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BIOLOGICAL TREATMENT FOR WASTE STREAMS FROM PROPELLANTS AND EXPLOSIVES MANUFACTURING

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ABSTRACT

The liquid waste streams from the propellants and explosives production operations are different from the standard industrial waste streams because of the presence of military unique pollutants. Three pilot studies were conducted on each of the unique streams from Holston AAP, Radford AAP, and a stimulated stream for a new facility being considered for the production of RDX/HMX. Both the activated sludge system and the rotating biological contactor system were investigated. Both systems show a high degree of BOD removal. Each exhibited certain advantages. In both systems carbon columns are needed to remove the nonbiodegradable contaminates from the streams. An optimum treatment approach may be a hybrid system.

INTRODUCTION

Most of the Army propellant and explosives plants were built in the early 1940s to supply munitions for World War II. Since pollution abatement requirement were considerably less strict then than at present, these plants could not meet current water quality standards. Because of this, the Army conducted extensive modernization and pollution abatement programs at all of its ammunition plants. The treatment of waste process waters from these plants requires development of new or modification of existing technology because of the unique nature of the pollutants in the water. These wastewater treatment studies were funded by the U.S. Army Armament Research and Development Command, Dover, New Jersey.

RADFORD ARMY AMMUNITION PLANT STUDY

In 1970, extensive laboratory bench-scale studies were initiated at Radford Army Ammunition Plant (RAAP) on the various water streams to determine their chemical and physical makeup, and the most effective treatment methods (ref. 1).

Studies were conducted to determine which wastewaters could be discharged without treatment, recycled, reused in another process area, and which wastewaters required pretreatment. As a result of these studies, the quantity of water requiring treatment was reduced from 95,000 m^3/d to a maximum of 9500 m^3/d. The principal contaminants in this wastewater are ethyl alcohol, ether, acetone, with traces of nitroglycerin (NG) and other nitrate esters, and miscellaneous propellant ingredients. The studies demonstrated that the wastewater could be treated by a biological system; however, pilot-scale studies were required to define the design criteria for a full-scale facility. An activated sludge system was selected for this pilot-plant study.

Activated sludge system evaluation

The biological pilot plant evaluation studies were initiated in 1975 to provide the design criteria for the treatment of wastewater from propellant manufacturing operations, and the pretreated wastewater from the NG manufacturing areas (ref. 2)

The activated sludge pilot plant used for this evaluation consisted of a storage and mix tank, an aeration basin, and a clarifier (Fig. 1).

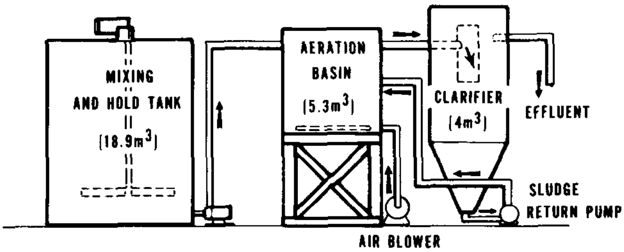

Fig. 1. Activated sludge pilot plant operation, RAAP

The influent wastewater for the pilot plant was mixed in an effort to produce a wastewater mixture having a chemical oxygen demand (COD) of approximately 400 mg/l and a biochemical oxygen demand (BOD) of about 160 mg/l to simulate the wastewater expected after the wastewater flow is reduced to 9500 m^3/d in the new collection system.

During the first two weeks of pilot plant operation, the activated sludge settled good, sludge production was high, the effluent suspended solids was low, and the BOD removal efficiency remained above 90 percent most of the time. After the seventeenth day of operation, the sludge became dispersed, losing its ability to settle, and started washing out of the system which greatly increased the effluent suspended solids. Efforts were made to allow the system to recover; however, eleven days later the system had deteriorated to a state where recovery seemed improbable and the run was terminated. Figure 2 shows the organic loadings mixed liquor volatile suspended solids (MLVSS), and organic removal efficiencies for this test period.

