EPA-600/2-75-039
September 1975

Environmental Protection Technology Series

IMPROVED LIQUID-SOLIDS SEPARATION BY AN ALUMINUM COMPOUND IN ACTIVATED SLUDGE TREATMENT

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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IMPROVED LIQUID-SOLIDS SEPARATION BY AN ALUMINUM COMPOUND IN ACTIVATED SLUDGE TREATMENT

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Project No. 17030 EBH

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DISCLAIMER

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

This report describes more efficient wastewater treatment obtained by addition of aluminum compounds to the process.

ABSTRACT

This study demonstrates that feeding liquid alkaline alumina, identified as sodium aluminate, to a small to medium (2.5 million gal per day) activated sludge wastewater treatment plant is a practical method of gaining several operational benefits. Specific benefits were found in the areas of solids handling and ease of sludge volume index control. Additional benefit was noted in the concentration of aerobically digested solids, particularly in cold weather. Reduction of suspended solids carryout of secondary clarifiers resulted from the sodium aluminate feed, reducing the loading to the tertiary treatment unit. The increased sludge density from the inorganic chemical introduced into the plant permitted the plant to protect itself against solids washout during spot flows (periods of infiltration/in-flow) at greater than 164% of designed plant capacity. Phosphorus removal in amounts approaching 80% were achieved with feed rates of 10 mg/liter as Al to the aeration basins. The cost of alkaline alumina addition was 2.6¢ per 1000 gallons of raw wastewater flow.

This report was submitted by the Greene County Sanitary Engineering Department, (T. E. Troutman, Sanitary Engineer), 651 Dayton-Xenia Road, Xenia, Ohio, 45383 in fulfillment of Grant Number 17030 EBH under the sponsorship of the U. S. Environmental Protection Agency.

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SECTION I

INTRODUCTION

This study was undertaken to determine the effects of sodium aluminate additions on the activated sludge waste treatment process. It was postulated that considerable benefit could be obtained by adding the chemical to the primary and aeration basins. Improvements were expected in the areas of sludge volume index control, waste sludge handling and concentration through dewatering of the digester solids. The benefits of sodium aluminate usage for phosphate removal are well documented in the literature. This benefit, although important in helping the plant reach discharge requirements, was secondary to the study.

Also of primary interest was the feasibility of chemical dosing in small wastewater treatment plants as a normal part of daily operation.

It also appeared reasonable that improved solids handling could have major impact on hydraulic size requirements, power consumption and tertiary treatment design. A thorough study was needed to measure the long-term impact of sodium aluminate dosing and the treatability with disposal of the resultant solids. It is entirely probable that future wastewater treatment plant design will call for chemical flocculation of organic colloidal solids prior to final treatment. This study should provide background on the use of sodium aluminate for this purpose.

SECTION II

CONCLUSION AND COMMENTS

The conclusions drawn by the authors of this report are based on the analytical and operations data summaries from Greene County - Beavercreek Wastewater Treatment Plant, as well as from opinions of operating personnel resulting from actual plant experiences.

1. Waste water throughout the study was typical of the normal, domestic sewage treated at the plant.

2. No attempt was made to adjust plant flow or treatment conditions other than as necessary to maintain good, efficient wastewater treatment operations.

3. The plant is designed for treatment of 2.5 million gal per day average on an annual basis. During the study, flow rates from a weekly average low of 1.715 million gal per day to a high of 4.098 million gal per day, from 69 to 164% of design, were treated.

4. Various injection points throughout the primary and aeration basins were evaluated. It was found that the most efficient point to treat the mixed liquor stream was at the outlet of the primary.

5. Chemical cost during the project, exclusive of freight charges, was computed to be 2.6¢ per thousand gallons of flow.

6. It was determined that residual benefits accrued for 10 days after aluminate feed was stopped. This time lag was subsequently identified as alumina overlap. Conversely, it took from 3 days to a week after starting the aluminate to see optimum conditions in the secondary clarifier. Plant observations of aeration basins and secondary clarifiers showed the presence of sodium aluminate within 24 hours of startup by improved solids settling.

7. The addition of sodium aluminate permitted maintenance of a sludge blanket in the secondary clarifier, even at flow rates as high as 164% of plant design. A case history documenting flow conditions where a washout of solids in the secondary clarifier was expected but did not occur while on sodium aluminate feed is included.

8. With sodium aluminate in the flow stream, Sludge Volume Index (SVI) was greatly improved. Control of Mixed Liquor Suspended Solids (MLSS) was easier because of improved settling characteristics. Thicker return sludge resulted from the feed of sodium aluminate and this permitted a substantial reduction in waste activated sludge volumes to be handled.

9. Higher levels of MLSS could be retained in the secondary clarifier during aluminate application.

10. Return sludge volume rate was lower because the plant could deliver the same amount of microorganisms with less total flow volume. This resulted in less power needed to pump the sludge plus less liquor volume hydraulically added ahead of the aeration basin.

11. Improved solids removal with sodium aluminate reduced the loading on the microstrainers used for tertiary treatment. This improved the efficiency of the tertiary treatment.

12. Chlorine demand was reduced while on sodium aluminate because of less solids and BOD entering the chlorine contact tank.

13. The man-hours required for operation of the chlorine contact tank were also reduced because less time was required for routine cleaning and maintenance.

14. The addition of sodium aluminate resulted in a greater ability to concentrate solids in the aerobic digesters. Previous to the use of sodium aluminate, it was difficult to supernate the digester, particularly in cold weather.

15. In this plant it became a practice to build the solids in the final clarifiers to a depth of 4 ft before wasting sludge while feeding the sodium aluminate. Using this process of solids concentration, a discharge to the digesters of Waste Activated Sludge (WAS) as high as 1 1/2% by weight dry solids became possible. By pumping thicker sludge to the digesters, the flow volume was reduced, which increased digester capacity.

16. It was found that BOD and Suspended Solids (SS) loadings to the aeration tanks were reduced and increased concentrations of primary tank solids (raw sludge) resulted when alumina (contained in the solids on the microstrainer) was recycled.

17. With greater solids concentration in the digester (due to more concentrated feed and the ability to decant), the resulting effect of less sludge to be disposed of meant less hauling time and lower total hauling cost to the plant.

18. Chemical feed of this type has its place in small to medium-size plant operations. Chemical addition, as a normal part of daily operations, proved to be a relatively simple operator's function. Once the sodium aluminate feed was under way, it was quickly found that, rather than being a time-consuming liability to the daily operation, the sodium aluminate enhanced several areas of the operation.

SECTION III

RECOMMENDATIONS

1. Adequate bulk storage of sodium aluminate or coagulants must be designed into the plant to insure sufficient product availability at all times, plus additional capacity to take advantage of minimum freight charges at maximum bulk shipment pricing. We suggest, for a 2 million gallon per day plant, that storage for a minimum of 5,000 gallons bulk liquid be provided.

2. Best results were obtained by feeding the product neat. No advantage was noted by the addition of dilution water. All lines and valves that are installed should be compatible with the chemicals used. In this plant, best results were obtained with ductile iron valves and polyvinyl chloride valves and lines.

3. Standby or dual pumping capability should be provided.

4. Chemical feed rates should be measurable at any time and the chemical feed rate should be totalized. Sight glasses on the bulk tanks were provided and found to be a reliable gauge of tank inventory.

5. Bulk unloading lines to the tanks should be readily accessible to a delivery truck. This line should be a 2-inch fill line with either a 2-inch quick-release coupling or a threaded 2-inch nipple.

6. Train operators to respond to changes that require adjustments in process control and chemical feed rate. Plant flow rates, color, odor, turbidity, settling characteristics, quality of digester supernatant, and clarity of secondary and clarifier effluent should be observed and adjusted as required. Waste water temperature, pH, dissolved oxygen, and

settled solids are also important operations criteria. Periodic and routine checks of the feeding equipment, with measurement of chemical dosage, are required to ensure that the correct amount of chemical is being fed.

7. Results depend on continuous and proportionate chemical feed. Personnel should be provided for as many hours a day as is feasible; 24-hour-per-day coverage is ideal, but not mandatory.

8. Equalize the flow through the plant by every available means to keep conditions as near constant as possible.

9. Provide flexibility to allow optimization of chemical feed for each individual plant. We recommend feed points ahead of the primary and at the end of the primary basins as well as to at least three points in the aeration system, i.e. inlet, midway and outlet.

10. Plant records should be maintained to monitor the results of chemical feed. We recommend the following basic operating criteria be monitored.

    a. Suspended solids throughout the plant.

    b. Incoming and effluent BOD.

    c. Turbidity out of secondary clarifier and plant effluent.

    d. Dry solids basis of the sludge handling system.

    e. Phosphorus levels.

SECTION IV

PROJECT DEVELOPMENT AND SCHEDULE

The project was fully under way by October 1, 1973 and was completed by August 1, 1974. Table 1 shows the actual dosing schedule.

TABLE 1 - SODIUM ALUMINATE DOSING SCHEDULE

Time Period	Dosing
10-1-73 thru 10-24-73	10 mg/l additions of aluminum to the aeration tanks
10-25-73 thru 11-25-73	no aluminum additions
11-26-73 thru 12-22-73	10 mg/l additions of aluminum to the aeration tanks
12-23-73 thru 1-13-74	no aluminum additions
1-14-74 thru 2-11-74	10 mg/l additions of aluminum to the aeration tanks
2-11-74 thru 3-10-74	no aluminum additions
3-10-74 thru 5-5-74	10 mg/l additions of aluminum to the aeration tanks
5-5-74 thru 7-28-74	no aluminum additions

Samples of raw water and settled wastes, and final plant effluent were collected every two weeks and submitted for outside-plant laboratory analysis. These data are shown in Table 2.

TABLE 2 - ANALYTICAL DATA SUMMARY*

Sample	Sample Location	Ammonia NH_3	Nitrate NO_3	Nitrite NO_2	Total P Phosphorus	Kjeldahl Nitrogen	Total P Soluble Phosphorus
10/15	Raw	27	1.0	.01	10.0	33	9.4
	Settled	27	1.0	.01	10.0	-	10.0
	Final	12.0	51.0	1.4	2.0	-	1.7
11/12	Raw	30	1.0	.01	12.0	43	11.0
	Settled	27	1.0	.01	10.0	31	10.0
	Final	19.0	23.0	.67	7.9	21.0	7.8
12/10	Raw	26	4.0	.09	8.8	38	8.8
	Settled	25	4.0	.10	8.5	37	7.4
	Final	15.0	18.0	.30	2.7	15.0	2.2
1/28	Raw	11	4.0	.10	5.1	19	4.7
	Settled	9.7	2.0	.01	5.9	32	5.4
	Final	5.2	1.0	14.0	1.0	6.5	0.8
2/27	Raw	25	2.0	.01	9.5	37	9.1
	Settled	-	-	-	-	-	-
	Final	8.9	17.0	.82	4.4	14.0	3.9
3/25	Raw	24	3.0	.01	8.8	160	8.8
	Settled	23	4.0	.01	9.8	29	8.2
	Final	7.8	43.0	.99	1.7	7.8	1.5
4/22	Raw	23	1.0	.01	23.0	42	7.9
	Settled	21	6.0	.01	7.0	43	5.9
	Final	8.1	31.0	.30	2.8	12	1.7
5/10	Raw	25	1.0	.01	7.8	40	7.2
	Settled	28	1.0	.01	7.0	34	6.6
	Final	13.0	9.0	.43	5.1	15	5.0
5/20	Raw	31	1.0	.01	8.8	37	8.8
	Settled	27	1.0	.05	8.1	30	7.5
	Final	6.5	40.0	.99	4.9	7.9	4.9

*Results in mg/l

Routine plant operations analytical work sheets were used to provide the basic data on sludge volume index, solids control, etc. Dosing of the liquid sodium aluminate was set and maintained at 10 milligrams per liter as Al. The original time sequence for dosing was four weeks on and four weeks off. This permitted comparison of plant data under a wide range of operating conditions. The only exception to this dosing schedule was near the end of the study when we extended one dosing period to a full eight weeks from March 11 to May 5. This was done to minimize the apparent alumina overlap and to obtain data on longer operations.

The sodium aluminate was delivered bulk into three 1000-gallon storage tanks. Details of the chemical feed system are shown in Figures 1, 2, 5 and 6.

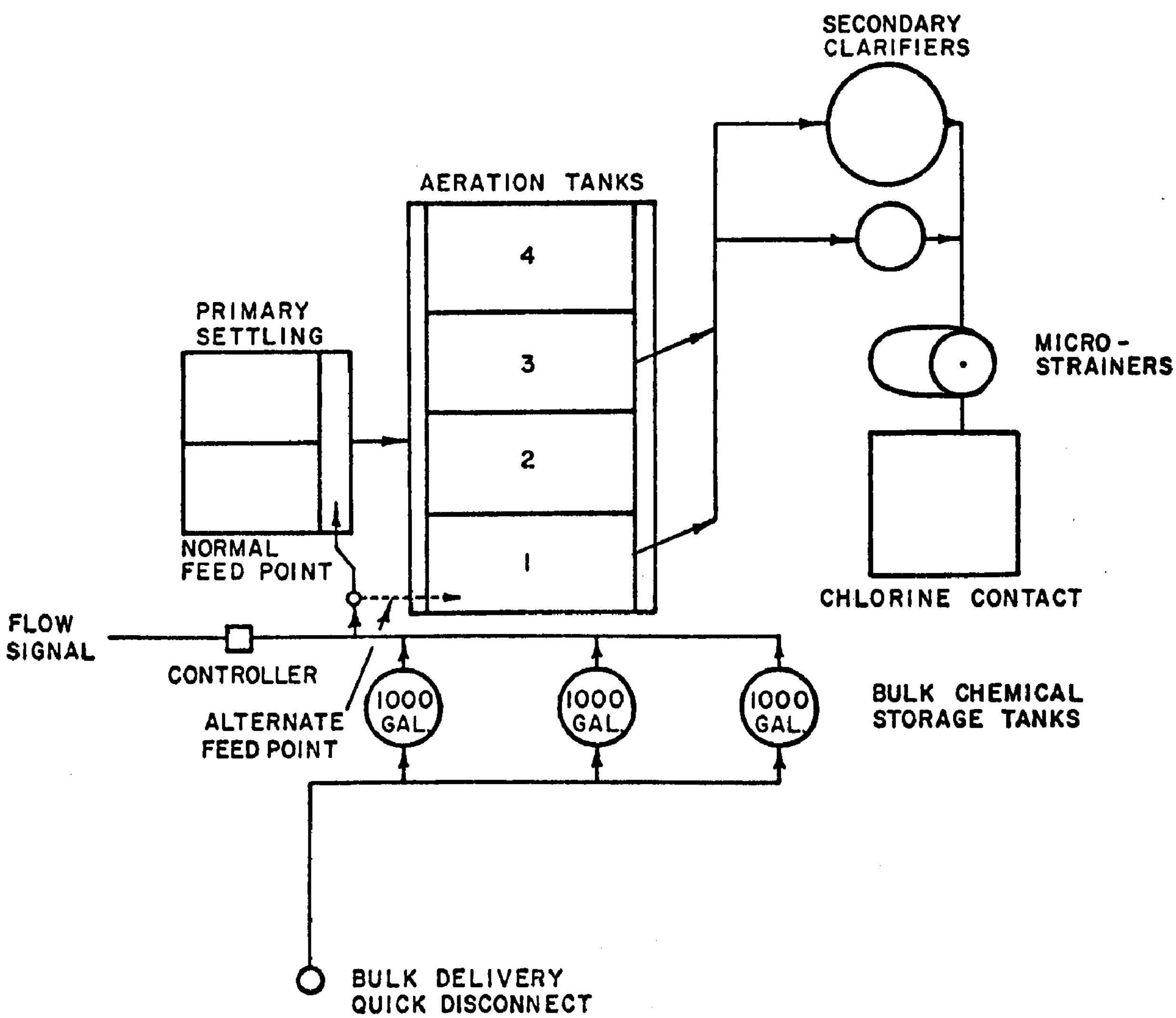

FIGURE 1 - CHEMICAL FEED SCHEMATIC

FIGURE 2 - CHEMICAL APPLICATION POINT, PRIMARY TANK WEIR TROUGH

The aluminum does not interfere with biological nitrification or carbon and solids removal. The compounds of alumina are usually colored white, which accounted for the lighter tan appearance of the activated sludge observed when dosing with sodium aluminate.

Because sodium aluminate is an alkaline aluminum salt, its usage does not contribute sulfates, chlorides, or other dissolved solids except for a small amount of sodium to the wastewater treatment plant effluent. Sodium aluminate does not reduce alkalinity in the waste stream; consequently, it will not depress the pH (See Figure 20). It is noted that acid metal salts (such as alum, ferric chloride or ferric sulfate) use up alkalinity and can depress the pH in a waste stream that is not sufficiently buffered to absorb the alkalinity reduction.

Sodium aluminate reduces phosphorus in a wastewater treatment plant by chemically precipitating soluble phosphorus and "floc sweeping" this insoluble phosphate down with the flocculated colloidal matter and settleable suspended solids. The chemical reaction of sodium aluminate in phosphorus removal is as follows:

$$Na_2\ Al_2O_4 + 2\ PO_4^{-3} + 4\ H_2O = 2\ AlPO_4 + 2\ NaOH + 6\ OH^{-1}$$

The precipitated aluminum phosphate retains its identity through aerobic and anaerobic sludge digestion and is not resolubilized. This will result in a reduction in supernatant phosphorus recycle and insure removal of phosphorus with the digested sludge.

Application data from other activated sludge treatment plants show the Al:P ratio when using sodium aluminate for phosphorus removal has varied from 0.5:1 to 2.0:1. Most applications require an Al:P ratio of about 1.4:1.

In this study, the controlled removal of phosphorus was of secondary importance. For this reason, no attempt was made to maintain a specific ratio of sodium aluminate feed to incoming raw inlet phosphorus levels. Figure 3 demonstrates, however, that the average phosphorus (as P) removal while feeding sodium aluminate (S.A.) at Greene County - Beavercreek Wastewater Treatment Plant was 79.6%. This compares to removal levels of 41.7% without sodium aluminate feed.

