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Activated Sludge and Activated Carbon Treatment of a Wood Preserving Effluent Containing Pentachlorophenol

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ACTIVATED SLUDGE AND ACTIVATED CARBON TREATMENT OF A WOOD PRESERVING EFFLUENT CONTAINING PENTACHLOROPHENOL

by

P.H.M. Guo, P.J.A. Fowlie, V.W. Cairns and B.E. Jank
Wastewater Technology Centre
Environmental Protection Service
ENVIRONMENT CANADA

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ABSTRACT

A six-month monitoring and wastewater treatment plant effluent upgrading program was carried out at Abitibi-Northern Wood Preservers Limited, Thunder Bay, Ontario, a plant which preserves wood with creosote, pentachlorophenol (PCP) and chromated copper arsenate (CCA). Treatment of the wastewater, after oil separation and flow equalization by the extended aeration activated sludge process, gave good removal of most organics; however, PCP removal averaged only 35% and the effluent was toxic to rainbow trout. Treatment of the activated sludge effluent by carbon adsorption resulted in effective PCP removal and non-toxic effluents. Activated carbon treatment of wastewater, after oil separation and flow equalization, gave good removals of organics and PCP.

RÉSUMÉ

Un programme de surveillance et de traitement des effluents de la station d'épuration de l'Abitibi-Northern Wood Preservers Limited (Thunder Bay, Ontario) s'est poursuivi durant six mois. Cette firme utilise de la créosote, du pentachlorophénol (PCP) et de l'arséniate de cuivre en présence d'un chromate comme agents de conservation du bois. Après séparation d'avec leur fraction huileuse et stabilisation par aération prolongée des boues activées, les eaux usées ont été débarassées de la plupart de leurs substances organiques. Le PCP n'ayant toutefois été éliminé qu'à 35% en moyenne, l'effluent est demeuré toxique pour la truite arc-en-ciel, ce qui n'a plus été le cas après adsorption au charbon actif. Ce traitement supplémentaire est efficace contre les substances organiques et le PCP.

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CONCLUSIONS

1. Wastewater characteristics from Abitibi-Northern Wood Preservers Limited were monitored over a period of six months. The wastewater, after oil separation, exhibited highly variable characteristics. Ranges for the major parameters determined were: BOD_5, 370 to 3000 mg/L; COD, 1000 to 5400 mg/L; TOC, 210 to 1800 mg/L; phenol, 180 to 1340 mg/L; pentachlorophenol (PCP), 0.30 to 14.9 mg/L; oil and grease, 23 to 210 mg/L; and suspended solids, 6 to 188 mg/L. Polychlorinated biphenyl (PCB) was not detected in the wastewater (<0.02 µg/L).
2. The extended aeration activated sludge plant, operated at an organic loading of 0.02 to 0.06 kg BOD_5/kg MLSS•d, successfully removed organic compounds from the wood preserving wastewater. During two monitoring periods, the average effluent characteristics were: BOD_5, 19 and 26 mg/L; COD, 265 and 300 mg/L; TOC, 31 and 52 mg/L; phenol, 0.16 and 0.16 mg/L; PCP, 5.5 and 3.6 mg/L; and suspended solids, 69 and 58 mg/L. Oil and grease, monitored during one period only, averaged 14.5 mg/L. The effluent from the activated sludge plant was extremely toxic to rainbow trout.
3. The extended aeration activated sludge process, followed by granular activated carbon adsorption, provided a combined treatment system having the following effluent quality: BOD_5, 23 mg/L; COD, 155 mg/L; TOC, 13 mg/L; phenol, 0.08 mg/L; PCP, 0.03 mg/L; oil and grease, 6 mg/L; and suspended solids, 16 mg/L. This effluent was non-toxic to rainbow trout. The carbon adsorption system had not reached exhaustion after 42 days of operation which corresponded to the treatment of 500 empty bed volumes of activated sludge effluent.
4. When the activated carbon system was used to treat wastewater directly, the average effluent quality was as follows: BOD_5, 152 mg/L; COD, 264 mg/L; TOC, 84 mg/L; phenol, 5.3 mg/L; PCP, 0.02 mg/L; oil and grease, 6 mg/L; and suspended solids, 2 mg/L. The system experienced breakthrough with respect to BOD_5, COD, TOC and phenol after eight days' operation which corresponded to the treatment of 96 empty bed volumes of wastewater.

1 INTRODUCTION

Regulations and guidelines for controlling the wastewater from the wood preservation industry are currently being considered by Environment Canada. In the event that it is decided to proceed with the development of effluent regulations/guidelines, it is necessary to establish a data base in order to define best practicable technology (BPT) for the treatment of wood preserving wastes. To accomplish this, the Wastewater Technology Centre, Burlington, Ontario, undertook a comprehensive sampling and monitoring program at the activated sludge system at Abitibi-Northern Wood Preservers Limited, Thunder Bay, Ontario.

The program was carried out from November 1, 1977 to May 1, 1978 and was divided into three phases. The first phase involved the monitoring and upgrading of the existing full scale activated sludge system. In the second phase, the activated sludge effluent was treated by a granular activated carbon column system. During the last phase of the study, the activated sludge system was by-passed and the wastewater, after oil separation and flow equalization, was treated in the activated carbon system.

The specific objectives of the study were to collect information which could be used in the identification of BPT for the treatment of wood preserving wastes and to provide a data base to be used in the development of regulations limiting the discharge of deleterious substances to the environment.

2 MATERIALS AND METHODS

2.1 Experimental Schedule

During the first phase of the operation, the full scale activated sludge system was operated for six weeks at a flow rate of 13 m^3/d. As the activated sludge effluent was extremely toxic during the first phase of the project, a pilot scale activated carbon system was installed to provide additional treatment of the effluent from the biological system. While the biological system was operated at the same flow rate as in the Phase 1 operation, the activated carbon columns were fed at 0.6 m^3/d. As the carbon adsorption system successfully detoxified the effluent, attempts were made to investigate whether it was feasible to treat the waste in an activated carbon system without the biological treatment step. Therefore, in the last phase of the study, the wastewater following oil separation and flow equalization was fed directly to the carbon adsorption system at the same flow rate (0.6 m^3/d) used in the second phase. The experimental schedule is shown in Table 1.

TABLE 1. PROGRAM SCHEDULE

Phase	Date of Operation	Type of Treatment Systems	Feed Rate (m^3/d)
1	Nov. 1 - Dec. 16, 1977	activated sludge	13
2	Mar. 3 - Apr. 13, 1978	activated sludge followed by activated carbon	13 and 0.6, respectively, for the activated sludge and activated carbon systems
3	Apr. 20 - May 1, 1978	activated carbon	0.6

2.2 Source of Wastewater

The Abitibi-Northern Wood Preservers Limited, Thunder Bay, Ontario, preserves various wood products such as telephone poles, railway ties, and lumber for decks and wharfs. Three different preservatives, pentachlorophenol (PCP), creosote, and chromated copper arsenate (CCA), are used in the wood preserving operation. Hydro poles are treated with PCP, railway ties with creosote, and lumber for decks and wharfs with CCA. Wood conditioning and treatment are carried out in three retorts. Creosote is used in two of the retorts, with the third used for either PCP or CCA preservative. The plant is processing approximately 196 000 m^3 of wood annually.

The wastewater discharged to the treatment plant is the condensate generated during open steam conditioning. The condensate is contaminated with water-soluble wood extractives, primarily carbohydrates. Because wood conditioning and treatment are carried out in the same retort, the condensate generated following treatment with the oil-borne preservatives, creosote and PCP is highly contaminated. This problem does not exist following treatment with CCA as the water-borne preservative drains from the retort and is completely recovered. The condensates produced during conditioning following CCA treatment may contain traces of chromium, copper and arsenic; however, they are generally considered to be uncontaminated by the preservative.

2.3 Existing Collection and Treatment System

A schematic of the wastewater collection and treatment system is presented in Figure 1. An average of 13 m^3/d wastewater is generated from the creosote and PCP operations. Once-through cooling water is returned to Lake Superior. The waste stream from the wood treatment area is first collected in a concrete pit and pumped to an oil separation tank where floating oils are recovered. It then flows by gravity to a divided oil separation basin where the settled heavy oils are retained in the first cell. The overflow is collected in the second cell and pumped to the first tank of the flow equalization system, a 14.1-m^3 holding tank. This tank was originally designed for storing the excess sludge produced in the activated sludge system. Because of negligible sludge accumulation in the treatment system, this tank was later converted to a liquid holding tank to expand the capacity of the original flow equalization facility. The two tanks are connected in series and provide a total working volume of 34.2 m^3.

The temperature of the wastewater is maintained between 29 and 40°C by steam injection. After continuous pH adjustment with NaOH, and

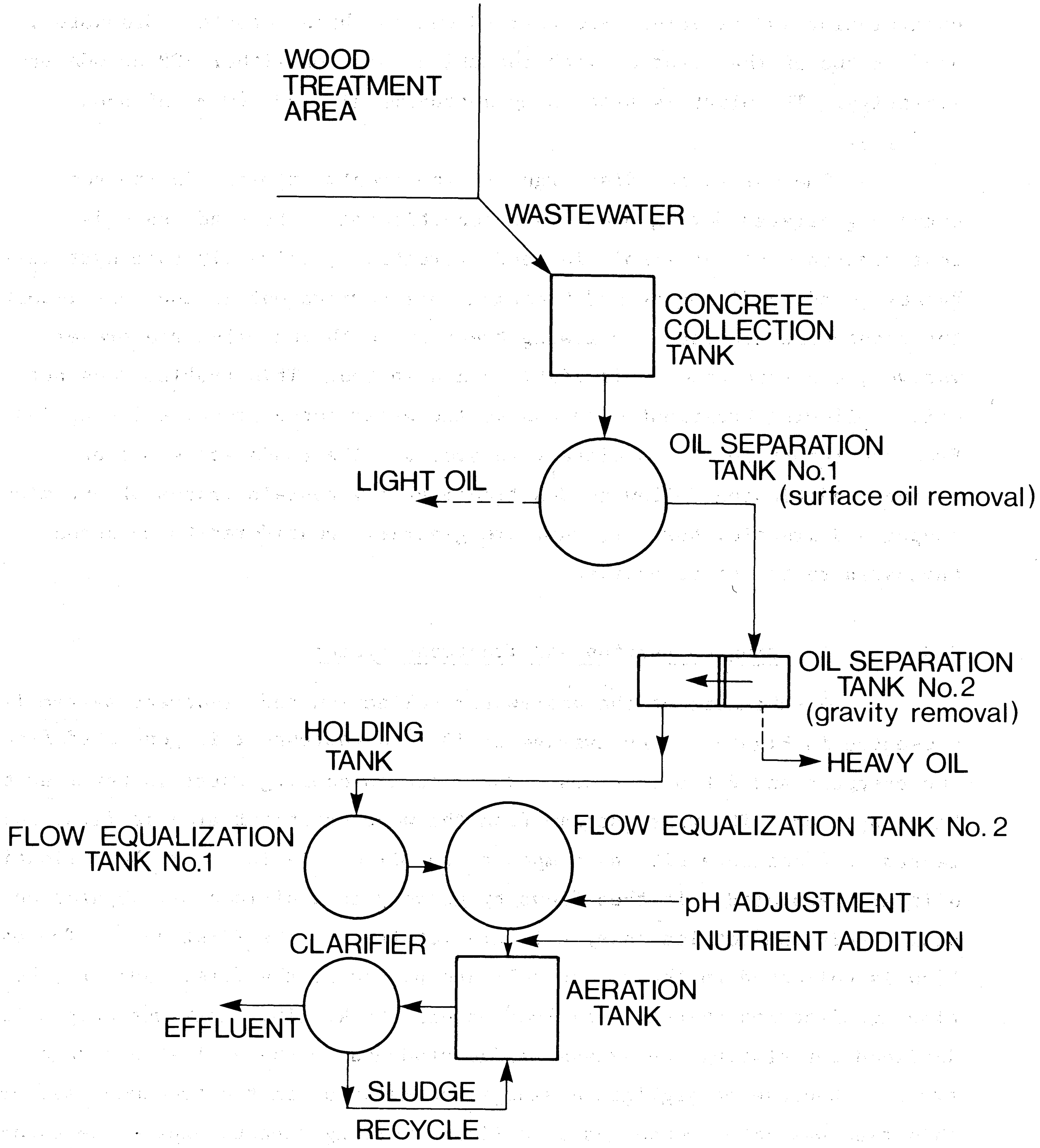

FIGURE 1. EXISTING WASTEWATER COLLECTION AND TREATMENT SYSTEM

continuous metering of NH_4OH and H_3PO_4 as nutrients, the wastewater is pumped to a constant head tank which feeds the aeration tank at a constant rate. NH_4OH and H_3PO_4 dosages were selected to provide a BOD_5:N:P ratio of 100:5:1 in the wastewater.

The aeration tank, having a volume of 36.6 m^3, is equipped with a 1.4-m diameter Simcar aerator driven by a 3.8-kW motor. Mixed liquor suspended solids flow by gravity to a 3.8-m^3 clarifier, and the clarified effluent discharges to the harbour. A sludge scraping mechanism is provided in the clarifier for sludge collection. Settled sludge is recycled back continuously to the aeration tank by a centrifugal pump. Further pH adjustment with lime is carried out by direct addition to the aeration tank three times weekly.

2.4 Pilot Scale Carbon Adsorption System

The carbon adsorption system used for Phase 2 and Phase 3 of the operation consisted of three, 100-mm diameter, 3-m high PVC columns which were preceded by a granular media filter, a 100-mm diameter, 1.5-m high PVC column. These columns were operated in series in downflow mode. The granular media filter contained 11 kg of anthracite filtering media which occupied 1 m of the column. Each of the three carbon adsorption columns contained 6.8 kg of Filtrasorb 400* granular activated carbon which filled the columns to a depth of 2.1 m. The flow diagrams for the three phases of the operation are shown in Figure 2.

2.5 Monitoring Programs

The detailed monitoring program for each individual phase of the operation is discussed in the following sections.

2.5.1 Phase 1

During this phase of the operation, the activated sludge system was monitored by:

(a) Collection of 24-hour composite samples of influent and effluent five days per week. Chemical oxygen demand (COD),

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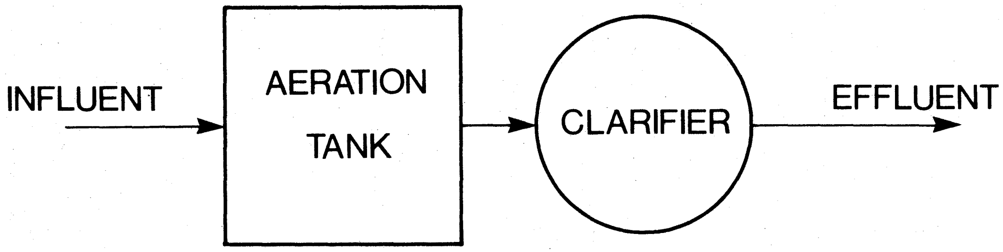
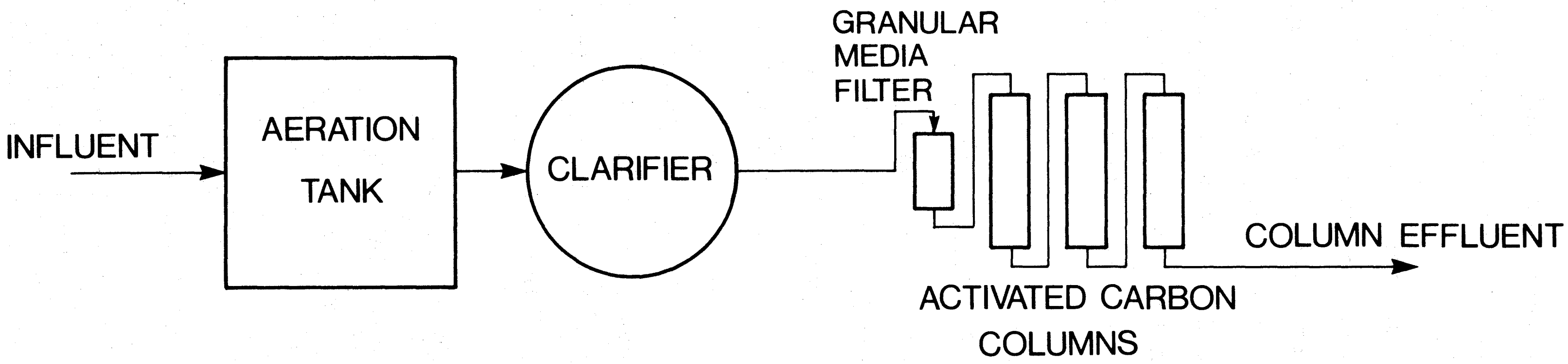
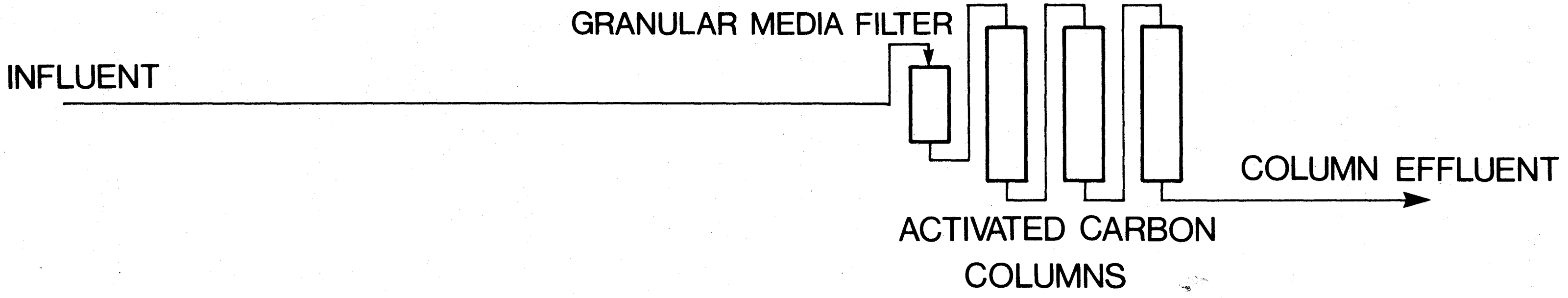
* Calgon Corporation, PO Box 1346, Pittsburgh, Pa. 15230.



PHASE 1 – ACTIVATED SLUDGE TREATMENT



PHASE 2 – ACTIVATED SLUDGE PLUS ACTIVATED CARBON TREATMENT



PHASE 3 – ACTIVATED CARBON TREATMENT

FIGURE 2. FLOW DIAGRAMS FOR THREE PHASES OF OPERATION

five-day biochemical oxygen demand (BOD_5), total Kjeldahl nitrogen (TKN), pH, total phosphorus (TP) and suspended solids were determined on unfiltered samples. Ammonia-nitrogen (NH_3-N) and total organic carbon (TOC) were determined on filtered samples.

(b) Collection of grab samples three to four times weekly for the determination of oil and grease, phenol, PCP and polychlorinated biphenyl (PCB).

(c) Daily measurement in situ of pH and temperature of the plant influent, effluent and mixed liquor as well as the mixed liquor dissolved oxygen and sludge volume index (SVI).

(d) Collection of an effluent sample once or twice per week for the testing of toxicity to rainbow trout.

(e) Daily measurement of influent and return sludge flow rates.

2.5.2 Phase 2

The activated sludge plant was monitored seven days per week, according to Section 2.5.1, with the exception of toxicity testing which was carried out five days per week. It should be noted that PCB analyses were not performed during Phases 2 and 3 since PCB was not detected during Phase 1. The activated carbon adsorption system was monitored by:

(a) Daily collection of composite samples of effluent from the last column for the analyses of pH, PCP, BOD_5, COD, TKN, total phosphorus and suspended solids on unfiltered samples, and for the analyses of TOC and ammonia on filtered samples.

(b) Daily collection of grab samples from the same sampling location as identified in (a) for phenols, oil and grease analyses, and toxicity testing.

(c) Daily collection of grab samples from the effluent of the granular media filter for TOC, PCP, and suspended solids analyses.

(d) Daily collection of composite samples from the effluent of the first and second activated carbon columns for TOC, PCP, and suspended solids analyses.

(e) Daily measurement of flow rate and pressure drop in the carbon columns. When the column was being backwashed, samples were collected at one-minute intervals for PCP and suspended solids analyses.

2.5.3 Phase 3

As the untreated waste was fed directly to the carbon adsorption system, the activated sludge plant was not monitored during this phase of the operation. The monitoring program for the carbon adsorption system was the same as that mentioned in Section 2.5.2, except for the toxicity testing. During the twelve-day operating period, only two samples were collected for bioassay testing.

2.6 Analytical Methods

BOD_5, COD, phenols, and oil and grease were determined according to procedures specified in Standard Methods (APHA, 1971). Influent, effluent and mixed liquor suspended solids (MLSS) were performed using GF/A fibreglass filter papers. Total phosphorus, ammonia and TKN were analyzed by wet chemical colourimetric techniques according to methods specified by Technicon Instruments Corporation. PCP analysis was carried out using the procedure specified in the Analytical Methods Manual (1974).

2.7 Bioassay Testing

2.7.1 Fish

Bioassays were conducted with juvenile rainbow trout (Salmo gairdneri) weighing an average of 2.7 g and having an average condition factor (100 x weight/length^3) of 1.4. The fish were obtained from Goossens Trout Farm, Otterville, Ontario, and held in the bioassay laboratory at the Wastewater Technology Centre for a minimum of four weeks before testing. During this time, the trout were maintained at 15 ± 1°C in dechlorinated Burlington municipal water under a 14-hour light, 10-hour dark photoperiod and fed a daily ration of Silver Cup trout pellets equal to 3% of their body weight. Mortality in the holding tanks during this period was negligible.

