EPA 904/9-76-006

TECHNICAL ASSISTANCE PROJECT
AT THE
OMUSSEE WASTEWATER TREATMENT PLANT
DOTHAN, ALABAMA

January, 1976

Environmental Protection Agency
Region IV
Surveillance and Analysis Division
Athens, Georgia

TECHNICAL ASSISTANCE PROJECT
AT THE
OMUSSEE WASTEWATER TREATMENT PLANT
DOTHAN, ALABAMA

January, 1976

Environmental Protection Agency
Region IV
Surveillance and Analysis Division
Athens, Georgia

CONTENTS

INTRODUCTION

A technical assistance study of operation and maintenance problems at the Omussee Wastewater Treatment Plant (WTP) serving Dothan, Alabama was conducted January 12-16, 1976 by the Region IV, Surveillance and Analysis Division, U. S. Environmental Protection Agency. Operation and maintenance technical assistance studies are designed to assist wastewater treatment plant operators in maximizing treatment efficiencies as well as assisting with special operational problems. Municipal wastewater treatment plants are selected for technical assistance studies after consultation with state pollution control authorities. Visits are made to each prospective plant prior to the study to determine if assistance is desired and if study efforts would be productive.

This plant was selected because of difficulty in achieving design treatment efficiencies. In addition, excessive solids are frequently lost in the effluent. The specific study objectives were to:

- Optimize treatment through control testing and recommended operation and maintenance modifications,
- Determine influent and effluent wastewater characteristics,
- Assist laboratory personnel with any possible laboratory procedure problems, and
- Compare design and current loadings.

A follow-up assessment of plant operation and maintenance practices will be made at a later date. This will be accomplished by utilizing data generated by plant personnel and, if necessary, subsequent visits to the facility will be made. The follow-up assessment will determine if recommendations were successful in improving plant operations and if further assistance is required.

The cooperation of the Alabama Water Improvement Commision is gratefully acknowledged. The technical assistance team is especially appreciative of the cooperation and assistance received from personnel of the Omussee WTP.

SUMMARY

The Omussee WTP was designed as a 3 mgd activated sludge facility with flexibility to operate in either the conventional, tapered aeration, step feed or contact stabilization modes. The plant serves a population of about 30,000 and industrial sources, primarily slaughterhouses, which account for approximately 30 percent of the plant flow.

The dissolved oxygen concentrations were critically low in the aeration basins and excessively high in the aerobic digester. Large air leaks were observed in the air line to the diffusers. Presently, air is supplied uniformly to all basins. These low dissolved oxygen concentrations contributed to reduced treatment efficiencies.

Sludge is wasted to the aerobic digester on a batch rather than continuous basis. Conditioned digester sludge is pumped to the drying beds on an infrequent schedule controlled by available drying bed space. The digester is refilled with waste sludge which is batch conditioned until drying bed space again becomes available and this process results in the following problems.

Although 100 percent of the settled sludge is returned to the aeration basins, settleability tests and visual observations indicated a young, poor settling sludge. The young sludge resulted from excessive solids lost in the final effluent. The poor settleability of the sludge results in reduced treatment efficiency.

The plant has recently obtained sophisticated analytical equipment which will necessitate additional training for the quantity and type of analytical work to be performed.

RECOMMENDATIONS

Based on observations and data collected during the study, it is recommended that the following measures be taken to improve treatment and plant operation:

- The leak in the air line to the diffusers should be repaired immediately.
- Dissolved oxygen should be monitored throughout the aeration basin and aerobic digester.
- Air supplied to the aeration basins and aerobic digester should be regulated such that a uniform dissolved oxygen concentration of approximately 2 mg/l is maintained in both units.
- Sludge should be wasted to the aerobic digester on a continuous schedule.
- The scum decant unit should be modified with a baffle across part of the basin to prevent short circuiting and around the supernatant discharge pipe to prevent scum discharge.
- The sludge age should be increased to improve settleability. This could be accomplished by the addition of polymers to reduce solids lost in the effluent and/or pumping of digester sludge back to the aeration basin.
- Clarifier effluent weirs should be kept clean.
- A chlorine residual must be maintained in the final effluent.
- Sludge should be pumped out of the chlorine contact chamber as often as necessary to prohibit anaerobic conditions and excessive chlorine demands.
- Laboratory personnel need additional training in laboratory procedures and techniques.
- Trend charts of key parameters should be maintained.

Contingent on the success of the above recommendations, additional long range suggestions include:

- Additional sludge drying beds should be constructed.

- Blocking off the outside clarifier effluent weir may improve settling in the clarifier.

TREATMENT FACILITY

TREATMENT PROCESSES

A schematic diagram of the 3 mgd Omussee WTP is presented in Figure 1. Design data are enumerated in Table I. The activated sludge WTP began operation in February, 1971, serving an approximate population of 30,000 and industrial sources, primarily slaughterhouses, which account for approximately 30 percent of the plant flow. Design of the plant is flexible with the capability of operating in a number of activated sludge operational modes, e.g., conventional, tapered aeration, step feed, and contact stabilization.

All influent wastewater enters the plant by gravity, flows through a comminutor and bar screen and then is pumped to the aerated grit chamber by three 40 hp, variable speed pumps. Wastewater flows through the remainder of the plant by gravity.

The aeration basin was operated as a conventional (plug flow) activated sludge system during the study. Diffused air is supplied to the aeration basins and aerobic digester by three 200 hp blowers, one of which was out of service at the time of the study. Return sludge is pumped back to the head of the plant and mixed with raw wastewater in the aeration basin influent channel.

Waste sludge is conditioned in an aerobic digester prior to discharge to sludge drying beds. Filtrate from the sludge drying bed flows back to the influent line and mixes with the raw influent wastewater.

Clarifier effluent is chlorinated in the chlorine contact chamber. Chlorinated effluent flows over a three foot rectangular weir and through a pipe for approximately 200 yards to where it is discharged to a swampy area adjacent to Omussee Creek.

PERSONNEL

The plant staff consists of 12 persons including 2 operators, 2 laboratory technicians, 3 assistant operators, and 4 helpers. Four of the operators are certified; two are Class IV and two are Class III. The plant is manned 24 hours per day, 7 days per week.

