AD/A-007 006

AIR MOBILE WASTEWATER RECLAMATION UNIT 200 HOUR SERVICE TEST

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Prepared for:

Army Mobility Equipment Research and Development Center

February 1975

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFCEC-TR-75-5	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER AD/A-007006
4. TITLE (and Subtitle) Air Mobile Wastewater Reclamation Unit - 200 Hour Service Test		5. TYPE OF REPORT & PERIOD COVERED Final Report July 1972 - August 1972
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John G. Vlahakis, PhD		8. CONTRACT OR GRANT NUMBER(s) MIPR No. FICECS 4108
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army MERDC Sanitary Sciences Division Ft Belvoir VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 64721F/2054/02 04
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Civil Engineering Center Directorate of Engineering Tyndall AFB FL 32401		12. REPORT DATE February 1975
		13. NUMBER OF PAGES 32
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Wastewater Treatment
Powdered Carbon
Cationic Polyelectrolyte
Water Purification Unit
Laundry Effluents
Air Mobile

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a 200 hour service test on a prototype air mobile wastewater reclamation unit. Simulated wastewater of a USAF Bare Base cold water field laundry was used for the test. The unit consists of powdered activated carbon and cationic polyelectrolyte feeders, diatomaceous earth filter, mixing tank, ERDLator and associated piping mounted in a standard Air Force expandable shelter container (ES/C), 8' wide x 8' high x 12' long in the shipping mode. The report concludes that this unit can be

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FOREWORD

The work described in this report was performed by the U.S. Army Mobility Equipment Research and Development Center (MERDC), Ft Belvoir, VA, for the U.S. Air Force Civil Engineering Center, Tyndall Air Force Base, Florida, under MIPR No. FICECS 4108. The Center project engineer was Freddie L. Beason, P.E. The test conductor at MERDC was John G. Vlahakis of the Sanitary Sciences Division of the Military Technology Department.

This report has been reviewed by the Information Officer (IO) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved.

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used to recycle synthetic cold-water laundry wastewater for reuse.

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TREATMENT OF COLD WATER MILITARY LAUNDRY WASTEWATER

I. INTRODUCTION

1. Subject: The purpose of this field study was to investigate the feasibility of treating synthetic cold water laundry wastewater utilizing powdered activated carbon, cationic polyelectrolyte, and a modified standard military water purification unit (ERDLator). The ultimate goal was treatment of laundry wastewater for reuse in laundry operations. A recycle system has the advantages of not only providing for improved pollution abatement of a troublesome wastewater, but also enhanced operational flexibility through production of a supply of usable water both in the field and at fixed installations.

2. Background: The Sanitary Sciences Division, MERDC, as part of its basic mission, has been actively investigating treatment of wastewaters from field military operations. Several years ago this Divison developed an air-transportable treatment system for the renovation of field shower, kitchen, and laundry wastewaters under the sponsorship of and for the USAF Bare Base program. The original system utilized batch coagulation, sedimentation, dual-media filtration, granular carbon adsorption, and reverse osmosis (RO) demineralization. However, the settling tanks for batch coagulation were large and difficult to protect in freezing environments. A later study, sponsored by the USAF Bare Base program, was initiated to test the applicability of using the standard military water purification unit (ERDLator) for wastewater treatment in order to reduce size of equipment and to provide dual purpose equipment. It was shown that use of standard coagulants led to inordinately large sludge production and created operating problems in the upflow clarifier. Also, use of metal salt coagulants increased the total dissolved solids of the product water and proved sensitive to variations in wastewater compositions. The introduction of a powdered activated carbon/cationic polyelectrolyte scheme was employed to overcome these problems.

Tests on synthetic wastewaters at Fort Belvoir, Virginia, as well as two field studies at Camp A. P. Hill, Virginia, on actual shower, laundry, and kitchen wastewaters with a breadboard system proved the carbon/polymer process successful in field military operations. Following this program a 420 gallon per hour (10,000 gpd) prototype unit was designed for the USAF Bare Base program and packaged in an 8' wide x 8' high x 12' long Expandable Shelter Container. This unit was transported to Sterling Laundry, Washington, D.C., to test the carbon/polymer ERDLator process on renovating commercial (power) laundry wastewaters. The study was jointly supported by USAMERDC and the International Fabricare Institute, representing about

12,000 commercial laundry members. The conclusions from this study were that: (a) the process can effectively treat power laundry effluents for reuse or discharge into navigable waters in accordance with EPA guidelines; (b) the quality of the effluent was not sensitive to the wide fluctuations in chemical characteristics exhibited by the feed water.[1]

The testing of this packaged unit continued in a detailed study on the renovation of synthetic MUST (Medical Unit Self-contained Transportable) field hospital wastewaters for recycle - a project jointly supported by USAMERDC and the USA Medical R&D Command.[2] In this study, the same carbon/polymer process coupled with diatomaceous earth filtration was used as a pretreatment. However, demineralization with spiral-wound cellulose acetate reverse osmosis (RO) membranes was added as post treatment to reduce TDS.

Extensive laboratory jar testing of specific and composite MUST wastewaters was followed by two 100-hour continuous field tests of the 10,000 gallon per day pilot plant. X-ray, operating room, kitchen, shower, and laboratory wastewaters were blended into a mix tank at programmed rates prior to treatment in order to simulate the time-varying effluents from an actual MUST field hospital encampment. The system performed well during the tests, reducing the composite average turbidity from approximately 30 JTU to 0.3 JTU, average TOC from over 100 mg/l to 25 mg/l, and average COD from 445 mg/l to about 50 mg/l. The research reported in this paper is thus an integral part of an extensive testing program designed to ascertain the versatility and efficacy of the treatment processes combined in the 10,000 GPD Wastewater Reclamation Unit described earlier.

[1] Lent, D.S., "Study on Power Laundry Wastewater Treatment", Nov 1974, USAMERDC Technical Report No. 2113.

[2] Vlahakis, J.G., "Studies on MUST Field Hospital Wastewater Treatment", Dec 1974, USAMERDC Technical Report No. 2121.

II. INVESTIGATION

3. Adsorption-Coagulation Jar Tests:

a. General. Adsorption-coagulation jar tests on the synthetic laundry wastewater were performed to determine optimum type and dosages of carbon and polymer to be used in the pilot scale-up. While the results of such laboratory experiments cannot be directly applied to the pilot system, they can furnish general information on effective dosage ranges and expected product water quality. Such laboratory testing would also indicate any problems that might arise in using a coagulation process to treat laundry wastewater in a viable system.

