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AAL-TDR-62-9

WATER CONSERVATION THROUGH REUSE OF FLUSHING FLUID IN AN AEROBIC SEWAGE TREATMENT PROCESS

TECHNICAL DOCUMENTARY REPORT AAL-TDR-62-9

August 1962

ARCTIC AEROMEDICAL LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
FORT WAINWRIGHT, ALASKA

Project 8246-1

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FOREWORD

This research project was supported by a Cross Service Agreement (CSA 61-1) from the Arctic Aeromedical Laboratory, United States Air Force, Fort Wainwright, Alaska, with the Arctic Health Research Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Anchorage, Alaska.

This report was prepared by C. F. Walters and J. A. Anderegg, Environmental Sanitation Section, Arctic Health Research Center.

Presented at the Eleventh Alaskan Science Conference of the Alaska Division, American Association for the Advancement of Science, August 30, 1960, at Anchorage, Alaska.

ABSTRACT

The Arctic Health Research Center was requested to design, fabricate and operate under field conditions an aerobic waste treatment system wherein the effluent is reused as the water carrier, to be used at various remote Air Force Stations in Alaska. The plant was to serve approximately 10 men.

Three such units were built and installed in three different locations in Alaska, but because of the extreme difficulty in transportation, routine sampling was impossible.

In August 1958, a recirculating waste treatment unit was installed near Anchorage consisting of comminution, aeration, settling and recirculation of settled fluid for flushing purposes. For 16 months, weekly samples were obtained from the latter unit and analyzed for: total solids, total volatile solids, organic and ammonia nitrogen, pH, and chlorides. In addition, the daily usage of the system was recorded along with the volume of overflow.

The results of chemical analyses indicate a gradual buildup of solids, ammonia, and organic nitrogen and chlorides. With a theoretical detention time (in the aeration chamber) of 53 days, the pH remained extremely low and total solids content increased to above 20,000 mg/l.

PUBLICATION REVIEW

HORACE F. DRURY
Director of Research

WATER CONSERVATION THROUGH REUSE OF FLUSHING LIQUID IN AN AEROBIC SEWAGE TREATMENT PROCESS

SECTION 1. INTRODUCTION

In an effort to conserve water and to minimize the liquid waste disposal problem at small isolated communities subject to extremely cold temperatures, the Arctic Health Research Center of the U. S. Public Health Service has been studying the feasibility of an aerobic waste treatment process wherein the effluent is reused as the water carrier. Although sponsored primarily by the United States Air Force on behalf of its remote aircraft control and warning stations, the study has been carried out with the idea that a workable system would have broad application in the Arctic, where the lack of water precludes a conventional water carriage system.

Current Arctic waste disposal practices are divided into two major categories which are distinguished solely by the availability of water. For the few well organized and populated cities in Alaska that have water distribution systems, the problems of human waste disposal are familiar to the sanitary engineer, and basic conventional design standards, influenced perhaps by local geographical and climatological conditions, may be successfully employed. On the other hand, many small villages, incorporating almost 35 percent of the population of Alaska, have no water distribution systems. In these areas the only method of human waste disposal is the pit privy or more primitive means. In a recent survey (Alaska Division of Health, 1959) of 42 communities in the Fairbanks area, only one city had a water distribution system. The most common method of water procurement and storage in the remaining 41 communities involved the 5-gallon can. In those few areas where systematic excreta disposal was reported, limited use of pit privies was the mode.

In general, the extremely wide contrast in water distribution systems of the Arctic has dictated waste disposal practice and ultimately has influenced economic and public health standards. The recirculating waste treatment unit is an attempt to provide a human waste disposal system somewhere between the so-called modern system and the "standard" primitive methods.

Information concerning the operation of these recirculating units is sparse. Bloodgood (1952) reported on a small activated sludge unit that operated for 111 days as a completely closed system with the effluent from a settling chamber being used as the flushing liquid. With the unit receiving 16.8 uses/day, the mixed liquor solids increased from 3600 to 7100 mg/1 during the test period. No adverse aesthetic reactions were reported. Working with a similar unit, Rigby (1954) investigated a completely closed system that operated for 113 days and received 8.1 uses/day. At the end of the test period a four-inch layer of solids had built up in the sedimentation chamber and the mixed liquor solids increased steadily from zero to a maximum of 3300 mg/1. A strong musty odor was detected from this unit.