FIGURE 1
OMUSSEE WASTEWATER TREATMENT PLANT
DOTHAN, ALABAMA

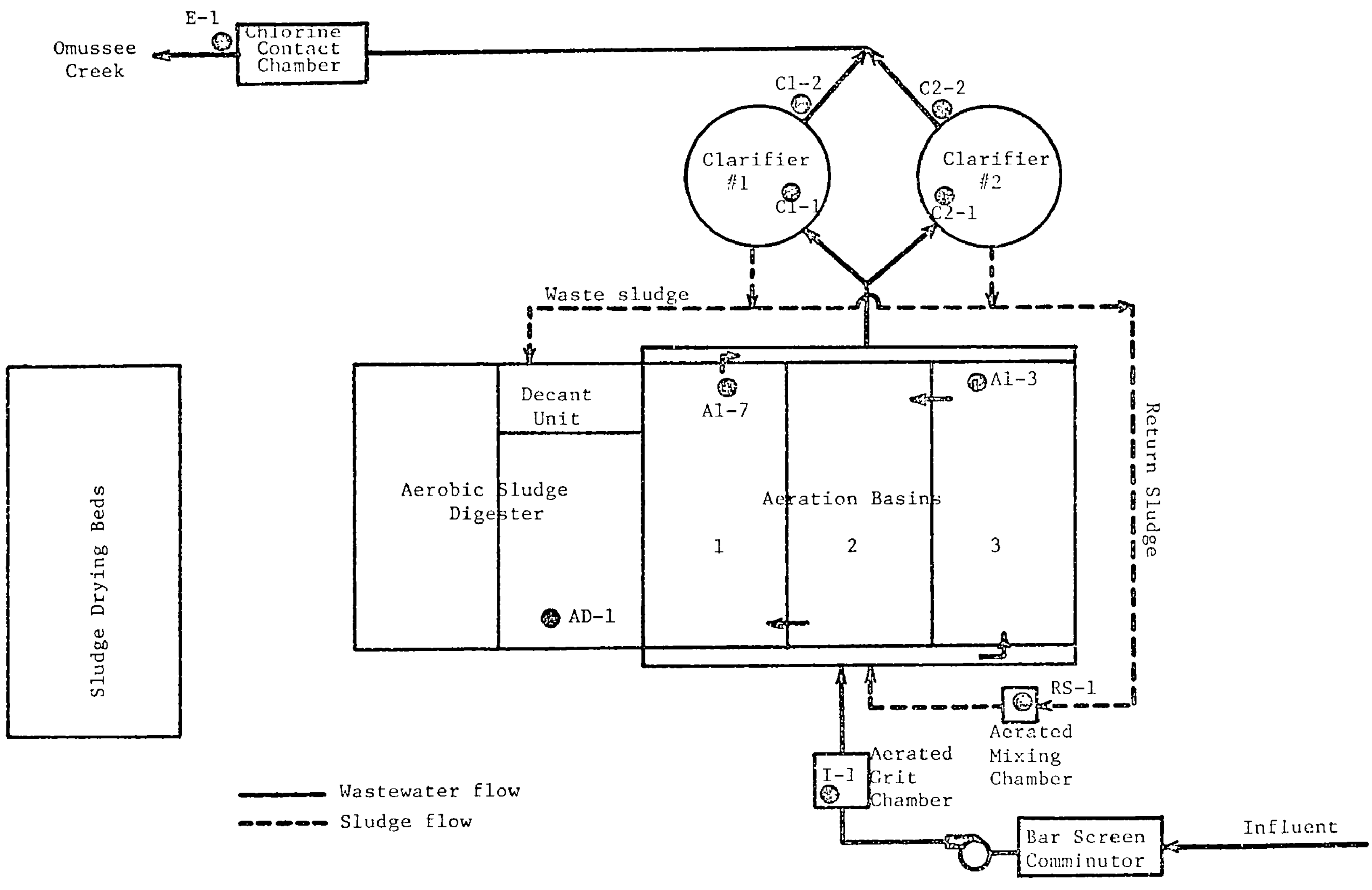


TABLE I
DESIGN DATA
OMUSSEE WTP
DOTHAN, ALABAMA

FLOW MEASUREMENT

Type	Rectangular weir, recorder, totalizer
Size	36-in.

AERATED GRIT CHAMBER

Length	18 ft.
Width	18 ft.
Depth	9 ft.
Aerator	Diffused aeration

AERATION BASINS

Number	3
Length	100 ft.
Width	41 ft.
Depth (water)	18 ft.
Volume	73,800 cu. ft. (.552 m.g.)

CLARIFIERS

Number	2
Diameter	60 ft.
Depth (mean)	11 ft.
Area	2,827 sq. ft.
Volume	31,102 cu. ft. (.233 m.g.)
Weir Length	342 ft.

CHLORINE CONTACT CHAMBER

Area	1650 sq. ft
Depth (water)	6 ft.
Volume	9900 cu. ft. (.074 m.g.)
Contact time at design flow	35 min.

AEROBIC DIGESTER

Basins	2
(1) Volume	45,000 cu. ft. (.337 m.g.)
(2) Volume	37,800 cu. ft. (.283 m.g.)
Depth (water)	18 ft.

SLUDGE DECANT UNIT

Basins	1
Volume	4,920 cu. ft. (.037 m.g.)
Depth (water)	12.3 ft.

DRYING BEDS

Number	6
Length	100 ft.
Width	50 ft.
Depth	18 in.

STUDY RESULTS AND OBSERVATIONS

A complete listing of all analytical data and study methods are presented in Appendices A, B and C. Formulae used for general calculations are enumerated in Appendix D. Significant results and observations made during the study are discussed in the following sections.

FLOW

Plant flow was measured with a 36 inch, sharp crested, rectangular weir with end contractions which was equipped with a totalizer and recorder. The weir, installed at the effluent of the chlorine contact chamber, was level and the totalizer and recorder were recording accurately.

Average hourly flow from the plant during the study period is presented in Figure 2. The average flow was 2.94 mgd with mean hourly flows varying from a low of 1.5 mgd to a maximum of 4.0 mgd. Plant personnel stated that wet weather flows exceed 6.5 mgd because of infiltration. When wet weather flows exceed 6.5 mgd they are bypassed. The annual average daily flow during 1975 was 3.03 mgd.

Approximately 30 percent of the total plant flow was industrial wastewater, primarily from slaughterhouses, which operate 5 days a week.

Flow from the aeration basin was split and discharged into two clarifiers. A magnetic flow meter, with recorder and totalizer, monitored the individual influent flows.

Activated sludge from the final clarifiers was returned to the head of the plant at an average rate of approximately 3.1 mgd and was measured with a magnetic flow meter, recorder, and totalizer.

WASTE CHARACTERISTICS AND REMOVAL EFFICIENCIES

Table II presents a chemical description of the influent and effluent with calculated percent reductions. Analyses were made on 24-hour composite samples. Presented is an average of all data during the study.