TOC and turbidity removals were used as criteria of effectiveness for this process. Analyses were performed on the raw synthetic wastewater and those treated waters with apparent good floc formation and subsidence of floc. Treated waters that were milky or that had suspended carbon fines were not evaluated as these characteristics rendered them unacceptable because of poor filterability.

b. Procedure. For each jar test, 500 ml of synthetic laundry wastewater was placed in a 1000 ml beaker and mixed with a Phipps and Bird gang stirrer at low speed. Hydrodarco C or Darco G-60 powdered activated carbon was then added to the beakers in specific, varying dosages. As the stirrer speed was increased to 90 RPM, the polymer (Cat-floc) was added. The polymer is a cationic polyelectrolyte of the quaternary ammonium type. The stirrer speed was maintained at 90 RPM for a one minute mix time and then reduced to 30 RPM for a flocculation time of 60 minutes. The flocculated samples were allowed to settle for 15 minutes. About 30 ml of the supernatent was then pipetted from near the center of the beaker, approximately one-half inch below the surface of the liquid for analysis.

c. Results and Discussion. The results of approximately 25 jar tests are summarized in Table 1. These results indicate that both carbons were equivalent in performance. The optimum dosages of carbon and polymer as determined by these tests were 750 mg/l Hydrodarco C and 50-100 mg/l Cat-floc. Table 2 gives several properties of the carbons.

All the dosages yielding usable treated water maintained high TOC removal, ranging from 86.8-92.5% reduction. Very high turbidity removals were also noted in each case, ranging from 94.7-99.7% reduction. No serious problems in coagulation were encountered in this laboratory testing and similar high-quality results were expected when the adsorption-coagulation process was tried in the pilot plant system.

TABLE 1

COLD WATER FORMULA DETERGENT
LAUNDRY WASTEWATER JAR TEST SUMMARY

CARBON DOSAGE (mg/1)	POLYMER DOSAGE (mg/1)	TOC RAW	TOC TREATED	% REDUCTION	TURBIDITY RAW	TURBIDITY TREATED	% REDUCTION	REMARKS
100	1	53	-	-	47	-	-	NC
250	5	53	-	-	47	-	-	NC
500	10	53	-	-	47	-	-	NC
500	25	53	-	-	47	-	-	NC
500	50	53	6	88.7	47	.64	98.6	
500	100	53	6	88.7	47	1.3	97.2	
750	25	53	7	86.8	47	2.5	94.7	
750	50	53	4	92.5	47	.52	98.8	optimum dosage
750	100	53	5	90.6	47	1.3	97.2	good reduction
1000	1	53	-	-	47	-	-	NC
1000	5	53	-	-	47	-	-	NC
1000	10	53	-	-	47	-	-	NC
1000	25	53	5.5	89.6	47	1.85	96.6	
1000 G-60	25	53	6	88.7	47	.50	98.9	
1000	100	53	6	88.7	47	1.5	96.8	

TABLE 1 Cont'd.

COLD WATER FORMULA DETERGENT
LAUNDRY WASTEWATER JAR TEST SUMMARY

CARBON DOSAGE (mg/1)	POLYMER DOSAGE (mg/1)	TOC RAW	TOC TREATED	% REDUCTION	TURBIDITY RAW	TURBIDITY TREATED	% REDUCTION	REMARKS
1500	50	53	6	88.7	47	0.26	99.4	
1500 G-60	50	53	7	86.8	47	0.70	98.5	
2000	100	53	6	88.7	47	0.13	99.7	
2000 G-60	100	53	5	90.6	47	0.74	98.4	

NOTE: Carbon type is Hydrodarco C except as noted by G-60 for Darco G-60
NC indicates No Coagulation

TABLE 2

PROPERTIES OF POWDERED CARBONS

	HYDRODARCO C	DARCO G-60
Particle Size		
% through 100 Mesh	-	95
% through 300 Mesh	65	70
Apparent Density lb/ft^3	30.8	25
Wetability	Superior	Excellent

4. Wastewater Reclamation Unit Test:

a. Description of System Treatment. The principles of the system involve carbon-polyelectrolyte aided coagulation, upflow, solids-contact clarification, and pressure diatomaceous earth filtration.

Details of the Wastewater Reclamation Unit and a simplified flow diagram are shown in Fig. 1-5. The laundry wastewater is pumped into the Wastewater Reclamation Unit 500 gallon mixing tank. The powdered carbon is added through a venturi-type eductor by a standard commercial volumetric dry feeder. The Cat-floc polymer solution is pumped under pressure to a point between the carbon eductor and the mix tank. The contents of the mix tank have approximately a one hour residence time. This mixture is pumped from the mixing tank to the upflow, solids-contact clarifier. At the design flow of 420 GPH the retention time is 20 minutes and the rise rate is 1.1 gal/min/sq ft. Effluent from the clarifier is collected in a clear well and is then pumped through a diatomaceous earth pressure filter. The filter is usually operated with a precoat of 0.1 lb/sq ft and a continuous body feed of 20 mg/l. Approximately 10% of the clarifier flow is drawn through the sludge concentrator with the overflow returning to the clearwell of the clarifier.

For this study two (2) 3000 gallon collapsible rubber/nylon tanks were used as feedwater and product water collection tanks. The carbon used was Atlas Darco G-60.

b. Procedures. During the first phase of the experiments the product water was run to waste For the second phase, however, the product water was directly reused. As one 3000 gallon tank of laundry water was being fed to the unit, the other tank would collect the product water. The laundry contaminants were added as a concentrate to the product water and then reused as the new feed water.

The formula used for the cold water detergent laundry water appears below.