2.7.2 Bioassays

The acute lethality of Abitibi-Northern Wood Preservers Limited effluent was determined in accordance with the presently accepted Environmental Protection Service regulatory test method. Twenty-litre samples of biologically treated effluent, and 60-litre samples of biologically treated effluent with activated carbon treatment were transported by air. Upon arrival at the Wastewater Technology Centre the samples were mixed, sampled for total Cu, total As, As^{+3}, total Cr and PCP analysis, and the temperature adjusted to 15 ± 1°C. Bioassays were started within 48 hours after sample collection.

Routine monitoring bioassays were 96-hour static tests in which five rainbow trout were exposed to a single 100% effluent concentration. All tests were conducted at 15 ± 1°C and aerated with 6 cc air/L•min to maintain the dissolved oxygen above 7.0 mg/L. The samples were not pH adjusted. Effluent volume to fish weight ratio averaged 0.4 L/g•d for biologically treated samples and 1.0 L/g•d for samples receiving both biological and activated carbon treatment. In cases where more specific information was required, the 96-hour LC_{50} was determined from a range of five effluent concentrations. The 96-hour LC_{50} represented the concentration of effluent which produced 50% mortality within 96 hours and was calculated by the method of Litchfield and Wilcoxon (1949).

A static with replacement bioassay was used to determine the 96-hour LC_{50} of pentachlorophenol in dechlorinated water. Fish were exposed to seven concentrations of pentachlorophenol ranging from 500 to 23 μg/L. Solutions were renewed every 24 hours, providing a volume to weight ratio of 0.8 L/g•d. Ten fish were used in each concentration and the solutions were aerated with 6 cc air/L•min. Bioassay test conditions are reported in Table 2.

TABLE 2. RANGE OF BIOASSAY TEST CONDITIONS

Test	Dissolved Oxygen (mg/L)	pH	Temp. (°C)
Biologically treated effluent	7.0 - 9.5	6.4 - 8.3	14 - 15
96-hour LC_{50} with biologically treated effluent	8.0 - 9.3	7.3 - 8.1	14 - 15
Biological plus activated carbon treatment	7.0 - 9.5	6.9 - 8.6	14 - 15
Pentachlorophenol plus water	7.5 - 9.0	7.5 - 8.0	14 - 15

3 WASTEWATER CHARACTERISTICS

As mentioned earlier, the same retort was used for wood conditioning and treatment; thus, the major wastewater contaminants were creosote, oil, tar and pentachlorophenol. Average wastewater characteristics for the three experimental phases are presented in Table 3. Daily values for the wastewater parameters are presented in Appendix I. It should be noted that during Phase 1 and Phase 2 of the operation, the influent fed to the biological system was collected after oil separation, pH adjustment, nutrient addition, and flow equalization. During the third phase of the operation, the raw wastewater was applied directly to the carbon adsorption system without pH adjustment or nutrient addition; therefore, the values for pH, ammonia-nitrogen, TKN and TP were lower than those in Phase 1 and Phase 2 of the operation.

TABLE 3. WASTEWATER CHARACTERISTICS*

Parameter	Phase 1		Phase 2		Phase 3	
	Avg.	Range	Avg.	Range	Avg.	Range
pH		7.5 - 10.5		8.0 - 9.2		4.0 - 5.6
BOD_5	570	370 - 820	1 400	700 - 3 000	1 500	1 100 - 1 700
COD	1 330	1 000 - 1 700	2 800	1 830 - 5 400	3 050	2 800 - 3 400
TOC	350	210 - 470	900	520 - 1 800	1 070	790 - 1 400
Phenol	225	180 - 290	570	250 - 1 340	700	540 - 840
PCP	8.4	5.2 - 11.5	8.5	3.7 - 14.9	0.44	0.30 - 0.55
Oil & Grease			95	23 - 210	60	23 - 100
NH_3-N	13.1	2.0 - 49.0	29.7	4.8 - 85	4.5	1.8 - 11.0
TKN	26.0	11.6 - 53.1	46.4	15.9 - 93	27.8	8.5 - 34.7
Total P	16.1	1.3 - 40.0	6.0	1.5 - 16.0	0.4	<0.1 - 1.9
Suspended Solids	41	23 - 69	56	11 - 188	25	6 - 83
Temperature	35	29 - 40	37	32 - 41	34	31 - 38

* All in mg/L except for pH and temperature which are expressed in pH units and °C, respectively.

As shown in Table 3, the wastewater strength during the second and third phases of the operation was much greater than that during the first phase of the operation. This could be explained by the fact that during these two phases of the operation most of the wood conditioned and treated was green, which resulted in leaching of a greater quantity of organics from the wood. Because no PCP was used in the wood treatment plant during the third phase of the operation, its concentration in the waste dropped significantly.

Based on the values in Table 3, the ratio of BOD_5:N:P was calculated to be 100:5:3 for the first phase of the operation. Compared to the ratio of 100:5:1, which is considered optimum for biological treatment, it was apparent that the nitrogen supply was adequate and that phosphorus was in excess. During the second phase of the operation, the phosphorus dosage was reduced. As a result, the BOD_5:P ratio was decreased to 100:1. Due to an increase in the organic strength, the BOD_5:N ratio was 100:4 for the second phase of the operation. No operational problems were encountered in the activated sludge system during this phase, even though the BOD_5:N ratio was less than what is considered to be optimum.

4 WASTE TREATMENT SYSTEM OPERATING PARAMETERS

4.1 Phase 1

During this phase of the operation, the waste flow rate to the activated sludge treatment system was kept constant at 13 m^3/d, which corresponded to a detention time of 2.8 days in the aeration tank. Prior to initiating the study, the treatment system was operated at a MLSS concentration of 11 300 mg/L and a sludge return rate of 550% of the plant influent. Chemical addition for pH adjustment and nutrient supplement was carried out every second day on a batch basis. As the results for the first two weeks of the study indicated that the effluent was high in suspended solids concentration and extremely toxic to rainbow trout, the following modifications were made to provide the best operating conditions for the treatment system:

(1) reduction of the MLSS concentration in the aeration tank to approximately 7 000 mg/L,
(2) continuous pH adjustment and nutrient addition,
(3) decrease of sludge return rate to 125% of the plant influent.

Dates of major changes are shown in Appendix II. Operating parameters for the treatment system, before and after the modifications, are presented in Table 4. Daily mixed liquor data are shown in Appendix III.

The organic loading, before and after process modifications, was 0.02 and 0.03 kg BOD_5/kg MLSS·d, respectively, indicating that the plant was operating as an extended aeration activated sludge process. The aeration tank pH ranged from 4.9 to 6.2 before continuous NaOH addition, and from 6.3 to 7.3 during continuous NaOH addition. During the sampling period, the dissolved oxygen concentration varied from 1.7 to 4.7 mg/L and averaged 3.7 mg/L. The mixed liquor temperature ranged from 23 to 31°C and averaged 28°C.

Clarifier operating parameters for both return sludge ratios are also presented in Table 4. The change in return sludge ratio from 550 to 125% of influent increased the clarifier detention time from 1.1 to 3.1 hours with the corresponding surface loadings being 40.6 and 14.1 $m^3/m^2 \cdot d$, respectively. The solids loading in the clarifier was 490 $kg/m^2 \cdot d$ before the changes were made. After the changes, it was reduced to 104 $kg/m^2 \cdot d$.

TABLE 4. OPERATING PARAMETERS DURING PHASE 1 OPERATION

Aeration Tank	Before the Modifications	After the Modifications
Flow Rate:		
(m^3/d)	13	13
MLSS (mg/L)	11 300	7 000
Detention Time (d)	2.8	2.8
Organic Loading:		
(kg BOD_5/kg MLSS•d)	0.02	0.03
Dissolved Oxygen (mg/L)	1.7 - 4.7	1.7 - 4.7
Temperature:		
(°C)	23 - 31	23 - 31
pH	4.9 - 6.2	6.3 - 7.3
Return Sludge Rate:		
(% of Plant Influent)	550	125
Clarifier		
Detention Time (h)*	1.1	3.1
Surface Loading*:		
(m^3/m^2•d)	40.6	14.1
Solids Loading*:		
(kg/m^2•d)	490	104

* Includes return sludge.

4.2 Phase 2

The average operating parameters of the activated sludge system for Phase 2 of the operation are presented in Table 5. The waste flow rate to the activated sludge system was the same as in the previous phase of the operation. The MLSS concentration averaged 8 700 mg/L. Nutrient addition and pH adjustment were carried out continuously as in Phase 1. The return sludge rate was 125% of the influent.

TABLE 5. OPERATING PARAMETERS DURING PHASE 2 OPERATION

1. Activated Sludge System	
Aeration Tank:	
Flow Rate (m^3/d)	13
MLSS (mg/L)	8 700
Detention Time (d)	2.8
Organic Loading (kg BOD_5/kg MLSS•d)	0.06
Temperature (°C)	23 - 31
pH	6.8 - 7.8
Sludge Return Rate (% of Plant Influent)	125
Dissolved Oxygen (mg/L)	0.7 - 2.4
Clarifier:	
Detention Time (h)[1]	3.1
Surface Loading (m^3/m^2•d)[1]	14.1
Solids Loading (kg/m^2•d)[1]	129
2. Granular Media Filter	
Flow Rate (m^3/d)	0.6
Hydraulic Loading (m^3/m^2•d)	76
Contact Time (h)[2]	0.31
Solids Loading (kg/m^2•d)[3]	7.4
Solids Loading (kg/m^2•d)[4]	23.7
3. Activated Carbon System	
Flow Rate (m^3/d)	0.6
Hydraulic Loading (m^3/m^2•d)	76
Contact Time (h)[2]	2.0
Carbon: Filtrasorb 400	
Effective Size of Carbon (mm)	0.55 - 0.65
Uniformity Coefficient	1.9

[1] Includes return sludge.
[2] Empty bed basis.
[3] Prior to April 3.
[4] After April 4.

The increased strength of the wastewater during this phase of the operation increased the organic loading to 0.06 kg BOD_5/kg MLSS•d, indicating that the system was still operated as an extended aeration activated sludge process. The aeration tank pH varied from 6.8 to 7.8. Dissolved oxygen ranged from 0.7 to 2.4 mg/L and averaged 1.5 mg/L, which was considerably lower than during the first phase of the operation. This was attributable to the increased organic loading due to an increase in the waste strength. The aeration tank temperature ranged from 23 to 31°C and averaged 27°C.

The detention time and surface loading of the clarifier remained the same as for Phase 1 of the operation. The clarifier was operated at a solids loading of 129 kg/m^2•d during the second phase of the operation.

Operating parameters of the carbon adsorption system are shown in Table 5. The applied flow rate to the columns was 0.6 m^3/d or 4.6% of the total plant flow. This resulted in a hydraulic loading of 76 m^3/m^2•d and a contact time of 2.0 hours (empty bed basis).

4.3 Phase 3

Before this phase of the operation was initiated, the granular media filter and the three carbon adsorption columns were recharged with virgin anthracite and activated carbon. The raw wastewater was applied directly to the activated carbon system at 0.6 m^3/d. The hydraulic loading and contact time were the same as for the carbon system in Phase 2 of the operation and are shown in Table 5. The operating parameters for the granular media filter were the same as during Phase 2 with the exception of solids loading which was reduced to 3.2 kg/m^2•d due to a lower suspended solids concentration applied to the filter.

5 RESULTS AND DISCUSSION

5.1 Phase 1

Operating results for the activated sludge treatment plant for Phase 1 are presented in Table 6. Due to a problem with the analytical procedure, oil and grease analysis is not available for Phase 1. Daily operating results are shown in Figures 3 to 11 and in Appendix I. As can be seen from Tables 3 and 6, phenolic compounds were degraded from 225 to 0.16 mg/L resulting in greater than 99% removal. BOD_5, COD and TOC removals ranged from 80 to 97%. PCP removal was only 35% resulting in an average effluent PCP concentration of 5.5 mg/L. The removal of PCP by the activated sludge system was not as complete as found by Etzel and Kirsch (1975) who achieved biological degradation of PCP from 20 mg/L, to <0.2 to 1.9 mg/L using various PCP samples.

TABLE 6. ACTIVATED SLUDGE EFFLUENT CHARACTERISTICS DURING PHASE 1*

Parameter	Average	Range	% Removal
pH		7.1 - 7.2	
BOD_5	19	9 - 41	97
COD	265	200 - 450	80
TOC	31	13 - 54	91
Phenol	0.16	0.09 - 0.53	>99
PCP	5.5	0.79 - 8.6	35
NH_3-N	1.8	<0.1 - 9.0	86
TKN	12.0	3.5 - 23.3	55
Total P	15.8	3.3 - 21.8	2
Suspended Solids	69	32 - 112	
Temperature	27	22 - 31	

* All in mg/L except pH and temperature which are expressed in pH units and °C, respectively. Data used for period from November 2 to December 9.

Thompson et al (1978), treating PCP contaminated groundwater from Abitibi-Northern Wood Preservers Limited, found that activated sludge treatment reduced the PCP concentration from 3.35 to 2.15 mg/L. This removal is