FIGURE 2
FLOW AND pH

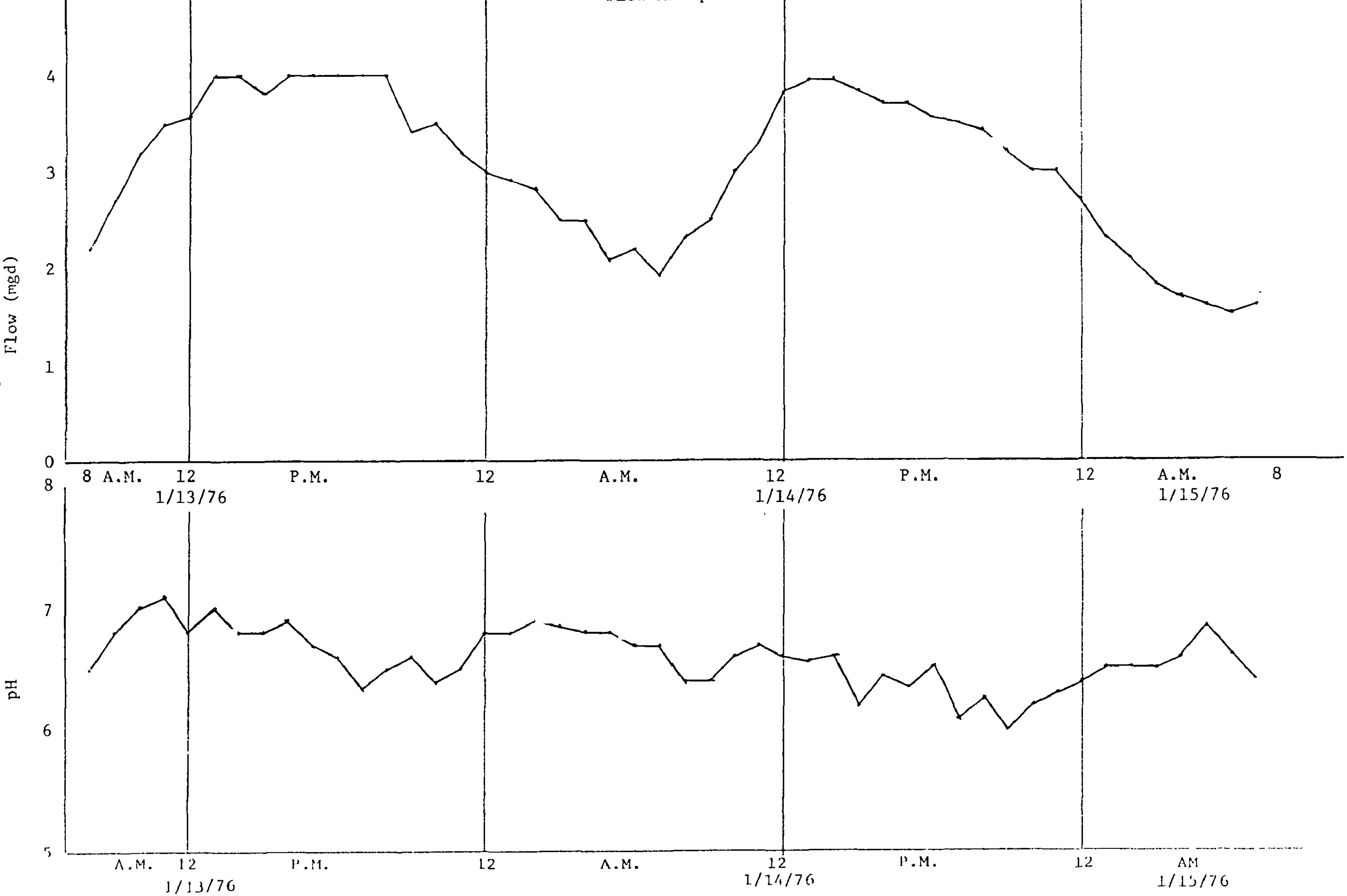


TABLE II
WASTE CHARACTERISTICS AND REMOVAL EFFICIENCIES

Parameter	Influent	Effluent	% Reduction
BOD_5 (mg/l)	245	52	79
COD (mg/l)	320	222	31
Suspended Solids (mg/l)	250	132	47
Total Solids (mg/l)	620	381	38
NH_3-N (mg/l)	15.3	15.8	--
NO_3-NO_2-N (mg/l)	*<.01	<.01	--
Total Phosphorus (mg/l)	7.1	6.0	15
Pb (μg/l)	<50	< 50	--
Cr (μg/l)	**<80	< 80	--
Cd (μg/l)	<20	< 20	--
Cu (μg/l)	67	35	48
Zn (μg/l)	426	164	62

* Was .09 mg/l one day
** Was 95 μg/l one day

DISSOLVED OXYGEN

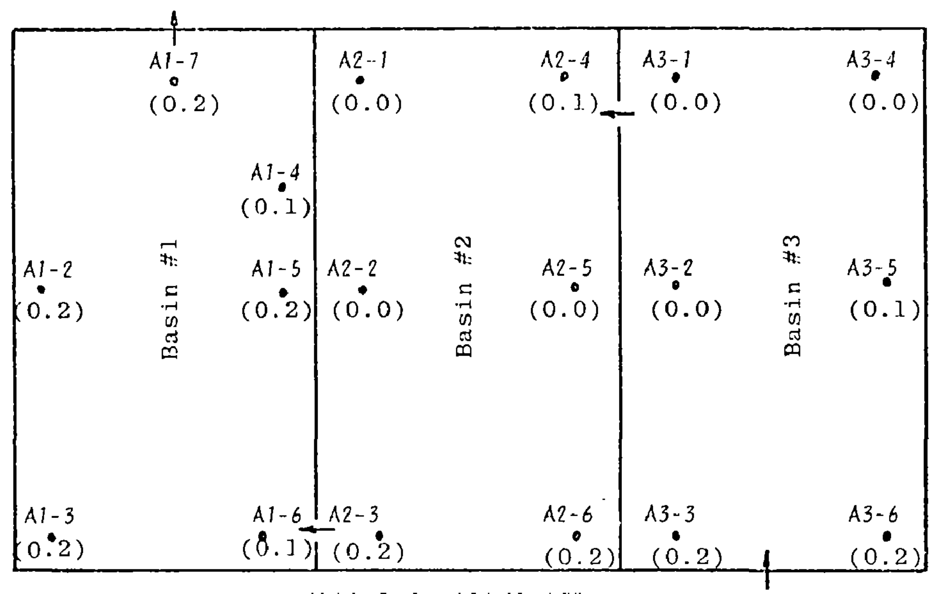
A complete listing of dissolved oxygen (DO) concentrations throughout the plant is presented in Appendix B. On January 14, the following DO concentrations were observed.