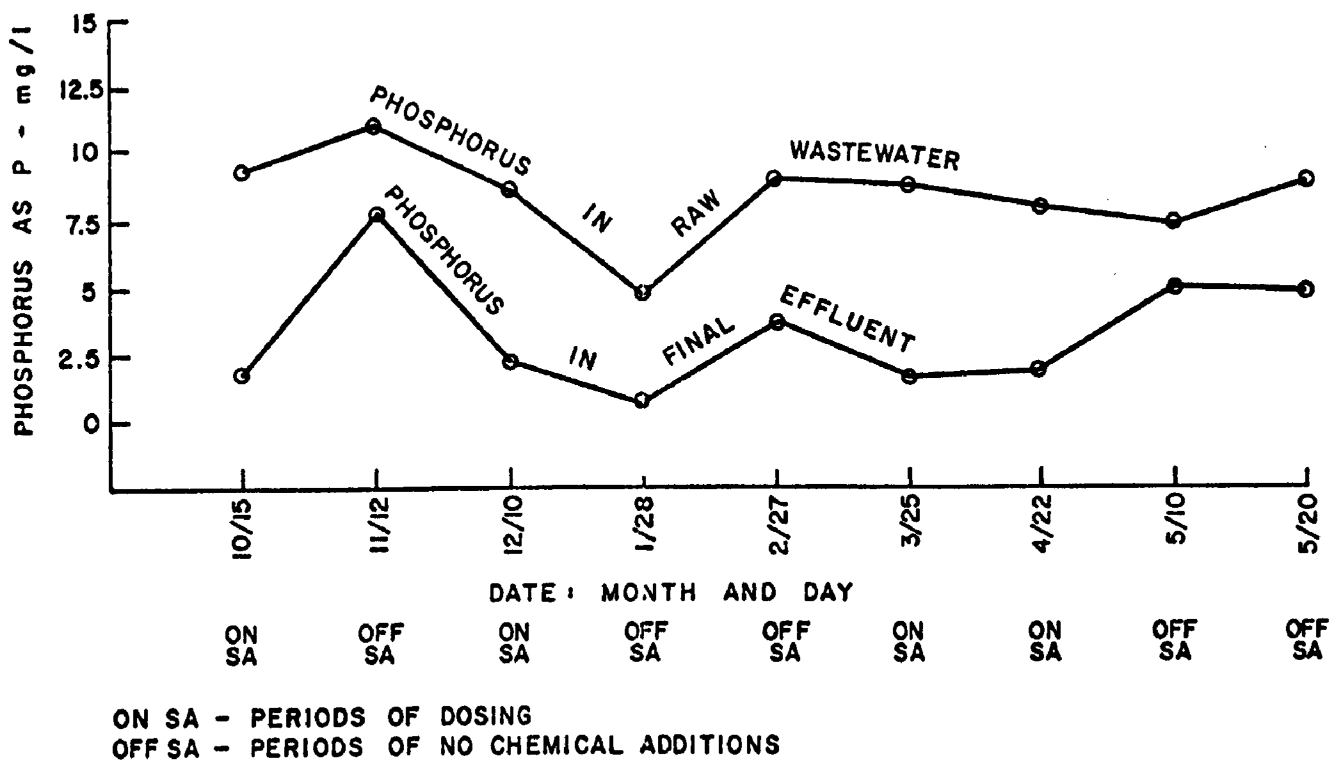

FIGURE 3 - PHOSPHORUS VARIATIONS WITH SODIUM ALUMINATE ADDITIONS

Figure 3 shows a direct comparison of incoming phosphorus levels to final phosphorus content of the plant effluent. Incoming raw waste phosphorus levels (as P) range from a high of 11.0 mg/l to a low of 4.5 mg/l. Phosphorus levels in the final range from a high of 7.7 to a low of 3.5 without sodium aluminate feed. Phosphorus levels in the final plant effluent while feeding sodium aluminate range from a high of 2.2 mg/l to a low of 0.8 mg/l.

This activated sludge wastewater treatment plant benefited greatly from metallic ion addition. The chemical-biological floc, produced by alumina ion addition, provided a readily settleable mixed liquor with the important side benefit of phosphorus removal. There was also residual benefit because the mixed liquor stream contained recycled alumina for some time after the aluminate feed was discontinued. For purposes of this study, the time period where benefit was noted following discontinued sodium aluminate feed is called "alumina overlap."

It is generally accepted that the use of high molecular weight polymer flocculants can even further increase the efficiency of metal salts. For the purpose of this study, though, it was decided to investigate the role of an aluminum compound alone. In any final design, polymer flocculant capabilities should be included.

SECTION V

DETAILED DATA ON TREATMENT UNITS AND DESCRIPTION OF TREATMENT FACILITIES

Detailed plant data and brief descriptions of the treatment facilities are outlined below. Plant schematic shown on Figure 4.

The plant is rated to have a nominal capacity of 2.5 million gal per day (average design flow for a 24-hour period on an annual basis) and is capable of biologically treating the wastes from a population equivalent of 25,000 people. It will hydraulically take peak flows of approximately 2 1/2 times the average flow or 6 million gal per day.

Efficiencies Expected

The treatment plant with all equipment on line will normally operate at 95% efficiency in the reduction of BOD and suspended solids. Based upon raw wastes of approximately 200 mg/l of BOD and suspended solids of 240 mg/l the effluent will average approximately 10 mg/l of BOD and 12 mg/l of suspended solids.

Utilities

Electric power for the Beavercreek Wastewater Treatment Plant is furnished by the Dayton Power & Light Company and services are reliable.

Grit Chamber

Grit removal also provides protection for plant equipment by removing abrasive material such as sand, stones, cinders or other heavy inorganic materials. These materials can cause: (1) wear by abrasion of the mechanical equipment that the flow comes in contact with, (2) clogging of pipe lines, tanks and hoppers and, (3) problems with sludge handling and disposal.

These materials, once removed, can be disposed of by using them as fill or by burying them.

Comminutor

The purpose of a comminutor is to shred debris and rags that, if not altered, could cause line stoppages, pump clogging and interference with proper operation of valves.

Screening

Screening in the Beavercreek Wastewater Treatment Plant is provided as an alternative to comminuting in the event of mechanical difficulties encountered with the comminutor.

Primary Sedimentation

The purpose of the primary settling tank is to remove the settleable solids as well as a portion of the BOD. The settled solids are then pumped as raw sludge to the aerobic digestion process.

Floatable material in the wastewater flow is also removed at the outlet end of the primary tanks by hand operated skimmers. Grease removal is an important step in the treatment process. These skimmings are disposed of by burial.

Chemical Additions

As the requirements for removal of nutrients from the wastewater stream are becoming more stringent, provisions to dose the waste stream with one of many available chemical coagulants have been added to many wastewater treatment plants. The Beavercreek plant has the necessary equipment to dose aluminum salts to the waste stream. This is accomplished by pumping sodium aluminate into the effluent weir trough at the primary settling tank. The entire contents of the aeration tanks then become entrained with the aluminum coagulants so that, along with removing phosphorus, there are the additional benefits of improved settling characteristics of the mixed liquor.

Activated Sludge Process

In the activated sludge system, flocculated microbiological growths are continuously circulated and mixed with organic wastes in the presence of oxygen. Oxidation and diminution in the size of the waste particles is accomplished in the aeration step which is followed by solids/liquid separation. A portion of the separated solids is returned to the incoming waste during the aeration phase to maintain proper mixed-liquor/suspended-solids concentration. The remainder of the solids is washed from the system.

The Beavercreek plant also has the flexibility to permit operation as a reaeration process or a contact stabilization process, which are modifications of the activated sludge process.

Secondary Clarification

Like primary clarification, the purpose of secondary clarification is to remove solids. The secondary tanks should remove the flocculent biological solids produced by an aeration process. These solids are then returned to the point of the process where it mixes with the settled sewage. This is bacteria-enriched sludge that becomes excellent "seed" material when mixed with the settled sewage.

Return Sludge Pumps

Return sludge is the material that settles to the bottom of the secondary clarifiers. The purpose of return sludge facilities is to return this sludge to the primary effluent as well as to "waste" excesses of this material out of the activated sludge (aeration) system.

Microstrainers (Effluent Screens)

These are drums covered with wire mesh used to retain and remove suspended or floating solids that can be present in the effluent from the secondary clarifiers.

Chlorination

The purpose of chlorination at the Beavercreek plant is to disinfect the effluent. This destroys bacteria which might be harmful to water supplies, bathing beaches and other recreational areas. The chlorine contact tank also serves as an additional tank that provides space to remove any solids that will settle. A skimming area is also provided with the chlorine contact tank.

Aerobic Digestion of Sludges

This process involves the digestion of suspended organic matter by means of aeration. Aerobic digestion takes place in the presence of dissolved oxygen. This method alters organic solids to: (1) effectively control or destroy agents of disease and infection, (2) decompose organic matter to relatively stable organic or inorganic compounds, and (3) reduce the volume of material to be handled.

Land Application of Liquid Sludge

Once the raw and waste activated sludges are fully digested and stabilized, the ultimate disposal of the liquid sludge is to apply it to the land. This acceptable and highly recommended procedure is accomplished by trucking the liquid sludge to various farm sites where the sludge is applied to the land. The valuable nutrients and soil conditioning properties improve the productivity of the land.

Basic Design Data

The following design data is for the total plant; this includes the original plant as well as recent additions and expansion:

(1) Design Conditions

Design year (originally projected)	to 1985
Actual design population	25,000 people
Design capacity BOD @ 0.17 lbs per capita	" "
Design capacity SS @ 0.20 lbs per capita	" "
Present Population	22,500 "
Design flow per capita	100 gal per capita/day
Average design	2.5 million gal/day
Maximum design	6.0 " " "
Wastewater characteristics:	
Biochemical Oxygen Demand - BOD 200 mg/l =	4170 lbs per day
Suspended Solids - SS 240 mg/l =	5004 lbs per day
Degree of treatment required:	
BOD removal	85 - 95%
SS removal	85 - 95%
Average Flow	2,500,000 gpd
" "	104,167 gph
" "	1736 gpm
" "	28.93 gps
" "	3.86 cfs

(2) Grit Removal

Type	constant velocity
Physical Removal	buckets with chain drive
Number	one
Size (@ design flow)	25.25 x 4.5 x 1.33 ft SWD (side wall depth)
Volume	151 cu ft
Capacity	1132 gal
Displacement velocity @ avg flow	.64 fps
Detention time @ avg flow	39 sec

Grit removal bypass:

Type	constant velocity
Physical removal	hand cleaned
Number	1
Size (@ design flow)	25.25 x 4.5 x 1.33 ft SWD
Displacement velocity @ avg flow	0.64 fps
Detention time @ avg flow	39 sec

(3) Screening

Type	comminutor
Number & nominal capacity	1 @ 2.5 million gal/day
Maximum capacity	7.5 million gal/day
Alternate:	
Type	bar screen
Physical removal	hand cleaned
Size	3.5 ft wide x 6.25 ft high
Construction	1-1/2 x 1/2 inch steel bars
Size of openings	1-1/2 inches
Slope	45° angle
Displacement velocity @ avg flow @ 1.3 ft SWD	0.83 fps

(4) Pumping Raw Wastewater

Type	centrifugal
Number	2
Driver horsepower	125 HP each
Size	14 x 14 x 14-3/4 inches
Capacity	6250 gpm @ 53 ft of head

(5) Primary Clarification

Number	1
Size	54 ft long x 25 ft wide x 13 ft SWD
Volume of the tank	17,550 cu ft
Capacity	131,625 gal
Detention time @ design flow	1.3 hours
Surface settling rate	1852 gpd/sq ft
Weir length	96 ft
Weir overflow rate	36,042 gpd/lin ft
Surface area weir length ratio	14 sq ft/ft
Solids loading (disregarding recycle)	3.7 lb/day/sq ft
Expected removals from design flow:	
Suspended solids	46%
BOD	25%

(6) Aeration Tanks

Number	4
Size	93 ft long x 24 ft wide x 12.7 ft SWD
Volume each	28,346 cu ft
Volume total	113,384 cu ft
Capacity each	212,595 gal
Capacity total	850,380 gal
BOD to aeration	3127 lbs/day
BOD loading	27.6 lbs/day/1000 cu ft
Detention time (@ design)	8.2 hours

(7) Air Requirements - Activated Sludge

Aeration tanks	1600 cu ft/lb BOD
Air required	3475 cfm
Blower capacity (7 centrifugal @ 600 cfm ea. - 2 positive displacement @ 900 cfm ea.)	6000 cfm
Total capacity	8,640,000 cu ft/day
Air available at design	2763 cu ft air/lb BOD

(8) Return Sludge Pumps

Type	centrifugal
Number	2
Size	6 x 11 x 10-1/4 inches
"	4 x 3 x 3 inches
Capacity	2000 gpm @ 24 ft of head
"	150 gpm @ 36 ft of head
Total capacity (average flow)	10% to 175% of 2.5 million gal per day

(9) Secondary Clarification Tanks

Type	circular
Number	2
Size	1 @ 90 ft dia x 10 ft SWD
"	1 @ 50 ft dia x 10 ft SWD
Surface area	1 @ 6,359 sq ft
" "	1 @ 1,962 sq ft
Total surface area	8,321 sq ft
Volume	1 @ 63,590 cu ft
"	1 @ 19,620 cu ft
Total volume	83,210 cu ft
Capacity	1 @ 476,925 gal
"	1 @ 147,150 gal
Total capacity	624,075 gal

Detention time (total)	6.0 hr @ 2.5 million gal per day
Surface settling rate (@2.5 mgd)	300 gal/day/sq ft
Solids loading - MLSS @ 2500 mg/l	6.3 lb/day/sq ft

(10) Microstrainers

Type - Drum - continuously cleaned	
Number	2
Size	10 ft dia x 10 ft long
Surface area	314 sq ft each
Total surface area	628 sq ft
Effective surface area	235 sq ft each
Total effective surface area	470 sq ft
Loading - 1 unit on line @ avg flow	7.4 gal/sq ft/min
Loading - 2 units on line @ avg flow	3.7 gal/sq ft/min

(11) Chlorination

Number	1
Contract chamber size	41 x 36 ft
Volume less baffles	9,333 cu ft
Capacity	70,000 gal
Detention time @ design flow	40 min
Chlorination capacity	50 to 1000 lb/day

(12) Centrifuges

Number	2
Type	solid bowl
Mountings	vertical
Maximum rpm	1400
Maximum G's	1300
Bowl capacity	16.0 cu ft
Nominal capacity	50 gpm
Production (@ feed of 50 gpm with 1% DS)	250 dry lb solids/hr
Thickened sludge	to digestion

(13) Sludge Digestion

Number	2
Type	aerobic
Size (each)	50 ft dia; 20 ft SWD
Volume (each)	39,200 cu ft
Volume (total)	78,400 cu ft
Capacity (each)	294,000 gal
Capacity (total)	788,000 gal

Capacity (cu ft/capita)	3.1
Detention time @ 4% sludge	74 days
Volatile solids loading	0.03 lb/cu ft/day

(14) Air Requirements Sludge Digestion

Aerobic Digesters (600 cu ft/lb volatile solids)	1,605,000 cu ft/day
Air required	1115 cfm
Blower capacity (positive displacement)	5 @ 790 cfm
Air capacity	3950 cfm
Total air capacity	5,688,000 cfd
Air available/capita @ design	227
Air available @ design	2127 cu ft/lb volatile solids added/day

(15) Sludge Pumping

Raw sludge, transfer and digested sludge (piston type)	1 @ 0 to 150 gpm @ 41 ft head
Digested sludge, transfer and raw sludge (975 rpm centrifugal)	1 @ 150 gpm @ 36 ft head
Waste activated sludge (vari-speed centrifugal)	2 @ 100 to 400 gpm @ 24 ft head
Chlorine contact tank (submersible, centrifugal)	1 @ 525 gpm @ 20 ft head

(16) Chemical Storage

Mild steel tanks	
Number	3
Capacity (each)	1000 gal
Total capacity	3000 gal

(17) Chemical Feed Pump

Positive displacement, vari-speed	
Number	1
Capacity	0 to 7.5 gph

Land Application of Liquid Sludges

Method	Tank truck
Capacity	1 @ 6000 gal 1 @ 1500 gal

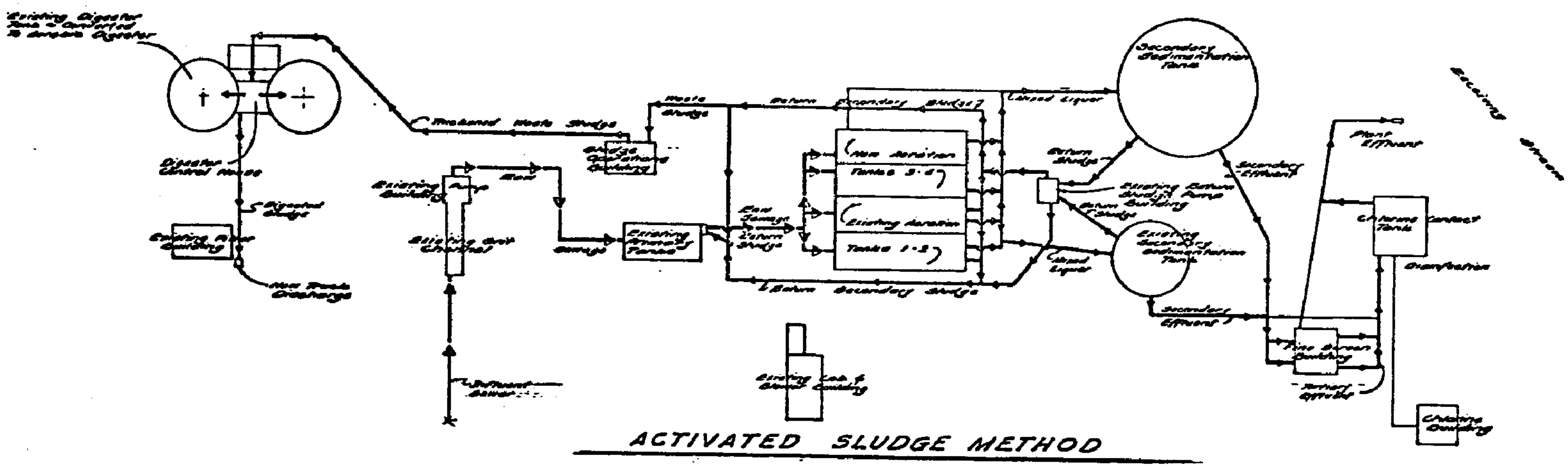

FIGURE 4 - BEAVERCREEK PLANT WASTEWATER TREATMENT SCHEMATIC FLOW DIAGRAM

Sodium Aluminate Properties

Some shelf life stability difficulties were found in the 26.4% aluminate product originally fed and the product was changed to 19.9% midway through the study. Adjustment in chemical feed rate was made to maintain the same ratio of Al_2O_3 to plant influent.

Technical description of products used are as follows. Product A was the first material used. It was followed by Product B halfway through the study.

Product A

Color	clear
Specific gravity at 120° F	1.56
Weight per gallon	13.0 lbs
$Na_2Al_2O_4$ weight percent	42.5
$Al_2 O_3$ weight percent	26.4

Product B

Color	water white to straw
Na_2O to Al_2O_3 ratio	1.5 to 1.0
Specific gravity at 100° F	1.45 to 1.46
Al_2O_3 weight percent	19.9

The product used is supplied commercially and is an alkaline solution of alumina. It is chemically identified as sodium aluminate. The viscosity of Product B at 0° F was 14,000 cp, at 20° F, 2,000 cp; and at 40° F, 280 cp. The pH of the 5% solution of this liquid sodium aluminate was 12.7.