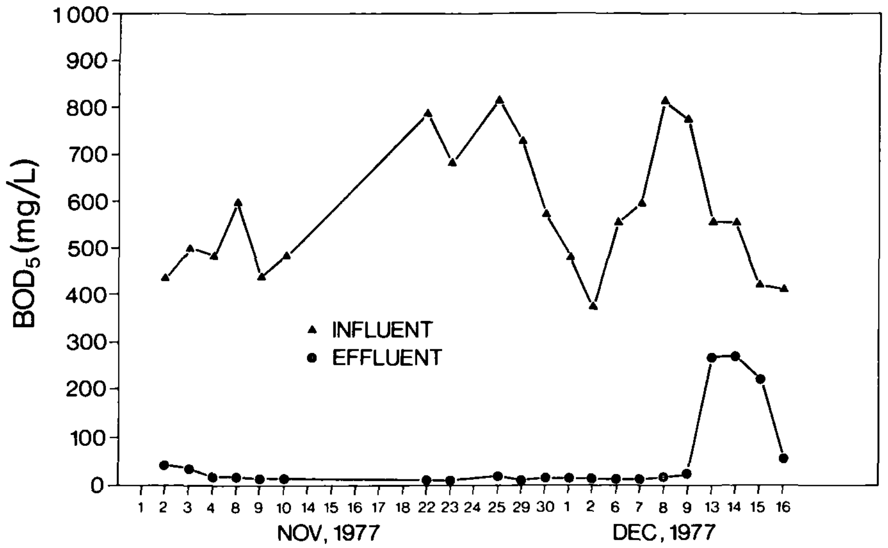


FIGURE 3 BOD_5 DATA - PHASE 1

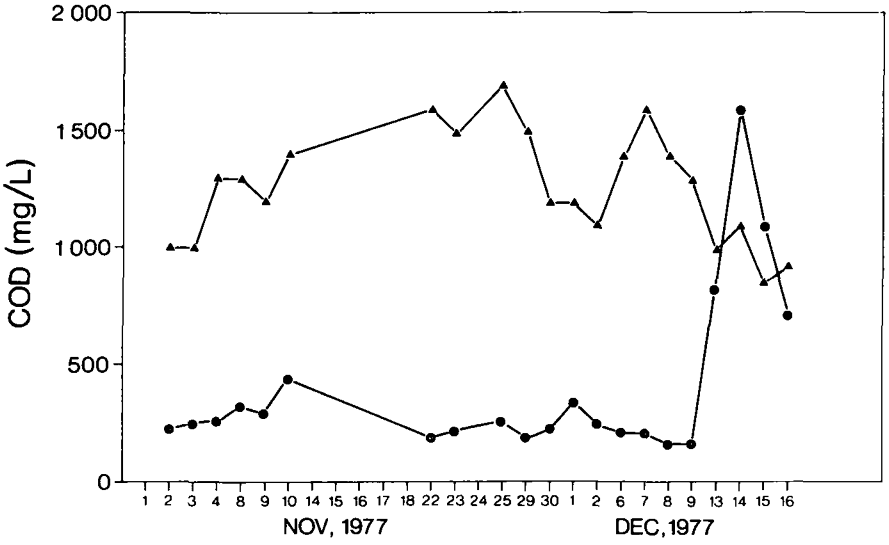


FIGURE 4. COD DATA - PHASE 1

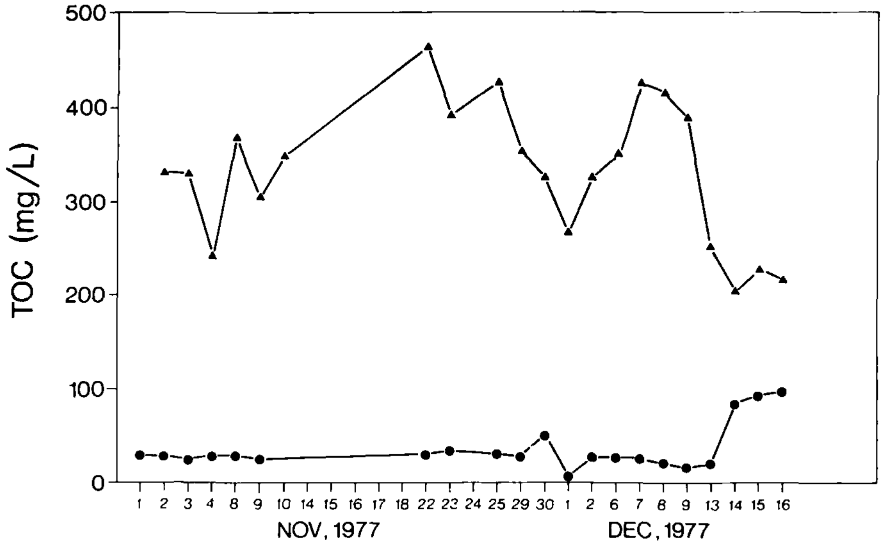


FIGURE 5 TOC DATA - PHASE 1

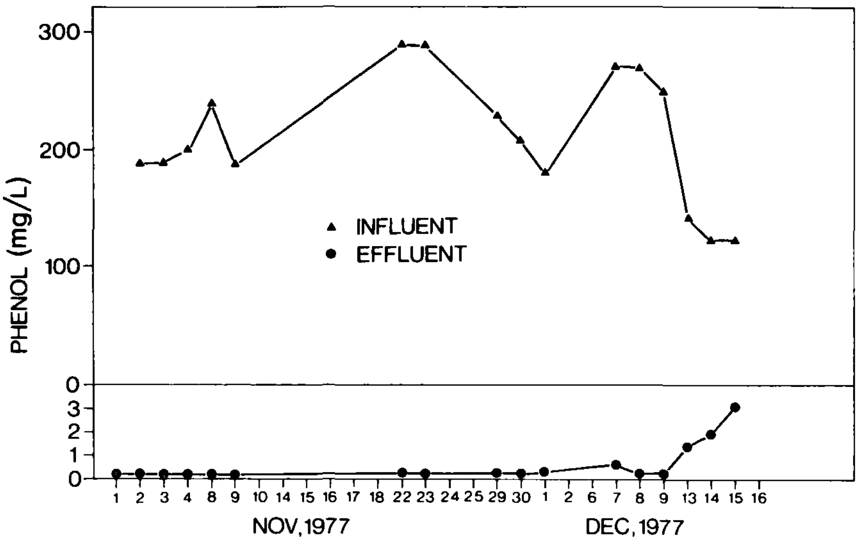


FIGURE 6 PHENOL DATA-PHASE 1

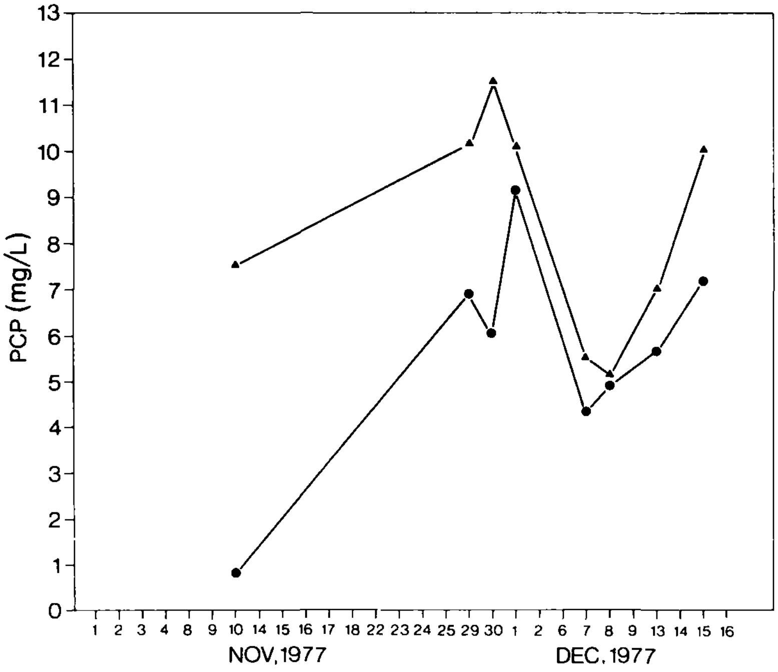


FIGURE 7 PCP DATA - PHASE 1

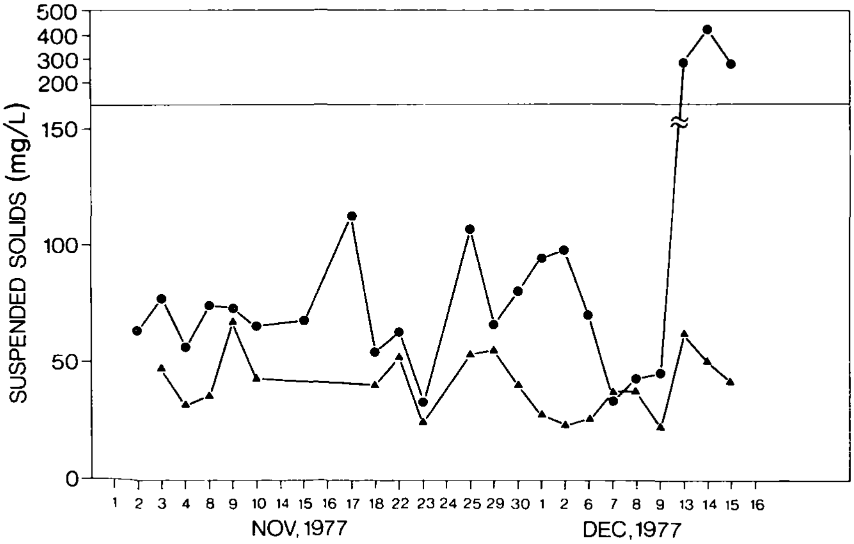


FIGURE 8 SUSPENDED SOLIDS DATA-PHASE 1

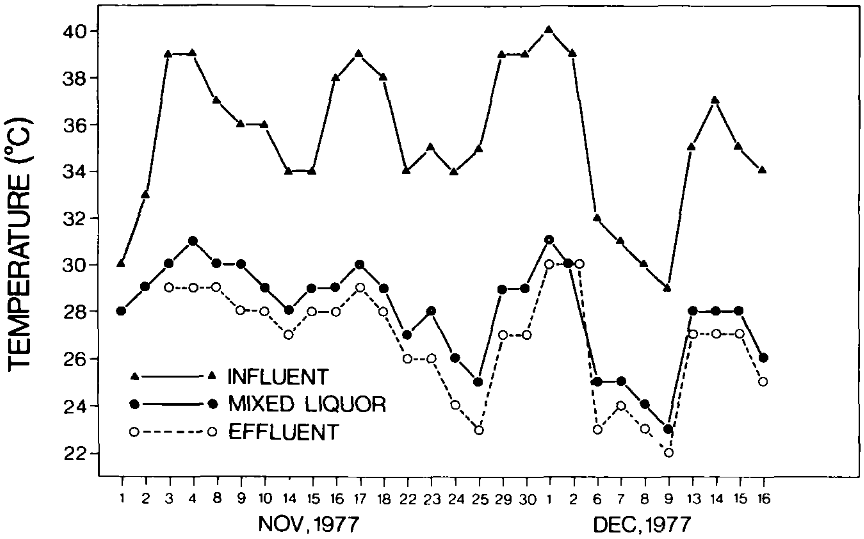


FIGURE 9 TEMPERATURE DATA-PHASE 1

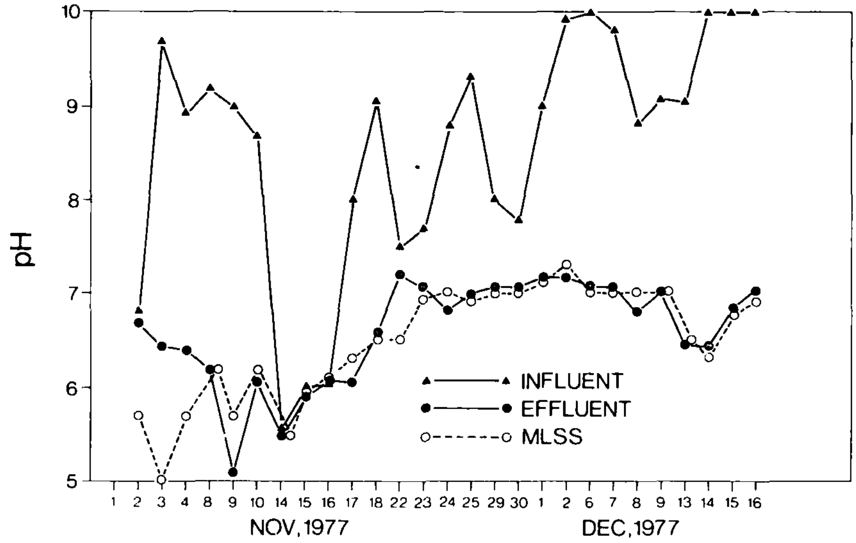


FIGURE 10 pH DATA - PHASE 1

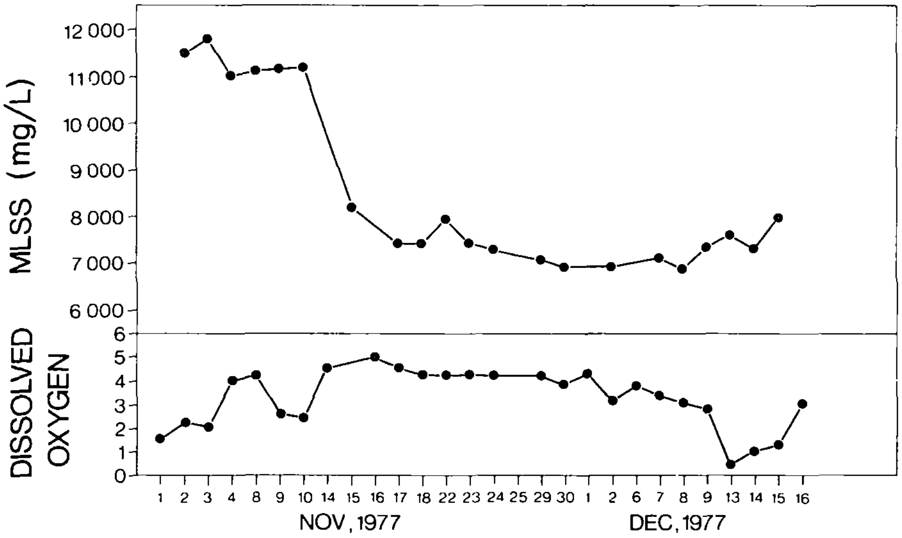


FIGURE 11 MLSS AND DISSOLVED OXYGEN DATA -PHASE 1

comparable to that achieved in the present study. Suspended solids in the activated sludge effluent were greater than in the influent. From the results presented in Figures 3 to 10, it can be seen that modifications to the treatment plant during the period from November 14 to December 1, 1977, had little effect on the performance of the wastewater treatment system.

On the morning of December 12, 1977, oil separation tank #1 was empty and the water depth in the holding tank was half its normal level. This was caused by a shortage of wastewater on the weekend and likely resulted in the pumping of floating oils from the holding tank to the aeration tank. As shown in Figures 3 to 6, subsequent effluent samples collected from December 13 to 16 showed a substantial increase in organic compounds. During this period the effluent had an oily appearance and the suspended solids increased to the 200 to 400 mg/L range (Figure 8). The dissolved oxygen level dropped significantly (Figure 11) and the pH of the MLSS decreased slightly (Figure 10).

5.2 Bench Scale Carbon Adsorption Study

Results of the first phase of the operation indicated that the activated sludge system successfully removed the organics in the wood preserving wastes; however, its effluent was extremely toxic to rainbow trout. Although the cause of toxicity was not identified, it was considered that PCP could be the major toxicity contributor. The effluent contained an average PCP concentration of 5.5 mg/L which is approximately 100 times the lethal concentration of 50 to 100 µg/L reported by Davis and Hoos (1975). In an attempt to detoxify the effluent, bench scale experiments were carried out at the Wastewater Technology Centre, Burlington, Ontario, to investigate the feasibility of using activated carbon to remove PCP from the activated sludge effluent.

Results of the adsorption isotherm study using Filtrasorb 300 to treat effluent from the activated sludge system are shown in Figure 12. Based on the relationship shown in Figure 12, PCP could be effectively removed by the activated carbon to a level as low as 11 µg/L. Figure 12 shows that an effluent PCP concentration of less than 50 µg/L, which is considered to be non-toxic to rainbow trout, could be achieved at a loading of 26 mg PCP per gram of carbon.

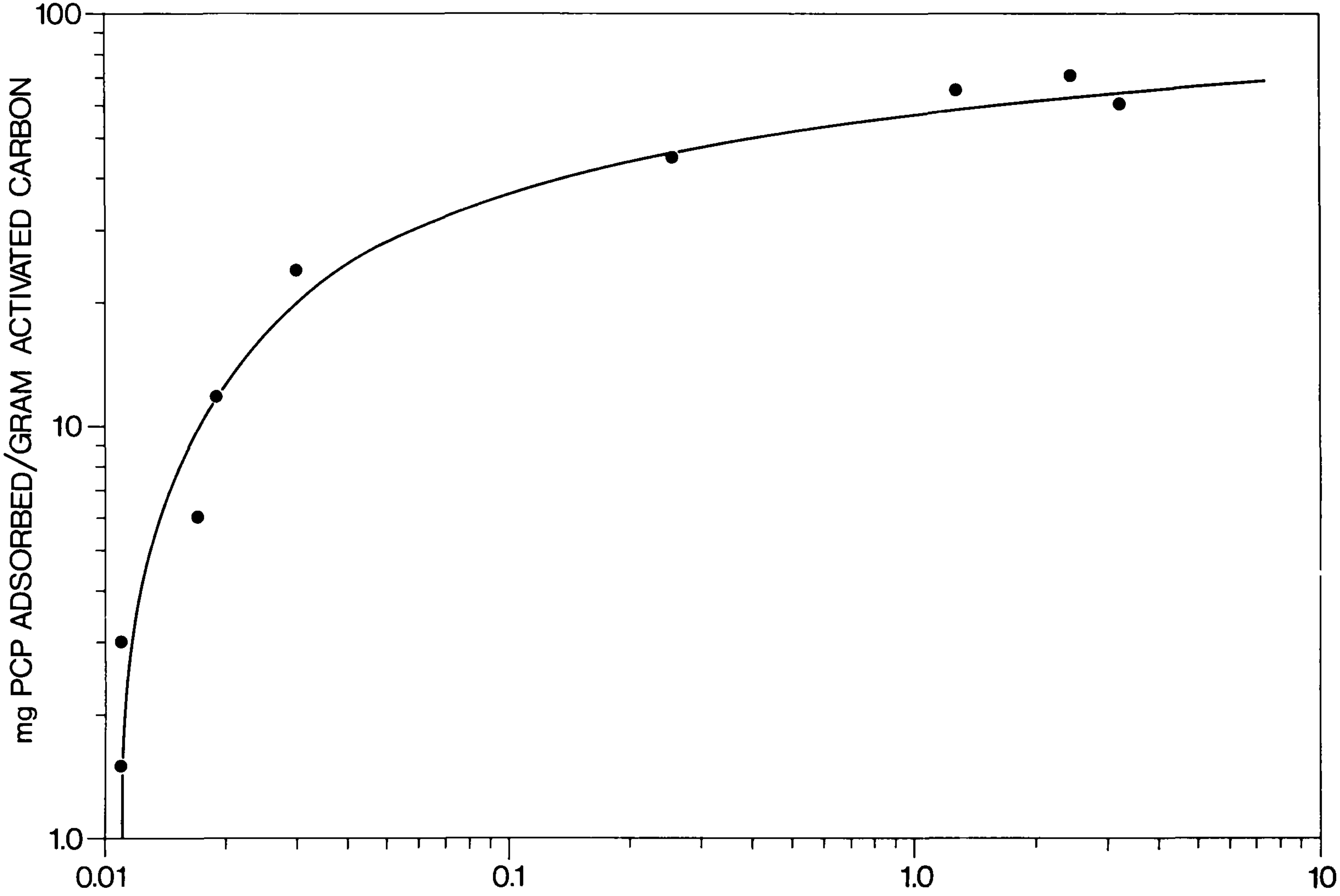


FIGURE 12. PCP ADSORPTION ISOTHERM (Filtrasorb 300)

Based on the results obtained from the bench scale study, the pilot scale carbon adsorption system was designed and installed on site for the treatment of the effluent from the activated sludge system. It should be noted that instead of Filtrasorb 300, which was used in the bench scale experiment, a smaller particle size activated carbon, Filtrasorb 400, was used for the pilot scale study.

5.3 Phase 2

During this phase of the project, the wastewater was treated by a combined activated sludge and activated carbon process. The wastewater was fed to the full scale activated sludge system at the same rate as in Phase 1 of the operation. The activated carbon system, which received the effluent from the activated sludge process, was operated at a constant rate of 0.6 m^3/d. The operating results for this phase are discussed in the following sections.

5.3.1 Activated sludge system

Daily operating results are shown in Figures 13 to 20. As can be seen from the figures, the results can be divided into two groups. The first group covered the operating period from March 3 to April 3 dealing with the normal operation of the treatment system. The second group consisted of data collected after April 4 when the strength of the untreated waste increased substantially, resulting in an unsatisfactory performance of the treatment system. A summary of both groups of results is shown in Table 7.

As shown during the operating period from March 3 to April 3, the reduction in organics ranged from 58% for PCP to greater than 99% for phenols. Compared to the results shown in Table 6, it can be seen that the performance of the activated sludge system during Phase 2 of the operation was slightly better than that in Phase 1 of the operation.

As the phosphoric acid added to the untreated waste as nutrient supplement was reduced during the second phase of the operation, the effluent phosphorus concentration was significantly lower than that in the previous operation.