Raw Influent Wastewater	0.2 mg/l
Aerated Grit Chamber	0.7 mg/l
Aeration Basin (mean)	0.1 mg/l
Final Clarifiers (mean)	0.1 gm/l
Final Effluent	7.5 mg/l
Aerobic Digester	10.2 mg/l

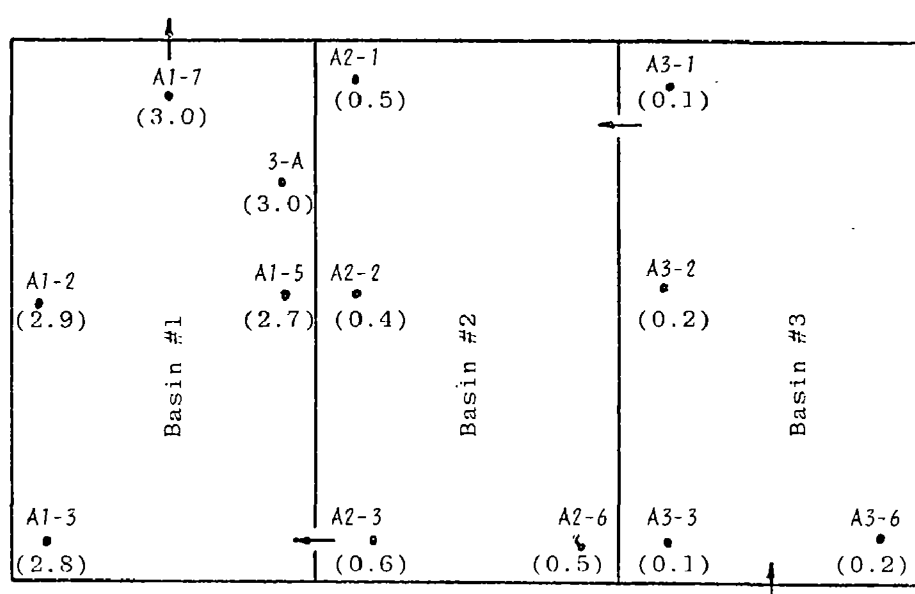
Dissolved oxygen concentrations measured throughout the plant were critically low except in the effluent following the chlorine contact chamber. Higher DO concentrations were measured in the effluent due to aeration in the pipe line from the clarifiers to the chlorine contact basin. The DO in all three aeration basins ranged from 0.0 to 0.3 mg/l and was uniform with depth (see Figure 3).

On January 15, the air supplied to the aeration basins was increased, and the resulting mean DO concentrations in Basins 1, 2, and 3 increased to 2.9, 0.5, and 0.2 mg/l, respectively. The greatest oxygen demand was exerted in Basin #3 where the raw, incoming flow entered. A lesser demand in the following basins resulted in increased DO concentrations (see Figure 3). A more efficient method of aeration would be to taper the air supplied to the aeration basins by increasing air to Basin #3 and gradually decreasing air in successive basins.

FIGURE 3
AERATION BASIN DISSOLVED OXYGEN



BEFORE INCREASING AIR



AFTER INCREASING AIR

() - Dissolved oxygen concentration in mg/l

The DO concentration measured in the aerobic digester was always greater than 8 mg/l throughout the study period. This condition resulted from both excessive air supplied to the digester and the oxidized condition of the sludge. Air supplied to the digester should be adjusted to maintain approximately 2 mg/l throughout.

Air was furnished to the aeration basins and aerobic digester by two 200 hp blowers; the third 200 hp blower was out of service during the study. The total average air flow during the study was 10,132 cubic feet/minute (cfm); however, a large air leak reduced the amount actually reaching the basins.

These results indicate a poor balance of air distribution in the aerobic digester and aeration basins. Adjustment of the diffusers to maintain an approximate DO concentration of 2 mg/l is critical to efficient plant operation.

GRIT CHAMBER

Aeration is accomplished by air diffusers. The hydraulic detention time is approximately 10 minutes at the average design flow of 3 mgd.

According to plant personnel, the only problem with the grit chamber is insufficient bottom slope to efficiently collect and remove grit. Consequently, significant quantities of grit enters the aeration basin.

AERATION BASINS

Grab samples were taken at the point of discharge from the aeration basin (Station A1-7) and at an intermediate point in the aeration basin (Station A3-1). Samples were analyzed for total suspended solids (TSS), volatile suspended solids (VSS), percent solids by centrifuge, and settleability as determined by the settlometer.

Presented in Table III are various activated sludge operational parameters calculated during the study period and the corresponding recommended values for the conventional activated sludge process. The true sludge age was less than the calculated value of 5.8 days due to the significant loss of solids in the effluent. The activated sludge appeared to be young based on visual observations and sludge settleability. Temporary recycling of digester sludge back to the aeration basin could improve sludge settleability by increasing sludge age.

The excessive return sludge flows observed during the study should have resulted in increased MLSS and sludge age. However, this was not the case, the average TSS of return sludge was 4,880 mg/l (7.5% by centrifuge) of which 82 percent were volatile SS. The return sludge flow rate is maintained fairly constant.

The aeration basin diffusers have a tendency to become clogged with undesirable materials not removed by the bar screen.

TABLE III
ACTUAL AND RECOMMENDED PARAMETERS FOR THE CONVENTIONAL ACTIVATED SLUDGE PROCESS

	Actual	Recommended (5)(6)
Hydraulic Retention Time (hours)	6.6	4-8
Mean Cell Residence Time (days)	6.7	5-15
Sludge Age (days)	5.8	3.5-10
Lbs BOD_5/day/lb MLVSS (F/M)	0.21	0.2-0.4
Lbs COD/day/lb MLVSS	0.27	0.5-1.0
Lbs BOD_5/day/1000 cu. ft.	28	20-40
MLSS	2,598	1,500-3,000
Return Sludge Rate (% of average design flow)	100	15-75
Average Flow (mgd)	3.0	3.0 (Design)

CLARIFIERS

The primary problem in the final clarifier was frequent solids carryover. The average turbidity of the effluent from both clarifiers was 8.2 standard turbidity units (STU) based on four grab samples. Observation of individual hourly samples indicated a high concentration of solids in the effluent from approximately 9 p.m. until 4 a.m. On the evening of January 12, an extremely high concentration of solids were discharged from the clarifiers. According to plant personnel, this excessive discharge of solids occurred two or three times weekly.

Significant quantities of grease balls and algal growths were clogging the V-notch effluent weirs. According to plant personnel, these weirs are usually cleaned daily; however, foul weather occurring prior to the study had hampered the routine.

The addition of a dye to the influent of both clarifiers on three different occasions indicated non uniform flow distribution and short circuiting. Concentrated slugs of dye were observed passing over sections of the weirs in as short a time as 25 minutes.