A recent publication of the National Research Council (1958) reports on the development of design and operating criteria for the use of individual household aerobic sewage treatment systems. In establishing the conditions under which these various systems may be used, the Council considered a closed system as a substitute "for more primitive methods of sewage disposal, such as pit privies... or the can and carry system of the arctic." Among several other conditions was another one suitable for Arctic application, i.e., where "water supply is extremely limited or costly." Considerable emphasis was placed on aesthetic factors involved in operation and in effluent disposal. In the recirculating type of unit such nuisances as odor, foam, scum and color of flushing fluid are to be considered in the evaluation and testing of individual household sewage treatment systems.

Three experimental aerobic recirculating waste treatment systems have been installed by the Arctic Health Research Center. In 1957, by invitation of the United States Air Force, one unit was installed at an aircraft control and warning site called Tatalina (225 air miles from Anchorage), and the following year a similar unit was installed at another site called Sparrevohn (178 air miles from Anchorage). Initially, a study of these two units was limited to observations by the site engineering staff and consisted primarily of noting mechanical failures and nuisances involved in the everyday operation of the unit. Because of the logistical problems involved in obtaining periodic samples for chemical analyses from either of these two units, a third one was installed on Elmendorf AFB just outside Anchorage in August of 1958.

SECTION 2. SUMMARY

The Tatalina unit, a closed system loaded by 6 to 8 men 24 hours a day, began emitting ammonia odors two months after it was put into operation and continued in that state until it was deactivated. Because of odors, surveillance of the unit was neglected resulting in a number of maintenance problems.

The Sparrevohn unit, with an overflow of 1.8 gpd from a lavatory and loaded by three men, operated successfully for over two years. No odors were reported.

A unit operated at the Federal Prison Camp near Anchorage was sampled and observed twice a week. During this time, the data collected revealed the following:

a. Eight men used the system 14 hours a day on the average of three times/day.

b. During the 2-year period no odors were detected.

c. The color of the flushing fluid turned brown during the first week of operation and remained that way during the entire run.

d. At overflow rates between 5.5 gpd and 32.2 gpd, solids, C.O.D., ammonia nitrogen and chlorides accumulated in the aeration chamber.

e. The rate of accumulation varied indirectly with the overflow rate.

f. Floating solids accumulated in the settling chamber to a maximum of 17 inches.

g. No complaints were registered by the individuals using the system.

SECTION 3. TATALINA SYSTEM

The Tatalina unit consisted of a 500-gallon circular tank compartmented into an aeration chamber and a settling chamber. Wastes from the toilet above passed through a household garbage grinder into the aeration compartment where they were aerated using a 1.5 cfm aerator. When the settled effluent was recirculated through the toilet, the fluid from the aeration chamber flowed through 4-inch square holes at the top of the baffle into the settling chamber where quiescent conditions allowed the solids to slide down a hopper and back through another 4-inch square opening in the bottom of the baffle for return and further mixing in the aeration chamber.

The unit was operated originally as a closed system; that is, no additional water was added. After five months a noticeable decrease in liquid level indicated that urine contributions were not sufficient to maintain an overflow, and it was then decided to add dilution water to the tank at periodic intervals to maintain liquid at the overflow level.

The unit operated over a period of 14 months during which time it was completely drained and recharged twice, the first time after seven months of operation, and again three and one-half months later. In November 1958 the unit was deactivated in favor of a water carriage system and heated septic tanks.

During the experiment a great deal of time was spent maintaining the system in a useful state. More than any other single factor, offensive ammonia odors contributed to the poor operation of this installation. The first indication of odors occurred two months after the unit was put into operation. Thereafter, correspondence with site personnel and visits by AHRC engineers indicated that the odor problem never ceased completely.

SECTION 4. SPARREVOHN SYSTEM

The Sparrevohn unit was similar in design to the Tatalina unit except that air was supplied by cavitation instead of through air diffusers. This unit received the wastes from three individuals and the overflow of 1.8 gpd from a hand washing sink. The operational history of the system has been conspicuously free of malfunctions. Since the installation was made in April 1958, there have been no complaints or reports of any mechanical or biological failures. Only the remoteness of the Sparrevohn site has prevented better use being made of the experimental system there.

