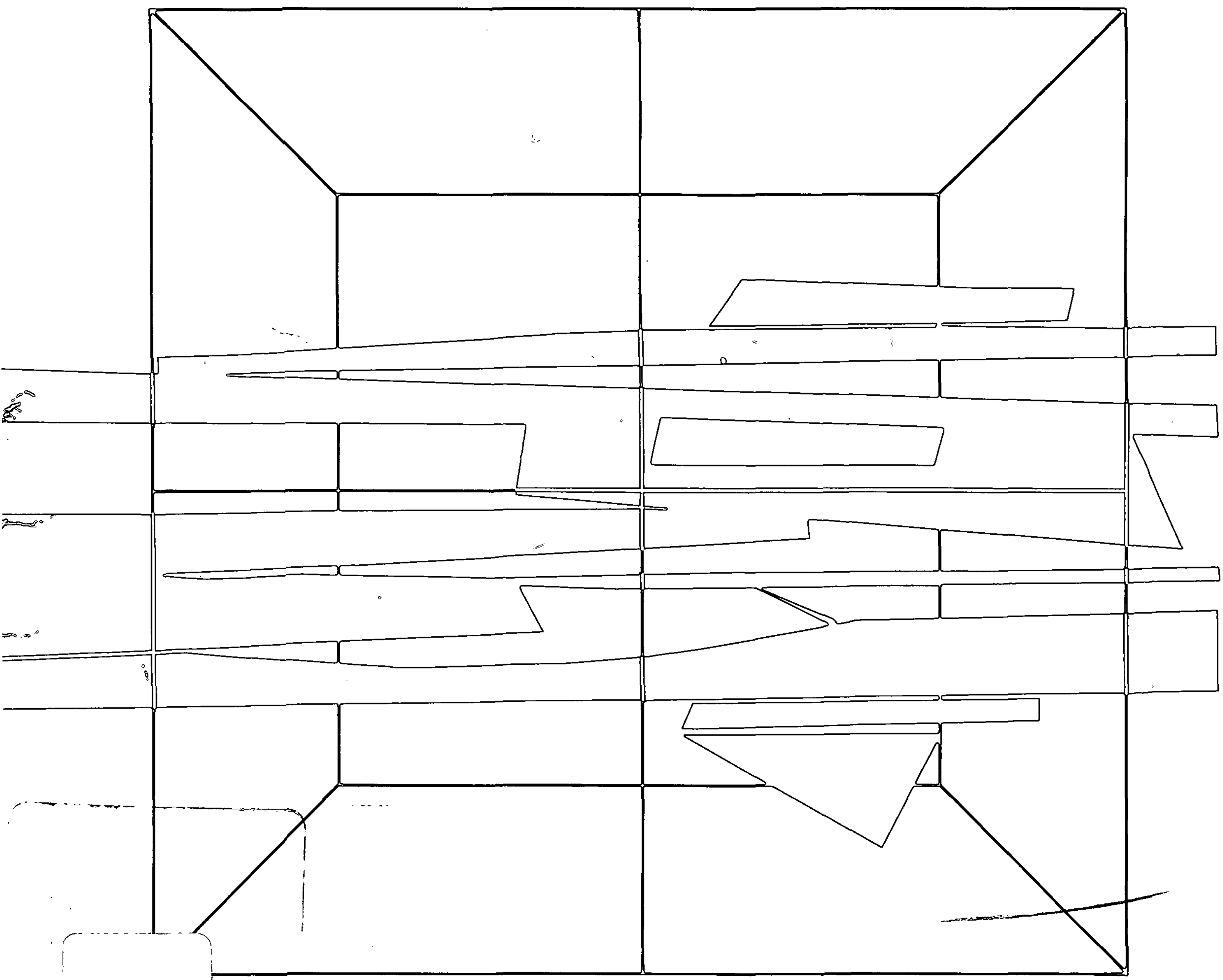
Biological Treatment of Textile Finishing Mill Effluent

Report EPS 3/PF/3
March 1987



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BIOLOGICAL TREATMENT OF TEXTILE FINISHING MILL EFFLUENT

by

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ABSTRACT

The treatability of textile mill effluents was examined using a pilot-scale activated sludge, extended aeration plant at the Dominion Textile Inc. finishing mill in Magog, Quebec. The objectives were to define the design and operating criteria for biological treatment facilities treating textile mill effluents.

The results showed that, contrary to U.S. criteria of long hydraulic retention times for wastewaters with similar characteristics, these effluents were best treated at a hydraulic retention time (HRT) of 18 hours and a solids retention time (SRT) of 30 days, at a pH between 7 and 9 with adequate nutrient supply. Under these operating conditions no foaming problems occurred, and colour removal was optimal, although this was affected by the intensity of colour in the influent. Solids production ranged from 0.13 to 0.21 g volatile suspended solids (VSS) per gram chemical oxygen demand (COD) removed, depending on the operating conditions. Oxygen uptake rate was 0.2 mg $O_2/d \cdot mg^{-1}$ mixed liquor volatile suspended solids (MLVSS), at optimum conditions. The treatment system produced an effluent containing less than 20 mg/L of suspended solids with a COD removal efficiency of 80%. The effluent was not lethal to fish using the 96-hour static toxicity test. The pilot system was operated at 21°C and the temperature in the aeration basin of the full scale plant was 22°C.

The optimal operating conditions defined in the pilot-scale tests produced the same treatment performance when applied in the full-scale facility. The pilot tests indicated not only excellent reproducibility of results when experimental conditions were repeated, but also good stability in the activated sludge system, and provided a reliable tool with which to predict the behaviour of the full-scale system.

It was found that a particular system response resulted from changes in each control parameter, i.e., changes in SRT and/or HRT had a direct impact on the treatment system's performance.

RÉSUMÉ

Ce rapport présente les résultats d'une étude sur le traitement des eaux usées de l'usine d'ennoblissement des tissus de la Dominion Textile Inc., à Magog. Les objectifs de l'étude étaient d'examiner le rendement d'un modèle réduit de station d'épuration à boues activées et aération prolongée, de reproduire les opérations de la station d'épuration existante et de dégager des critères de conception et d'opération d'installations d'épuration pour ce type d'eaux usées.

Si l'on s'en tient aux critères nord-américains, le temps de séjour recommandé pour le traitement d'influents ayant les mêmes caractéristiques est assez prolongé (3 à 4 jours). Lors des essais-pilotes, les meilleurs résultats correspondaient cependant à un temps de séjour hydraulique de 18 heures et un âge des boues de 30 jours. Le pH était maintenu entre 7 et 9, et l'apport de nutriants n'était pas limité. Dans de telles conditions, on est parvenu à supprimer les problèmes de mousse, et la décoloration de l'effluent était meilleure que celle obtenue à d'autres régimes de fonctionnement. Il faut retenir que la décoloration était essentiellement fonction de l'intensité de la couleur de l'influent. La production de solides variait entre 0,13 g et 0,21 g de solides volatiles par gramme de DCO éliminée, tout dépendant des conditions d'opération. La consommation d'oxygène par la masse de boues activées était de 0,2 mg d'O_2/mg de MVS, aux conditions d'opération optimales.

Toujours dans des conditions optimales, la teneur en solides en suspension (MSS) était inférieure à 20 mg par litre et la DCO était réduite de 80 p. 100. Aucune mortalité n'a été notée lors d'un essai de recherche de la toxicité pour la truite arc-en-ciel effectué en conditions statiques (TLm 96 h). Pour les essais sur modèle réduit (biostation-pilote), la température moyenne était de 21°C alors qu'elle était de 22°C dans le bassin d'aération existant.

Les résultats en conditions réelles corroborent ceux obtenus en unité-pilote. La simulation biologique sur modèle réduit s'est avérée un outil indispensable pour prévoir le rendement en conditions réelles. Les essais de répétabilité conduits en unité-pilote ont aussi montré que le procédé à boues activées était très stable.

Signalons pour terminer que le système de traitement à boues activées avait un rendement précis pour un mode d'opération précis. Toute modification, par exemple un changement du temps de rétention des solides (âge des boues) ou du temps de séjour hydraulique, influençait le rendement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The textile industry is well established in Canada. There are close to 1000 mills in all, most of them located in Quebec and Ontario. Wastewaters from mills that are not connected to a municipal sewer system are either treated in separate treatment plants or discharged directly into a body of water.

Three areas of concern are associated with wastewaters from textile mills:

- the combined treatment of textile mill and domestic wastewater in municipal treatment plants;
- the design of treatment plants specifically for raw wastewater from textile mills;
- the operation and performance of these treatment systems.

It is generally acknowledged that raw wastewater generated by the textile industry lends itself to biological treatment, either by extended aeration or aerated lagoons (Alspaugh et al., 1979; Hutton and Robertaccio, 1979; Schaffer et al., 1979). However, determining criteria for system design and the best operating methods demands closer examination of the treatability of the wastewater. General design criteria can be established but the question of colour intensity is often overlooked, despite its importance.

Lessard (1981) maintained that the combined treatment of textile mill and domestic wastewater posed no particular problem provided that facilities were designed for a hydraulic retention time (HRT) of 15 hours and a solids retention time (SRT) of 20 days.

Lessard (1981) also pointed out that effluent colour removal depended essentially on the quantity and nature of the dyes in the wastewater. The Department of Textiles of Clemson University (1971) also found that biological treatment was suitable for raw wastewater from textile mills, either alone or in combination with domestic waste, but cautioned that some of the products used in the mill processes may be bioresistant or toxic. Clemson University claimed that 90% reduction in the five-day biochemical oxygen demand (BOD_5) can be expected provided that pH is kept within acceptable limits, the temperature remains relatively constant, organic matter is biodegradable, and nutrients are added.

The U.S. Environmental Protection Agency (1978) reported that activated sludge treatment with extended aeration was effective for treating wastewater from finishing mills if the treatment plant operated at an hydraulic retention time of three or four days. The chemical oxygen demand (COD) and BOD_5 figures quoted by the U.S. EPA for the textile industry as a whole are of the same order of magnitude as the findings of this study. The reduction in BOD_5 seems to hover around 90% but COD removal is only 50% to 60%. A recent study published by Environment Canada (1982) concluded that BOD_5 and COD concentrations and the suspended solids content of wastewaters from Canadian and U.S. textile mills were similar.

The U.S. EPA (1978) also noted that textile mill wastewater is frequently deficient in nitrogen and that this must be remedied during treatment. Foaming is a frequent problem in extended aeration systems, requiring the use of antifoaming agents or powdered activated carbon. Activated carbon also helps to reduce BOD_5 and COD and to decolourize the wastewater.

Hutton and Robertaccio (1979) came to the same conclusions, adding that powdered activated carbon can effectively eliminate certain toxic components in this effluent. Similarly, Bettens (1979) demonstrated at the Desso Intermonde mill's biological treatment plant in Belgium that the use of powdered activated carbon (50 mg/L) substantially reduced COD and BOD_5 and helped remove colour.

U.S. literature indicates that the required retention time can be as long as three or four days and that foaming and nutrient deficiency are common problems. With such long hydraulic retention times, it is impossible to control the activated sludge process by means of solids retention time. Moreover, the technical documents consulted made no reference to the control methods used. The treatment plant considered in this study had an acute foaming problem which affected the entire aeration tank, and particularly the settling tanks. Solids retention time (sludge age) was not controlled and pH was not regularly adjusted to bring it within acceptable limits. The hydraulic retention time was approximately 18 hours and the influent had a marked nutrient deficiency. Analyses of two series of samples taken in March 1980 and October 1981 showed that COD and BOD_5 were reduced by about 60% and 78%, respectively. This was considered unsatisfactory.

2 OBJECTIVES OF THE STUDY

The purpose of the study was two-fold: to determine which biological treatment strategy provided the best results in terms of organic matter and colour removal, and to establish design and operating criteria for treatment facilities. The study involved:

a) determining influent characteristic and assessing the performance of the Dominion Textile Inc. treatment plant at Magog, Québec;
b) examining on a pilot-scale the biological treatability of such wastewater when sufficient nutrients were added and pH was controlled;
c) defining the best operating conditions and evaluating organic matter and colour removal;
d) operating the pilot plant without nutrient addition or pH adjustment, at the optimum solids retention time and hydraulic retention time, to determine whether nutrient supply or pH was the most influential parameter;
e) recommending operational improvements for the mill's treatment plant; and
f) assessing by laboratory tests the effectiveness of powdered activated carbon in reducing the organic loading in the effluent.

3 TEXTILE FINISHING PROCESSES

Operations at the Dominion Textile Inc. finishing mill at Magog, Quebec, fall into four categories: preparation, engraving and printing, dyeing, and finishing. Most of the wastewater originates in the preparation, dyeing and printing sectors of the mill. In 1980/81, the mill processed 33 000 tonnes of cotton fabrics and cotton and polyester blends, broken down as follows:

- printed fabrics 33%
- cotton twill 25%
- corduroy 20%
- dyed fabrics 17%
- white fabrics 5%

Cotton accounted for approximately 75% of total output and polyester for the remainder.

4 FULL-SCALE TREATMENT PLANT DESCRIPTION

Wastewater from the Magog finishing mill has been treated biologically since 1975. The treatment plant was designed to process 22 700 m^3 of wastewater per day, with a hydraulic retention time of 17.3 hours.

Coarse fibres are screened out and wastewater flow is controlled by a 45.7-cm (18-inch) Parshall flume. The aeration tank has a capacity of 16 300 m^3 and is fitted with seven surface aerators, four of which are in operation. Activated sludge is decanted into two secondary settling tanks set up in parallel. Sludge return is limited to a maximum of 50% of the rated flow. The plant has no sludge treatment facilities but the matter is under study.

Septic sludge is used, although the plant is equipped for automatic nutrient addition; pH is monitored only sporadically.

5 EXPERIMENTAL PROGRAM

For the purposes of this study, Dominion Textile installed in its Magog laboratory a 130-litre pilot unit similar in geometry to the existing full-scale plant, except that the bottom slope of the secondary settling tanks was changed to a more satisfactory 30°. The settling tanks were fitted with scrapers operating at 1.5 rpm. The pilot unit was fitted with air intakes and Masterflex peristaltic pumps for wastewater supply and sludge return. Ammonia nitrogen and phosphate were added in proportions of BOD:N:P of 100:5:1. Wastewater pH was maintained at 7.6. Once the best operating method had been determined, pH adjustment ceased, as did the addition of nutrients, in order to study how the unit behaved under conditions identical to those in the full-scale treatment plant. Before studies began, a series of tests were performed to check short-circuiting in the pilot unit aeration tank. In view of the test results, it was decided to install a baffle at the aeration tank outlet, and the number and location of air diffusers in the tank were determined.

pH and dissolved oxygen in the aeration tank were measured daily; rate of flow and nutrient levels were also monitored daily.

Wastewater characteristics and flow rates were determined twice, one series of measurements being taken at the start of the study and the other while it was under way, in order to taken into account changes in textile finishing processes. Comparisons were also made of influent quality at the full-scale plant and the pilot unit.

All analyses of suspended solids and mixed liquor were done at the company's Magog laboratory, while the Environment Canada laboratory at Longueuil analysed COD, BOD_5 and other parameters. Samples were sent by courier.

6 INFLUENT CHARACTERISTICS

6.1 Flow Rates

Before drawing up the experimental program, the variations that could be expected in hydraulic loading had to be evaluated. An Esterline Angus pneumatic flow meter was therefore installed on the Parshall flume to measure flow variations during one month. Measurements were then compared with the plant integrator's data to determine the most representative supply method for the pilot plant.