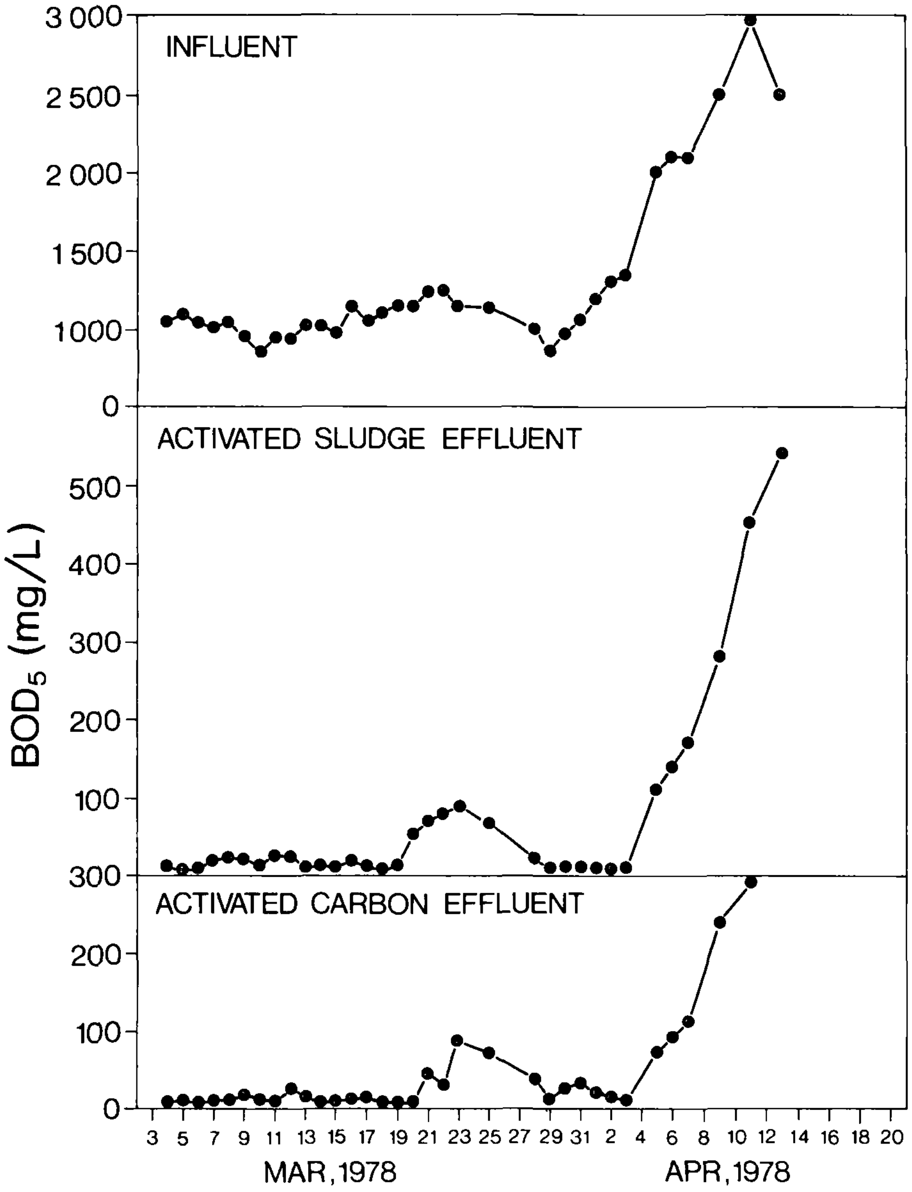


FIGURE 13. BOD_5 DATA – PHASE 2

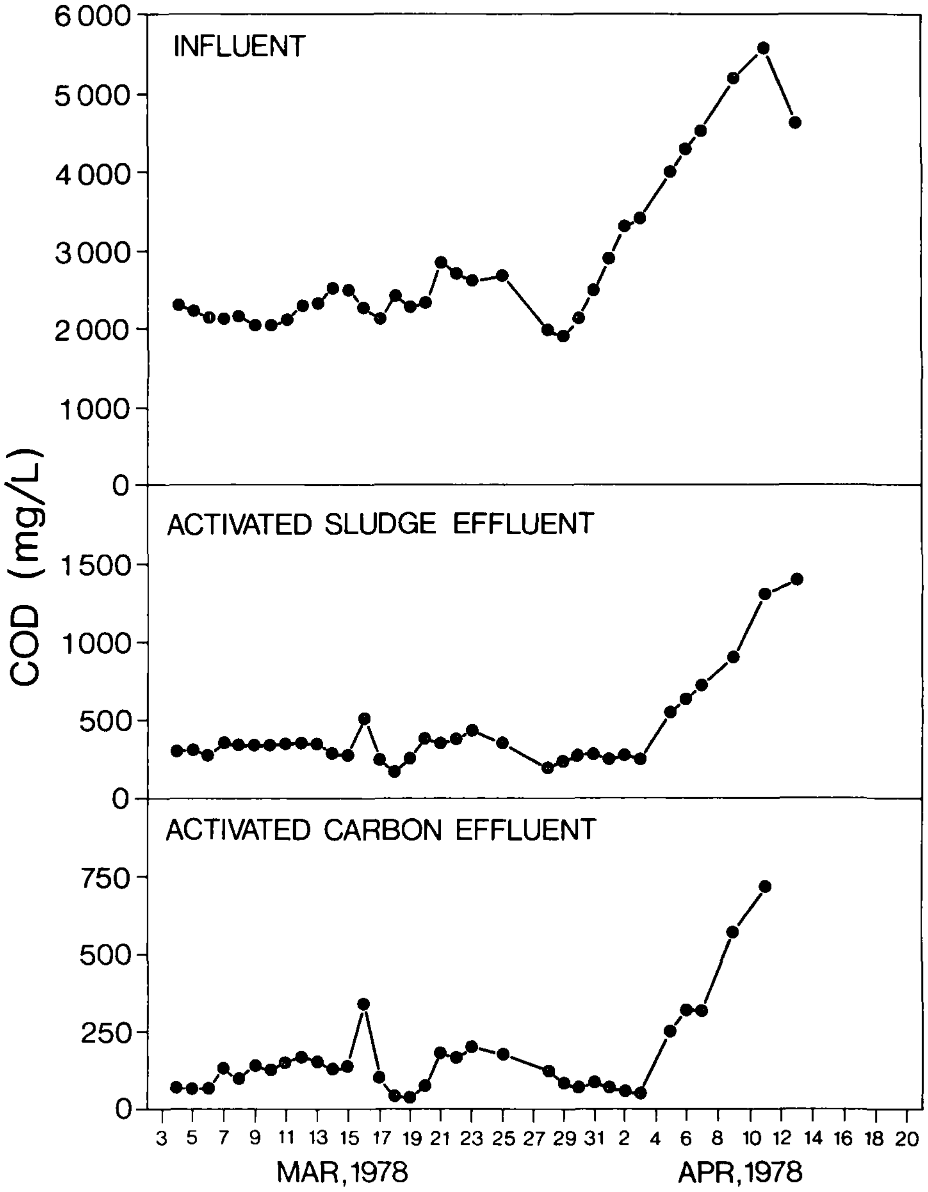


FIGURE 14. COD DATA – PHASE 2

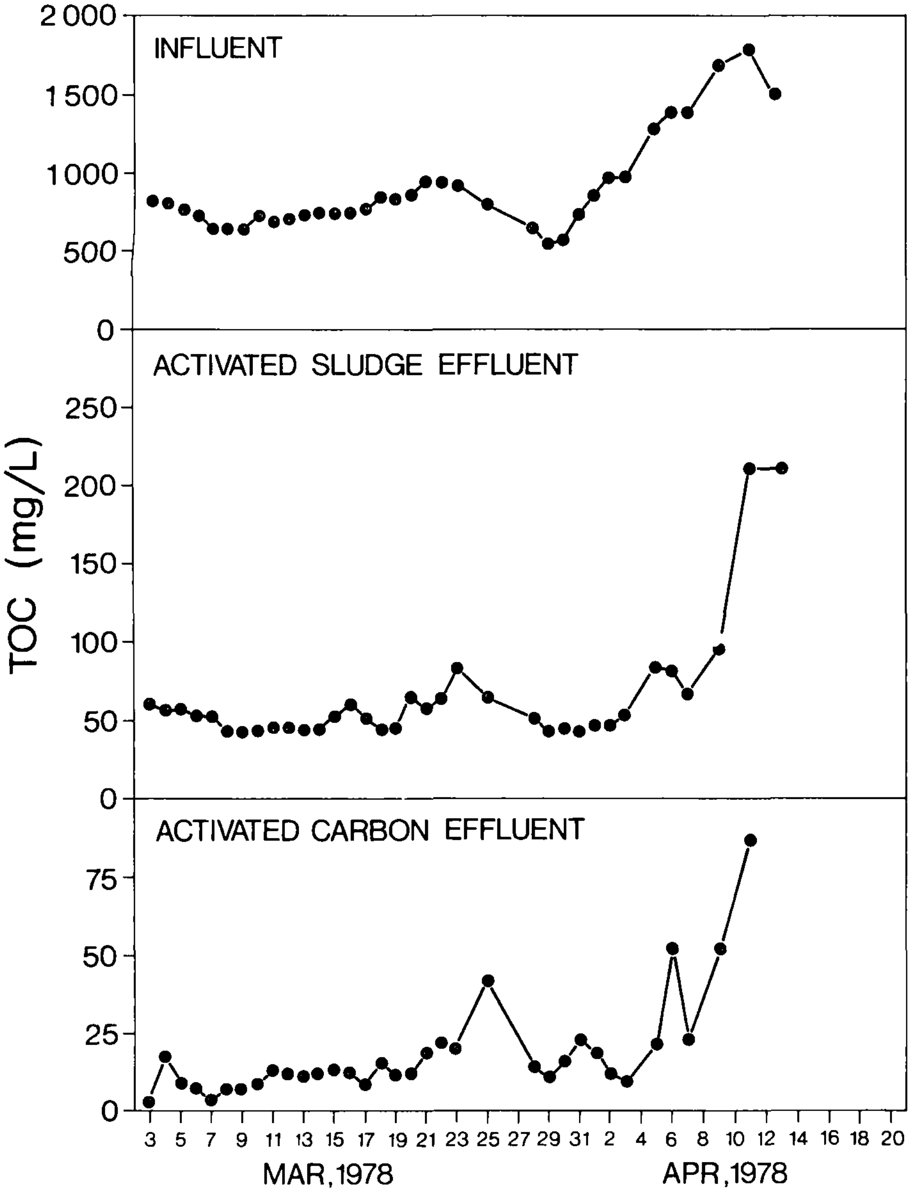


FIGURE 15. TOC DATA – PHASE 2

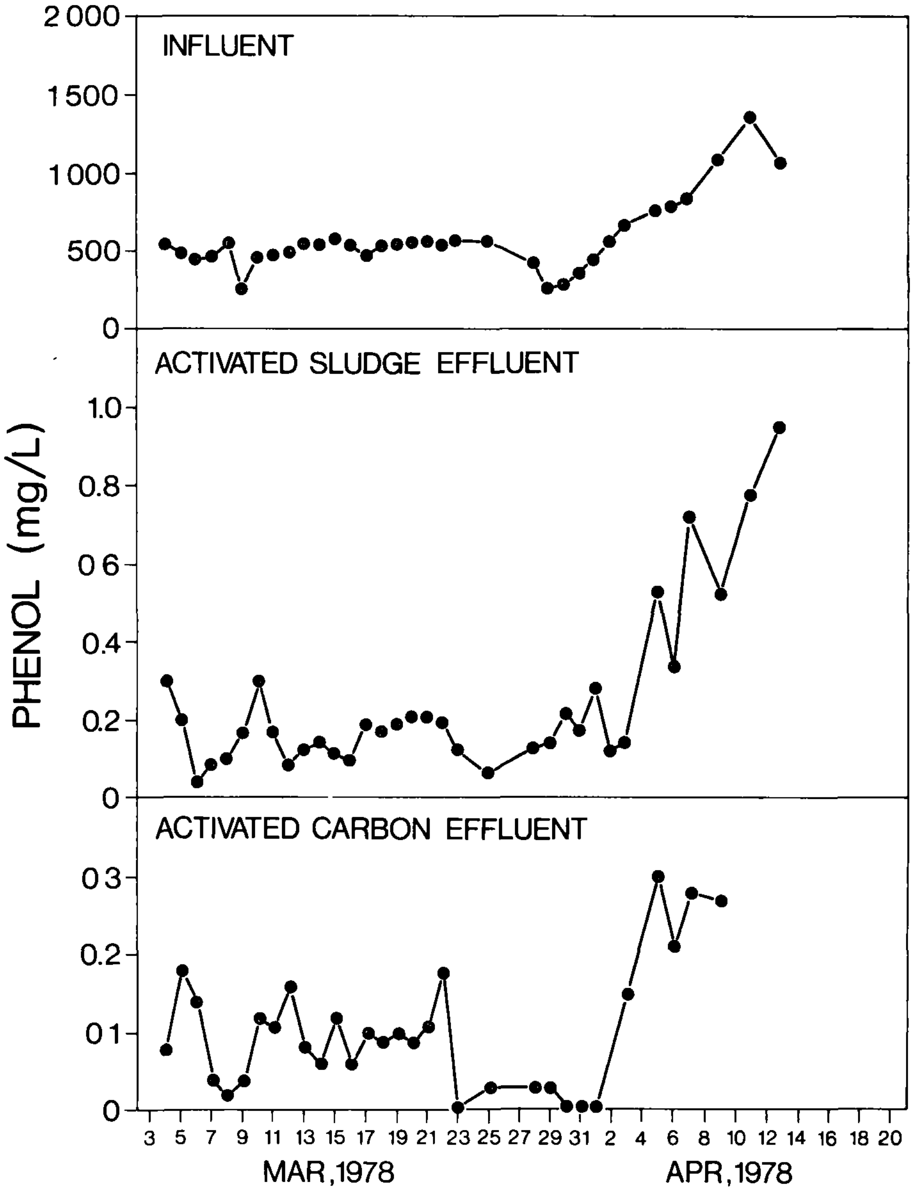


FIGURE 16. PHENOL DATA – PHASE 2

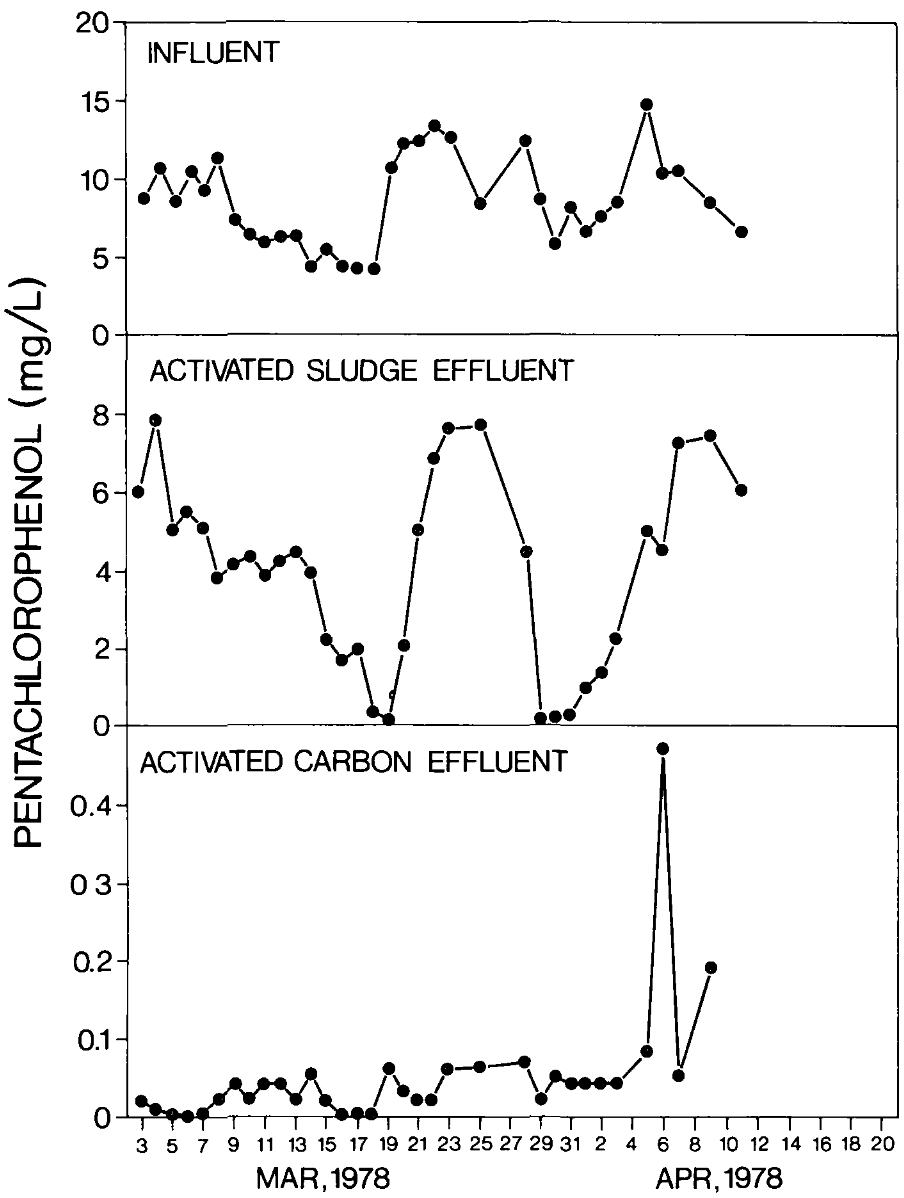


FIGURE 17. PENTACHLOROPHENOL DATA - PHASE 2

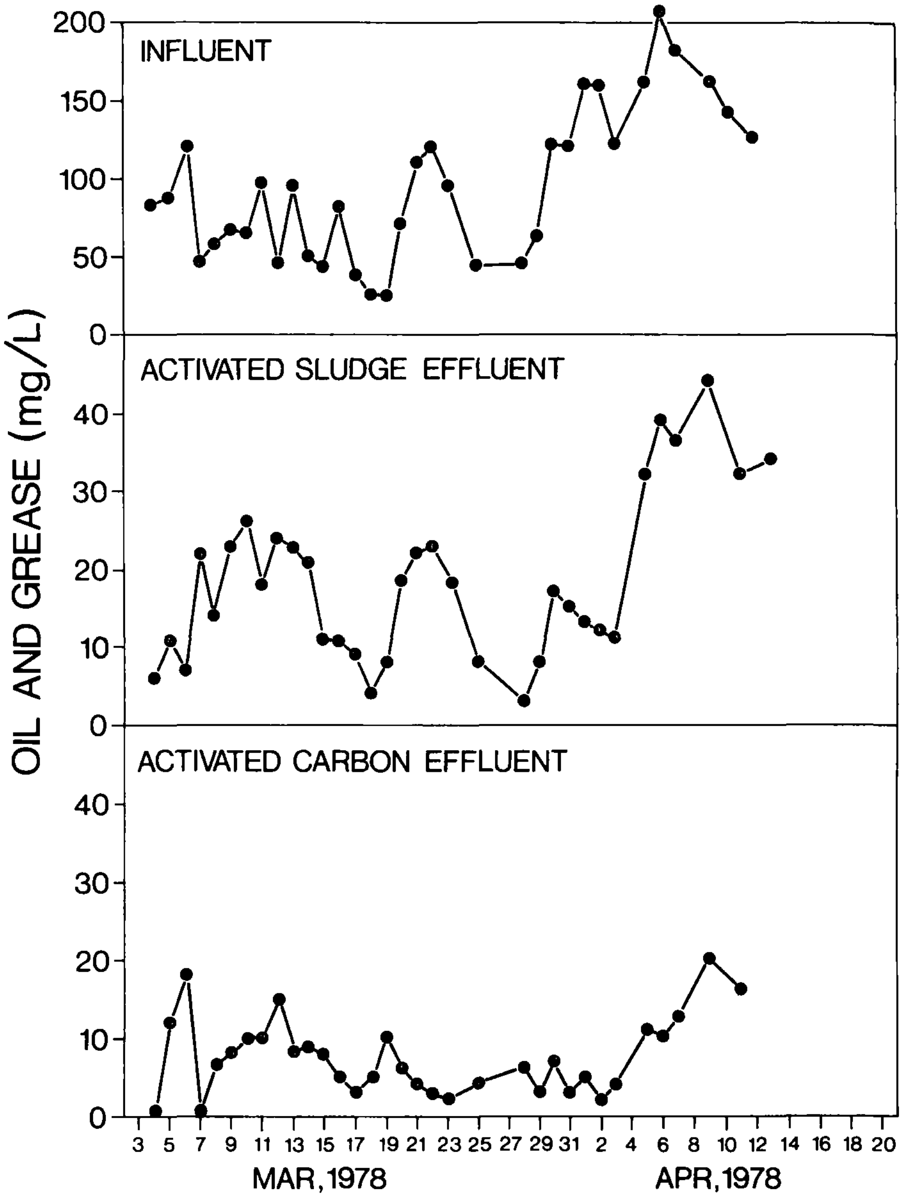


FIGURE 18. OIL AND GREASE DATA - PHASE 2

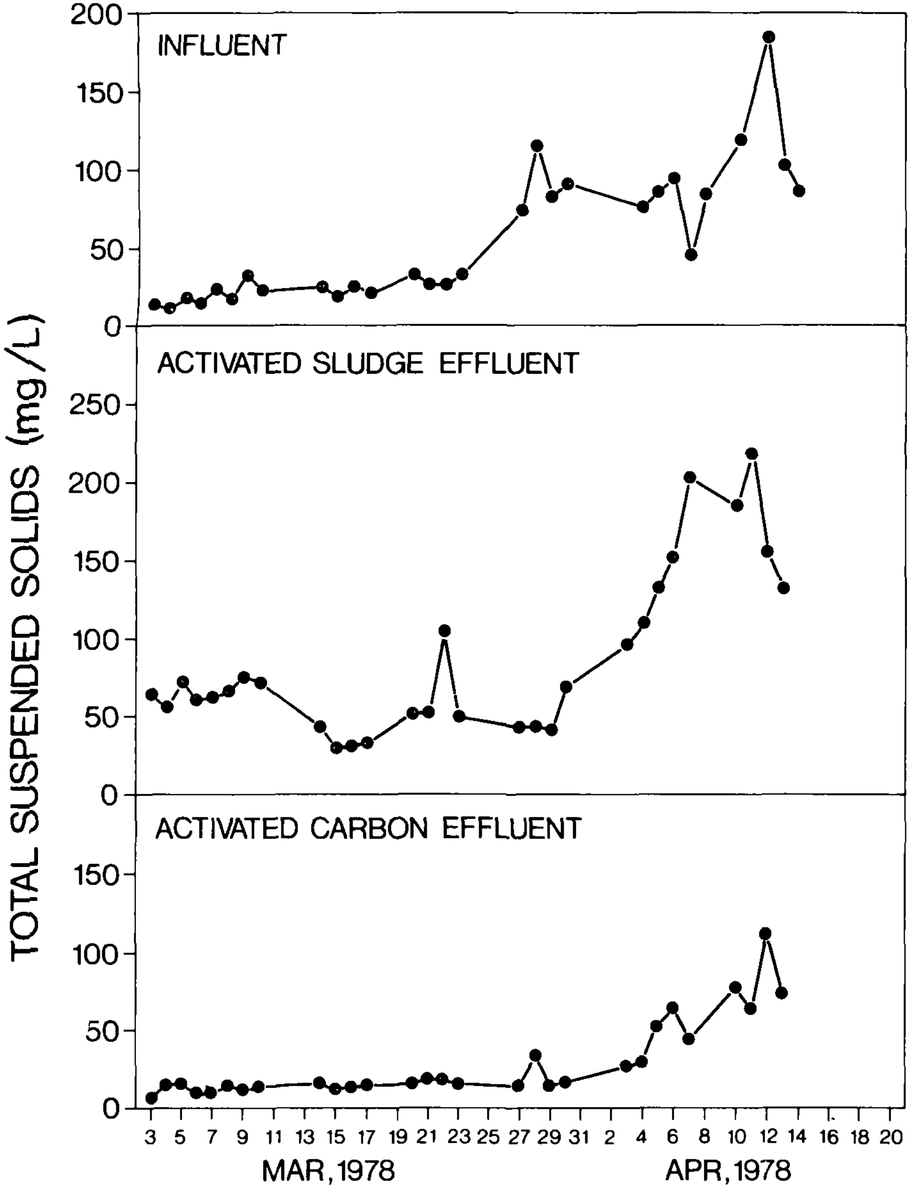


FIGURE 19. SUSPENDED SOLIDS DATA – PHASE 2

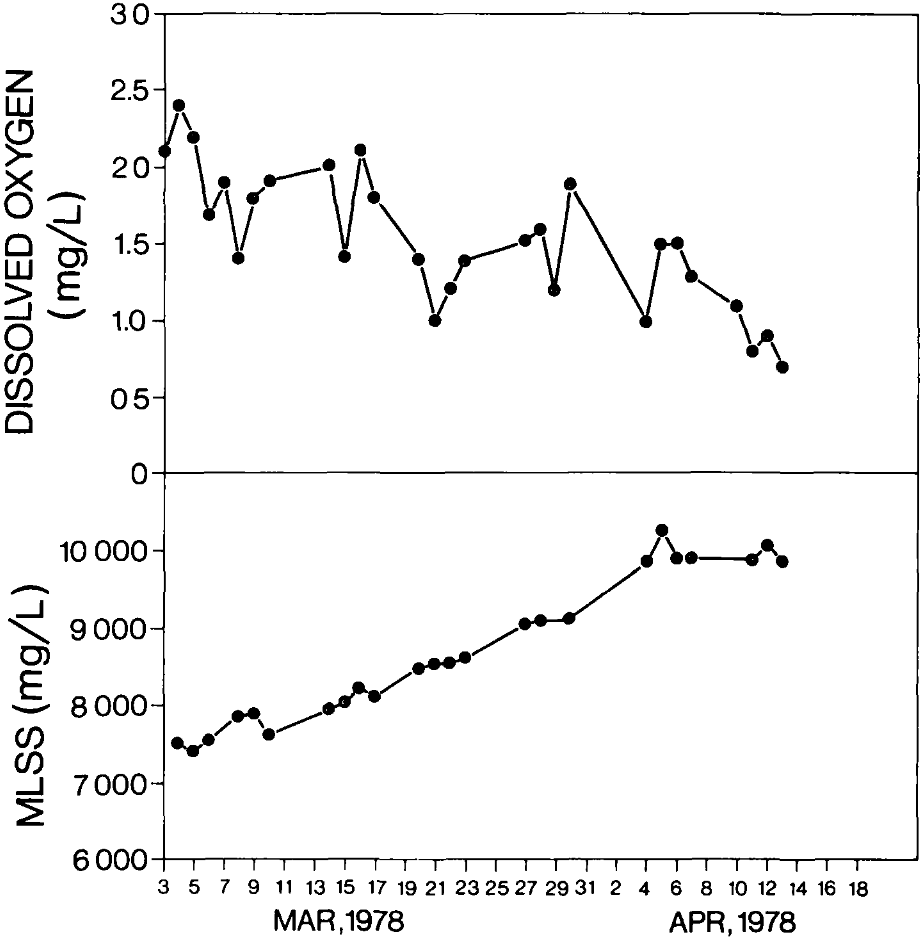


FIGURE 20. MLSS AND DISSOLVED OXYGEN DATA – PHASE 2

TABLE 7. ACTIVATED SLUDGE EFFLUENT CHARACTERISTICS DURING PHASE 2*

Parameter	March 3 to April 3, 1978			April 4 to April 13, 1978		
	Average	Range	% Removal	Average	Range	% Removal
pH		6.8 - 7.8			7.1 - 7.6	
BOD_5	26	7 - 87	98	282	110 - 540	88
COD	300	180 - 500	89	920	550 - 1 400	80
TOC	52	41 - 84	94	124	82 - 210	92
Phenol	0.16	0.04 - 0.30	>99	0.65	0.36 - 0.95	>99
PCP	3.6	0.02 - 7.9	58	5.5	3.1 - 7.4	40
Oil & Grease	14.5	3 - 26	85	36	32 - 44	78
NH_3-N	6.0	0.9 - 25.0	80	13.0	11.0 - 15.0	82
TKN	20.7	3.9 - 35.9	55	15.4	13.1 - 21.0	80
Total P	2.7	0.8 - 5.8	55	2.2	1.7 - 3.1	19
Suspended Solids	58	30 - 107		186	110 - 220	
Temperature	26	21 - 30		25	22 - 28	

* All in mg/L except pH and temperature which are expressed in pH units and °C, respectively.

The substantial increase in the wastewater strength after April 4 resulted in a steady deterioration of the effluent quality. There was no explanation for this change in process performance.

5.3.2 Carbon adsorption system

Operating results for the carbon adsorption system are shown in Figures 13 to 19. They were divided into two groups and summarized in Table 8. The results indicate that the carbon adsorption system substantially improved the quality of effluent from the activated sludge system. The PCP concentration in the adsorption system effluent from March 3 to April 3 averaged 0.03 mg/L which corresponded to a 98% treatment efficiency. For the same period a significant reduction in COD, TOC, oil and grease, phenols and TKN concentrations ranging from 48 to 75% was also observed; BOD_5, NH_3-N and total phosphorus concentrations decreased by 12, 7 and 22%, respectively.