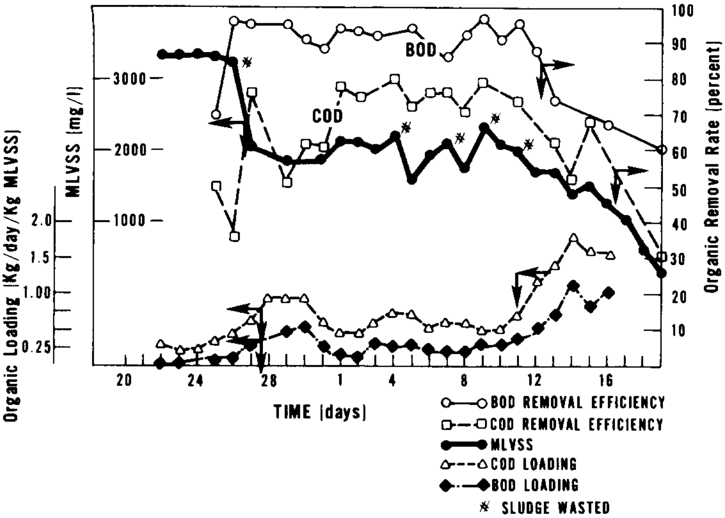

Fig. 2. Activated sludge pilot plant results, RAAP

Several additional runs were conducted using fresh sludge from local activated sludge treatment plants. Similar problems were encountered on each of these runs with the dispersed sludge or a bulking or high filamentous sludge when the organic loadings were increased. Studies were conducted to determine the cause of the dispersed sludge, but without success.

From this evaluation it was concluded that an activated sludge biological treatment facility was not suitable for RAAP wastewaters because of the dispersed sludge problem, and an alternate treatment method would be required.

Aerobic rotating biological contactor (RBC) pilot plant evaluation

A 0.5 meter diameter 1.6 meter long RBC pilot plant was leased from Autotrol Inc. for an evaluation of a RBC process on the RAAP wastewaters (Fig. 3). The RBC unit consisted of a series of 36 corrugated polyethylene discs containing a total of 23.2 m^2 of surface area. Approximately 40 percent of the disc media was submerged in the wastewater contained in a semicircular aluminum tank. With a nominal amount of biomass on the operating media this tank contained approximately 100 liters of wastewater.

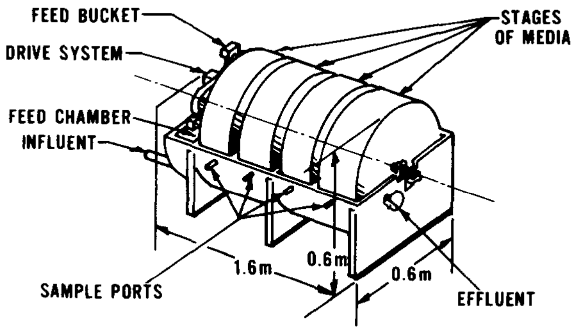

Fig. 3. Rotating biological contractor (RBC) pilot plant, RAAP

The discs and tank were divided into four stages separated by bulkheads. The bulkhead between the first and second stage was removable. The wastewater was pumped into the feed chamber by a metering pump where it was picked up by buckets on feed arms which rotated with the disc. As the arm rotated, the wastewater flowed through the hollow arm into the center of the aluminum tank. Microorganisms produced from the decomposition of the organic material in the wastewater attached and grew on the polyethylene discs, securing the necessary oxygen from the air when not submerged, and carrying it into the water. Excess biomass sheared from the disc from its motion through the wastewater was kept in suspension by rotational mixing forces until the hydraulic flow carried it out of the pilot plant. This unit was installed in a small enclosed shelter beside the activated sludge pilot plant, where it was evaluated concurrently with the activated sludge pilot plant. The RBC unit was started at a hydraulic loading of 0.09 $m^3/m^2 \cdot d$ of surface area, or 2 m^3/d, and an organic loading of approximately 35 kg/1000 $m^2 \cdot d$ of surface area. The COD removal efficiency of the four stages ranged between 73 and 87 percent during the first month of operation. During the second month, the pilot plant continued to be operated at a hydrualic load of 0.08 $m^3/m^2 \cdot d$. The BOD and COD loadings remained similar to the previous month. The removal efficiency was above 90 percent for the BOD and above 80 percent for the COD for most of the period.

