia Nitrogen		Organic Nitrogen		Total Sulfides	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
8/18/69	145	91	44	71	101	20	-	-
20	133	94	30	73	103	21	20	13
22	94	90	45	70	49	20	21	15
25	147	90	56	66	91	24	20	16
27	137	87	50	64	87	23	15	15
29	140	89	54	62	86	27	19	14
9/3/69	143	84	52	59	91	25	20	15
5	128	79	44	55	84	24	19	13
11	140	71	52	48	88	23	-	-
16	135	85	45	57	90	28	18	14
17	143	85	50	56	93	29	-	-
22	142	77	46	44	96	33	19	16
24	153	69	59	43	94	26	19	15
26	147	95	54	58	93	37	18	14
29	152	83	63	46	89	37	19	14
10/1/69	149	82	57	47	92	35	19	15
3	148	79	58	44	90	35	19	15
6	135	92	46	50	79	42	18	14
8	130	91	59	49	71	42	19	16
10	125	94	56	48	69	46	-	-
10/13/69	109	97	53	52	56	45	19	14
15	133	95	57	50	76	45	19	15
17	133	93	56	50	77	43	19	15
20	116	95	54	52	62	43	21	14
22	117	96	50	52	67	44	20	14
24	126	96	53	51	73	45	18	14

Table 17: Performance of Full Scale Biological Treatment System

Date	Sample	20°C BOD by Days in mg/l 1	2	3	4	5	6	7
5/22/69	Influent	-	-	952	1024	1084	1155	-
	Effluent	-	-	181	204	230	254	-
5/23/69	Influent	-	-	940	1024	1120	1155	-
	Effluent	-	-	168	194	228	246	-
6/3/69	Influent	441	788	-	-	1192	1241	1289
	Effluent	68	84	-	-	141	157	170
6/4/69	Influent	429	800	-	-	1192	1278	1338
	Effluent	63	79	-	-	133	147	162
6/10/69	Influent	418	739	-	998	1132	1205	-
	Effluent	65	86	-	128	139	147	-
6/11/69	Influent	455	764	-	1047	1132	1205	-
	Effluent	50	65	-	94	115	131	-
6/17/69	Influent	280	661	-	-	952	1098	1131
	Effluent	55	71	-	-	115	144	152
6/18/69	Influent	213	672	-	-	952	1064	1142
	Effluent	63	79	-	-	118	133	136
6/25/69	Influent	355	-	937	972	1045	1179	1206
	Effluent	52	-	81	97	105	141	-
6/26/69	Influent	243	-	873	934	984	1080	1106
	Effluent	55	-	92	105	118	136	138

Table 17: Performance of Full Scale Biological Treatment System

Date	Sample	20° C BOD by Days in mg/l 1	2	3	4	5	6	7
7/3/69	Influent	521	693	929	1127	-	1236	-
	Effluent	26	33	39	42	-	55	-
7/11/69	Influent	333	630	804	1002	-	1199	-
	Effluent	26	38	50	52	-	76	-
	*Effluent	16	24	31	37	-	63	-
7/12/69	Influent	336	853	188	1159	1336	-	-
	Effluent	92	115	131	160	173	-	204
7/14/69	Influent	392	644	821	853	928	-	1047
	Effluent	102	160	183	208	249	-	274
7/18/69	Influent	504	779	923	1016	1118	-	1215
	Effluent	84	149	173	201	221	-	256
7/21/69	Influent	573	1165	1335	1643	1790	-	2089
	Effluent	111	157	191	220	241	-	262
	*Effluent	88	141	170	199	222	-	238
7/28/69	Influent	465	722	870	965	-	1163	-
	Effluent	76	115	144	165	-	191	-
7/29/69	Influent	452	868	808	978	-	1126	1150
	Effluent	73	97	123	162	-	170	181
	*Effluent	71	92	118	141	-	165	170

*Filtered Sample

Table 17: Performance of Full Scale Biological Treatment System

Date	Sample	20° C BOD by Days in mg/l 1	2	3	4	5	6	7
8/4/69	Influent	490	823	984	1157	1230	1329	1415
	Effluent	68	89	102	113	131	136	144
8/12/69	Influent	432	730	902	1000	1037	1093	-
	Effluent	33	39	55	65	73	79	-
8/15/69	Influent	419	680	878	989	-	-	-
	Effluent	24	37	42	50	-	-	-
8/18/69	Influent	433	730	890	951	1038	-	-
	Effluent	26	39	50	63	65	-	-
	*Effluent	24	31	37	42	50	-	-
8/22/69	Influent	308	605	928	1201	1375	1498	1597
	Effluent	26	39	52	55	60	68	71
8/23/69	Influent	490	871	1010	1107	1157	1243	-
	Effluent	73	89	97	115	118	120	-
	*Effluent	65	79	89	102	107	111	-
8/28/69	Influent	580	866	1002	1125	1211	1235	1259
	Effluent	26	31	44	60	71	79	81
8/29/69	Influent	519	941	1139	1361	1597	1732	1856
	Effluent	31	44	52	63	76	89	99
	*Effluent	21	24	34	47	55	71	71

*Filtered Sample

Table 17: Performance of Full Scale Biological Treatment System

Date	Sample	20°C BOD by Days in mg/l 1	2	3	4	5	6	7
9/3/69	Influent	245	506	728	870	1037	1173	-
	Effluent	26	29	34	44	50	58	-
9/4/69	Influent	258	543	778	1013	1186	1335	-
	Effluent	31	42	52	68	79	81	-
9/10/69	Influent	202	331	491	539	713	811	-
	Effluent	26	34	39	42	50	55	-
9/11/69	Influent	208	306	466	502	688	986	-
	Effluent	34	44	63	71	79	89	-
9/17/69	Influent	493	688	958	1091	1202	1299	1384
	Effluent	50	99	126	165	181	196	217
9/18/69	Influent	469	738	983	1130	1239	1349	1459
	Effluent	39	76	113	147	160	183	201
9/19/69	Influent	589	793	927	1025	1120	1142	1176
	Effluent	71	107	123	144	191	222	238
9/22/69	Influent	501	781	865	950	1021	1067	1128
	Effluent	76	141	165	183	220	249	272
9/29/69	Influent	630	964	1120	1167	1338	1484	1595
	Effluent	52	94	118	133	170	201	235

Table 17: Performance of Full Scale Biological Treatment System

		20°C BOD by Days in mg/l						
Date	Sample	1	2	3	4	5	6	7
9/30/69	Influent	605	852	1167	1167	1238	1310	1346
	Effluent	42	63	115	139	162	194	209
10/6/69	Influent	477	859	1051	1183	1329	1362	1398
	Effluent	72	110	170	212	251	290	301
10/7/69	Influent	490	777	927	1126	1217	1274	1310
	Effluent	68	118	183	238	273	306	327
10/8/69	Influent	556	881	1049	1205	1236	1285	1320
	Effluent	65	118	173	225	274	304	319
10/20/69	Influent	564	782	966	1037	1109	1143	1177
	Effluent	71	105	131	157	201	243	288
10/21/69	Influent	514	758	817	938	985	1081	1190
	Effluent	79	126	154	186	209	241	267

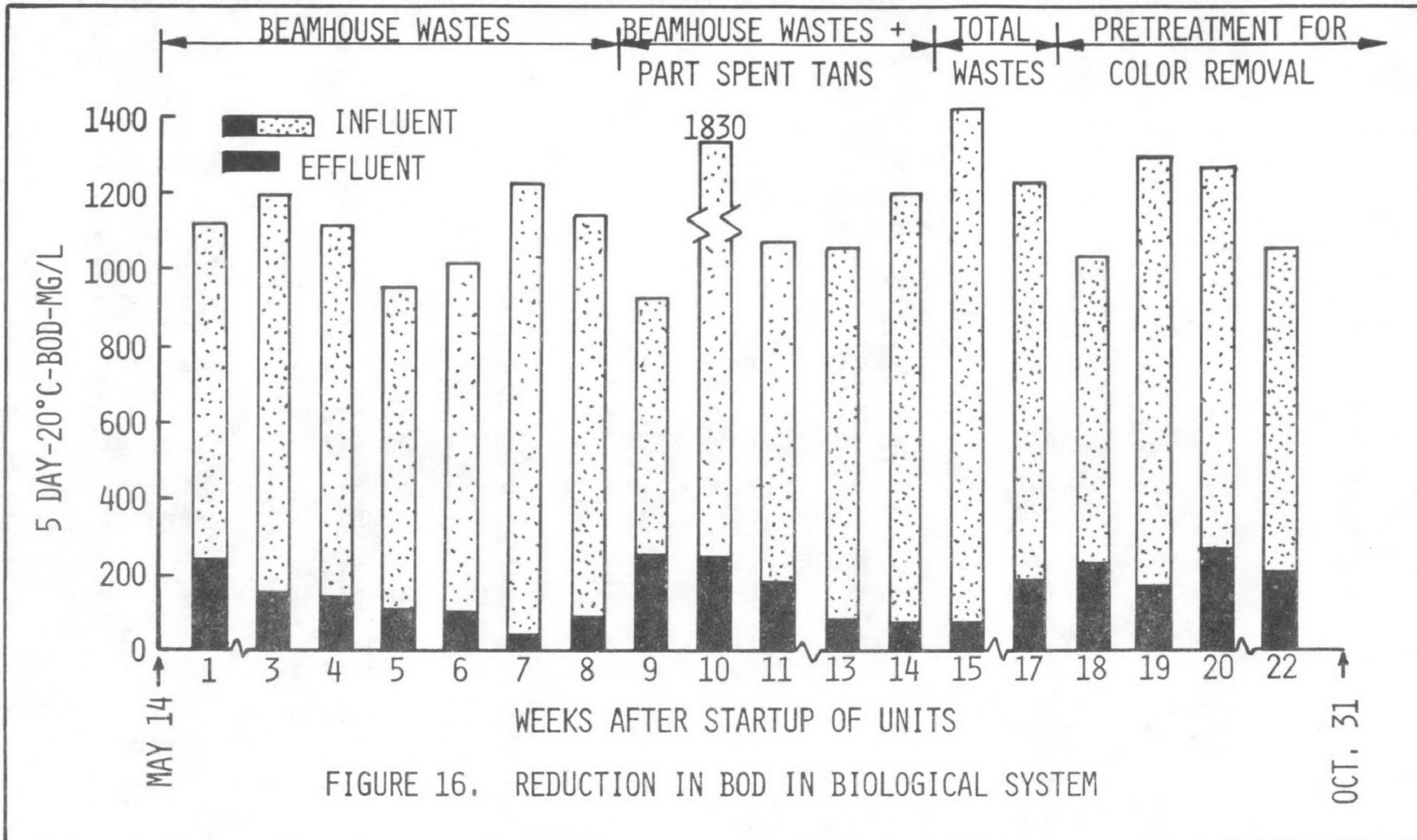


FIGURE 16. REDUCTION IN BOD IN BIOLOGICAL SYSTEM

data often are significant from a design and operational standpoint. A number of long term BOD determinations were made to determine the relationship between the 5-day values and the corresponding 20-day values. The data presented in Table 18 and in Figures 17 and 18 show that for the effluent samples the 5-day BOD represented a major fraction of the ultimate BOD. This was somewhat surprising because of the relatively high ammonia concentration in the effluent from the lagoons.

Some of the long term BOD values for the influent samples were considerably higher than the 5-day values. In the selection of aeration equipment for a lagoon with a detention time greatly in excess of five days, long term BOD data must be given serious consideration. The calculated loading intensity for the system, Table 19, ranged from 1.9 to 7.0 pounds of 5-day, 20°C. BOD/day/ 1000 cu.ft.

The actual aeration requirements probably were considerably higher, since the detention time in the aerobic portion of the system was 10-12 days. This factor coupled with the rapid loss of oxygen from tannery wastes, Figure 19, probably accounts for the low dissolved oxygen levels observed in the aerated lagoons throughout the period of operation.