In a 3000 gallon batch of tap water:

Cascade	6.0 lbs
Cold Power	6.0
Clay	1.2
Bar Soap	0.9
Lubricating oil	0.3

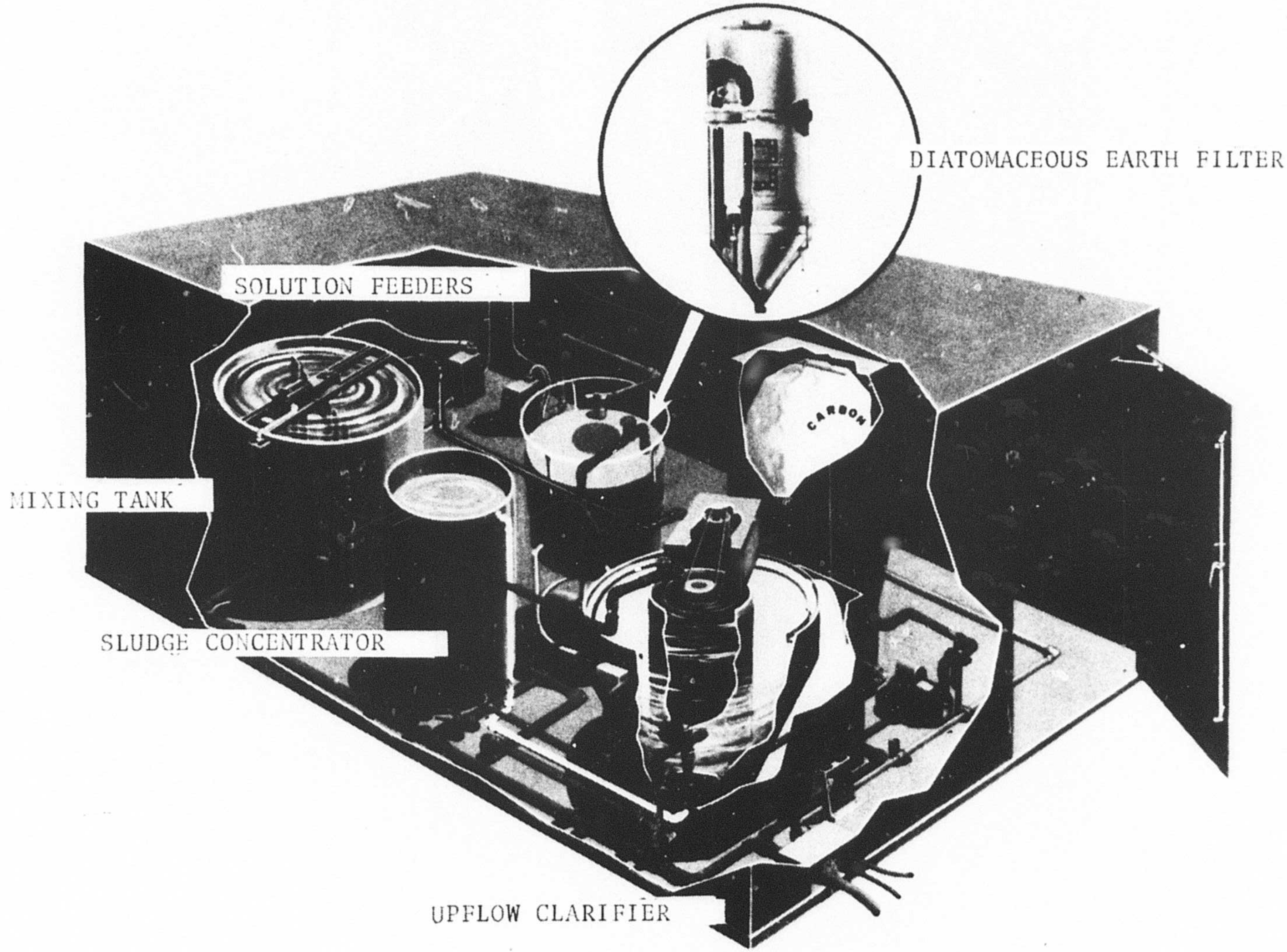

FIGURE 1 WASTEWATER RECLAMATION UNIT

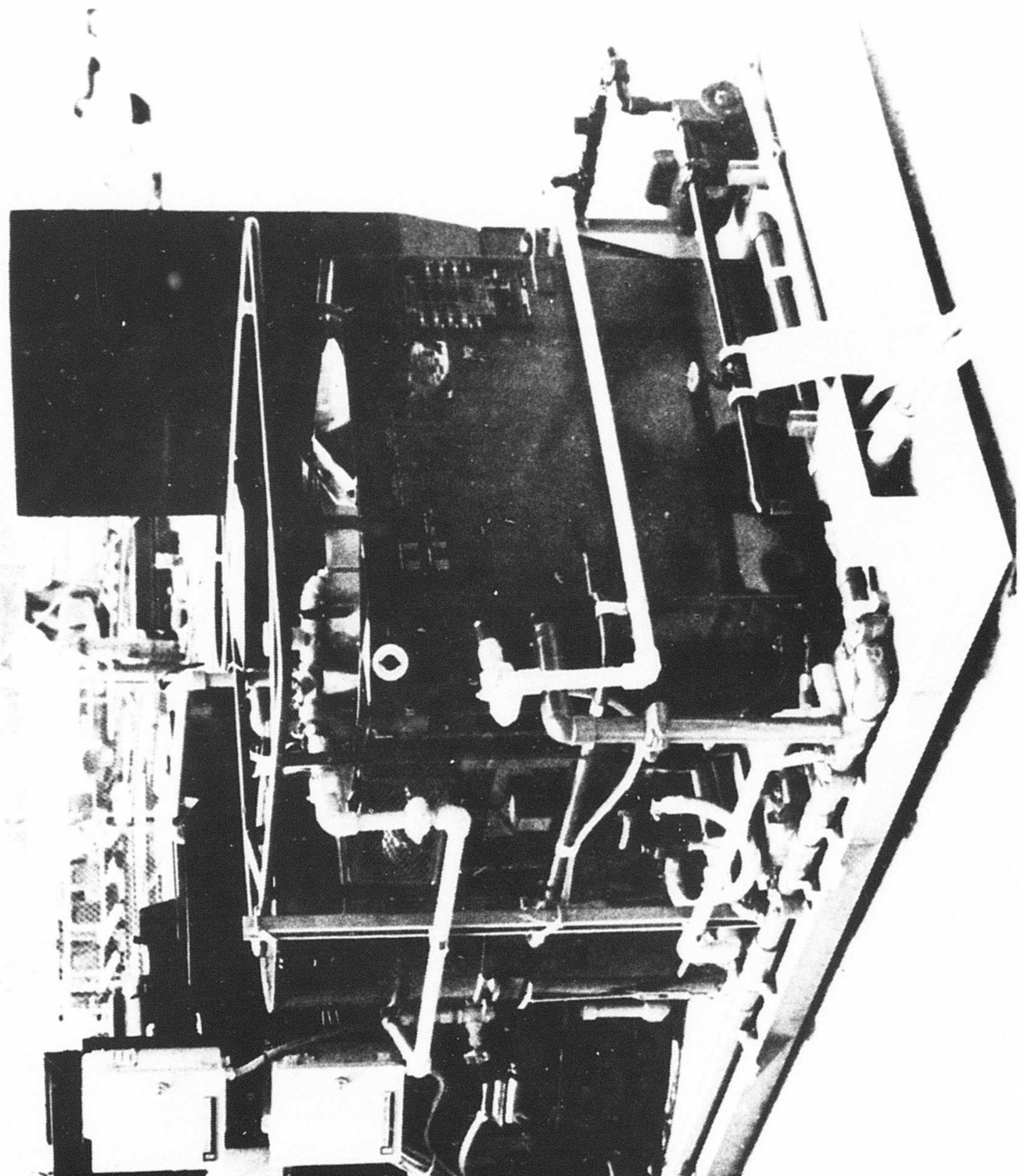

FIGURE 2 WASTEWATER RECLAMATION UNIT

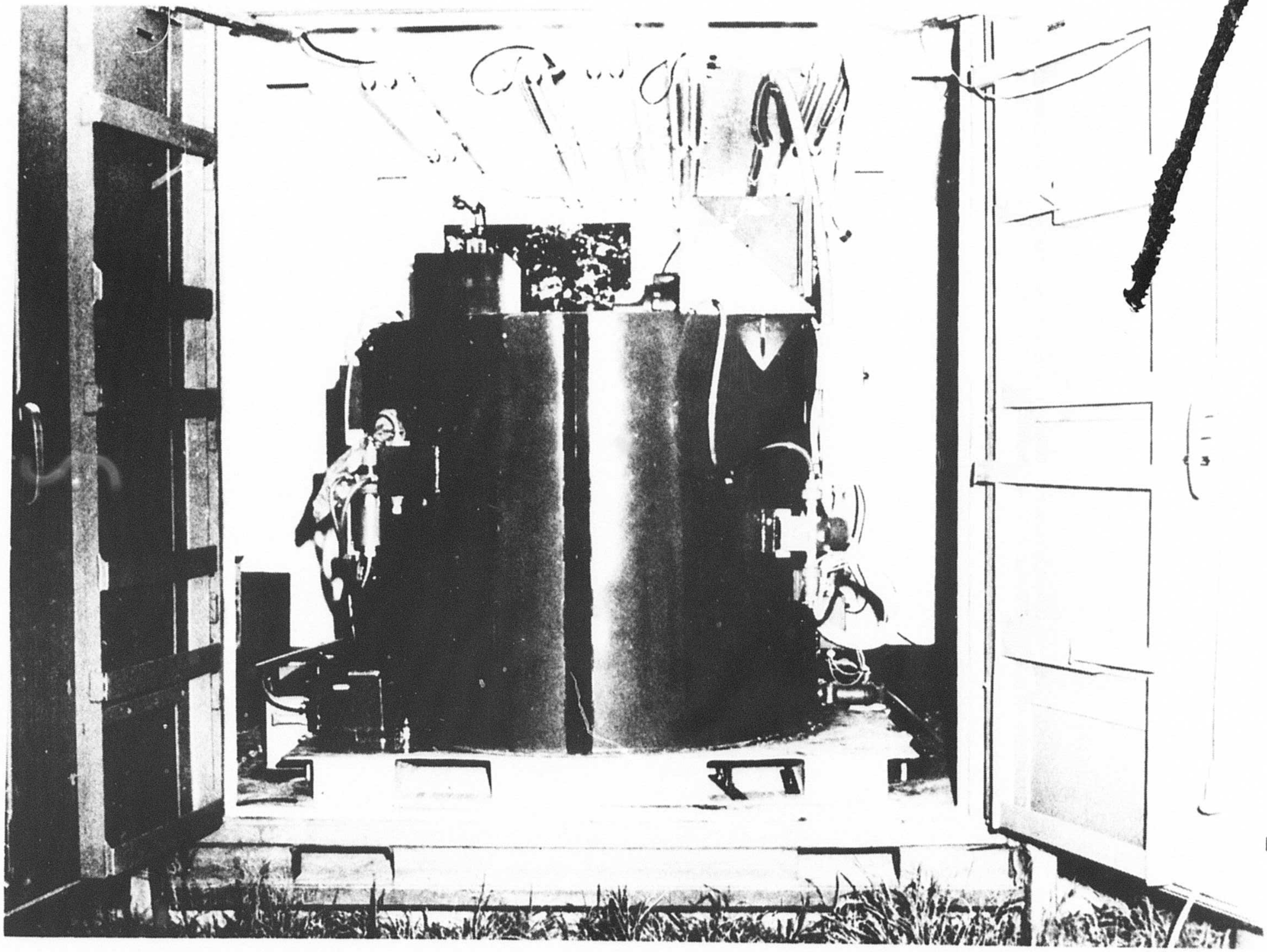

FIGURE 3 WASTEWATER RECLAMATION UNIT MOUNTED IN EXPANDABLE SHELTER CONTAINER

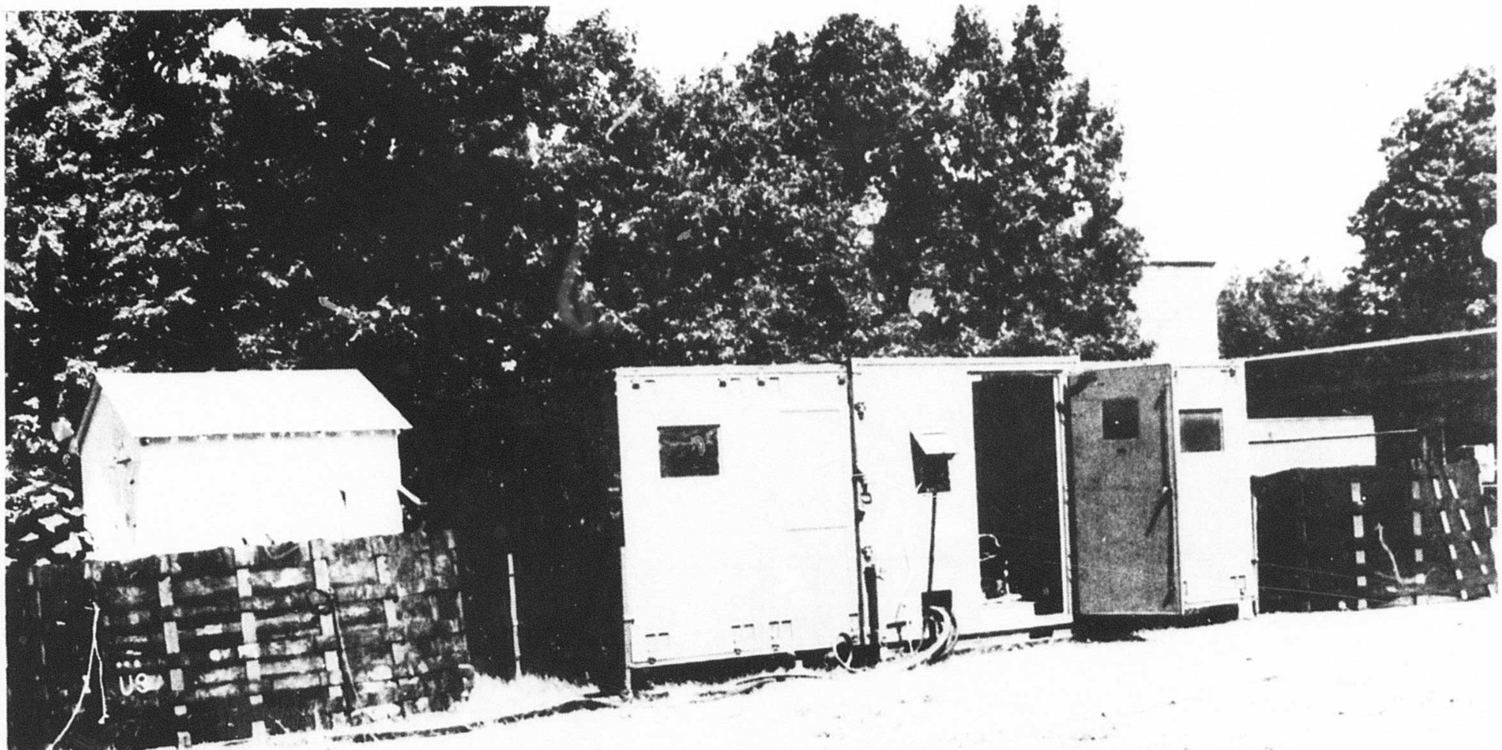

