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Exploration Camp Wastewater Characterization and Treatment Plant Assessment

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Report EPS 4-WP-81-1

Water Pollution Control Directorate
February 1981

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EXPLORATION CAMP WASTEWATER CHARACTERIZATION AND TREATMENT PLANT ASSESEMENT

by

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for the

Environmental Protection Service
ENVIRONMENT CANADA

and

HYDRO QUEBEC

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ABSTRACT

Wastewater generated at the exploration camp operated by Hydro Quebec at Poste de la Baleine was characterized, and the performances of an activated sludge process (Oxyvor) and a rotating biological contactor (RBC) treating the wastewater from the exploration camp were assessed.

Water consumption and wastewater flow were measured and their fluctuations defined. Flow-proportioned samples were analyzed for total BOD_5, filtered BOD_5, total COD, filtered COD, filtered TKN, filtered orthophosphates, alkalinity, pH, oil and grease, total suspended solids and volatile suspended solids. Liquid temperature and ambient air temperature were recorded at the time of sample collection.

The two treatment units were operated in parallel during a three-month period. Results of the study indicated that the RBC could withstand diurnal flow variations without detrimental effects to the biological slimes; a slight deterioration of effluent quality was observed. This almost maintenance-free treatment unit continuously produced a stable effluent of acceptable quality.

The performance of the Oxyvor system, on the other hand, was affected by the frequent wash-out of mixed liquor suspended solids. There were no process control variables that could be manipulated to improve the process performance. This resulted in a very erratic and unacceptable effluent quality for the duration of the study.

RÉSUMÉ

Les eaux usées du chantier d'exploration de l'Hydro-québec au Poste-de-la-Baleine ont été caractérisées et leur traitement par boues activées (Oxyvor) et par disques biologiques a été évalué.

On a mesuré la consommation d'eau et le débit des eaux usées et défini leurs fluctuations. A partir d'échantillons de volume proportionnel au débit, on a déterminé la DBO_5 et la DCO totales et filtrables, le $N_{K.T.}$ et les orthophosphates filtrables, l'alcalinité, le pH, la teneur en huiles et en graisses et en MES totales et volatiles. On avait pris note de la température de l'eau et de l'air ambiant au moment des prélèvements.

Pendant trois mois, les deux dispositifs de traitement des eaux ont fonctionné en parallèle. On a observé que la pellicule biologique des disques peut supporter les variations diurnes du débit; on a noté une faible baisse de la qualité de l'effluent. Ce dispositif qui ne demande presque pas d'entretien n'a cessé de produire un effluent de qualité acceptable.

Quant au dispositif Oxyvor, il a souffert des lâchures fréquentes de MES de la liqueur mixte et il était impossible d'agir sur quelque facteur pour améliorer son efficacité. La qualité de l'effluent a donc été, tout au cours de l'étude, très fluctuante et inacceptable.

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SUMMARY AND RECOMMENDATIONS

Wastewater generated at the exploration camp at Poste de la Baleine was characterized from September to December, 1979, and the following results obtained:

1. The average water demand was 250 L/d per person from September 7 to October 9 and 445 L/d per person from October 10 to December 8. The increased water demand was attributed to continuous bleeding of tap water into the collection system to prevent freezing.
2. The volume of wastewater generated was measured using a V-notch weir and found to be 93% of the water demand measured by the water meters. The maximum error was estimated to be $\pm 10\%$.
3. Analyses of flow-proportioned samples gave the following average concentrations: 230 mg/L BOD_5, 102 mg/L TSS, and 41 mg/L fitered TKN. Although BOD_5 concentrations were not measured prior to October 10, COD measurements verified that the increased water demand resulted in reduced organic concentrations. Average TSS concentrations actually increased with the increased water demand; this trend could not be explained.
4. The average organic loading during the period November 4 to December 5 was 84 g BOD_5/d per person.
5. Approximately 10 kg of grease was generated every week at the camp. The grease trap, made of two 205-L drums, removed 65% of the oil and grease resulting in an average oil and grease concentration of 28 mg/L in the wastewater.

Because Poste de la Baleine is a base camp with office facilities, its wastewater characteristics might not be representative of other exploration camps.

An Oxyvor activated sludge process and a rotating biological contactor (RBC) were operated in parallel at Poste de la Baleine to assess the feasibility of using the processes in the treatment of exploration camp wastewater.

The RBC consistently produced a stable effluent of acceptable quality. Average concentrations of 34 mg/L BOD_5 and 27 mg/L TSS were obtained when the system was operated with flow equalization. When the system was operated without flow equalization, the average TSS concentration was 37 mg/L; BOD_5 measurements are not available for this period of operation. The process withstood a varying and intermittent flow without sloughing of biological slime from supporting discs. It also operated at a low liquid temperature of 4°C during one week without the effluent quality deteriorating. Future designs, however, should provide facilities for sludge withdrawal, the frequency of which was impossible to establish during this study.

Results from this study indicated that the effectiveness of the clarification zone of the Oxyvor system was affected by the degree of agitation in the aeration basin. After a period of mixed liquor agitation, the level of suspended solids in the effluent reached a maximum value. At the end of the period when the aeration basin was not mixed, the effluent suspended solids decreased to a minimum value. The variation in effluent quality was attributed to turbulence within the settling zone, which was directly related to the degree of agitation within the aeration zone. Other than adjusting the time the aerator was on, there were no process variables that could be manipulated to bring the system under control and reduce solids loss in the effluent. Reduction of aeration to improve solid-liquid separation would limit the oxygen supply. Increasing the aeration time to provide an adequate oxygen supply creates conditions inhibiting solid-liquid separation. During the three-month operating period, there were only 12 days in which the effluent quality approached an acceptable level. With flow equalization, BOD_5 and TSS concentrations for the 12 days averaged 32 and 47 mg/L, respectively.

Since the Oxyvor system has no control variables which can be manipulated to provide process control, it is recommended that serious consideration be given to modifying the design of the unit. Removal of the integral clarifier, and provision of external clarification and positive displacement sludge return pumps is one alternative that merits examination.

1 INTRODUCTION

The development of hydro-electric power in northern Quebec has resulted in the establishment of small temporary communities for exploration and construction projects. Hydro Quebec operates many of these exploration and construction camps in the James Bay and Hudson Bay regions. Although all camps are equipped with wastewater treatment systems, the characteristics of the wastewater and the quality of treated effluents have never been completely determined.

A septic tank followed by a tile bed is the most common system for treating the wastewater from these small communities. However, at some remote locations where the ground is rocky, installation of a septic tank and building of a tile bed are too difficult or at times impossible. In this situation the utilization of a small package treatment system should represent an acceptable solution to the problem. The chosen system, however, must perform reasonably well at these camps in the middle north under conditions of cold weather, high variations in flow, and the usual lack of qualified operating personnel. Ambient air temperatures in this area may be -40°C for extended periods of time.

Hydro Quebec purchased two small package treatment systems, a rotating biological contactor (RBC) and an activated sludge process (Oxyvor), to investigate the feasibility of using mechanical processes in the treatment of exploration camp wastewater. The systems were installed at the camp at Poste de la Baleine in August, 1979. An experimental program was conducted from September to December, 1979. The study was undertaken as a joint project by Hydro Quebec and the Environmental Protection Service (EPS) of Environment Canada. The objectives were:

- to characterize the wastewater generated at the exploration camp operated by Hydro Quebec at Poste de la Baleine;
- to assess the performances of the Oxyvor and the RBC treating the wastewater from the exploration camp located at Poste de la Baleine; and
- to determine the difficulties in installing and operating treatment systems at exploration camps.

2 WASTE CHARACTERIZATION PROGRAM

2.1 Description of the Exploration Camp

Poste de la Baleine is in northern Quebec, overlooking Hudson Bay at the mouth of the Great Whale River. The community is approximately 1000 km north of Montreal. The Hydro Quebec camp located at Poste de la Baleine is an exploration camp and a base camp for the Grande Baleine project. It serves as a transit camp for workers at smaller exploration camps such as Denys, GB1 and GB2. Its population varies from 40 to 100 persons in the summer to 40 or less in the winter.

The layout of the camp in August, 1979, is shown in Figure 1. The terrain and subsurface is mainly sand. Two wells with pumping equipment provide tap water for the camp. Laundry and toilet facilities are found in three buildings: the kitchen, the staff house and the lavatory. Sink and toilet facilities are available only in the office, the foreman's house, and the nursing station.

In August, 1979, the wastewater treatment system consisted of two septic tanks in series receiving wastewater from three sewer lines, as shown in Figure 1. The septic tank system was originally selected and installed because the subsurface soil is sand. The septic tanks were made of wood and were approximately five years old. Because the tanks had deteriorated and wastewater was leaking from both vessels, the septic tanks were not used in the new treatment system. The sewers are 100-mm diameter pipes made of polyvinyl chloride (PVC). The insulated pipes are buried at a depth of approximately one meter.

In September, 1979, a grease trap made of two 205-L drums was connected to the kitchen sewer line. The three sewer lines were joined to give only one discharge point for sampling purposes. They were also lifted up to allow gravity feeding of wastewater into treatment processes. Wooden cases filled with glass wool were used to insulate the sewer line. The Oxyvor and the RBC were installed and operated in parallel. A newly built tile bed received the effluents from both processes. The new treatment installation (Figure 2) is described in detail in the next section.