The values provided by the integrator were, on average, 10% below those of the pneumatic flow meter; this was considered acceptable. Analysis of integrator data for the 12 months from October 1979 to October 1980 showed that flow averaged 23 911 m^3 (5.26 million gallons) a day, for an average hydraulic retention time of 16 hours. The latter ranged from a minimum of 13 hours to a maximum of 42 hours.

Figure 1 shows hourly fluctuations in the wastewater flow rate on a typical day and Figure 2 the cumulative flow for one day. As evidenced by the straight line shown in Figure 2, it was not necessary to equalize input flows. The data indicate that treatment should not be affected adversely by weekend shutdowns in production between 5 pm on Saturdays and midnight on Sundays.

It was decided, on the basis of these conclusions, that the pilot plant could be supplied at a steady rate of flow seven days a week.

6.2 Wastewater Characteristics

The finishing mill wastewater characteristics are listed in Table 1.

The first series of measurements were taken in March 1980. Whey and septic sludge were then being used as nutrients; the whey being added directly to the aeration tank. A persistent foam covered the clarifiers and aeration tank, and several sludge balls were floating in the latter. The wastewater was high in phosphates and only a small proportion of the organic nitrogen in the influent was being used.

The second series of measurements (October 1981) showed a high uptake of available influent nitrogen after the addition of whey was discontinued, and a substantial drop in the phosphate content of the wastewater effluent.

Since the Dominion Textile plant was not equipped for sludge treatment, sludge was not being removed regularly. Instead, it was fully recycled in the aeration tank, and the system self-stabilized by discharging part of the sludge along with the

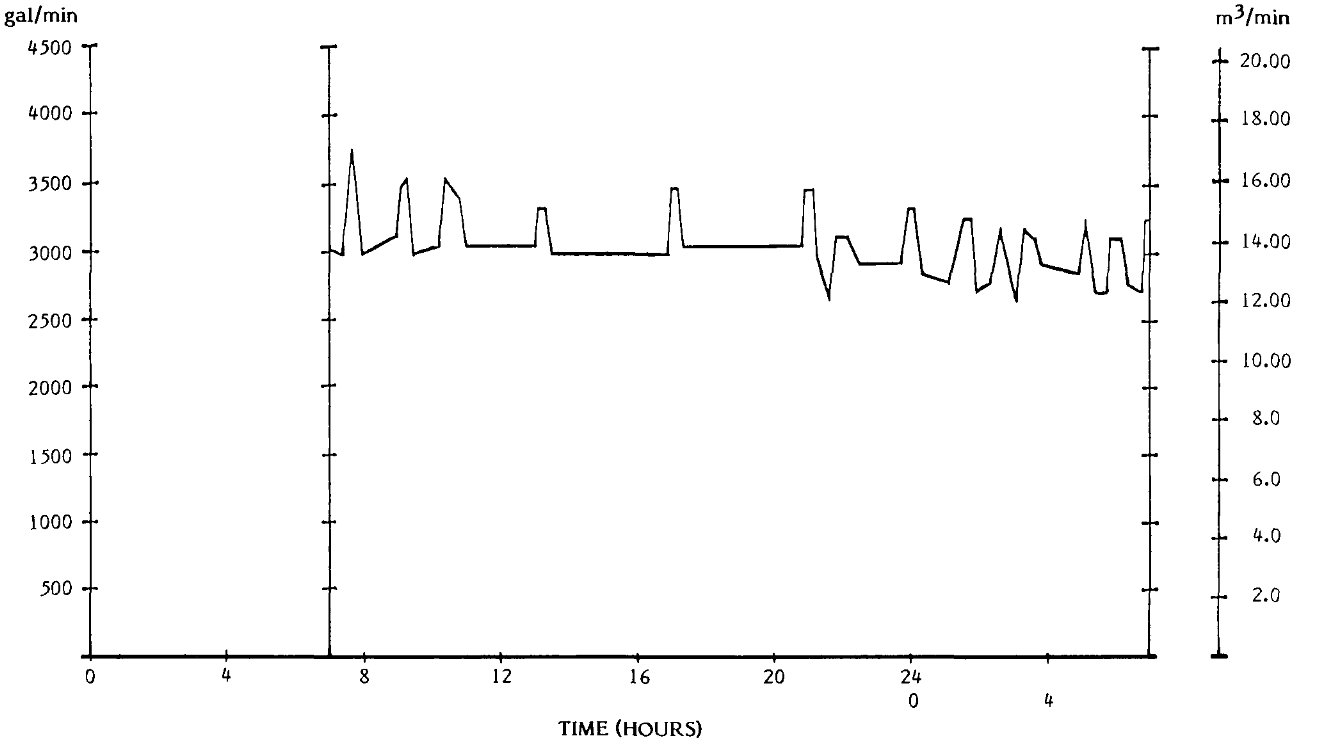


FIGURE 1 DAILY WASTEWATER FLOW VARIATION

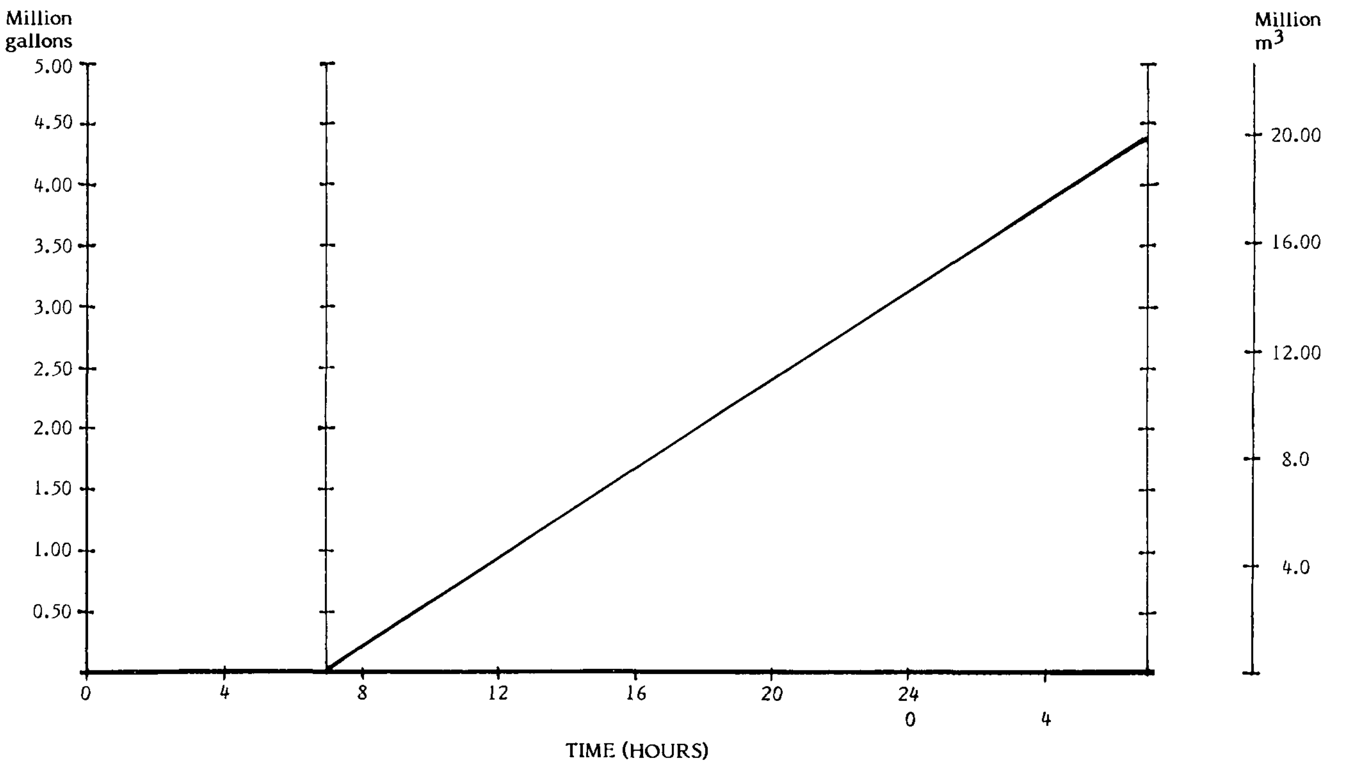


FIGURE 2 CUMULATIVE FLOW RATE

TABLE 1 WASTEWATER CHARACTERISTICS

Date		Parameters* (mg/L) COD	BOD_5	SS	O&G	PO_4	TKN	NH_3	TOC	Alk.
<u>1st series of measurements</u>										
05/03/80	Influent	740	320	90	19	0.36	15	0.6	62	165
	Effluent	470	130	84	10	2	10	0.4	150	365
06/03/80	Influent	740	300	50	60	0.98	15	1.1	280	290
	Effluent	390	93	75	6	1.8	5	0.3	120	330
07/03/80	Influent	780	310	59	14	2	7.5	0.9	270	300
	Effluent	270	60	60	8	1.7	7.5	0.4	130	350
08/03/80	Influent	700	360	48	16	1.1	10	0.6	240	255
	Effluent	390	79	69	6	1.4	10	0.4	120	360
09/03/80	Influent	350	150	50	11	1.6	10	1.4	120	165
	Effluent	270	36	54	24	1.5	10	0.6	70	310
10/03/80**	Influent	120	63	16	5	0.78	10	0.2	40	240
	Effluent	270	83	57	8	1.7	10	3.8	87	310
Average flow rate	14 530 m^3/d									
<u>2nd series of measurements</u>										
27/10/81	Influent	1100	640	160	-	1.4	10	2.1	360	1280
	Effluent	300	180	27	-	0.12	3	0.1	88	740
28/10/81	Influent	1100	740	200	-	1.3	15	0.9	420	1100
	Effluent	360	200	26	-	0.05	3	0.1	120	1000
29/10/81	Influent	940	510	170	-	0.96	9	0.8	370	830
	Effluent	430	220	56	-	0.12	5	0.1	140	1100
Average flow rate	19 295 m^3/d									

Influent COD/BOD_5 ratio = 1.94; COD/TOC = 3.04.

* COD = Chemical oxygen demand; BOD_5 = 5-day biochemical oxygen demand; SS = Suspended solids; O&G = Oil and grease; PO_4 = Phosphate; TKN = Total kjeldahl nitrogen; NH_3 = Ammonia (nitrogen); TOC = Total organic carbon; Alk. = Alkalinity (as $CaCO_3$)

** Mill operations stop at 5 pm on Saturdays and resume at midnight on Sundays, which may explain the discrepancy in the measurements taken on March 10, 1980. That was a Monday, and the composite samples were collected at 8 am.

treated effluent. The resulting high solids retention time (approximately 50 days) produced highly coloured wastewater with a high suspended solids content.

This resulted in the aeration and the settling tanks being covered with thick foam. Moreover, pH exceeded 9.5.

The COD_t/BOD_t ratio was approximately 1.94, slightly higher than the norm for domestic wastewater. The COD/TOC ratio was 3.04. The pilot plant was fed daily with influent consisting of a composite sample taken over a two-hour period. This method was chosen because the installation of a direct feed pipe would have been too costly. As shown in Figure 3, the influent fed to the pilot plant was remarkably similar in quality to the influent at the full-scale plant and was considered representative both in terms of daily COD fluctuations and total COD concentration.

In accordance with the objectives of the study and the operating constraints of the full-scale treatment plant, the program was confined to exploring a range of operating conditions until the best combination was identified. Tests began using solids retention times (SRT) of 32 and 40 days and a hydraulic retention time (HRT) of 25 hours. Adjustments were made by altering the parameter that seemed most influential until the best combination was found. Results are shown in Table 2.

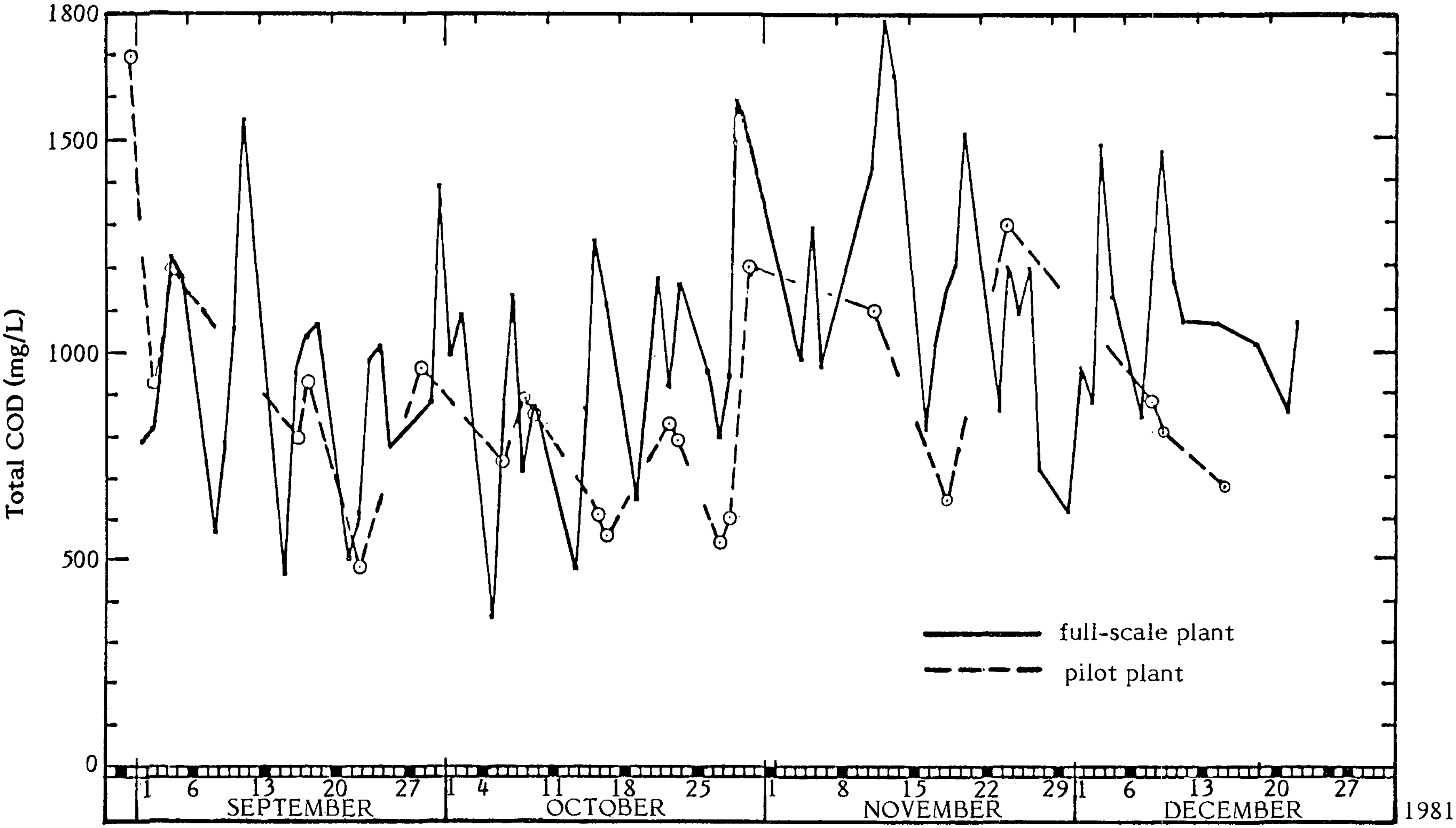


FIGURE 3 COMPARISON OF INFLUENTS TO FULL-SCALE AND PILOT PLANTS

TABLE 2 SUMMARY OF OPERATING RESULTS

Date	Mixed liquor* (g/L)	SRT (days)	HRT (h)	Sludge grown (g/d)	Influent COD (mg/L)	Effluent COD (mg/L)	COD Removed (g/d)	F/M Ratio	g Sludge grown/ g COD removed	Effluent suspended solids* (mg/L)	COD removal (%)
28/07 to 16/08/80	2.7	32	25	11.6	660	190	59.5	0.17	0.195	70	71
25/08 to 12/09/80	3.4	40	25	11.2	759	233	66.5	0.15	0.17	60	69.5
20/10 to 07/11/80	2.7	32	22	12.2	640	185	64	0.18	0.19	35	71
23 to 27/03, 13 to 16/04 24 to 01/05/81	4.6	32	22	20.3	856	189	94	0.16	0.21	40	78
18/05 to 15/06/81	4.4	32	18	19.6	845	140	122	0.21	0.16	13	83.5
22/06 to 09/07/81	3.3	21	18	22.8	783	153	109	0.25	0.21	28	80.5
01/09 to 02/10/81	4.6	40	18	15	818	131	119	0.2	0.13	33	84
13/10 to 30/10/81	3.9	32	18	16	680	165	89	0.18	0.18	15	77
07/11 to 18/12/81 No pH/N ajustment	5.8	30	18	25.4	983	220	132	0.18	0.19	17	78

* Volatile.