Dissolved oxygen measurements made almost daily at the water surface around the periphery of the lagoons revealed a very low oxygen concentration, Table 20. A detailed study made on September 18 showed that dissolved oxygen was present in the aerated lagoons to a depth of about 44 inches, Table 21. Since the total water depth ranged from 5 to 6 feet, a large portion of the system was aerobic.

<u>Effect of Effluent on the Receiving Stream:</u>

The effluent became highly colored soon after spent tan liquors were added to the biological units. A survey of the receiving stream revealed that the effluent reduced the D.O. in a narrow segment of the stream immediately below the point of discharge, Figures 20 and 21. This segment of the stream also was highly colored but aquatic life was abundant. The discoloration persisted for at least one mile downstream. It is believed that dispersal of the wastes across the entire width of the stream would reduce the color to a more acceptable range although the entire stream would be slightly discolored during periods

Table 18: Long-Term BOD Values For Lagoons

Time Days	Dates On Which Samples Were Composited 7-29-69 Inf.	7-29-69 Eff.	8-28-69 Inf.	8-28-69 Eff.	8-29-69 Inf.	8-29-69 Eff.	9-19-69 Inf.	9-19-69 Eff.
1	452	73	580	26	519	31	589	71
2	686	97	866	31	941	44	793	107
3	808	123	1002	44	1139	52	927	123
4	978	162	1125	60	1361	63	1025	144
5	-	-	1211	71	1597	76	1120	191
6	1126	170	1235	79	1732	89	1142	222
7	1149	181	1259	81	1856	99	1176	238
8	1160	194	1259	81	1905	99	1213	264
9	1210	196	1283	89	1942	105	1224	272
10	1222	199	1295	97	1979	107	1225	277
11	1222	207	1300	99	2028	115	1225	277
12	1222	207	1318	105	2074	118	1225	277
13	1222	209	1324	105	2074	120	1225	277
14	1222	209	1324	105	2079	120	1225	277
15	1222	209	1324	105	2079	120	-	-
16	1222	209	1324	105	2079	120	-	-
17	1233	209	1324	107	2079	120	-	-
18	1233	209	1330	107	2114	126	-	-
19	1233	209	1330	107	2138	128	-	-
20	1233	209	1341	114	2200	133	-	-
21	-	-	1354	115	2212	133	-	-

Table 18: Long-Term BOD Values for Lagoons

Time Days	Dates On Which Samples Were Composited 10-6-69 Inf.	Eff.	10-7-69 Inf.	Eff.
1	477	72	490	68
2	859	110	777	118
3	1051	170	927	183
4	1183	212	1126	238
5	1328	251	1216	273
6	1362	290	1274	306
7	1398	301	1311	327
8	1370	308	1312	353
9	1429	314	1342	369
10	1440	324	1378	385
11	1451	348	1388	395
12	1451	366	1418	406
13	1451	379	1418	416
14	1451	392	1555	419
15	1451	403	1555	419
16	1451	408	1555	421
17	1451	416	1555	424
18	1451	416	1555	424
19	1451	416	1555	424
20	1451	416	1555	424
21	1451	416	1555	424

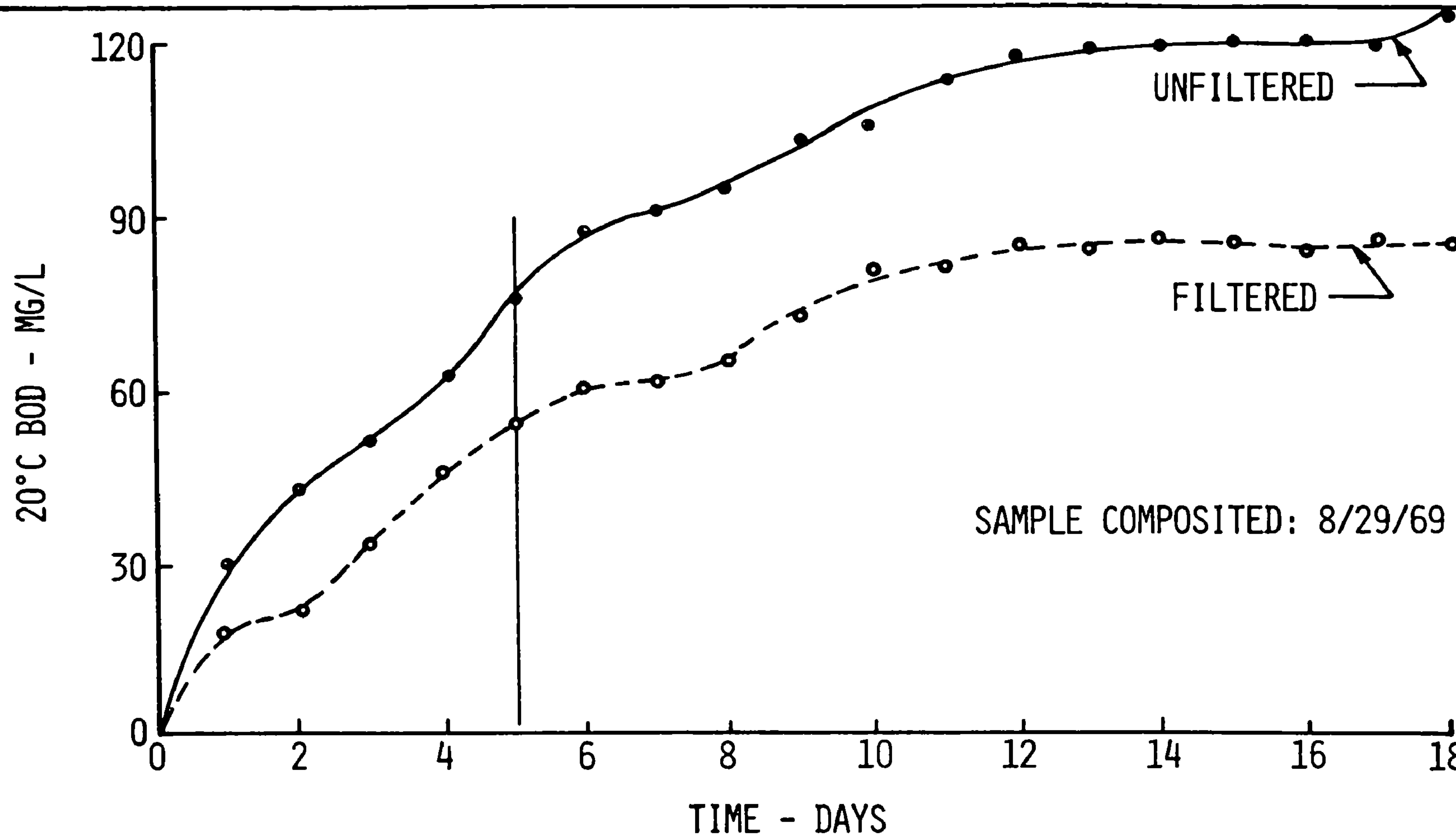


FIGURE 17. EFFLUENT BOD VS TIME

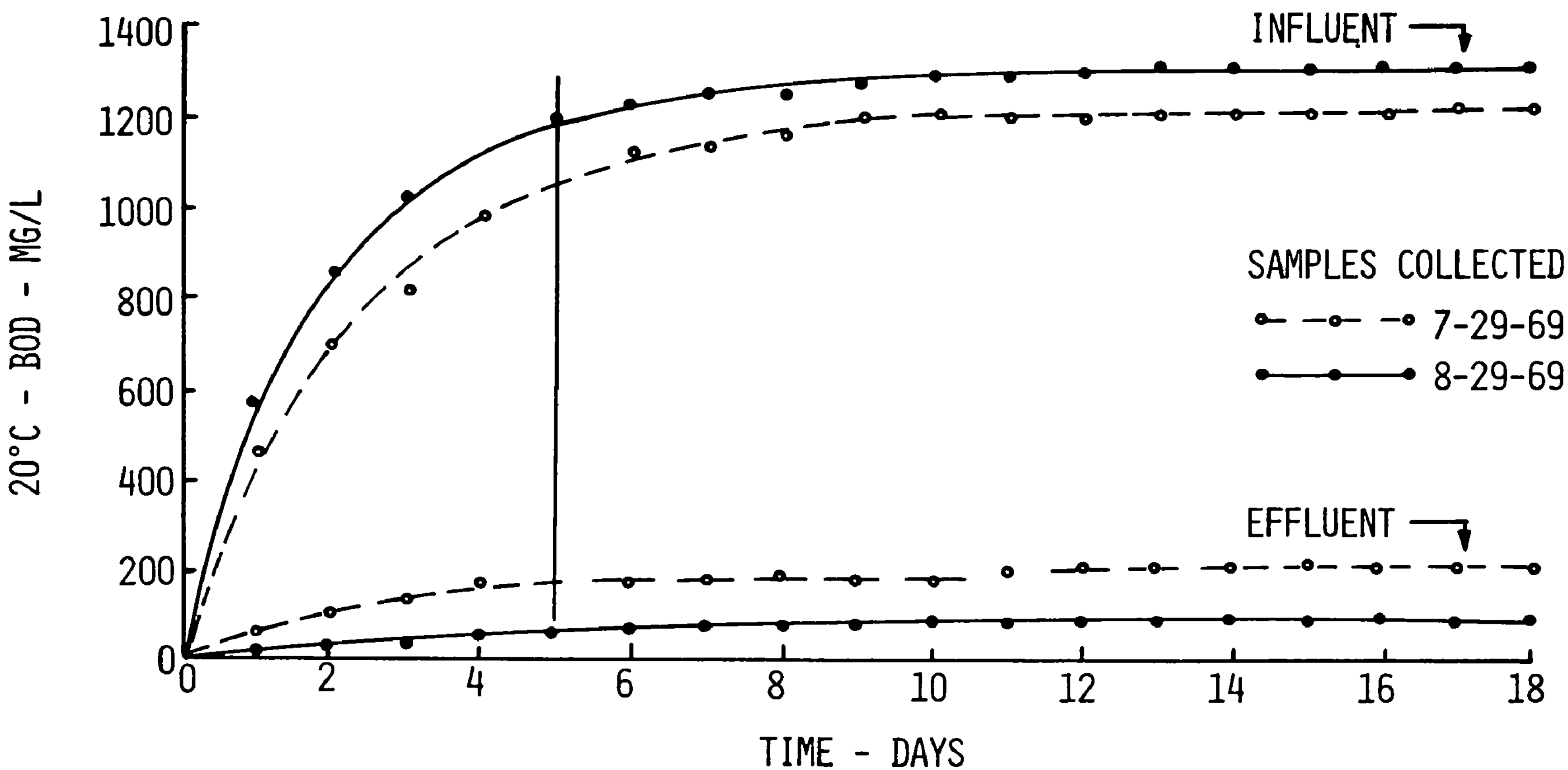


FIGURE 18. LONG TERM BOD VALUES

Table 19: Organic Loading and Flow to Lagoons

Date	Flow gpd	Applied Load COD #/day	Applied Load BOD #/day	Lagoon Loading COD #/day/1000ft^3	Intensity BOD #/day/1000ft^3
6/12/69	117,300	1760	-	5.7	-
13	129,400	1610	-	5.1	-
16	98,000	1310	-	4.3	-
18	140,800	1940	1180	6.4	3.9
19	161,800	2200	-	7.2	-
20	153,300	2080	-	6.8	-
27	164,700	2890	-	9.4	-
30	156,900	2560	-	8.4	-
7/1/69	64,450	1130	-	3.7	-
2	153,300	2960	-	9.7	-
3	151,650	3060	1520	9.9	4.9
8	92,750	1630	-	5.3	-
7/9/69	161,500	2640	-	8.6	-
10	165,300	2880	-	9.4	-
11	167,750	2610	1535	8.5	5.0
15	87,750	1170	-	3.9	-
16	150,150	3060	-	9.9	-
17	149,500	2600	-	8.5	-
18	150,250	2450	1400	7.9	4.5
7/21/69	143,000	2150	2140	7.0	7.0
22	84,350	1160	-	3.7	-
23	164,900	2660	-	8.6	-
24	166,100	2510	-	8.2	-
25	155,400	2330	-	7.6	-
28	157,900	2690	1400	8.8	4.5
29	86,900	1565	760	5.0	2.5
30	147,750	2410	-	7.8	-
31	146,500	2320	-	7.6	-
8/1/69	146,100	2360	-	7.7	-
4	164,650	2700	1690	8.7	5.4
5	81,500	1230	-	4.0	-
6	143,250	2180	-	7.0	-
7	142,500	2210	-	7.2	-
8	143,000	2240	-	7.3	-
11	143,600	2290	-	7.4	-
12	66,000	1110	570	3.6	1.9
13	148,950	2210	-	7.2	-
14	149,300	2340	-	7.6	-
15	156,250	2280	1370	7.4	4.5
18	156,500	2450	1360	8.0	4.4