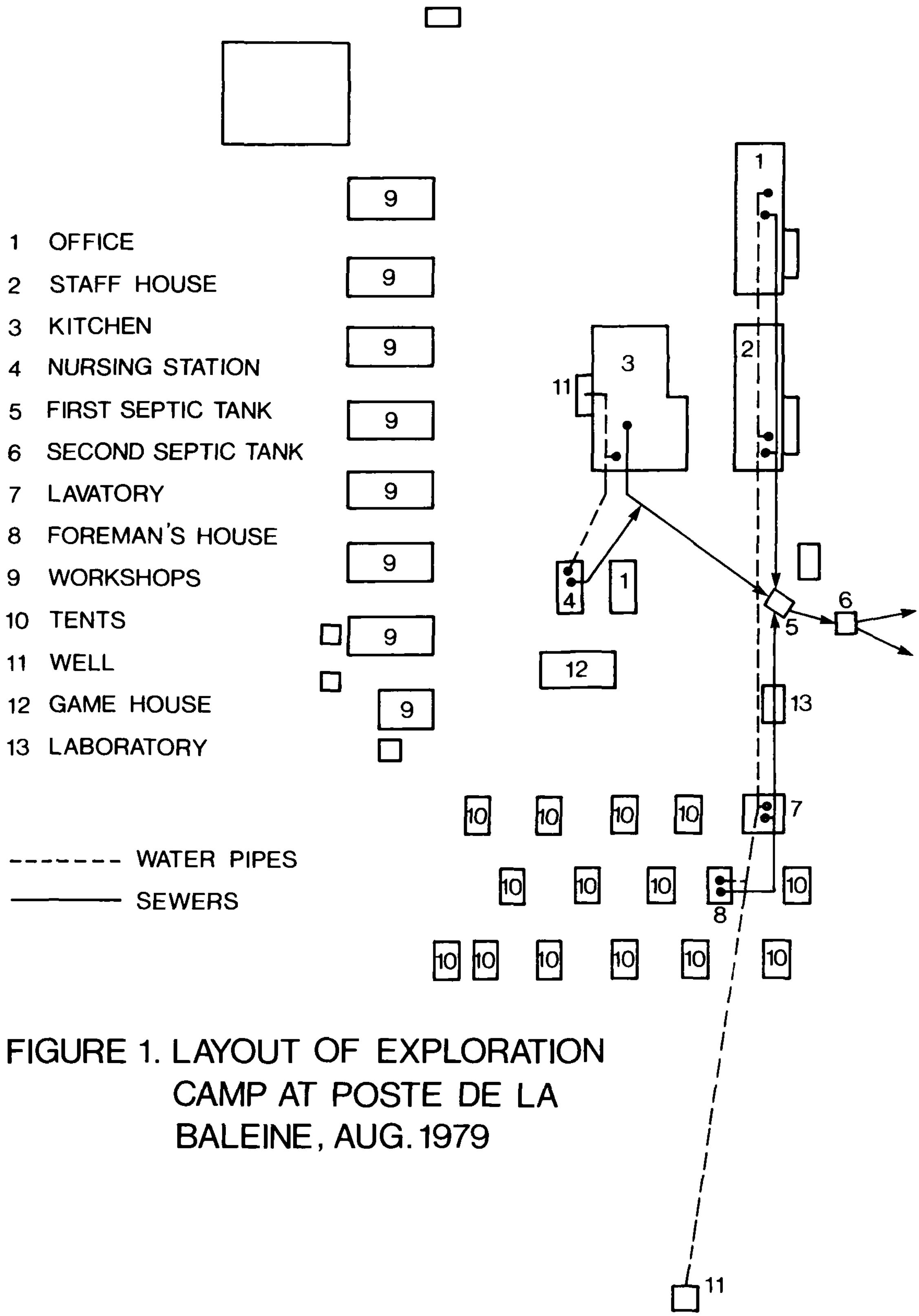

FIGURE 1. LAYOUT OF EXPLORATION CAMP AT POSTE DE LA BALEINE, AUG. 1979

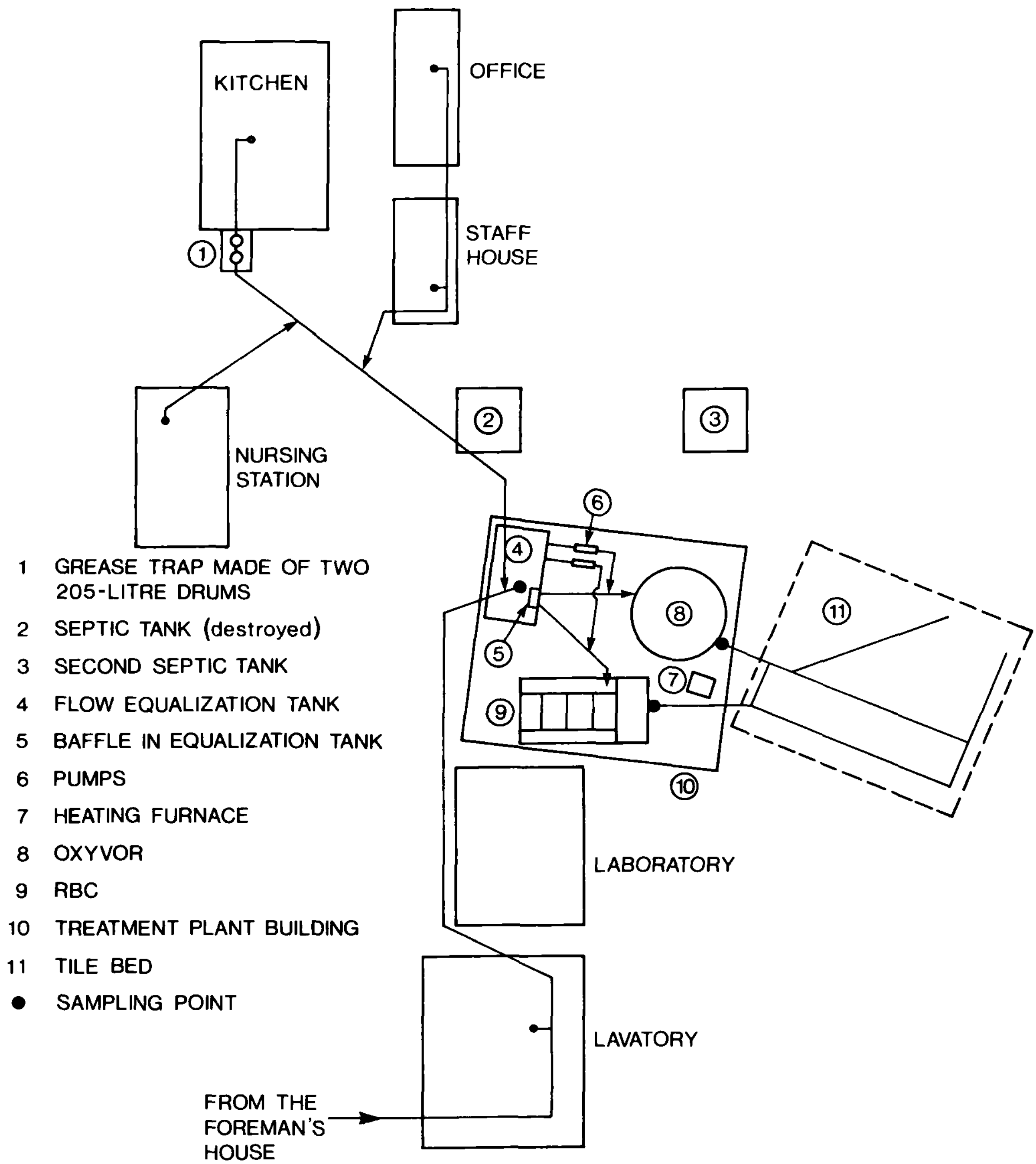

FIGURE 2. LAYOUT OF SEWERAGE SYSTEM AT POSTE DE LA BALEINE, OCT. 15, 1979

2.2 Description of Wastewater Characterization Program

At the Poste de la Baleine camp, wastewater samples and total water demand measurements were collected daily over the period September to December, 1979.

Wastewater flow measurements using a V-notch weir failed to give accurate data over extended periods because floating solids accumulated at the weir. By providing continuous surveillance, a number of V-notch weir measurements were made and are presented herein to show the true variation of wastewater flow (Figure 3). Total water demand was measured by flow meters at the two wells. As all (or practically all) consumed water went into the sewage system, water demand measurements should give a good approximation of wastewater flow. Every month, hourly water demand was recorded for three or four days. The number of persons in the camp was recorded every day.

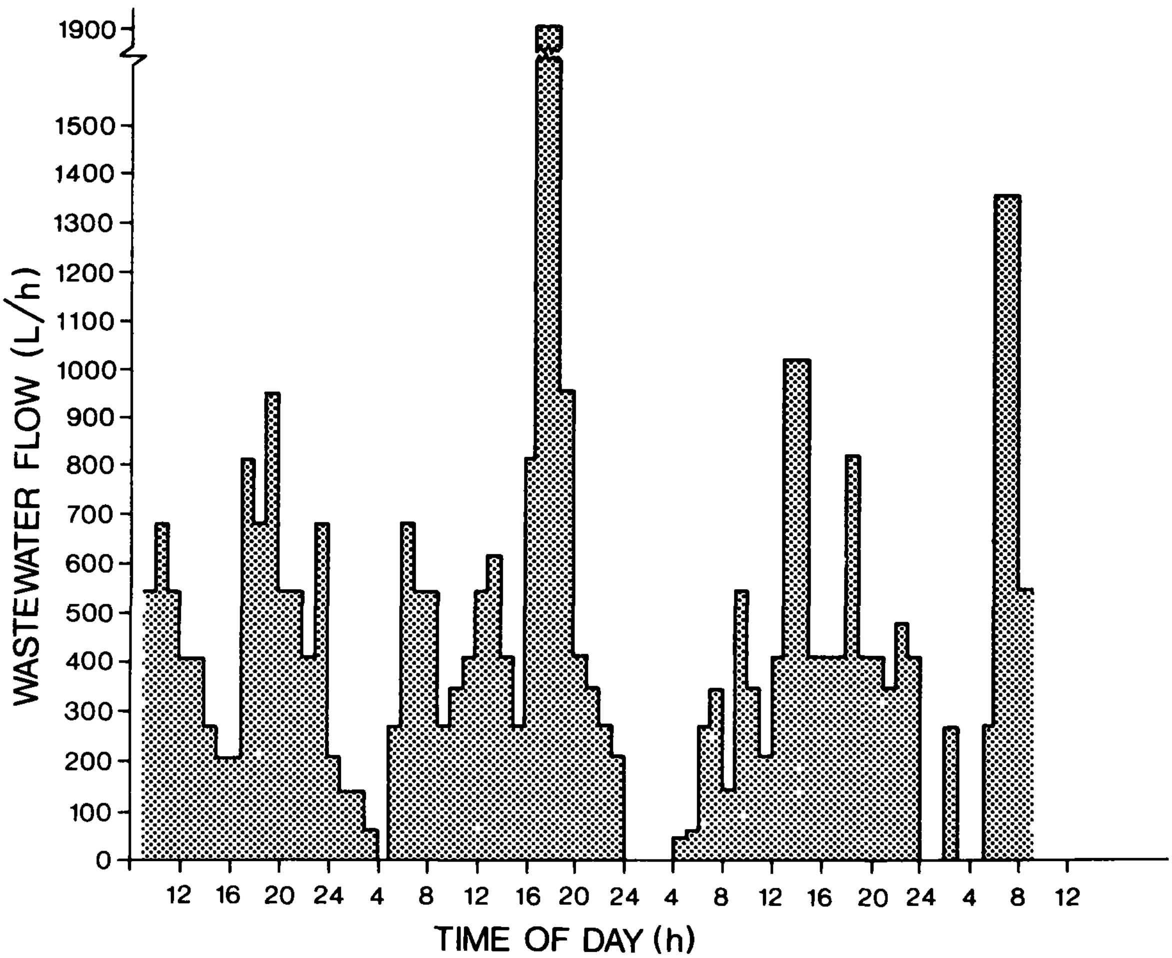

FIGURE 3. WASTEWATER FLOW MEASURED BY WEIR

An ISCO automatic hour-by-hour, 24-h sampler was used for daily collection of untreated wastewater samples. Figure 2 indicates the sampling point. The composite samples were flow-proportioned by using fixed flow ratios established for the periods 11:00 pm to 6:00 am, 6:00 am to 10:00 am, 10:00 am to 2:00 pm, 2:00 pm to 4:00 pm, and 4:00 pm to 11:00 pm. These ratios were multiplied by the average hourly flow rate measured by the flow meters for the corresponding sampling day to obtain the estimated flow rates shown in Figure 4. The flow-proportioned composite samples were analyzed for total five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and chemical oxygen demand (COD) at the laboratory at Poste de la Baleine. Composite samples were also sent to the Environment Canada laboratory at Longueil, Quebec, for oil and grease, total Kjeldahl nitrogen (TKN) and BOD_5 analyses. Five samples were analyzed completely by Environment Canada for total BOD_5, filtered BOD_5, total COD, filtered COD, filtered TKN, filtered orthophosphate, alkalinity, pH, oil and grease, total suspended solids, and volatile suspended solids. All chemical analyses followed the procedures of Standard Methods (1976).

2.3 Data Analysis

Daily water demand and the number of persons in the camp are presented in Figure 5. Two levels of water demand clearly differentiate the periods September 7 to October 9, 1979 and October 10 to December 8, 1979. By October 10, 1979, the air temperature had dropped to the point that the wastewater was freezing in the insulated pipes. For the remainder of the study period, tap water was allowed to leak constantly in the staff house to prevent freezing in the sewer line. During this second period, the average number of persons in the camp dropped to 44 from an average of 60 in the initial period. Because of the bleeding of water and the reduced camp population, the average water demand per person per day almost doubled. Figure 6 shows that one person used about 250 L/d during the initial period and 445 L/d during the low temperature period. Although Figure 6 indicates that water demand was much more variable in the second period, the peak to mean ratio was about the same (1.4:1.0) throughout the study period. Figures 3, 4 and 7 present hourly variations of water demand and wastewater flow. From these figures, similar trends