FIGURE 4 EXPANDABLE SHELTER CONTAINER WITH WASTEWATER RECLAMATION UNIT MOUNTED INSIDE

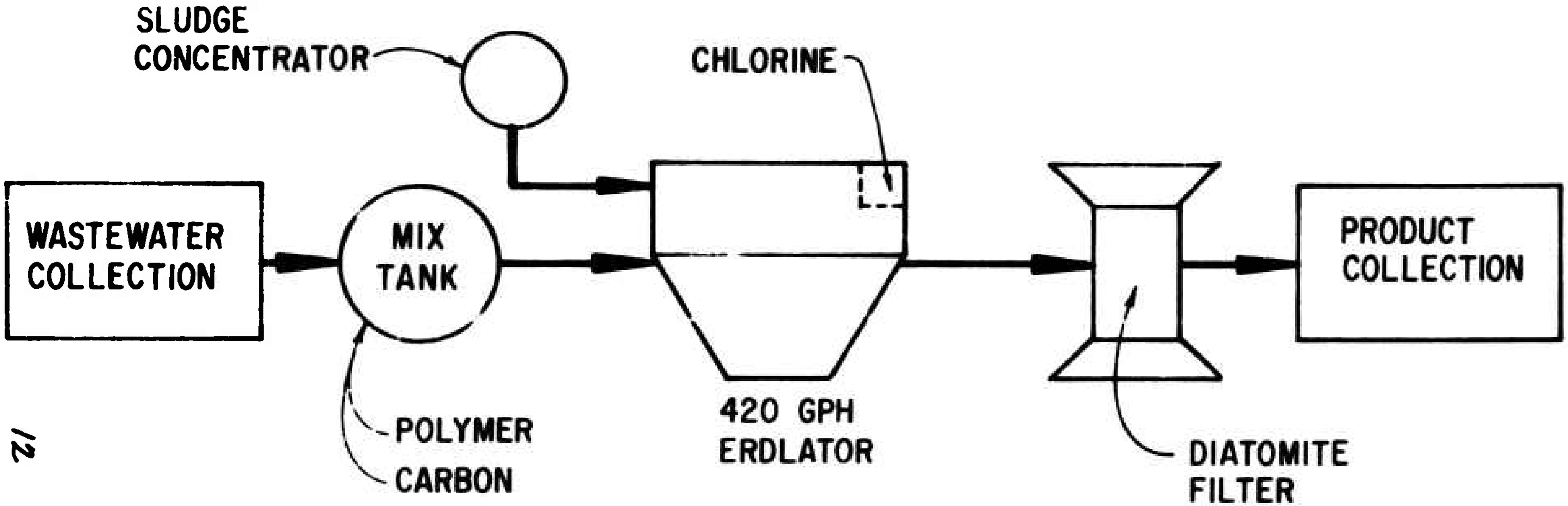

FIG. 5. FLOW DIAGRAM WASTE WATER RENOVATION UNIT

The sources of these materials are described in detail as follows:

Cold Power manufactured by Colgate-Palmolive Co., New York, New York, contains sodium sulfate, sodium silicate, alkylbenzene sulfonate, soap, ethoxylated alcohol, moisture, carboxymethylcellulose, cold water brightness, aluminum silicates, colorant and perfume.

Cascade Detergent manufactured by Procter and Gamble, Cincinnati, Ohio, contains complex sodium phosphates, chlorinated trisodium phosphate, nonionic surfactant, sodium silicate, sodium sulfate, colorant and perfume.

Clay-Powdered Volclay Bentonite SPV supplied by American Colloid Company, Skokie, Illinois, contains silica, aluminum, iron, magnesium, sodium, potassium, calcium, and others.