TABLE 8. CARBON ADSORPTION SYSTEM EFFLUENT CHARACTERISTICS DURING PHASE 2*

Parameter	March 3 to April 3, 1978			April 4 to April 13, 1978		
	Average	Range	% Removal	Average	Range	% Removal
pH		6.9 - 7.7			7.1 - 7.5	
BOD_5	23	7 - 82	12	164	75 - 300	42
COD	155	46 - 340	48	428	250 - 710	53
TOC	13	3 - 42	75	39	21 - 86	69
Phenol	0.08	<0.001 - 0.18	50	0.27	0.21 - 0.30	58
PCP	0.03	<0.001 - 0.89	98	0.19	0.08 - 0.47	97
Oil & Grease	6	1 - 18	58	14	10 - 20	61
NH_3-N	5.6	0.4 - 23.0	7	13.6	13.0 - 16.0	0
TKN	10.3	2.0 - 30.3	50	15.9	13.9 - 18.2	0
Total P	2.1	0.5 - 4.9	22	1.9	1.1 - 2.5	14
Suspended Solids	16	8 - 34	72	64	30 - 111	66
Temperature	19	14 - 22		18	15 - 20	

* All in mg/L except pH and temperature which are expressed in pH units and °C, respectively.

The quantity of organics adsorbed onto the activated carbon is presented in Table 9. The term X/M (mg/g) represents the cumulative weight of organics (X) adsorbed per unit weight of carbon (M) in the columns. For the 42 days of Phase 2 operation, which corresponded to the treatment of 500 empty bed volumes of activated sludge effluent, X/M values ranged from 0.17 mg/g for phenolic compounds to 311 mg/g for COD. These X/M values were much less than those achieved in Phase 3 of the operation (Section 5.4). This response was expected as the effluent concentrations of the contaminants were much higher in Phase 3.

Figure 21 illustrates the relationship between time and the accumulated quantity of PCP and TOC adsorbed per gram of carbon. As there was no reduction in the rate of accumulation of organics adsorbed per gram of carbon, it can be concluded that the carbon adsorption system had not reached exhaustion.

TABLE 9. ADSORPTION OF ORGANICS BY THE CARBON ADSORPTION SYSTEM DURING PHASE 2 OPERATION

Parameter	X/M (mg/g)	
	From March 3 to April 3, 1978	From March 3 to April 13, 1978
BOD_5	2.8	33.6
COD	138	311
TOC	37.0	57
Phenol	0.08	0.17
PCP	3.6	4.8
Oil & Grease	8.1	12.5

The increased wastewater strength from April 4 to 13, resulted in a deterioration of effluent quality from both the activated sludge process and the activated carbon system. Even though there was only a twofold increase in the F/M ratio, from 0.03 to 0.06 kg BOD_5/kg MLSS•d, it is possible that the complexity of the wastewater during this period may have substantially decreased the efficiency of the activated sludge system. The effectiveness of the activated carbon may have been reduced by surface fouling due to the higher concentrations of colloidal suspended solids and oil and grease in the activated sludge effluent.

As mentioned previously, samples for PCP, TOC and suspended solids were also taken from effluents of the granular media filter and the three individual activated carbon columns. The average analytical results are presented in Table 10. The granular media filter, operated as a roughing filter, had little effect on PCP and TOC concentration, but removed 57% of suspended solids. Most of the removal of PCP and TOC occurred in the first carbon column with almost no further PCP removal and little TOC removal in the following columns.

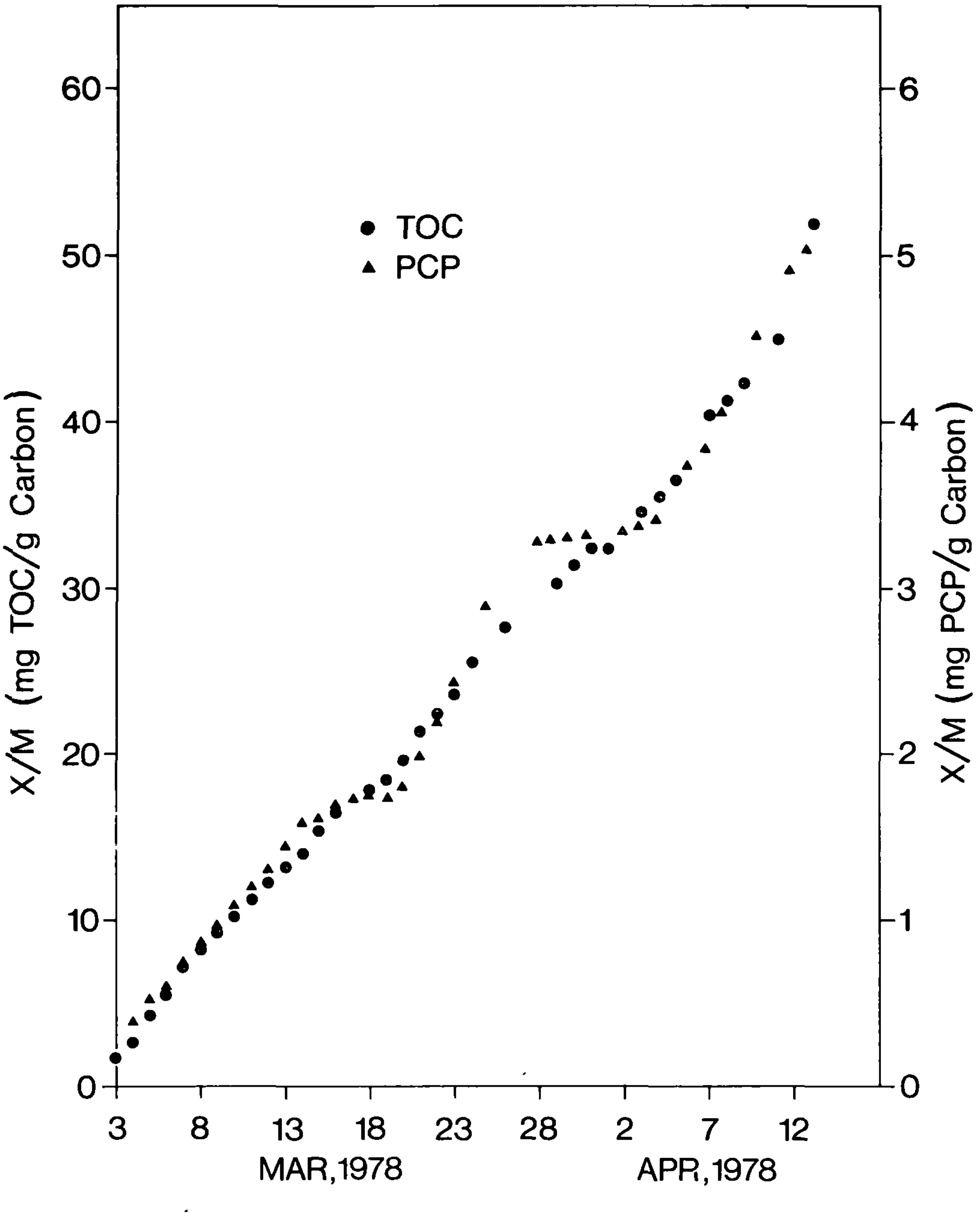


FIGURE 21. CUMULATIVE ADSORPTION CURVE FOR TOC AND PCP - PHASE 2

TABLE 10. AVERAGE PCP, TOC AND SUSPENDED SOLIDS CONCENTRATIONS DURING PHASE 2 (MARCH 3 TO APRIL 3, 1978)

Sampling Location	PCP (mg/L)	TOC (mg/L)	SS (mg/L)
Influent	8.4	768	39
Activated Sludge Effluent	3.6	52	58
Filtration Unit Effluent	3.4	54	25
1st Carbon Column Effluent	0.08	29	21
2nd Carbon Column Effluent	0.05	24	18
3rd Carbon Column Effluent	0.03	13	16

5.4 Phase 3

The raw wastewater was fed directly to the carbon adsorption system which had been recharged with virgin activated carbon. During this phase of the operation, effluent results were obtained after the first and third carbon columns. Final effluent results for this phase of the operation are presented in Table 11. The average effluent values in Table 11 were compiled using data collected from April 20 to 27 and do not include data obtained after breakthrough. Influent and carbon column effluent results are plotted in Figures 22 to 29. X/M values for the first column and the three columns in series are shown in Table 12.

From the data presented in Figures 22 to 25, breakthrough occurred for BOD_5, COD, TOC and phenol after three days for one carbon column, and after eight days for the three carbon columns. The cumulative X/M curves for TOC and phenol shown in Figure 30 show roughly linear adsorption occurring up to breakthrough with no further adsorption occurring after the breakthrough. The X/M curves for BOD_5 and COD were similar to those for TOC and are presented in Figure 31. Examination of the X/M values for BOD_5, COD, TOC and phenol in Table 12 shows excellent agreement between the adsorption on one and three columns. These values, ranging from 156 mg/g for phenol to 694 mg/g for COD, represent the maximum adsorption capacities for these parameters for the influent concentrations encountered in Phase 3 (Table 3).

TABLE 11. CARBON ADSORPTION SYSTEM EFFLUENT CHARACTERISTICS DURING PHASE 3*

Parameter	Average	Range	% Removal
pH		4.0 - 5.2	
BOD_5	152	73 - 200	90
COD	264	150 - 400	91
TOC	84	41 - 130	92
Phenol	5.3	<0.01 - 14.0	<99
PCP	0.02	0.01 - 0.06	95
Oil & Grease	6	<1 - 29	90
NH_3-N	2.8	0.7 - 4.0	38
TKN	2.9	<0.1 - 5.5	90
Total P	0.2	<0.1 - 0.9	50
Suspended Solids	2	1 - 8	92
Temperature	24	22 - 26	

* All in mg/L except pH and temperature which are expressed in pH units and °C, respectively, and only include results prior to breakthrough.

TABLE 12. ADSORPTION OF ORGANICS BY THE CARBON ADSORPTION SYSTEM DURING PHASE 3 OPERATION

Parameter	X/M (mg/g)	
	One Column (6.8 kg carbon)	Three Columns (20.4 kg carbon)
BOD_5	313	319
COD	694	660
TOC	238	233
Phenol	156	164
PCP	0.42	0.15
Oil & Grease	58.7	19.8