Principles of Flocculation, Coagulation and Phosphorus Removal with Sodium Aluminate

Sodium Aluminate is an alkaline metal salt with the chemical formula $Na_2Al_2O_4$. A common trade name is soda alum. When dissolved in water, sodium aluminate releases hydroxide alkalinity and aluminum hydroxide.

$$Na_2Al_2O_4 + 4\ H_2O = 2\ Al(OH)_3 + 2\ NaOH$$

In wastewater clarification, sodium aluminate functions as both a flocculant and a coagulant. Its reaction in activated sludge treatment produces a chemical-biological floc with large surface area. This permits coagulation of colloidal material and flocculation of the fine percipitated particles. The aluminum hydroxide precipitate is tied up in the floc structure of the biomass.

SECTION VI

CHEMICAL FEEDING SYSTEM

The chemical handling and feeding system (Figure 1) has become an important link in the treatment process at the Beavercreek Wastewater Treatment Plant. The chemical system at one time was a major maintenance problem. With the availability of improved Sodium Aluminate Product B and much rehabilitation, the chemical feed system has become a reliable asset to the treatment process. (Figures 1, 5 and 6 graphically indicate vital portions of the chemical feed system.)

Bulk chemical is delivered to the plant by tank trucks and is easily unloaded after attaching the hose on the truck to a 2-inch quick-disconnect coupling. To prevent aeration, which can cause CO_2 absorption and possible destabilization of $Na_2Al_2O_4$, chemical is unloaded by a bottom-fill procedure. Tank inventory is controlled by watching glass sight tubes mounted on the tanks. Feeding is done by pumping the sodium aluminate through 2-inch PVC lines to the point of discharge. The pumping is done by a Milton-Roy diaphragm pump that is proportioned to the incoming wastewater flow by a flow meter signal from a Foxboro magnetic flow meter through a Foxboro transmitting signal converter.

Experience has shown that at the Beavercreek plant the most reliable feeding point is at the discharge of the primary sedimentation tank. The product is dosed undiluted (neat). Since the ultimate objective is to dose the mixed liquor inventory, there is no significant benefit in adding dilution water to the chemical. The chemical feed pump is a positive displacement type with capacities from 0 to 7.5 GPH.

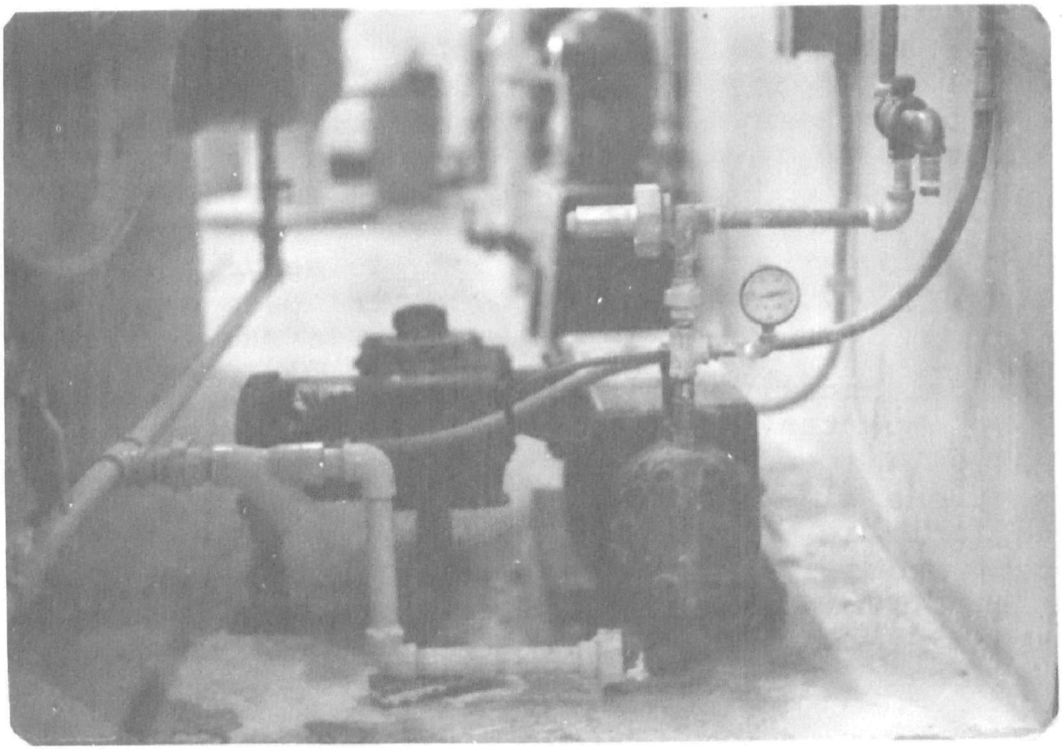

FIGURE 5 - CHEMICAL FEED PUMP

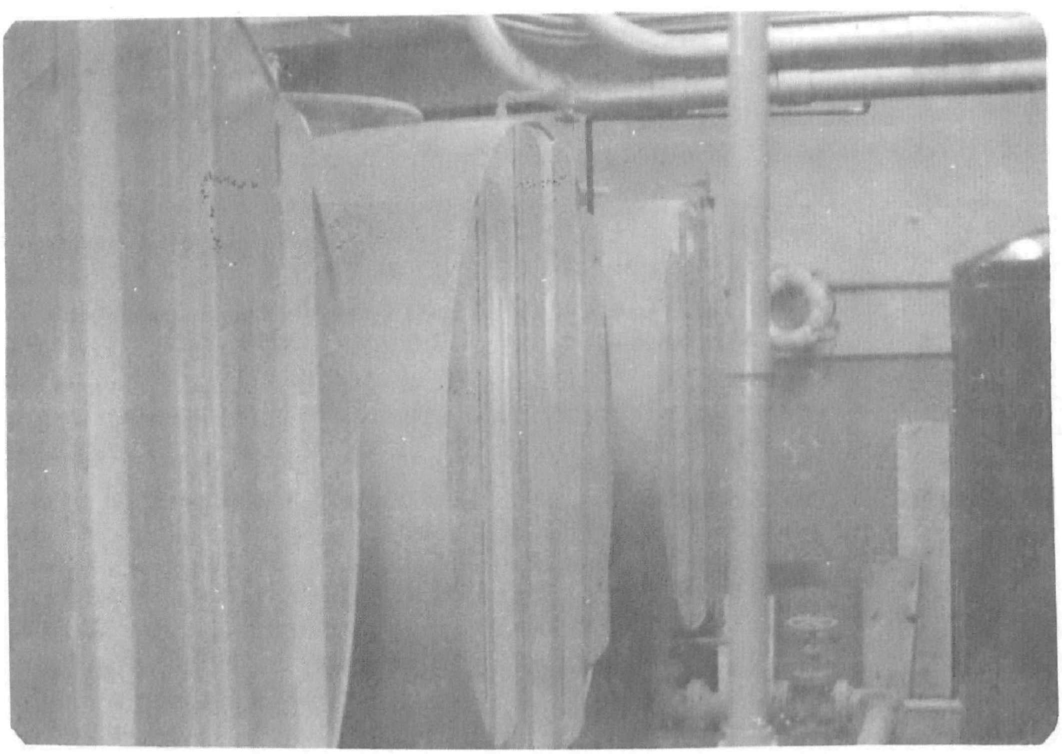

FIGURE 6 - BULK CHEMICAL STORAGE TANKS

SECTION VII

GENERAL DESCRIPTION - ACTIVATED SLUDGE PROCESS

Activated Sludge

The activated sludge process is used to convert nonsettleable substances and the finely divided, colloidal and dissolved solids into settleable sludge and to remove this newly formed sludge. The first phase is accomplished in the aeration tanks (Figures 8 and 9), the second in the secondary clarifier (Figure 7).

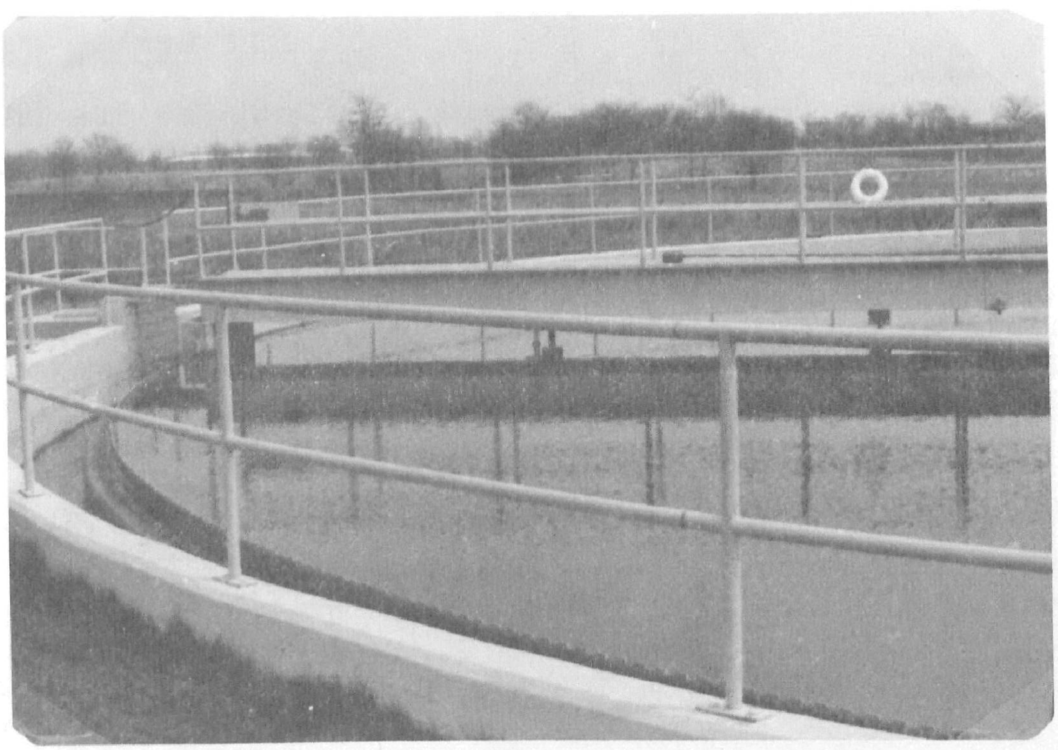

FIGURE 7 - SECONDARY CLARIFIER

FIGURE 8 - AERATION TANK OVERFLOW WEIR

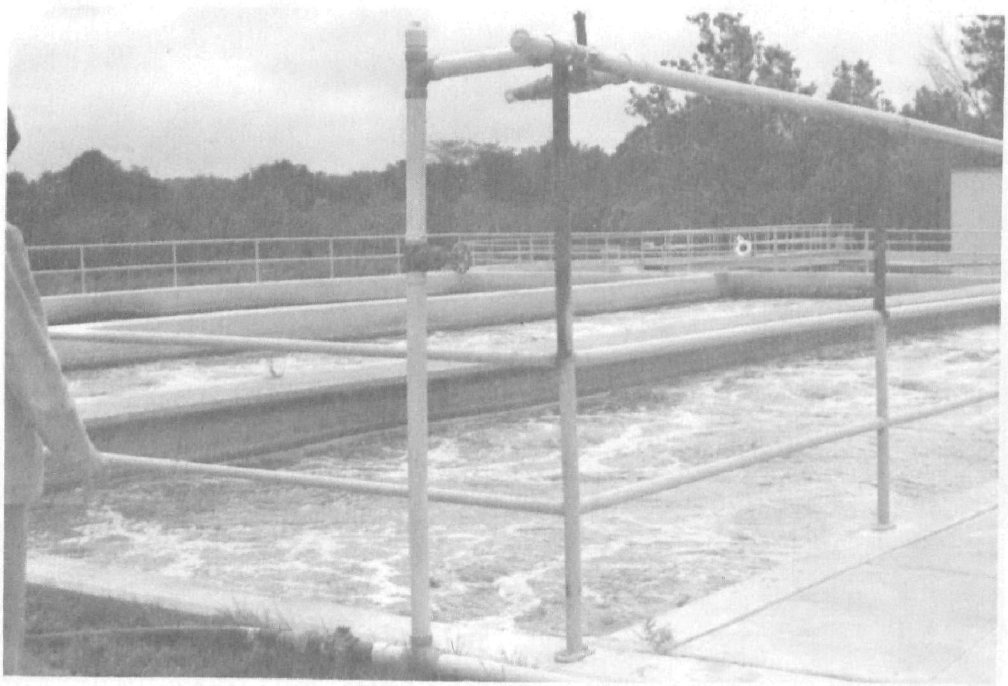

FIGURE 9 - AERATION TANK

The process depends on groups of microorganisms, i.e. bacteria and protozoa, that are nourished by the organic portion of wastewater solids. These microorganisms are provided with the proper environment in which they not only live, but also reproduce. The environment must be aerobic. After this, the activated sludge must be separated from the treated wastewater by sedimentation.

Secondary Clarification

Sedimentation efficiency depends on the weight and density of the sludge developed and the flocculent nature of the biomass. Absorption of oxygen and food by the microorganisms is an important function in the removal of organic material from the wastewater.

Basic requirements for a successful system are: (a) the activated sludge must contain sufficient numbers of purifying organisms; (b) dissolved oxygen must be present in sufficient amounts in the aeration tanks at all times; (c) the activated sludge (mixed liquor) must separate readily from the treated wastewater in the secondary clarifier; (d) the loading and sludge age should be controlled to maintain a well settled biomass.

Return Sludge

In the activated sludge process, untreated wastewater flows into an aeration tank where it is immediately mixed with activated sludge (return sludge). The mixing must be complete. The retention time in the aeration basin must be adequate to effect purification. Dissolved oxygen must always be present. The activated sludge is withdrawn from the secondary clarifier and a portion of the settled activated sludge (returned sludge) is pumped back to the start of the process. This supplies necessary microorganisms to aid in the treatment of additional wastewater flow.

Waste Activated Sludge

The activated sludge is constantly increasing in quantity as it removes organic material from the waste water and as the microorganisms continue to grow. It is vital that excess quantities of mixed liquor suspended solids be removed from the system. The sludge so removed is termed "waste activated sludge."

SECTION VIII

EFFECT OF SODIUM ALUMINATE FEED ON SOLIDS AND SOLIDS HANDLING

The overall goal of this study was to demonstrate the effect of alumina chemical dosing on wastewater solids and control of the resultant solids. To demonstrate the changes that took place in the plant, we selected three indicators normally monitored in waste activated sludge operations. These process barometers are as follows:

Percent Volume Mixed Liquor - 1/2 Hour Settling

This test method is described fully in standard methods. An abbreviated description of the test is the filling of a 1000-ml graduated cylinder with mixed liquor. This is allowed to settle for 30 minutes and the amount of sludge settled in this time is reported as percent volume mixed liquor.

This test defines how fast the mixed liquor solids settle, as well as the compaction rate. The plant personnel also visually observe the sample as it is drawn into the cylinder for the size of the floc. Experience has shown that the conditioning of the floc, and floc size, are important in sweeping down smaller particles as the floc settles. This test result provides not only a number but an observable condition of settleability. With chemical feed, you can easily see if you have the floc correctly conditioned for settling. With alumina conditioning, you will notice a slight color change from the conventional brown to a lighter tan.

The cross section of the cylinder stimulates the cross sectional area of the secondary clarifier. If the sludge does not settle in the cylinder test, you know it will not settle in the secondary clarifier and you can expect solids to carry over the clarifier weir.

Mixed Liquor Suspended Solids

This test method measures the amount of suspended solids in the mixed liquor. The sample is filtered through a weighed Gooch crucible - or filter paper, oven dried at 103^{o} C and the gain in weight reported as mixed liquor suspended solids.

This sample is collected at the end of the aeration basin (Figures 8 and 9), ahead of the secondary clarifier (Figure 7), and determines the amount of suspended matter to be settled in the secondary clarifier. This plant attempts to control the MLSS at 2200 - 2600 mg/l. Increased wasting of secondary sludge will reduce the MLSS. The MLSS is basically composed of biological floc. A control range of 2200 - 2600 for this plant provides optimum solids for aeration and makes available the desired sludge age. This concentraction of MLSS leaving the aeration basin must then settle in the secondary clarifier. The control range of 2200 - 2600 mg/l, based on plant operating experiences, provides the best solids concentration for settling and clarifier effluent quality.

Sludge Volume Index (SVI)

The sludge volume index is a relationship calculated from data obtained in the test for settled mixed liquor solids and milligrams per liter of suspended solids to mixed liquor.

Efficient activated sludge operation generally depends on maintenance of the sludge volume index at a number of 100 or less, for a good settling sludge. A high SVI value indicates poor settling characteristics.

We use the SVI as another indicator of how well the volume of sludge produced in the plant would settle in the secondary clarifier. For example, a condition of MLSS at 2400 mg/l could produce the following percent volume mixed liquor 1/2-hour settleability: 60%, 30%, 15%. The sludge volume index in these cases would be 272, 136, and 68, respectively. The better and faster the sludge settling in the secondary clarifier, the less chance you will have of solids carryout over the weir. Also, the more concentrated the sludge in the secondary clarifier, the less volume needed to recycle back as return activated sludge.

Results on SVI, percent MLSS volume 1/2-hour sedimentation and solids in mixed liquor are shown in Figures 11, 12 and 13.

Figure 10 is a plot of time (43 weeks) against the SVI. The plot point in each case for the SVI is the composite average of the readings for that particular week. The times when sodium aluminate was fed are identified on the horizontal axis by the words "on SA."

You can see in this curve the effect of sodium aluminate feed on the SVI. Starting from the first plot point, the SVI remained low. Stopping the feed of SA at the 4th week resulted in an upward increase of SVI. Starting the sodium aluminate feed again at the 8th week resulted in a downward trend of a rising curve index. This desirable index was lost again when sodium aluminate feed was stopped at the 12th week. The upward curve increased until the SVI reached 230. On their own initiative, the operators started the sodium aluminate chemical feed into the system to reestablish SVI control.