Ground bar soap - Military type 8520-551-0376/8520-205-3088, toilet, floating white.

Lubricating oil - Heavy duty (HD) oil, grade SAE-10, supplied by Penn Corporation, Butler, Pennsylvania.

The field system was tested on a 200 hour basis, 16 continuous hours per operating day. The performance of the system was determined by evaluating the following parameters: pH, turbidity, conductivity, phosphate, sulfate, detergents, TOC, BOD, iron, nickel, zinc, and lead. Soluble metals were determined by FWPCA methods [3] while other routine analyses were conducted as described in Standard Methods.[4]

[3] "FWPCA Methods for Chemical Analysis of Water and Wastes", U.S. Department of Interior, FWPCA Division of Water Quality Research, Cincinnati, Ohio, November 1969.

[4] "Standard Methods for the Examination of Water and Wastewater", 13th Edition, American Public Health Assoc., Inc., 1971.

Daily sampling was done by collecting grab samples of the filter effluent at 4 hour intervals and from the feed tank at 8 hour intervals. The Unit was operated from 0800 to 2400 during the weekdays. The following analyses were performed by the Sanitary Sciences Water Quality Laboratory using the procedures indicated.

(1) Turbidity. The turbidity was measured by a Hach Laboratory Turbidimeter, Model 1860 using the ten formazin turbidity unit standard supplied with the unit.

(2) Hydrogen Ion Concentration (pH). The Beckman Model 76A was used to measure pH. Fisher certified buffer solutions were used as standards.

(3) Detergents (MGAS). The Methyl green method, using a Hach direct reading colorimeter, was used for the determination of MGAS.

(4) Biochemical Oxygen Demand (BOD). BOD was determined by the technique cited in Standard Methods.[4] Seeding was not used.

(5) Conductivity. Conductivity was determined by a Beckman Model RC 16B2 Conductivity Ridge.

(6) Total Organic Carbon (TOC). The Beckman Model 915 total organic analyser was used to measure TOC.

(7) Heavy Metals. Heavy metals were measured on a Perkin-Elmer 503 Atomic Adsorption Spectrophotometer using the following techniques:

Lead, zinc, iron, and nickel. These metal concentrations were determined using technique 4.13 for soluble metals in FWPCA methods.[3] FWPCA states: "The data so obtained are significant in terms of "total" metals in the sample, with the reservation that something less than "total" is actually measured." Samples were refrigerated upon collection and usually acidified within a week.

III. DISCUSSION

The most serious operating problem encountered during the test was compaction of the sludge blanket in the upflow clarifier during shutdown. On start-up, compaction led to channeling, short circuiting, and inadequate treatment with water containing a higher degree of carbon fines than desired. This was the most significant factor in decreasing filter run time. Several methods were attempted to alleviate the problem. Injecting a pressurized jet of water into the base of the clarifier proved to be an effective technique for overcoming compaction.

Another operational problem of less importance was the clogging of the carbon feeder system. This occurred frequently and could have been of importance if the unit were left unattended for any extended period of time. Manual periodic cleaning approximately every 4 hours of the eductor orifice prevented clogging.

The two criteria used to judge effectiveness of the treatment process are quality of the product water as well as length of filter run. Length of the filter cycle is indicated in Table 3. Shutdown time between operating days 5 and 6 was 56 hours (one weekend), leading to bed compaction as discussed above. Once the problem was overcome during that week it did not recur over the following weekend (between operating days 10 and 11). During operating days 6, 7, 8, and 9 feed water quality had no discernible effect on the filter cycle due to the compaction problem.

Figure 6 shows that the total organic carbon content of the feed and product water versus operating time. The feed water TOC is in the range of 45 to 65 mg/l over the first five operating days. When recycle began, however, the total organic carbon value for the feed water began to rise and was 125 mg/l at the 200 hour operating time. It is obvious that the product water quality as measured by TOC was not significantly effected by the rise in TOC of the feed water. Although there is no definite explanation for the increase in the feed water TOC, it is felt that it was due to a net accumulation of laundry water contaminants in the feed tank. This phenomenon will be further investigated during future testing of this unit. TOC removal for this test was generally greater than 90%.

The BOD values shown are not as useful as the TOC values in evaluating this process because the synthetic laundry wastewaters did not contain truly representative flora for accurate BOD determination. The feed and product water samples were not seeded because it was felt that the TOC values obtained would be sufficient to evaluate the effectiveness of the process. BOD removals were excellent, averaging approximately 90%. Figure 7 shows the biochemical oxygen demand versus operating time. After recycle began (day 6) the fluctuations in BOD values are greater, and the feed water BOD values are rising. The BOD of the product water was not significantly effected by the perceptible rise in the BOD of the feed water. Although there is no definite explanation for the incease in the feed water BOD, it is felt that it was due to a net accumulation of laundry water contaminants in the feed tank. This phenomenon will be further investigated during future testing of this unit.

TABLE 3

DAILY OPERATING DATA LAUNDRY OPERATIONS

DOSAGES		AVE. FLOW RATE		FILTER CYCLE		
Carbon mg/1	Polymer mg/1	Influent Gal/Hr	Effluent Gal/Hr	Filter Day-Run No.	Duration Hr:Min	Terminal Pressure PSI
580	28	405	377	1-1	11:30	43
487	27	410	400	2-1	15:45	12
380	27	417	402	3-1	10:22	43
				3-2	5:15	11
400	23	408	403	4-1	15:15	27
525	22	406	404	5-1	15:20	12
360	21	423	368	6-1	1:35	46
				6-2	1:00	44
				6-3	1:55	46
				6-4	2:00	46
				6-5	0:35	46
				6-6	1:00	45
				6-7	6:00	46
400	23	385	335	7-1	1:00	46
				7-2	2:25	44
				7-3	3:09	45
				7-4	1:08	40
				7-5	1:30	42
614	23			7-6	1:30	43
				7-7	2:15	7

TABLE 3 Cont'd.