Table 19: Organic Loading and Flow to Lagoons

Date	Flow gpd	Applied Load COD #/day	Applied Load BOD #/day	Lagoon Loading COD #/day/1000ft^3	Intensity BOD #/day/1000ft^3
8/19/69	111,750	1730	-	5.6	-
20	166,500	2350	-	7.7	-
21	161,350	2140	-	6.9	-
22	147,900	2020	1690	6.6	5.5
25	116,600	1460	1120	4.8	3.6
26	71,350	1680	-	5.5	-
27	77,250	2020	-	6.6	-
28	120,250	2900	1240	9.4	4.0
29	126,500	2920	1680	9.5	5.5
9/2/69	151,500	3860	-	12.4	-
3	100,300	3110	900	10.1	2.9
4	156,100	3620	1530	11.7	5.0
8	142,500	5160	-	16.7	-
9	89,000	2790	-	9.0	-
10	144,650	4080	860	13.2	2.8
11	151,700	3260	872	10.5	2.8
12	157,150	4850	-	15.7	-
15	112,900	5800	-	18.8	-
16	141,000	7500	-	24.3	-
17	160,500	6880	1610	22.2	5.2
18	168,500	7160	1740	23.2	5.6
19	160,350	-	1500	-	4.9
22	167,380	2510	1430	8.1	4.6
23	157,000	2300	-	7.5	-
24	162,750	2400	-	7.8	-
25	153,250	2610	-	8.4	-
26	157,500	2510	-	8.1	-
29	156,800	2960	1750	9.6	5.7
10/1/69	143,500	2590	-	8.4	-
2	166,750	2900	-	9.4	-
3	165,250	3060	-	9.9	-
6	166,500	3160	1845	10.2	6.0
7	165,000	2760	1670	8.9	5.4
8	171,000	2750	1760	8.9	5.7
9	166,500	2660	-	8.6	-
10	164,100	2730	-	8.9	-

Table 19: Organic Loading and Flow to Lagoons

Date	Flow gpd	Applied Load COD #/day	Applied Load BOD #/day	Lagoon Loading COD #/day/1000ft^3	Intensity BOD #/day/1000ft^3
10/13/69	162,200	2710	-	8.8	-
14	84,000	1400	-	4.5	-
15	105,500	1700	-	5.5	-
16	125,500	2160	-	7.0	-
17	135,750	2200	-	7.1	-
20	87,750	1400	810	4.5	2.6
21	89,300	1360	734	4.4	2.4
22	150,500	2340	-	7.6	-
23	111,200	1810	-	5.8	-

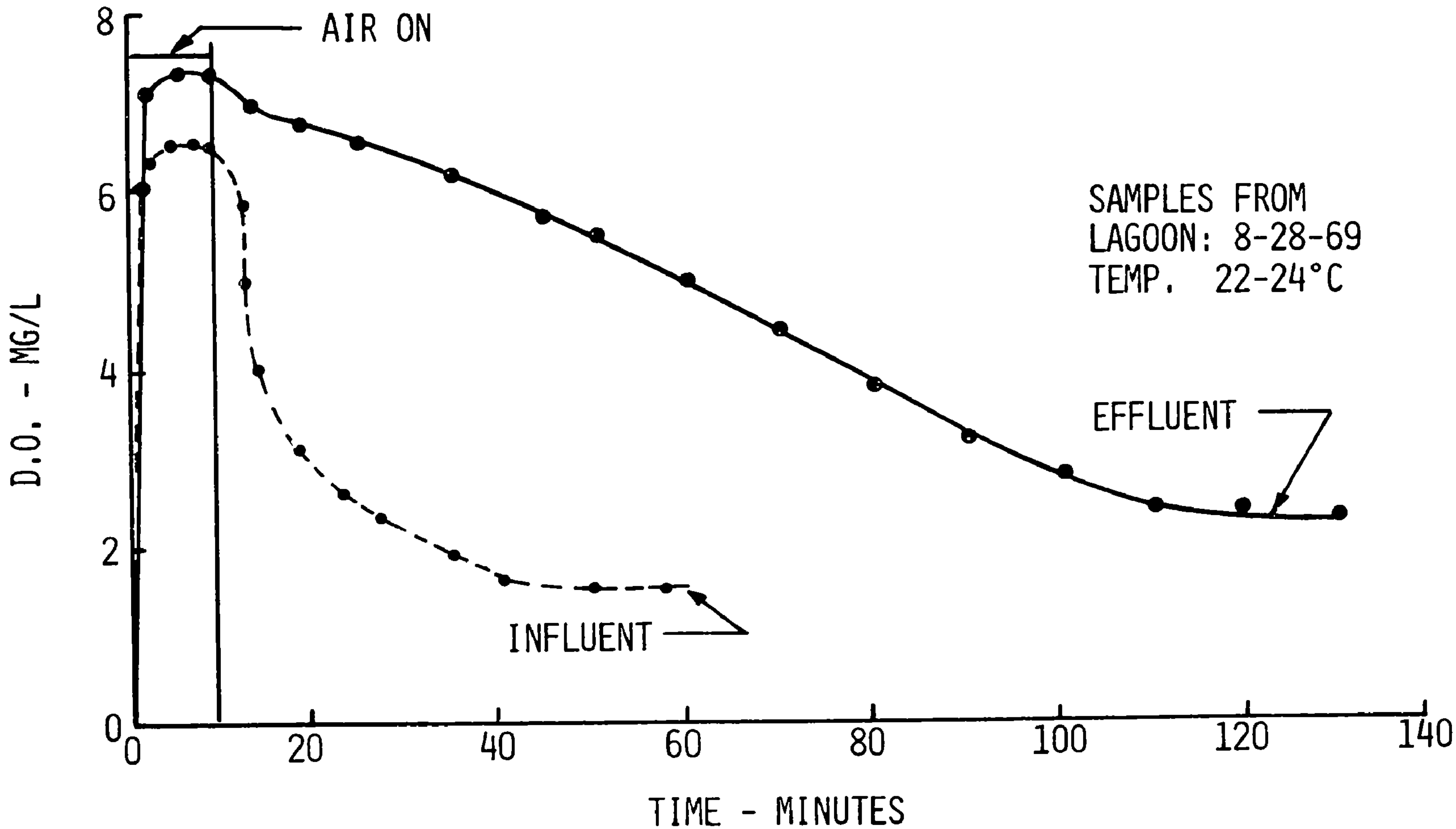


FIGURE 19. OXYGEN BUILD-UP AND UPTAKE

Table 20: Dissolved Oxygen Levels and Water Temperature at Water Surface Around Periphery of Lagoons

Date	L-1 D.O. mg/l	L-1 Temp. °C	L-2 D.O. mg/l	L-2 Temp. °C	L-3 D.O. mg/l	L-3 Temp. °C
6/16/69	5.2-6.5	22.0	2.8	22.0	0.6-0.8	21.6
17	1.0-2.0	20.6	4.7	20.5	0.5-2.0	20.4
18	0.6-2.0	20.0	2.5-4.0	20.0	0.5-0.7	20.0
19	0.8-1.2	20.0	0.8-1.2	20.0	0.4-0.6	20.0
20	0.8-2.0	21.0	1.0-1.5	21.0	0.8-1.0	21.0
23	0.6-1.0	22.0	0.8-1.0	21.5	0.6-0.8	21.5
6/24/69	0.5-0.8	22.0	0.8-1.0	22.0	0.4-0.6	22.0
26	0.4-1.0	22.5	0.6-1.0	22.5	0.3-0.5	22.5
27	0.4-0.9	22.5	0.5-1.2	22.5	0.4-0.6	22.5
30	0.8-1.5	23.0	1.5-2.4	23.0	0.6-0.8	23.0
7/1/69	1.0-1.8	22.0	2.2-3.2	22.0	0.4-0.6	22.0
2	1.0-1.2	23.0	1.7-2.1	23.0	0.5-0.8	23.0
3	0.4-0.8	24.0	0.5-0.9	24.0	0.4-0.6	24.0
7	1.0-2.4	25.0	1.5-2.8	25.0	0.4-0.8	25.0
8	0.8-1.5	24.0	-	24.0	0.4-2.6	24.0
10	0.5-1.5	22.0	0.5-0.6	22.0	0.3-0.4	22.0
11	0.6-0.8	21.0	0.6-1.0	21.0	0.3-0.5	21.0
14	1.0-2.2	23.5	1.0-2.0	23.5	0.5-0.6	23.5
15	0.6-1.0	23.5	0.8-1.0	23.5	0.3-0.5	24.0
16	0.5-0.8	24.0	0.6-1.0	24.0	0.3-0.4	24.0
17	0.6-0.9	24.0	0.8-1.0	24.0	0.3-0.4	24.0
18	0.4-0.8	24.0	0.6-0.8	24.0	0.2-0.4	24.0

Table 20: Dissolved Oxygen Levels and Water Temperature at Water Surface Around Periphery of Lagoons