The actual and recommended hydraulic loading, solids loading and weir overflow rates for final clarifiers following conventional activated sludge wastewater treatment are presented in Table IV.

TABLE IV
ACTUAL AND RECOMMENDED PARAMETERS FOR SECONDARY CLARIFIERS

	Actual	Recommended (2)(3)(6)
Hydraulic Loading (gpd/sq. ft.)	531	400-800
Solids Loading (lbs/day/sq. ft.)	23	20-30
Weir Overflow Rate (gpd/lin. ft.)	4,386	<15,000
Hydraulic Detention Time (hrs.)	3.7	2-3

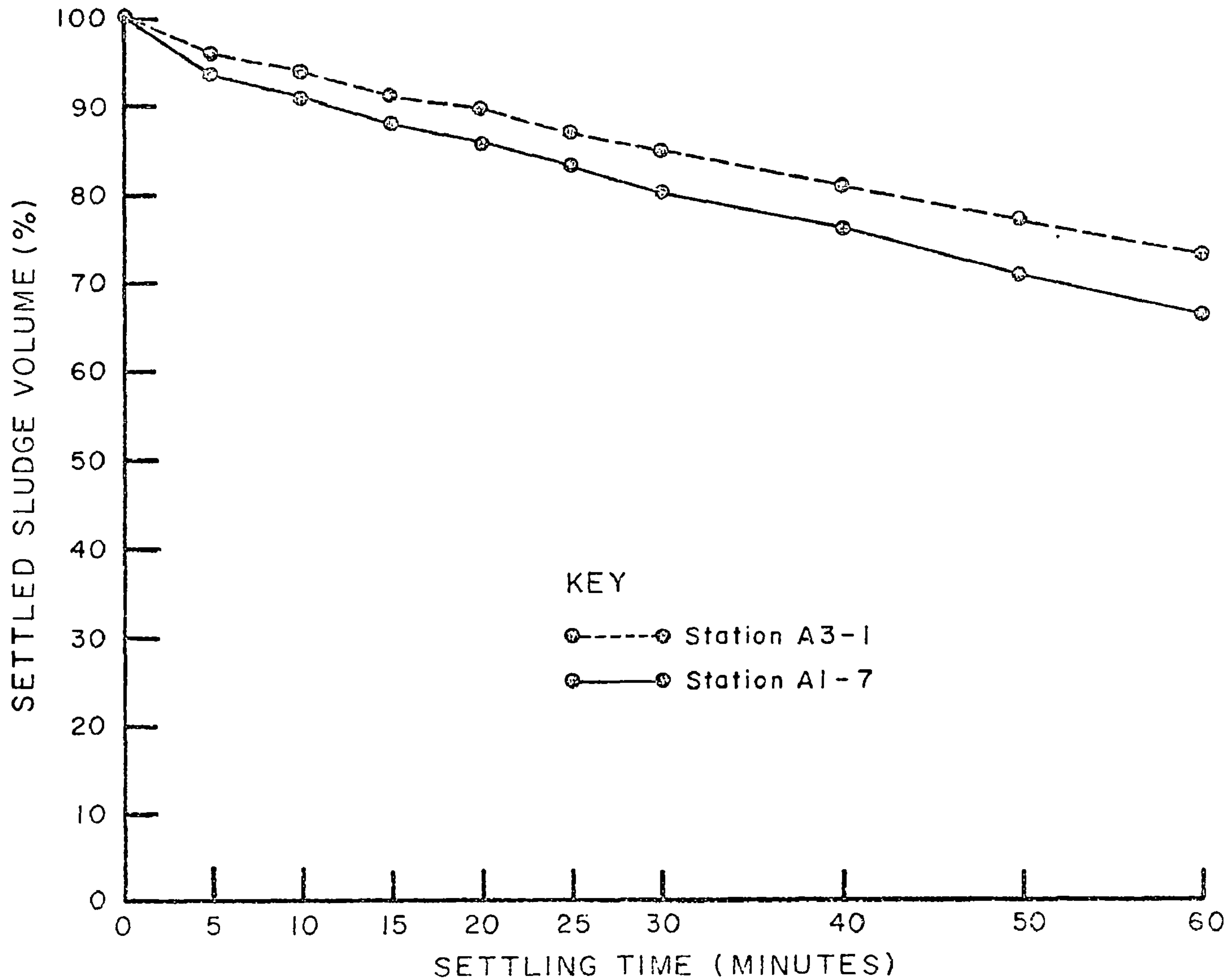
Calculations in Table IV are based on an average flow of 3 mgd. However, from observations of Figure 2, the maximum sustained flow was approximately 4 mgd. Based on a flow of 4 mgd, the hydraulic loading on the clarifier is 708 gpd/sq. ft. during significant periods of the day.

The settlometer test was performed daily on grab samples from stations A3-1 and A1-7 in the aeration basins. Poor settling characteristics were observed from both stations. The sludge settled slowly, was fluffy in appearance, and light brown in color. These are all indications of a young, underoxidized sludge. The settleability of the activated sludge is shown graphically in Figure 4.

Calculated values in Table IV illustrate adequate hydraulic sizing of the clarifiers. Sludge quality and age could be improved by increased aeration in the aeration basin and control of solids carrying over the clarifier weirs. Temporarily adding polymers would help minimize solids lost in the effluent and increase sludge age. As the sludge age increases, settleability should improve allowing regular sludge wasting to the aerobic digester. Polymer addition would then be required only during upsets.

FIGURE 4
SETTLOMETER TEST

Station A3-1 ____________
Station A1-7 ------------



CHLORINE CONTACT CHAMBER

Detention time in the contact chamber was approximately 35 minutes at an average flow of 3 mgd. Chlorine was applied to the influent at the rate of 120 lbs/day. This application rate was not sufficient to produce a chlorine residual in the effluent during the study.

Solids accumulation in the chlorine contact chamber ranged from approximately 0.5 feet at the influent to 1.5 feet near the effluent weir. Bubbling, which is indicative of septic sludge conditions, was also observed in the chamber. Sludge should be pumped from the contact chamber as often as necessary to reduce the chlorine demand.

The dissolved oxygen level throughout the chamber was approximately 7.5 mg/l. Elevation differences between the final clarifier weirs and contact chamber resulted in aerating the wastewater as it flowed to the chamber. This aeration produced a white foam which covered approximately 1/3 of chamber surface.

AEROBIC DIGESTER AND DRYING BEDS

Waste sludge is batch conditioned in the aerobic digester. When space is available on the sludge drying beds, the aerators are turned off, the digester contents allowed to settle and then pumped to the drying beds. To refill the digester a large portion of return sludge is routed to the decant unit for additional thickening and thence to the aerobic digester. The contents of the digester are then aerated until space again becomes available on the drying beds. Plant records revealed that no sludge was wasted from November 1 - December 11, 1975 and December 13, 1975 - January 14, 1976 indicating retention times of 30+ days. Design cirteria for aerobic digesters (5) recommend hydraulic detention times of 16 to 18 days at 20°C.