SECTION 5. ELMENDORF AFB PRISON FARM SYSTEM

In order to have a unit close to the AHRC Laboratory for the purpose of routine sampling and analyses, a 500-gallon system was installed at the Federal Prison Farm just outside Anchorage. The tank was similar in design to the first two tanks and included an aerator, recirculating pump, diffuser tube and toilet with integral grinder. Domestic sewage (fecal and urine discharges) and water from one hand washing sink were the only wastes discharged to the tank. The overflow ran into a small sump, from which it was pumped to the sewer system. Magnetic counters connected across the float-actuated sump pump and the recirculating pump circuit determined the volume of water flowing through the unit and the number of uses it received. During the winter months the tank contents were heated by thermostatically controlled immersed cables, and ambient heat was supplied by an electrical room heater. Figure 1 is a schematic of the aerobic recirculating waste treatment system that was used during most of the period covered in this report.

Initially, the flow from aeration to sedimentation chamber was through a 4-inch round opening in the top of the baffle, and settled sludge solids were returned to the aeration chamber through a 4-inch square hole in the bottom of the baffle. The purpose of the upper baffle opening was to provide sufficient surface agitation to discourage the accumulation of scum in the settling chamber. This original design was altered several months after it became obvious that a short circuiting current was established between the upper and lower openings in the baffle, resulting in poor settling characteristics of the solids. Soon after the hole was covered, a definite decrease in total and volatile solids was noticed in the flushing fluid.

The study reported on herein is divided into two runs. Run 1 started September 22, 1958, and terminated February 10, 1960, 506 days later. On that day a gallon of paint thinner was discharged to the tank through the toilet by an inmate who did not realize the consequences. The unit was pumped down, cleaned and recharged with 423 gallons of tap water.

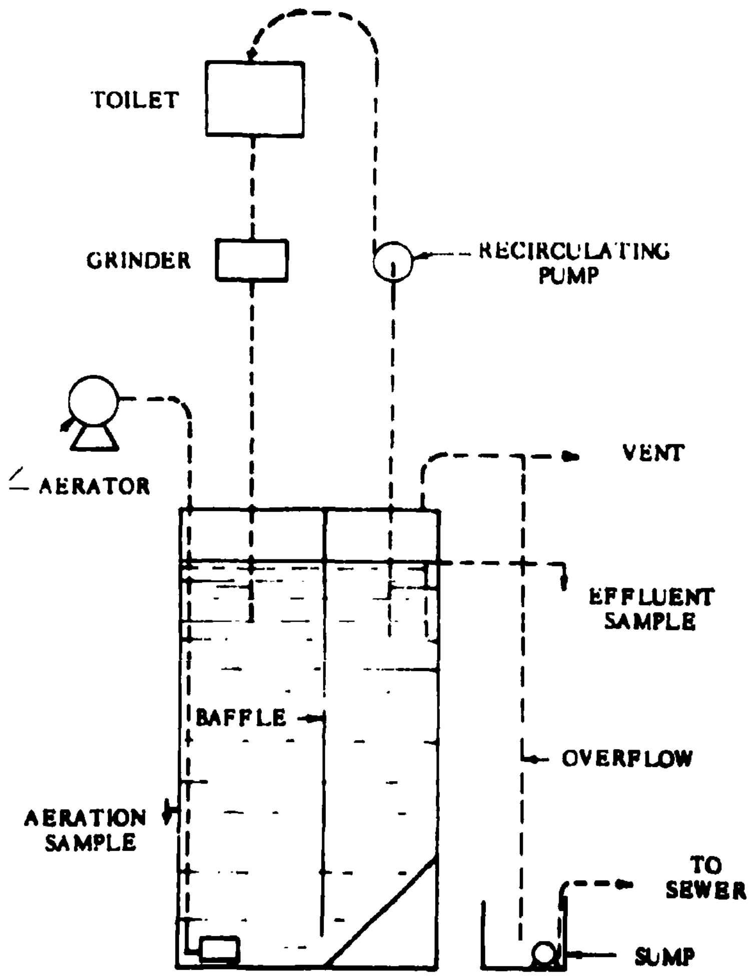

FIGURE 1

Aerobic recirculating waste treatment unit

Run 1 is subdivided into two phases. Phase 1 covered the first nine months of operation, during which time the volume of lavatory waste water varied considerably. Phase II covered the remaining eight months of Run 1, during which time the overflow volume was restricted to a uniform daily rate.