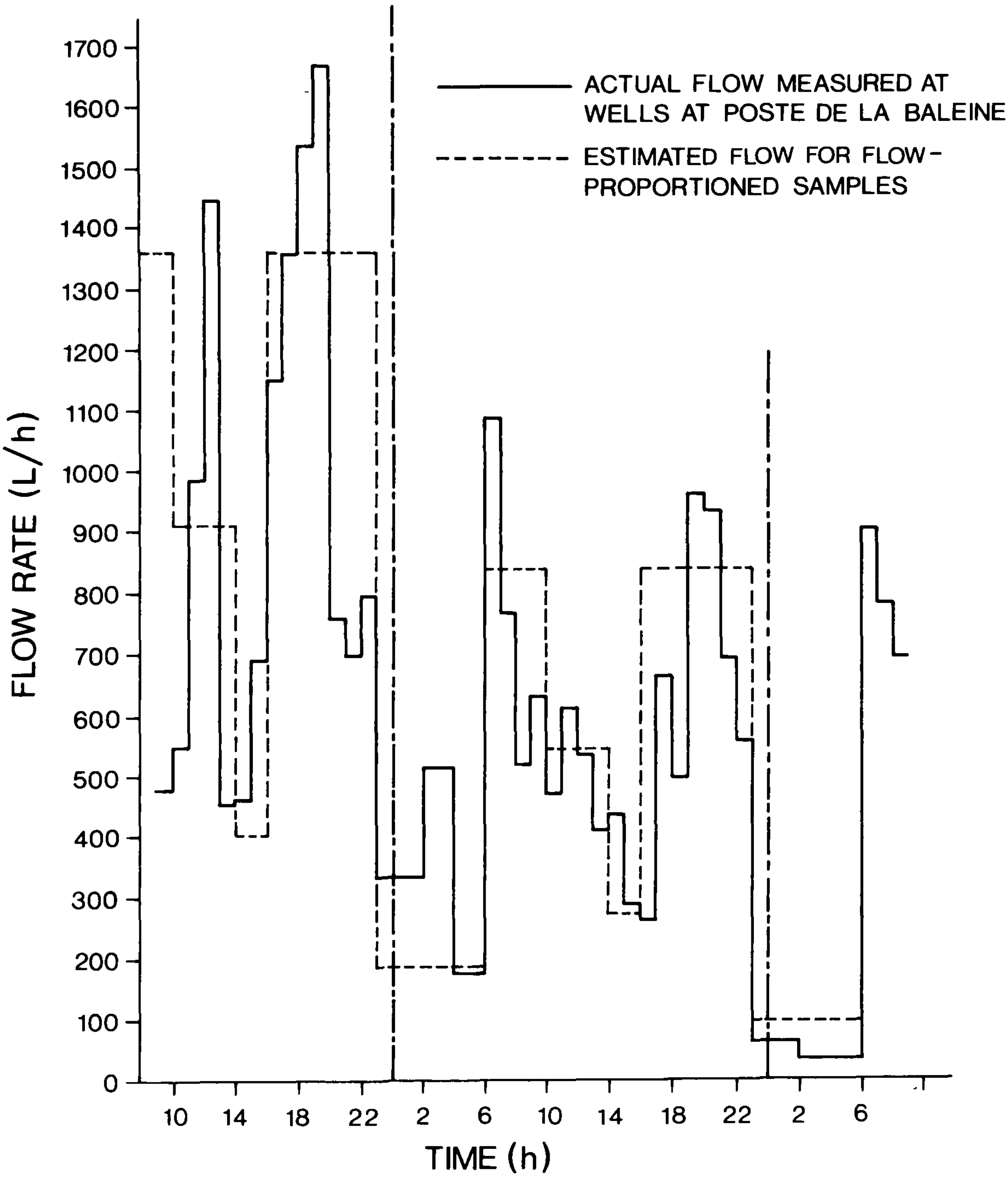

FIGURE 4. TYPICAL FLOW RATE USED FOR FLOW-PROPORTIONED SAMPLES

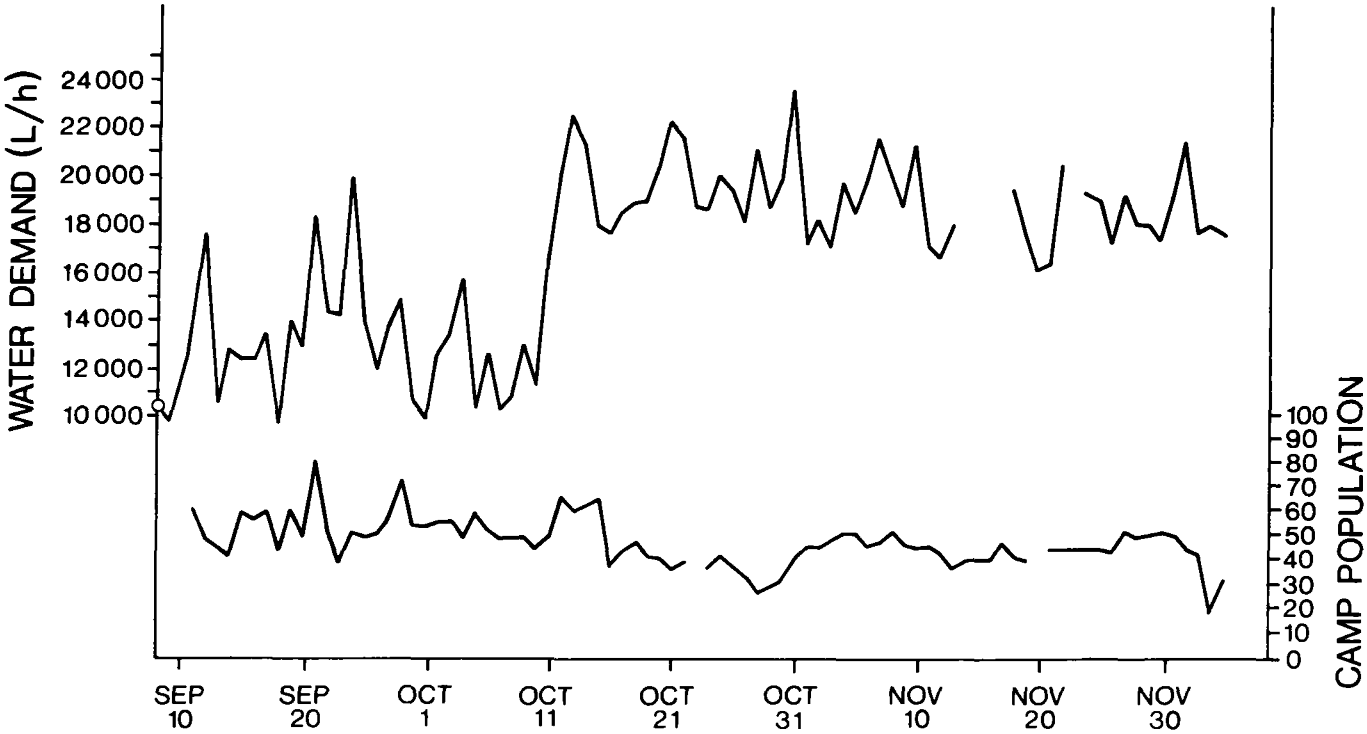

FIGURE 5. DAILY WATER DEMAND AND CAMP POPULATION

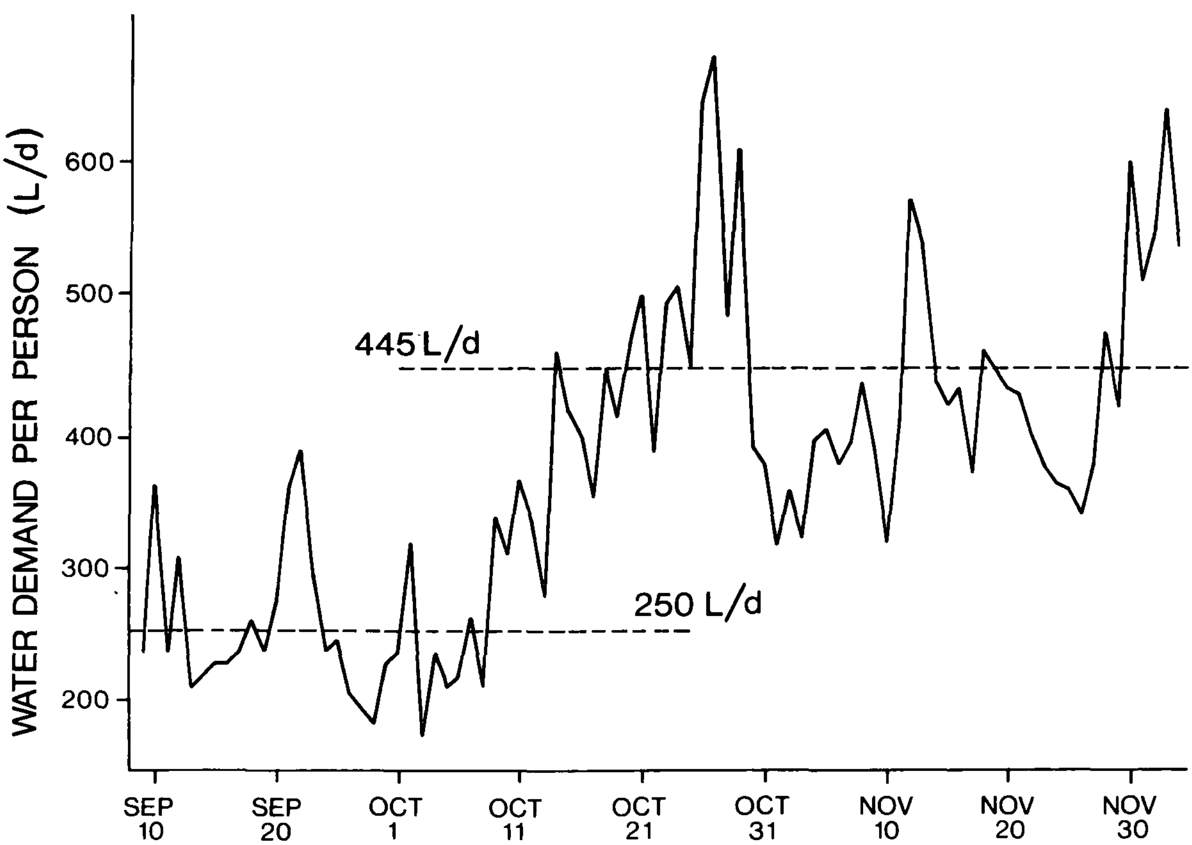

FIGURE 6. DAILY WATER DEMAND PER PERSON

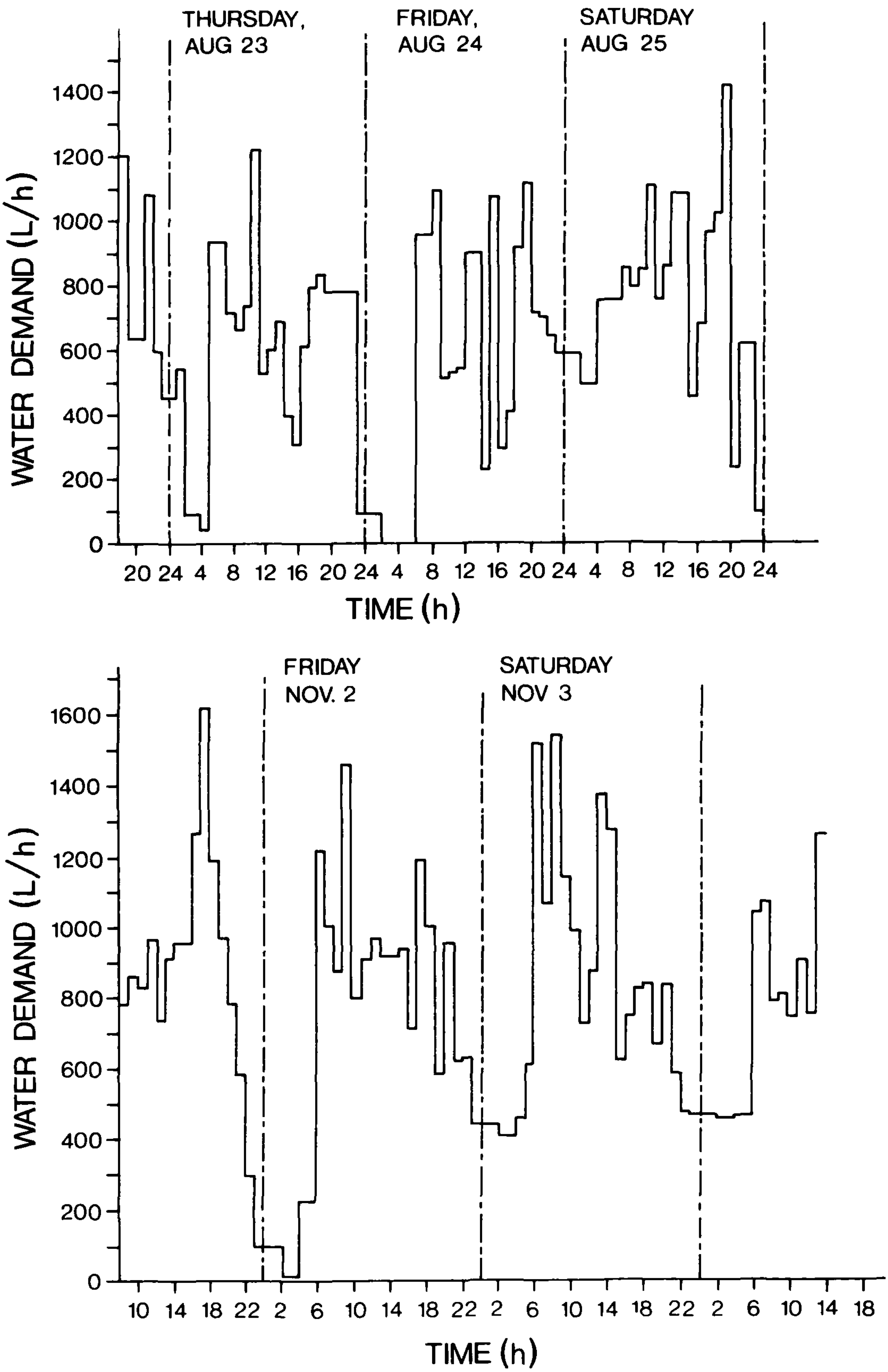

FIGURE 7. HOURLY WATER DEMAND MEASURED AT WELLS

between water demand and wastewater flow can be observed. Diurnal flow does not vary as much as expected. A typical diurnal flow can be represented by a peak to mean to minimum ratio of 2.2:1.0:0.2. Flows increased sharply at breakfast time (6:00 am), decreased during the morning to a low period between 2:00 pm and 4:00 pm, and then increased and remained high until 11:00 pm. Practically no flow was observed at night (11:00 pm to 5:00 am) except on weekend nights or during the low-temperature period.

During the period when pumps fed the treatment processes, daily water demand was correlated with wastewater generated each day. Wastewater volume represented, on average, 93% of the consumed water. The flow meter at the well can, therefore, be used to measure wastewater flows in exploration camps where potable water and wastewater are in a closed loop system. The maximum error is estimated to be $\pm$10%.

A summary of physical, chemical, and biological characteristics, and concentrations of the camp wastewater is presented in Table 1. Values were obtained by averaging all representative data presented in Table A1 of the Appendix. Figures 8, 9 and 10 show the distributions of different variables in the period from September 4 to October 9, 1979 (TSS, COD) and in the period from October 10 to December 5, 1979 (TSS, BOD_5, COD). TSS data do not show any effect from the flow increase in the low-temperature period. COD concentrations, however, decreased from an average of 615 to 392 mg/L (Table 1).

Daily organic loadings were calculated using wastewater flows estimated from the daily water demand. The BOD_5 loadings for the period from November 4 to December 5, 1979 were 84 g/d per person.

Grease was removed from the grease trap three times during the experimental period. The average weight of grease collected was 6.3 kg/week. This represents 65% of the total weight of grease generated at the camp. The remaining quantity was discharged in the wastewater with an average oil and grease concentration of 28 mg/L.