7 RESULTS OF EXTENDED AERATION TREATMENT IN THE PILOT PLANT

7.1 COD Reduction

Following a period of acclimatization of the activated sludge to a steady input of nutrients, the system operated without interruption from July 28, 1980, to November 7, 1980. During this period, system operation was evaluated at hydraulic retention times of 25 and 22 hours and solids retention times of 32 and 40 days. Pilot plant tests had to be virtually discontinued from November 8, 1980, to May 1, 1981, because of mechanical defects, overflows caused by clogged pipes, power failures, and repairs to settling tank scrapers. Thereafter, tests continued without interruption until December 18, 1981.

Figures 4 to 10 show the pilot plant performance under a range of operating conditions. The following points are worth noting:

a) Despite variations in influent COD, fluctuations in the effluent COD were buffered.
b) Within the narrow margins of 20 to 40 days sludge retention time, hydraulic retention time was the primary factor in COD removal. There is, however, an optimum combination within that range.
c) System efficiency was increased when the HRT was reduced from 25 hours to 18 hours.
d) COD removals of up to 80-84% can be achieved with SRTs of 20, 30 and 40 hours and an HRT of 18 hours.
e) System performance as a function of the food-to-microorganism (F/M) ratio is shown in Figure 11. Reductions in total COD are greatest when the ratio is 0.20 or more.

7.2 Suspended Solids Removal

Figures 4 to 10 also show the suspended solids content of the effluent. The results indicate that:

a) Reducing the HRT from 25 hours to 18 hours has a marked effect on floc quality, flocculation and settling properties, and system stability. Effluent characteristics become much more stable as optimum conditions are approached.
b) Solids retention time has a considerable effect on flocculation characteristics, which improve substantially as optimum sludge age is approached. The effect of HRT and sludge age on system performance is shown in Figure 12.

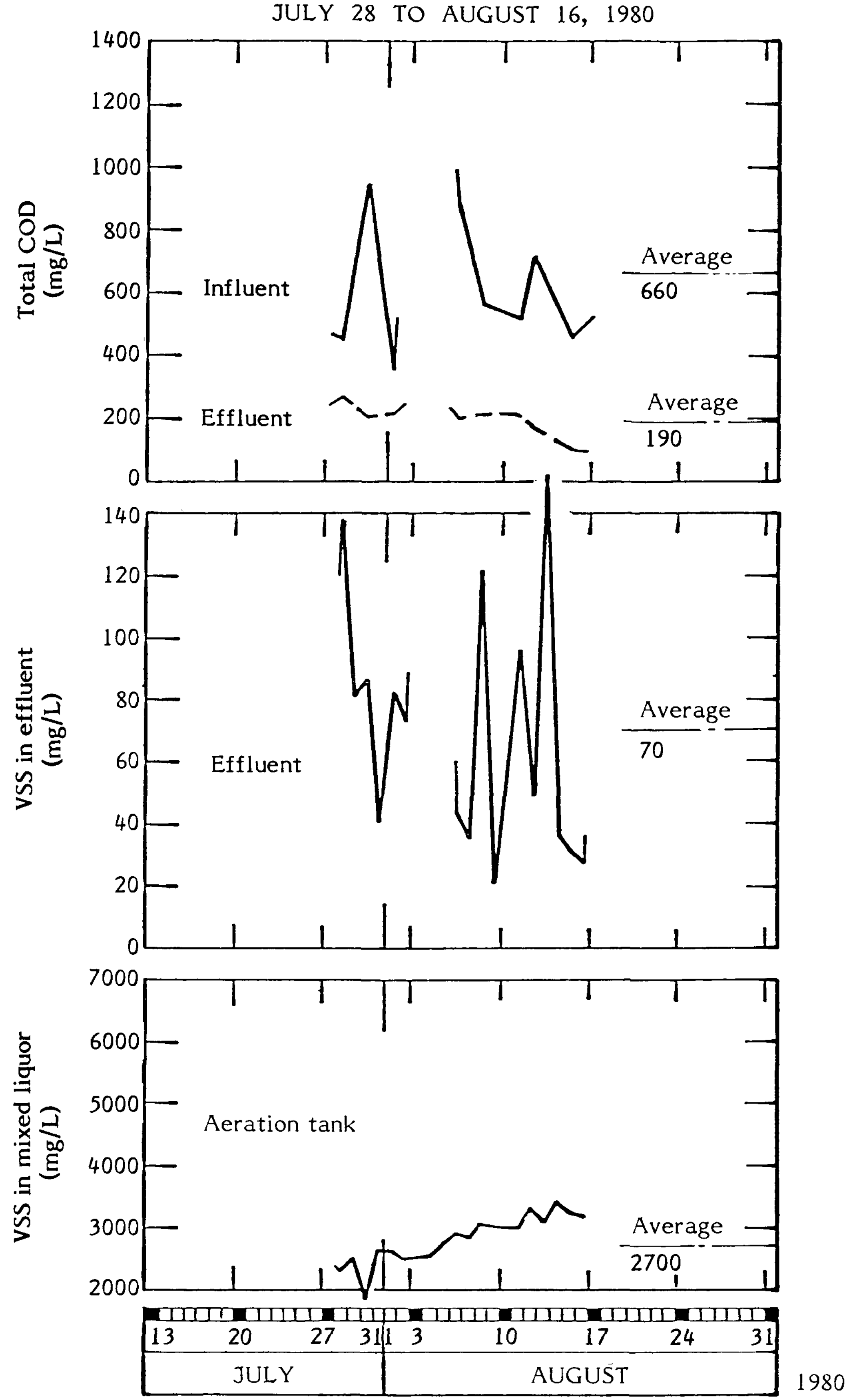


FIGURE 4 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 25 h; solids retention time = 32 d)

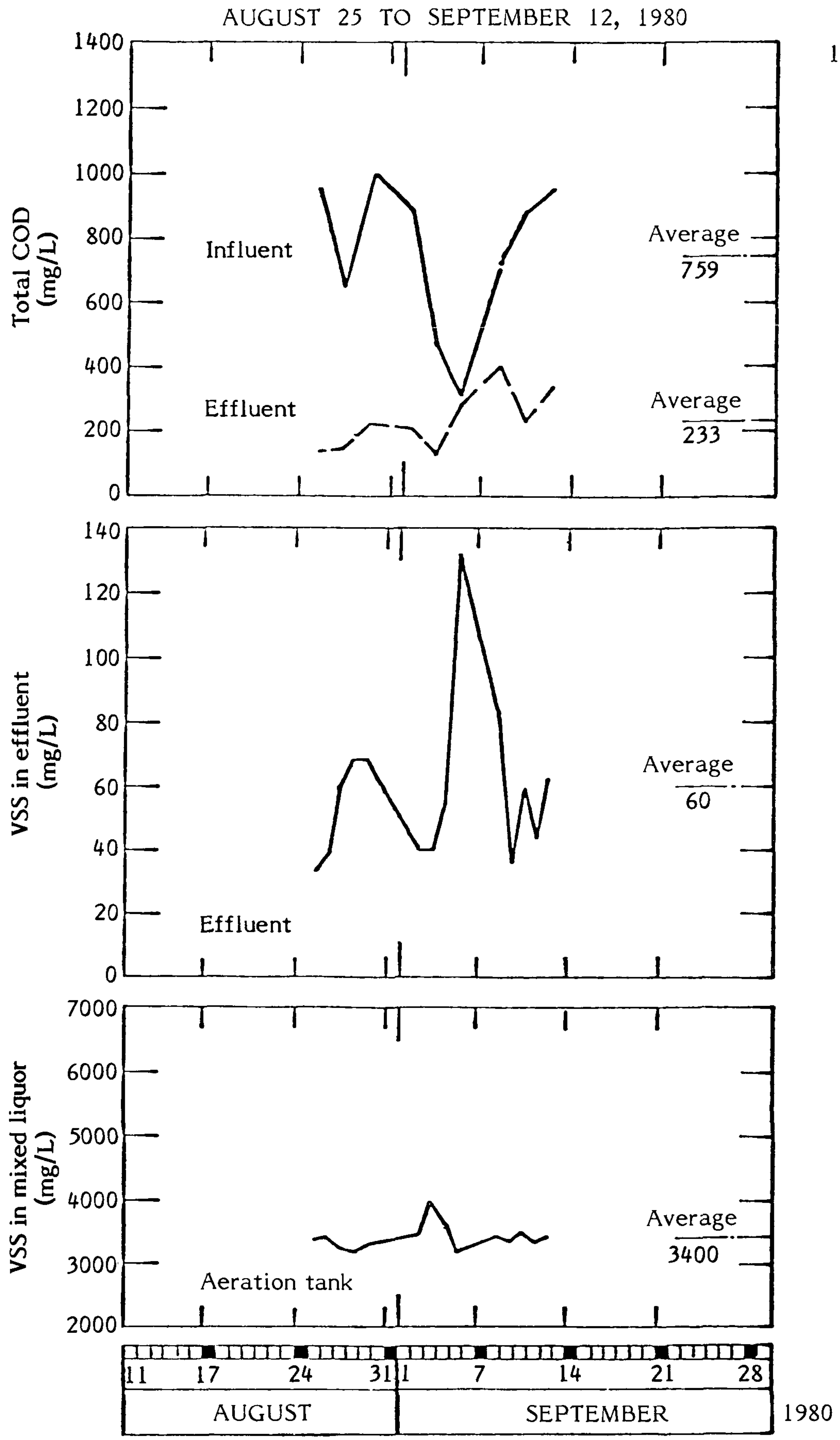


FIGURE 5 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 25 h; solids retention time = 40 d)

OCTOBER 20 TO NOVEMBER 7, 1980

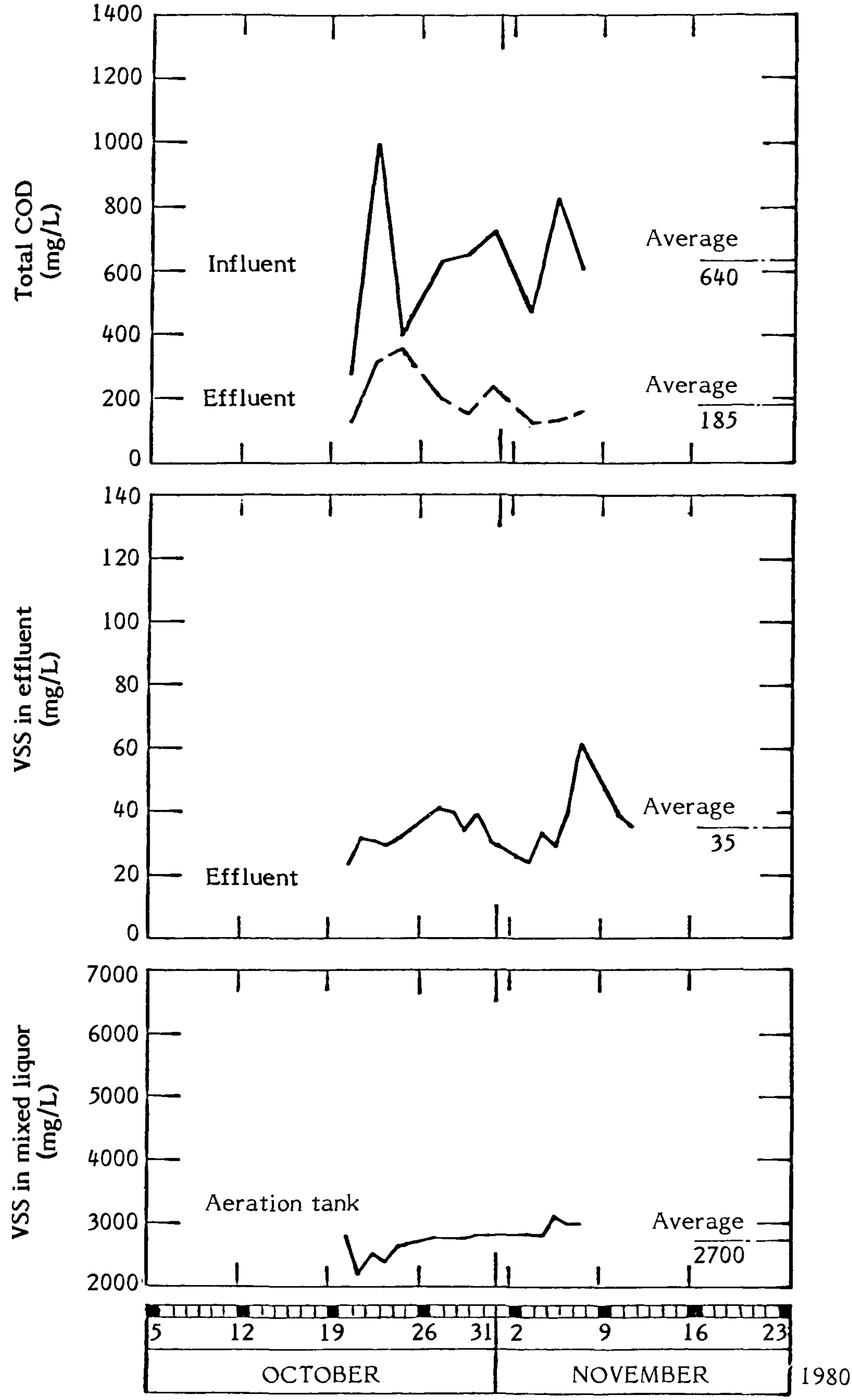


FIGURE 6 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 22 h; solids retention time = 32 d)