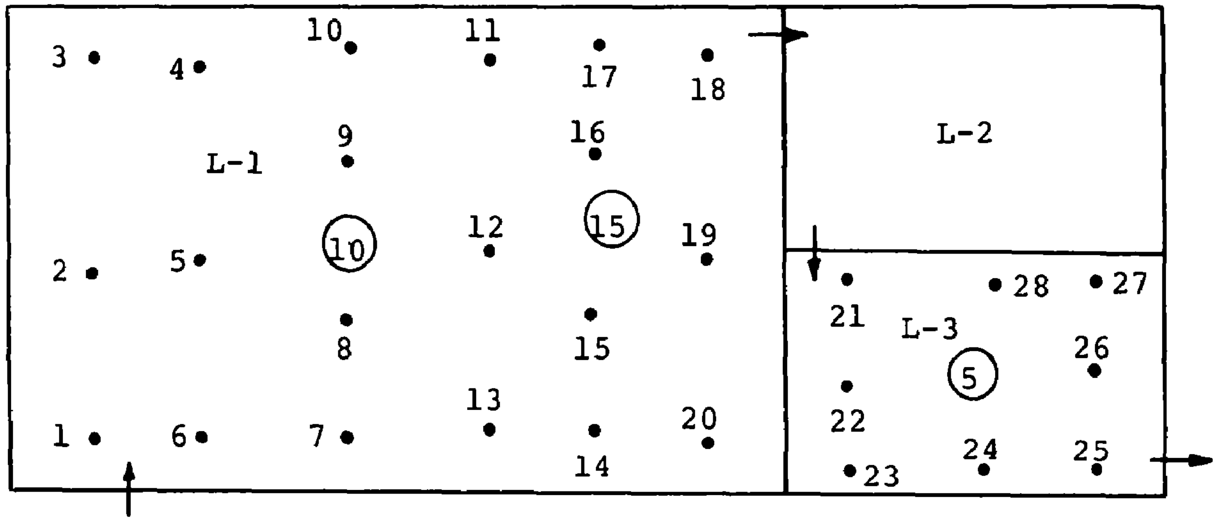
Date	L-1 D.O. mg/l	L-1 Temp. °C	L-2 D.O. mg/l	L-2 Temp. °C	L-3 D.O. mg/l	L-3 Temp. °C
7/21/69	1.2-1.8	25.0	2.0-3.5	25.0	0.2-0.4	25.0
22	0.8-1.0	25.0	1.0-1.5	25.0	0.2-0.5	25.0
23	0.6-1.0	25.0	0.5-0.8	25.0	0.1-0.4	24.5
24	0.6-1.2	25.0	0.5-1.2	25.0	0.3-0.7	25.0
25	0.5-0.8	25.0	0.6-0.9	25.0	0.3-0.5	25.0
28	1.8-2.6	25.0	2.2-3.1	25.0	0.8-1.4	25.0
29	0.8-1.0	24.0	1.6-1.9	24.0	0.6-0.8	24.0
30	0.8-1.0	23.0	1.0-1.2	23.0	0.4-0.6	23.0
31	0.6-0.8	23.0	0.8-1.0	23.0	0.3-0.6	23.0
8/1/69	0.5-0.8	24.0	0.8-1.0	24.0	0.2-0.4	24.0
4	1.4-2.4	23.0	2.0-3.4	23.0	1.0-1.4	23.0
5	1.0-1.5	23.0	1.2-1.6	23.0	0.6-0.8	23.0
7	0.9-1.1	24.0	0.8-1.0	23.5	0.4-0.6	23.5
8	0.6-0.9	24.0	0.8-1.0	23.5	0.4-0.6	23.5
11	2.4-3.6	22.0	3.1-3.8	22.0	1.0-1.6	22.0
12	2.1-3.0	22.0	2.5-2.9	22.0	1.2-1.6	22.0
13	1.4-1.8	22.0	1.8-2.0	22.0	0.5-0.8	22.0
14	0.6-1.0	22.0	2.0-2.8	22.0	0.4-0.5	22.0
15	0.8-1.2	23.0	1.6-1.8	23.0	0.5-0.6	23.0
18	2.7-3.1	24.0	3.2-3.8	24.0	1.6-1.9	24.0
19	2.2-2.6	24.0	2.6-2.9	24.0	0.9-1.2	24.0
20	1.6-2.0	24.0	1.8-2.0	24.0	0.4-0.6	24.0
21	0.9-1.2	24.0	1.8-3.2	24.0	0.3-0.6	24.0
25	1.3-1.8	22.0	1.5-2.0	22.0	0.6-1.0	22.0
26	1.4-2.1	21.0	1.8-2.5	21.0	0.5-0.8	21.0
27	1.2-1.4	21.0	1.4-1.6	21.0	0.4-0.8	21.0

Table 20: Dissolved Oxygen Levels and Water Temperature at Water Surface Around Periphery of Lagoons

Date	L-1		L-2		L-3	
	D.O. mg/l	Temp. °C	D.O. mg/l	Temp. °C	D.O. mg/l	Temp. °C
8/29/69	0.6-0.9	21.0	0.8-1.0	21.0	0.4-0.6	21.0
9/2/69	1.0-1.5	23.0	1.8-2.6	23.0	1.0-1.8	24.0
3	1.0-1.2	23.0	1.6-1.8	23.0	0.5-1.0	23.0
4	0.4-0.6	24.0	0.6-0.8	24.0	0.2-0.5	24.0
10	1.0-1.2	24.0	1.2-1.4	24.0	0.4-0.5	24.0
*22	0.6-1.2	23.0	0.4-0.5	23.0	1.0-1.4	23.0
*24	0.8-1.0	23.0	0.3-0.5	23.0	0.8-1.0	23.0
26	0.5-0.8	24.0	0.8-1.2	24.0	0.4-0.6	24.0
29	0.6-0.8	23.0	0.8-1.0	23.0	0.4-0.6	23.0
10/1/69	0.5-0.7	24.0	0.6-0.9	24.0	0.3-0.4	24.0
2	0.5-0.8	24.0	0.5-0.6	24.0	0.2-0.4	24.0
6	0.4-0.7	22.0	0.4-0.8	22.0	0.2-0.4	22.0
8	0.5-0.8	23.0	0.7-0.9	23.0	0.2-0.5	23.0
10	0.6-0.8	22.0	0.8-1.0	22.0	0.2-0.4	22.0
13	0.6-0.9	22.0	0.6-1.0	22.0	0.2-0.4	22.0
16	0.8-1.0	21.0	0.6-0.8	21.0	0.2-0.5	21.0

*5 H.P. Aerator moved from L-2 to L-3.

Table 21: Dissolved Oxygen Levels
In Lagoons



Station No.	Depth In.	Temp. °C	D.O. mg/l	Station No.	Depth In.	Temp. °C	D.O. mg/l
1	2	21	0.6	6	2	21	0.6
	22	21	0.3		22	21	0.3
	44	21	0.0		44	21	0.1
2	2	21	0.5	7	2	21	0.5
	22	21	0.3		22	21	0.2
	44	21	0.2		44	21	0.0
3	2	21	0.4	8	2	21	1.0
	22	21	0.2		22	21	0.4
	44	21	0.2		44	21	0.3
4	2	21	0.5	9	2	21	1.0
	22	21	0.2		22	21	0.6
	44	21	0.2		44	21	0.3
5	2	21	0.8	10	2	21	0.5
	22	21	0.5		22	21	0.2
	44	21	0.3		44	21	0.0

Table 21: Dissolved Oxygen Levels In Lagoons

Station No.	Depth In.	Temp. °C	D.O. mg/l	Station No.	Depth In.	Temp. °C	D.O. mg/l
11	2	21	0.6	20	2	21	0.5
	22	21	0.3		22	21	0.2
	44	21	0.0		44	21	0.0
12	2	21	0.9	21	2	20.8	1.0
	22	21	0.5		22	20.8	0.8
	44	21	0.3		44	20.8	0.5
13	2	21	0.5	22	2	20.8	0.9
	22	21	0.3		22	20.8	0.6
	44	21	0.1		44	20.8	0.5
14	2	21	0.5	23	2	20.8	0.7
	22	21	0.2		22	20.8	0.4
	44	21	0.1		44	20.8	0.2
15	2	21	0.6	24	2	20.8	1.0
	22	21	0.3		22	20.8	0.6
	44	21	0.1		44	20.8	0.4
16	2	21	0.8	25	2	20.8	1.0
	22	21	0.4		22	20.8	0.6
	44	21	0.3		44	20.8	0.5
17	2	21	0.8	26	2	20.8	1.2
	22	21	0.4		22	20.8	0.8
	44	21	0.2		44	20.8	0.8
18	2	21	0.6	27	2	20.8	1.2
	22	21	0.2		22	20.8	0.9
	44	21	0.0		44	20.8	0.8
19	2	21	0.5	28	2	20.8	1.2
	22	21	0.2		22	20.8	0.8
	44	21	0.1		44	20.8	0.6