Run 2 started with a uniform overflow rate and maintained that rate for seven months, in contrast with Run 1 where the overflow rate varied considerably during the first nine months of operation.

The basic difference between Run 1 and Run 2 is in the initial overflow rate, the former having a variable nonuniform overflow rate whereas the latter had a controlled and uniform flow of water through the unit.

Run 1

During the 506 days of operation, chemical analyses and physical observations were obtained on an average of twice a week. Analyses of the aeration compartment contents included pH, total solids, total volatile solids, organic and ammonia nitrogen, and chloride. Physical observations included overflow, number of uses, and depth of scum in the settling compartment. Figures 2 and 3 are graphic representations of the data accumulated over the 17-month period.

The unit was used a total of 12,398 times or an average of 24.5 times/day. The facilities were in use 14 hours a day, seven days a week, and were used by eight persons. During Phase I the overflow rate varied from a minimum of 8.1 gpd to a maximum of 32.2 gpd, with an average of 21.3 gpd. Phase II began at the end of this period, when spring-loaded faucets were installed on the lavatory. This resulted in a uniform overflow rate of 6.0 gpd.

The temperature of the tank contents remained at 20° C throughout the entire Run 1.

Values of pH varied from 4.9 to 8.3. During Phase I the average pH was 7.2, while in Phase II the pH averaged 5.9.

Because the unit was not seeded, the remaining chemical analyses reflect gradually increasing concentrations from the minimum amount that was present in the tap water to a maximum as noted.