DAILY OPERATING DATA LAUNDRY OPERATIONS

DOSAGES		AVE. FLOW RATE		FILTER CYCLE		
Carbon mg/1	Polymer mg/1	Influent Gal/Hr	Effluent Gal/Hr	Filter Day-Run No.	Duration Hr:min	Terminal Pressure PSI
483	27	386	363	8-1	1:10	44
				8-2	1:15	44
				8-3	1:35	44
				8-4	2:30	44
				8-5	3:06	43
550	27	400	380	8-6	5:43	4
				9-1	3:00	47
				9-2	3:00	10 (Sludge conc.)
				9-3	8:25	4
535	27	367	357	10-1	15:15	20
555	26	367	346	11-1	15:45	39
285	24	361	347	12-1	9:19	43
329	24	369	336	12-2	6:15	5
				13-1	8:00	16

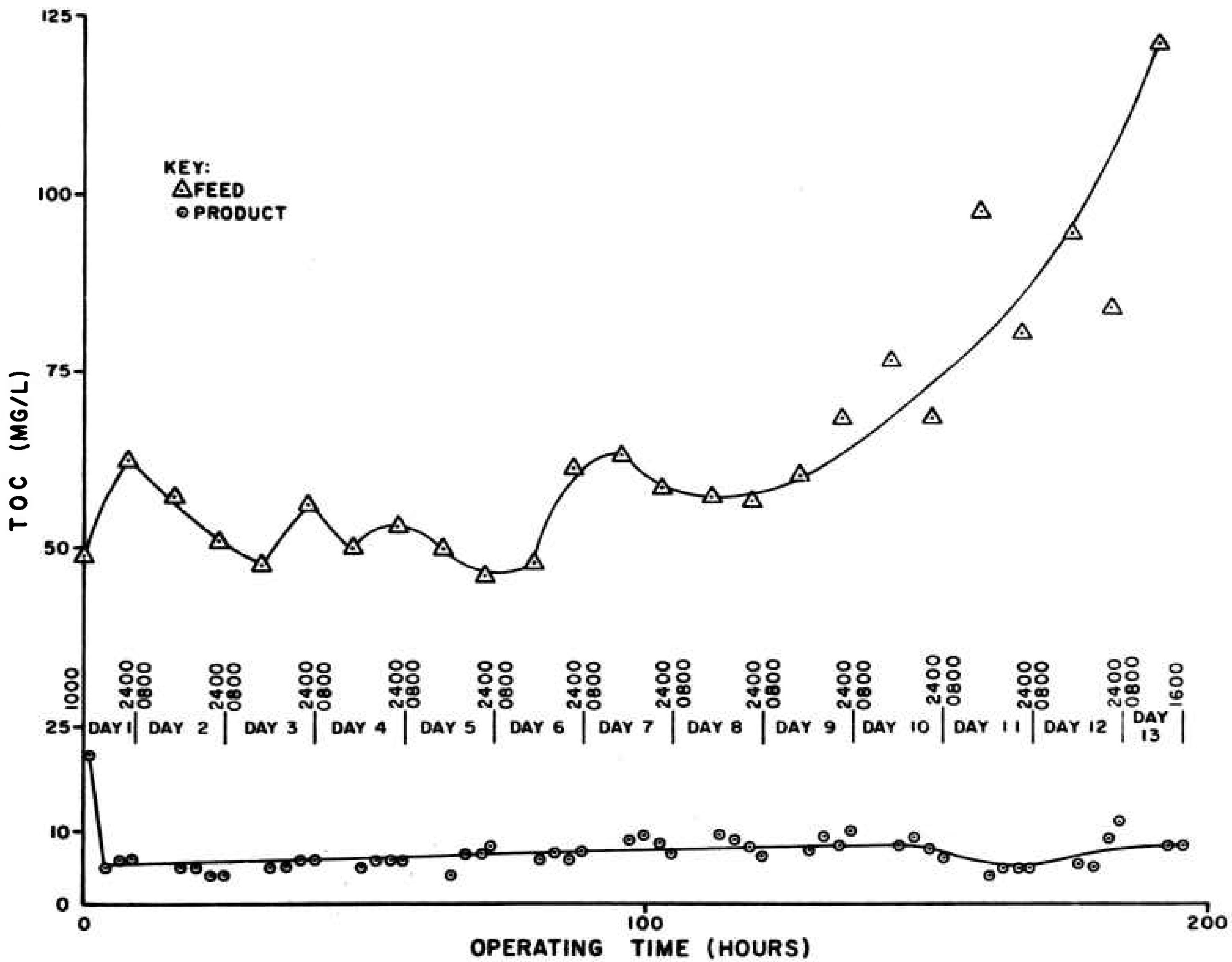

FIGURE 6

TOTAL ORGANIC CARBON VERSUS TIME
PERIOD: 22 JULY - 7 AUGUST
SYNTHETIC LAUNDRY WASTEWATER STUDY

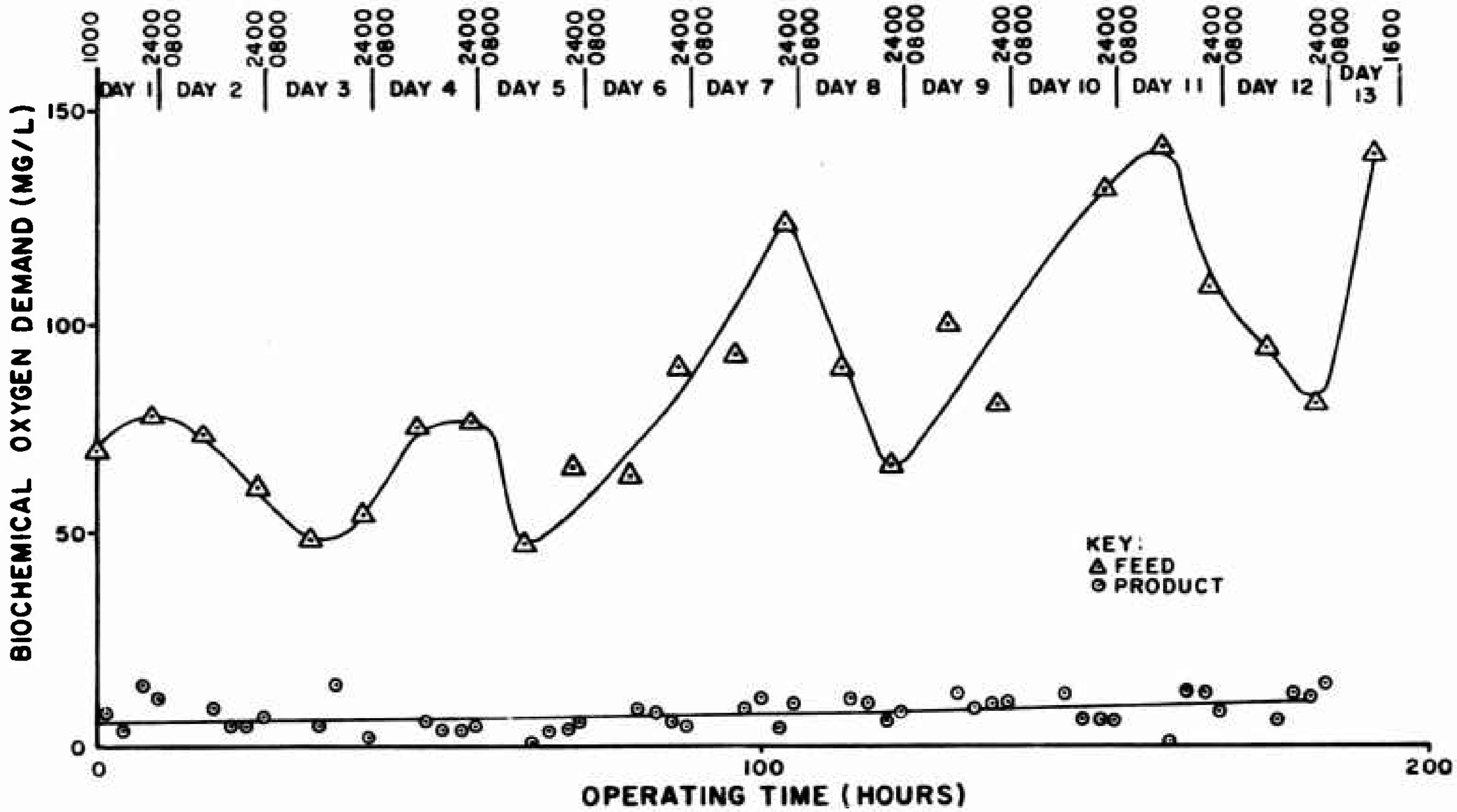

FIGURE 7 BIOCHEMICAL OXYGEN DEMAND VERSUS TIME
PERIOD: 22 JULY - 7 AUGUST
SYNTHETIC LAUNDRY WASTEWATER STUDY

Table 4 gives the average and range of feed product for twelve water quality parameters, including TOC and BOD previously mentioned. Turbidity and detergent reductions were excellent, while conductivity, phosphate, and sulfate levels accumulated as a function of time after recycle began. Of the heavy metals, iron removal is greatest. It is difficult to draw any definite conclusions, however, particularly in regard to nickel, zinc, and lead removals when instrument sensitivity and analytical techniques are taken into account.

Table 5 is a comparison of several water quality parameters from the synthetic water in this report. The feedwater quality in each case is comparable in respect to pH, conductivity, and heavy metals except for zinc. The treated water is also similar in these values. Power laundry feedwater is higher in TOC, BOD, and turbidity, but the percentage removals of TOC and BOD are comparable for both waters. Detergents averaged much higher in the synthetic cold water formula than in the power laundry wastewater. However, detergent removals were good in each case. Overall, it can be seen that the synthetic water was a good medium for testing the Wastewater Reclamation Unit.