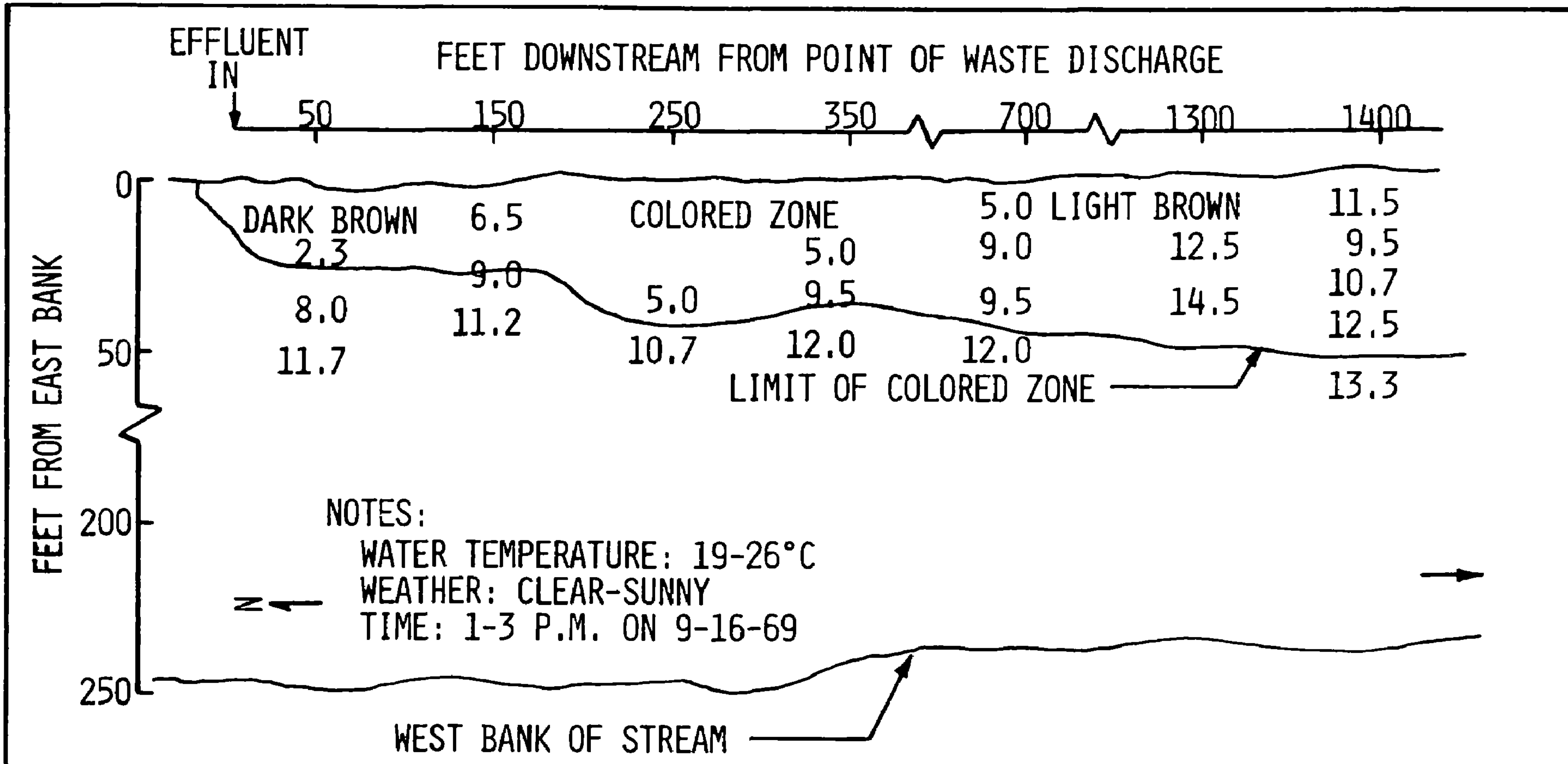


FIGURE 20. DISSOLVED OXYGEN LEVELS IN RECEIVING STREAM

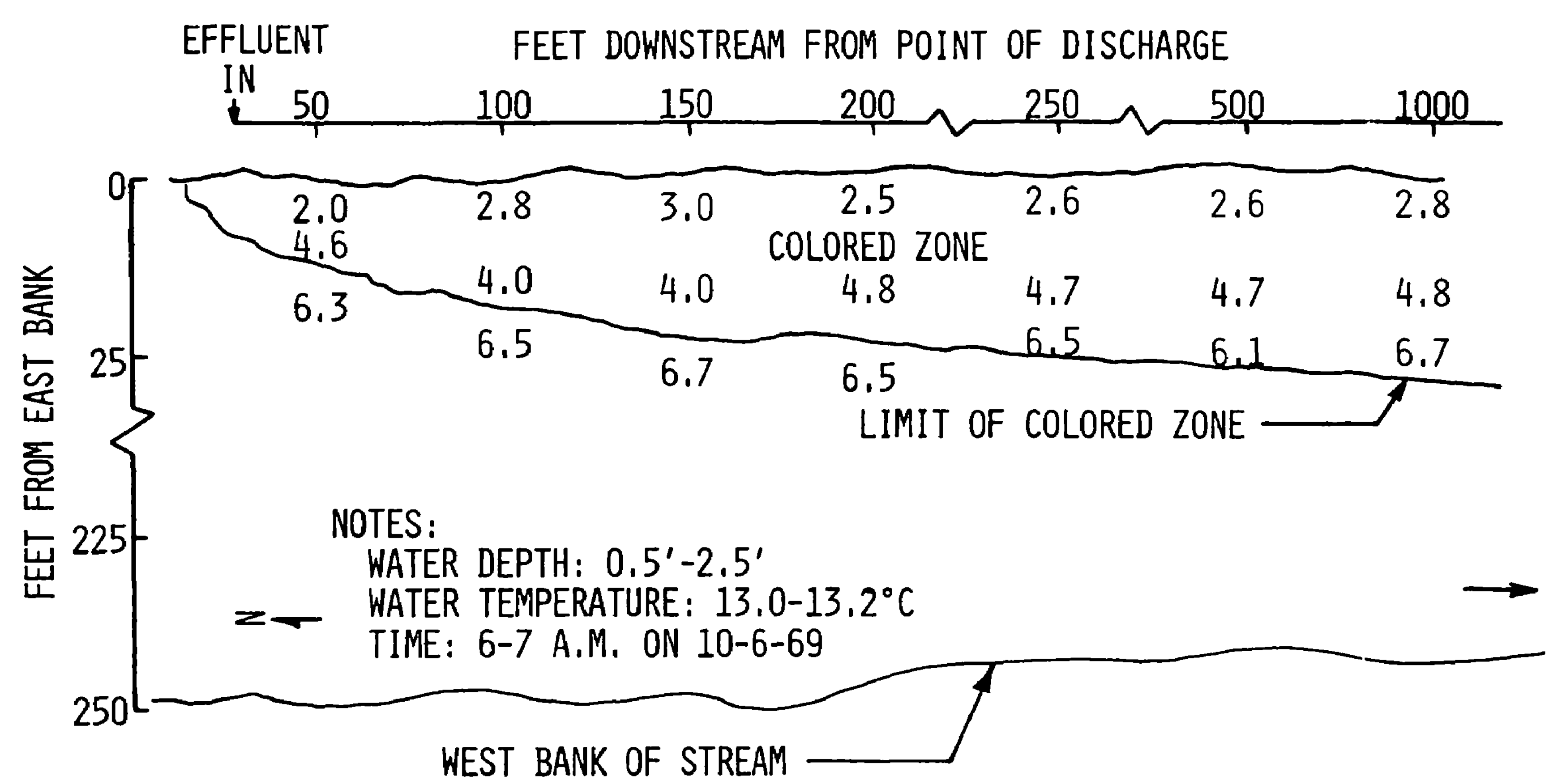


FIGURE 21. DISSOLVED OXYGEN LEVELS IN RECEIVING STREAM

of low stream flow.

Removal of Color:

After having determined that the total tannery wastes could be treated effectively in an anaerobic-aerobic biological system, it was decided that efforts should be made to remove the residual color from the lagoon effluent. Detailed laboratory and pilot plant studies demonstrated that the residual color in the lagoon effluent could be precipitated effectively by adding lime to bring the pH to about 12.0. The addition of an anionic polyelectrolyte (NALCO-675) at a dosage of 2-5 mg/l produced rapid settling of the precipitated color compounds leaving the effluent with only a pale yellow tinge.

A reduction in color of at least 90 percent was achieved (estimated by dilution with river water) and the volume of sludge produced was small. The dosage of lime required to increase the pH of the effluent to 12.0, however, was in excess of 2,000 mg/l. This fact coupled with the necessity of reducing the pH to 10.0 or less before final discharge rendered the process uneconomical.

The studies then were directed toward precipitating the color before biological treatment. It was found that by mixing the spent tan liquors with the highly alkaline beamhouse waste fractions, the colored materials were precipitated when the pH was maintained above 11.5. In the laboratory and pilot plant studies, the mixture of the two waste fractions produced a large volume of sludge that settled poorly. Efforts to overcome the sludge problem by use of polyelectrolytes (in a reasonable dosage range) were unsuccessful.

It was decided, however, to conduct a full scale experiment in mixing the two wastes prior to discharging them to the biological treatment unit. The two waste fractions were mixed in a small lagoon and allowed to pass through several larger lagoons before reaching the biological unit. The reduction in color was dramatic and the resulting precipitates settled rapidly and appeared to compact readily. This finding is quite surprising in light of the laboratory and pilot plant experience.

Continuous operation of the color removal process has shown that unless the total waste volume is maintained at a pH of 10.5 or greater, color will be released from the precipitated materials. It appears also that complete color removal will not be achieved unless the pH of the two waste fractions is above 11.5 after mixing. It is likely, therefore, that a more sophisticated mixing, clarification and sludge handling system which can be controlled closely will be required.

Section 4

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Individuals who have participated directly in the project and their major role are as follows:

Mr. Stephen Graef, Mr. Stephen Lackey, Mr. John Aldous and Mr. Lawrence Liu, Graduate Students from The University of Cincinnati served as Project Engineers at various times during the study. Mr. J. C. Burchinal, Professor of Sanitary Engineering, West Virginia University and Mr. Edgar Henry, Director of the West Virginia Water Resources Commission, served as consultants and advisors on the Project. Mr. Stevan Pierce and Mr. Frederic Lamoureux, Graduate Students from The University of Cincinnati, conducted specialized studies relating to the major project. The late Mr. Richard Jones, former Superintendant of The International Shoe Company Tannery and Mr. Thomas Morrison, Superintendant of The International Shoe Company Tannery, provided technical, financial and mechanical assistance in all phases of the study. Mr. Harold E. Cutlip, of the International Shoe Company, served as Assistant Project Engineer for the field studies and is now in direct charge of the total project.

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Section 5

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Section 6

Appendix

Table A-1: Performance of Clarification System

Date	Suspended Solids Inf. mg/l	Suspended Solids Eff. mg/l	Suspended Solids Red. %	Total Alkalinity Inf. mg/l	Total Alkalinity Eff. mg/l	Total Alkalinity Red. %	COD Inf. mg/l	COD Eff. mg/l	COD Red. %	A-10 Dose mg/l	Overflow Rate gpd/ft^2
1/3/68	5420	480	91.0	7560	3176	58.0	-	-	-	11.2	885
4	5000	460	90.8	6750	2913	56.8	-	-	-	10.0	885
5	3220	2920	9.3	5546	4798	13.5	-	-	-	None	1090
8	2820	600	78.7	4464	2960	33.7	-	-	-	9.9	1060
9	4140	540	87.0	6720	2544	60.6	-	-	-	9.6	1520
10	3760	400	89.4	6008	2864	51.7	-	-	-	9.6	860
1/11/68	2640	500	81.0	3136	2448	21.9	-	-	-	9.8	1220
12	3360	460	86.3	5704	2624	53.8	-	-	-	9.6	1400
15	3680	520	85.9	3584	2504	30.1	-	-	-	9.8	1560
16	3800	440	88.4	6744	2480	63.2	-	-	-	12.0	1410
17	3540	480	86.5	5776	1712	70.3	-	-	-	11.2	1220
18	3860	600	84.5	5880	2304	60.7	-	-	-	10.1	1200
19	3800	400	89.5	6208	2464	60.3	-	-	-	11.9	775
1/22/68	3380	320	90.5	5312	2160	59.3	2910	1888	35.2	13.2	380
23	2580	280	89.2	4240	1936	54.4	3425	1616	52.7	10.2	625
24	3360	320	90.5	4728	2288	51.7	3304	1898	42.5	11.3	505
25	3180	500	84.3	4792	2488	48.2	3646	2383	34.7	9.4	1290
26	2220	600	73.0	4296	2440	43.2	3328	2403	27.8	9.8	1240
29	3040	500	83.6	1870	1220	34.8	2812	2404	14.5	9.5	1390
30	3420	420	87.7	5600	2496	55.4	3775	2195	41.8	10.3	1430
31	3460	620	82.0	4664	1680	64.0	3311	2286	31.0	11.7	1450
2/1/68	3980	960	76.0	5776	3312	42.7	3868	2415	37.6	7.1	1410
2	3520	2600	26.2	5200	4864	6.5	3524	3221	8.6	6.8	1390
5	4420	920	79.2	6832	3168	53.6	3911	2767	29.3	5.7	1400
6	4360	1660	61.9	6984	4008	42.6	3954	2775	29.8	5.2	1440

Table A-1: Performance of Clarification System

Date	Suspended Solids Inf. mg/l	Suspended Solids Eff. mg/l	Suspended Solids Red. %	Total Alkalinity Inf. mg/l	Total Alkalinity Eff. mg/l	Total Alkalinity Red. %	COD Inf. mg/l	COD Eff. mg/l	COD Red. %	A-109 Dose mg/l	Overflow Rate gpd/ft^2
2/7/68	4060	840	79.3	6304	4136	34.4	3802	2283	39.9	3.7	1410
8	5360	720	86.6	7480	2800	62.6	4512	2427	46.3	3.7	1410
9	4760	800	83.2	7280	3088	57.6	3910	2336	40.2	10.3	1540
15	5780	480	91.7	7944	2656	66.6	5041	2327	53.7	10.1	1500
16	4500	800	82.2	7264	2872	60.3	4214	2304	45.2	9.6	1390
19	4680	680	85.5	5944	2560	57.0	3999	2297	42.6	7.9	1520
20	3920	360	90.8	4952	2880	41.7	3917	2398	38.7	9.7	1520
21	3120	600	80.8	4576	2880	37.2	3929	2340	40.3	9.3	1540
22	4640	880	81.1	6544	3168	51.5	3081	2692	12.6	8.0	1540
23	3880	580	85.0	5376	2704	49.8	5400	2347	56.5	8.0	1550
26	6040	2120	65.0	7264	4320	40.6	7040	3688	47.6	7.4	1550
27	3700	680	81.6	-	-	-	-	-	-	7.9	1550
28	3340	360	89.2	5208	2624	49.6	4465	2575	42.3	8.1	1550
29	3160	400	87.3	-	-	-	-	-	-	8.0	1520
3/1/68	4220	3240	23.2	5740	5548	3.4	5896	3775	36.0	8.2	1500
4	3460	700	79.8	4707	3040	35.3	4183	2887	31.0	8.4	1580
11	3800	920	75.8	4416	3200	27.5	3764	2801	25.6	6.1	1640
12	3660	660	82.0	-	-	-	-	-	-	8.8	1620
13	3360	560	83.3	4624	2608	43.4	4559	2872	36.9	8.8	1590
14	3680	680	81.5	-	-	-	-	-	-	8.8	1590
15	3998	560	86.2	5248	2704	48.6	4713	2386	49.3	9.4	1590
18	3220	560	82.6	4192	2520	40.0	4209	2414	42.6	9.3	1590
19	5680	1040	81.7	-	-	-	-	-	-	10.3	1590
20	5060	700	87.2	6216	2424	61.0	-	-	-	9.0	1600
21	3900	580	85.1	-	-	-	-	-	-	7.8	1600
22	4980	500	90.0	5024	2672	46.8	-	-	-	7.9	1600
4/1/68	2680	220	91.8	4624	2952	36.2	-	-	-	8.8	1520
2	3980	440	88.9	-	-	-	-	-	-	8.3	1590
3	5960	420	92.8	7616	3080	59.4	-	-	-	9.6	1610