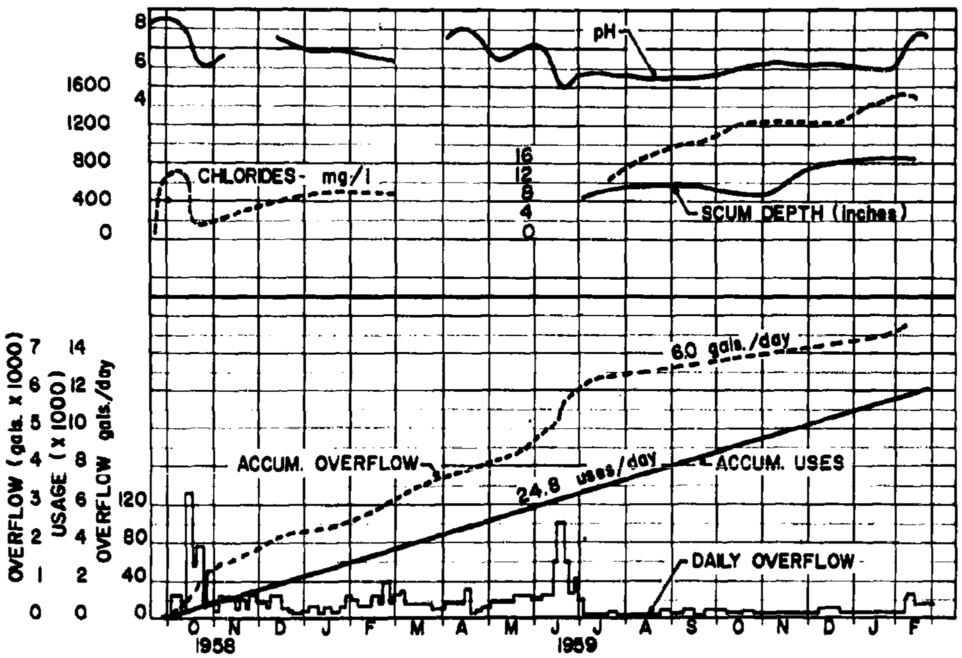

FIGURE 2

OPERATIONAL DATA RUN 1

Aerobic recirculating waste treatment unit

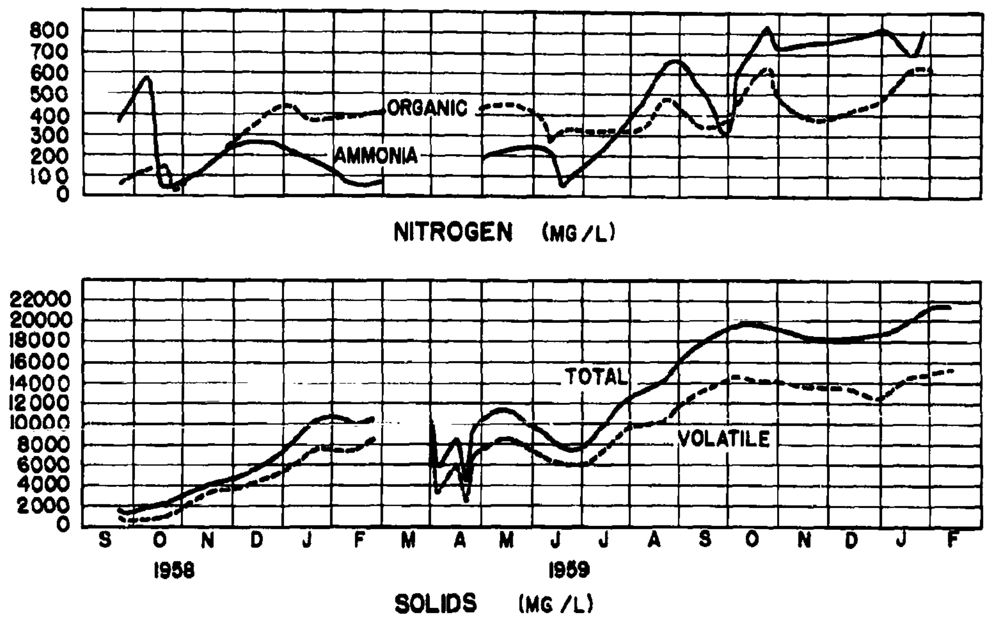

FIGURE 3

OPERATIONAL DATA RUN 1

Aerobic recirculating waste treatment unit

Chlorides increased at a rate of 26.6 mg/l/day during the first 18 days of operation, and throughout the entire run were inversely affected by the rate of water flowing through the unit. For example, on one occasion the lavatory faucets were accidentally left on overnight allowing 527 gallons of water to be discharged through the tank. Sampling prior to and after the incident revealed the chloride content had dropped from 518 mg/l to 146 mg/l. During a 4-month period when the average overflow rate was 15.8 gpd, the rate of increase in chlorides was 3.6 mg/l/day; however, when the overflow rate decreased to 6.0 gpd, the rate of increase was almost doubled to 7.0 mg/l/day.

The organic nitrogen content of the aeration chamber remained between 300 and 500 mg/l for more than 60 per cent of the time and did not exhibit any general tendency toward increasing. On the other hand, ammonia nitrogen exhibited an overall tendency to increase in the aeration chamber. At the beginning of the experiment the concentration increased at a rate of 32.8 mg/l/day for 18 days and then decreased to 26 mg/l as a result of 527 gallons of water being discharged through the lavatory. Since it is well known that the nitrifying organisms are slow in establishing nitrification processes, the reason for the rapid increase of ammonia in solution seems apparent. After the unit was flushed out, there was probably enough seed material remaining to prevent a similar rapid increase (see Figure 2).

As would be expected of an activated sludge unit starting without seed sludge, the total volatile solids increased with time. The maximum concentration, reached at the end of the run, was 16,100 mg/l. In general the rate of increase was higher during the latter part of the operation, when a lower volume of water was flowing through the system, than in the earlier part of the study when high flows were noted.

As in the case of the chlorides, the increase in volatile solids was found to be related to the quantity of water flowing through the system. At an overflow rate of 14.5 gpd volatile solids increased 47.4 mg/l/day, whereas at 6.0 gpd the solids increase was 99.8 mg/l/day.

On July 1, 1959, a depth gage was installed in the sedimentation chamber for the purpose of measuring scum accumulation. The scum depth increased from 8.5 inches at the time of installation to a maximum depth of 17 inches (the level at which liquid overflows from the sedimentation chamber). Analysis of scum depth and volatile solids in the aeration chamber indicated that solids were being transferred from the aeration chamber to the scum layer.