TABLE 1. POST DE LA BALEINE RAW WASTEWATER CHARACTERISTICS

	September 7 to October 9			October 10 to December 3		
	Average	Number of Measurements	Standard Deviation	Average	Number of Measurements	Standard Deviation
Flow Rate (L/d per person)	250	29	54	445	58	100
Total BOD_5 (mg/L)	-	-	-	230	35	103
Filtered BOD_5 (mg/L)	-	-	-	130	12	47
Total COD (mg/L)	615	13	124	392	18	110
Filtered COD (mg/L)	473	5	96	276	7	42
Filtered TKN (mg/L)	-	-	-	41	5	14
Filtered PO_4 (mg/L)	15	2	3.5	16	4	8
Alkalinity (mg/L $CaCO_3$)	165	2	7	139	3	27
Total Suspended Solids (mg/L)	99	33	31	104	52	50
Volatile Suspended Solids (mg/L)	85	31	28	87	52	45
Oil and Grease (mg/L)	-	-	-	28	27	9
pH	7	33	-	7.7	29	0.5
Liquid Temperature (°C)	16	33	4	12	55	4
Ambient Air Temperature* (°C)	6	33	2	4	58	4
Organic Loadings (g BOD_5/d per person)	-	-	-	84	28	34

* Temperature of ambient air in the wastewater treatment building.

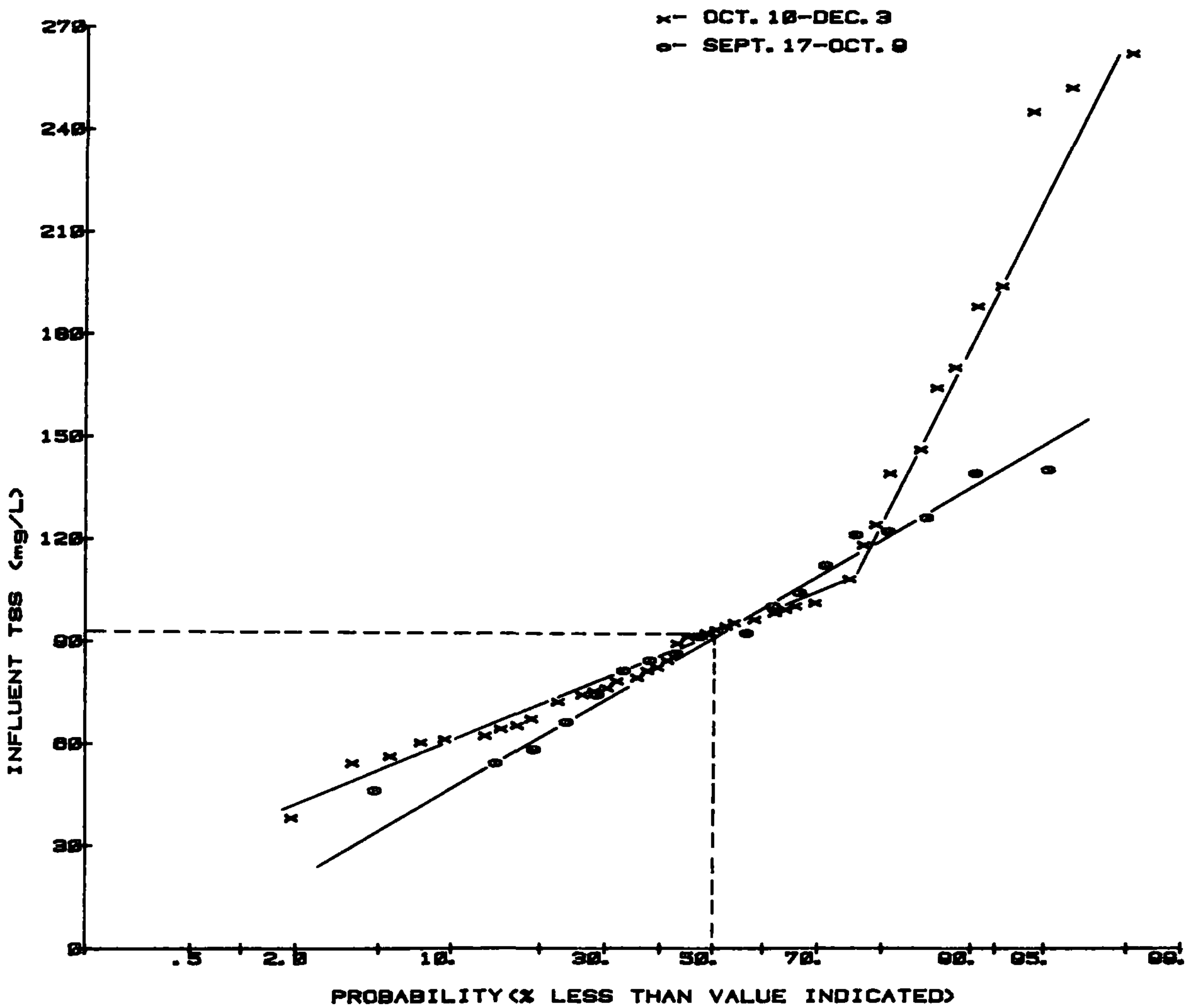

FIGURE 8. INFLUENT SUSPENDED SOLIDS CONCENTRATION

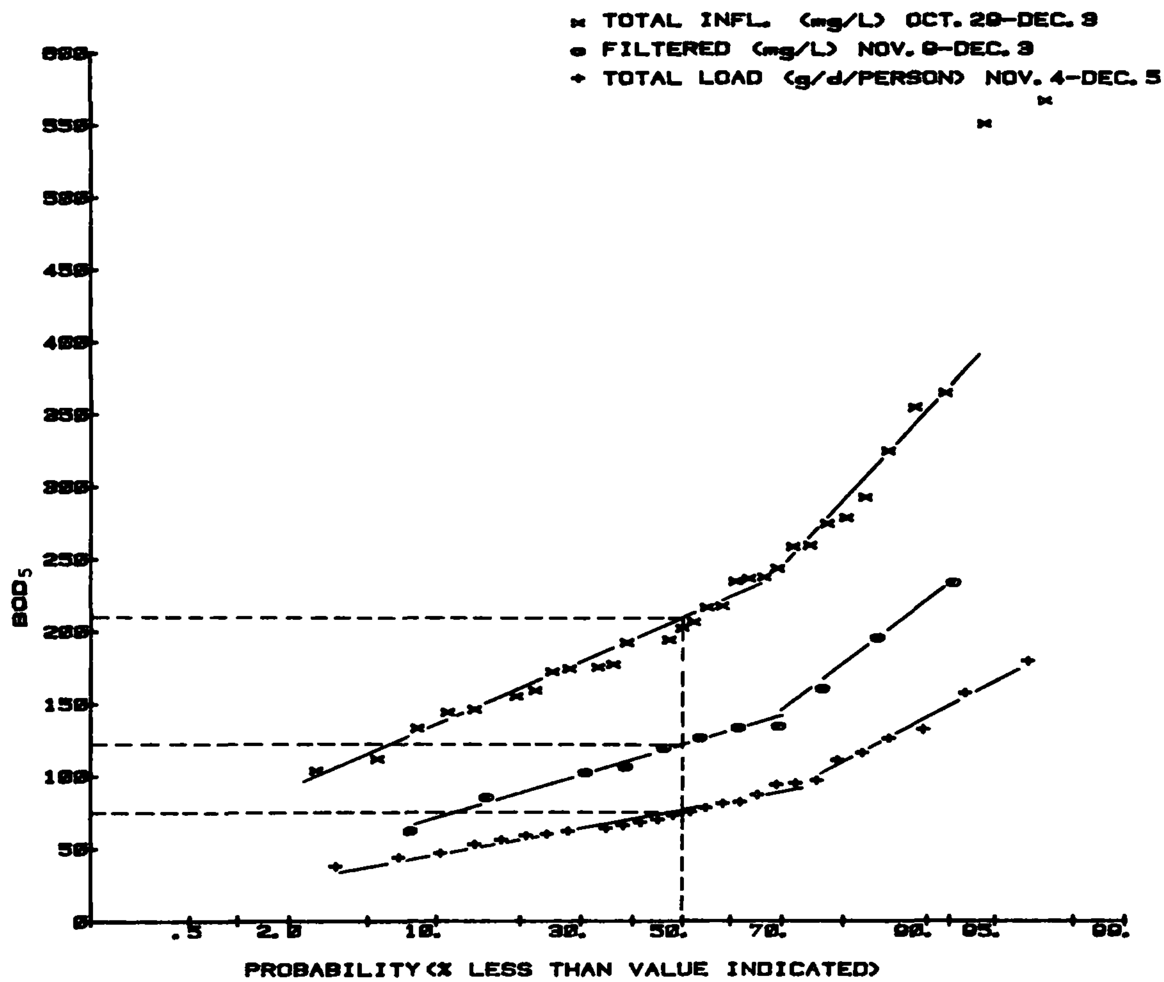

FIGURE 9. INFLUENT TOTAL AND FILTERED BOD_5 CONCENTRATION AND LOADING

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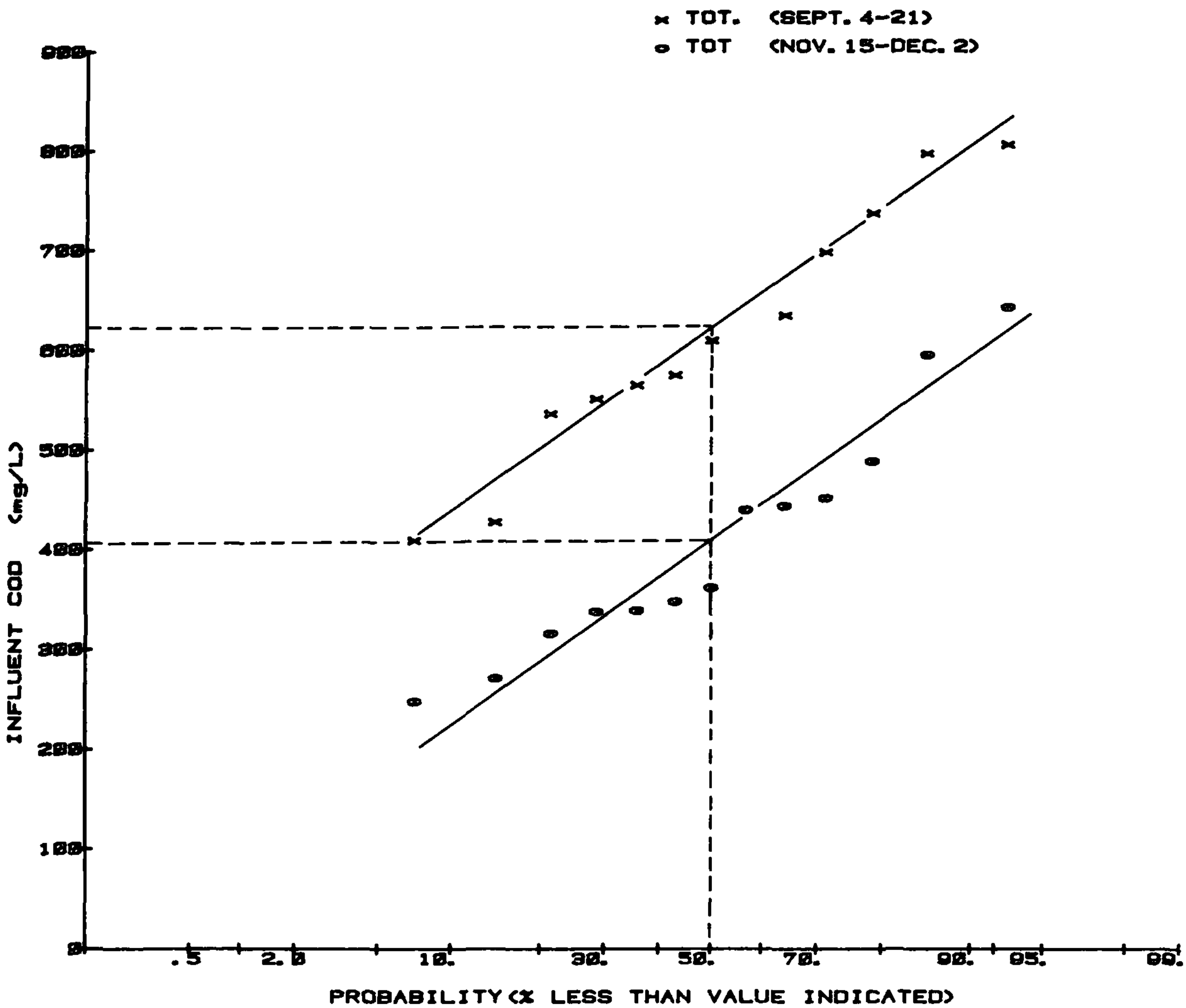


FIGURE 10. INFLUENT TOTAL COD CONCENTRATION

3 TREATMENT ASSESSMENT PROGRAM

3.1 Equipment and Procedures

3.1.1 Treatment plant layout

Figure 2 illustrates the actual layout of the wastewater system at Poste de la Baleine from October to December, 1979. Two main sewer lines discharged wastewater into an equalization tank with an effective capacity of 2500 L. From this unmixed equalization facility, which was sized using a hydrograph prepared in September, 1979 (Figure 11), the two treatment units could be fed by pumping at a constant flow rate or by gravity at a variable flow rate. In the latter case, the normal diurnal flow variability is dampened slightly by the volumetric capacity of the equalization tank; this operating condition does not provide significant flow equalization. Effluents from the treatment units were directed to a tile bed. Variable speed Moyno pumps were used for pumping to the treatment units.