Table A-2: Performance of Clarification System

Date	Inf.		Eff.		Removal - %			A-10 Dose	Overflow Rate
	TSS	FSS	TSS	FSS	TSS	FSS	VSS	mg/l	gpd/ft^2
6/11/68	7620	6840	180	100	97.6	98.5	89.7	8.6	1600
12	7400	6100	580	320	92.2	94.6	80.0	10.2	1600
13	4620	2640	420	80	90.9	96.8	82.8	10.6	1600
14	4760	2540	540	280	88.7	89.0	88.4	9.8	1600
17	3660	1620	560	180	84.7	89.0	81.4	9.4	1600
18	7100	6180	720	400	89.9	93.6	65.3	9.1	1600
19	3400	3200	380	180	88.8	95.0	0.0	10.2	1600
20	5600	3280	540	180	90.4	94.5	85.5	10.8	1600
21	3700	2640	380	220	89.7	91.7	85.0	10.3	1600
24	1760	860	320	80	81.8	90.8	73.3	10.0	1600
25	5120	4100	520	200	89.8	95.2	68.0	10.6	1600
26	4720	3800	680	260	85.6	93.2	54.4	10.2	1600
7/15/68	3220	1640	340	80	89.4	95.2	83.5	8.8	1600
16	6940	6160	560	320	91.9	94.7	69.3	9.7	1600
17	7200	6020	380	220	96.4	96.4	86.5	9.9	1600
18	4760	2300	500	100	89.5	95.6	83.7	9.5	1600
19	4240	2980	320	160	97.2	94.6	87.3	8.7	1600
22	4720	4020	600	320	87.3	92.8	60.0	10.2	1600
23	5110	3240	360	180	92.9	94.4	90.5	9.5	1600
24	4200	1800	320	140	92.4	92.3	92.3	9.8	1600
25	2760	920	700	200	74.6	78.2	72.8	4-10	2000-3000
26	5980	4500	920	500	84.6	88.9	71.6	4-10	2000-3000
29	5800	3140	1080	560	81.4	82.1	80.4	4-10	2000-3000
30	6220	5580	720	500	88.4	91.1	65.6	4-10	2000-3000
31	5600	3480	520	200	90.7	94.3	84.7	4-10	2000-3000

Table A-2: Performance of Clarification System

Date	Influent		Effluent		Removal - %			A-10 Dose mg/l	Overflow Rate gpd/ft^2
	TSS	FSS	TSS	FSS	TSS	FSS	VSS		
8/1/68	5540	4600	480	420	91.4	90.7	93.7	4-10	2000-3000
2	3720	2060	380	140	89.8	93.2	85.5	4-10	2000-3000
5	6400	5200	1880	760	70.6	85.2	6.7	4-10	2000-3000
6	5160	4340	340	160	93.4	96.4	78.0	4-10	2000-3000
7	6260	5760	880	140	85.9	97.6	-	4-10	2000-3000
8	11580	11120	460	180	96.0	98.3	39.1	4-10	2000-3000
9	3960	2400	340	140	91.4	94.2	91.0	4-10	2000-3000
12	7100	3700	340	40	95.2	99.0	91.1	4-10	2000-3000
13	4300	2620	2480	1160	42.3	58.0	21.4	4-10	2000-3000
14	4580	3560	120	-	97.4	-	-	4-10	2000-3000
15	6600	4380	200	40	97.0	99.1	92.8	4-10	2000-3000
16	5680	2760	280	80	95.1	-	-	4-10	2000-3000
19	5100	4180	740	360	85.5	78.0	-	4-10	2000-3000
20	2980	-	3780	-	-	-	-	0	2000-3000
21	2580	980	2720	1100	-	-	-	0	2000-3000
22	3420	1920	1300	940	32.7	21.9	61.8	0	2000-3000
23	2320	1640	540	160	76.7	58.5	-	8.0	2000-3000
26	2880	1740	1820	640	36.8	34.5	-	0	2000-3000
27	2880	1740	1660	1000	42.3	34.5	34.0	8.2	3460
28	2320	1000	920	380	60.3	-	-	8.0	3460
9/3/68	3380	2160	880	400	74.0	81.5	60.6	7.4	3460
4	2060	940	860	400	58.3	57.5	58.8	6.8	3460
9	2380	800	3840	2480	-	-	45.1	0	-
10	3540	2160	8740	2200	-	36.5	-	0	-
11	5220	2640	1860	1140	64.4	56.7	72.2	4-10	-

Table A-2: Performance of Clarification System

Date	Influent		Effluent		Removal - %			A-10 Dose mg/l	Overflow Rate gpd/ft^2
	TSS	FSS	TSS	FSS	TSS	FSS	VSS		
9/12/68	2280	1380	1800	1020	21.1	34.8	23.5	4-10	-
17	5900	2860	920	240	84.4	91.6	77.5	4-10	2000
18	2320	1820	500	220	78.5	87.8	44.0	4-10	2200
19	4180	2880	480	240	88.5	91.7	81.6	12.0	2520
20	2300	1080	1200	380	47.8	64.8	32.8	-	2520
23	2900	1840	560	380	80.7	79.3	83.0	-	2520
24	6460	4920	1760	1420	72.8	71.0	78.0	-	2520
25	2720	-	1000	-	63.2	-	-	5.0	2670
26	2980	1580	900	520	69.8	67.0	72.8	7.0	2740
27	6660	6140	1240	640	81.4	91.2	-	8.2	2420
10/1/68	4760	2980	1180	600	75.2	80.0	67.5	7.4	2700
3	6480	4380	940	320	85.5	95.0	70.4	7.5	2460
4	10180	9220	1480	880	85.5	90.5	37.6	6.9	2420
8	3740	2580	1160	400	69.0	84.4	34.5	6.2	2450
10	3500	3220	660	240	81.1	92.5	-	6.2	2460
11	3740	1760	820	340	78.0	80.6	75.8	5.6	2660
11/11/68	6760	5080	1400	680	79.3	86.7	57.2	5.9	2720
12	7220	5340	1460	520	79.8	90.2	50.0	4.7	2660
13	5300	2700	1460	580	72.5	78.5	69.6	6.1	2610
14	4660	3860	1200	760	74.2	80.4	45.0	6.5	2480
15	4320	2060	1780	700	58.8	66.0	52.2	7.0	2000
18	3840	2360	680	320	82.3	86.5	75.6	8.7	2020
19	5960	5300	1400	900	76.5	79.2	24.2	4.9	1940
20	5520	4740	780	560	85.9	88.4	71.8	6.7	2340

Table A-2: Performance of Clarification System

Date	Influent TSS	Influent FSS	Effluent TSS	Effluent FSS	Removal - % TSS	Removal - % FSS	Removal - % VSS	A-10 Dose mg/l	Overflow Rate gpd/ft^2
11/21/68	6900	6100	1080	640	84.4	89.6	45.0	4.4	2260
22	6640	4520	1400	600	78.9	86.7	62.4	6.3	2290
26	4680	2440	1020	360	78.2	85.2	70.5	6.9	2290
27	4640	3700	1640	820	64.7	77.8	12.8	5.6	2340
29	4160	2920	1640	780	60.6	73.4	30.6	3.7	2450
12/2/68	4240	2040	1240	500	70.8	75.4	66.4	5.8	2470
3	3520	2240	1420	600	59.7	73.2	36.0	5.6	2530
4	4980	2720	2440	840	51.0	67.6	29.2	5.8	2460
5	3780	2680	600	320	89.4	88.0	74.5	6.7	2290
6	4240	2580	1240	420	70.6	83.6	50.6	8.5	1930
12/9/68	3420	2480	600	280	-82.5	88.6	66.0	9.5	1840
10	6160	4840	2740	1660	55.5	65.7	16.7	6.1	2740
11	3200	2200	1340	740	58.1	66.4	40.0	6.6	2600
12	4400	3060	2720	1340	38.1	56.2	-	5.9	2720
13	3780	1680	1320	560	65.1	66.6	63.8	4.3	2680
17	4720	3400	1260	580	73.3	82.9	49.0	4.8	2720
18	4240	3300	1860	1080	56.1	66.7	17.0	6.2	2620
19	5120	3480	1120	680	78.1	80.6	73.2	6.5	2260
20	4440	2840	1200	540	73.0	81.0	58.7	4.8	2460
12/23/68	6220	4160	1860	800	70.1	80.6	48.5	4.5	2500
24	3660	2080	560	220	84.7	89.5	78.3	14.9	2630
26	3280	2040	1280	420	70.0	79.5	30.6	8.8	2580
27	5760	4360	1240	840	78.5	80.7	71.4	9.8	2580
30	6120	3760	1240	400	79.7	89.3	64.5	9.6	2660

Table A-2: Performance of Clarification System

Date	Influent TSS	Influent FSS	Effluent TSS	Effluent FSS	Removal - % TSS	Removal - % FSS	Removal - % VSS	A-10 Dose mg/l	Overflow Rate gpd/ft²
12/31/68	3660	1000	880	280	76.0	72.0	77.5	10.9	2610
1/2/69	4400	3620	1140	400	74.1	89.0	5.1	11.1	2580
3	6220	3500	620	200	90.0	94.3	84.4	8.5	2640
6	5000	4540	1080	380	78.4	91.7	-	8.9	2500
7	5680	4560	920	420	83.8	90.6	55.4	9.2	2530
8	4640	3380	920	240	80.2	92.8	46.0	8.1	2640
9	6280	5400	1320	540	79.0	90.0	11.4	5.2	2460
10	3500	2380	940	580	73.1	75.7	67.8	7.3	2540
13	3260	1720	1220	460	62.6	73.3	50.7	6.1	2600
14	3960	2480	1380	520	65.2	79.0	41.8	8.5	2480
15	4640	3860	740	340	84.1	91.6	48.7	5.8	2470
16	4340	3160	1080	340	75.1	89.1	37.3	7.0	2460
17	3140	1440	1260	440	59.9	69.5	51.8	9.3	2420
20	6020	4660	620	220	89.7	95.1	71.8	9.4	2480
21	4960	3920	780	380	87.5	90.4	61.6	7.1	2420
22	4260	3020	820	380	80.8	86.8	64.5	6.3	2690
23	5680	4360	760	260	86.6	93.8	62.2	8.2	2570
24	7500	4240	600	160	92.0	96.2	65.1	8.6	2560
27	9780	8780	600	220	93.9	97.7	62.0	10.6	2420
28	6140	5320	1180	500	80.8	90.6	17.1	11.0	2420
29	4960	3760	1840	780	62.9	79.2	11.7	10.1	2420
30	4800	3560	780	240	83.8	93.2	56.5	10.1	2440

Table A-2: Performance of Clarification System

Date	Influent		Effluent		Removal - %			A-10 Dose mg/l	Overflow Rate gpd/ft^2
	TSS	FSS	TSS	FSS	TSS	FSS	VSS		
2/1/69	5220	2820	440	200	91.6	93.0	90.0	9.0	2450
3	7220	5780	980	340	86.4	94.0	55.6	8.7	2500
4	3760	2600	1340	740	64.4	69.2	48.3	8.3	2460
5	7200	5820	1160	540	83.9	90.7	55.0	7.7	2450
6	4760	1920	1540	460	67.7	76.0	62.0	8.3	2450
7	4300	2640	620	240	85.6	90.8	77.0	8.4	2410
2/10/69	4220	3300	1000	600	76.3	81.7	56.5	8.1	2440
11	4800	4340	1040	480	78.3	89.1	-	8.5	2420
12	3480	2000	1200	200	65.5	90.0	32.4	8.3	2440
13	4020	2840	1160	580	71.1	79.5	42.3	8.5	2420
14	3820	2040	440	200	88.5	90.2	86.6	9.2	2420
17	6980	5760	500	180	92.8	96.7	73.7	9.5	2460
18	2720	1380	980	380	64.0	72.4	55.2	9.2	2420
19	5580	4200	740	400	86.7	90.5	75.3	8.2	2460
20	4620	3600	800	480	82.7	86.7	68.6	10.5	2380
21	7680	6080	1260	540	83.5	91.1	55.0	10.7	2450
24	3480	1640	780	240	77.6	85.3	70.7	9.5	2390
25	5420	4740	580	240	89.3	95.0	50.0	10.0	2430
26	4180	3300	340	140	91.9	95.7	77.3	9.8	2430
27	6400	5600	880	440	83.3	92.3	40.0	9.3	2520
28	3900	2680	680	400	82.6	88.3	81.6	8.6	2500