The average volatile solids content during the study was 69 percent. The high DO (>8 mg/l) in the basins and length of time under aeration (30 days) demonstrated that the cell tissue had been oxidized as far as possible. More efficient use of the digester would be accomplished by continuously wasting the sludge, thereby maintaining a constant oxidation rate.

Continuous wasting would require slight modification of the decant unit. Sludge wasted into the digester would displace supernatant from the decant unit. An existing adjustable pipe should be modified with a collar/baffle to hold back scum but allow supernatant to discharge back to the aeration basin. A section of 10 inch pipe welded to the existing pipe should work satisfactorily. In addition, a baffle across a portion of the unit would be required to prohibit short circuiting.

Discharging sludge to the drying beds is limited by available bed space. Additional drying beds would allow additional solids control in the entire treatment system and subsequent improved overall treatment efficiency. Land is available for additional bed construction.

OXYGEN UPTAKE RATES

General activity of an activated sludge can be determined by comparing oxygen uptake rates (in mg/l per minute) of a return sludge mixed with raw influent (fed) to a return sludge mixed with non chlorinated effluent (unfed). A load ratio can be calculated from this relationship as follows:

$$\text{Load Ratio} = \frac{\Delta\text{DO/min. of fed sludge}}{\Delta\text{DO/min. of unfed sludge}}$$

The procedure and significance of this test are presented in Appendix E.

Presented in Table V is a listing of the oxygen uptake data with a calculated load ratio.

TABLE V
OXYGEN UPTAKE RATES

Date	Time	%RS 1/	FRS 2/	UFRS 3/	Load Ratio
1/13/76	1600	45	1.30	0.55	2.36
1/14/76	1400	45	1.55	0.60	2.58
1/15/76	1400	45	1.46	0.30	4.50

1/ %RS = percent return sludge volume to volume mixed with influent and effluent
2/ FRS = fed return sludge
3/ UFRS = unfed return sludge

The calculated load ratios indicate a readily biodegradable waste and a well acclimated sludge.

LABORATORY

At the time of this study the Omussee WTP laboratory was being expanded to increase analytical capabilities. New equipment had been recently purchased which included such instrumentation as a total organic carbon analyzer and an atomic absorption spectrophotometer. Future plans are for the facility to become a regional laboratory, performing environmental analyses on samples from other sources in the area.

The facility had a control testing routine, however, monitoring of DO in the aeration basins was not included. DO levels in the aeration basins need to be closely monitored to be certain aerobic conditions are maintained. These measurements are best determined by an electronic meter and probe. The WTP has a portable meter with laboratory and field probes; however, there had been some difficulty with the field probe. EPA and plant personnel checked the DO measuring apparatus and found it to be working satisfactorily.

The plotting of control data on a graph is extremely helpful to an operator. These graphs or trend charts reveal increases or decreases of a particular parameter with time. This helps the operator anticipate changing conditions in his plant and make necessary adjustments before a critical situation develops.

Observations of laboratory operations revealed a conscientious attitude of the personnel involved and, in general, techniques were good. Due to the planned expansion of analytical responsibilities, however, it is suggested that training in laboratory instrumentation and procedures be obtained.

REFERENCES

1. "Process Design Manual for Suspended Solids Removal", US-EPA Technology Transfer, January 1975.

2. "Process Design Manual for Upgrading Existing Wastewater Treatment Plants", US-EPA Technology Transfer, October 1974.

3. "Sewage Treatment Plant Design", American Society of Civil Engineers, Manual of Engineering Practice No. 36, 1959.

4. "Standards for Sewage Works", Upper Mississippi River Board of State Sanitary Engineers, Revised Edition, 1971.

5. "Wastewater Engineering", Metcalf and Eddy, Inc., 1972.

6. "Operation of Wastewater Treatment Plants", A Field Study Training Program, US-EPA, Technical Training Grant No. 5TT1-WP-16-03, 1970.

7. "Standard Methods for the Examination of Water and Wastewater", 13th Edition, 1971.

APPENDIX A
CHEMICAL LABORATORY DATA
OMUSSEE WASTEWATER TREATMENT PLANT
DOTHAN, ALABAMA

INFLUENT & EFFLUENT

STATION	MONTH	DAY	YEAR	TIME	Residual Chlorine (mg/l)	Settleable Solids (ml/l)	Turbidity (STU)	BOD5 (mg/l)	COD (mg/l)	Suspended Solids (mg/l)	Volatile Suspended Solids (mg/l)	Total Solids (mg/l)	Total Volatile Solids (mg/l)	NH_3-N (mg/l)	NO_2-NO_3-N (mg/l)	Total-P (mg/l)	Pb (µg/l)	Cr (µg/l)	Cd (µg/l)	Cu (µg/l)	Zn (µg/l)
I-1	1	13/14	76	24-hr comp		4		250	308	275	220	602	329	13.6	.09	7.4	<50	95	<20	70	515
I-1	1	14/15	76	24-hr comp				240	332	225	168	637	364	17.0	<.01	6.8	<50	<80	<20	65	337
E-1	1	13/14	76	24-hr comp		20		45	269	156	112	391	155	17.8	<.01	6.9	<50	<80	<20	40	198
E-1	1	14/15	76	24-hr comp				60	175	108	76	371	124	13.8	<.01	5.1	<50	<80	<20	30	129
E-1	1	14	76	1300	<.05		9.3														
E-1	1	15	76	0900	<.05																

APPENDIX A (cont'd)
CHEMICAL LABORATORY DATA

STATION	MONTH	DAY	YEAR	TIME	Suspended Solids (mg/1)	Volatile Suspended Solids (mg/1)	% Solids by Centrifuge (V/V)	Turbidity (STU)
RS-1	1	13	76	0900	4610	3800	7.0	
RS-1	1	14	76	1315	4720	3900	8.5	
RS-1	1	15	76	1000	5312	4338	7.1	
C1-2	1	14	76	1320	12	11		8.4
C1-2	1	15	76	1000	8	7		7.4
C2-2	1	14	76	1320	4	4		7.3
C2-2	1	15	76	1000	10	10		9.6
AD-1	1	13	76	0900	4600	3100	6.1	
AD-1	1	15	76	1000	4280	3020	5.0	
DB-1	1	14	76	1315	1420	960	2.1	
DB-2	1	14	76	1600	8625	5800	12.2	