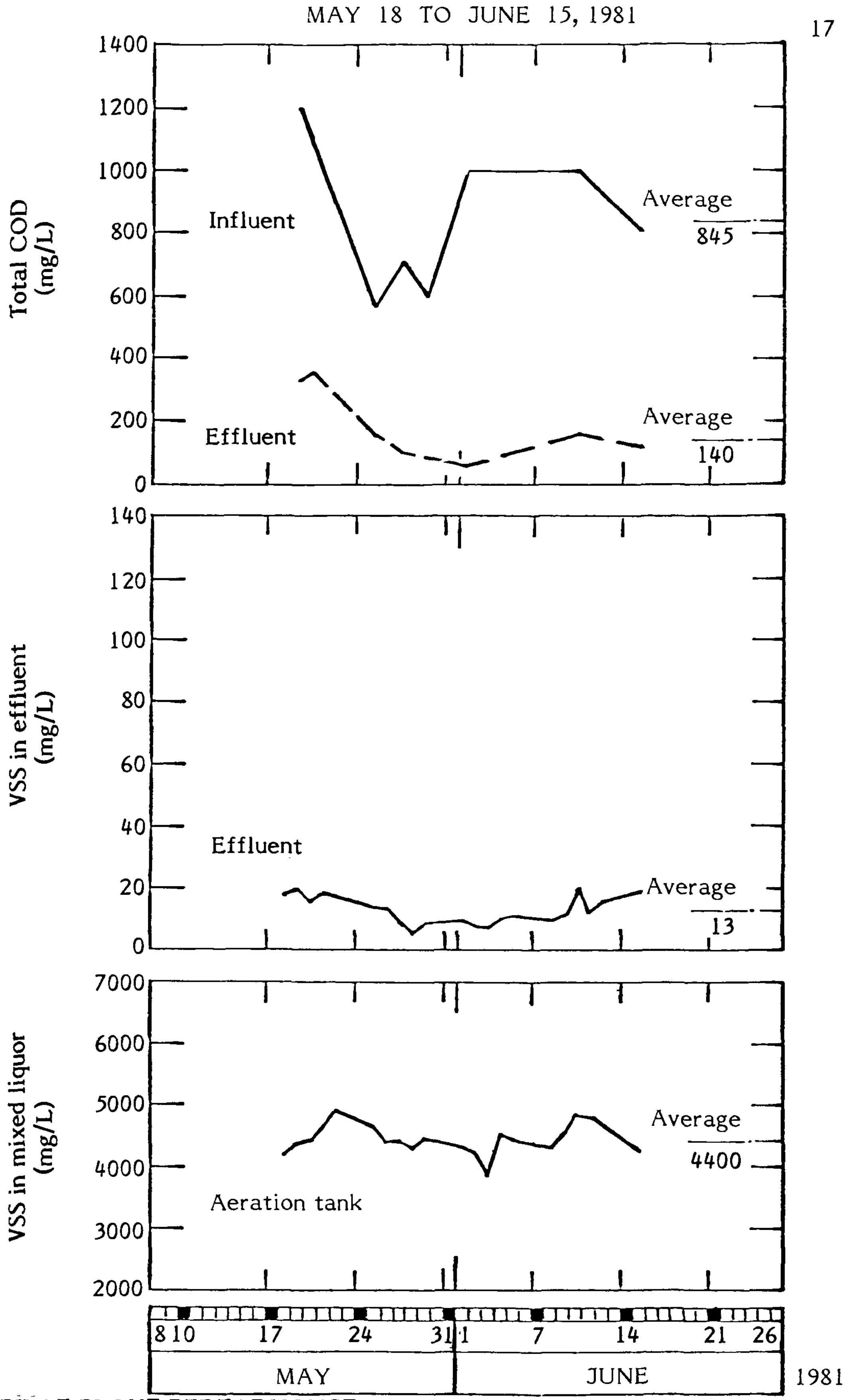


FIGURE 7 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 18 h; solids retention time = 32 d)

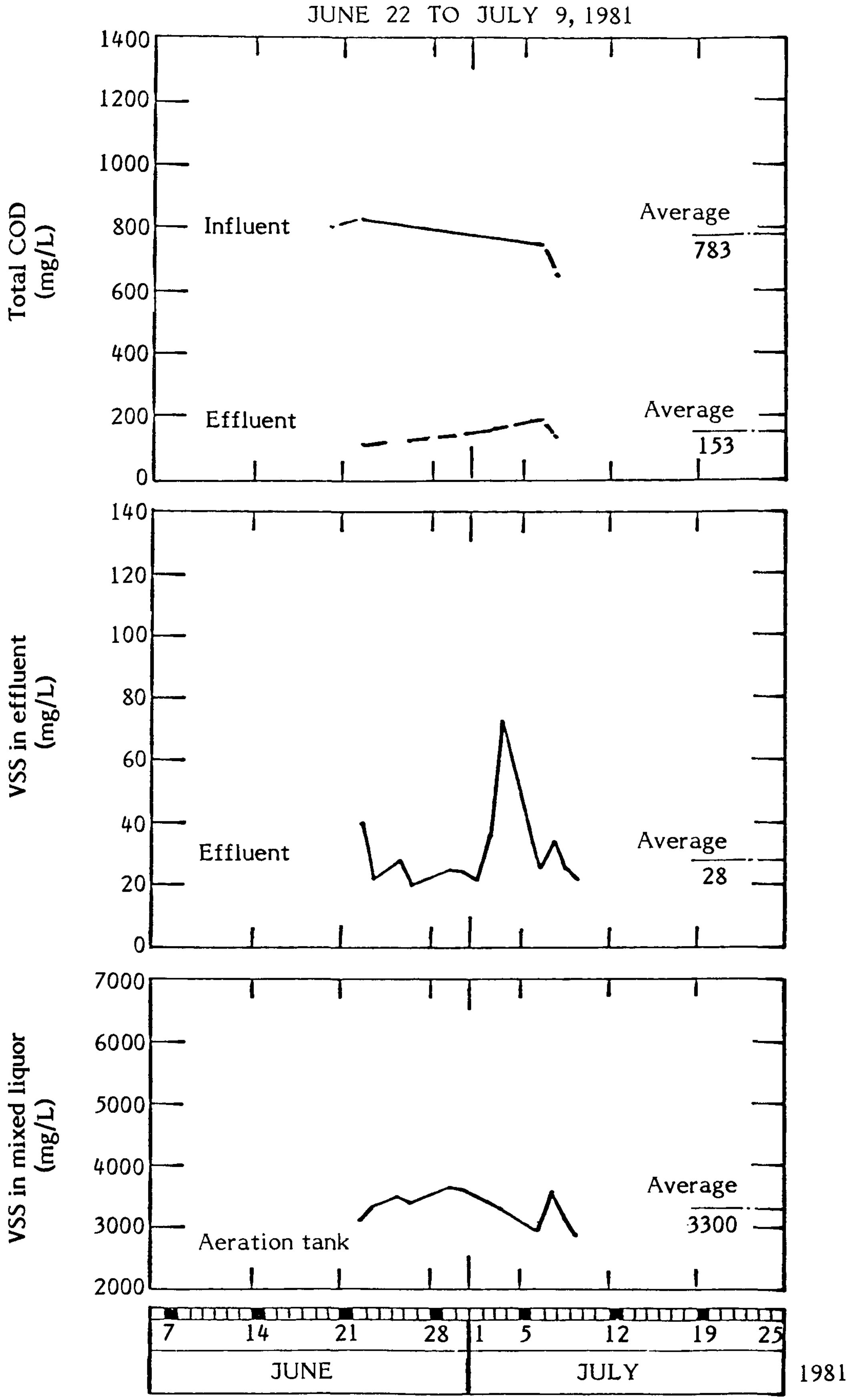


FIGURE 8 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 18 h; solids retention time = 21 d)

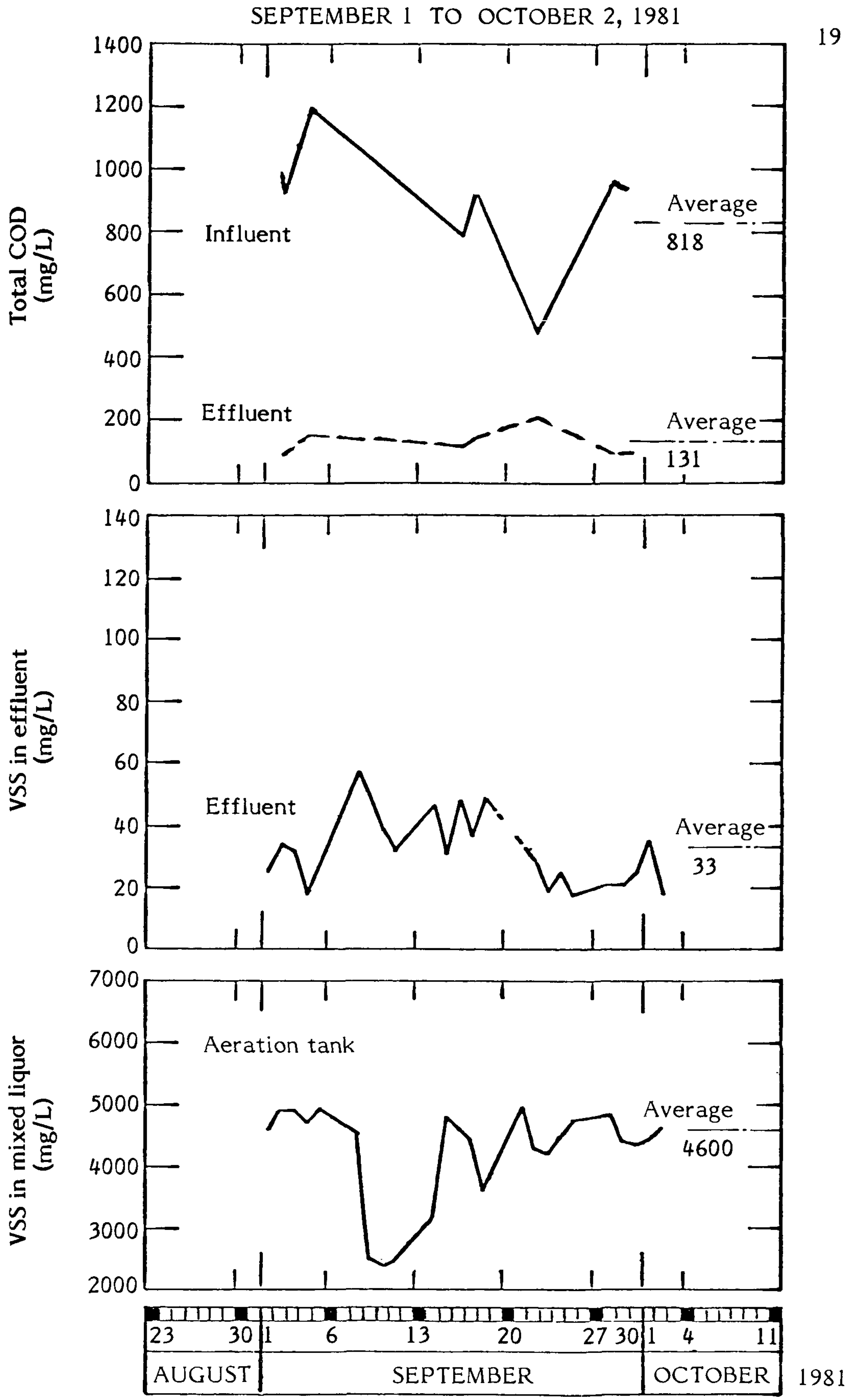


FIGURE 9 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 18 h; solids retention time = 40 d)

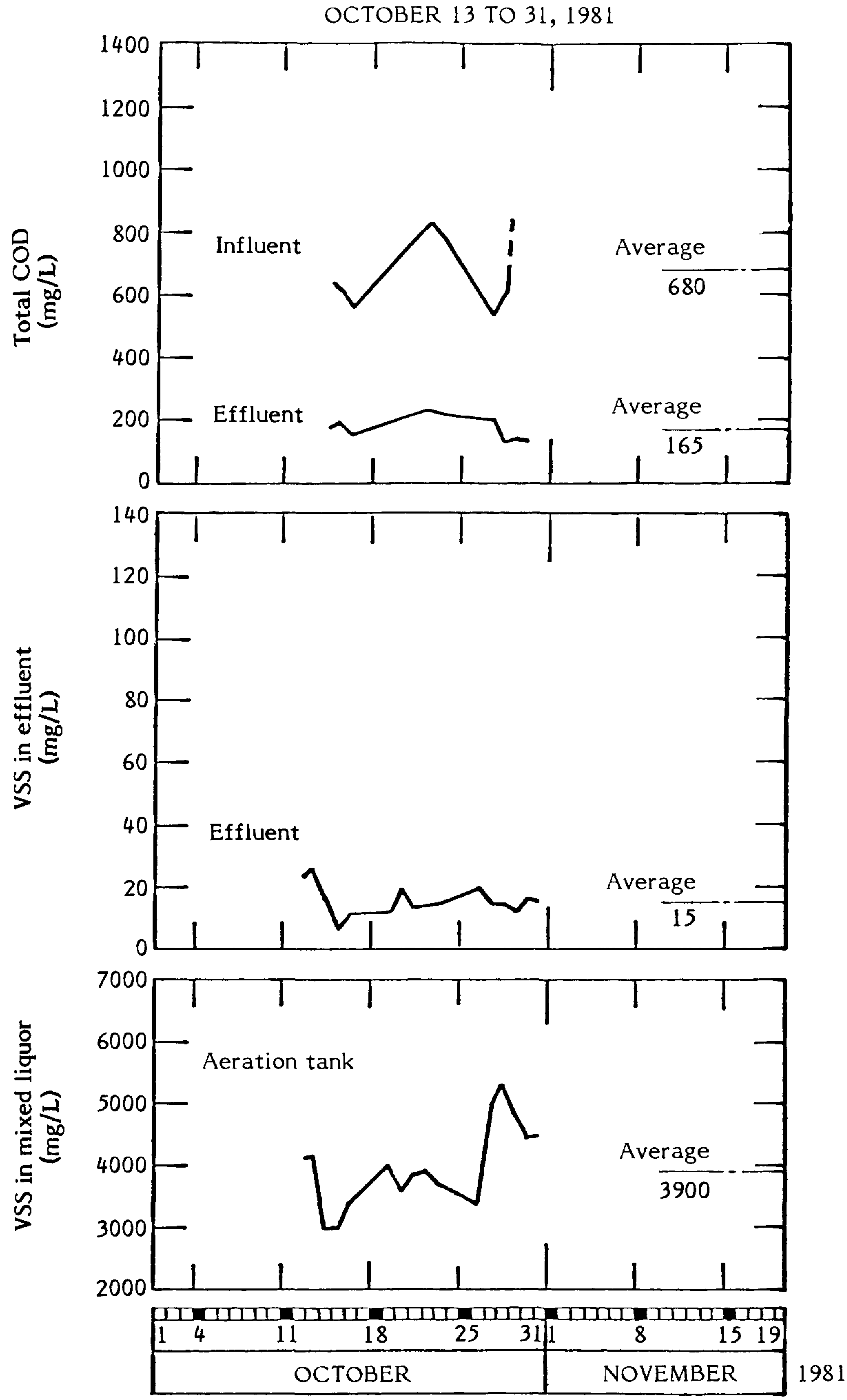


FIGURE 10 PILOT PLANT PERFORMANCE
(Hydraulic retention time = 18 h; solids retention time = 32 d)