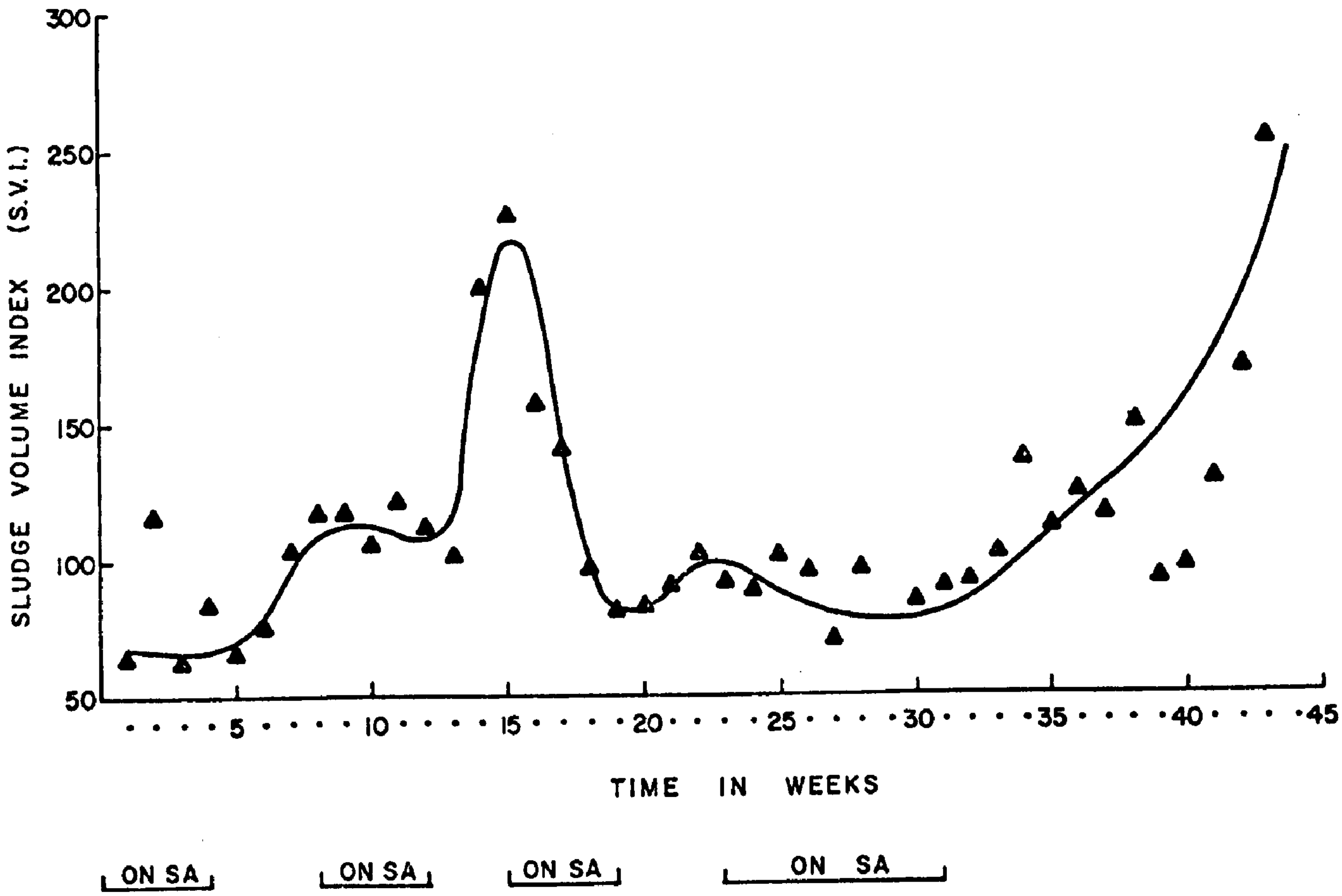

FIGURE 10 - SLUDGE VOLUME INDEX

This cycle repeats again with each starting and stopping of the aluminate feed. Control throughout the full 8-week sodium aluminate injection time period (between the 23rd week and 31st week of the study) was excellent. The curve trend again starts upward at the conclusion of this last feeding period on sodium aluminate. During the 8-week period without dosing the sodium aluminate, the SVI reached intolerable levels on the 160 to 250 SVI range. Note on the curve a time after sodium aluminate feed is stopped but before the upward SVI trend starts. We call this time period "alumina overlap." It is a condition we describe where alumina is still present in the system because of residual in the mixed liquor.

Mathematically, the average difference between the sodium aluminate addition periods was a 25% lower SVI during sodium aluminate feed. More typically, however, allowing for alumina overlap, the median SVI while on sodium aluminate would be 86. Not feeding the sodium aluminate, the median SVI would be 146. Figure 11 is a part of the 43-week time period, as in Figure 10, against the percent volume mixed liquor 1/2 hour settling.

You can see this curve closely parallels the Figure 10 curve on SVI. Again, the impact on the settleable solids is readily noted during the chemical dosing periods on sodium aluminate. The "alumina overlap" is noted at the end of each sodium aluminate chemical feed period.

Typically, (Figure 11, as related to Figure 10) when sodium aluminate was being fed the 1/2-hour percent volume mixed liquor settling rates were in the 10 to 20% range. Most "alumina overlap" periods were in the 20 to 30% range and extended no-feed periods resulted in a poor quality, 40 to 60% 1/2-hour settleability.

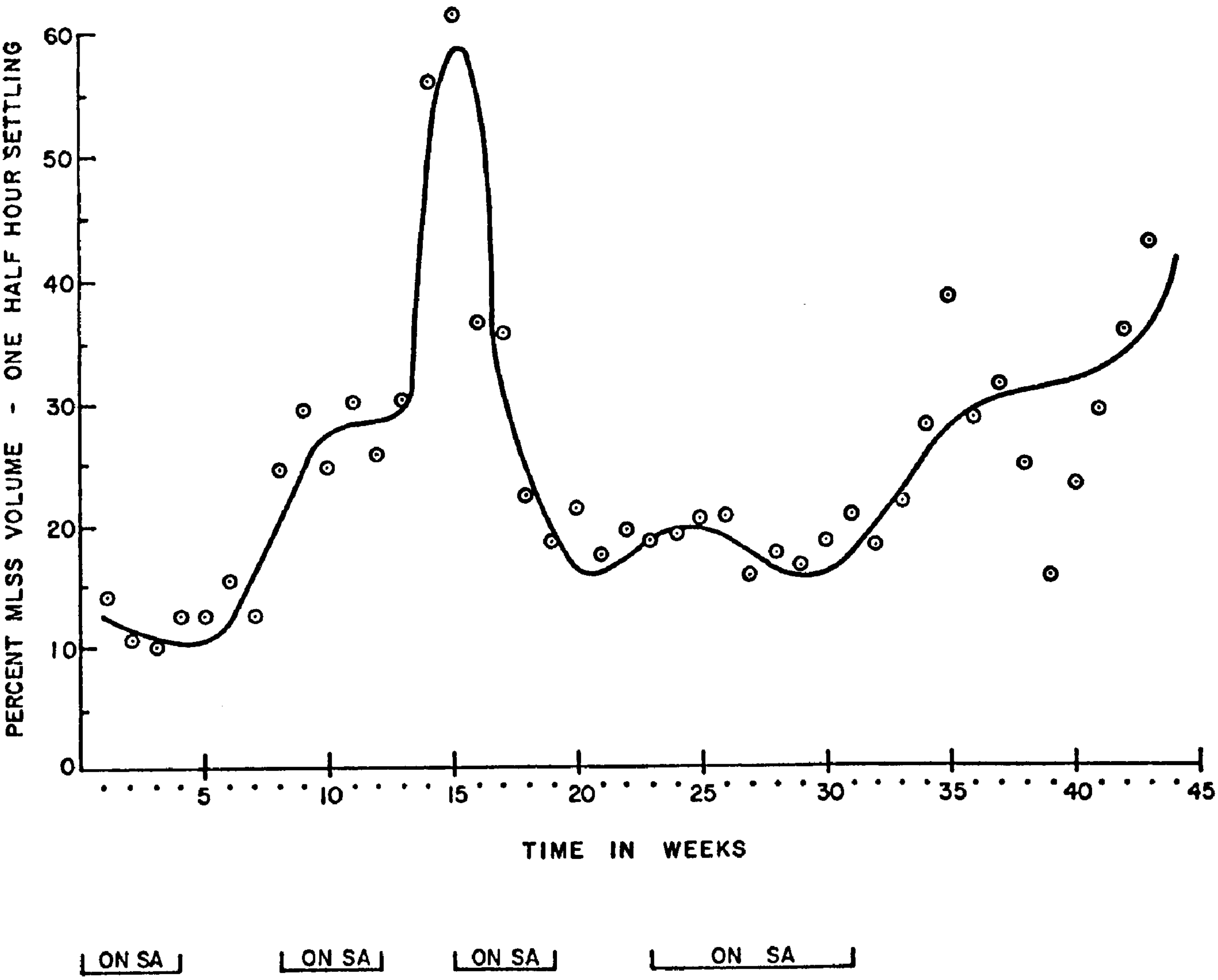

FIGURE 11 - PERCENT MLSS VOLUME ONE HALF HOUR SEDIMENTATION

Settleable Solids

Figure 12 is added to show the solids in mixed liquor, weekly averages, plotted against the 43-week study period.

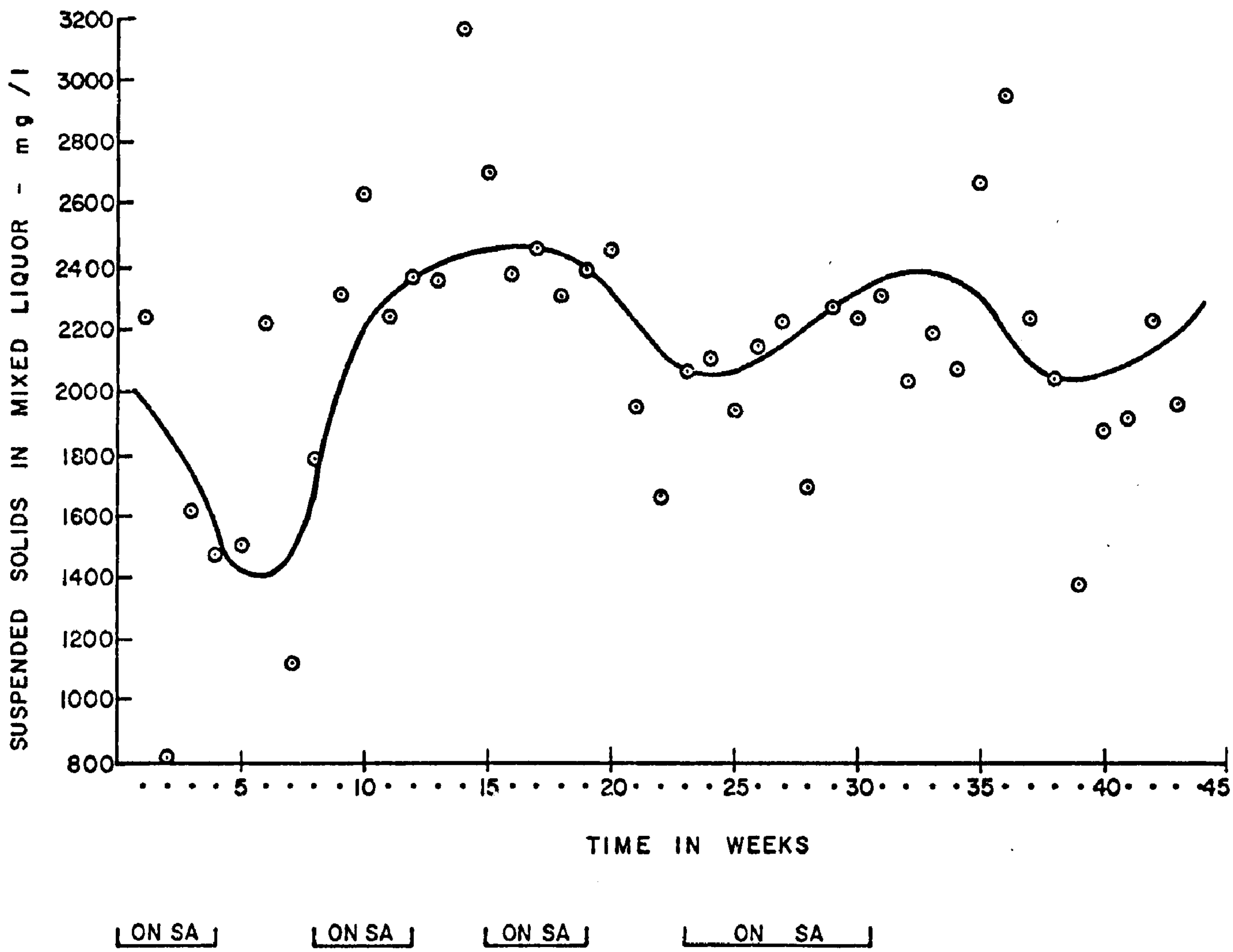

FIGURE 12 - SOLIDS IN MIXED LIQUOR mg/l

It is noted that the solids in the mixed liquor remain fairly constant between 2000 and 2400 throughout the test program. This indicates that the solids in the mixed liquor were not a significant variable on the SVI. It demonstrates that the major impact on the settleability of the mixed liquor solids came from sodium aluminate feed.

Return Sludge

Figure 13, return sludge suspended solids in milligrams per liter, points out that the daily return sludge suspended solids were kept at a median level in the 5500 to 7500 mg/l range. This indicates a consistent ability to waste sufficient mixed liquor solids for smooth operation. It is also noted that during the 7th and 8th weeks, without sodium aluminate feed, mixed liquor suspended solids were difficult to thicken.

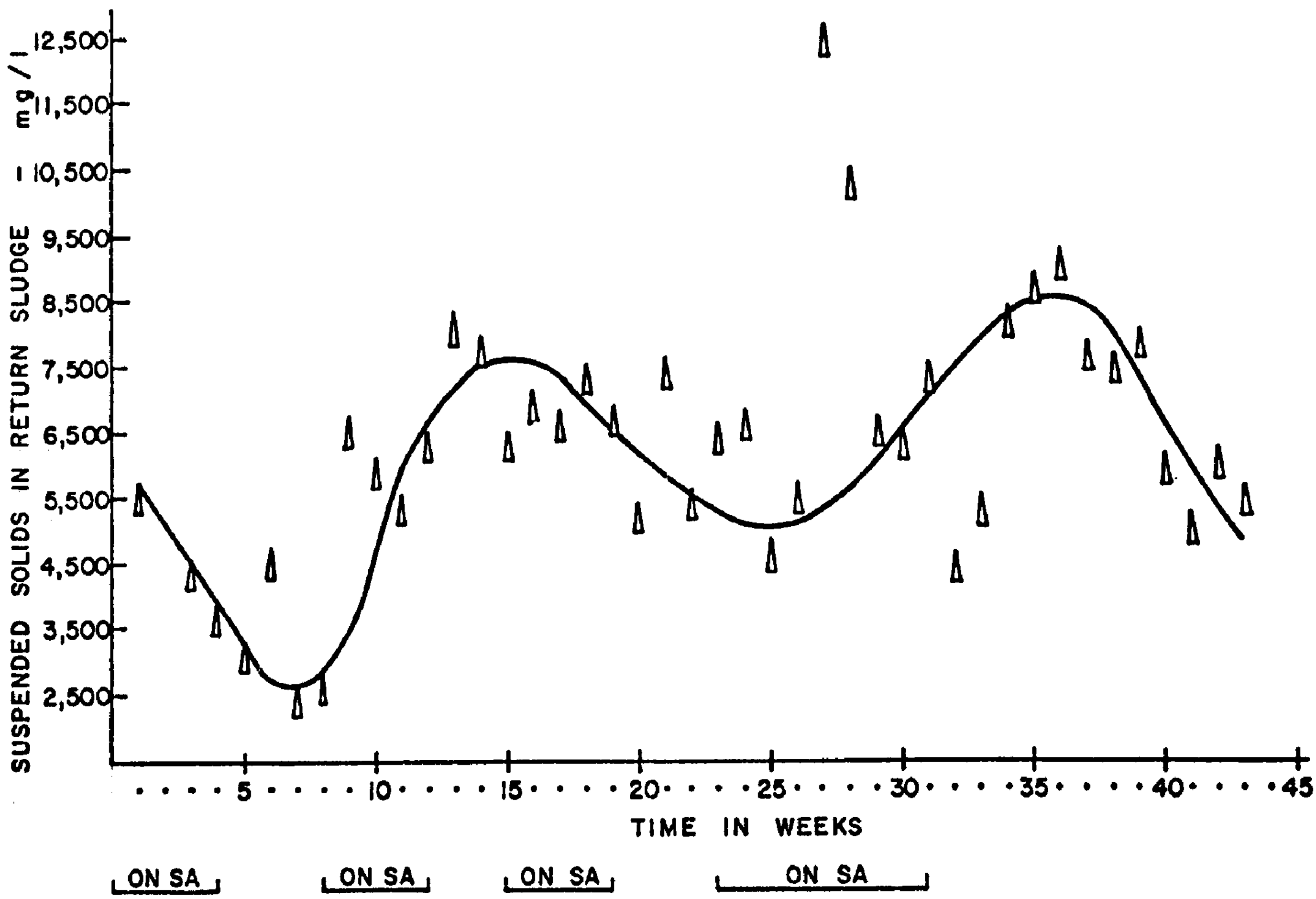

FIGURE 13 - RETURN SLUDGE SS mg/l

During the 27th and 28th weeks of the trial, which was the middle of the 8-week feed period, attempts were made to reduce the volume of returned sludge pumped daily. This resulted in ability to concentrate the returned sludge solids to levels in the 10,000 to 12,600 mg/l range.

No detriment to the secondary clarifier effluent was evidenced by increasing levels of solids in the secondary clarifiers at that time. Without more process control equipment to positively control return sludge thickness and volume, it was difficult to control solids concentrations as effectively as desired.

Waste Activated Sludge

It became operational practice, however, to allow a sludge blanket to develop in the secondary clarifier at time of wasting of activated sludge. This was accomplished by shutting off the return sludge pump until the sludge blanket increased to 3 - 4 feet. Waste activated sludge suspended solids of 1% to 1.5% could always be expected when this procedure was followed while dosing sodium aluminate to the flow stream.

This procedure was also tried without sodium aluminate in the system, and floc carryover was always evident before the sludge blanket could be removed from the secondary clarifier, once the blanket approached the 3 to 4 foot range.

Dissolved Oxygen

Dissolved oxygen control at the Beavercreek Wastewater Treatment Plant is validated by Figure 14. Assurance of an aerobic environment in the aeration tank is vital to the activated sludge process. Figure 14 indicates that the effluent of the aeration system always contained a minimum of 1.5 mg/l of dissolved oxygen. On two of the cumulative weekly averages dissolved oxygen levels of 4.8 to 5.2 mg/l were reached.

The important trend that Figure 14 establishes is that the DO's were in the range of 1.5 to 4.0 mg/l. These guidelines are a basic criteria to the Beavercreek Wastewater Treatment Plant operation.