Run 2

During the 183 days of operation, chemical analyses and physical observations were obtained on a twice-a-week schedule. Analyses of the aeration compartment contents and of the effluent included pH, total solids, total volatile solids, chemical oxygen demand (C. O. D.) and chlorides. In addition, ammonia nitrogen also was determined on the mixed liquor. Physical observations were made to obtain the overflow rate and the daily use of the unit. Figures 4 and 5 represent the data collected over the 7-month period.

The toilet was used 4,078 times for an average of 21.0 times/day. As in Run 1, the unit was in use 14 hours a day, seven days a week, by eight persons. The average uniform overflow was 5.5 gpd. The temperature of the tank contents was maintained at 28° C.

The pH of both the mixed liquor and the effluent increased slightly during the first two weeks of operation and then decreased to below 6.0, where it remained for over three months.

The concentration of chlorides in the aeration chamber and in the effluent increased logarithmically. During the first month of operation the rate of increase was 22.7 mg/l/day, whereas during the last month the rate was 1.7 mg/l/day.

Ammonia nitrogen exhibited the same characteristics as were found in Run 1, increasing rapidly during the first two weeks of operation (27.0 mg/l/day) until the nitrification processes became established, then leveling off to a much lower rate of increase (3.86 mg/l/day) for the balance of the run.

Volatile solids in the aeration chamber increased to 6,000 mg/l during the first one and one-half months of operation, an average increase of 125 mg/l/day. Thereafter the increase was at a lesser rate of 42.6 mg/l/day. In analyzing the data it becomes evident that solids accumulate in the aeration chamber at a rate dependent on the rate of water flowing through the unit.

Suspended volatile solids analyses performed over a two and one-half month period (May-July 1960) on samples from both the aeration chamber and the effluent were consistently near 6,000 mg/l (± 500 mg/l) while the total volatile solids were increasing. This indicates that the build-up in the aeration chamber was due primarily to dissolved solids.