Less than 1/2% of the influent water was wasted as sludge. The water was recycled 13 times, but make-up water constituted 5% of the total. A volume of 77,940 gallons of wastewater was treated using 283.5 pounds of Darco G-60 and 16.3 pounds of Cat-floc polymer. Since the laboratory test results indicated equivalent performances of Darco G-60 and Hydrodarco C carbons, the chemical cost is calculated on the basis of the cost of the cheaper Hydrodarco C. Assuming costs of $0.25 per pound for carbon and $0.50 per pound for polymer, the chemical costs are $1.01 per thousand gallons of feedwater or $1.07 per thousand gallons of product.

Based on a production buy of 10 to 25 units, the estimated cost of the wastewater reclamacion unit is $30,500 to $28,500, respectively.

TABLE 4

SUMMARY OF WASTEWATER &
PRODUCT WATER CHARACTERISTICS

Characteristic	FEED		PRODUCT	
	Average	Range	Average	Range
pH, units	9.5	8.0-9.9	9.2	814-10.0
Turbidity, JTU	37.4	17-75	0.39	0.08-1.6
Conductivity, micromhos/cm	1283	365-3550	1211	408-3360
Phosphate	707	155-2800	670	112-2000
Sulfate	230	65-700	254	84-700
Detergents	26.2	12.3-40	1.1	0.1-2.7
TOC	64.7	46.5-120.5	7.0	4.0-11.5
BOD	82.4	14-141	7.9	1-17
Iron	0.47	0.23-1.44	0.05	0.00-0.21
Nickel	0.04	0.00-0.10	0.04	0.00-0.36
Zinc	0.064	.035-.161	0.017	.001-.032
Lead	0.127	0.02-0.48	0.073	0.00-0.19

NOTE: All units are mg/1 except as noted.

TABLE 5

COMPARISON OF AVERAGE WATER QUALITY PARAMETERS

	Power Laundry Wastewater[1]		Synthetic Cold Water Formula*	
	Feed	Product	Feed	Product
Turbidity (JTU)	106	2.04	37	0.39
pH, units	10.3	10.1	9.5	9.2
Conductivity	1204	1177	1283	1211
Detergents	3	0.34	26	1.1
TOC	183	20	65	7.0
BOD, 5-Day	152	14	82	7.9
Lead	0.16	0.05	0.127	0.07
Zinc	0.41	0.27	0.064	0.017
Iron	0.71	0.09	0.47	0.05
Nickel	0.05	0.02	0.04	0.04

Units in mg/l when not shown.

*This report

[1] Lent, D. S., "Study on Power Laundry Wastewater Treatment," November 1974, USAMERDC Technical Report No. 2118.

IV. CONCLUSIONS

1. A carbon-polymer treatment process can effectively renovate synthetic cold-water formula laundry water for reuse.

2. Several parameters which indicate the quality of the renovated water are dependent on the number of times direct recycle is employed. Conductivity, phosphate, and sulphate accumulations occur in feed and product water as a function of the number of times recycled, but turbidity, detergent level, TOC, and BOD build-up in the product do not occur.