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: Beamhouse Wastes Only: Det. Time - 10 days										
10/1/68	-	-	-	-	2147	866	-	-	-	-
2	12.0	8.0	582	568	2150	1079	-	-	-	-
4	11.8	8.2	650	468	-	-	-	-	-	-
7	11.8	8.2	-	-	-	-	-	-	-	-
8	-	-	-	-	2316	687	-	-	-	-
9	11.9	8.2	1510	696	-	-	-	-	-	-
10	-	-	-	-	2627	494	-	-	-	-
11	12.0	8.2	-	-	-	-	-	-	-	-
Feed: 3 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: Det. Time - 10 days										
10/14/68	8.9	8.1	-	-	-	-	-	-	-	-
15	-	-	310	385	3778	385	-	-	-	-
17	8.8	8.2	-	-	5543	643	-	-	-	-
21	8.9	8.1	360	524	2183	705	120	20	920	140
22	8.7	8.2	502	520	2597	721	140	40	1140	100
23	9.4	8.2	764	516	-	-	260	20	1320	100
24	-	-	-	-	5650	874	-	-	-	-
25	9.3	8.1	-	-	-	-	380	20	2280	0
28	8.9	8.2	392	528	-	-	80	20	140	40
29	-	-	-	-	2456	1084	-	-	-	-
30	10.4	8.2	1540	520	-	-	700	60	1860	160
31	-	-	-	-	5499	859	-	-	-	-

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 3 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: Det. Time - 10 days										
11/1/68	10.8	8.2	-	-	-	-	560	20	680	20
4	9.2	8.0	544	604	4896	1267	260	20	920	40
5	9.6	8.2	-	-	5973	1058	220	20	1300	40
6	9.9	8.2	1044	476	6115	733	400	20	2000	60
7	10.0	8.2	-	-	6025	874	420	20	1440	20
8	10.3	8.1	1264	496	5039	923	520	20	1340	140
11	11.8	8.1	2844	524	7494	886	880	60	2400	80
12	10.0	8.2	-	-	4932	822	360	60	1580	140
13	9.8	8.1	816	464	3913	880	240	40	1400	180
14	9.4	8.2	-	-	6460	866	200	40	1360	320
15	11.8	8.2	1084	484	2789	1050	200	160	540	100
18	6.8	8.2	80	496	-	1064	20	140	260	480
19	9.7	8.3	-	-	4924	796	200	0	1120	40
20	9.9	8.3	952	404	5768	804	400	60	1420	260
21	9.7	8.3	-	-	6444	806	340	40	1500	40
22	9.9	8.3	1104	416	6360	932	380	60	1380	40
26	9.8	8.3	-	-	5073	914	220	40	1620	220
27	10.1	8.2	1064	456	5691	873	140	60	2320	220
29	9.9	8.0	1124	404	5334	1034	-	-	-	-

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 3 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: 1 L Sewage: Det. Time - 15 days										
12/2/68	11.4	8.2	1056	560	2703	1042	160	60	680	200
3	9.4	8.2	-	-	6089	1059	240	40	1940	240
4	9.6	8.2	800	476	5926	1148	320	80	1460	280
5	9.4	8.1	-	-	5230	1053	280	40	1420	180
6	9.9	8.1	972	482	4788	1142	360	120	1400	200
7	10.0	8.2	-	-	6414	1153	440	0	1940	180
8	9.9	8.2	-	-	6255	1146	580	40	2140	320
9	9.6	8.3	884	520	7048	1182	360	20	2300	380
10	10.8	8.3	-	-	4670	1203	380	80	1140	420
11	11.1	8.2	1200	412	4249	1283	280	20	1300	340
12	10.2	8.2	-	-	3722	1305	400	320	1020	200
13	9.8	8.2	-	-	5946	1184	540	240	2080	200
14	9.4	8.2	-	-	6918	1088	560	40	2300	320
15	9.1	8.2	-	-	16,344	1103	880	40	5480	260
16	9.2	8.2	-	-	4770	1306	360	40	1260	320
17	9.4	8.1	-	-	6701	1614	380	160	2220	460
18	9.3	8.1	-	-	7196	1551	420	60	2020	500
19	10.1	8.1	-	-	7706	1788	700	140	2880	600
20	11.2	8.2	1444	620	6922	1763	660	120	2420	500
21	9.8	8.1	1020	636	6114	1813	520	160	2360	740
22	10.2	10.2	1040	608	6092	1656	840	840	1580	1580

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 3 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: 1 L Sewage: Det. Time - 15 days										
12/23/68	10.1	8.2	856	612	5312	1711	420	220	1560	480
24	10.4	10.4	-	-	7898	1662	600	80	2100	160
25	9.8	8.1	796	712	5051	1969	320	200	1460	360
26	9.5	8.2	-	-	5600	1859	360	160	1780	500
27	10.4	8.2	1764	592	7286	1315	380	240	2140	480
Anaerobic Zone Thoroughly Mixed on 12/27/68										
28	10.0	8.1	1240	1316	6795	3248	540	700	2440	1560
29	11.7	8.1	1316	2152	5496	5259	520	1780	2140	2980
30	8.3	8.2	780	1280	8824	3318	2560	800	4320	1860
31	8.9	8.2	-	-	5333	5584	220	1660	2000	3740
Feed: Beamhouse Wastes - Det. Time 10 Days										
1/2/69	11.4	8.1	-	-	4345	5282	400	780	1040	2660
3	11.8	8.1	1200	976	7093	4130	400	540	1280	1920
6	11.6	8.1	1228	952	4097	4306	380	580	1200	2140
7	8.6	8.2	-	-	5992	3152	560	280	1340	1020
8	10.3	8.1	952	576	4031	2322	360	260	1160	760
9	8.2	8.1	-	-	7539	1800	340	200	2260	620
10	8.3	8.1	564	520	4523	1800	240	160	1320	560

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: Beamhouse Wastes - Det. Time 10 Days										
1/11/69	10.0	8.0	1500	516	7907	1751	560	140	2060	620
12	10.5	8.0	2728	576	12279	2165	1000	80	4240	740
13	10.7	8.0	940	696	3361	1977	280	140	1280	740
14	10.5	8.0	-	-	3678	2041	240	180	1320	620
15	9.8	8.0	1488	740	7830	2258	700	140	2780	840
16	10.1	8.0	-	-	6704	2358	600	260	2180	800
17	10.3	8.0	1440	764	6674	2388	600	280	2220	820
18	9.6	8.0	1416	732	8962	2091	420	200	2900	900
19	9.2	8.1	596	744	5494	2375	260	240	1640	1080
20	9.8	8.1	764	756	5055	2153	240	180	1500	900
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors 0.9 L Sewage: Det. Time - 20 Days										
21	9.9	8.0	964	740	5460	2307	340	240	2940	900
22	9.6	8.0	1204	712	7051	2235	600	240	2400	880
23	9.8	8.0	1368	692	7815	2222	680	260	2460	800
24	-	8.0	1568	696	9260	2252	680	240	3260	820
25	9.9	8.0	1104	720	7509	2174	520	220	2540	860
26	10.0	8.0	1240	664	6560	1778	440	140	2120	500
27	10.5	8.0	1248	620	6363	1818	420	140	2020	580
28	9.7	8.0	976	608	6314	1898	480	180	2060	460
29	9.7	8.0	1316	636	8824	1843	560	200	2440	640

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors 0.9 L Sewage: Det. Time - 20 Days										
1/30/69	9.5	8.0	816	684	4693	2406	340	260	1620	960
31	9.1	8.0	1080	1096	8992	2311	400	120	2260	860
2/1/69	8.9	8.0	900	704	10679	2532	320	120	3040	880
2	8.4	8.0	856	756	19960	2804	680	160	10720	1380
3	10.2	8.0	964	700	6951	2827	300	220	1900	1160
4	9.2	8.0	900	700	6948	3334	400	200	2600	1540
5	9.3	8.0	936	680	8315	3176	580	360	2840	1360
6	10.1	8.0	1192	696	6881	2859	600	340	2220	1220
7	7.9	8.1	532	700	8192	3117	240	120	1580	1260
8	8.7	8.0	420	684	4157	2557	320	120	1440	1120
9	9.7	8.1	632	668	4353	2635	360	220	1300	1100
10	10.2	8.1	664	600	3020	2247	260	140	1200	460
11	10.1	8.1	972	632	4733	2090	360	200	1680	560
12	9.6	8.1	668	568	7139	1908	480	160	4580	620
13	9.4	8.1	980	572	8006	1785	340	140	2660	480
14	9.5	8.1	960	556	7089	1656	400	80	2160	440
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors Det. Time - 20 Days										
2/15/69	9.2	8.0	928	564	8276	1497	280	100	2540	400
16	8.6	8.0	784	572	15840	1394	620	160	5980	240

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors Det. Time - 20 Days										
2/17/69	10.1	8.0	888	596	6772	1798	380	200	1500	440
18	9.1	8.0	744	680	7438	2833	400	260	2600	1120
19	9.1	8.1	940	736	8821	2758	240	400	2620	1040
20	9.8	8.1	668	664	9660	2344	360	280	1500	780
21	8.5	8.1	460	640	7883	-	240	220	1560	740
22	7.9	8.1	502	664	6141	2314	220	200	1440	780
23	7.7	8.1	504	648	6257	2065	200	200	1560	640
24	9.6	8.1	828	682	5854	2284	380	280	2020	1000
25	8.0	8.1	696	636	10752	2430	320	180	2480	920
26	9.0	8.1	804	668	6112	2679	220	260	1140	940
27	9.0	8.1	840	660	10280	2671	360	220	2080	900
28	9.0	8.1	804	644	8630	2664	440	240	2280	1040
3/1/69	8.8	8.1	876	716	9798	2749	320	300	2280	1060
2	8.9	8.1	796	740	7385	2881	380	240	2100	1260
3	9.5	8.1	868	740	10566	2969	380	220	3640	1200
4	4.2	8.1	-	680	6730	2753	120	160	1320	860
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors 0.9 L Sewage: Det. Time - 20 Days										
3/5/69	9.5	8.1	700	700	5392	3021	340	240	2100	1120
6	9.4	8.1	760	620	6904	2777	380	180	1900	960

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors [illegible].9 L Sewage: Det. Time - 20 Days										
3/7/69	6.6	8.1	280	720	5923	2981	120	220	1200	1220
8	8.8	8.2	644	600	5770	2960	200	160	1580	1280
9	5.4	8.3	96	580	6344	2408	380	140	2000	760
10	9.8	8.3	828	600	4946	2408	80	160	1420	1040
11	9.3	8.2	1228	588	10269	2480	640	160	3540	1080
12	9.4	8.2	788	564	6820	2573	460	160	1440	1000
13	9.9	8.2	1024	560	5770	2339	560	160	1840	820
14	7.2	8.2	508	612	5308	2623	200	160	800	1100
15	6.5	8.2	480	644	6980	2452	80	240	1240	1260
16	7.1	8.2	500	564	6753	2083	100	140	2200	640
17	8.3	8.2	428	636	4263	2496	220	260	1100	1160
18	7.1	8.2	604	600	7634	2635	60	180	1140	960
19	6.9	8.2	584	588	4942	2452	40	200	560	800
20	7.9	8.2	340	560	6263	2452	60	100	960	820
21	6.2	8.2	220	540	5352	2342	60	100	820	700
22	6.5	8.2	236	760	12866	2364	420	480	5640	2680
23	6.3	8.2	364	540	6355	2403	80	80	1640	580
24	5.8	8.1	164	520	8870	2004	240	120	3280	1000
25	9.8	8.0	836	484	6415	2051	360	140	1680	500
26	8.3	8.0	600	536	7765	2565	320	260	1880	2040
27	8.1	8.1	884	472	17608	2298	880	180	7120	460
28	6.8	8.0	540	516	7040	2137	140	60	1240	780