APPENDIX A (cont'd)
CHEMICAL LABORATORY DATA

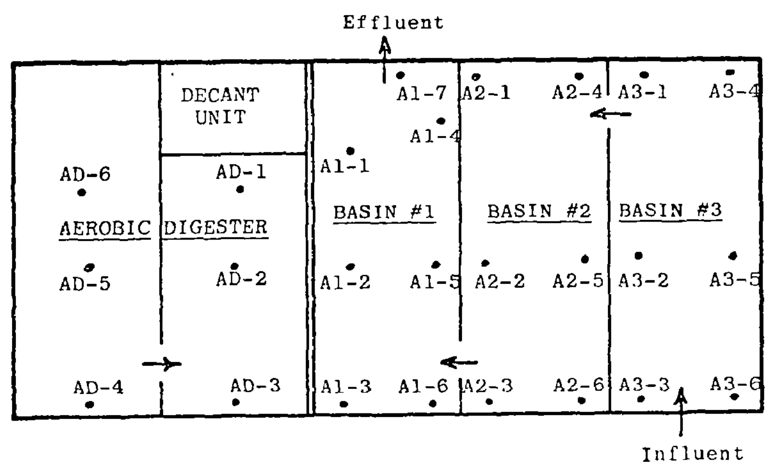
AERATION BASIN

STATION	MONTH	DAY	YEAR	TIME	SETTLOMETER (% SETTLED) 5	10	15	20	25	30	40	50	60	COMMENTS	% Solids by Centrifuge (V/V)	Suspended Solids (mg/l)	Volatile Suspended Solids (mg/l)
A3-1	1	13	76	0900	92	91	91	90	87	85	84	77	74	All tests	3.7	2640	2160
A3-1	1	13	76	1345	92	86	80	74	69	66	61	57	53	during study	3.2		
A3-1	1	14	76	1315	95	90	86	82	78	75	70	66	62	evidenced very	4.0	2650	2160
A3-1	1	15	76	1000	97	95	93	93	91	88	84	84	77	fluffy, young	3.8	2820	2290
A1-7	1	13	76	0900	95	94	94	93	91	90	88	84	82	type sludge	3.5	2360	1880
A1-7	1	13	76	1345	93	90	88	83	80	77	71	66	63	characteristics	3.5		
A1-7	1	14	76	1315	97	96	93	91	87	86	80	77	74		4.0	2580	2100
A1-7	1	15	76	1000	98	95	93	93	91	89	85	85	78		3.3	2540	2180
A1-7	1	15	76	1330	95	93	91	90	88	84	83	73	66		3.7		

APPENDIX B
DISSOLVED OXYGEN[1/]

Basin #	Date '76	Time	Station	Temperature (°C)	1 ft. DO	5 ft. DO	9 ft. DO	15 ft. DO
A1	1-13	1445	2	19	0.3	0.2	0.2	
			3		0.2	0.1	0.1	
			5		0.2	0.2	0.1	
			6		0.2	0.2	0.2	
			7		0.2	0.2	0.2	
A2			1	19	0.0	0.0	0.0	
			2		0.1	0.0	0.0	
			3		0.2	0.2	0.2	
			4		0.1	0.1	0.0	
			5		0.0	0.0	0.0	
			6		0.2	0.2	0.1	
A3			1	19	0.1	0.0	0.0	
			2		0.0	0.0	0.0	
			3		0.2	0.2	0.1	
			4		0.0	0.0	0.0	
			5		0.2	0.1	0.1	
			6		0.2	0.2	0.2	
A1	1-14	1045	3	19	0.2	0.2	0.1	
			4		0.1	--	0.1	
			6		0.2	--	0.1	
A2			4		0.1	--	--	
A3			4		0.1	--	--	
A1	1-15	1400	2	18.5	3.0	3.0	2.7	2.8
			3		2.9	2.8	2.8	--
			5		2.9	2.9	2.5	2.5
			7		3.0	3.0	3.0	3.0
			3-A		3.0	3.0	3.0	3.0
A2			1		0.5	0.5	0.4	0.5
			2		0.6	0.4	0.4	0.4
			3		0.7	0.6	0.6	--
			6		0.6	0.5	0.4	0.4
A3			1		0.1	0.1	0.1	0.2
			2		0.2	0.2	0.2	0.3
			3		0.2	0.2	0.1	0.1
			6		0.2	0.2	0.2	0.2

Basin	Date	Time	Station	Temperature (°C)	1 ft. DO	5 ft. DO	9 ft. DO	15 ft. DO
AD	1-13	1600	1	14	12.5	--	--	--
			3		12.1	--	12.1	--
			4		12.5	--	12.2	--
			6		12.0		12.0	
AD	1-14	1045	1	14	9.6	--	9.6	--
			3		9.4	9.3	9.3	--
			4		8.4	--	8.4	--
			6		8.6	--	--	--
AD	1-15	1530	1	14.5	10.6	10.6	--	10.6
			4		8.4	--	8.4	8.4



A - Aeration Basin
AD - Aerobic Digester

1/ DO concentrations in mg/l

APPENDIX C
GENERAL STUDY METHODS

To accomplish the stated objectives, the study included extensive sampling, physical measurements and daily observations. Plant influent and effluent sample stations I-1 and E-1, respectively, were sampled for two consecutive 24-hour periods with ISCO Model 1392-X automatic samplers. Aliquots of sample were pumped at hourly intervals into individual refrigerated glass bottles which were composited proportional to flow at the end of each sampling period.

Dissolved oxygen was determined initially at all stations throughout the plant and thence daily at stations in the aeration basins and aerobic digester using a YSI model 51A dissolved oxygen meter.

The plant flow totalizer was used to determine total daily flow and the recorder was used for hourly flows. Accuracy of the plant flow recorder and totalizer was checked with instantaneous readings from the effluent weir.

Temperature was recorded while measuring the dissolved oxygen concentration. Individual samples of the two 24-hour compositing periods were used to determine hourly influent pH variation.

Depth of the secondary clarifier sludge blankets were determined daily using equipment suggested by Alfred W. West, EPA, NFIC Cincinnati.

Sludge activity was determined by the oxygen uptake procedure presented in Appendix E.

Samples of sludge discharged to the drying beds were analyzed for suspended solids and volatile suspended solids.

A series of standard operational control tests were run daily:

- Settleability of mixed liquor suspended solids (MLSS) as determined by the settlometer test;
- Percent solids of the mixed liquor and return sludge determined by centrifuge;
- Suspended Solids and Volatile Suspended Solids analysis on the aeration basin mixed liquor and return sludge;
- Turbidity of each final clarifier effluent.

An amperometric titrator (Fischer & Porter Model 17T1010) was used to determine effluent chlorine concentrations.