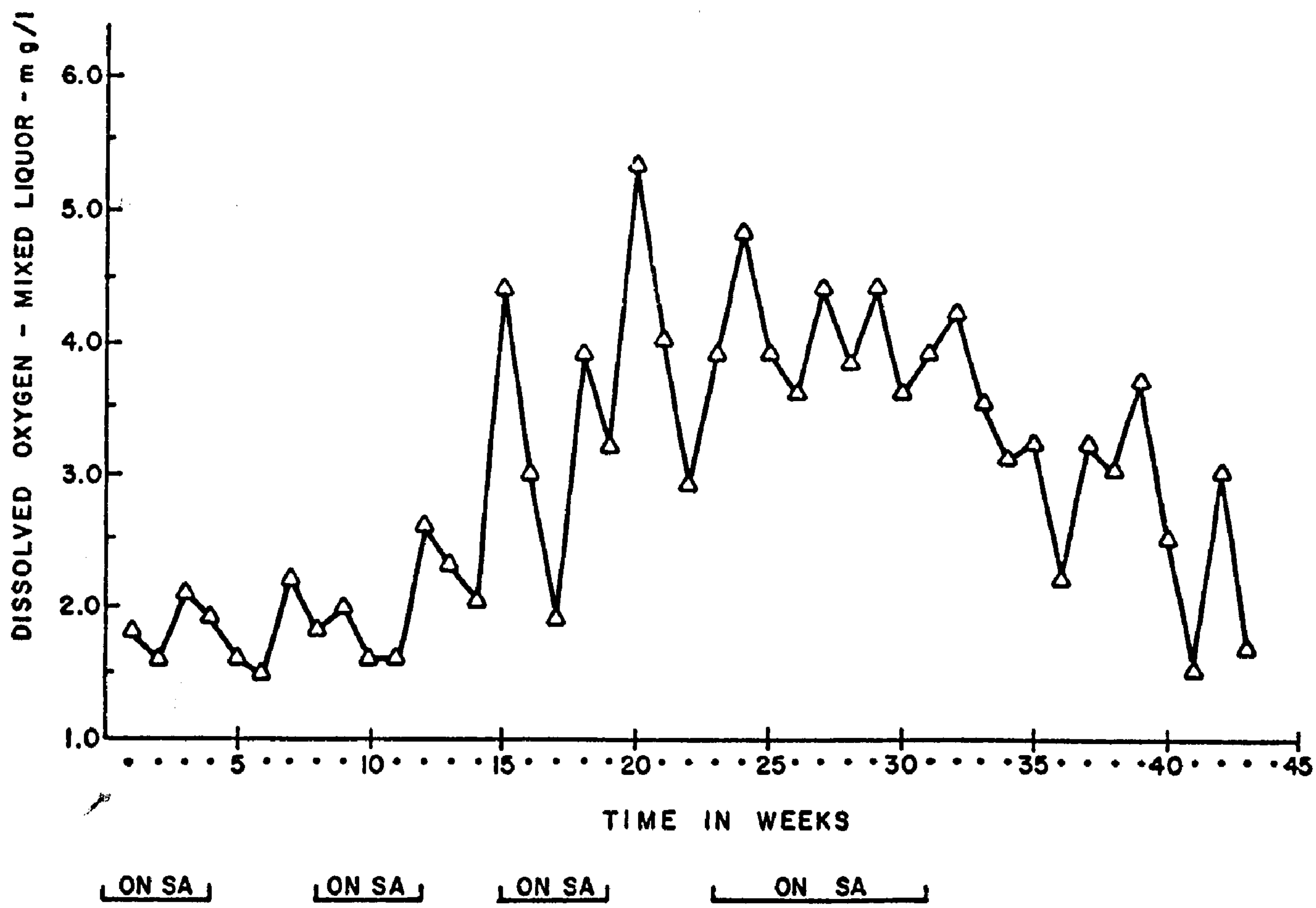

FIGURE 14 - MIXED LIQUOR DISSOLVED OXYGEN

Plant Flow

The plant flow during the study is shown in Figure 15. Each plot point on the graph represents the average for each week of the study.

Plant flow ranged from a low weekly average of 1.715 million gal/day to a high of 4.098 million gal/day. Short-term flow exceeded 5.5 million gal/day. Figure 15 points out that the flows were near the 2.5 million gal/day design capacity of the Beavercreek plant. Higher flows than 2.5 million gal/day were attributed to infiltration in the collection system as a result of rainfall. It is noted that the peak flows came by coincidence at the times sodium aluminate was being fed. These times were during the 9th, 16th, 17th, 27th and 28th weeks of the study. Of importance is that, with these peak flows, the plant did not have the expected sludge upset of "solids washout." The reason offered here is that the sodium aluminate increases floc density, thus keeping the sludge down in the secondary clarifier. Sodium aluminate demonstrated its ability to coagulate and flocculate solids, thus adding weight to the MLSS. A more compact sludge in the secondary clarifier resulted from sodium aluminate feed. This treated sludge stayed down at much higher flows than plant design.

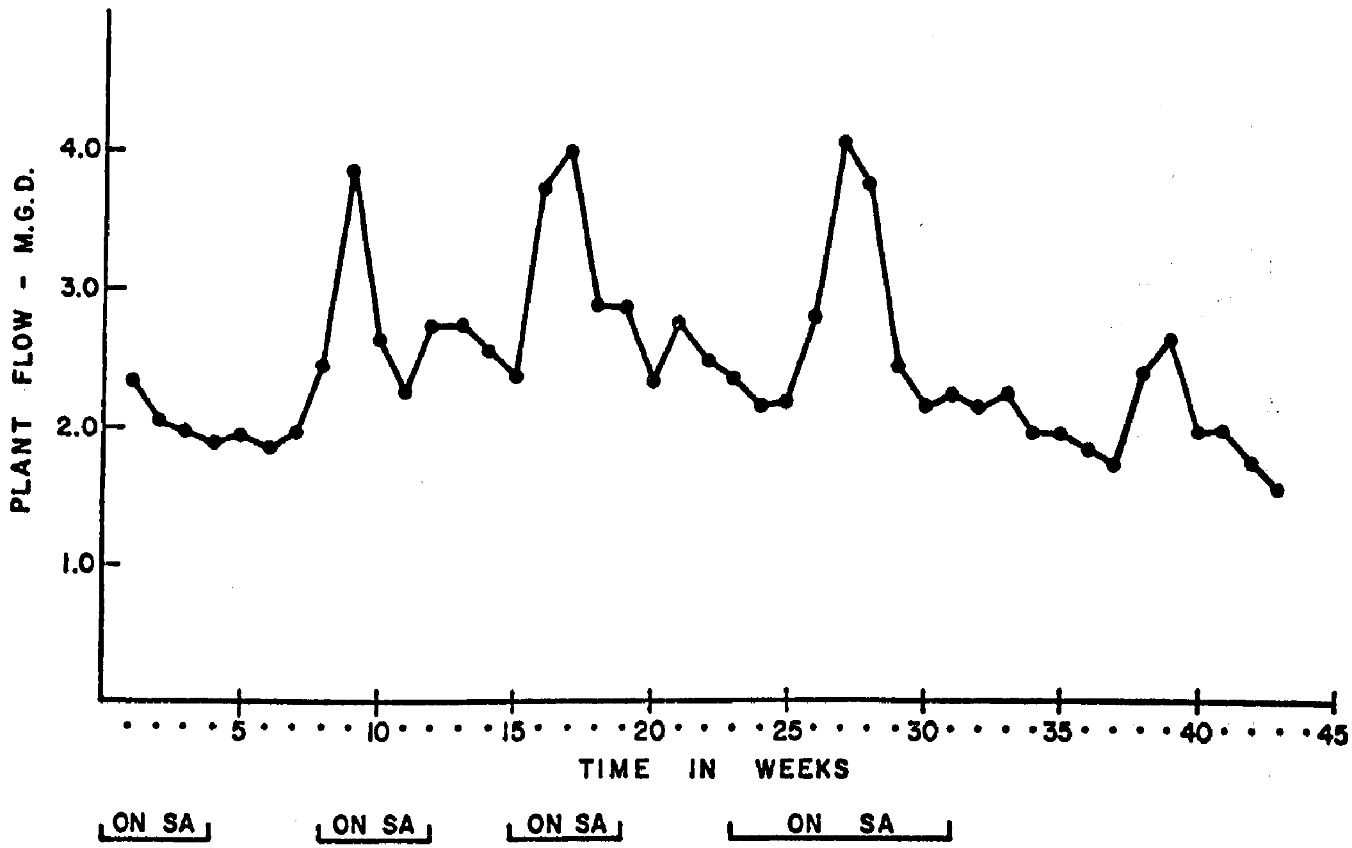

FIGURE 15 - PLANT FLOW MILLION GAL/DAY

Case Histories

The following are two case histories of the advantages of having a coagulant aid in the mixed liquor flow stream when the Beavercreek Wastewater Treatment Plant or similar wastewater treatment plants are surcharged with excessive wet weather (storm) flows. Both cases occurred in the spring of 1974: April 1, 1974 and June 22, 1974.

The following circumstances describe the events involved. The Beavercreek Plant is operated in a mode so that the raw wastewater influent control gate is set to allow a maximum wet weather flow rate into the plant of 5.0 million gal/day or twice the design flow of the plant. It has been determined that this much flow can be handled although somewhat less effectively than "normal" high flow rates of 3.0 to 3.5 million gal/day. Previous to both dates involved, it had been necessary to perform maintenance on the grit removal equipment which altered the inlet gate position and the gate can only be reset by trial and error adjustments at higher flows. Other factors in the sequence of events that led to the surcharge comparisons were:

1. Several days of mild rainfall preceding the surcharge.
2. A concentrated rainfall of one inch or more over a short period of time (1 - 2 hours).
3. Both surcharges occurred at night when the treatment plant is not manned.

On April 1, 1974 the plant was checked by the Wastewater Superintendent at 11:45 P.M. after several lift station problems were corrected. An intense storm caused power outages and one inch of rain in less than two hours. The flow meter indicated that excessive flows had occurred for approximately five hours. The flow meter was pegged at a 5.5 million gal/day rate. Pumping rates were so high that raw wastewater was overflowing the primary clarifier. Flows were estimated to exceed 12 million gal/day rates. Sodium aluminate was being dosed to the flow at that time. The control gate was throttled back to an actual 5.0 million gal/day rate. Although the secondary clarifiers were slightly turbid in appearance at this time, there was no evidence of loss of mixed liquor blankets. This observation was substantiated the following day when the plant laboratory determined that the MLSS concentration had increased from 2098 mg/l to 2847 mg/l. This indicated that not only had the 15,231 lbs of MLSS been retained but solids capture of an additional 5394 lbs of solids washed in with the storm flow had been accomplished. It is believed that the preceding experience points out that much benefit was realized by having the sodium aluminate in the flow stream.

On June 22, 1974, after several previous days of rain, the Beavercreek area was deluged with a one-inch rain storm. Even though several adjustments of the inlet gate had been made to control the quantity of influent to the Beavercreek Plant, the flow once again increased to the point that the flow meter was pegged at 5.5 million gal/day and it was estimated at this time that the flow peaked at 7 to 8 million gal/day or three times the design flow. This situation existed for approximately 4 hours before the pumps overcame the surcharge and reduced the flow to the 4.5 million gal/day range. When the operator arrived the following morning, it was noted that no mixed liquor solids were visible in the aeration system. The laboratory analysis showed that the MLSS had been reduced from 2400 mg/l to 826 mg/l due to the surcharge flows. This "wash out" represented a mixed liquor solids loss of 11,427 pounds. Assuming that an additional 5,300 pounds of suspended solids were contributed by the high flows, it is easy to arrive at a total of 16,727 pounds of suspended solids that were lost.

The conclusion is therefore drawn that sodium aluminate not only enhances normal operations but also protects small and medium-sized operations from high flow wash-out problems. In many cases wet weather by-passes can be entirely avoided if a coagulant is being dosed to the flow stream.

Temperature of Raw Sewage

Figure 16 shows the weekly averages of the temperature of the plant influent. Raw sewage temperatures ranged from a high of 63° F to a low of 51° F during the study.

Waste stream temperatures in a waste activated sludge plant have an important effect on plant operations. Without provision for temperature adjustment, the efficiency of plant operations typically is at the mercy of the elements. Biological activity decreases as the temperature falls. Referring to Figure 11, it is noted that when the raw wastewater temperature was at its lowest point, the 1/2 hour mixed liquor settling test shows sludge compaction above 80% while feeding sodium aluminate.

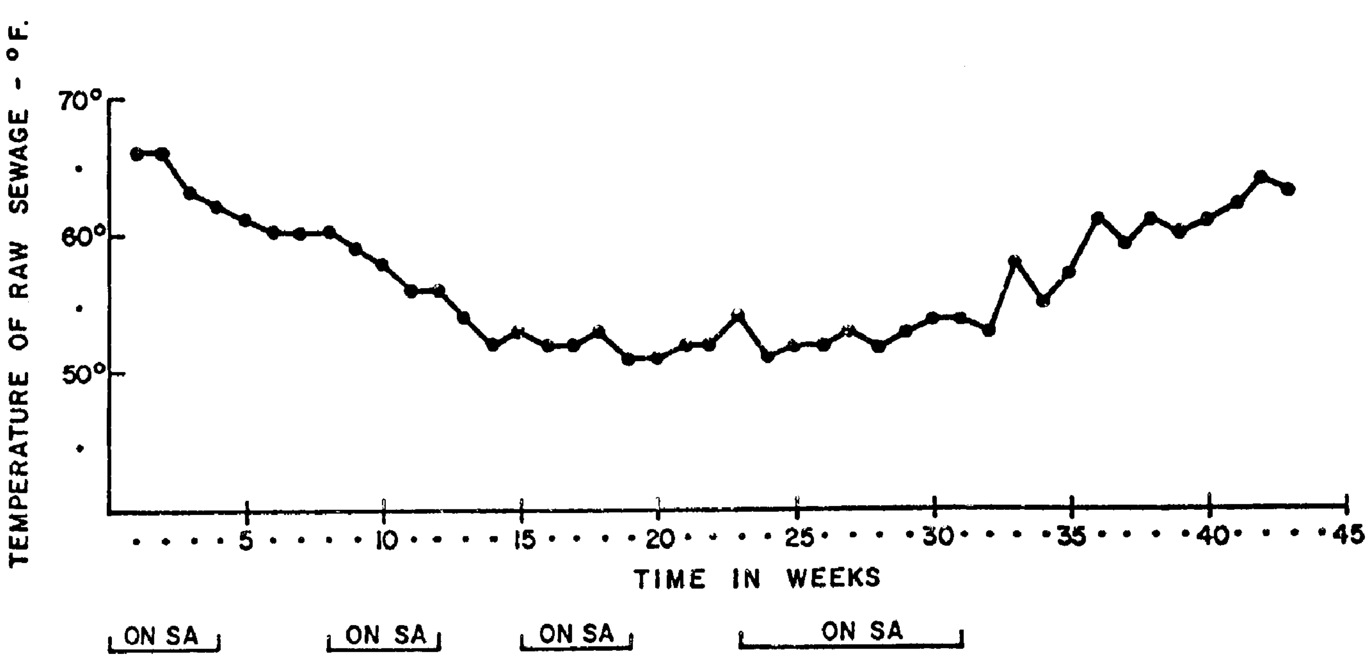

FIGURE 16 - TEMPERATURE OF RAW SEWAGE

Secondary Clarifier Suspended Solids

Figure 17 demonstrates the impact of sodium aluminate on suspended solids in the effluent of the secondary clarifier. It is noted that the lowest levels of suspended solids present in the effluent are during, or immediately following, sodium aluminate feed. Only during sodium aluminate feed do the levels of suspended solids drop to 5 mg/l or less in the clarifier effluent. The resultant decrease of suspended solids while feeding sodium aluminate improved the performance of the tertiary microstrainers.

NOTE: On, or shortly after sodium aluminate feed, is the only time the final suspended solids drop to 5 mg/l or below.

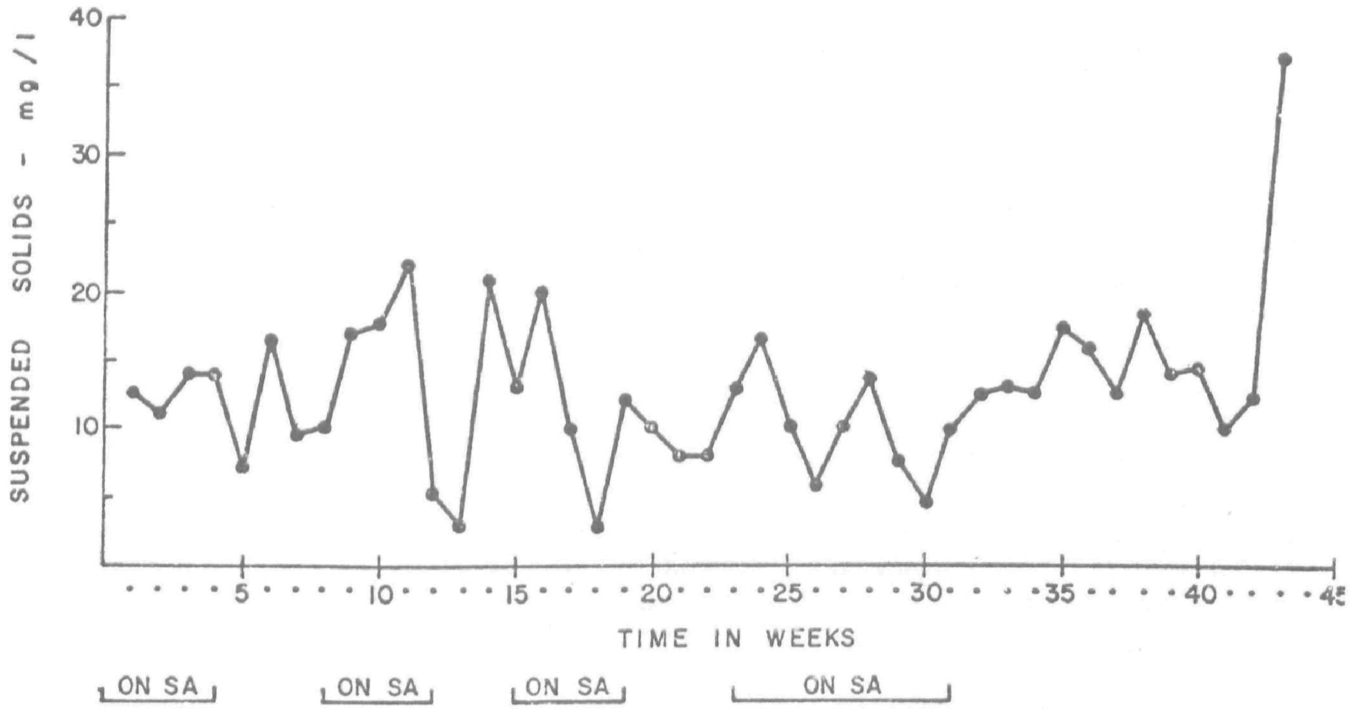

FIGURE 17 - SECONDARY CLARIFIER, SUSPENDED SOLIDS mg/l

Beavercreek Wastewater Treatment Plant utilizes microstrainers (Figure 18) for polishing of the secondary clarifier effluent. During the time of this study, the microstrainer operation was intermittent due to start-up and mechanical difficulties. It was observed that when the microstrainers were operational, charging them with secondary clarifier effluent not treated with sodium aluminate resulted in an overloaded solids condition.