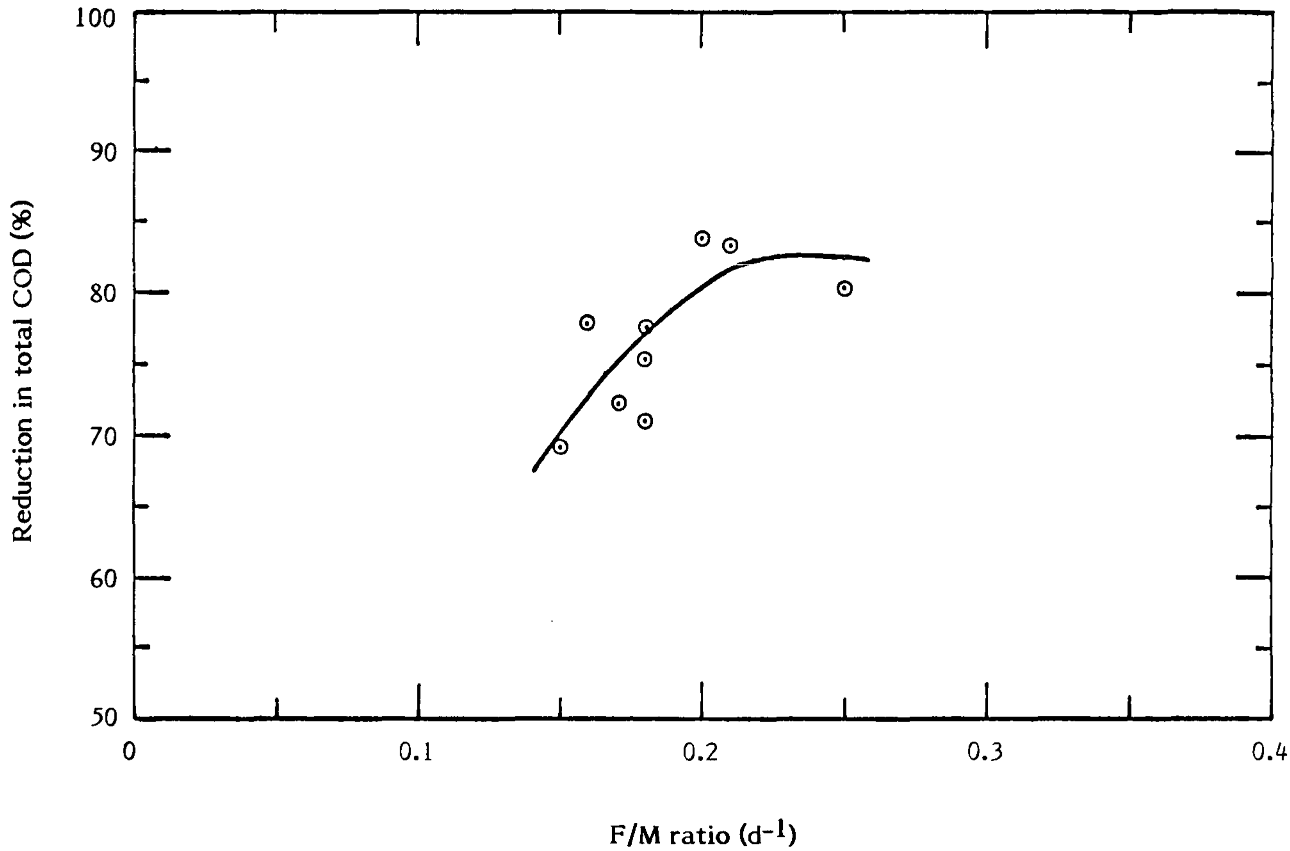


FIGURE 11 COD REMOVAL AS A FUNCTION OF F/M RATIO

c) System control was particularly difficult at an HRT of 25 hours. Insufficient sludge was produced and it was consequently impossible to maintain an SRT of more than 40 days.

d) The best results were obtained with an SRT (sludge age) of 32 days and an HRT of 18 hours.

7.3 Pilot Plant Stability

The pilot plant proved extremely flexible and stable under test conditions. Two reproducibility tests were done to corroborate results and check unit response.

Table 2 summarizes the results of reproducibility experiments run at an SRT of 32 days and HRTs of 22 h and 18 h, respectively.

The system responded well to daily fluctuations in organic load.

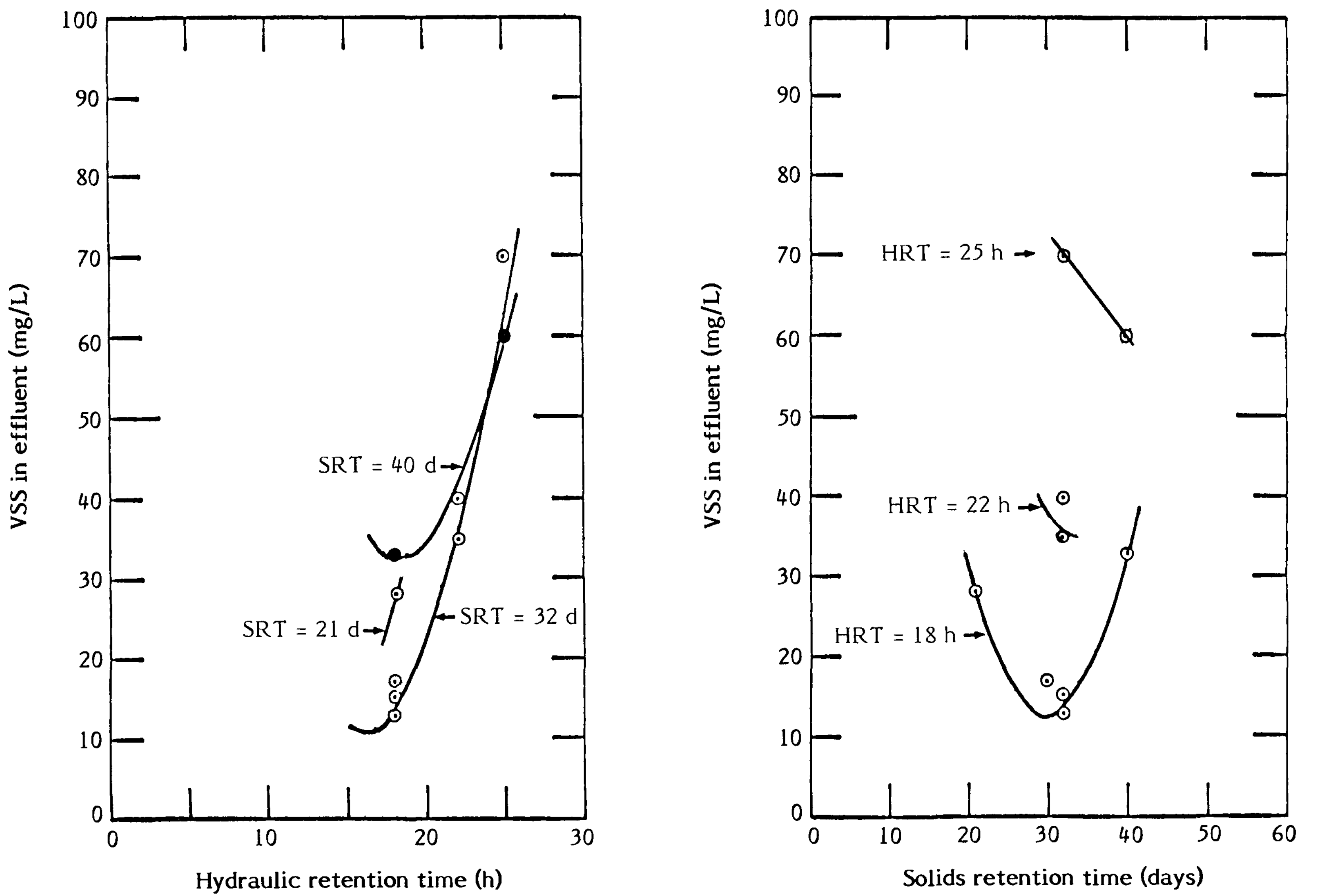


FIGURE 12 EFFECT OF VARIATIONS IN HRT AND SRT ON ACTIVATED SLUDGE SYSTEM

7.4 Simulation of Full-scale Conditions

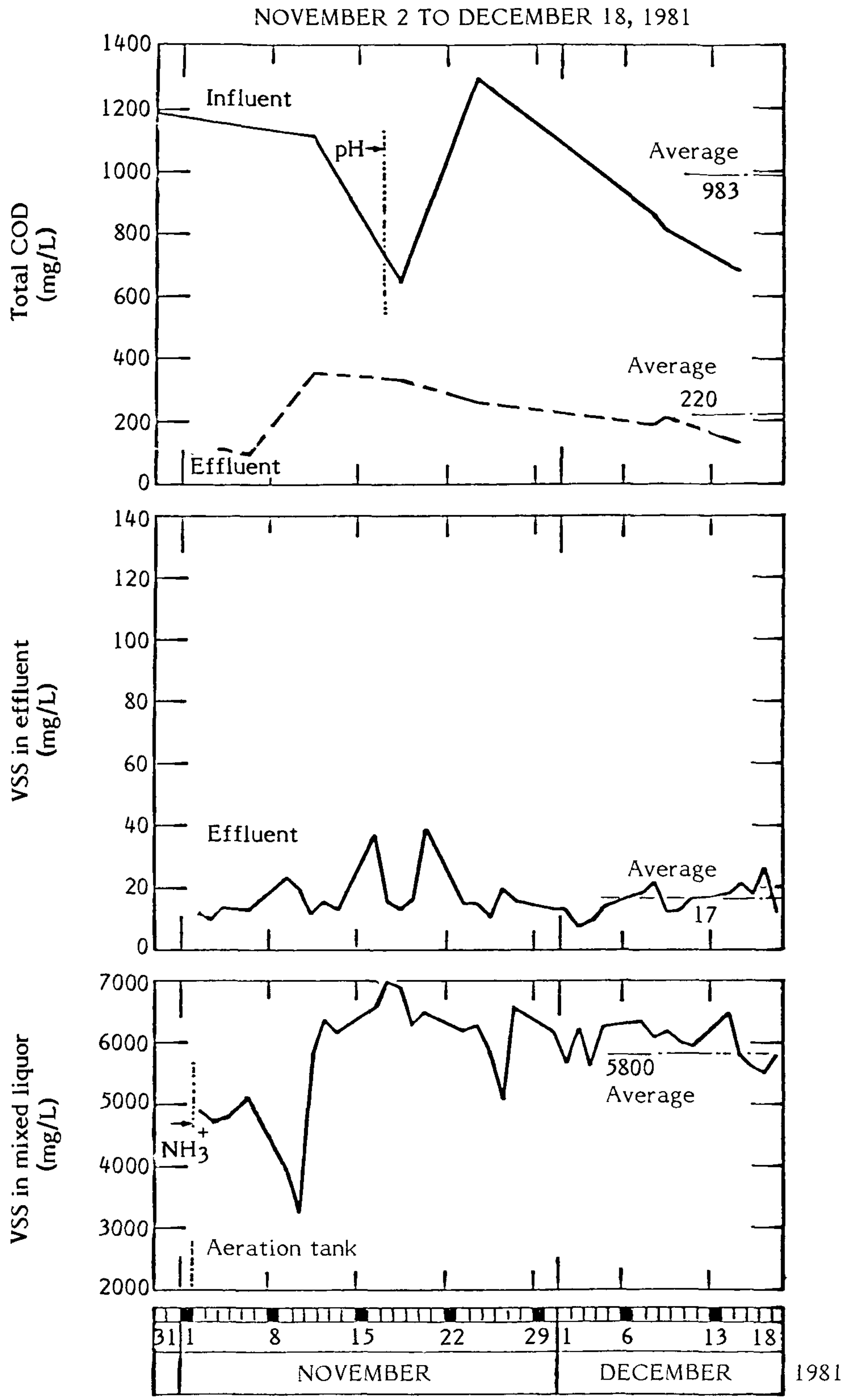
A series of simulation pilot plant tests was carried out to evaluate the full-scale system performance in optimum conditions (SRT and HRT controlled) but without adding nitrogen and phosphorus or adjusting the pH. As stated earlier, sludge age was not controlled at full-scale, pH was not neutralized, and septic sludge was used as the nutrient. Table A1 (see Appendix A) shows how the unit behaved from September 1, 1981, to December 22, 1981.

The simulation tests were done after optimum operating conditions had been determined. The purpose was to assess the effectiveness of pilot plant treatment in what were felt to be optimum conditions of a 32-day SRT and an 18-hour HRT, first without adding nutrients and then without adjusting the pH. The results (Figure 13) show that the absence of nutrients and pH control had no apparent adverse effect, despite a 30% organic overload.

From the end of October to November 8, 1981, the COD of the raw wastewater increased from an average of 680 mg/L to 983 mg/L, while the volume of activated sludge in the aeration tank rose from 3900 mg/L to 5800 mg/L. This overload caused foaming over the entire aeration tank and an increase in oxygen requirements. After this transient shock occurred, the activated sludge system stabilized and the foam disappeared completely. The suspended solids content of the wastewater rose slightly and averaged 17 mg/L. COD reduction efficiency was approximately 78%, with a filtered effluent average of 220 mg/L. Unfortunately, few samples were collected for nitrate analysis. The nitrogen balance indicated that available nitrogen was being used for biosynthesis, leaving an unavailable residue of 3 mg/L of TKN-N. Results also indicated that nitrification did not occur.

During the simulation tests, the BOD_5/N ratio was 100:2, substantially lower than the usual 100:5 or 100:7 reported in the previous two series of tests, when there was an adequate supply of nutrients, an hydraulic retention time of 18 hours, and a solids retention time of 40 days in one series and 32 in the other.

The results are shown in Tables 3 and 4. Figure 14 shows how the system responded without pH neutralization. It appeared that no adverse effect resulted and that the buffering effect was good. From November 17 to December 18, 1981, pH averaged 7.6, as it did during the tests when neutralization at 7.2-7.5 was used.



November 16: Influent neutralization (by H_2SO_4) ceases.
November 1: Addition of nutrients ($(NH_4)_2HPO_4$) to mixed liquor ceases.

FIGURE 13 PILOT PLANT PERFORMANCE DURING SIMULATION TESTS (Hydraulic retention time = 18 h; solids retention time = 32 d)

TABLE 3 NITROGEN UPTAKE IN CONTROLLED CONDITIONS

Date	SRT (days)	HRT (h)	BOD_5 (mg/L)	Nitrogen uptake (mg/L)	BOD/N ratio
13/10 to 30/10/81	32	18	170	13	100:7
1/09/81 to 2/10/81	40	18	370	35	100:5

TABLE 4 OPERATION WITHOUT NUTRIENT ADDITION OR pH ADJUSTMENT: SUMMARY RESULTS

Date	Parameter	Influent (mg/L)	Effluent (mg/L)	Composite samples
6/11/81 to 15/12/81	Total COD	983	243	6
	Filtered COD	656	220	6
	Total BOD_5	350	18	6
	Filtered BOD_5	310	17	6
	TKN-N	9	3	5
	NO_2/NO_3-N	0.7	0.63	3
	NH_3-N	0.3	0.1	5
	PO_4-P	0.9	0.5	5

BOD_5/N ratio = 100:2

7.5 Sludge Production and Oxygen Uptake

Figure 15 shows the relationship between sludge production and the F/M ratio, giving the equation 1/SRT = 0.2 F/M - 0.006.

Sludge production is calculated at 0.2 g of solids per gram of COD removed. This figure includes the sludge lost in the form of suspended solids in the wastewater after secondary settling. Tests to determine oxygen uptake by the biomass at optimum conditions showed that consumption was approximately 0.2 mg of O_2/day per gram of mixed liquor.