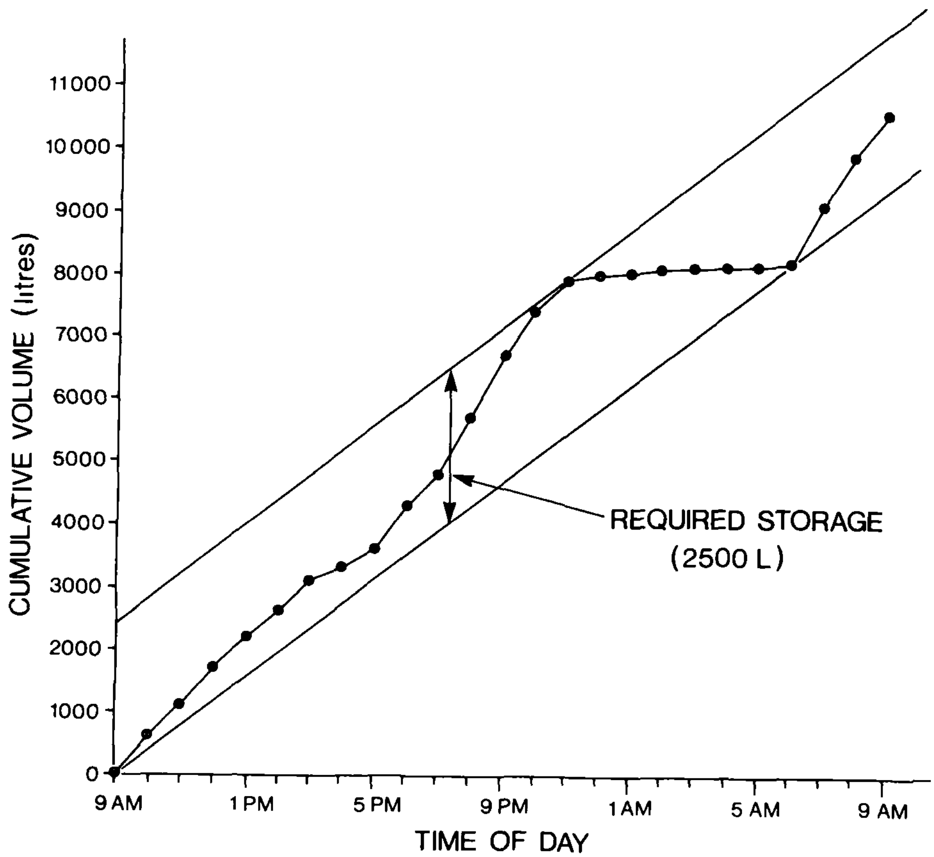


FIGURE 11 HYDROGRAPH FOR SIZING THE EQUALIZATION TANK

The wastewater system underwent a number of changes from initial installation in August, 1979, until the development of the final configuration used in the experimental program. Table A2 of the Appendix summarizes events that took place during installation, start-up and the experimental period.

3.1.2 Description of treatment processes

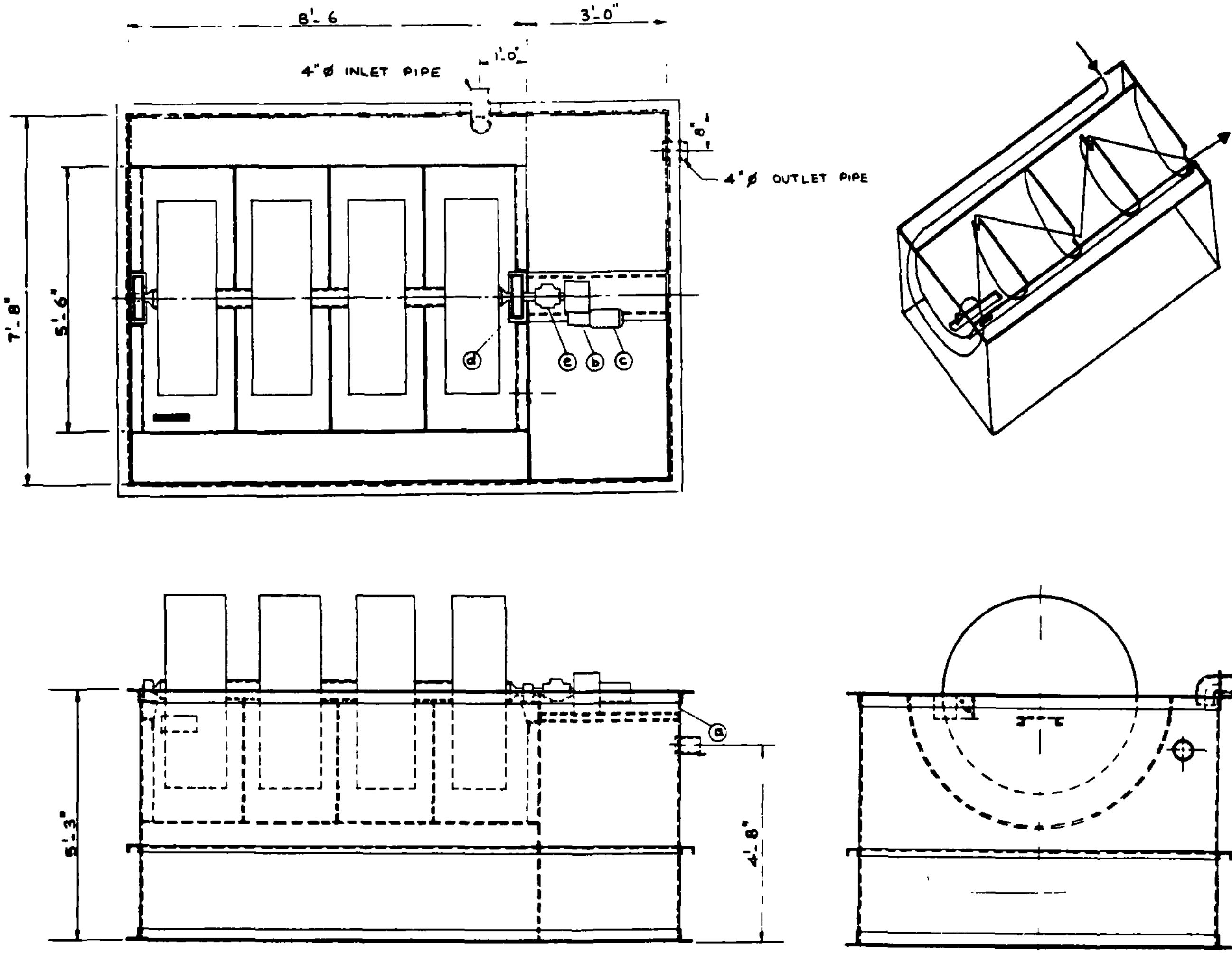
The RBC is an aerobic biological treatment system based on the biosorption principle. Biological slimes are formed on a series of closely spaced rotating discs. The disc surfaces are alternately exposed to the wastewater and to the atmosphere. The four-stage package system used in the study had a surface area of 233 m^2. It was shipped in one piece, complete with primary and secondary settling tankage. Pumping equipment and fittings for sludge withdrawal were not provided. An illustration and details of the unit are presented in Figure 12.

The Oxyvor 50 unit is an activated sludge process designed for a population of 50 persons or a flow of 10 000 L/d. The process is illustrated in Figure 13. Wastewater is discharged in an aeration basin where a surface aerator performs mixing and aeration. The mixed liquor suspended solids (MLSS) flocculate and settle in a clarification zone. The "clarifier" forms an outer shell surrounding the aeration basin separated by a cylindrical wall. Details of the process are presented in Table 2.

3.1.3 Summary of experimental program

The program was designed to assess the feasibility of using the processes for the treatment of exploration camp wastewater in two phases between September and December, 1979. The units were operated in parallel during both phases. In the first phase, (September 17 to October 16), wastewater was discharged by gravity via the equalization tank into both units. In the second phase, the flow equalization phase (October 17 to December 3), a constant flow was provided to both units by pumping.

Table A2 provides a chronological description of the activities which took place during the project. It also describes the abnormal occurrences during the experimental program.



NOTES

1. ALL MECHANICAL PARTS SANDBLASTED, ONE COAT OF #71 PRIMER, TWO COATS OF #78 AMERCOAT COAL TAR EPOXY, 16 MLS MINIMUM THICKNESS (OR EQUIVALENT)
2. UNIT TO BE PLACED LEVEL ON CONCRETE PAD OR WELL COMPACTED GRAVEL
3. COVER CAN BE SUPPLIED (OPTIONAL EXTRA)
4. PLEASE SPECIFY POWER REQUIREMENTS (PREFERRED SPEC 575V, 3PH, 60 CYC)

SHIPPING WEIGHT	3150 KG	6900 LBS
OVERALL HEIGHT	2 20 M	7'-3"
OVERALL WIDTH	2 50 M	8'-2"
OVERALL LENGTH	3.66 M	12'-0"
SHIPPING DETAIL		

ITEM	DETAILS	MAT'L	QUANT
e	COUPLING STEELFLEX 60T10 FALK	STD	1
d	BEARINGS SNA-22510-1U TA SKF	STD	2
c	MOTOR ¼ H.P. 1800 RPM, TEFC	STD	1
b	REDUCER MAAUD 287,600 1 RATIO [illegible]	STD	1
a	STEEL TANK	MS	1

15	BIO SUPPORT MEDIA DIAM	122 M	4.0 FT
14	HYDRAULIC CAPACITY	[illegible]	2400 IGPD
13	ROTORZONE RETENTION		5 HRS
12	ROTORZONE CAPACITY	2 18 CU M	77 CU FT
11	SLUDGE STORAGE FINAL	0 80 CU M	28 CU FT
10	SLUDGE STORAGE PRIMARY	5 00 CU M	177 CU FT
9	TWL FINAL	1 37 M	4 50 FT
8	TWL PRIMARY	1 45 M	4 75 FT
7	BIO SUPPORT MEDIA	223 SQ M	2400 SQ FT
6	CHLORINE TANK RETENTION		
5	CHLORINE TANK CAPACITY (OPTIONAL)		
4	FINAL TANK RETENTION		4 HRS
3	FINAL TANK CAPACITY	2 60 CU M	92 CU FT
2	PRIMARY TANK RETENTION		6 HRS
1	PRIMARY TANK CAPACITY	7 73 CU M	273 CU FT
	DETAILS		

DRAWING TITLE
GENERAL ARRANGEMENT OF S40 ROTORDISK IN STEEL TANK

SCALE ¾" = 1'-0" | DATE AUG 11/78 | DRAWING NO. S40.15-D

FIGURE 12. THE RBC PROCESS

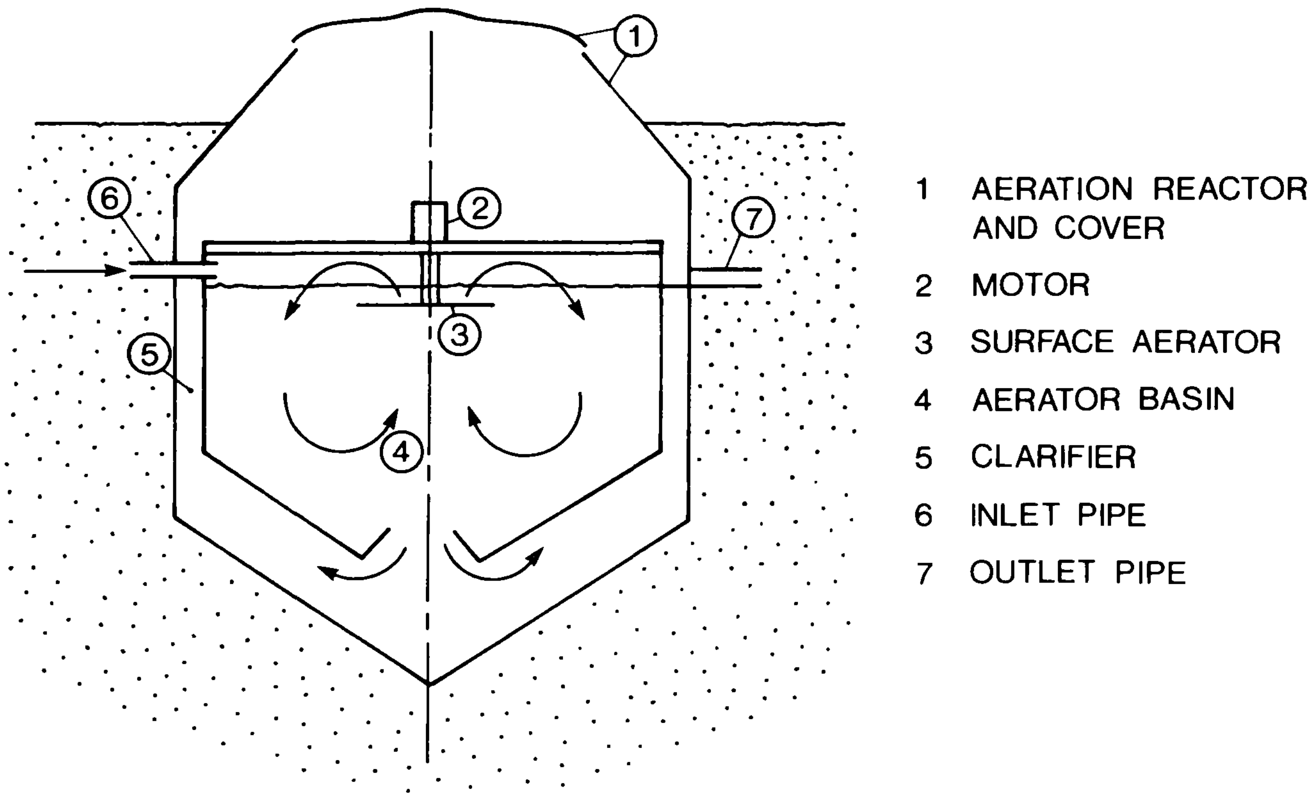


FIGURE 13. THE OXYVOR PROCESS

TABLE 2. DESCRIPTION OF OXYVOR PROCESS

Material	Fibreglass
Height	2.6 m
Maximum diameter	2.9 m
Aeration tank capacity	6.2 m^3
Clarifier capacity	2.2 m^3
Clarifier surface area	1.7 m^2
Aeration motor	0.56 kW, 1725 rpm

Twenty-four-hour composite samplers collected daily samples of the effluent of the treatment systems. Samples were analyzed for total BOD_5, COD and TSS. The suspended solids concentration, pH, dissolved oxygen (DO), oxygen uptake rate, temperature, and sludge volume index (SVI) of the Oxyvor mixed liquor were measured daily. For the RBC, pH and liquid temperature were measured daily. Ambient temperature in the building covering the systems was also recorded daily.