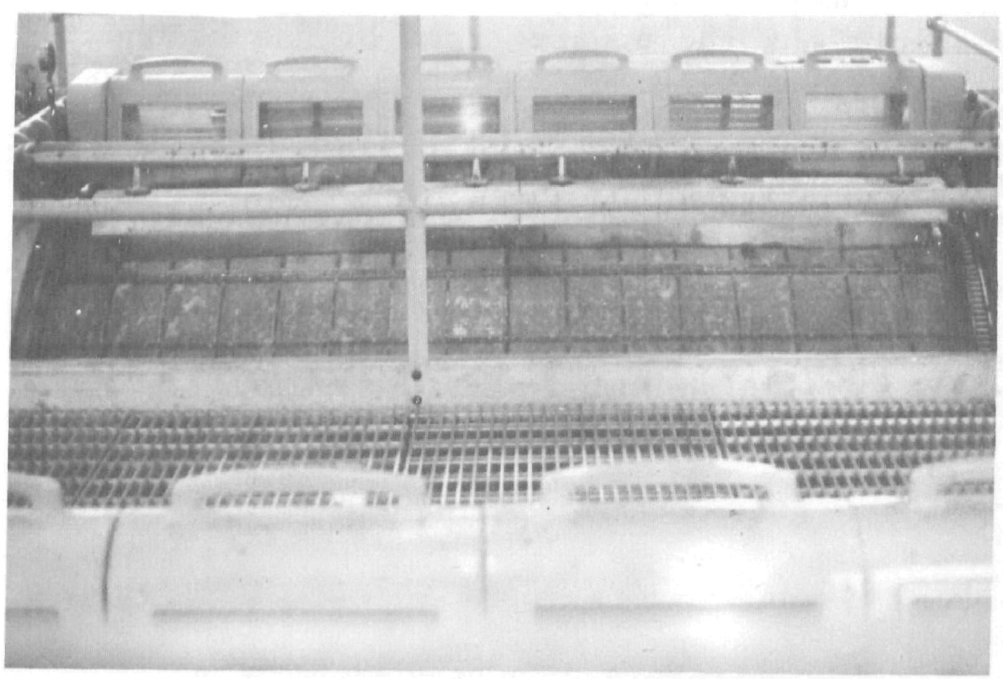

FIGURE 18 - MICROSTRAINERS

This overload could be a result of solids contributed either as suspended or in a colloidal form. The net result would be a greater differential across the screens because the nature and quantity of the suspended solids would blind the screen media. This caused the microstrainer drum to speed up as a means of adjusting solids removal rate. When the drum reaches maximum speed and the differential still exists, a portion of the flow to the microstrainers is automatically by-passed.

It was not within the scope of this study to evaluate tertiary devices with regard to removal of suspended solids. However, we offer the idea that chemical coagulation is a necessary prerequisite to efficient operation of physical tertiary devices for reduction of suspended solids. In our experience, chemical coagulation to resolve colloidal solids prior to the microstrainer application is a necessity at Beavercreek Wastewater Treatment Plant.

Secondary Clarifier BOD

The secondary clarifier BOD_5 (Figure 19) indicates that the BOD effluent from the secondary clarifier was generally in a range of 8 to 18 mg/l. The Beavercreek Wastewater Treatment Plant is no different from most other wastewater treatment plants in that various upsets of the biological process must be dealt with and sludge characteristics will be uncertain. It is therefore desirable to make the treatment process more reliable. It is felt that this is accomplished at the Beavercreek Wastewater Treatment Plant when dosing the flow stream with sodium aluminate.

Figure 19 points out the upward trend of the secondary clarifier effluent BOD in the 22nd and 23rd weeks of the study when sodium aluminate was not being dosed. The most graphic example, however, was in the 41st, 42nd and 43rd (Figure 19) weeks of the study when the sodium aluminate dosing had been discontinued for 10 weeks and secondary effluent BOD escalated to the high 20's and 30's.

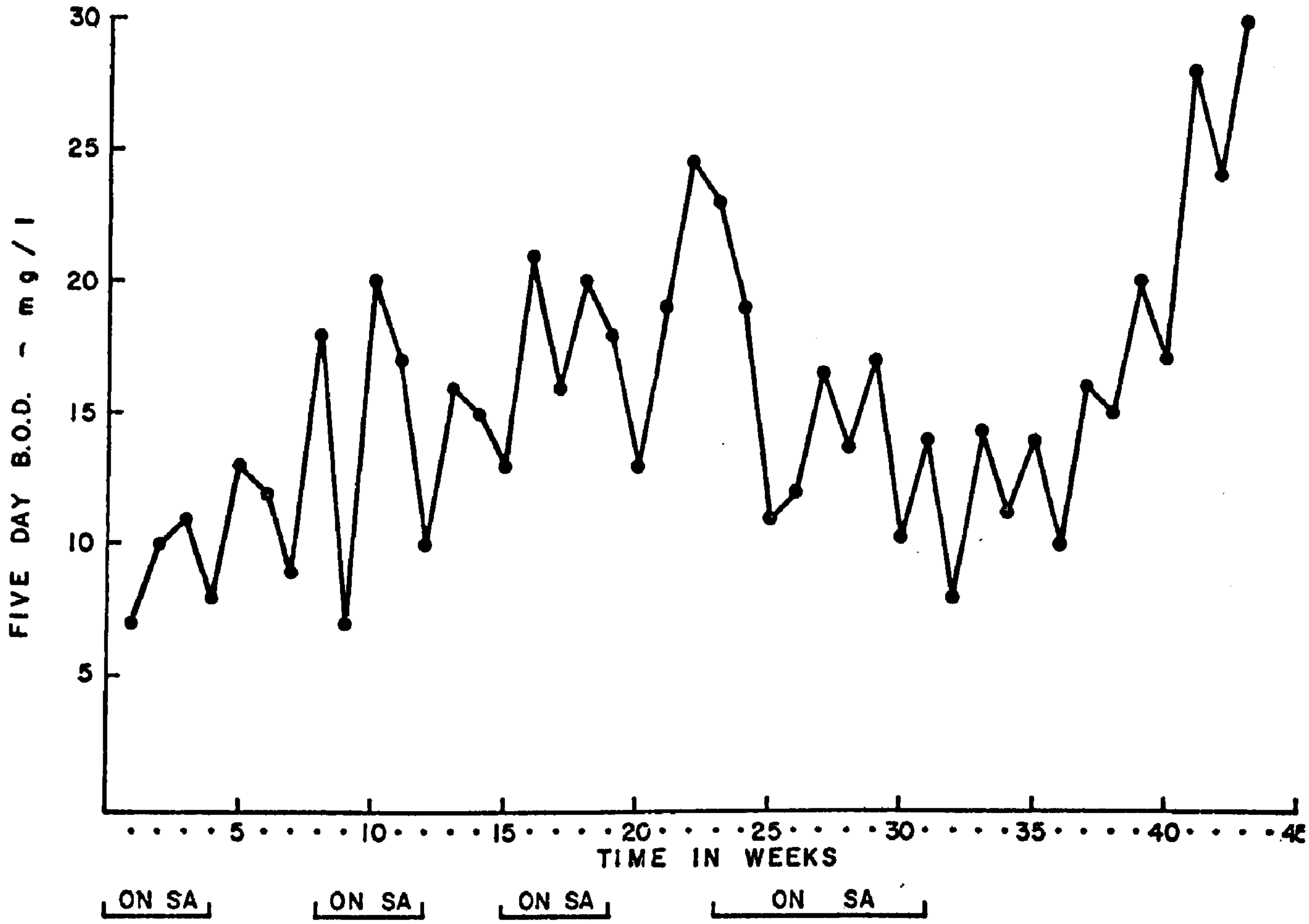

FIGURE 19 - SECONDARY CLARIFIER BOD_5

The significant point that we wish to convey is that it is possible to operate wastewater treatment plants efficiently without coagulants a certain portion of the time. The long-term operation of a secondary treatment plant with effluent BOD and SS in the 10 - 20 mg/l range, sludge volume indexes always below 100 and stabilized mixed liquor masses is difficult to ensure without some type of coagulant addition.

It is the desire of the authors of this study that the information will be valuable to those entities that need a practical alternative to meet the newly-applied National Pollutant Discharge Elimination System regulations. Also we wish to provide information that could be helpful in optimizing existing tertiary operations.

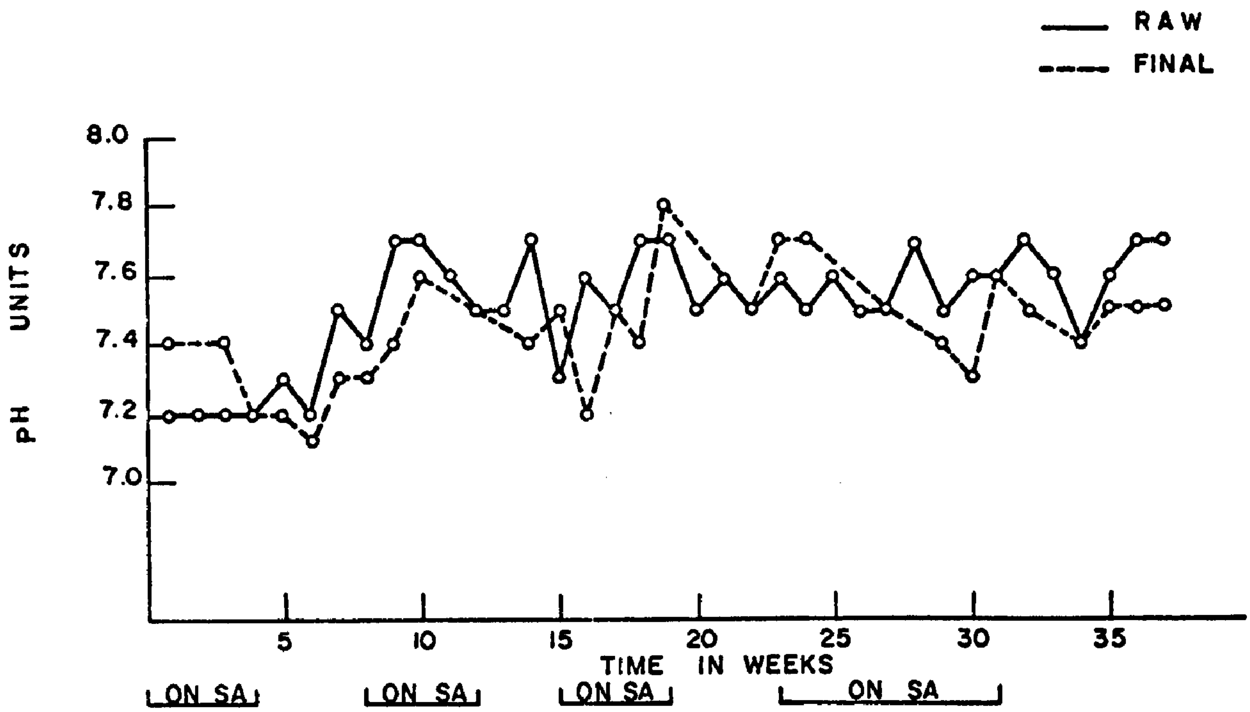

FIGURE 20 - RAW AND FINAL WASTEWATER pH

Overall Plant Performance

Figure 20 indicates that pH values at the Beavercreek Wastewater Treatment Plant are always in an acceptable range for a treatable raw wastewater and a good quality effluent. The raw wastewater and final effluent varied between the pH values of 7.1 and 7.8; therefore, caustic or acid balancing agents are not required.

The raw wastewater, other than having treatable temperature and pH values, also possessed expected domestic wastewater BOD_5 characteristics.

There are the normally expected changes in BOD_5 as Figure 21 shows.

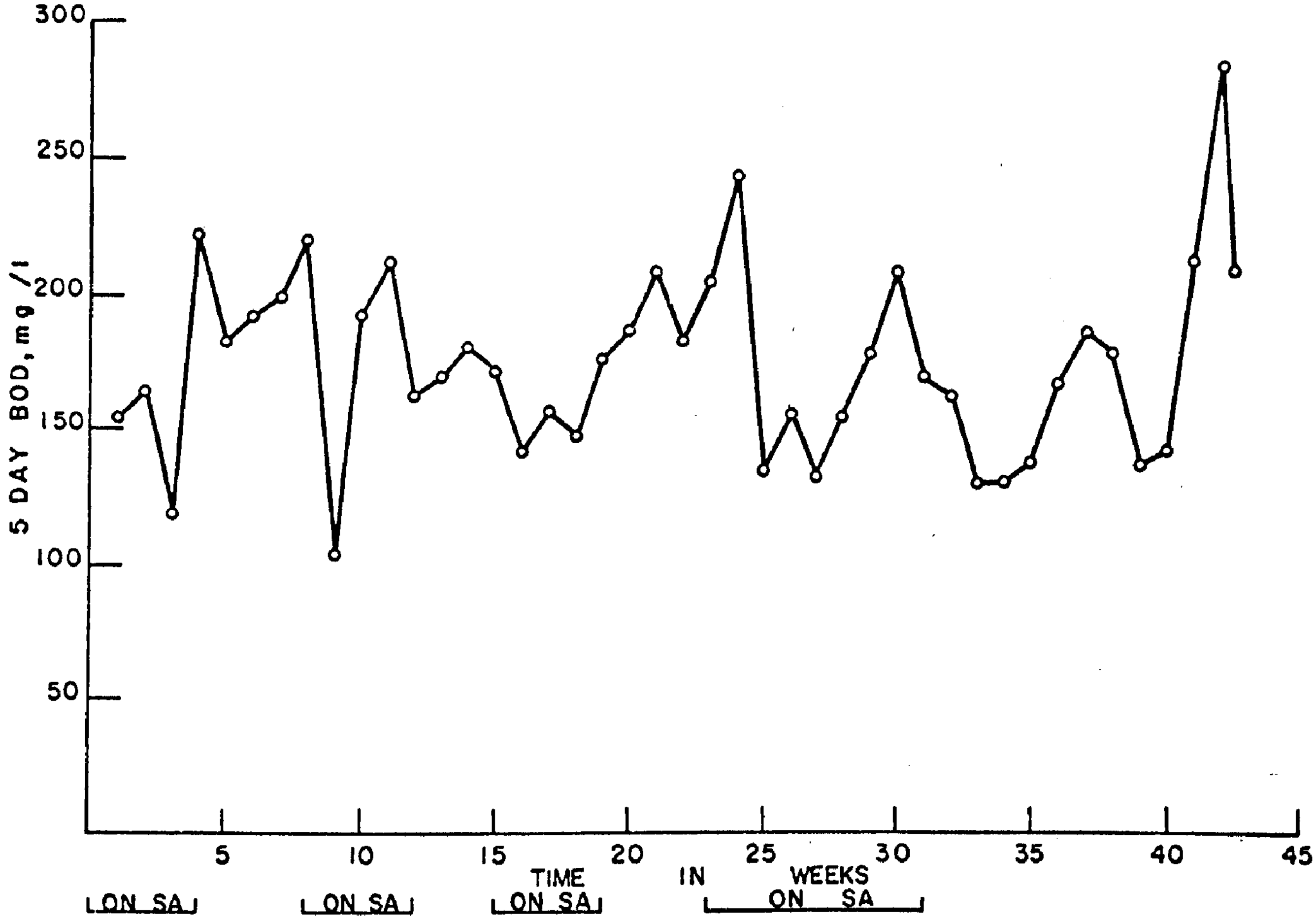

FIGURE 21 - RAW WASTEWATER BOD_5

The curve drawn through Figure 22 indicates that the raw wastewater BOD can be expected to be in a range of 160 to 180 mg/l. The only requirements necessary to adjust for the peaks and valleys of Figure 22 are to make air adjustments in the aeration tanks and waste excess activated sludge as required.

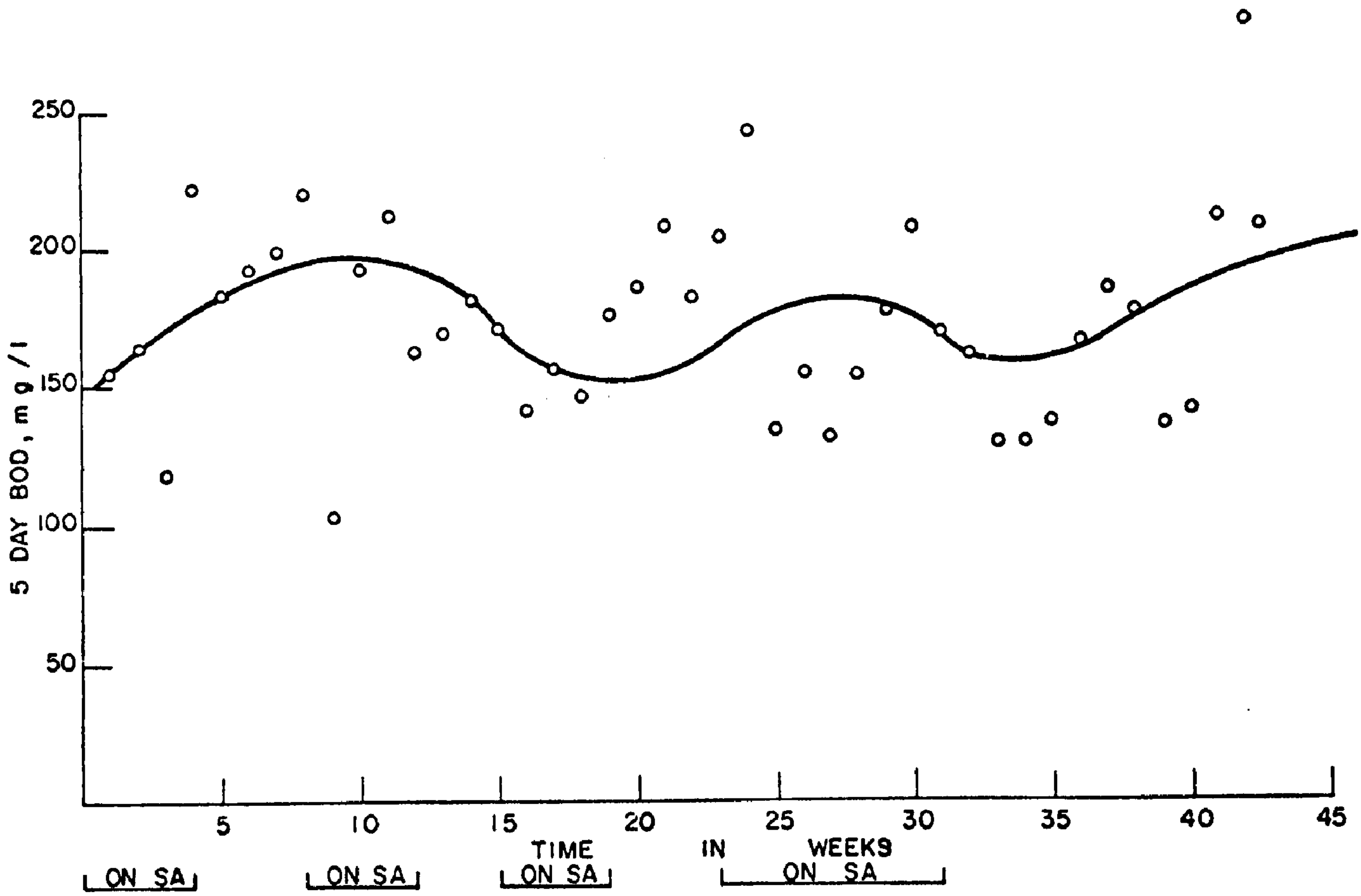

FIGURE 22 - RAW WASTEWATER BOD_5 AVERAGE CHARACTERISTICS

Figure 23 indicates the plant effectiveness of percent removal of BOD. It is difficult to draw exact conclusions from this study concerning the additions of coagulant aids in relation to BOD removals. Varying factors, such as sludge age, incoming BOD strength, MLSS concentrations, temperature and flow affect the degree of oxidation of organic matter. Figure 23 shows that during the study period 63% of the weekly averages of BOD removals were 90% greater. The few times that removals were below 85% were during weeks that sodium aluminate was not fed to the waste stream.