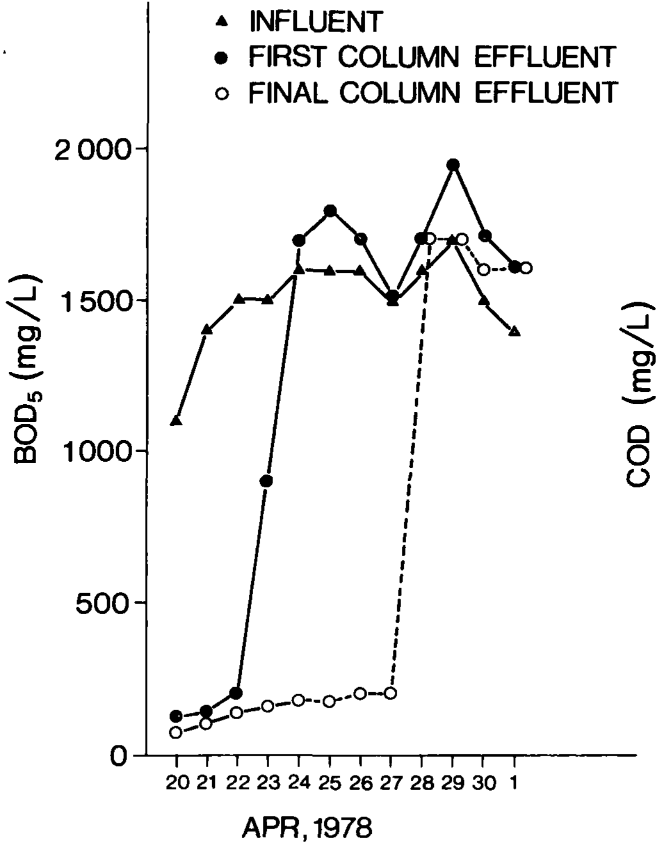


FIGURE 22. BOD$_5$ DATA – PHASE 3

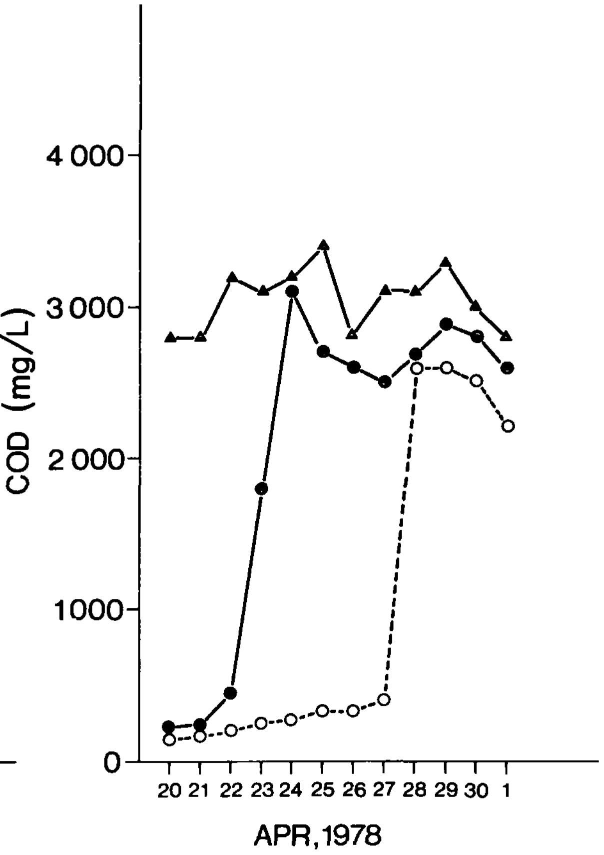


FIGURE 23. COD DATA – PHASE 3

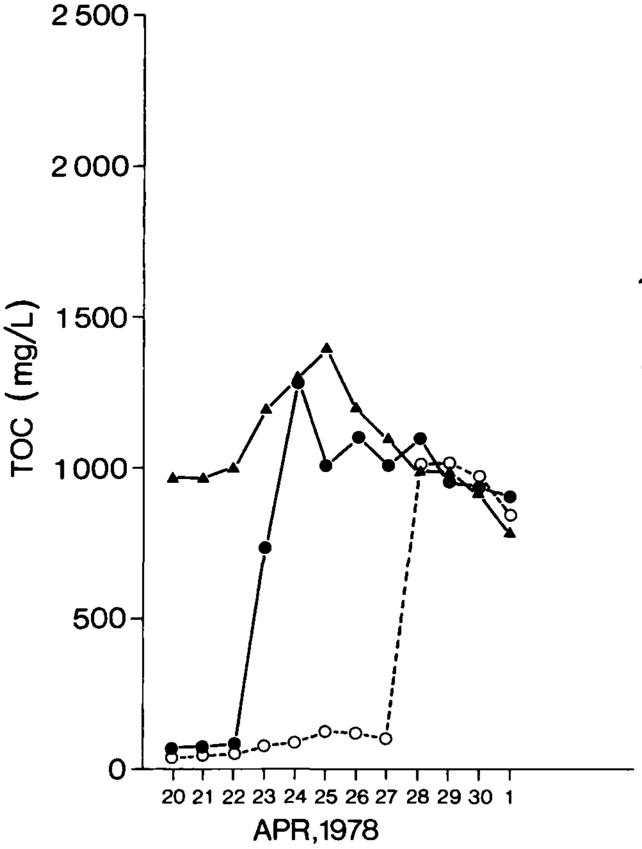


FIGURE 24. TOC DATA – PHASE 3

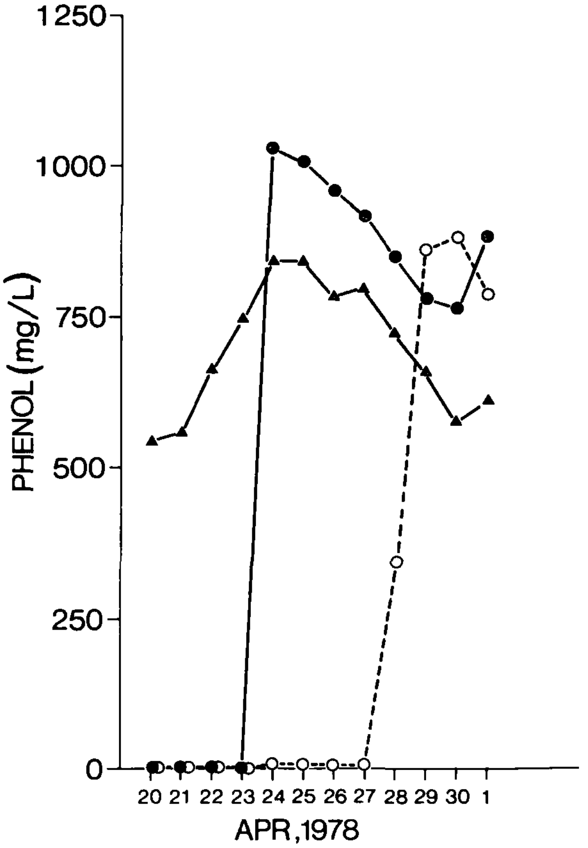


FIGURE 25. PHENOL DATA – PHASE 3

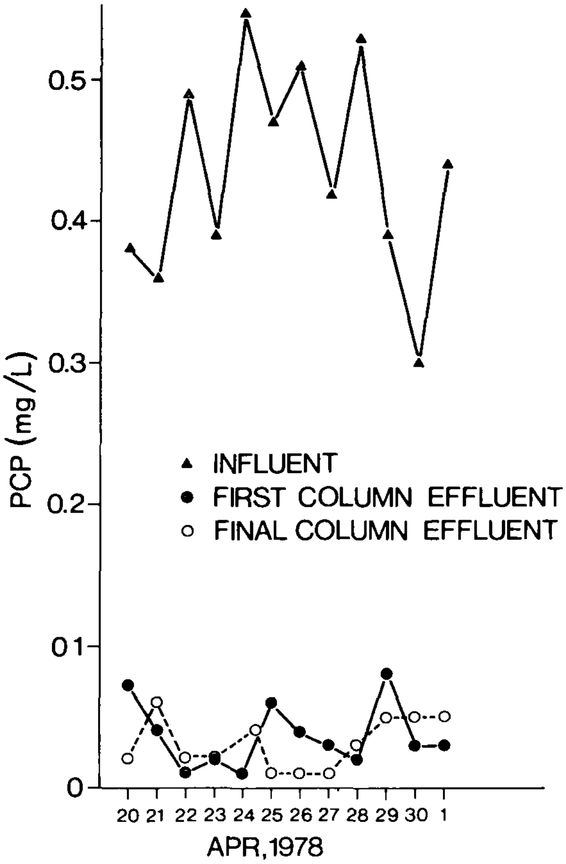


FIGURE 26. PCP DATA – PHASE 3

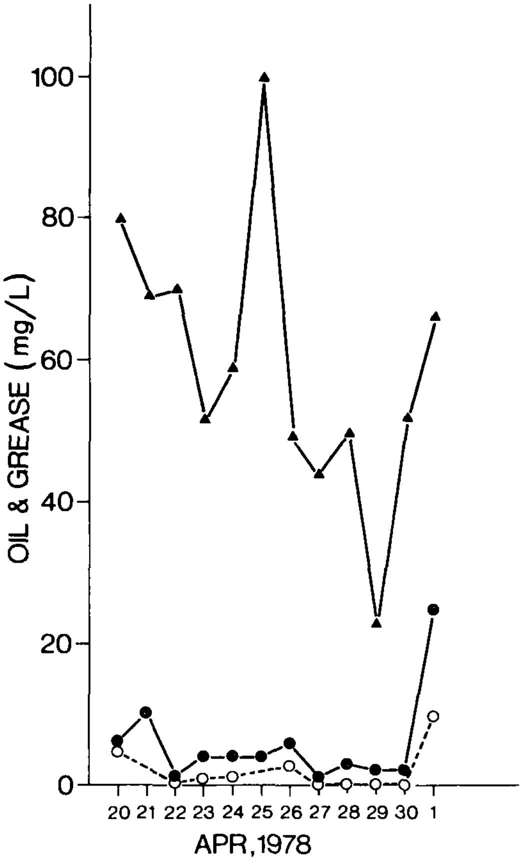


FIGURE 27. OIL AND GREASE DATA – PHASE 3

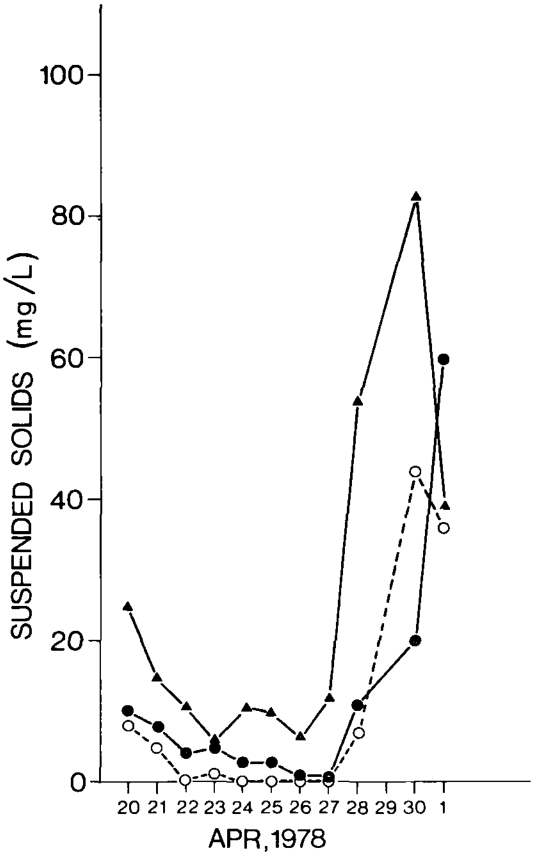


FIGURE 28. SUSPENDED SOLIDS DATA – PHASE 3

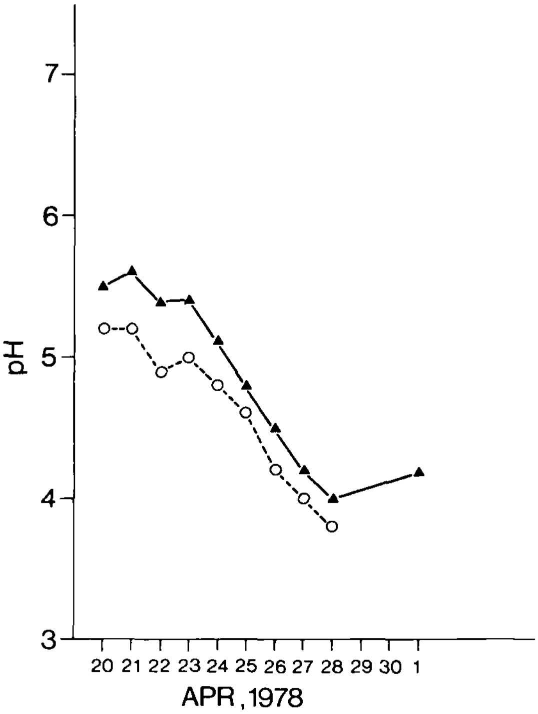


FIGURE 29. pH DATA – PHASE 3

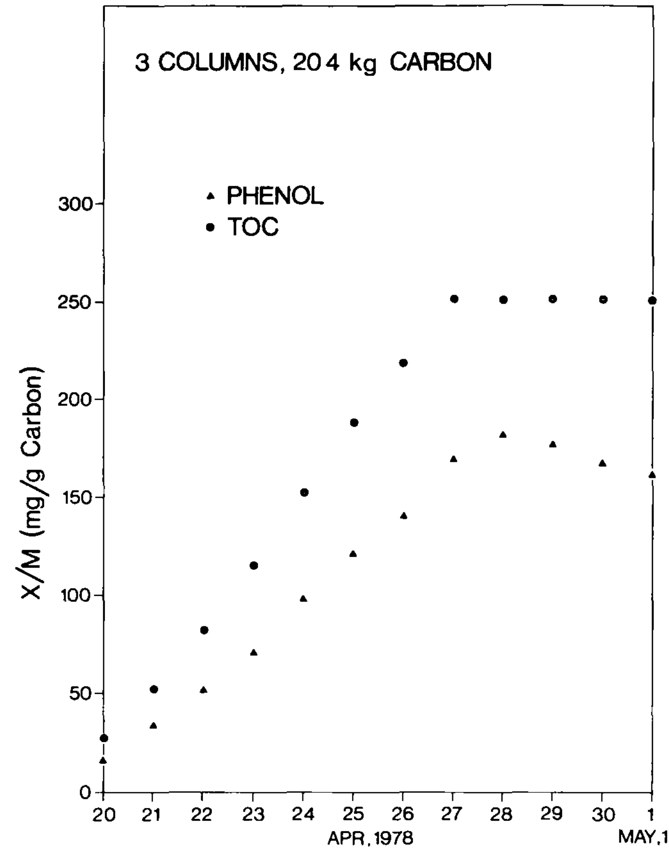


FIGURE 30 CUMULATIVE ADSORPTION CURVES FOR TOC AND PHENOL - PHASE 3

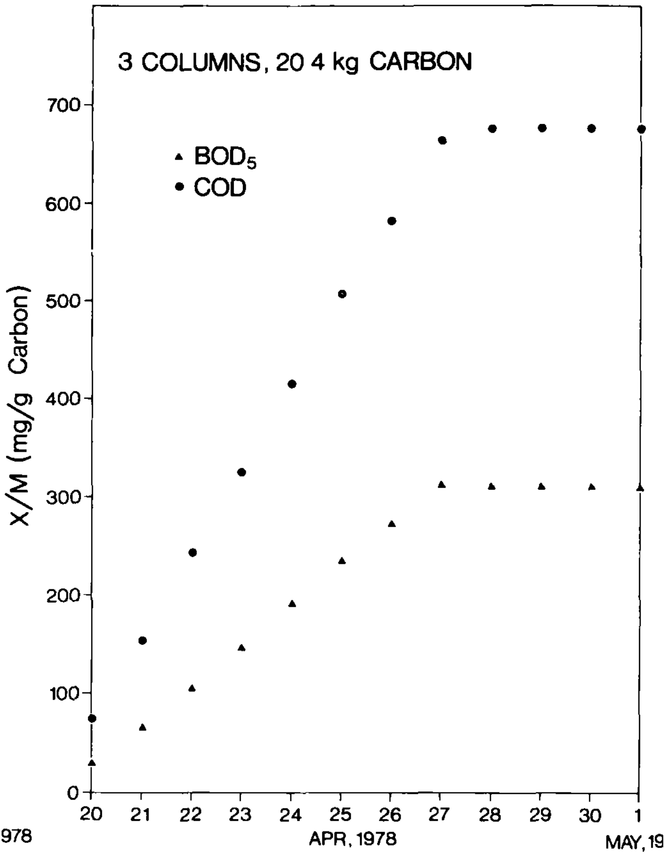


FIGURE 31 CUMULATIVE ADSORPTION CURVES FOR BOD_5 AND COD - PHASE 3

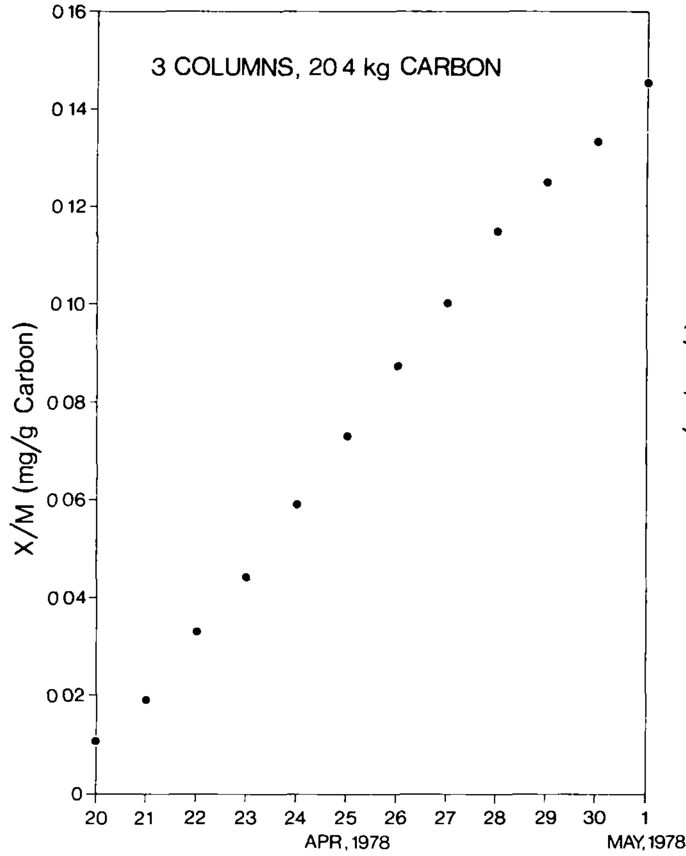


FIGURE 32 CUMULATIVE ADSORPTION CURVE FOR PCP - PHASE 3

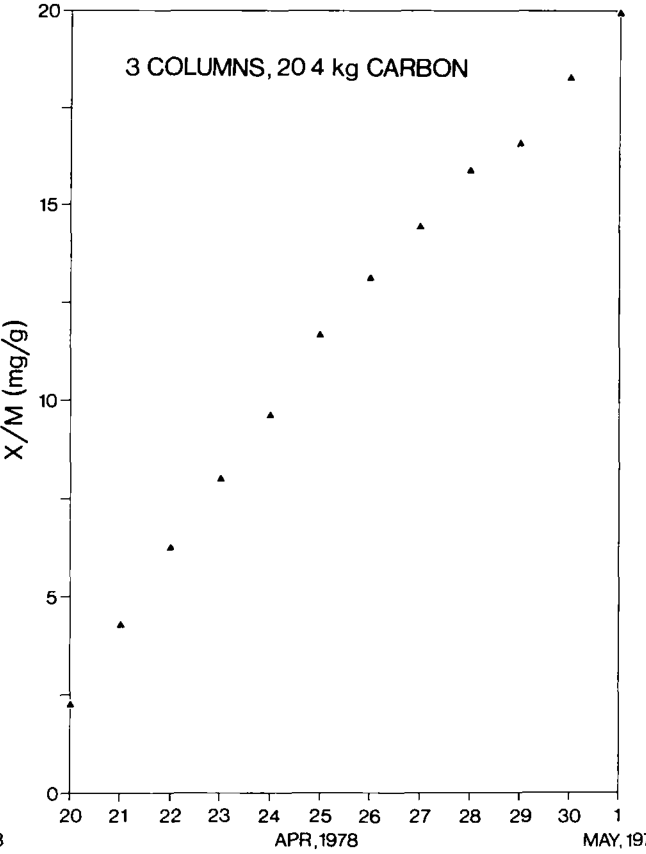


FIGURE 33 CUMULATIVE ADSORPTION CURVE FOR OIL AND GREASE - PHASE 3

Plots presented in Figures 26 and 27, as well as X/M curves shown in Figures 32 and 33, show that no breakthrough occurred in 12 days for PCP or for oil and grease. The X/M values for PCP were 0.42 mg/g for the first column and 0.15 mg/g if the three columns were used in the calculation, indicating that the majority of the PCP had adsorbed on the first column. These values were much lower than those obtained during Phase 2 and much less than the 26 mg/g values obtained from bench scale testing. The X/M values for oil and grease during Phase 3 were 58.7 mg/g for the first column, and 19.8 mg/g if the three columns were used in the calculation. These results show that virtually all of the oil and grease adsorption occurred on the first carbon column.

As shown in Table 11, the percent removal of all organic parameters from the wastewater was greater than 90%. PCP concentration was reduced from 0.44 to 0.02 mg/L, for 95% removal. This effluent concentration compared favourably to the 0.03 mg/L residual for PCP during Phase 2 of the operation when the average influent PCP concentration was 3.6 mg/L. The removal of phenols was greater than 99%, from 700 to 5.3 mg/L, but the residual phenol is considerably higher than the 0.08 mg/L effluents experienced during the previous phase of the operation. Percent removal of BOD_5, COD and TOC were 90, 91 and 92%, respectively, yielding effluent averages of 152, 264 and 84 mg/L, respectively, which in each case was considerably greater than effluent averages experienced during Phase 2 of the operation. The effluent oil and grease concentration averaged 6 mg/L, which was less than that of the previous phase of the operation. The average effluent concentrations of NH_3-N, TKN and total phosphorus were 2.8, 2.9 and 0.2 mg/L, respectively, which were lower than during Phase 2 of the operation since ammonia and phosphoric acid were not added to the influent during Phase 3.

Thompson et al (1978) treated Abitibi-Northern Wood Preservers Limited groundwater containing 35.8 mg/L phenol and 3.15 mg/L PCP with activated carbon. They achieved effluent phenol and PCP concentrations of 0.3 and 0.05 mg/L, respectively. The influent and effluent phenol concentrations found were greater than those experienced during Phase 2, but lower than during Phase 3 of the present study. Influent and effluent PCP concentrations were comparable to those in the present study.

Richardson (1978) reported the carbon absorption treatment of wood preserving wastewaters using two, 600-mm diameter, 3-m high columns. The columns were operated in series at 111 $m^3/m^2 \cdot d$. Influent values for phenol, PCP, oil and grease, and COD were 81, 4.3, 128, and 921, respectively. Effluent phenol concentrations compare well with Phase 2 effluents; however, they were much lower than during Phase 3 of the present study since their influent concentration was lower. Removal of PCP compares with that achieved in Phase 2. Oil and grease and COD removals were somewhat better than those achieved in this study.

5.5 Column Backwash

5.5.1 Granular media filter

Backwashing of all columns was performed manually using final carbon column effluent when effluent quality was suitable, or using tap water when the effluent quality deteriorated. The granular media filter was backwashed on a daily basis at a flow rate of 0.64 $m^3/m^2 \cdot min$. This flow rate was sufficient to provide a bed expansion of 20 to 30%. Pressure build-up due to solids accumulation was not a problem as the solids applied to the column tended to percolate through the anthracite bed. After 24 hours, the solids passed to about half the bed depth and were then removed by backwashing.

Backwashing curves for the granular media filters are presented in Figure 34 for Phase 2 and in Figure 35 for Phase 3 of the operation. From the results shown, it is apparent that the solids were removed from the column within five minutes. This indicated that 26 L or 4% of the daily through-put of the columns was required for backwash.

The suspended solids concentration in the backwash water during Phase 2 of the operation after one minute of backwashing was about 900 mg/L, and after five minutes had been reduced to less than 50 mg/L. As shown in Figure 35 for Phase 3, the suspended solids concentration after one minute was about 300 mg/L, and after five minutes was reduced to less than 30 mg/L. The lower suspended solids concentration in the feed to the carbon system during Phase 3 was the reason for the lower solids concentration in the wash water during Phase 3 of the operation.

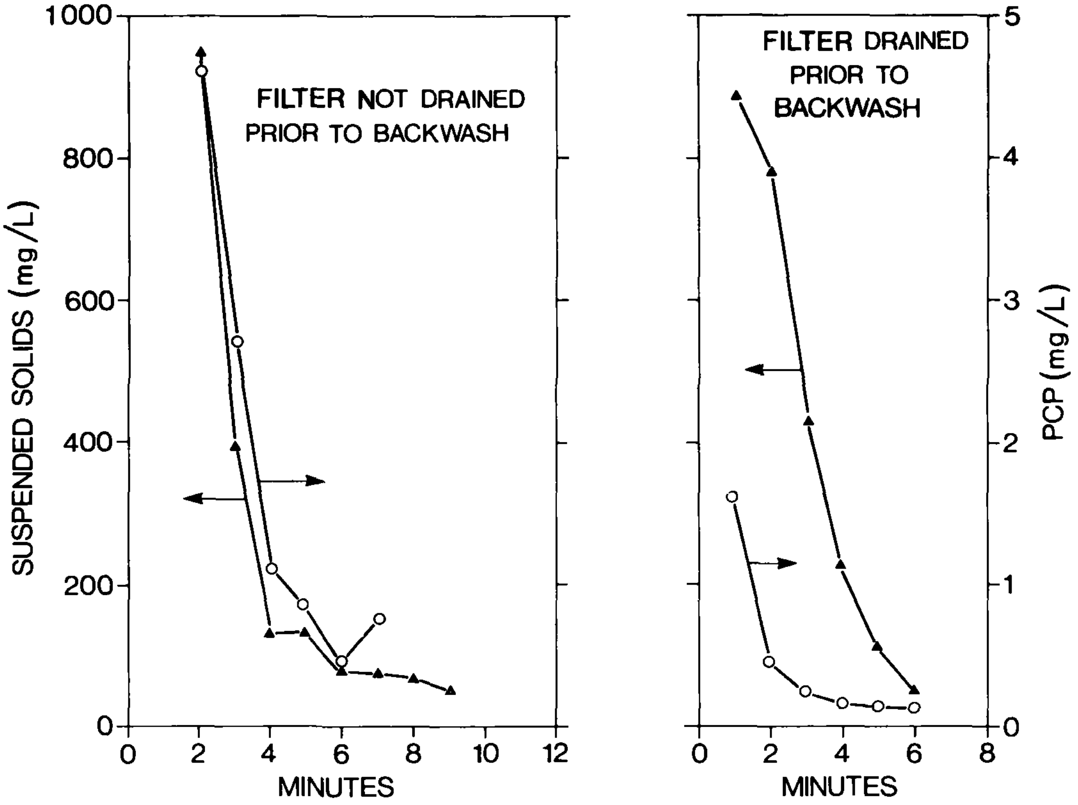


FIGURE 34. BACKWASH CURVES FOR GRANULAR MEDIA FILTER - PHASE 2

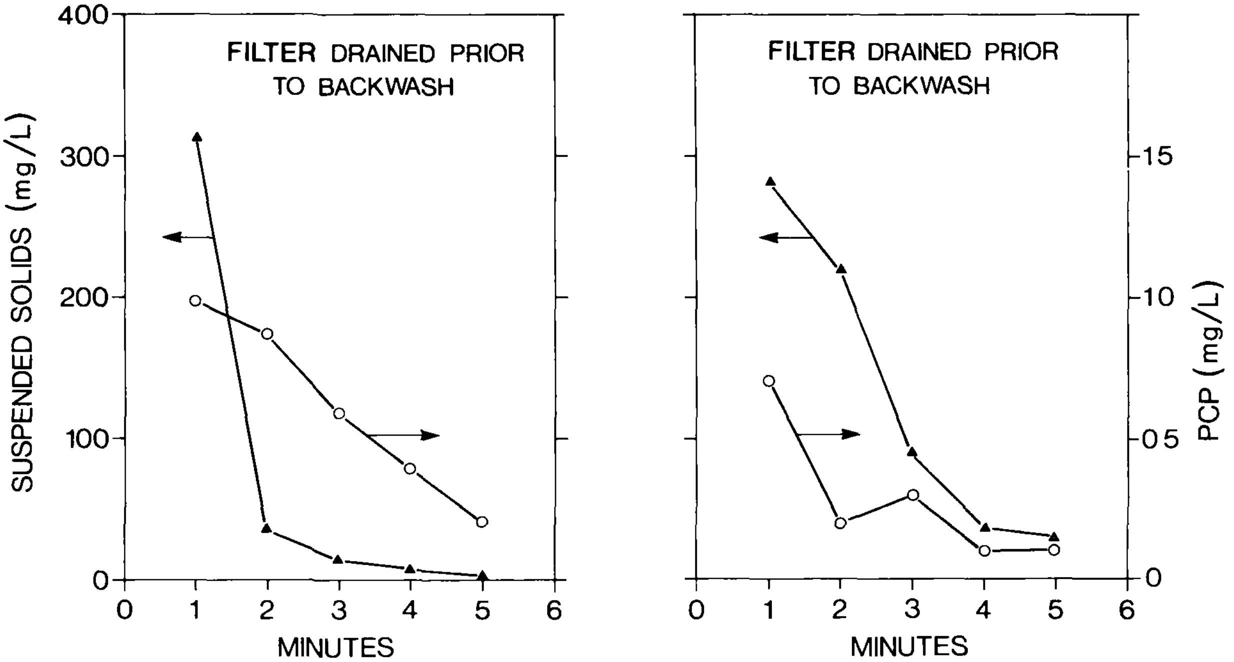


FIGURE 35. BACKWASH CURVES FOR GRANULAR MEDIA FILTER - PHASE 3

Some PCP appeared in the backwash water during the early minutes of backwashing, as is shown in Figures 34 and 35. This was not due to desorption of PCP from the anthracite column since, as shown in Table 10, PCP was not removed by the anthracite column. The appearance of PCP in the backwash water was due to washout of residual feed in the column.

5.5.2 Carbon adsorption columns

The carbon adsorption columns were backwashed when the pressure measured at the top of a column reached 172 to 207 kPa. Solids which passed through the roughing filter tended to accumulate at the top of the first carbon column and caused a pressure drop at that point. Because of pressure build-up, backwashing of the first carbon column was required on March 22 after 19 days of operation, and subsequently on April 4, after 12 days of operation. After April 4, because of the high suspended solids concentration applied to the carbon adsorption system, backwashing was required several times per week. Solids which passed through the first carbon column tended to accumulate at the top of the second carbon column which was first backwashed on April 4 after 31 days of operation, and on April 7 and 12 due to the high solids applied to the system.

Backwashing curves for the second carbon adsorption column are presented in Figure 36 for Phase 2 of the operation, and in Figure 37 for Phase 3 of the operation. Backwashing was carried out at a flow rate of 0.55 $m^3/m^2 \cdot min$. It was found that this flow rate was sufficient to provide a bed expansion of 20 to 30%. It is apparent that 15 minutes of backwashing is necessary to remove accumulated solids from the column. This longer backwashing period than required for the granular media filter presumably was due to the lower backwash flow rate and the greater depth of the column. From Figures 36 and 37 it can be seen that PCP was not desorbed from the column since the PCP concentration in the backwash water was generally less than 0.05 mg/L, which was comparable to column effluent.