3.2 Evaluation of Process Performance

This section describes the results of three months of operation of the two biological treatment systems at Poste de la Baleine. The performance evaluation is based upon effluent quality criteria, mainly BOD_5 and TSS. Advantages and disadvantages of each process are discussed as functions of the consistency of effluent quality, operation and maintenance requirements, effects of shock loads, etc.

The characteristics of the influent, already discussed in the second section, remained consistent throughout the study period. The pH values varied between 7 and 8. The average daily flow rates increased from 13 000 to 19 000 L when water was bled continuously to the collection system. A peak to average to minimum diurnal flow ratio of 2.2:1.0:0.2 was generally observed. The RBC and Oxyvor operating conditions and effluent characteristics for the duration of the experimental program are presented in Table A3 in the Appendix.

3.2.1 Performance of RBC

The RBC is a well-known process that has been evaluated many times. It has been shown to be reliable with relatively maintenance-free operation.

At Poste de la Baleine, the RBC was acclimated within two weeks of start-up. It was operated at an organic BOD_5 loading of 7.3 kg/1000 m^2·d. Liquid temperature in the fourth stage remained around 10°C, except during one week in November when it dropped to 4°C. This low temperature problem was overcome when a heating furnace was installed in the building.

The RBC system operated without trouble throughout the study period. No maintenance work was necessary. It was, however, impossible to measure the quantity of solids which had accumulated in the primary and secondary settling tanks. As a result, the frequency of solids withdrawal could not be established. The hydraulic loading was well under the design value of 11 000 L/d, but the organic loading of 7.3 kg BOD_5/1000 m^2· was in the range recommended by Murphy and Wilson (1980). Results from this study demonstrate clearly the good performance that is claimed for RBC systems. Figures 14 and 15 indicate that with flow equalization the RBC produced a very stable effluent containing an average BOD_5 of 34 mg/L and an average TSS of 27 mg/L. With gravity feeding, TSS data in Figure 14 show larger variations and a higher average (37 mg/L). The difference was small but statistically significant. Although BOD_5 values are not available for the gravity feed period, they should have varied similarly to the suspended solids. On the other hand, within the flow equalization period, during five days (October 27 to November 1) of gravity feeding resulting from pump failure, no increase in suspended solids and BOD_5 concentrations were noted.

3.2.2 Performance of Oxyvor

In any activated sludge system there are two factors that have great impact on performance: the quality of the microbial population or mixed liquor, and the solid-liquid separation in the clarifier.

The quality of the biomass is controlled by operating the system at the proper sludge age or food-to-microorganism ratio (F/M), and providing an adequate oxygen supply. The conventional activated sludge process is generally operated at a sludge age of 4 to 14 days, a F/M ratio of 0.2 to 0.5 kg BOD_5/kg MLSS·d, and a minimum of 2 mg/L dissolved oxygen. To minimize the production of sludge, the process would be run under an extended aeration mode. This means that the sludge age is kept higher (20 to 30 days), and the F/M ratio lower (0.05 to 0.2 kg BOD_5/kg MLSS·d). A healthy mixed liquor microbial population usually exists if there is a high percentage of BOD_5 removal (85% minimum) and a good settling sludge.

The second important factor is solid-liquid separation in the clarifier or clarification zone. Inadequate separation leads obviously to poor performance, even though wastewater could be well treated in the aeration basin. Moreover, the uncontrolled loss of microbial cells in the effluent directly affects sludge age and F/M ratio and, thus, the mixed liquor quality.

Over the three-month period, the Oxyvor system only produced reasonable quality effluent for 12 days (November 21 to December 3, 1979). The temperature of the mixed liquor was approximately 12°C, and pH around 7.5. Dissolved oxygen values dropped to the 1 mg/L level whenever the

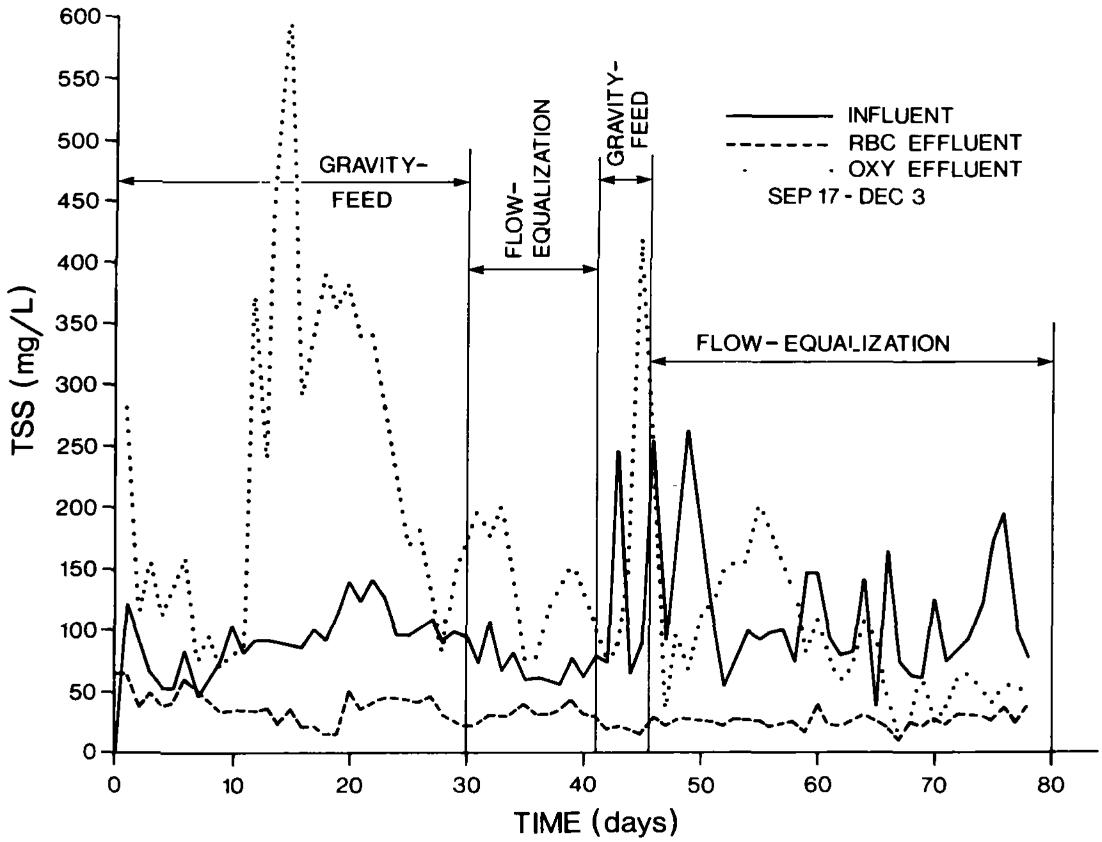


FIGURE 14. DAILY INFLUENT AND EFFLUENT SUSPENDED SOLIDS CONCENTRATIONS

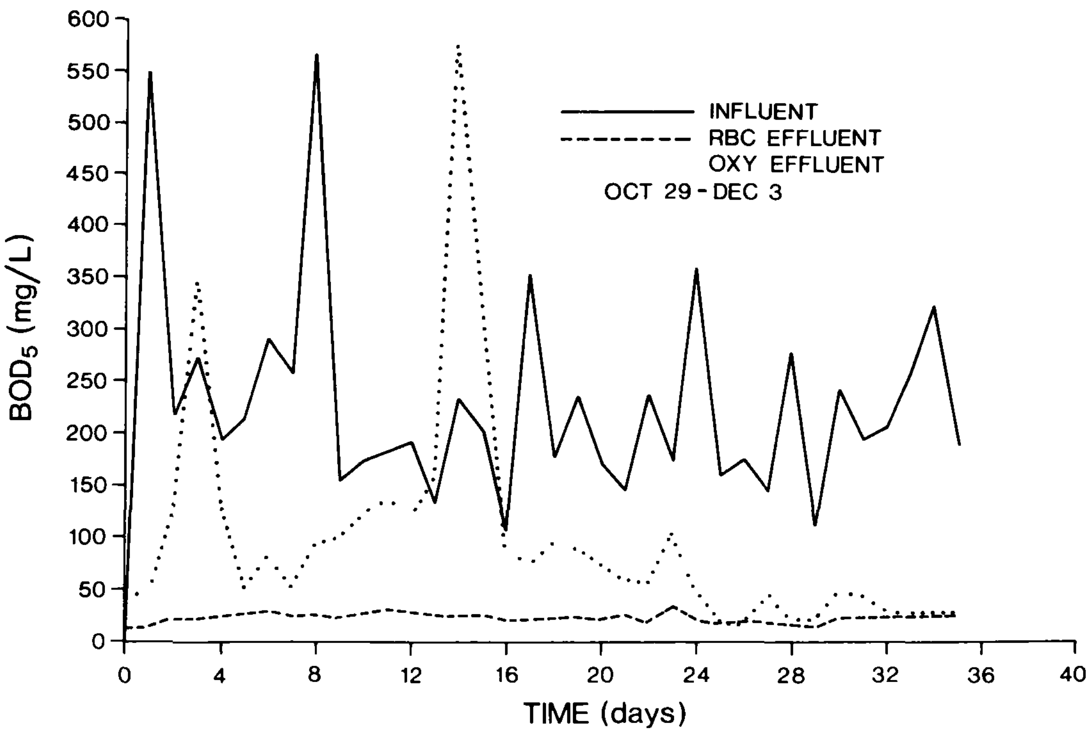


FIGURE 15. DAILY INFLUENT AND EFFLUENT BOD_5 CONCENTRATIONS

mixed liquor suspended solids concentration reached 2000 mg/L. Although the sludge volume index (SVI) varied between 50 and 160, turbid effluents were obtained most of the time.

The major problem was that the aeration in the main reactor affected solid-liquid separation in the clarification zone. Figure 16 demonstrates clearly the influence of aeration on effluent suspended solids. The aeration timing of five minutes "on" and ten minutes "off" (5 and 10) created a condition which caused a continuous loss of biomass in the effluent. Data in Table A3 in the Appendix indicate that with this aeration mode the Oxyvor effluent never had a TSS concentration lower than 68 mg/L. This minimum concentration was obtained during a period when the mixed liquor was in the 1500 to 1800 mg/L range.

During the flow equalization phase, microorganisms lost in the effluent were minimized by cutting down agitation in the aeration basin. Different sets of aeration timing (e.g., 5 and 25, 2 and 10, 2 and 4, etc.) were tried. Of course, this procedure could create an anaerobic condition as more and more microorganisms accumulate in the system. Two minutes appeared to be the maximum aeration time to provide a minimum effect of agitation on effluent solids (Figure 16). The process provided better treatment during the 12 days from November 21 to December 3, 1979. The effluent contained an average of 32 mg/L BOD_5 and 47 mg/L TSS.

After this short period, a defect in the aerator timer left the aerator "on" overnight. This caused a high solids loss in the effluent during the following days. TSS concentrations increased from a level of 60 to 400 mg/L. Another short continuous aeration period in September created the same effect. The mixed liquor concentration, on the other hand, cannot be controlled by any means. This makes the system very sensitive to any abnormal occurrence and it is well known that an activated sludge system takes a considerable period of time to restabilize after a wash-out.

In summary, the design of the Oxyvor system provides no process control variables which can be manipulated to control the performance of the system. Reduction of aeration to improve solid-liquid separation will limit the oxygen supply. Increasing the aeration time to provide an adequate oxygen supply creates conditions inhibiting solid-liquid separation.