7.6 Colour Removal

The effectiveness of biological treatment in removing colour was assessed from September 1 to December 1, 1981. This evaluation was done at the same time as the

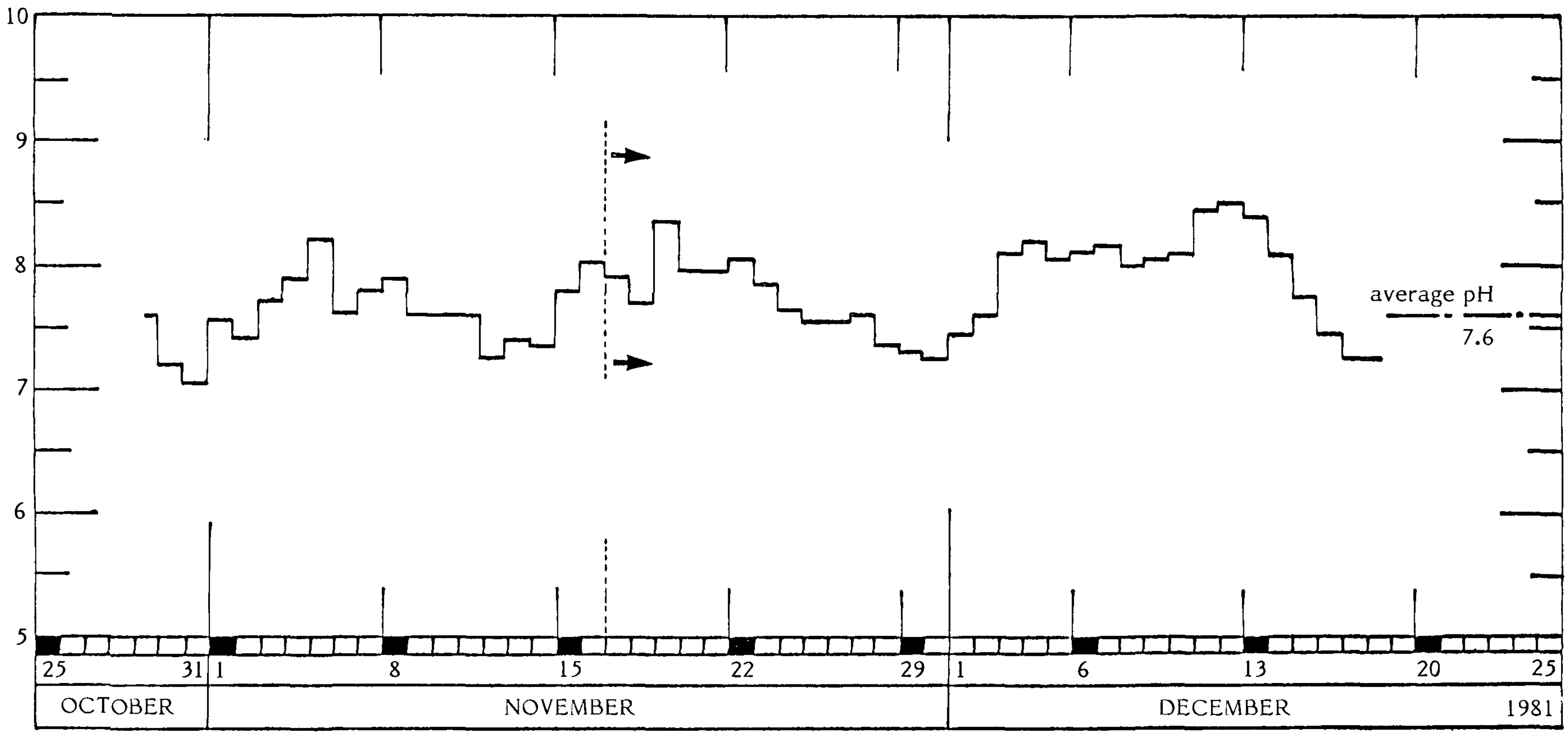


FIGURE 14 AVERAGE AERATION TANK pH
(Influent neutralization ceased November 17, 1981)

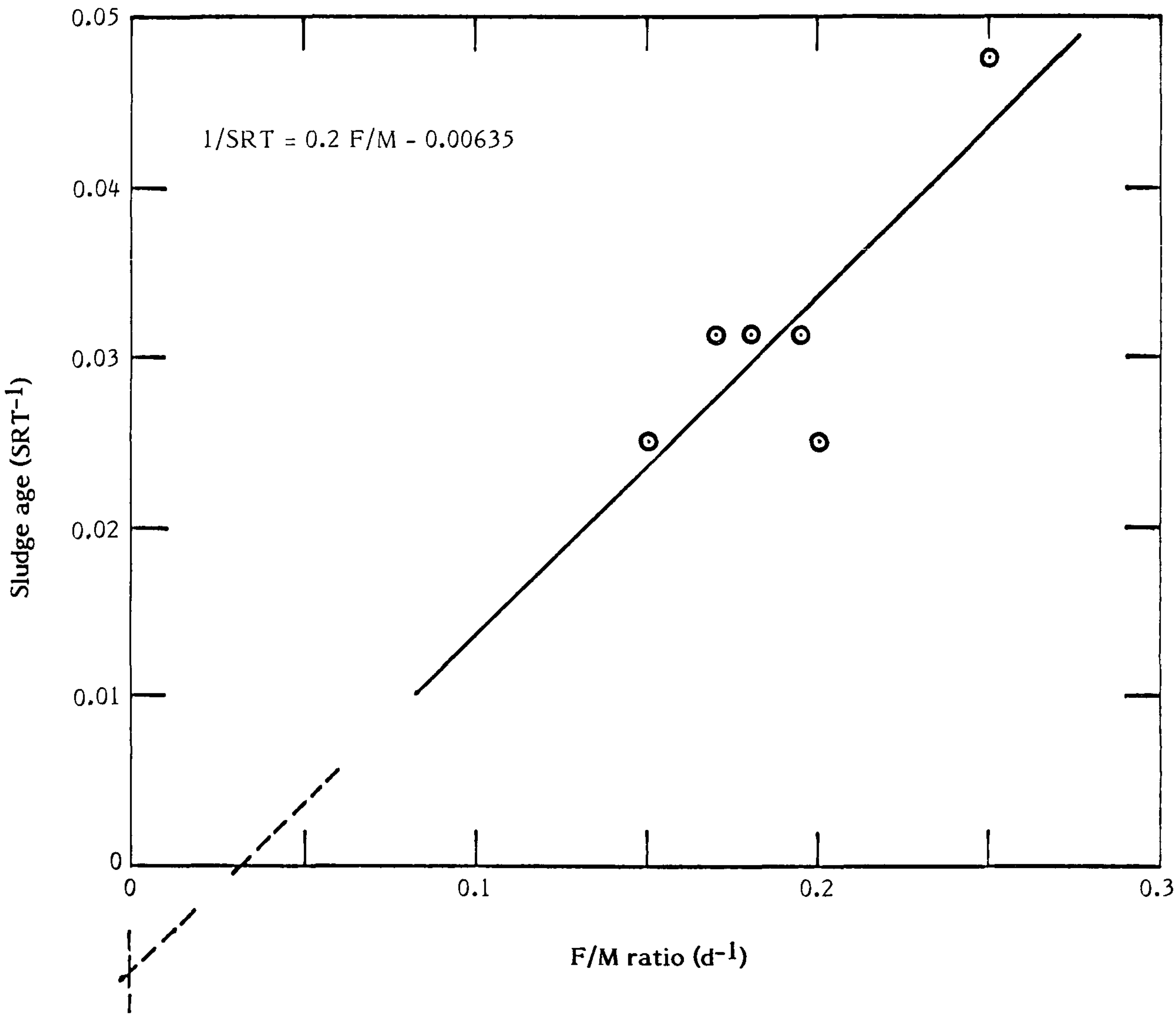
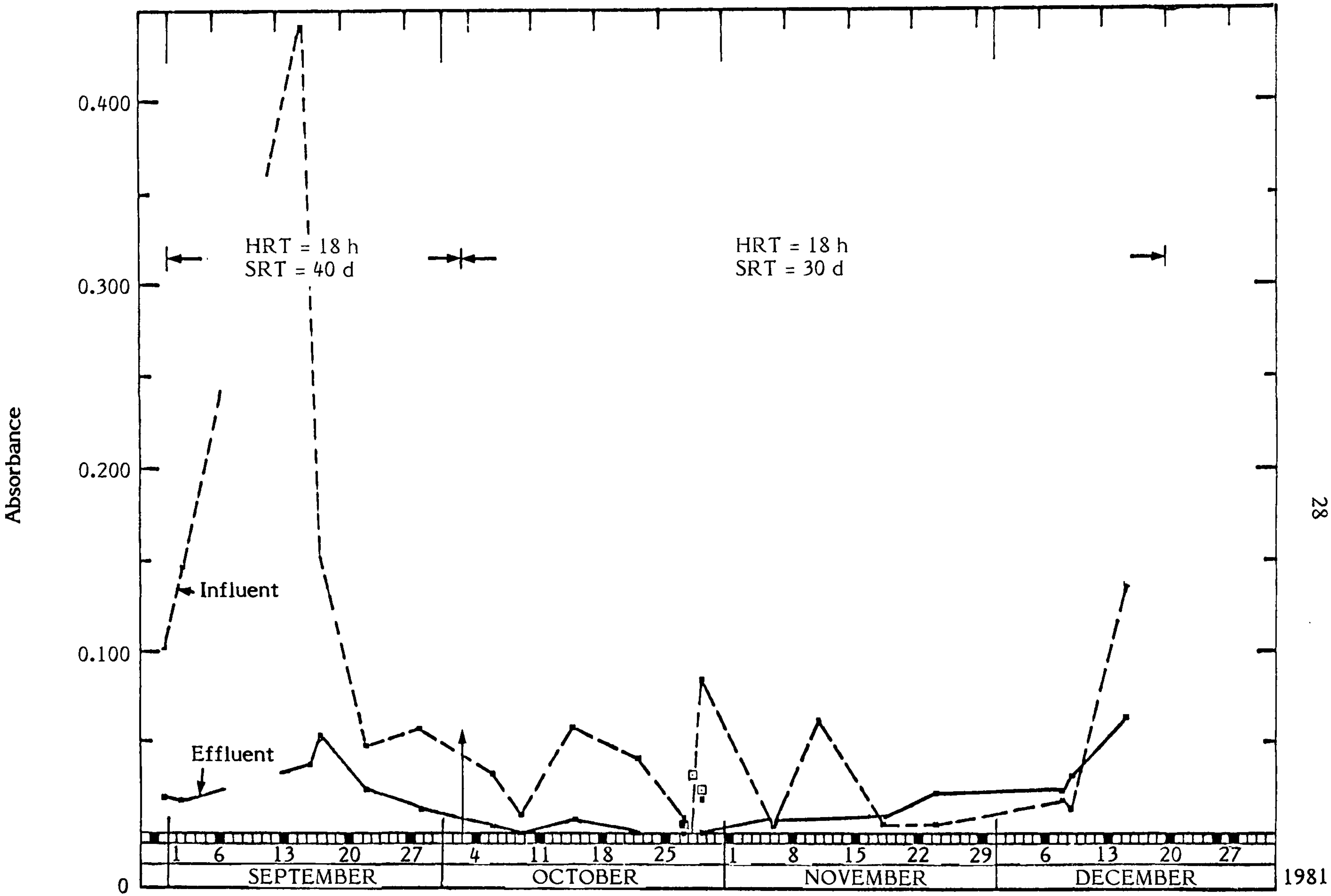


FIGURE 15 RELATIONSHIP BETWEEN SOLIDS RETENTION TIME AND F/M RATIO

tests based on hydraulic retention time of 18 hours and sludge ages of 40 days and 32 days, respectively, and the simulation tests where no nutrients were added and the pH was not adjusted.

True colour was measured by absorption on three wave-lengths (4222 Å, 5848 Å and 6459 Å). The reference colour of the Magog River was 0.000. Test results are shown in Figure 16.



November 18: Influent neutralization (H_2SO_4) ceases.
November 1: Addition of $(NH_4)_2$ HPO_5 to influent ceases.

FIGURE 16 COLOUR REMOVAL (Average ratio of intensity of light between intake and outlet on three wavelengths of the visible spectrum, red (4222Å), yellow (5448Å) and blue (6459Å).)

Tests showed that:

1) Biological treatment removes much of the colour from wastewater, but a certain amount remains.
2) Treatment demonstrated a good buffering effect, despite fluctuations in influent colour.
3) The greatest colour removal was achieved at an hydraulic retention time of 18 hours and a sludge age of 32 days, when colour was very close to 0.000. Visual examination of a one-litre sample showed a slight pink or mauve tinge, while the same sample examined in a test tube measured colour-free.
4) Nutrient deficiency seems to affect colour removal. Data indicate that treated wastewater was sometimes more coloured than the influent.
5) Colour removal depends very much on influent colour intensity and the dye types used.

7.7 COD Reduction and Colour Removal by Powdered Activated Carbon

Powdered activated carbon was used in a series of laboratory batch tests to determine the residual COD reduction potential. As Figure 17 shows, the results are conclusive: 0.000 colour and 50 mg/L of residual COD after filtration. On visual examination, carbon-treated wastewater was wholly free of colour. Activated carbon increased COD removal efficiency by an additional 64%, for a total of 95%. The findings support those of Bettens (1979) and Shaul et al. (1983).

It was estimated that an activated carbon dosage rate of 50 g/m^3 should, on balance, give similar results. Hydro Darco-C activated carbon was used.

These tests were not performed at pilot scale and no other carbon types were evaluated. If Hydro Darco-C, which cost $1.53 a kilo in 1983, were used at a rate of 50 g per cubic metre, the total cost would be more than $500 000 a year, excluding the necessary equipment. If, however, only colour removal was intended, less than 50 g/m^3 would be required.

7.8 Toxicity

Wastewater was tested for acute lethal toxicity after treatment at an SRT of 32 days and an HRT of 18 hours. No acute lethal toxicity was found. Appendix B provides the results of the toxicity tests.