5.6 Bioassay Results

The bioassay results for activated sludge effluents generated during Phases 1 and 2 are presented in Section 5.6.1. The bioassay results

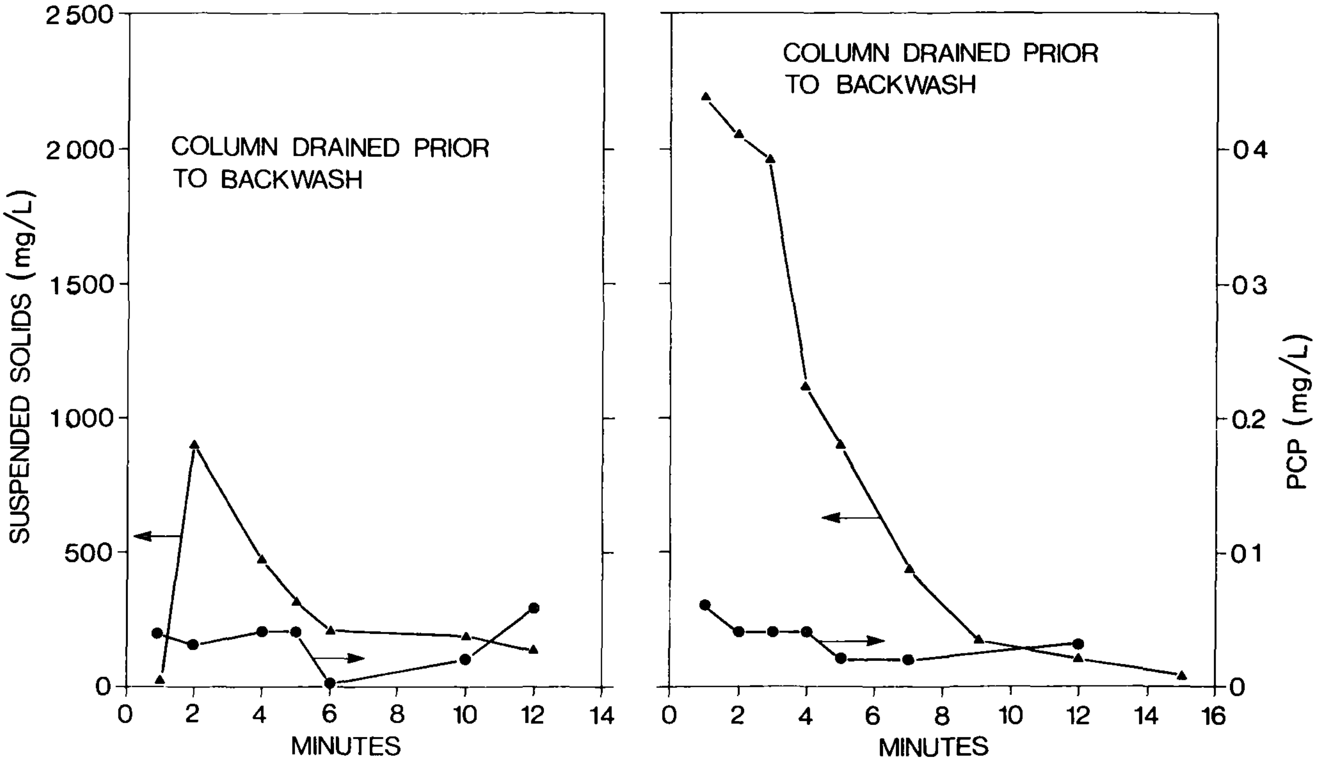


FIGURE 36 BACKWASH CURVES FOR CARBON ADSORPTION COLUMN-PHASE 2

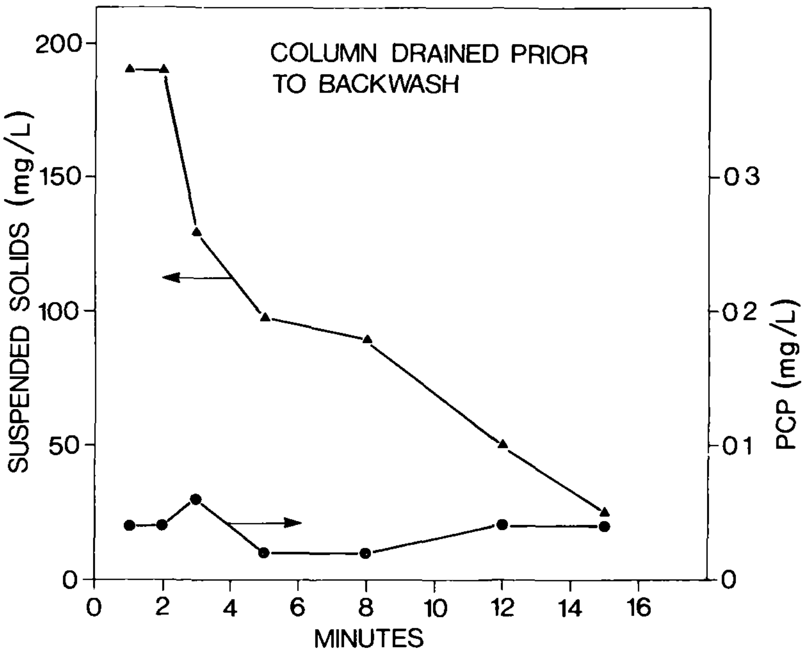


FIGURE 37. BACKWASH CURVES FOR CARBON ADSORPTION COLUMN-PHASE 3

for effluents from the Phase 2 combined biological and activated carbon treatment, and the Phase 3 activated carbon system without biological treatment, are discussed in Section 5.6.2.

5.6.1 Activated sludge treatment

Toxicity data are shown in Table 13. Biological treatment did not remove the acutely lethal substances from the wastewater. Thirty-five of the thirty-seven samples collected during Phases 1 and 2 of the study were acutely lethal to juvenile rainbow trout. Two samples, collected during Phase 2 (March 18/19) were non-lethal in 100% biologically-treated effluent after 96 hours.

Median survival times, i.e., the time to 50% mortality in 100% effluent, were calculated (Litchfield, 1949) for most of the samples and ranged from 0.2 to 5.2 hours indicating an extremely toxic effluent. Four 96-hour LC_{50}'s were calculated during Phase 1 when the biological treatment system was felt to be operating satisfactorily. Each of the 96-hour LC_{50}'s fell within the range of 1 to 5% effluent on a volume-to-volume basis and the average median survival time was 0.6 hours. Median survival times for biologically-treated effluent did not change substantially during these two phases of the program, suggesting that the toxicity of the effluent remained relatively constant with the exception of the March 18/19 period.

The substances responsible for the toxicity of biologically-treated effluent could not be specifically determined. Many potential toxic substances including copper, chromium, arsenic, creosote and pentachlorophenol were used as preservatives during the treatment process. Chemical analyses of biologically-treated effluent indicated average filtered chromium and arsenic concentrations to be 0.35 and 0.58 mg/L, respectively (Table 14). These concentrations were too low to produce the observed mortality. Chromium is found in both the trivalent (Cr^{+3}) and the more toxic hexavalent (Cr^{+6}) form. Benoit (1976) reported the 96-hour LC_{50} of hexavalent chromium to be 69 mg/L for rainbow trout, suggesting that the concentrations found in biologically-treated effluent would not directly cause acute lethality. Arsenic is reported by Dixon (1978) to have a 144-hour incipient lethal level of 13.4 mg/L to rainbow trout and, thus, is unlikely to be the toxic agent.

TABLE 13. THE ACUTE LETHALITY AND CHEMICAL CHARACTERISTICS OF BIOLOGICALLY-TREATED EFFLUENT

Date	No. of Samples	% Mortality		MST (h)		Cu (mg/L)		Cr (mg/L)		As (mg/L)		PCP (mg/L)	
		24-h	96-h	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
Phase 1													
Oct. 25 - Feb. 3	10	100	100	0.6	0.2-5.2	0.41	0.13-1.2	0.25	0.09-0.8	0.85	0.49-1.0	3.14	0.3-7.95
Phase 2													
Mar. 3-17	11	100	100	0.3	0.2-0.4	0.57	0.40-0.64	0.44	0.22-0.61	0.43	0.24-0.55	4.7	2.0-6.7
Mar. 18	1	0	0	-		0.24		0.15		0.22		<0.02	
Mar. 19	1	0	0	-						0.57		<0.01	
Mar. 20	1	100	100	2.2		0.46		0.29		0.38		<0.07	
Mar. 21 - Apr. 9	13	100	100	0.8*	0.5-1.5	0.57*	0.49-0.77	0.39*	0.28-0.48	0.54	0.38-0.83	3.8	0.01-7.5

* Only five of the thirteen samples were analyzed.

TABLE 14. AVERAGE CHEMICAL CHARACTERISTICS OF BIOLOGICALLY-TREATED EFFLUENT

Parameter	Concentration (mg/L)
Ca	8.4*
Mg	5.5*
Hardness (as $CaCO_3$)	29*
Na	67.3*
Zn	0.03*
Cu	0.52
Cr	0.38
As (Total)	0.55
As^{+3}	0.06
PCP	3.58

* n = 5.
n >20 for other parameters.

Total filtered copper concentrations in biologically-treated effluent averaged 0.50 mg/L (Table 14) and exceeded the concentrations normally associated with toxicity. Copper is lethal in the cupric (Cu^{+2}) form and the toxicity depends on the pH and hardness of the sample (Howarth, 1976). The treated effluent had a relatively low total hardness of 29 mg/L expressed as $CaCO_3$ (Table 14), which, at a pH of 8.0 should produce a 96-hour LC_{50} of approximately 0.03 mg/L (Howarth, 1976). Although total copper concentrations exceeded this level, it is not known whether copper was available to the fish. Brown et al (1974) concluded that neither total nor soluble concentrations of copper could be used to predict the toxicity of copper in an effluent containing copper complexing agents. The precise chemical nature of the copper treated in the effluent was not determined, but activated carbon treatment reduced average filtered copper concentrations in the biologically-treated effluent from 0.50 to 0.19 mg/L (Tables 14 and 16). The activated carbon effluents having filtered copper concentrations up to 0.39 mg/L (Table 15) were not acutely lethal, verifying that in these effluents, total copper concentrations much in excess of 0.03 mg/L could be tolerated by the fish.

TABLE 15. THE ACUTE LETHALITY AND CHEMICAL CHARACTERISTICS OF BIOLOGICAL PLUS ACTIVATED CARBON TREATED EFFLUENT - PHASE 2

Date	No. of Samples	% Mortality		Cu (mg/L)		Cr (mg/L)		As (mg/L)		PCP (mg/L)	
		24-h	96-h	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
Mar. 3-20	18	0	0	0.15	0.06-0.39	0.15	0.05-0.69	0.28	0.09-0.55	<0.02	<0.01-0.09
Mar. 21	1	0	100	0.27		0.08		0.36		<0.01	
Mar. 22	1	0	100	0.41		0.10		0.45		<0.01	
Mar. 23	1	0	80	0.52		0.16		0.33		<0.01	
Mar. 25-27	2	0	0	0.19	0.18-0.21	0.07	0.05-0.08	0.31	0.27-0.34	<0.01	
Mar. 28	1	0	100	0.07		0.05		0.37		<0.01	
Mar. 29 - Apr. 7	10	0	0	-	0.05-0.31*	-	0.02-0.16*	0.44	0.29-0.61	<0.02	<0.01-0.06
Apr. 9	1	0	100	0.51		0.14		0.29		0.10	

* Only two samples were analyzed during this period.

TABLE 16. AVERAGE CHEMICAL CHARACTERISTICS OF BIOLOGICAL PLUS ACTIVATED CARBON TREATED EFFLUENT

Parameter	Concentration (mg/L)
Zn	0.04
Cu	0.20
Cr	0.13
As (Total)	0.33
As^{+3}	0.08*
PCP	0.02

* n = 9.
n >20 for other parameters.

Biologically-treated effluent contained sufficient pentachlorophenol to produce the observed toxicity. Pentachlorophenol concentrations averaged 3.58 mg/L and were approximately 30 times the nominal 96-hour LC_{50} of 0.13 mg/L determined from static bioassays (Figure 38). This data agrees reasonably well with the 50 to 100 µg/L range of 96-hour LC_{50}'s reported by Davis and Hoos (1975). The two non-acutely lethal biologically treated effluents (March 18/19) contained less than 0.02 and 0.01 mg/L of pentachlorophenol, respectively (Table 13). However, toxic samples collected on March 20 and 27 contained less than 0.07 and 0.01 mg/L of pentachlorophenol, respectively, suggesting that toxicants other than pentachlorophenol were occasionally present in the biologically-treated effluent.

Creosote is used extensively in the preservation of wood and has a reported 96-hour LC_{50} of 0.99 mg/L (Webb, 1975); however, the concentration of creosote remaining after biological treatment was unknown.

5.6.2 Activated carbon treatment

Supplementing biological treatment with activated carbon treatment effectively removed the acute lethality in 30 of the 35 samples tested (Table 15). The five remaining samples (March 21 22, 23, 28 and April 9) were acutely lethal, but the cause of mortality could not be confirmed. Concentrations of chromium and arsenic were much less than lethal levels (Table 15) and pentachlorophenol concentrations were less than 0.01 mg/L with the exception of the April 9 sample, indicating the activated carbon treatment system was still performing satisfactorily. Copper concentrations in three of the toxic samples exceeded concentrations in the non-lethal samples, but again, the specific form of copper in the effluent was unknown. In two instances (March 21 and 28) all the parameters measured were less than values for samples which were non-toxic, suggesting that other factors were responsible for the toxicity.

During Phase 3, two samples of effluent which had been treated with activated carbon alone were tested on April 20 and 27. The April 20 sample was non-acutely lethal. The April 27 sample was acutely lethal, but the cause of toxicity was unknown as samples were not submitted for chemical analyses.

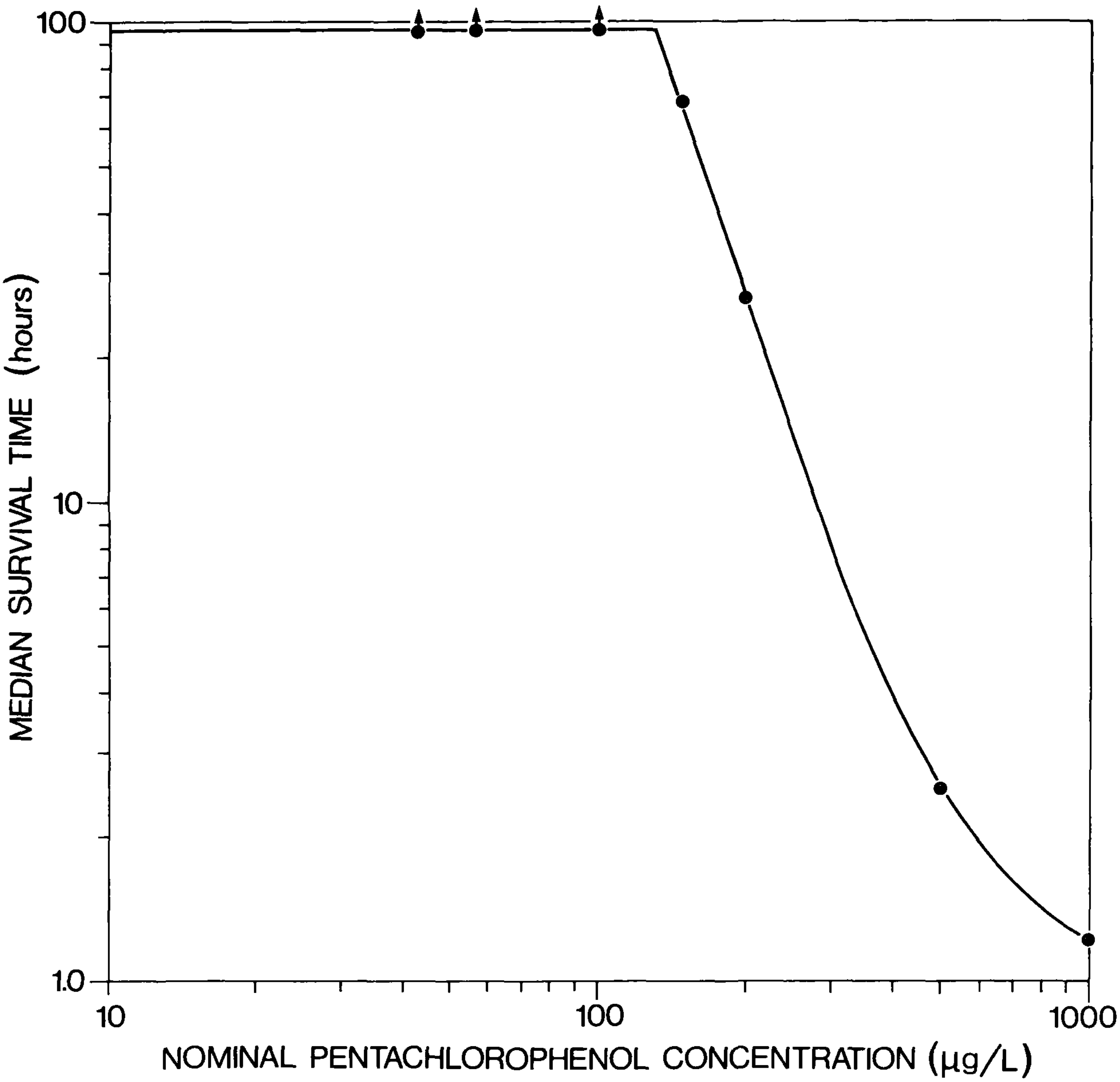


FIGURE 38. TOXICITY OF PENTACHLOROPHENOL TO JUVENILE RAINBOW TROUT

The results of this study suggest that activated sludge treatment alone is incapable of removing all the toxic substances, especially pentachlorophenol from the Abitibi-Northern Wood Preservers Limited's wastewater. However, if biological treatment is followed by activated carbon treatment, the effluent could be rendered non-acutely lethal. In the few instances where activated carbon treated effluent was lethal, the mortality was not solely due to pentachlorophenol, chromium or arsenic. The specific toxic agents could not be identified.

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APPENDIX I

Daily Influent and Effluent Data

TABLE I-1. INFLUENT - PHASE 1

Date (1977)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Nov. 1	30	-	-	-	-	-	-	-	-	-	-	-
2	33	6.8	440	1 000	330	-	190	-	10.1	22.8	13.5	-
3	39	9.7	500	1 000	330	49	190	-	32.0	48.3	4.1	-
4	39	8.9	480	1 300	240	33	200	-	17.0	27.9	1.3	-
8	37	9.2	600	1 300	370	37	240	-	19.0	20.1	17.0	-
9	36	9.0	440	1 200	310	69	186	-	15.0	21.7	21.0	-
10	36	8.7	480	1 400	350	42	-	-	49.0	53.1	40.0	7.5
14	34	5.6	-	-	-	-	-	-	-	-	-	-
15	34	6.0	-	-	-	-	-	-	-	-	-	-
16	38	6.1	-	-	-	-	-	-	-	-	-	-
17	39	8.0	-	-	-	-	-	-	-	-	-	-
18	38	9.1	-	-	-	40	-	-	-	-	-	-
22	34	7.5	780	1 600	470	52	289	-	13.3	19.0	33.0	-
23	35	7.7	680	1 500	390	26	290	-	9.0	18.9	9.1	-
24	34	8.8	-	-	-	-	-	-	-	-	-	-
25	35	9.3	820	1 700	430	54	-	-	20.0	36.7	12.0	-
29	39	8.0	730	1 500	360	56	230	2 500	6.3	16.1	17.0	10.2
30	39	7.8	580	1 200	330	40	210	2 500	11.0	24.6	25.0	11.5
Dec. 1	40	9.0	480	1 200	270	28	180	970	2.0	-	-	10.2
2	39	9.9	370	1 100	330	23	-	-	11.0	-	-	-
6	32	10.0	560	1 400	360	27	-	-	2.0	11.6	1.8	-
7	31	9.8	600	1 600	430	37	270	1 740	6.0	24.8	14.6	5.5
8	30	8.8	820	1 400	420	38	270	549	8.4	21.0	9.9	5.2
9	29	9.1	780	1 300	390	23	250	-	12.7	27.2	9.8	-
13	35	9.1	570	1 000	260	62	140	-	3.4	10.7	3.0	6.9
14	37	10.5	560	1 100	210	50	120	-	7.7	26.4	5.0	-
15	35	10.2	430	870	230	41	120	-	7.0	24.9	4.3	10.1
16	34	10.2	420	940	220	-	-	-	13.0	27.7	5.5	-

TABLE I-2. ACTIVATED SLUDGE EFFLUENT - PHASE 1

Date (1977)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Nov.												
01	-	-	-	-	-	-	-	-	-	-	-	-
02	-	6.7	41	230	35	64	0.18	-	8.7	23.1	21.8	-
03	29	6.4	37	250	35	78	0.11	-	3.9	18.3	19.8	-
04	29	6.4	14	260	29	57	0.10	-	0.8	15.3	20.9	-
08	29	6.2	16	320	34	75	0 09	-	9.0	23.2	19.3	-
09	28	5.1	13	300	33	73	0.09	-	5.0	16.9	19.7	-
10	28	6.1	15	450	28	66	-	-	3.0	23.1	21.4	0.79
14	27	5.5	-	-	-	-	-	-	-	-	-	-
15	28	5.9	-	-	-	69	-	-	-	-	-	-
16	28	6.1	-	-	-	-	-	-	-	-	-	-
17	29	6.1	-	-	-	112	-	-	-	-	-	-
18	28	6.6	-	-	-	54	-	-	-	-	-	-
22	26	7.2	9	200	30	62	0.10	-	0.1	3.5	16.6	-
23	26	7.1	13	220	38	32	0.14	-	1.0	5.5	13.6	-
24	24	6.8	-	-	-	-	-	-	-	-	-	-
25	23	7.0	23	270	35	108	-	-	0	7.3	10.0	-
29	27	7.1	17	200	33	67	0.12	620	0	5.7	16.0	6.9
30	27	7.1	16	240	54	80	0.15	530	0	6.2	20.0	6.0
Dec.												
01	31	7.2	19	340	13	94	0.12	506	0.2	-	-	8.6
02	30	7.2	18	260	29	98	-	-	0.5	-	-	-
06	23	7.1	15	220	31	70	-	-	0.5	4.7	3.6	-
07	24	7.1	13	220	29	35	0.53	410	0.2	3.5	3.3	4.3
08	23	6.8	23	190	25	41	0.06	133	0.1	1.4	3.3	4.9
09	22	7.0	20	190	23	45	0.08	-	0.1	0.9	3.7	-
13	28	6.4	280	830	25	281	1.3	-	0.6	29.7	13.0	5.6
14	27	6.4	270	1 600	91	418	1.9	-	1.7	34.5	13.4	-
15	27	6.8	230	1 100	98	276	3.0	-	1.5	24.2	9.8	7.2
16	25	7.0	69	720	100	-	-	-	0.8	22.5	8.5	-