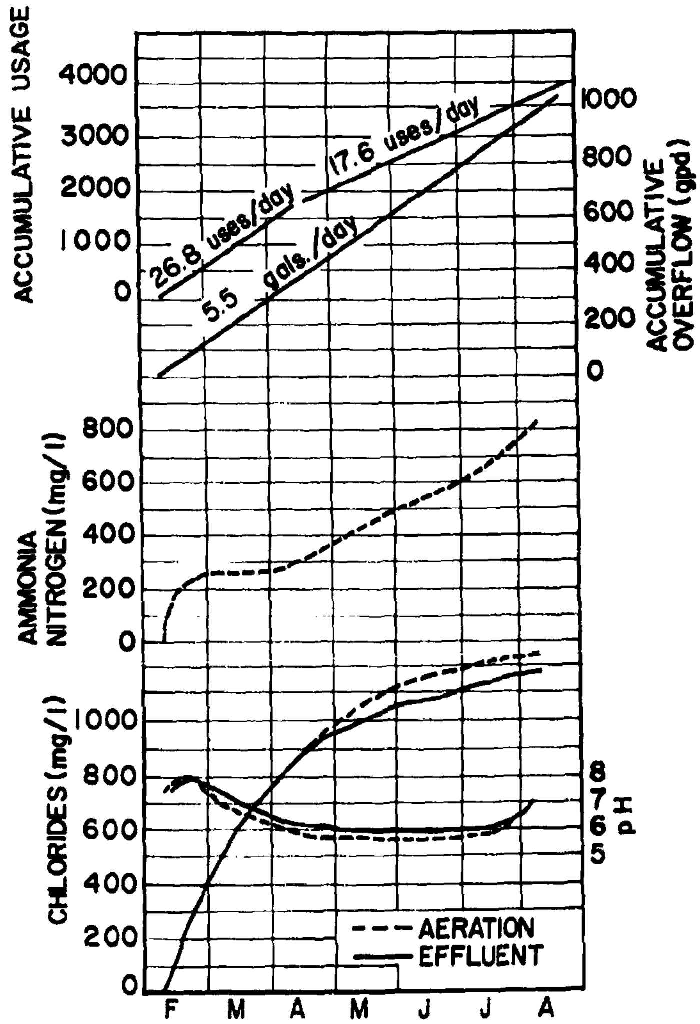

FIGURE 4

OPERATIONAL DATA RUN 2

Aerobic recirculating waste treatment unit

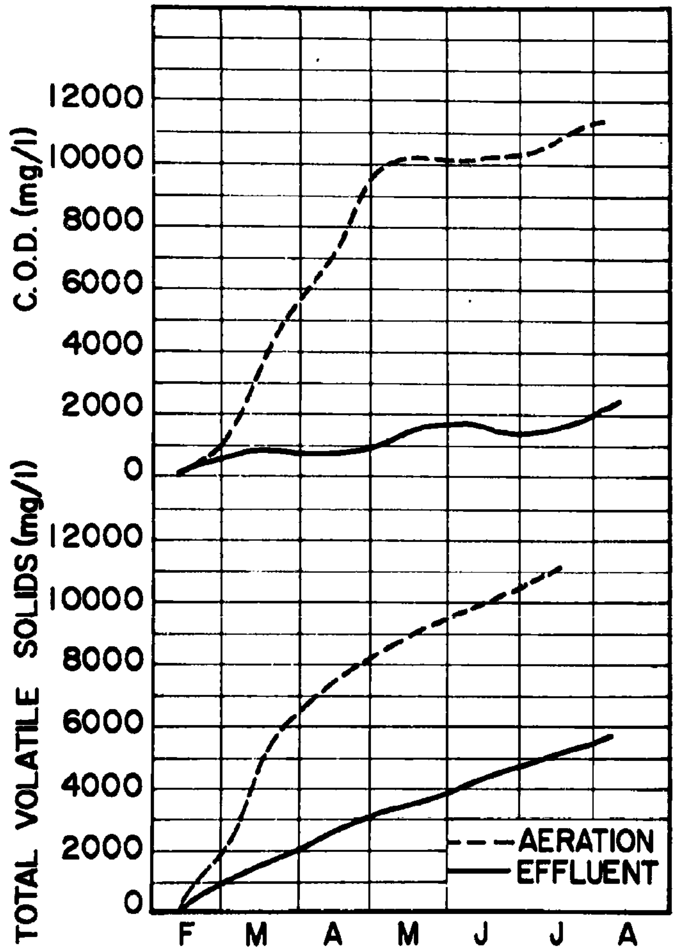

FIGURE 5

OPERATIONAL DATA RUN 2

Aerobic recirculating waste treatment unit

Chemical oxygen demand (C. O. D.) of the mixed liquor solids followed a similar pattern as volatile solids; that is, a very rapid increase initially, followed by a lesser rate of increase. The C. O. D. of the effluent, although considerably less than the aeration, was exceedingly high according to NRC standards (National Research Council, 1958).

Two samples of the effluent collected on July 7 and July 21, 1960, were filtered through millipore filters (0.45 micron pore diameter) and the filtrate analyzed for C. O. D. The soluble material held 98.5 per cent and 92.9 per cent, respectively, of the total C. O. D.

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Rpt. AAL-TDR-62-9. WATER CONSERVATION THROUGH REUSE OF FLUSHING LIQUID IN AN AEROBIC SEWAGE TREATMENT PROCESS. August 1962. 14p. incl illus., 4 ref.

Unclassified Report

The Arctic Health Research Center was requested to design, fabricate and operate under field conditions an aerobic waste treatment system wherein the effluent is reused as the water carrier, to be used at various remote Air Force Stations in Alaska. The plant was to serve approximately 10 men. In August 1958, a recirculating waste treatment unit was installed near Anchorage consisting of comminution, aeration, settling and recirculation of settled fluid for flushing purposes. For 16 months, weekly samples were obtained from the

latter unit and analyzed for: total solids, total volatile solids, organic and ammonia nitrogen, pH, and chlorides. In addition, the daily usage of the system was recorded along with the volume of overflow. The results of chemical analyses indicate a gradual buildup of solids, ammonia, and organic nitrogen and chlorides. With a theoretical detention time (in the aeration chamber) of 53 days, the pH remained extremely low and total solids content increased to above 20,000 mg/l.

1. Disposal
2. Sewage
3. Latrines
4. Alaska
5. Arctic Regions

I. Project 8246-1
II. CSA 61-1
III. Arctic Health Research Center, Anchorage, Alaska
IV. Walters, C. F. and J. Anderegg
V. Available from OTS
VI. In ASTIA collection

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