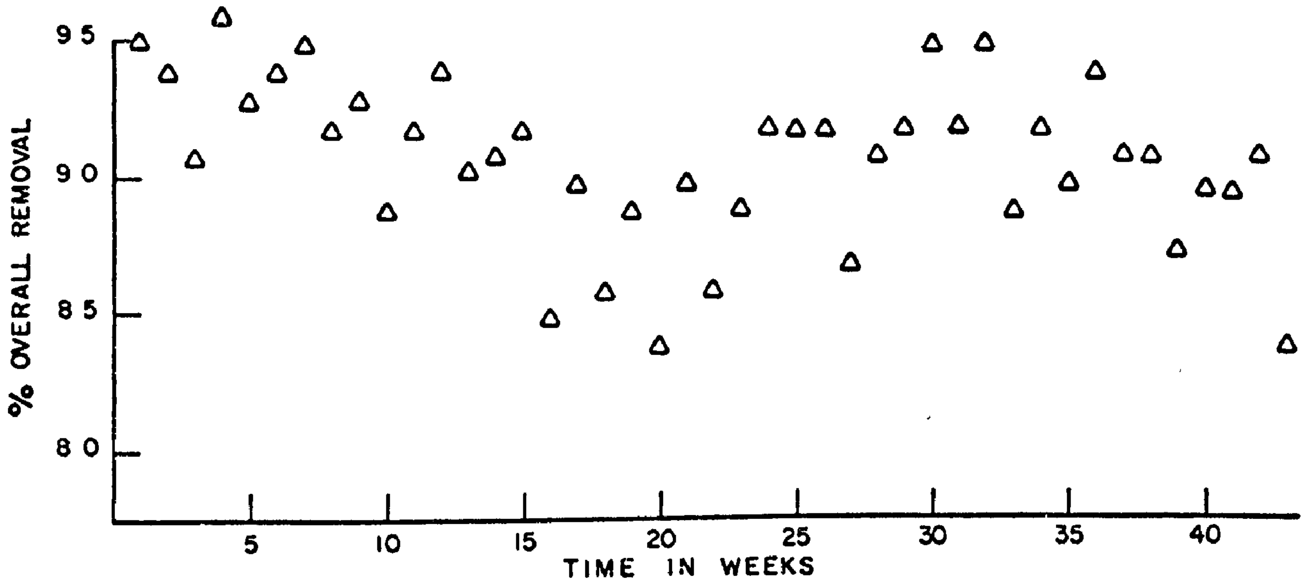

FIGURE 23 - PERCENT BOD REMOVAL

Figures 24 and 25 trace the plant performance characteristics through the nitrogen cycle. The average ammonia reductions (Figure 24) were 61.6 percent during the study.

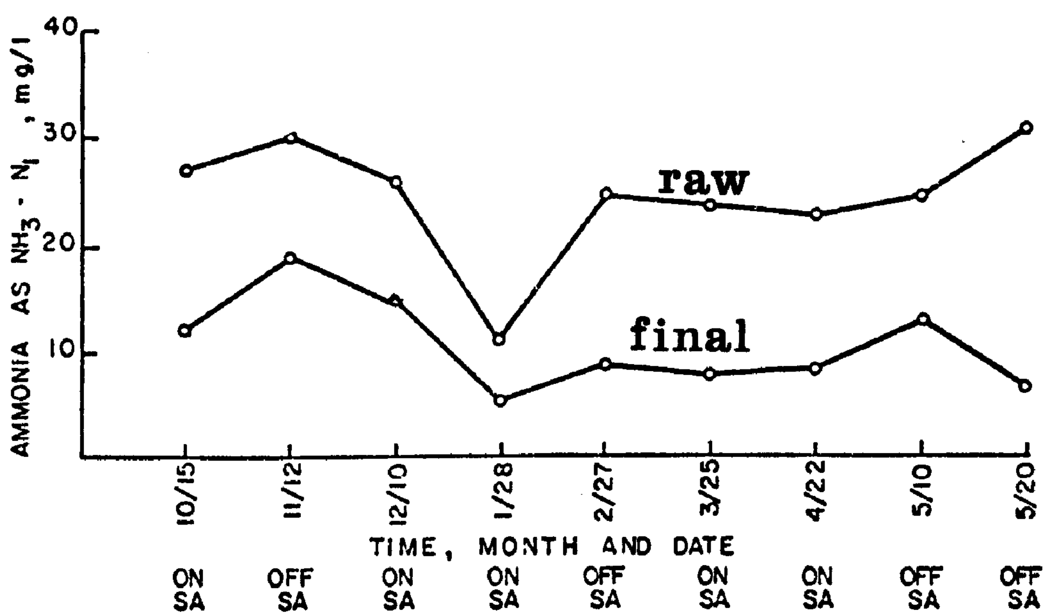

FIGURE 24 - ANALYSIS OF AMMONIA NITROGEN, RAW & FINAL

Nitrification was always achieved as Figure 25 also points out. Nitrate nitrogen (Figure 25) shows that the secondary clarifier NO_3-N varied between 0.9 and 45 mg/l. Nitrification could be accomplished at all times with the degree of nitrification depending on length of aeration time as well as dissolved oxygen available.

The sodium aluminate additions have no apparent effect on either the ammonia reduction or nitrification.

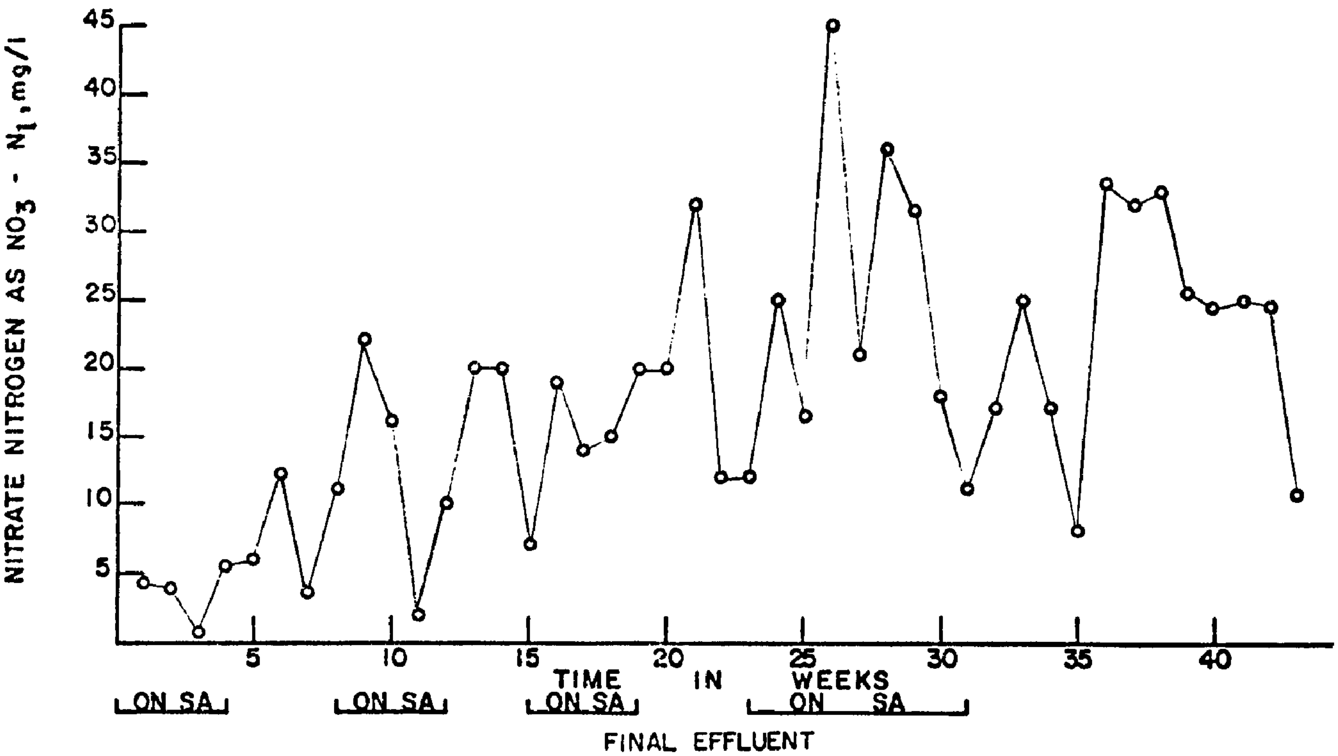

FIGURE 25 - ANALYSIS OF NITRATE NITROGEN, NO_3-N

Aerobic Sludge Digestion

The Beavercreek Wastewater Treatment Plant has two aerobic sludge digesters (Figure 26). The addition of sodium aluminate has been helpful in the aerobic digestion process.

Previous to alumina additions to the plant flow, it was impossible to produce any quantity of low solids and low BOD supernatant. It was found that once the mixed liquor became entrained with the sodium aluminate the waste-activated sludge carried alumina with it to the aerobic digesters and significant benefits to the operation occurred.

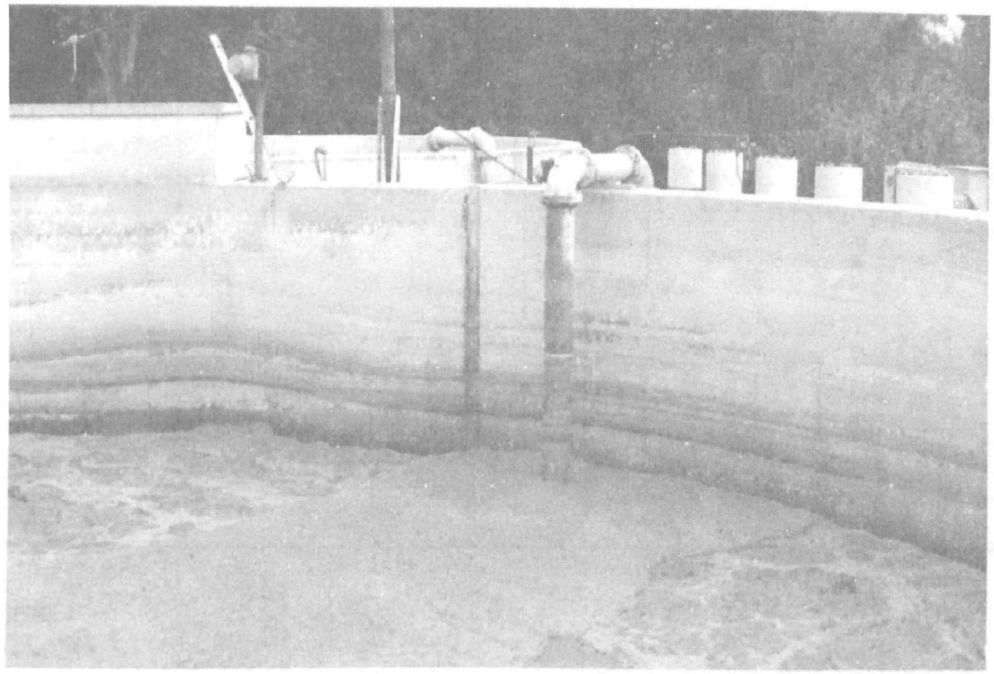

FIGURE 26 - AEROBIC DIGESTION IN SERVICE

The first observation was that high volumes of good quality supernatant became available after initiating sodium aluminate feed. Figures 27, 28 and 29 show that exceptional quantities of low BOD, low suspended solids supernatant were withdrawn from the sludge digestion tanks.

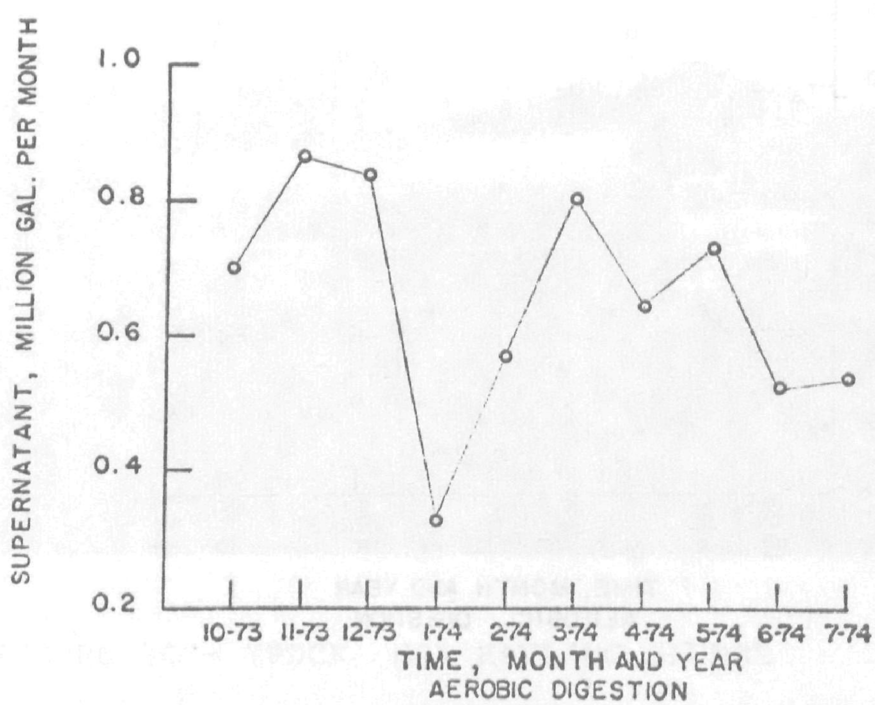

FIGURE 27 - SUPERNATANT VOLUME (GALLONS)

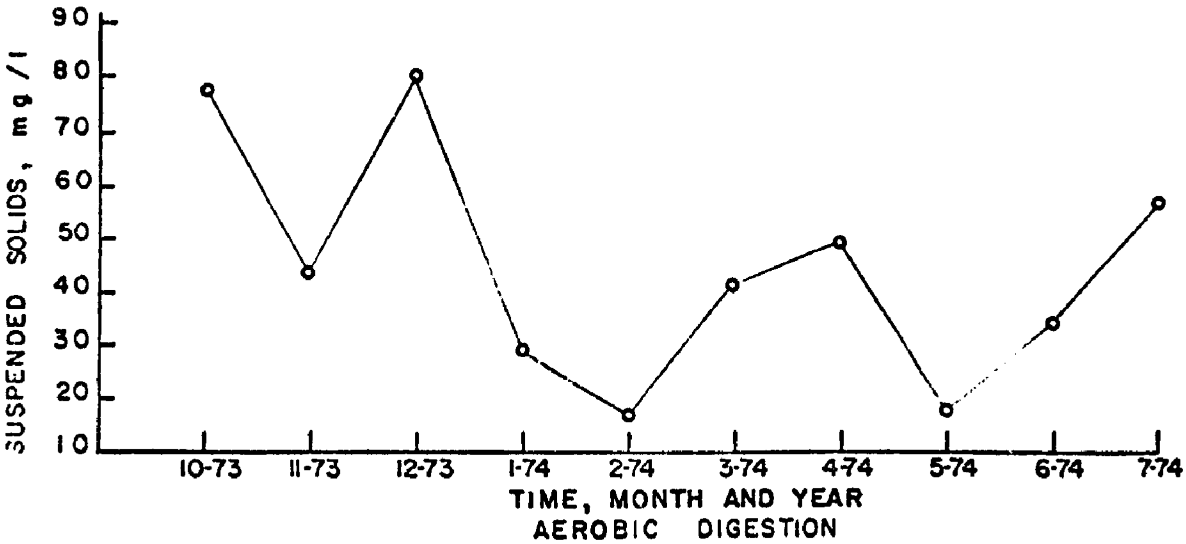

FIGURE 28 - SUPERNATANT SS mg/l

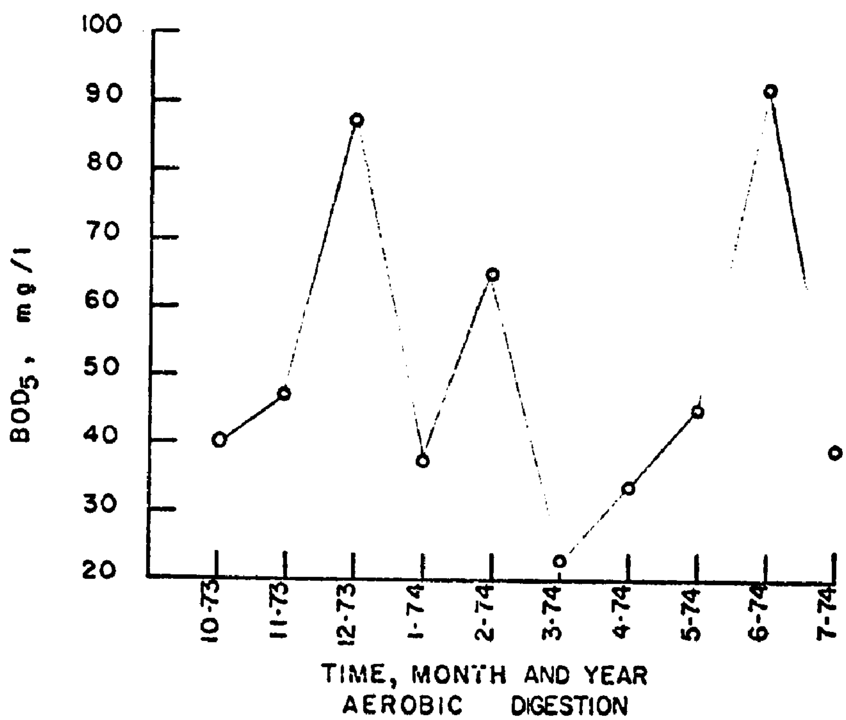

FIGURE 29 - SUPERNATANT BOD mg/l

On a monthly basis, Figure 27 points out that supernatant quantities of 230,000 to 870,000 gallons were drawn. Lower volumes were drawn when carrying low liquid levels in the digesters. Colder temperatures of the digester contents resulted in poorer settling characteristics - and fewer gallons of supernatant drawn. Figures 28 and 29 illustrate that supernatant SS and BOD quality were exceptionally good. Supernatant SS (Figure 28) ranged from 18 to 81 mg/l. Supernatant BOD (Figure 29) ranged from 23 to 92 mg/l.