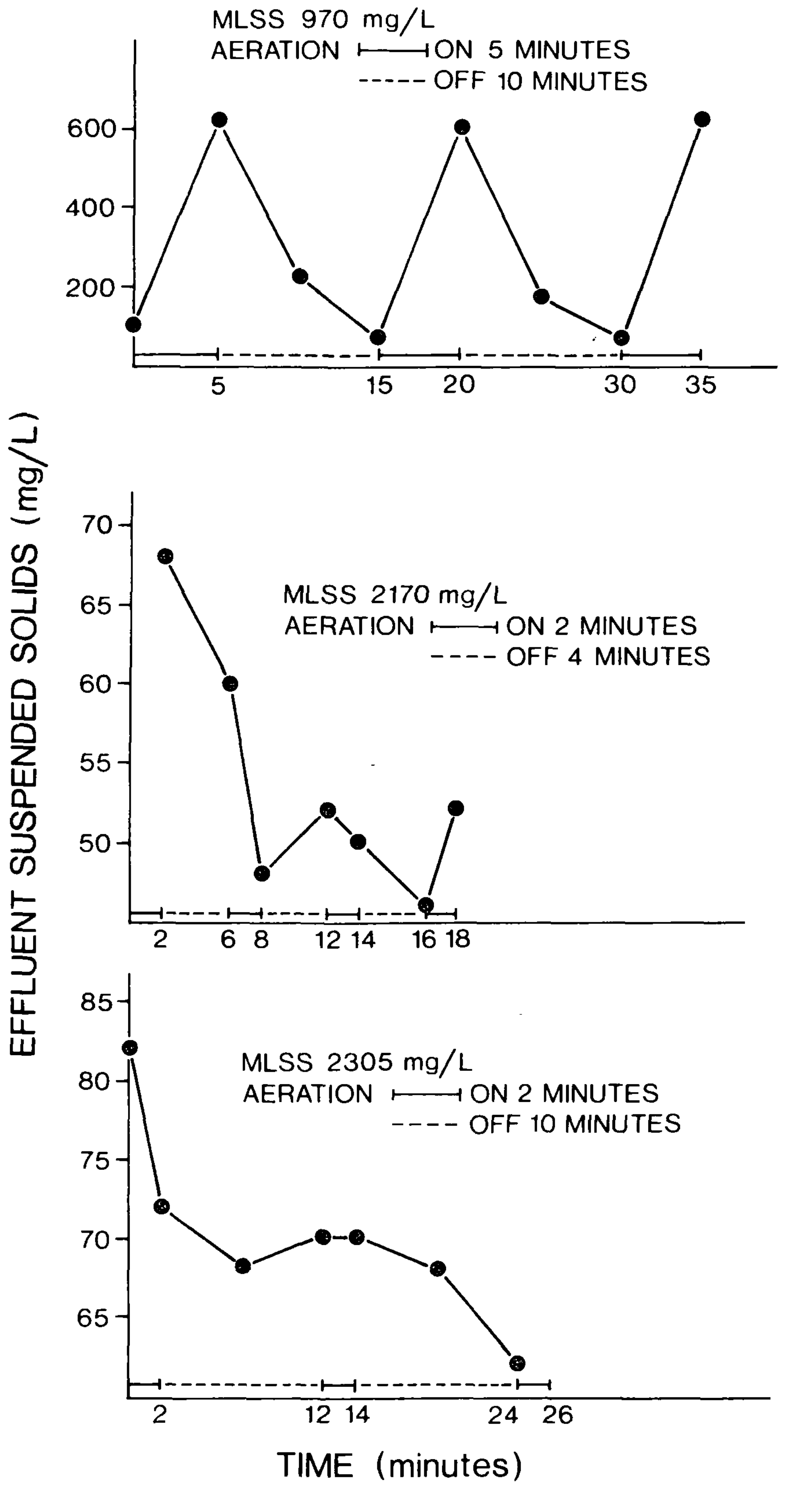


FIGURE 16. OXYVOR EFFLUENT SUSPENDED SOLIDS vs AERATION TIME

3.2.3 Comparison and discussion

This section points out the pros and cons of package treatment plant systems based upon transportation and installation problems and a comparison of operation and performance capabilities and system costs.

3.2.3.1 Transportation and installation problems. Because of the weight and size of the steel RBC tankage, problems were encountered in the transportation of the system to Poste de la Baleine. Shipping a similar unit to a remote exploration camp in the middle-north would seem to be impractical. The unit could be assembled on-site, but problems such as levelling and alignment of the rotating shaft would likely be encountered as heavy construction equipment would not be available for installation.

Transportation of the Oxyvor unit to Poste de la Baleine was not a problem as the components were shipped and the unit assembled on-site. A technician from the manufacturer was required for installation.

3.2.3.2 Operation and performance. This study has proven again that the RBC is simple to operate and is maintenance-free. It produced an effluent of consistent quality and withstood shock loads without sloughing of biological slimes. The effluent quality deteriorated slightly when the system was subjected to diurnal flow variations. In addition, the RBC performed well at a liquid temperature of 4°C for one week. In the design of the system greater attention should be paid to facilities for sludge withdrawal from both the primary and secondary clarifiers.

Proper operation of the Oxyvor unit was limited by the fact that there were no process variables which could be manipulated to provide process control. It is recommended that serious consideration be given to modifying the design of the unit. Removal of the integral clarifier and provision of external clarification and positive displacement sludge return pumps is one alternative that merits examination.

3.2.3.3 Cost comparison. Table 3 provides actual costs expended for the purchase, transportation, and installation of both units and their common support facilities. The capital and transportation costs of the RBC unit were almost triple the Oxyvor's. The installation cost of the RBC unit, however, was lower since heavy machinery was available at Poste de la Baleine.

TABLE 3. COST OF EXPERIMENTAL TREATMENT SYSTEM AT POSTE DE LA BALEINE

	RBC	Oxyvor	Total
Package Plant	$18 475	$7 484	
Transportation	1 453	247	
Installation	1 119	2 119	
Sub-Total	$21 047	$9 850	$30 895
Common facilities:			
Building	4 044		
Tile Bed	1 550		
Sewer System	2 639		
Transportation of pumps and motors	2 232		
	$10 465		$10 465
		Total Cost:	$41 360

As the Oxyvor unit did not produce an effluent of satisfactory quality, it is difficult to compare operation and maintenance costs of both processes. However, a conventional activated sludge process would require at least 400 man-hours/year for its operation and maintenance, while a properly designed and operated RBC would require somewhat less operator attention with approximately the same maintenance requirement.

4 DISCUSSION OF PROBLEMS ENCOUNTERED

Some problems encountered during the characterization of wastewater and the installation and operation of treatment systems are discussed in this chapter. Remoteness, cold weather, and the rocky terrain of the middle-north are undoubtedly the cause of many difficulties.

First of all, means of transportation are limited. At some locations they are simply not available during certain periods. High costs and long delays must be expected. It is important, therefore, to order the proper equipment well in advance. This means that plans should be made to send equipment which will perform properly with minimal operator attention. The equipment must be durable and come with an adequate supply of spare parts.

The low and intermittent wastewater flows of exploration camps are difficult to measure. Flow measuring devices for these conditions, such as weirs or flumes, require levelling. With the measuring device level, solid and paper accumulation can invalidate flow measurements. Bar screens and comminutors appear to be necessary equipment for accurate flow measurement. Moreover, most existing sewer lines have only a slight slope, just enough for gravity discharge of wastewater. The installation of a weir box would be impossible without adjusting the level of sewer lines. Flow meters installed at wells indicating water demand gave good estimates of wastewater amounts and discharge patterns.

Another problem related to flow was the equal division of flow into the RBC and Oxyvor. Throughout the study period, the systems either received wastewater by gravity or by pumping and it was not known whether each system received exactly half of the hydrualic loading.

Feeding the wastewater to the treatment system by gravity eliminates many problems associated with operating and maintenance of pumps. This means, however, that the treatment system must be installed at an appropriate level and that heavy machinery is needed. If pumping is the only alternative left, the following points must be taken into consideration:

- If equalization tanks are necessary, they should be designed for the higher flow of the winter period; equalization tank mixing required to keep the solids in suspension could be provided by diffused aeration which will also ensure that septic conditions will not occur.
- During this study many problems were encountered with the Moyno pumps which were supposedly appropriate for the handling of liquids with high solids concentrations. The problems were caused by coarse solids such as paper pillowcases which frequently plugged the pump's influent piping. A comminutor or bar screen would have eliminated this problem; however, the low intermittent flows limit the choice of equipment for this application.
- Electrical devices such as contactors, relays, etc., also created problems because of initial quality of the equipment and the humidity in the treatment building.
- The availability of electrical power is usually limited at exploration camps; an extra generator might be necessary.

REFERENCES

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Appreciation is also extended to Mr. Hung La for his assistance in the preparation of this report.

APPENDIX

TABLE A1. CHARACTERISTICS OF INFLUENT WASTEWATER

Date (1979)	Flow[1] (L/d)	Total BOD_5 (mg/L)	Filtered BOD_5 (mg/L)	Total COD (mg/L)	Filtered COD (mg/L)	TSS (mg/L)	VSS (mg/L)	Temp.[2] (°C)
September 4	-			799	571	122		
September 5	-			537	350	118		
September 6	-			700	416	133	129	15
September 7	10 320			739	567	127	112	13
September 8	9 843			611	459	79	74	13
September 9	11 622			808		185	161	13
September 10	14 287			566		119	89	23
September 11	17 801			636		126	102	18
September 12	10 587			-		68	57	16
September 13	12 875			636		115	102	22
September 14	12 403			-		82	73	17
September 15	12 471			552		105	99	12
September 16	13 497			-		54	54	10
September 17	9 725			576		121	104	10
September 18	13 956			-		-	-	17
September 19	12 903			410		66	60	17
September 20	18 237			-		54	46	15
September 21	14 332			428		54	51	13
September 22	14 201			-		84	66	15
September 23	19 862			-		46	42	16
September 24	14 165			-		58	48	12
September 25	11 963			-		74	71	17
September 26	13 852			-		104	76	16

1 Flow measured at wells.
2 Temperature measured daily at 10:00 am in the equalization tank.

Cont'd.../

TABLE A1 (CONT'D). CHARACTERISTICS OF INFLUENT WASTEWATER

Date (1979)	Flow[1] (L/d)	Total BOD_5 (mg/L)	Filtered BOD_5 (mg/L)	Total COD (mg/L)	Filtered COD (mg/L)	TSS (mg/L)	VSS (mg/L)	Temp.[2] (°C)
September 27	14 764			-		81	69	18
September 28	10 614			-		92	89	20
September 29	9 934			-		92	68	-
September 30	12 648			-		-	-	19
October 1	13 420					-	-	17
October 2	15 631					86	72	17
October 3	10 328					100	92	18
October 4	12 571					91	74	17
October 5	10 278					112	99	20
October 6	10 778					139	112	20
October 7	12 957					122	113	17
October 8	11 386					140	120	25
October 9	16 480					126	105	8
October 10	20 158					96	80	11
October 11	22 400					96	78	13
October 12	21 370					101	89	14
October 13	17 892					108	99	12
October 14	17 674					91	80	14
October 15	18 446					98	79	21
October 16	18 846					94	74	13
October 17	18 914					72	65	15
October 18	20 271					108	96	13
October 19	22 278					67	61	19

1 Flow measured at wells.
2 Temperature measured daily at 10:00 am in the equalization tank.

Cont'd.../

TABLE A1 (CONT'D). CHARACTERISTICS OF INFLUENT WASTEWATER

Date (1979)	Flow[1] (L/d)	Total BOD_5 (mg/L)	Filtered BOD_5 (mg/L)	Total COD (mg/L)	Filtered COD (mg/L)	TSS (mg/L)	VSS (mg/L)	Temp.[2] (°C)
October 20	21 066					81	75	13
October 21	18 764					60	52	17
October 22	18 569					61	54	12
October 23	1 994					-	-	13
October 24	19 454					56	39	10
October 25	18 096					76	56	7
October 26	21 002					62	50	21
October 27	18 641					78	68	11
October 28	17 697					72	60	14
October 29	23 413	550				245	214	9
October 30	17 148	217				65	45	12
October 31	18 060	274		275		89	80	12
November 1	16 970	194		450		252	215	7
November 2	19 758	216		330		92	70	10
November 3	18 392	292		415		188	160	8
November 4	19 744	259		-		262	240	15
November 5	21 492	566		-		-	-	18
November 6	19 885	155		290		108	88	11
November 7	18 623	175		-		54	40	10
November 8	21 210	-		-		-	-	8
November 9	17 007	192	126	-		99	76	9
November 10	16 598	133		-		92	92	10
November 11	17 810	234		-		92	78	6

1 Flow measured at wells.
2 Temperature measured daily at 10:00 am in the equalization tank.

Cont'd.../

TABLE A1 (CONT'D). CHARACTERISTICS OF INFLUENT WASTEWATER

Date (1979)	Flow[1] (L/d)	Total BOD_5 (mg/L)	Filtered BOD_5 (mg/L)	Total COD (mg/L)	Filtered COD (mg/L)	TSS (mg/L)	VSS (mg/L)	Temp.[2] (°C)
November 12	-	202		-		100	94	7
November 13	-	104		-		74	46	7
November 14	21 651	354		-		146	128	20
November 15	-	177		452		146	117	11
November 16	19 400	236		444		95	77	17
November 17	17 406	172		362		79	61	8
November 18	16 149	146	85	271		82	66	10
November 19	16 317	237	160	489	291	139	122	13
November 20	20 348	174	102	-	-	38	38	12
November 21	-	364	233	-	-	164	155	14
November 22	19 245	159	-	-	-	75	72	10
November 23	18 968	175	133	348	288	64	52	20
November 24	17 125	144	-	248	-	62	54	12
November 25	19 140	278	102	644	-	124	54	12
November 26	17 888	112	62	-	-	74	62	11
November 27	17 838	243		-	-	84	74	11
November 28	17 279	194	-	339	339	93	73	17
November 29	19 109	206	-	316	292	118	91	11
November 30	21 252	258	134	440	228	170	149	18
December 1	17 647	324	195	596	284	194	161	9
December 2	17 878	194	119	338	214	101	76	10
December 3	17 543	155	106	-	-	79	47	14

1 Flow measured at wells.
2 Temperature measured daily at 10:00 am in the equalization tank.

TABLE A2. SUMMARY OF EVENTS DURING INSTALLATION, START-UP AND EXPERIMENTAL PROGRAM

Date	Activity or Operating Condition	Abnormal Occurrences
August 1 to 31 - Installation		
August 1	Wastewater was being discharged from three sewer lines (lavatory, kitchen, office) into septic tanks.	
August 15	Installation of treatment units: RBC and Oxyvor.	
August 21	Building of tile bed.	
August 22	Installation of grease trap.	
September 1 to 16 - Start-up		
September 1	Connection of lavatory and kitchen sewer lines. Gravity feeding of wastewater into treatment units through a weir box and a flow splitter.	
	Wastewater discharge from the office and staff house sewer line into septic tanks.	
September 12	Lavatory and kitchen wastewater treatment by the RBC only.	Defective Oxyvor aerator timer.
September 13	Construction of a building to cover the treatment units.	
September 17 to October 17 - Gravity Feed		
September 16	Installation and connection of a "cargo box" used as an equalization tank. Gravity feed via equalization tank into both units.	
September 22	Connection of office and staff house sewer line to kitchen sewer line. Total wastewater treatment by RBC and Oxyvor.	
September 29	Installation and connection of a second "cargo box" to double the size of the equalization tank.	Half a day discharge of total wastewater into the Oxyvor.
September 30	Removed first septic tank. Provided 10 hours continuous aeration in the Oxyvor to compensate for increased organic loading.	Removal of the first septic tank resulting in a shock load on treatment units from septic tank overflow.