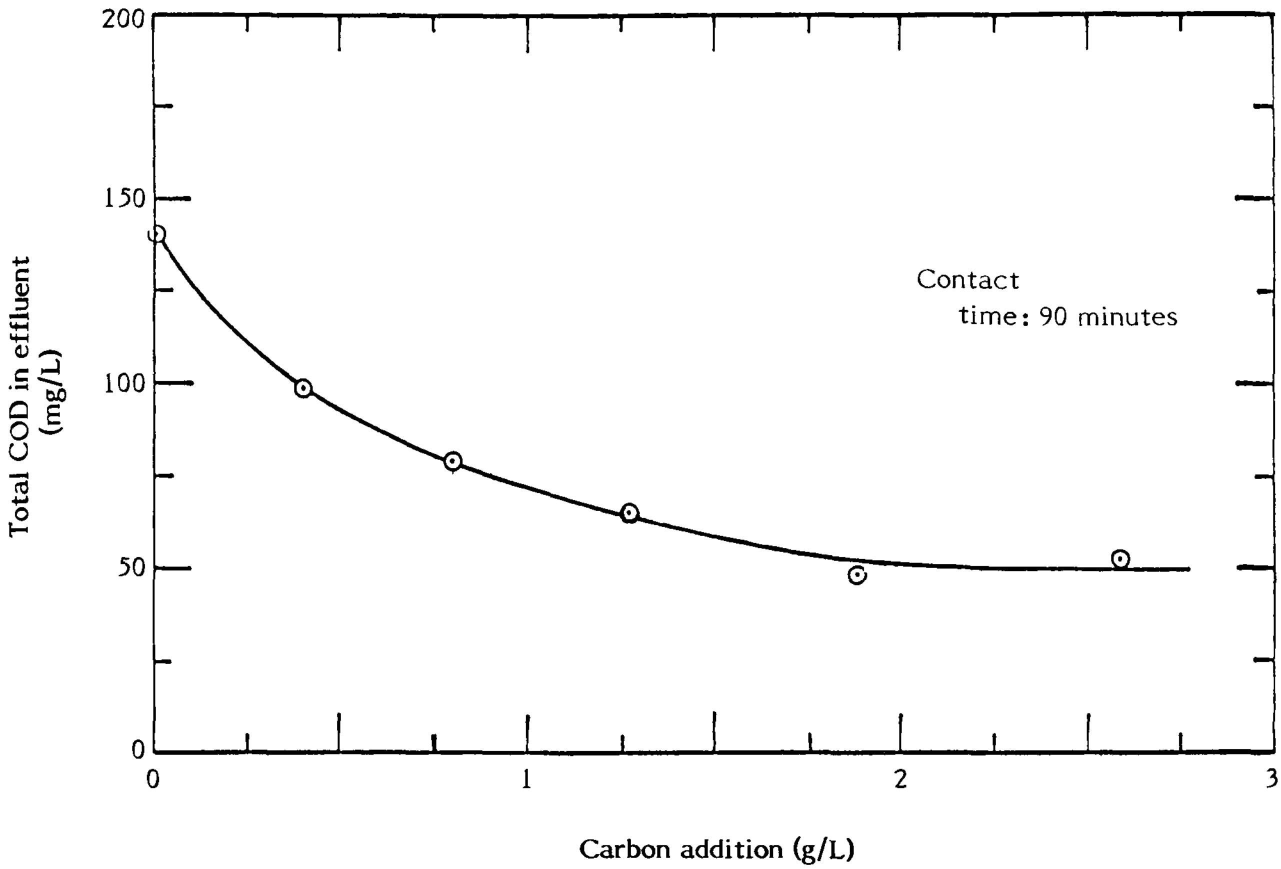


FIGURE 17 REDUCTION IN TOTAL COD ACHIEVED BY ADDITION OF POWDERED ACTIVATED CARBON

8 APPLICATION OF PILOT-SCALE RESULTS TO FULL-SCALE TREATMENT PLANT

Pilot-scale results showed that, at the design hydraulic retention time of the plant, sludge age had the greatest impact on system performance. Nutrient deficiencies primarily affected colour removal. Available nitrogen seemed to have been used solely for biosynthesis but it cannot be stated positively that available nitrogen was sufficient for biomass requirements. During the same evaluation period, the buffering effect of activated sludge made it possible to rectify fluctuations in pH.

For the full-scale tests, the solids retention time in the textile mill's treatment plant was adjusted to 30 days, to conform to the pilot test results. Once the required equilibrium had been reached, performance was evaluated from April 14 to June 30, 1982.

Prior to that time, the settling tanks had been covered with a thick layer of foam, and foam surrounded aerator platforms that were not in operation. Since only four of the eight aerators were in operation, it was necessary to ensure that the biomass suspended sludge was receiving sufficient dissolved oxygen and that good mixing was being achieved. Samples were therefore taken across the depth of the aeration tank to measure dissolved oxygen and check the homogeneity of the mixture. Results indicated good mixing and ample oxygenation. Figures 18 to 20 show the results of tests under controlled conditions.

Figure 18 shows how the total COD content of influent and effluent varied over time. COD removal efficiency averaged 79%. Organic content averaged 870 mg/L in influent and 182 mg/L in effluent. This performance, sustained over two and a half months, proved the effectiveness of the strategy adopted and the reliability of the pilot-scale results.

The total COD removal rate in the pilot plant was also around 79% and the foam in the settling and aeration tanks completely disappeared. Under the optimum pilot plant operating conditions, foaming was not a problem, and this observation was also confirmed at full-scale.

Figure 19 shows the effectiveness of activated sludge treatment in removing suspended solids. The SS content of effluent averaged 20 mg/L, which is in close agreement with pilot-scale results obtained under similar operating conditions, i.e., with no pH adjustment or nutrient addition.

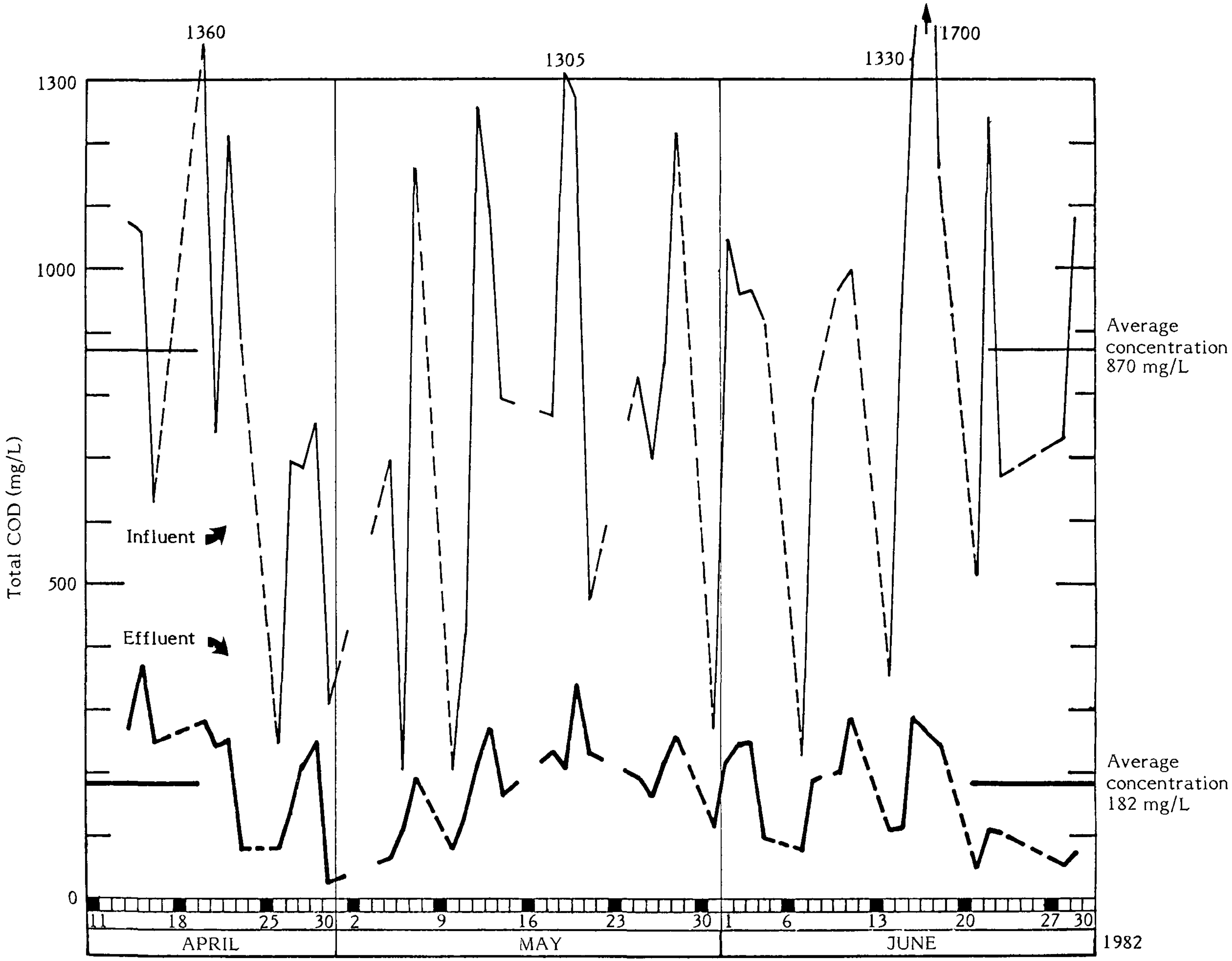


FIGURE 18 TOTAL COD REMOVAL, FULL-SCALE TREATMENT PLANT

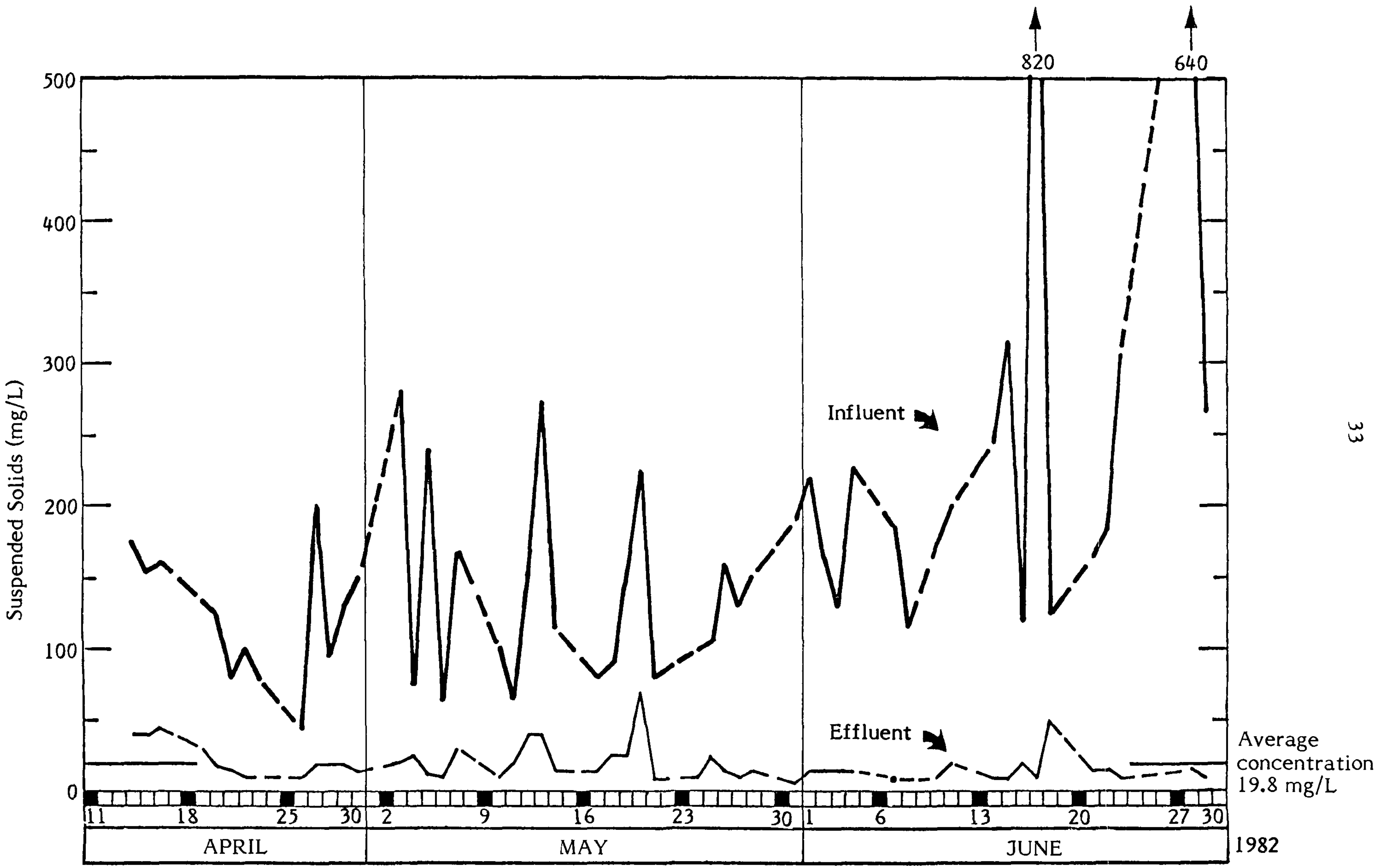


FIGURE 19 SUSPENDED SOLIDS REMOVAL, FULL-SCALE TREATMENT PLANT

Figure 20 shows the fluctuations in pH, when pH was not being adjusted. Influent pH rose to 11.8. The effect of merely altering the solids retention time is apparent; a 30-day sludge age produced sufficient carbon dioxide (CO_2) to neutralize raw wastewater pH and provide the desired buffering effect. The pH of the wastewater, and consequently in the aeration tank, varied from 7 to 9, comparable to the 7 to 8.5 recorded during the pilot-plant simulation tests done after influent neutralization ceased (see Figure 14).

Sludge age control improved performance considerably compared with the situation prior to the application of the pilot-scale test results (see Table A2, Appendix A). Nitrogen deficiency did not seem to have any particular effect on system performance. Nutrient supply was through the addition of septic tank sludge as is used regularly at the treatment plant. Since no analyses were made of the quantities of nutrients contained in this sludge, its supplementary effect could not be evaluated.

Pilot study results indicated that the traditional BOD_5/N ratio of 5:100 was not met but that a ratio of 100:2 gave satisfactory results except for colour removal. Nutrient addition and pH control should be practised since adverse effects could occur over a longer period.

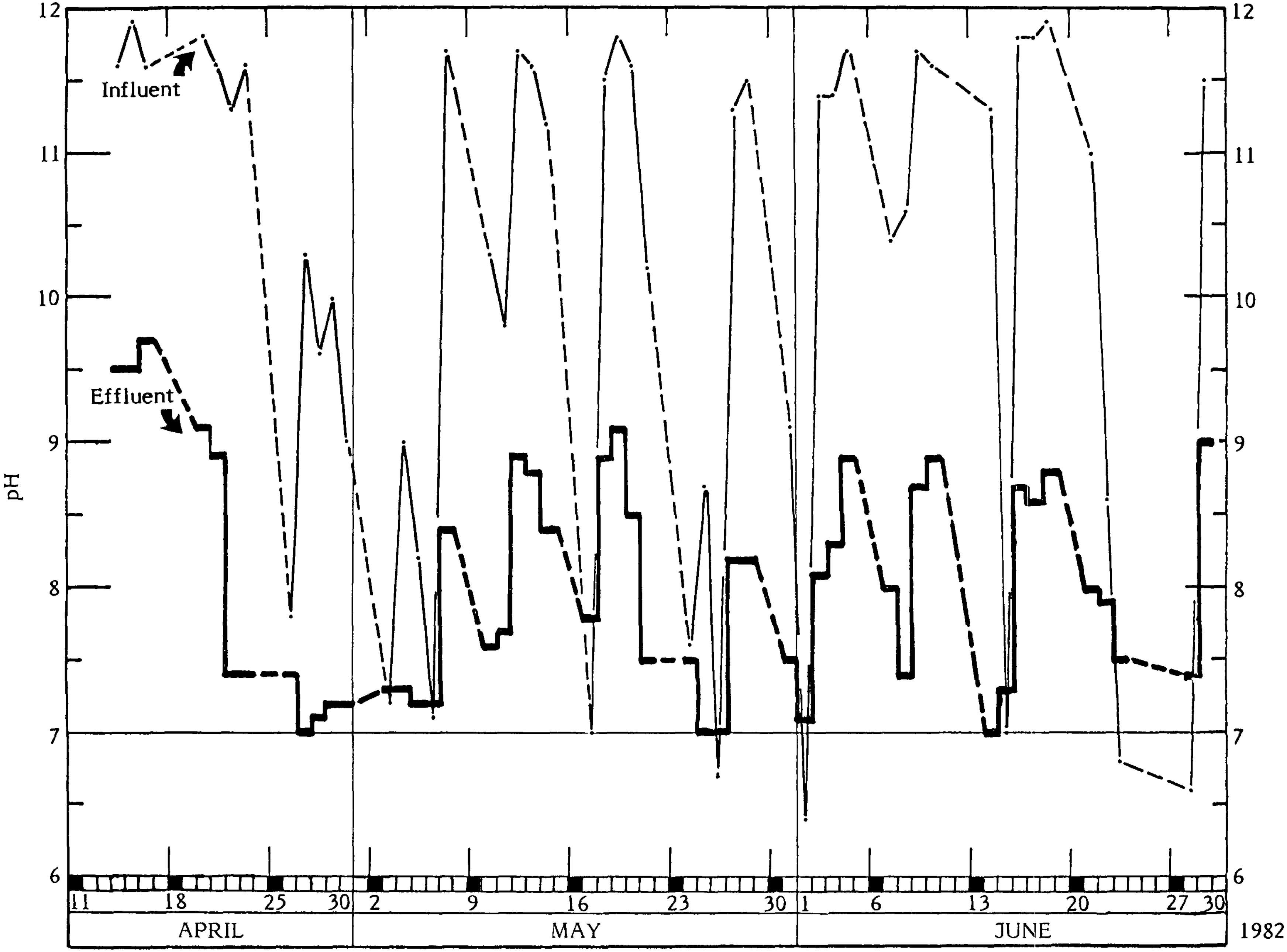


FIGURE 20 pH FLUCTUATIONS, FULL-SCALE TREATMENT PLANT

9 CONCLUSIONS AND RECOMMENDATIONS

1) This study showed the effectiveness of biological treatment of wastewater from a textile finishing mill.