TABLE I-3. INFLUENT - PHASE 2

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Mar.												
3	39	8.9	-	-	810	13	-	-	-	-	-	8.9
4	40	8.6	1 150	2 330	800	11	520	83	11.0	31.0	1.5	10.8
5	39	8.6	1 190	2 280	770	19	480	89	16.0	37.1	6.5	8.7
6	39	6.7	1 060	2 160	730	16	420	120	16.2	35.4	2.6	10.9
7	37	9.0	1 011	2 130	625	25	464	48	16.0	35.8	4.9	9.1
8	38	8.8	1 069	2 190	645	18	524	58	12.0	30.9	2.0	11.6
9	35	8.0	957	2 040	645	32	256	69	10.0	29.9	2.8	7.5
10	34	8.2	790	2 010	715	22	436	63	4.8	24.2	10.5	6.8
11	-	-	889	2 130	690	-	484	98	8.3	26.4	5.4	6.0
12	-	-	889	2 270	700	-	496	48	5.9	23.5	7.0	6.1
13	-	-	1 003	2 330	740	-	528	96	14.8	32.5	7.2	6.5
14	41	8.7	1 034	2 550	740	26	508	49	14.6	37.4	3.9	4.7
15	40	8.8	996	2 500	720	20	572	44	36.0	46.8	9.2	5.7
16	40	8.3	1 300	2 270	750	26	504	81	23.0	43.4	8.8	4.6
17	34	7.6	1 100	2 100	790	21	472	36	9.0	38.7	2.3	4.4
18	-	-	1 200	2 400	850	-	504	26	8.8	30.4	1.6	4.2
19	-	-	1 300	2 300	820	-	528	23	13.0	49.4	8.0	10.9
20	32	8.0	1 300	2 340	860	33	540	70	17.0	48.7	5.6	12.2
21	33	9.1	1 500	2 800	960	27	566	110	22.0	57.9	2.4	12.5
22	35	8.8	1 500	2 700	930	29	516	120	20.0	49.1	9.0	13.4
23	36	8.4	1 300	2 600	910	32	584	96	35.0	49.3	3.2	12.7
24												
25	-	-	1 300	2 700	800	-	536	42	30.0	41.8	16.0	8.3
26												
27	36	8.1	-	-	-	75	-	-	-	-	-	-
28	38	8.8	1 000	1 950	650	117	400	42	39.0	58.4	14.7	12.4
29	38	8.7	770	1 830	520	82	248	61	21.0	33.6	8.6	8.6
30	39	8.4	970	2 100	540	91	280	120	22.0	37.6	5.5	5.9
31	-	-	1 100	2 500	740	-	360	120	13.0	15.9	4.9	8.0

Continued ..../

TABLE I-3 (CONT'D). INFLUENT - PHASE 2

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Apr.												
1	-	-	1 400	2 900	870	-	456	160	38.0	49.0	5.7	6.6
2	-	-	1 600	3 300	980	-	570	157	45.0	53.2	4.9	7.4
3	38	8.2	1 700	3 400	990	79	660	120	67.0	74.3	5.4	8.2
4	40	8.4	-	-	-	88	-	-	-	-	-	-
5	40	8.6	2 000	4 000	1 300	96	748	160	75.0	81.5	6.9	14.9
6	34	8.6	2 200	4 300	1 400	49	780	210	73.0	76.0	5.9	10.2
7	35	8.6	2 200	4 500	1 400	88	838	180	72.0	76.0	5.9	10.3
8	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	2 500	5 200	1 700	-	1 088	160	85.0	93.0	6.8	8.4
10	36	9.2	-	-	-	120	-	-	-	-	-	-
11	35	8.4	3 000	5 400	1 800	188	1 340	140	74.0	81.0	5.5	6.8
12	34	8.8	-	-	-	104	-	-	-	-	-	-
13	34	8.6	2 500	4 600	1 500	89	1 056	122	42.0	49.7	3.9	3.7

TABLE I-4. ACTIVATED SLUDGE EFFLUENT - PHASE 2

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Mar.												
3	28	7.3	-	-	60	64	-	-	-	-	-	6.0
4	29	7.3	17	300	57	56	0.30	6	0.9	9.5	1.5	7.9
5	28	7.2	13	300	59	72	0.20	11	0.9	10.5	1.6	5.0
6	29	7.0	17	290	53	60	0.04	7	1.1	10.3	0.8	5.7
7	30	7.1	20	350	53	61	0.08	22	1.2	9.3	1.5	5.3
8	26	7.8	26	330	42	67	0.09	14	0.9	10.0	1.0	3.7
9	27	6.9	21	340	41	77	0.16	23	1.2	8.7	1.0	4.1
10	24	6.8	18	330	42	72	0.29	26	1.0	12.9	5.0	4.3
11	-	-	21	350	48	-	0.16	18	1.9	16.1	4.0	3.8
12	-	-	21	340	44	-	0.08	24	3.0	15.9	4.9	4.2
13	-	-	13	330	42	-	0.12	23	4.4	16.3	3.2	4.4
14	28	7.6	17	290	45	45	0.14	21	5.3	17.6	2.5	3.9
15	27	7.5	13	270	52	30	0.11	11	5.3	16.5	2.4	2.1
16	26	7.1	20	500	60	31	0.09	11	5.8	21.8	2.7	1.6
17	25	7.5	13	210	50	35	0.18	9	4.7	13.8	2.2	1.9
18	-	-	7	180	43	-	0.16	4	3.0	12.0	1.6	0.05
19	-	-	12	210	46	-	0.18	8	2.1	13.2	3.2	0.02
20	21	7.1	54	370	67	52	0.20	19	10.0	29.7	4.0	2.0
21	22	7.6	70	350	59	53	0.20	22	10.0	32.0	2.4	6.8
22	22	7.7	80	380	64	107	0.19	23	11.0	35.9	3.6	6.8
23	24	7.3	87	420	84	50	0.12	18	22.0	35.4	2.8	7.6
24	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	67	360	64	-	0.06	8	18.0	34.5	3.7	7.7
26	-	-	-	-	-	-	-	-	-	-	-	-
27	23	7.2	-	-	-	44	-	-	-	-	-	-
28	25	7.4	20	200	50	43	0.12	3	25.0	33.5	5.8	4.4
29	25	7.5	13	220	43	41	0.14	8	16.0	20.1	3.6	0.08
30	26	7.5	13	270	45	70	0.23	17	4.0	5.8	1.1	0.27
31	-	-	16	260	42	-	0.18	15	3.0	4.6	2.3	0.29

Continued ..../

TABLE I-4 (CONT'D). ACTIVATED SLUDGE EFFLUENT - PHASE 2

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Apr.												
1	-	-	14	270	48	-	0.28	13	2.0	4.8	2.7	0.89
2	-	-	9	240	48	-	0.12	12	3.0	5.9	2.7	1.3
3	24	7.4	11	260	52	98	0.14	11	2.0	3.9	1.8	2.1
4	26	7.5	-	-	-	110	-	-	-	-	-	-
5	27	7.6	110	550	82	135	0.53	32	15.0	21.0	2.2	5.0
6	28	-	140	660	80	154	0.36	39	14.0	15.0	1.9	4.4
7	25	7.6	170	710	68	204	0.72	36	13.0	14.8	2.0	7.2
8	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	280	900	94	-	0.53	44	11.0	13.1	3.1	7.4
10	22	7.2	-	-	-	187	-	-	-	-	-	-
11	23	7.1	450	1 300	210	220	0.78	32	13.0	15.0	1.7	6.0
12	23	7.3	-	-	-	157	-	-	-	-	-	-
13	25	7.5	540	1 400	210	132	0.95	34	12.0	13.6	2.2	3.1

TABLE 1-5. CARBON COLUMN EFFLUENT - PHASE 2

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Mar.												
3	22	7.4	-	-	3	8	-	-	-	-	-	0.14
4	18	7.0	10	65	17	15	0.08	1	0.4	2.2	0.8	0.01
5	20	7.1	7	59	8	16	0.18	12	0.5	2.8	0.5	<0.01
6	21	6.9	10	66	6	10	0.14	18	0.6	2.5	0.7	<0.01
7	19	7.1	13	130	4	10	0.04	1	0.8	2.0	0.5	<0.01
8	20	7.6	13	100	7	14	0.02	7	0.4	2.5	0.5	0.02
9	17	7.0	19	140	7	11	0.04	8	1.0	2.5	1.0	0.04
10	16	7.0	14	120	9	14	0.12	10	1.2	5.7	2.8	0.02
11	-	-	16	150	13	-	0.11	10	1.9	8.0	2.6	0.04
12	-	-	25	160	13	-	0.16	15	3.1	10.2	2.2	0.04
13	-	-	19	150	12	-	0.08	8	4.6	9.3	2.2	0.02
14	22	7.7	14	130	12	18	0.06	9	5.7	10.8	2.1	0.05
15	22	7.3	15	140	14	13	0.12	8	4.8	13.7	2.4	0.02
16	20	7.3	18	340	13	14	0.06	5	5.4	11.2	1.7	<0.01
17	18	7.2	17	100	9	14	0.10	3	4.7	8.7	1.8	<0.01
18	-	-	10	46	15	-	0.09	5	2.8	6.1	1.6	<0.01
19	-	-	8	46	12	-	0.10	10	1.1	4.7	1.8	-
20	14	7.2	10	66	12	15	0.09	6	5.3	7.5	2.6	0.03
21	14	7.5	43	180	19	19	0.11	4	9.0	22.8	2.4	0.02
22	15	7.6	36	160	22	19	0.18	3	10.0	28.6	3.5	0.02
23	17	7.2	82	200	20	16	<0.01	2	20.0	26.3	2.8	0.06
24	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	73	180	42	-	0.03	4	18.0	25.2	2.4	0.06
26	-	-	-	-	-	-	-	-	-	-	-	-
27	18	7.0	-	-	-	18	-	-	-	-	-	-
28	17	7.2	40	120	14	34	0.03	6	23.0	30.3	4.9	0.07
29	18	7.5	13	84	10	13	0.03	3	12.0	17.2	3.4	0.02
30	18	7.4	23	70	15	16	<0.001	7	8.0	8.1	1.2	0.05
31	-	-	39	94	23	-	<0.001	3	6.0	7.3	2.4	0.04

Continued ..../

TABLE I-5 (CONT'D). CARBON COLUMN EFFLUENT - PHASE 2

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Apr.												
01	-	-	20	67	18	-	<.001	5	2.0	3.8	2.0	0.04
02	-	-	14	50	11	-	-	2	4.0	5.4	2.1	0.04
03	22	7.6	12	50	9	29	0.15	4	1.0	3.0	1.9	0.04
04	20	7.4	-	-	-	30	-	-	-	-	-	-
05	20	7.5	75	250	21	52	0.30	11	14.0	18.2	2.0	0.08
06	17	-	96	310	52	65	0.21	10	14.0	14.9	1.9	0.47
07	18	7.3	110	310	23	45	0.28	13	16.0	17.3	2.5	0.05
08	-	-	-	-	-	-	-	-	-	-	-	-
09	-	-	240	560	52	-	0.28	20	13.0	13.9	1.1	0.17
10	15	7.1	-	-	-	78	-	-	-	-	-	-
11	16	7.2	300	710	86	62	-	16	11.0	15.0	1.8	-
12	18	7.1	-	-	-	111	-	-	-	-	-	-
13	19	7.3	-	-	-	72	-	-	-	-	-	-

TABLE I-6. INFLUENT - PHASE 3

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Apr. 17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	38	5.5	1 100	2 800	970	25	540	80	1.8	8.5	1.9	0.38
21	37	5.6	1 400	2 800	960	15	560	69	1.8	29.3	0.4	0.36
22	36	5.4	1 500	3 200	1 000	11	660	70	3.1	25.4	0.1	0.49
23	35	5.4	1 500	3 100	1 200	6	748	54	3.0	33.3	<0.1	0.39
24	35	5.1	1 600	3 200	1 300	11	844	59	4.1	34.4	<0.1	0.55
25	32	4.8	1 600	3 400	1 400	10	840	100	4.2	30.2	<0.1	0.47
26	32	4.5	1 600	2 800	1 200	7	786	49	4.0	23.4	<0.1	0.51
27	33	4.2	1 500	3 100	1 100	12	796	44	5.1	24.8	0.1	0.42
28	31	4.0	1 600	3 100	990	54	724	50	5.0	34.7	0.5	0.53
29	-	-	1 700	3 300	990	-	660	23	5.0	29.5	1.0	0.39
30	-	-	1 500	3 000	920	83	576	52	6.0	28.7	0.5	0.30
May 01	33	4.1	1 400	2 800	790	39	612	66	11.0	31.9	0.2	0.44

TABLE I-7. FIRST CARBON COLUMN EFFLUENT - PHASE 3

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Apr.												
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	120	240	67	10	0.06	6	0.8	7.4	1.4	0.07
21	-	-	140	250	76	8	0.02	10	1.8	5.6	0.3	0.04
22	-	-	200	480	92	4	0.22	<1	2.0	10.4	0.3	0.01
23	-	-	900	1 800	740	5	0.10	4	2.9	25.4	<0.1	0.02
24	-	-	1 700	3 100	1 300	3	1060	4	4.0	31.3	<0.1	0.01
25	-	-	1 800	2 700	1 000	3	1010	4	4.0	20.4	<0.1	0.06
26	-	-	1 700	2 600	1 100	1	960	6	3.9	19.7	<0.1	0.04
27	-	-	1 500	2 500	1 000	1	870	1	4.9	20.8	0.1	0.03
28	-	-	1 700	2 700	1 100	11	808	3	4.0	36.3	0.1	0.01
29	-	-	1 900	2 900	950	-	772	2	5.0	32.2	0.8	0.08
30	-	-	1 700	2 800	920	20	768	2	6.0	26.1	0.4	0.03
May												
1	-	-	1 600	2 600	900	60	880	25	9.0	29.1	0.2	0.03

TABLE I-8. FINAL CARBON COLUMN EFFLUENT - PHASE 3

Date (1978)	Temp (°C)	pH	BOD_5 (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	Phenol (mg/L)	Oil & Grease (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	Total P (mg/L)	PCP (mg/L)
Apr.												
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	26	5.2	73	150	41	8	0.03	5	0.7	5.5	0.9	0.02
21	25	5.2	100	180	52	5	14.0	-	1.7	4.5	0.1	0.06
22	24	4.9	130	200	55	<1	4.0	<1	1.8	4.9	0.1	0.02
23	22	5.0	150	250	78	1	<0.01	1	2.7	5.8	<0.1	0.02
24	24	4.8	180	280	93	<1	10.0	1	3.8	0.1	<0.1	0.04
25	22	4.6	180	330	130	<1	5.0	29	4.0	0.3	<0.1	0.01
26	22	4.2	200	320	120	<1	4.0	3	3.9	0.3	0.5	0.01
27	23	4.0	200	400	100	<1	5.0	<1	3.9	1.8	0.1	0.01
28	22	3.8	1 700	2 600	1 000	7	340	<1	4.0	37.3	<0.1	0.03
29	-	-	1 700	2 600	1 000	-	860	<1	4.0	29.1	0.5	0.05
30	-	-	1 600	2 500	970	44	880	<1	5.0	26.7	0.3	<0.05
May												
1	-	-	1 600	2 200	840	36	788	10	9.0	29.3	0.3	0.05

APPENDIX II

Operating Conditions

TABLE II-1. OPERATING CONDITIONS - PHASE 1

Date		Operating Condition
Nov. 1	-	Start of program, PCP treating in retort #3, creosote treating in retorts #1 and #2
Nov. 2	-	First composite sample collected
Nov. 14	-	2 400 gal mixed liquor wasted, CCA treating started in retort #3
Nov. 16	-	1 000 gal mixed liquor wasted
Nov. 17	-	Continuous addition of NH_3, H_3PO_4, $FeCl_3$ and $MgSO_4$ started
Nov. 23	-	1 000 gal MLSS wasted
Nov. 25	-	1 000 gal MLSS wasted
Dec. 1	-	New return sludge pump installed to operate at 2.5 Igpm
Dec. 8	-	Snowstorm caused reduced production in the wood treating plant
Dec. 9	-	Production in wood treating plant reduced due to lack of charges to treat in retorts
Dec. 12	-	Plant operators noted that liquid level in holding tanks was low
Dec. 13	-	Oil and high suspended solids noted in effluent from pollution control plant. Sludge appeared and smelled oily. Mixed liquor pH dropped to 6.3
Dec. 14	-	CCA terminated, PCP started in retort #3
Dec. 15	-	1 000 gal mixed liquor wasted
Dec. 16	-	Last sampling day, a slight improvement noted in effluent appearance

TABLE II-2. OPERATIONS CONDITIONS - PHASE 2

Date		Operating Condition
Mar. 3	-	Start-up for pilot scale columns. CCA in retort #3
Mar. 20	-	Pressure build-up noticeable in column system
Mar. 22	-	Backwash first carbon column due to high pressure (26 psi). Floating sludge noted on clarifier
Mar. 28	-	Influent turned dark brown and was high in suspended solids
Apr. 1	-	PCP treating started in retort #3
Apr. 4	-	Backwashed first and second carbon columns due to high pressure (26 psi and 17 psi, respectively)
Apr. 5	-	Dark colour noted in liquid above carbon beds in first and second carbon columns
Apr. 6	-	Mixed liquor pH dropped to 5.0. Doubling NaOH dosage returned pH to normal in 12 hours
Apr. 7	-	All three carbon columns backwashed. CCA started in column #3
Apr. 11	-	First carbon column backwashed. Effluent appears brown and high in solids
Apr. 12	-	First and second carbon column backwashed
Apr. 13	-	Phase 2 terminated

TABLE II-3. OPERATING CONDITIONS - PHASE 3

Date		Operating Condition
Apr. 19	-	Start-up of Phase 3. All columns repacked. CCA treating in retort #3
Apr. 21	-	Effluent quality from first carbon column deteriorating
Apr. 22	-	Final column effluent sparkling clear
Apr. 28	-	Final column effluent slightly turbid
May 1	-	Termination of Phase 3

APPENDIX III

Daily Mixed Liquor Data

TABLE III-1. DAILY MIXED LIQUOR DATA - PHASE 1

Date (1977)	Temp. (°C)	pH	DO (mg/L)	SVI (mL/g)	SS (mg/L)
Nov.					
1	28	-	1.7	-	-
2	29	5.7	2.2	81	11 520
3	30	4.9	2.1	81	11 800
4	31	5.7	4.0	86	11 020
8	30	6.0	4.2	85	11 200
9	30	5.7	2.8	84	11 300
10	29	6.2	2.8	85	11 360
14	28	5.5	4.6	-	-
15	29	5.9	-	85	8 210
16	29	6.1	5.0	-	-
17	30	6.3	4.7	85	7 450
18	29	6.5	4.3	84	7 470
22	27	6.5	4.3	80	7 730
23	28	6.9	4.3	86	7 470
24	26	7.0	4.3	-	7 285
25	25	6.9	-	-	-
29	29	7.0	4.1	-	7 030
30	29	7.0	3.9	73	6 920
Dec.					
1	30	7.2	4.3	-	-
2	30	7.3	3.1	130	6 920
6	25	7.0	3.8	-	-
7	25	7.0	3.4	117	7 070
8	24	7.0	3.0	94	6 900
9	23	7.0	2.9	93	7 310
13	27	6.4	0.6	92	7 620
14	28	6.3	1.0	101	7 310
15	28	6.8	1.3	88	7 740
16	26	6.9	3.0	-	-

TABLE III-2 DAILY MIXED LIQUOR DATA - PHASE 2

Date 1978	MLSS	RSSS	pH	Temp. (°C)	DO	SVI
Mar.						
3	-	-	7.4	30	2.1	-
4	7 450	-	7.1	28	2.4	127
5	7 400	14 000	7.3	30	2.2	127
6	7 540	-	6.8	30	1.7	126
7	-	-	7.2	31	1.9	-
8	7 830	13 420	7.7	28	1.4	121
9	7 880	13 810	7.0	29	1.8	123
10	7 600	13 180	6.9	26	1.9	125
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	7 960	13 610	7.4	30	2.0	118
15	8 030	-	7.5	27	1.4	117
16	8 200	13 910	7.0	28	2.1	115
17	8 100	14 100	7.5	25	1.8	117
18	-	-	-	-	-	-
19	-	-	-	-	-	-
20	8 460	13 760	7.2	23	1.4	-
21	8 530	14 130	7.5	23	1.0	110
22	8 520	14 200	7.8	23	1.2	114
23	8 600	13 980	7.5	25	1.4	108
24	-	-	-	-	-	-
25	-	-	-	-	-	-
26	-	-	-	-	-	-
27	9 020	14 860	7.2	25	1.5	103
28	9 160	15 020	7.4	26	1.6	106
29	7 830	15 000	7.5	27	1.2	120
30	9 240	15 020	7.4	25	1.8	-
31	-	-	-	-	-	-

Continued ..../

TABLE III-2 (CONT'D). DAILY MIXED LIQUOR DATA - PHASE 2

Date 1978	MLSS	RSSS	pH	Temp. (°C)	DO	SVI
Apr.						
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	-	-	7.5	26		-
4	9 850	16 130	7.4	28	1.0	98
5	10 270	16 870	7.4	29	1.5	92
6	9 880	16 600	5.0	29	1.5	99
7	9 970	16 790	7.4	26	1.3	95
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	7.4	24	1.1	-
11	9 870	17 220	7.0	25	0.8	95
12	10 140	16 880	7.1	24	0.9	94
13	9 920	16 900	7.3	26	0.7	-