Cont'd.../

TABLE A2 (CONT'D). SUMMARY OF EVENTS DURING INSTALLATION, START-UP AND EXPERIMENTAL PROGRAM

Date	Activity or Operating Condition	Abnormal Occurrences
October 17 to December 3 - Flow Equalization		
October 17	Installation and operation of two Moyno pumps at a constant flow of 7 L/min.	Occasional overflow in the equalization tank due to its small volume.
October 21	Pump replaced.	Pump on the Oxyvor unit seized up due to an overnight dry run caused by influent line blockage.
October 27	Pumping stopped; systems fed by gravity flow.	Defective electrical relay; burnt out one pump motor.
November 2	Operation with one pump and two control valves.	Difficulties encountered in equal flow separation.
November 21	Replaced fuses.	Difficulties encountered in pump suction caused the motor to overheat.
November 29	Pump changed.	Blockage of pump inlet by a plastic cap. Dry pumping for an unknown period of time.
December 4		Defective aerator timer; the aerator operated continuously overnight.
		Mixed liquor solids were washed-out in the Oxyvor effluent.
December 7	Direct gravity feeding of total wastewater into the RBC.	

TABLE A3. RBC AND OXYVOR OPERATING CONDITIONS AND EFFLUENTS CHARACTERISTICS

	OXYVOR							RBC		
	Aeration Tank					Effluent		Reactor	Effluent	
Date	MLSS (mg/L)	MLVSS (mg/L)	DO (mg/L)	Temp (°C)	AT[2]	TSS (mg/L)	BOD_5 (mg/L)	Temp[1] (°C)	TSS (mg/L)	BOD_5 (mg/L)
September 4	562	463	8.9	10	A	183		-	-	
September 5	712	560	7.3	10	A	264		-	232	
September 6	1 250	902	9.3	10	A	186		-	75	
September 7	1 110	1 060	5.3	13	A	340		-	102	
September 8	1 000	997	5.5	12	A	320		-	47	
September 9	1 215	1 165	2.5	13	A	314		10	68	
September 10	-	-	-	-	E	228		10	56	
September 11	-	-	-	-	E	91		10	66	
September 12	-	-	-	-	E	64		10	34	
September 13	-	-	-	-	E	50		13	40	
September 14	-	-	-	-	E	73		13	63	
September 15	-	-	-	-	E	65		10	46	
September 16	1 600	1 574	-	-	D	-		10	34	
September 17	1 820	1 585	4.8	15	A	282		11	66	
September 18	1 290	1 070	6.6	13	A	110		11	39	
September 19	1 615	1 330	3.0	13	A	159		10	50	

1 Temperature in the fourth stage.
2 Aeration timing: A - 5 minutes "on", 10 minutes "off" (5 and 10).
B - 2 and 10, or 2 and 4.
C - Continuous.
D - 5 and 25, 10 and 50, or 5 and 55.
E - No aeration.

Cont'd.../

TABLE A3 (CONT'D). RBC AND OXYVOR OPERATING CONDITIONS AND EFFLUENTS CHARACTERISTICS

	OXYVOR							RBC		
	Aeration Tank					Effluent		Reactor	Effluent	
Date	MLSS (mg/L)	MLVSS (mg/L)	DO (mg/L)	Temp (°C)	AT[2]	TSS (mg/L)	BOD_5 (mg/L)	Temp[1] (°C)	TSS (mg/L)	BOD_5 (mg/L)
September 20	1 335	1 255	2.8	13	A	111		10	40	
September 21	1 460	1 415	2.3	13	A	134		10	43	
September 22	1 745	1 380	3.4	13	A	159		10	62	
September 23	1 530	1 350	1.7	14	A	72		10	-	
September 24	1 620	1 430	2.1	12	A	97		10	-	
September 25	1 750	1 555	4.0	14	A	68		12	35	
September 26	1 885	1 555	1.0	15	A	-		12	36	
September 27	1 780	1 460	2.8	14	A	88		11	36	
September 28	1 415	1 180	-	14	A	372		12	35	
September 29	1 405	1 125	1.5	14	A	238		11	38	
September 30	1 095	930	-	13	C	495		11	25	
October 1	1 190	900	1.8	14	A	595		10	36	
October 2	1 025	785	1.8	14	A	295		10	22	
October 3	870	730	4.0	13	A	338		9	23	
October 4	555	375	4.6	14	A	390		10	16	
October 5	515	440	6.0	15	A	362		11	16	

1 Temperature in the fourth stage.
2 Aeration timing: A - 5 minutes "on", 10 minutes "off" (5 and 10).
B - 2 and 10, or 2 and 4.
C - Continuous.
D - 5 and 25, 10 and 50, or 5 and 55.
E - No aeration.

Cont'd.../

TABLE A3 (CONT'D). RBC AND OXYVOR OPERATING CONDITIONS AND EFFLUENTS CHARACTERISTICS

	OXYVOR							RBC		
	Aeration Tank					Effluent		Reactor	Effluent	
Date	MLSS (mg/L)	MLVSS (mg/L)	DO (mg/L)	Temp (°C)	AT[2]	TSS (mg/L)	BOD_5 (mg/L)	Temp[1] (°C)	TSS (mg/L)	BOD_5 (mg/L)
October 6	528	438	4.9	15	A	380		13	50	
October 7	442	375	5.5	14	A	340		10	36	
October 8	478	418	5.3	13	A	340		9	42	
October 9	425	375	7.2	12	A	288		8	45	
October 10	320	280	7.6	11	A	225		8	44	
October 11	390	322	7.7	11	A	168		9	44	
October 12	398	382	6.9	11	A	182		9	42	
October 13	558	488	7.2	12	A	132		10	46	
October 14	558	465	5.6	13	A	80		11	32	
October 15	548	475	5.0	14	A	143		10	26	
October 16	550	482	5.2	13	A	169		11	22	
October 17	582	538	5.4	13	A	199		11	23	
October 18	522	452	6.9	13	A	174		11	31	
October 19	468	435	5.8	13	D	202		11	30	
October 20	525	505	5.5	12	D	146		11	32	
October 21	725	652	6.7	13	D	76		11	40	

1 Temperature in the fourth stage.
2 Aeration timing: A - 5 minutes "on", 10 minutes "off" (5 and 10).
B - 2 and 10, or 2 and 4.
C - Continuous.
D - 5 and 25, 10 and 50, or 5 and 55.
E - No aeration.

Cont'd.../

TABLE A3 (CONT'D). RBC AND OXYVOR OPERATING CONDITIONS AND EFFLUENTS CHARACTERISTICS

	OXYVOR							RBC		
	Aeration Tank					Effluent		Reactor	Effluent	
Date	MLSS (mg/L)	MLVSS (mg/L)	DO (mg/L)	Temp (°C)	AT[2]	TSS (mg/L)	BOD_5 (mg/L)	Temp[1] (°C)	TSS (mg/L)	BOD_5 (mg/L)
October 22	678	610	2.2	12	D	79		10	32	
October 23	702	650	3.3	12	D	114		11	32	
October 24	652	570	3.7	11	D	136		9	35	
October 25	788	692	2.0	10	D	152		7	44	
October 26	652	582	5.8	10	D	130		8	32	
October 27	-	-	-	-	D	-		8	30	
October 28	538	485	7.4	10	D	76		9	20	
October 29	598	545	6.6	11	D	83	46	8	22	15
October 30	184	162	8.3	8	D	169	123	8	18	23
October 31	222	200	6.7	11	D	420	348	10	16	23
November 1	170	150	8.6	11	D	253	134	11	30	26
November 2	192	160	7.4	10	D	36	52	13	22	28
November 3	300	262	7.6	12	D	97	82	9	28	31
November 4	338	312	2.9	13	D	65	53	11	28	26
November 5	510	452	1.5	12	D	108	95	11	26	27
November 6	555	495	1.5	11	D	118	99	10	26	24

1 Temperature in the fourth stage.
2 Aeration timing: A - 5 minutes "on", 10 minutes "off" (5 and 10).
B - 2 and 10, or 2 and 4.
C - Continuous.
D - 5 and 25, 10 and 50, or 5 and 55.
E - No aeration.

Cont'd.../

TABLE A3 (CONT'D). RBC AND OXYVOR OPERATING CONDITIONS AND EFFLUENTS CHARACTERISTICS

	OXYVOR							RBC		
	Aeration Tank					Effluent		Reactor	Effluent	
Date	MLSS (mg/L)	MLVSS (mg/L)	DO (mg/L)	Temp (°C)	AT[2]	TSS (mg/L)	BOD_5 (mg/L)	Temp[1] (°C)	TSS (mg/L)	BOD_5 (mg/L)
November 7	665	565	3.2	12	D	147	123	9	22	-
November 8	648	602	4.3	11	D	154	137	8	28	32
November 9	632	565	1.8	11	D	155	124	8	27	30
November 10	585	530	2.5	11	D	201	157	6	27	27
November 11	495	430	5.5	9	D	-	581	4	22	26
November 12	570	550	6.0	8	D	-	320	5	25	27
November 13	492	430	4.0	8	D	130	89	5	26	22
November 14	515	480	3.4	-	D	81	74	4	17	22
November 15	442	428	1.8	8	D	109	94	5	40	-
November 16	565	512	1.3	11	B	78	89	4	24	26
November 17	315	270	1.4	8	B	59	74	5	23	23
November 18	670	590	4.3	9	B	72	62	5	27	27
November 19	742	672	3.4	10	B	107	57	6	32	20
November 20	750	720	2.8	10	B	92	101	9	28	35
November 21	1 035	895	3.2	11	B	44	50	11	22	22
November 22	1 150	1 065	2.0	10	B	16	22	10	12	17

1 Temperature in the fourth stage.
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C - Continuous.
D - 5 and 25, 10 and 50, or 5 and 55.
E - No aeration.

Cont'd.../

TABLE A3 (CONT'D). RBC AND OXYVOR OPERATING CONDITIONS AND EFFLUENTS CHARACTERISTICS

	OXYVOR							RBC		
	Aeration Tank					Effluent		Reactor	Effluent	
Date	MLSS (mg/L)	MLVSS (mg/L)	DO (mg/L)	Temp (°C)	AT[2]	TSS (mg/L)	BOD_5 (mg/L)	Temp[1] (°C)	TSS (mg/L)	BOD_5 (mg/L)
November 23	1 210	1 010	1.4	11	B	28	17	9	26	21
November 24	1 675	1 470	1.5	11	B	69	44	10	22	19
November 25	1 640	1 430	2.3	11	B	25	22	11	29	18
November 26	1 670	1 445	1.4	12	B	40	22	10	24	15
November 27	2 305	2 035	1.2	13	B	64	49	11	32	24
November 28	2 170	1 900	1.7	13	B	65	45	10	32	24
November 29	2 070	1 660	1.8	12	B	50	31	9	31	25
November 30	2 145	1 815	2.5	10	B	42	28	9	28	26
December 1	2 270	1 880	1.6	11	B	56	31	9	28	25
December 2	2 150	1 775	3.2	12	B	51	27	10	26	28
December 3	2 020	1 660	2.9	12	B	56	30	10	38	-
December 4	1 400	1 220	5.5	11	C	367	-	11	40	-
December 5	1 350	1 115	3.0	11	B	161	-	10	-	-
December 6	1 155	890	5.6	11	B	90	-	9	-	-
December 7	970	790	-	11	A	108	-	10	-	-
December 8	570	420	-	-	A	300	-	-	-	-

1 Temperature in the fourth stage.
2 Aeration timing: A - 5 minutes "on", 10 minutes "off" (5 and 10).
B - 2 and 10, or 2 and 4.
C - Continuous.
D - 5 and 25, 10 and 50, or 5 and 55.
E - No aeration.