2) The best results were achieved with a solids retention time (sludge age) of 32 days, an hydraulic retention time of 18 hours, a sufficient supply of nutrients, and an adjusted pH.

3) Within the 30 to 40 day sludge age range, hydraulic retention time was the primary factor in COD removal.

4) Colour removal by means of biological treatment depends essentially on the intensity of influent colour, the best results being achieved under optimum operating conditions.

5) According to the pilot study results, extended aeration can remove 80% of the total COD and produce an effluent with a suspended solids content of less than 20 mg/L.

6) Sludge production is estimated at 0.2 g of solids per gram of COD removed. Oxygen uptake was 0.2 mg of O_2/day per milligram of mixed liquor.

7) With a 30-day SRT, no addition of nutrients and no adjustment of pH, the system provided a COD reduction rate of 80% and an effluent suspended solids content of 17 mg/L, despite a nitrogen deficiency. However, nitrogen deficiency appeared to have an adverse effect on colour removal. In spite of the deficiency, activated sludge had a good buffering effect and pH remained at 7.6. The lack of nitrogen could explain the low BOD_5/N ratio of 100:2 noted under these conditions. It appears that any available nitrogen was used for biosynthesis.

8) Treated effluent did not cause acute lethal toxicity.

9) The use of activated carbon at a rate of 50 mg/m^3 of wastewater further increased residual COD reduction by an additional 64%, for a total reduction efficiency of 95%. Far less than 50 mg/m^3 should be required if the objective is only to remove the residual colour.

10) Sludge age and hydraulic retention time have a marked effect on suspended solids removal.

11) Treatment plants for textile finishing mill wastewater should be designed in terms of sludge age and hydraulic retention time.

12) Visual identification of residual colour must be standardized since a sample in a one-litre beaker shows traces of colour, while the contents of a test tube appear colour-free.

13) Use of a pilot unit to simulate full-scale conditions proved to be an economical way of identifying a satisfactory operating mode. The treatment strategy used at full-scale was based on the pilot-scale tests. The effluent contained 20 mg/L of suspended solids and total COD was reduced by 79%.

14) The study showed the dependency of system performance on hydraulic retention time and sludge retention time.

ACKNOWLEDGMENTS

Mr. C. Planzer, Director of the environmental division at Dominion Textile Inc., and Mr. G. Blouin, Manager of the company's treatment plant at the time that this study was carried out, are gratefully acknowledged for their invaluable assistance.

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APPENDIX A

PERFORMANCE TEST RESULTS

TABLE A1 PILOT PLANT SIMULATION RESULTS (no control of sludge age, no pH adjustment and no nutrient addition)

	Total COD (mg/L)		Total BOD (mg/L)	
Date	Influent	Effluent	Influent	Effluent
September 1981				
1	795	138	-	-
2	815	242	-	-
3	1230	320	270	2
4	1180	306	305	5
8	565	80	-	-
9	790	136	278	14
10	1060	198	325	6
11	1545	196	540	9
14	-	-	-	-
15	470	64	-	-
16	950	198	305	19
17	1035	290	420	11
18	1065	222	365	2
21	500	88	-	-
22	620	174	-	-
23	980	254	218	13
24	1020	182	385	8
25	775	160	282	6
28	-	-	-	-
29	880	324	-	-
30	1395	398	340	12
October 1981				
1	995	268	320	6
2	1090	316	450	17
5	355	130	-	-
6	885	278	-	-
7	1130	276	-	-

TABLE A1 PILOT PLANT SIMULATION RESULTS (no control of sludge age, no pH adjustment and no nutrient addition) (Cont'd)

Date	Total COD (mg/L)		Total BOD (mg/L)	
	Influent	Effluent	Influent	Effluent
8	715	206	325	4
9	870	274	235	1
13	475	134	-	-
14	865	202	380	7
15	1260	280	445	6
16	1105	484	-	-
17	-	-	-	-
18	-	-	-	-
19	655	215	-	-
20	-	-	-	-
21	1170	388	315	4
22	915	328	315	6
23	1155	386	300	5
26	955	196	-	-
27	800	248	-	-
28	945	294	465	1
29	1575	430	415	5.5
30	1510	476	520	6.5
November 1981				
3	1050	392	-	-
4	980	428	365	17
5	1290	418	420	8.5
6	970	296	345	6
9	-	-	-	-
10	-	-	-	-
11	1430	364	520	3.5
12	1785	500	560	7.5
13	1650	584	340	0
16	710	228	-	-

TABLE A1 PILOT PLANT SIMULATION RESULTS (no control of sludge age, no pH adjustment and no nutrient addition) (Cont'd)

	Total COD (mg/L)		Total BOD (mg/L)	
Date	Influent	Effluent	Influent	Effluent
17	1015	346	-	-
18	1130	400	340	19
19	1200	454	410	36
20	1510	346	410	7
23	865	192	-	-
24	1200	296	-	-
25	1085	280	285	1
26	1200	328	375	16
27	720	236	320	6
30	620	186	-	-
December 1981				
1	955	358	-	-
2	875	308	282	15
3	1480	392	425	16.5
4	1125	396	330	8.5
7	845	172	-	-
8	-	-	-	-
9	1470	584	540	55
10	1170	424	320	12
11	1185	416	420	22
14	1090	186	-	-
15	-	-	-	-
16	-	-	-	-
17	-	-	-	-
18	1520	306	-	-
21	855	250	-	-
22	1070	236	-	-

TABLE A2 EFFECT OF SLUDGE AGE CONTROL ON FULL-SCALE TREATMENT PLANT PERFORMANCE (company data)

	Influent (mg/L except pH)				Effluent (mg/L except pH)			
Date	SS	COD	O&G	pH	SS	COD	O&G	pH
April 1982								
14	175	1075	36	11.6	40	270	2	9.5
15	155	1060		11.9	40	368		9.5
16	160	630		11.6	45	252		9.7
20	125	1360	16	11.8	30	280	0	9.1
21	80	740		11.6	20	246		8.9
22	100	1210		11.3	15	252		7.4
23	80	890		11.6	10	80		7.4
26	45	245		7.8	10	80		7.4
27	200	695	26	10.3	20	138	0	7.0
28	95	685		9.6	20	208		7.1
29	130	755		10.0	20	250		7.2
30	150	310		9.0	15	126		7.2
May 1982								
3	280	-		7.2	20	-	7.3	
4	75	-	4	9.0	25	-	7.3	
5	240	695		8.2	12	64		7.2
6	65	205		7.1	10	108		7.2
7	165	1160		11.7	30	192		8.4
10	100	205		10.3	10	80		7.6
11	65	420	10	9.8	20	124	2	7.7
12	150	1255		11.7	40	214		8.9
13	275	1100		11.6	40	270		8.8
14	115	795		11.2	15	164		8.4
17	80	-	-	7.0	15	-	-	7.8
18	90	765	8	11.5	25	234	2	8.9
19	145	1305		11.8	25	208		9.1
20	225	1270		11.6	70	340		8.5

TABLE A2 EFFECT OF SLUDGE AGE CONTROL ON FULL-SCALE TREATMENT PLANT PERFORMANCE (company data) (Cont'd)

	Influent (mg/L except pH)				Effluent (mg/L except pH)			
Date	SS	COD	O&G	pH	SS	COD	O&G	pH
21	80	475		10.2	10	232		7.5
24	100	--		7.6	10	--		7.5
25	105	825	12	8.7	25	192	4	7.0
26	160	700		6.7	15	164		7.0
27	130	850		11.3	10	218		8.2
28	150	1215		11.5	15	258		8.2
31	190	270		9.1	5	118		7.5
June 1982								
1	220	1045	34	6.4	15	220	0	7.1
2	165	960		11.4	15	244		8.1
3	130	965		11.4	15	248		8.3
4	225	920		11.7	15	98		8.9
7	185	230		10.4	10	80		8.0
8	115	795	20	10.6		192	2	7.4
10	175	965		11.7	10	202		8.7
11	200	995		11.6	20	286		8.9
14	245	355	50	10.8	10	108	0	7.0
15	315	935		7.0	10	116		7.3
16	120	1330		11.8	20	288		8.7
17	820	1700		11.8	5	264		8.6
18	125	1160		11.9	50	246		8.8
21	165	515		11.0	15	50		8.0
22	185	1240	26	8.6	15	110	4	7.9
23	305	670		6.8	10	104		7.5
28	640	730		6.6	15	54		7.4
29	265	1080	26	11.5	10	74	2	9.0

APPENDIX B

TOXICITY TEST RESULTS

ANALYSIS REPORT

SAMPLE: DOMTEX - MAGOG
Point A - Influent

Test no.	595	**Requested by:**	R. Zaloum, P. Eng.
Date of sample	27-10-81 ,	**by** EPS	
Date of test (1) **by:**	29-10-81 **(2)** R.L.	30-10-81 **(3)** P.C.	12-11-81 R.L.

RESULTS

TEST	**CONTROL**	**INTAKE WATER**	**SAMPLE**	___ **ORIGINAL** _X_ **ADJUSTED**
(1) TROUT			**100%**	**65% v v** ___ **% v v**
Mortality (%)	0	0	100	
TL-50 (h)		ND	1-4	
CL-50 (24 h)				___ % v v
CL-50 (96 h)				___ % v v
(2) Microtox®			**NONFILT.**	**FILT. 0.45 u**
Cl-50			2.6%v v	___ %v v
(3) Algae			**FILT. 0.2 u**	
			5.4%v v	

PARAMETERS SUSPECTED OF CAUSING MORTALITY

___ pH	___ Arsenic	___ Ammonium	Other:
___ DO	___ Aluminum	___ Chlorides	
___ BOD	___ Chrome	___ Cyanide	
___ Res. tot. Cl	___ Copper	___ Fluoride	
___ TS	___ Iron	___ Nitrate	
___ O&G	___ Nickel	___ Nitrite	
___ COD	___ Lead	___ Tot. Phos.	
___ Phenols	___ Zinc	___ Sulphur	

Sample Adjustments:

				X	HNO_3
pH_o =	12.8	pH_a = 7.4	with	___	NaOH

Tot. res. Cl: E. E. ____________ ppm
Sample ____________ neut. with $Na_2S_2O_3$

Other:

Trout Test Conditions:

Static - 96 h

Other:

Temp.	15°C	Vol./tank	50 L	Load	0.2 L/g/d
No. fish/tank	= 10		Average weight	6.0 g	
			Average length	___ cm	
Aeration	X 5 cm^3/min/L		Preaeration	___ h	
	___ 7.5 cm^3/min/L				

Remarks:

Test trout: Strong toxicity at point A; 50% lethality in 1-4 hours, probably attributable to ammonia nitrogen.

Algae: Sample proved toxic. Results for inorganic phosphorus, nitrites and nitrates, ammonia nitrogen and fertility potential (180 ppm) indicate heavy nutrient loading, leading to excessive enrichment of medium.

ANALYSIS REPORT

SAMPLE: DOMTEX - MAGOG
Point P_2: pilot plant effluent

Test no.	598	Requested by:	R. Zaloum, P. Eng.
Date of sample	27-10-81 ,	by EPS	
Date of test (1) by:	29-10-81 (2) R.L.	30-10-81 (3) P.C.	12-11-81 R.L.

RESULTS

TEST	CONTROL	INTAKE WATER	SAMPLE	___ ORIGINAL ___ ADJUSTED	
(1) TROUT			100%	65%v v	___ % v v
Mortality (%)	0	0	100		
TL-50 (h)		ND	ND		
CL-50 (24 h)				___ %v v	
CL-50 (96 h)				___ % v v	
(2) Microtox®			NONFILT.	FILT. 0.45 u	
Cl-50			ND %v v	___ %v v	
(3) Algae			FILT. 0.2 u		
			ND %v v		

PARAMETERS SUSPECTED OF CAUSING MORTALITY

___ pH	___ Arsenic	___ Ammonium	Other:
___ DO	___ Aluminum	___ Chlorides	
___ BOD	___ Chrome	___ Cyanide	
___ Res. tot. Cl	___ Copper	___ Fluoride	
___ TS	___ Iron	___ Nitrate	
___ O&G	___ Nickel	___ Nitrite	
___ COD	___ Lead	___ Tot. Phos.	
___ Phenols	___ Zinc	___ Sulphur	

Sample Adjustments:

pH$_o$ = 12.8 | pH$_a$ = 7.4 | with | X HNO_3 / ___ NaOH

Tot. res. Cl: | E. E. ____________ ppm
Sample ____________ neut. with $Na_2S_2O_3$

Other:

Trout Test Conditions:

Static - 96 h | Other:

Temp.	15°C	Vol./tank	50 L	Load	0.2 L/g/d
No. fish/tank =	10		Average weight 6.0 g		
			Average length ___ cm		
Aeration	X 5 cm^3/min/L		Preaeration ___ h		
	___ 7.5 cm^3/min/L				

Remarks:

APPENDIX C

MAJOR CHEMICALS USED IN DOMINION TEXTILE'S FINISHING MILL AT MAGOG (December 1981)

TABLE C1 MAJOR CHEMICALS USED IN DOMINION TEXTILE'S FINISHING MILL AT MAGOG (December 1981)

Substance	Quantity (metric tonnes)	Main compound	Discharged to
Ethyl alcohol, 95% technical grade	1060	99% Shellsol	atmosphere
Acids	548	95% acetic acid	wastewater
Bases	302	99% caustics	wastewater
Thermosetting resins	527		95% in fabric
Oxidizing agents	360	hydrogen peroxide	wastewater
Salts	364	NaCl	wastewater
Reducing agents	266	sodium bisulphite	wastewater
Conditioners/thickening agents	191		90% in fabric
Emulsifiers	187		wastewater
Sequestering agents	30	sodium hexametha-phosphate $(NaPO_3)_6$	wastewater
Catalysts	24		wastewater
Dye carriers	17	Levegal B	wastewater
TOTAL	3876		

TABLE C2 DYES USED IN DOMINION TEXTILE'S FINISHING MILL AT MAGOG (December 1981)

Dye type	Quantity (metric tonnes)
Pigment	674
Vat	595
Sulphur	520
Dispersed	100
Azo	56
Reactive	15
TOTAL	1960