Table A-3 Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors 0.9 L Sewage: Det. Time - 20 Days										
4/1/69	5.7	8.0	216	524	7192	2678	120	200	1280	1160
2	7.4	8.1	360	516	5394	2566	120	100	1200	740
3	9.4	8.1	800	464	7038	2408	400	180	1920	860
4	7.5	8.1	480	496	16186	2390	560	120	6820	760
5	11.1	8.0	1036	600	5410	2761	140	360	1680	1960
7	5.6	8.0	164	656	3769	2798	280	200	1240	720
8	3.5	8.0	0	516	7114	2812	120	200	1520	1350
9	9.6	8.0	1020	492	10578	2794	440	140	4380	740
10	8.7	7.9	660	472	8880	3027	480	240	1520	1540
11	9.5	7.9	1120	524	6972	2734	560	200	2000	760
12	9.3	8.0	1372	572	11048	3175	560	240	3200	1560
13	5.8	8.0	148	664	8332	3377	320	260	1320	1980
14	9.6	8.0	1216	644	14498	3267	960	220	5060	920
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors Det. Time - 20 Days										
15	8.4	8.1	524	620	7410	3176	240	260	2300	500
16	9.8	8.1	964	628	7788	2911	440	180	2340	840
17	9.9	8.1	1136	624	7488	2624	440	180	2060	780
18	9.8	8.1	1000	616	8699	2881	-	-	-	-
19	10.0	8.1	1260	684	8528	3570	100	320	1120	2020

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids Fixed		Suspended Solids Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors Det. Time - 20 Days										
4/20/69	9.8	8.1	1084	960	7104	3370	540	340	2620	1500
21	5.5	8.1	204	828	7797	3042	480	220	2520	840
22	7.9	8.1	576	676	18757	2724	640	120	6940	720
23	10.4	8.1	1364	768	8586	2896	780	320	2560	1140
24	7.7	8.1	524	724	8306	3780	380	200	2220	1180
25	10.1	8.1	1256	764	8137	4136	480	280	2300	1520
26	9.1	7.8	1200	940	8535	4412	560	480	2640	2680
27	4.8	7.9	104	744	18967	3896	400	240	7560	1640
28	8.5	8.0	376	744	2824	3979	140	420	300	1740
29	9.0	7.8	804	744	7545	4185	540	440	1820	1800
30	9.1	7.8	1000	644	9481	3327	440	180	2360	1080
5/1/69	9.0	7.7	1284	752	11560	5073	720	240	3760	2240
2	10.6	7.8	1128	720	4408	3061	540	200	1500	1040
3	10.1	7.8	1140	920	5271	4607	720	580	1780	2180
4	9.7	7.8	1368	860	8289	2917	1000	480	3620	1780
5	8.3	7.9	748	696	13207	2979	640	240	4380	1320
6	7.8	7.9	652	972	7750	3812	220	520	1560	2480
7	6.3	7.8	476	684	8095	2869	160	220	1040	1100
8	6.8	7.8	784	652	11631	3340	180	240	1660	980
9	9.3	7.8	820	648	5870	3405	300	200	1700	1140
10	8.0	7.8	682	976	7938	4903	400	500	2260	2220

Table A-3: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	pH		Total Alkalinity		COD		Suspended Solids			
							Fixed		Volatile	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors Det. Time - 20 Days										
5/11/69	8.1	7.8	480	964	6459	4222	360	240	2020	2110
12	9.3	7.9	752	736	8778	3327	540	360	2080	1220
13	7.7	7.8	556	664	9018	2906	320	120	2260	1500
14	6.2	7.8	320	620	7766	2636	180	40	1280	400
15	6.8	7.9	376	624	8813	2938	160	140	1240	980
16	7.0	7.9	404	636	6288	3064	160	120	1420	920
17	7.2	7.8	684	664	8660	3242	280	200	2240	1200

Table A-4: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	TKN		Ammonia Nitrogen		Organic Nitrogen		Total Sulfides	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
Feed: 3 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: Det. Time - 10 days								
10/22/68	273	160	179	127	94	34	15	9
24	222	163	121	126	102	38	13	6
29	207	159	111	121	96	38	18	15
31	321	114	187	106	134	-	-	-
11/5/68	216	132	105	99	111	33	-	-
7	221	128	104	101	117	27	16	13
12	217	128	107	95	110	33	14	13
14	202	128	94	94	108	34	12	15
19	211	122	95	88	116	34	12	11
21	221	112	101	83	121	29	16	13
26	188	116	70	78	118	39	16	10
Feed: 3 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: 1 L Sewage: Det. Time - 15 Days								
12/3/68	237	112	114	76	124	37	16	13
5	204	114	98	73	106	41	17	12
10	237	118	116	73	122	45	17	12
12	245	115	109	73	137	43	16	10
17	220	126	103	74	118	53	13	11
19	255	140	126	81	129	59	17	11
26	267	138	139	80	129	59	9	10
31	200	266	83	85	117	182	14	12
Feed: Beamhouse Wastes Only Det. Time - 10 Days								
1/2/69	190	229	67	75	123	154	14	10
7	195	146	90	75	105	70	13	7
9	251	141	119	75	132	66	10	6
14	241	155	124	83	117	73	8	6
16	253	167	125	85	128	82	10	7

Table A-4: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	TKN Inf.	TKN Eff.	Ammonia Nitrogen Inf.	Ammonia Nitrogen Eff.	Organic Nitrogen Inf.	Organic Nitrogen Eff.	Total Sulfides Inf.	Total Sulfides Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: 0.9 L Sewage: Det. Time - 20 Days								
1/21/69	220	161	108	84	112	77	11	8
23	256	153	135	82	121	71	16	11
1/28/69	233	141	123	81	110	60	9	10
30	218	155	117	80	101	75	-	-
2/4/69	231	166	102	75	129	91	-	-
6	259	160	128	78	131	82	-	-
11	183	136	84	81	99	55	-	-
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: Det. Time - 20 Days								
2/13/69	207	126	113	78	95	47	-	-
18	233	144	110	70	123	73	-	-
20	223	136	102	71	122	64	-	-
25	180	149	84	71	96	69	12	12
27	234	133	125	69	108	64	10	8
3/4/69	196	142	87	69	109	73	10	11
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: 0.9 L Sewage: Det. Time - 20 Days								
3/6/69	232	135	116	65	116	70	9	6
9	208	120	101	68	108	52	8	6
10	225	129	113	60	113	69	-	-
11	241	136	113	64	129	71	-	-
12	236	126	107	60	130	66	12	7
13	217	137	104	69	113	69	-	-
14	150	130	41	67	109	63	9	6
15	165	147	51	67	110	80	-	-
16	180	105	63	58	117	47	-	-
17	197	137	96	59	101	78	7	7
18	137	133	63	58	73	75	-	-
19	154	125	56	57	98	68	10	6
20	150	125	36	55	113	70	-	-
21	147	110	38	52	109	58	15	8

Table A-4: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	TKN Inf.	TKN Eff.	Ammonia Nitrogen Inf.	Ammonia Nitrogen Eff.	Organic Nitrogen Inf.	Organic Nitrogen Eff.	Total Sulfides Inf.	Total Sulfides Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: 0.9 L Sewage: Det. Time - 20 Days								
3/22/69	177	111	38	50	139	60	-	-
23	101	132	52	49	49	63	-	-
24	142	115	27	49	115	66	10	6
25	238	87	97	43	142	43	-	-
26	258	118	130	43	127	76	9	7
27	252	101	129	43	123	58	-	-
28	257	106	134	46	122	60	9	6
29	145	138	48	48	97	90	-	-
30	195	123	96	49	99	74	-	-
31	223	138	89	48	134	90	10	6
4/1/69	194	105	109	47	85	58	-	-
2	105	118	49	49	56	69	12	10
3	225	118	99	50	126	68	-	-
4	245	115	117	52	128	63	12	12
5	242	155	114	54	128	101	-	-
7	252	117	114	53	138	64	9	8
8	151	123	31	55	120	68	-	-
9	281	121	138	53	143	68	11	8
10	320	125	141	53	179	72	-	-
11	274	123	140	53	134	70	8	8
12	308	123	171	55	137	68	-	-
13	245	125	109	55	136	70	-	-
14	309	124	147	55	162	69	13	8
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: Det. Time - 20 Days								
15	254	128	118	56	136	72	-	-
16	252	130	131	57	121	73	12	10
17	331	133	170	58	161	75	-	-
18	288	141	150	60	138	81	14	12
19	261	145	137	62	124	83	-	-
20	269	135	139	63	130	72	-	-
21	283	137	144	64	139	73	8	10

Table A-4: Performance Characteristics of Anaerobic-Aerobic Pilot Unit

Date	TKN Inf.	TKN Eff.	Ammonia Nitrogen Inf.	Ammonia Nitrogen Eff.	Organic Nitrogen Inf.	Organic Nitrogen Eff.	Total Sulfides Inf.	Total Sulfides Eff.
Feed: 2 Parts Beamhouse Waste: 1 Part Spent Tan Liquors: Det. Time - 20 Days								
4/22/69	271	137	139	64	132	73	-	-
23	262	144	122	64	140	80	15	10
24	238	152	104	62	134	90	-	-
25	267	155	138	61	129	94	12	9
26	307	150	165	62	142	88	-	-
27	84	136	47	65	37	71	-	-
28	65	201	27	95	38	106	10	11
29	243	168	132	62	111	106	-	-
30	269	147	144	61	125	86	10	7
5/1/69	312	181	139	57	173	124	-	-
2	195	178	86	60	109	118	13	7
3	178	172	71	59	107	113	-	-
4	240	163	84	59	156	104	-	-
5	196	146	59	59	137	87	12	10
6	203	150	81	59	122	91	-	-
7	196	138	79	57	117	81	12	11
8	245	136	134	53	111	83	-	-
9	220	125	111	49	109	76	12	11
10	229	116	115	48	114	68	-	-
11	170	116	62	48	108	68	-	-
12	214	131	93	48	121	83	14	6
13	217	122	102	53	115	69	-	-
14	209	114	106	54	103	60	7	9
15	224	160	118	58	106	72	-	-
16	247	132	133	57	114	75	8	7
17	255	142	145	61	110	81	-	-

1 Accession Number	2 Subject Field & Group	
	05D	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 Organization

University of Cincinnati
Cincinnati, Ohio

6 Title

Treatment of Sole Leather Vegetable Tannery Wastes

10 Author(s)

Dr. J. David Eye

16 Project Designation

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23 Descriptors (Starred First)

Tannery
Pilot Plants
Prototype Plants
Waste Treatment
Industrial Wastes
Clarification
Anaerobic-Aerobic Lagoons

25 Identifiers (Starred First)

27 Abstract Four major studies, two pilot scale and two full scale, were carried out during the period of this investigation. The basic objective of the studies was to find a technically feasible and economical procedure for treating the wastes from a sole leather vegetable tannery. A detailed identification of the sources of all wastes as well as a comprehensive characterization of each waste fraction was made for the International Shoe Company Tannery located at Marlinton, West Virginia. It was found that a large percentage of the pollutants initially were contained in a relatively small fraction of the total waste volume. The treatment scheme consisted of separation and pretreatment of the individual waste streams followed by mixing all waste streams for additional treatment in an anaerobic-aerobic lagoon system. The lime bearing wastes from the beamhouse were screened, treated with polyelectrolytes, and then clarified. The lime sludge was used for landfill. The system was designed to treat one million gallons of waste per week. BOD was reduced 85-95 percent and the suspended solids reduction was in excess of 95 percent. Installed cost of the total system was approximately $40,000 and it is estimated that the operating cost will be about $15,000 per year or 7 cents per hide processed.

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