The procedure for the BOD_5 determination deviated from standard methods (7). Samples were set up and carried in an incubator back to Athens, Georgia for completion of the analyses.

Visual observations of individual unit processes were recorded.

Mention of trade names or commercial product does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

APPENDIX D

Activated Sludge

Formulae Used For General Calculations

Aeration Basin

1. lbs. of solids in aeration basin
   Basin volume = m.g.; MLSS (conc.) = mg/l
   (MLSS conc) x (Basin vol.) x 8.34 = lbs. of solids

2. Aeration basin loading (lbs. BOD or COD/day)
   Inf. flow to aeration basin = mgd
   Inf. BOD or COD = mg/l
   (BOD or COD) x flow x 8.34 = lbs. BOD or COD/day

3. Sludge Age (days)
   MLSS conc. (avg. of daily values) = mg/l
   Aeration Basin Vol. = m.g.
   TSS, Primary Eff. or Basin Inf. conc. = mg/l
   Plant Flow = mgd

$$\frac{(\text{MLSS}) \times (\text{Basin Vol.}) \times (8.34)}{(\text{TSS}) \times (\text{Flow}) \times 8.34}$$

4. Sludge Vol. Index (SVI)
   30 min. settleable solids (avg. of daily values) = %
   MLSS conc. = mg/l

$$\frac{(\%,\ 30\text{ min. set. solids}) \times (10{,}000)}{\text{MLSS}}$$

5. Sludge Density Index (SDI)
   SVI Value $\frac{100}{\text{SVI}}$

6. Detention time (hours)
   Volume of basins = gal.
   Plant flow = gal./day
   Return sludge flow = gal./day

$$\frac{\text{Basin volume} \times 24}{(\text{Flow}) + (\text{Return sludge flow})}$$

7. F/M Ratio (Food/Microorganism) BOD or COD
   Basins Inf. BOD_5 conc. (avg. or daily value) = mg/l
   Basins Inf. COD conc. (avg. or daily value) = mg/l
   Plant Flow = mgd
   MLVSS conc. (avg. or daily value, note Volatile SS) = mg/l
   Basin Vol. = m.g.

$$\frac{(BOD_5\text{ conc.}) \times (\text{plant flow}) \times (8.34)}{(\text{MLVSS}) \times (\text{Basin Vol.}) \times 8.34} = \text{lbs. BOD/lb. MLVSS}$$

$$\frac{(\text{COD conc.}) \times (\text{plant flow}) \times (8.34)}{(\text{MLVSS}) \times (\text{Basin Vol.}) \times (8.34)} = \text{lbs. COD/lb. MLVSS}$$

8. Mean cell residence time (MCRT) = days
   MLSS conc. (avg. or daily value) = mg/l
   Basin vol. = m.g.
   Clarifier vol. = m.g.
   Waste activated sludge conc. = mg/l
   Waste activated sludge flow rate·mgd
   Plant effl. TSS = mg/l
   Plant flow = mgd

$$\frac{(\text{MLSS}) \times (\text{Basin vol.} + \text{Clarifier vol.}) \times 8.34}{(\text{Waste activated sludge conc.}) \times (\text{waste flow}) \times 8.34 + (\text{Plant effl. TSS} \times \text{plant flow} \times 8.34)} = \text{days}$$

Clarifier

1. Detention time = hours
   Plant flow to each clarifier = gals/day
   Individual clarifier vol. = gals.

$$\frac{(\text{clarifier Vol. (each)} \times 24}{\text{Plant flow to each clarifier}} = \text{hours}$$

2. Surface loading rate = gal./day/sq. ft.
   Surface area/clarifier = sq. ft.
   plant flow to clarifier = gal./day

$$\frac{\text{Plant flow to clarifier}}{\text{Clarifier surface area}} = \text{gal./day/sq. ft.}$$

3. Weir Overflow Rate (gal./day/lin. ft.)
   Weir Length = ft.
   Plant flow to clarifier = gal./day

$$\frac{\text{Plant flow}}{\text{Weir length}} = \text{gal./day/lin. ft.}$$

APPENDIX E

OXYGEN UPTAKE PROCEDURE[3]

A. Apparatus

1. Electronic DO analyzer and bottle probe
2. Magnetic stirrer
3. Standard BOD bottles (3 or more)
4. Three wide mouth sampling containers (approx. 1 liter each)
5. DO titration assembly for instrument calibration
6. Graduated cylinder (250 ml)
7. Adapter for connecting two BOD bottles

B. Procedure

1. Collect samples of return sludge, aerator influent and final clarifier overflow. Aerate the return sludge sample promptly.

2. Mix the return sludge and measure that quantity for addition to a 300 ml BOD bottle that corresponds to the return sludge proportion of the plant aerator, i.e. for a 40% return sludge percentage in the plant the amount added to the test BOD bottle is:

$$\frac{300 \times .4}{1.0 + .4} = \frac{120}{1.4} = 86 \text{ ml}$$

3. Carefully add final clarifier overflow to fill the BOD bottle and to dilute the return sludge to the plant aerator mixed liquor solids concentration.

4. Connect the filled bottle and an empty BOD bottle with the BOD bottle adapter. Invert the combination and shake vigorously while transferring the contents. Re-invert and shake again while returning the sample to the original test bottle. The sample should now be well mixed and have a high D.O.

5. Insert a magnetic stirrer bar and the previously calibrated DO probe. Place on a magnetic stirrer and adjust agitation to maintain a good solids suspension.

6. Read sample temperature and DO at test time t=0. Read and record the DO again at 1 minute intervals until at least 3 consistent readings for the change in DO per minute are obtained (Δ DO/min). Check the final sample temperature. This approximates sludge activity in terms of oxygen use after stabilization of the sludge during aeration (unfed sludge activity).

7. Repeat steps 2 through 6 on a replicate sample of return sludge that has been diluted with aerator influent (fed mixture) rather than final effluent. This Δ DO/minute series reflects sludge activity after mixing with the new feed. The test results indicate the degree of sludge stabilization and the effect of the influent waste upon that sludge.

The load factor (LF), a derived figure, is helpful in evaluating sludge activity. It is calculated by dividing the DO/min of fed sludge by the DO/min of the unfed return sludge. The load ratio reflects the conditions at the beginning and end of aeration. Generally, a large factor means abundant, acceptable feed under favorable conditions. A small LF means dilute feed, incipient toxicity, or unfavorable conditions. A negative LR indicates that something in the wastewater shocked or poisoned the "bugs."

(3) Taken from "Dissolved Oxygen Testing Procedure," F. J. Ludzack and script for slide tape XT-43 (Dissolved Oxygen Analysis - Activated Sludge Control Testing) prepared by F. J. Ludzack, NERC, Cincinnati.