The limiting factor on the amount of supernatant to be drawn soon became the physical depth draw-off limitations of the digesters. The next benefit that followed the ability to draw supernatant was the thickening of the digested sludge, which ultimately resulted in fewer gallons of digested sludge to be transported for disposal. Since it is within the framework of the Beavercreek Wastewater Treatment Plant and the Greene County Sanitary Engineering Department policy to consider well-digested sludge as a resource, all digested sludge is ultimately applied to the land (Figure 30) in Greene County to be utilized for its soil conditioning ability. Therefore, the ability to haul fewer gallons of sludge becomes important to the plant process as well as reducing the operating costs of the wastewater treatment plant.

FIGURE 30 - TRUCK FOR HAULING SLUDGE

Several alumina analyses were run on the digested sludge. Concentrations of Al_2O_3 varied from 0.2 mg/l to 650 mg/l. The ability to compact the digested sludge remained as there was always alumina available in the digested sludge even though extended no-dose periods were involved. Having digested sludges of 2% dry solids or greater, resulted in lower overall hauling costs of the digested sludge because of fewer gallons to haul to farm land.

Figures 31 through 34 show that the quality of the digested sludge was excellent. The pH was in the range of 7.0 to 7.3, volatile solids between 47 and 58%, and volatile reductions between 47.3 and 65.3%. These are all considered excellent guidelines for a good quality digested sludge.

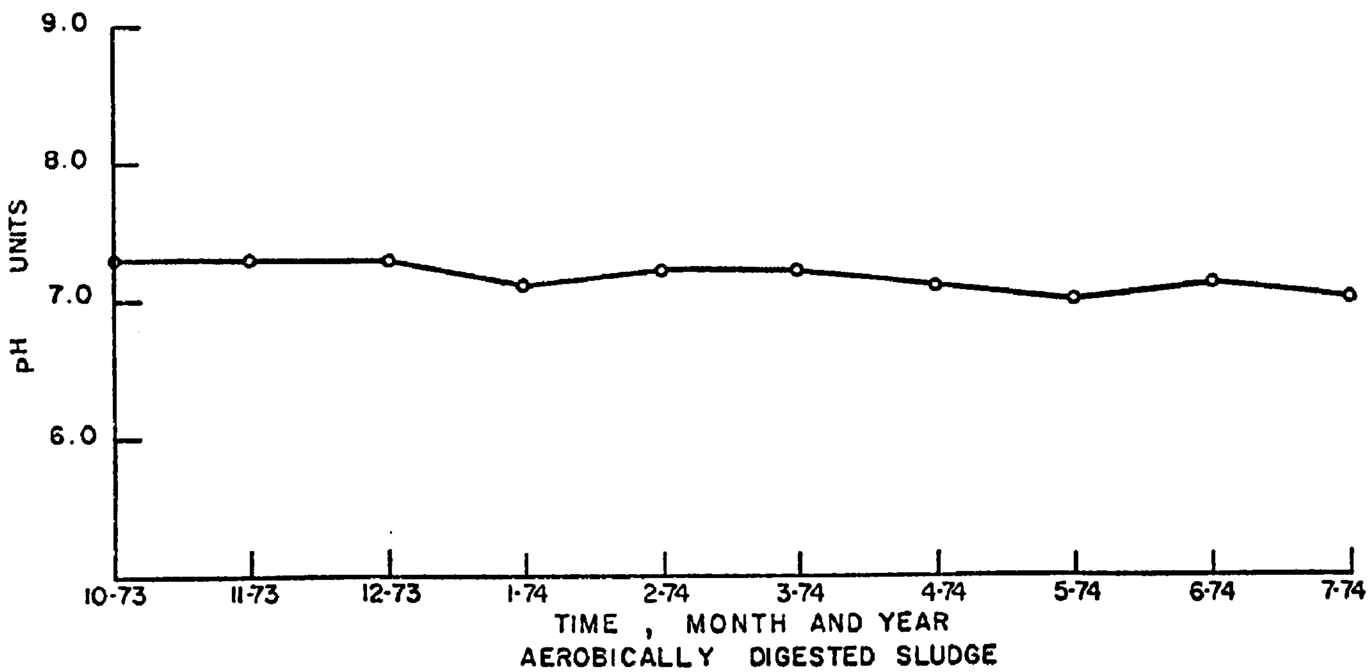

FIGURE 31 - DIGESTED SLUDGE pH

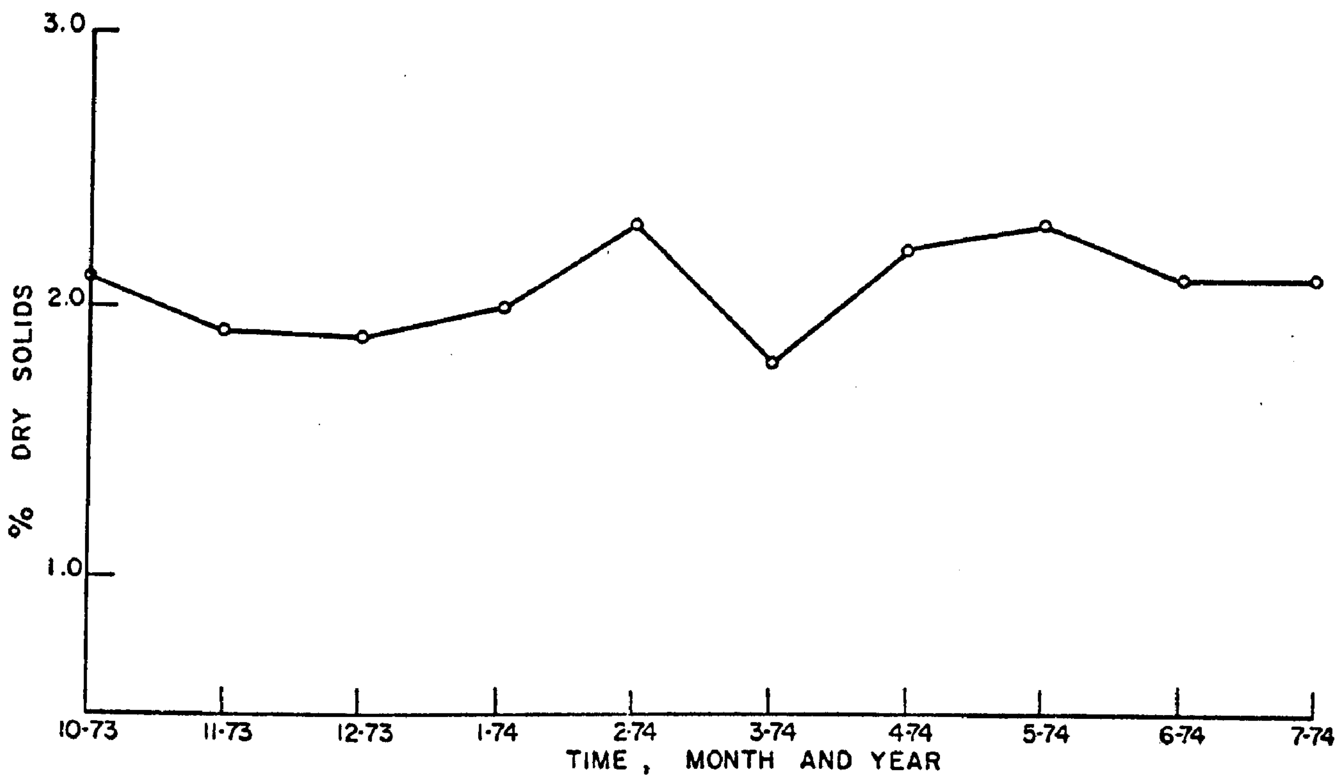

FIGURE 32 - DIGESTED SLUDGE - PERCENT DRY SOLIDS

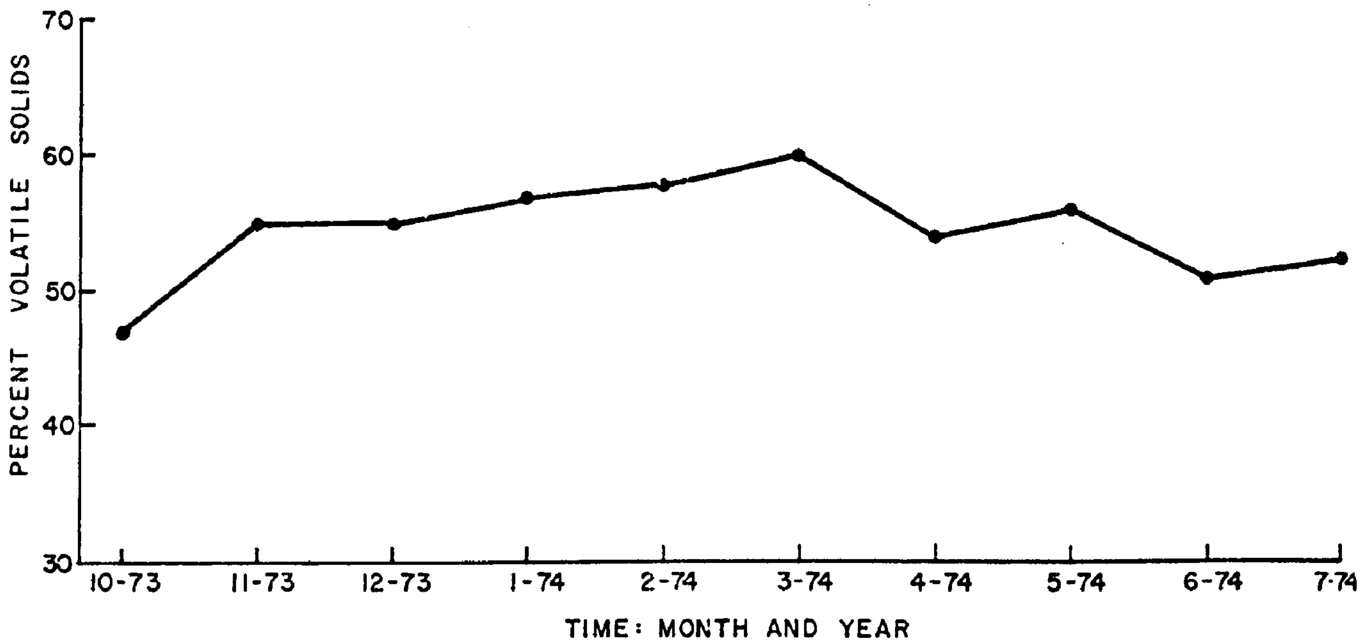

FIGURE 33 - DIGESTED SLUDGE - PERCENT VOLATILE SOLIDS

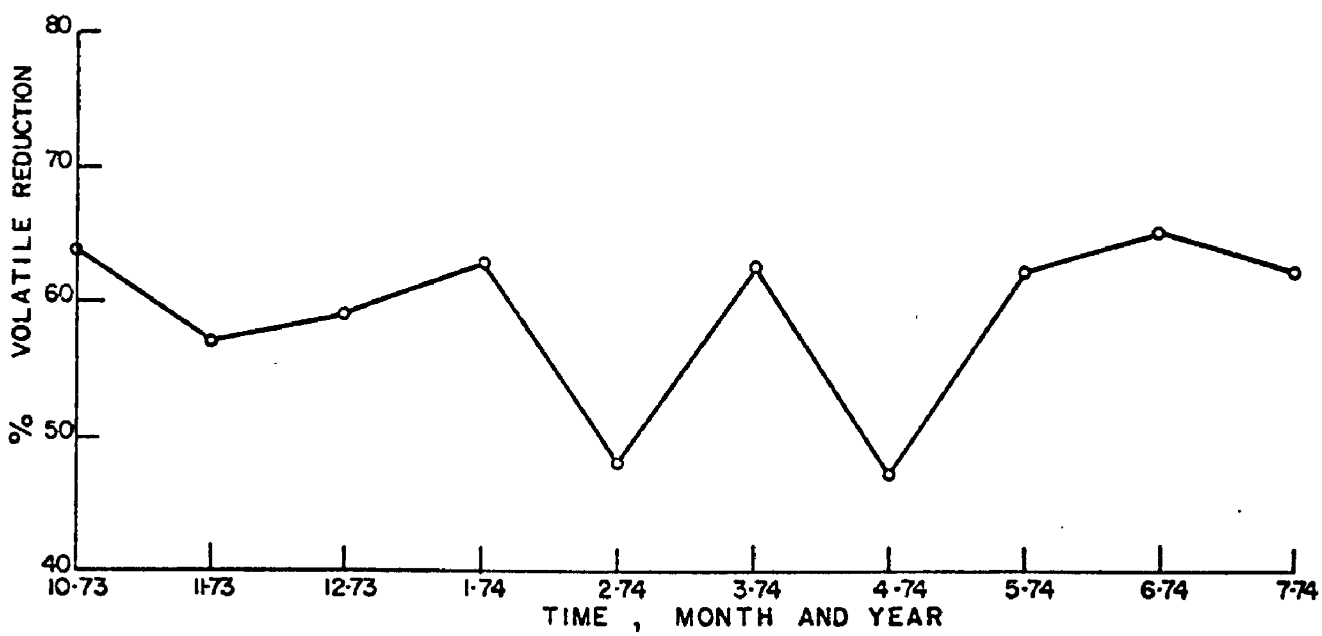

FIGURE 34 - DIGESTED SLUDGE - PERCENT VOLATILE REDUCTION

TABLE 3 - SUMMARY OF DIGESTED SLUDGE DATA FROM GREENE COUNTY BEAVERCREEK WASTEWATER TREATMENT PLANT*

Lab	10-25-73	2-8-74	6-27-74 Primary Digester	6-27-74 Secondary Digester
TKN	N.A.	N.A.	1210	730
NH_3,N	380	530	25.3	26.4
NO_2,N	0.1	N.A.	0.1	0.1
NO_3,N	1.0	N.A.	1.0	1.0
K	69	290	16.5	17.0
P - Total	510	840	330	330
P - Sol.	25	63	103	107
Mg	688	1330	77	87
Mn	N.A.	N.A.	1.0	1.2
Al - Sol. & Insol.	400	650	19	23
Fe - Sol. & Insol.	180	100	N.A.	N.A.
Na	N.A.	N.A.	190	190
Cl	609	359	N.A.	N.A.
SO_3	N.A.	N.A.	250	200
Cu	N.A.	N.A.	.3	.4
Pb	N.A.	N.A.	.5	.5
% Dry Solids	1.43	2.69	1.63	1.44
% Volatile Solids	52	54	58	56
pH	7.3	7.4	6.8	7.2
BOD	3600	5000	N.A.	N.A.
Temp. - °C	22	12	28	29

*Results in mg/l

N.A. - Not Analyzed

Table 3 indicates the many desirable characteristics of the aerobically digested sludge at the Beavercreek Wastewater Plant. The "big three," nitrogen, phosphorus and potassium (potash), are in abundant supply. The rationale for considering this digested sludge as a valuable resource for land disposal is discussed briefly as follows:

Nitrogen - Without nitrogen, plants will be yellowish rather than green. They will be unexpectedly small and sickly. The plants will be yellow because the lack of nitrogen keeps the chlorophyll from being formed. Nitrogen is a part of the material in plant cells. Without nitrogen, plant cells will not be healthy. They are unable to make chlorophyll that will provide the food for the plant.

Phosphorus - Phosphorus plays an important part in the younger, rapidly growing plant material. Without the element phosphorus, a plant does not make the right food chemicals for itself. Again the plant will be small. The plant will, however, be a very dark green. The supply of nitrogen in the plant food builds up because it does not get used as it should.

Potassium (Potash) - Potassium is needed in the root tips and in the growing tip of the stem. Potassium, like phosphorus, is needed for healthy growing plant material. Plants without potassium have spotted leaves and the edges of the leaves turn brown. The oldest leaves will turn brown first. Potassium is also important in forming the flower and, therefore, the fruit of the plant.

At the Beavercreek Wastewater Treatment Plant the final operation in the solids-handling section of the plant is the land application of liquid sludge. There is no other single portion of the operation as important as the liquid sludge hauling for land application.

Utilizing land application of the liquid sludge first depends on the quality of the sludge. Correctly digested, the sludge does not carry offensive odors, pathogens or other negative characteristics. The next step in making privately-owned land available for sludge utilization is selling the fact that the sludge is a valuable resource to the land owner. The last consideration is the proximity to the waste treatment facility of land suitable for liquid sludge assimilation. The application of sodium aluminate to the mixed liquor improved the aerobic digestion process and enhanced Greene County's approach to the consideration of digested sludge as a valuable natural resource.

Advantages Accompanying a Chemical Feed System

Most advantages of a chemical feed system are to be found in the net results of the efficiency of the wastewater treatment plant. Encouraging operators to observe any changes due to chemical additions, usually results in a keener awareness of the fine points of the operation. MLSS concentrations become more closely watched. Sludge volume index changes, and controls over wasting activated sludge are closely scrutinized by all concerned personnel. Reliability of the operation is greatly improved. For treatment plants unable to provide 24-hour a day seven day per week coverage, the addition of sodium aluminate to the mixed liquor serves an important purpose. The frequent adjustments of return sludge rates are not as necessary with a "weighted" mixed liquor mass. Manpower requirements for physical cleaning of chlorine contact tanks are reduced when fewer solids escape the secondary clarifier due to sodium aluminate additions. Actual chlorine requirements were also reduced by 50% when fewer biological solids escaped the secondary clarifier, making the "kill" requirement for disinfection lower.

Plant Personnel

In order to implement a new operational procedure or to modify an existing operational procedure, total cooperation from operating personnel must be developed. It becomes difficult to make recommendations concerning personnel without first knowing the organization. It was our experience that implementing the improved liquid-solids separation with an aluminum compound in an activated sludge wastewater treatment plant study was possible.

Requirements Accompanying a Chemical Feed System

Adequate time must be devoted to assigning various responsibilities of the operating procedure. Collection and processing of data should be as expedient as possible. Maintenance and operation of the chemical feeding system in the case of a chemical feeding operation is essential.

It is believed that all factors must be considered as there are definite liabilities and assets to a chemical feeding system. Consideration must be given to capital costs of the system. Chemicals and freight add expense to the operation. Safety of personnel handling chemicals must be considered, added personnel time to operate and maintain the chemical feeding system is required and the need for additional analysis will increase the load on the laboratory.

Not to be overlooked also is additional administrative and supervisory time for purchasing of chemicals, training personnel and processing adequate records.

In summary we would conclude that adaptation of small wastewater treatment plants to a chemical feed system is feasible. The total situation should be thoroughly evaluated. The benefit of having the ever-present "operator" (sodium aluminate) to improve the operation is considered a cost-effective investment at Greene County's Beavercreek Wastewater Treatment Plant.

Since the sodium aluminate study has been completed, Greene County has decided to dose sodium aluminate to the flow stream on a regular, continuous basis without interruptions in order to comply with NPDES requirements.

SECTION IX

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16. ABSTRACT

Addition of sodium aluminate to a full scale (10,000 m^3/day) activated sludge facility greatly enhanced solids separation processes.

Comparative data for periods with and without chemical dosing are provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Activated sludge process, Phosphorus, Sludge digestion, Settling, Chemical removal (sewage treatment)	Sodium aluminate, Aerobic digestion, Mixed liquor solids, Settleability, Suspended solids, Chemical dosing system, Microstrainer	13B

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