During the operation of the pilot plant, the dissolved oxygen (DO) was analyzed in each of the RBC compartments every two hours. During the first two months of operation, the following DO ranges were observed:

Stage	DO (mg/l)
1	1.0 to 2.5
2	2.2 to 4.1
3	4.1 to 5.6
4	5.0 to 6.9

In order to prevent periods of low DO (below 1.5) in the first stage with resulting reductions in biological activity and to better distribute the organic loading between the first and second section of the RBC, the pilot plant was changed to a three-stage system (one large and two small stages) at the end of the second month. This was accomplished by removing the weir between the first and second sections of the RBC.

This three-stage system was operated at a hydraulic loading of 0.8 $m^3/m^2 \cdot d$ a COD loading of 30 to 45 $kg/1000\ m^2 \cdot d$, and a BOD loading of 12 to 24 $kg/1000\ m^2 \cdot d$ for another one and a half months. During this period, the DO in the first stage ranged between 1.5 to 3.4 and the removal efficiencies were above 90 percent for the BOD and above 80 percent for the COD for most of the third month. During the first half of the fourth month, the BOD and COD removal efficiencies increased to above 95 and 90 percent, respectively (Fig. 4).

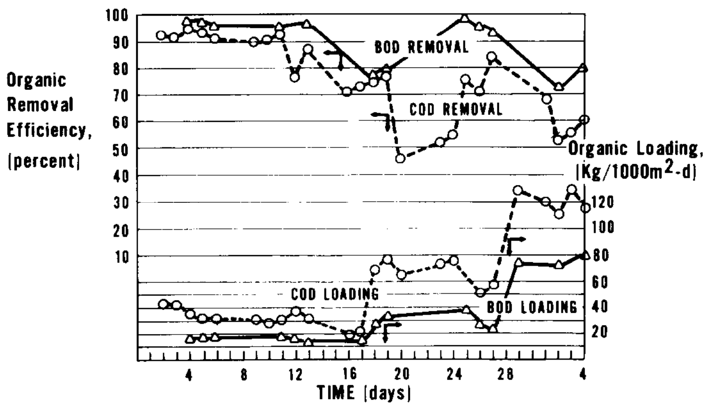

Fig. 4 RBC organic loadings and removal efficiency, RAAP

In order to be able to predict how the expected variations of hydraulic and organic loadings to the full-scale facility would affect the RBC performance, shock load testing was initiated on the fourteenth day. On this date the flow rate was suddenly increased from 2 to 4 m^3/d. In order not to affect the organic loading, the organic concentration in the wastewater was reduced. This change did reduce the COD removal efficiency; however, the effluent COD concentration did not change. On the eighteenth day, the organic concentration of the influent was doubled. This sudden increase caused the effluent COD to increase to 208 mg/l three days later, dropping the COD reduction to 46 percent. However, by the twenty-fifth day, the biomass on the RBC had become noticeably thicker and the BOD and COD removal had recovered and increased up to 98 and 76 percent, respectively. Another shock load was applied on the twenty-seventh day to further determine the systems tolerance to shock loads. This shock load caused the BOD and COD removal to decrease to 58 and 52 percent on the thirty-first day. Three days later, the system had started to recover. The evaluation was then terminated and the system shut down.

Anaerobic/aerobic RBC pilot plant evaluation

As part of the modernization program a Continuous Automated Multi-Base Line (CAMBL) manufacturing facility is planned for construction at RAAP to augment the present labor intensive batch process. As a result, additional studies were required to develop design criteria for a facility to treat the wastewaters that will be generated in the CAMBL (ref. 3).

Wastewater characterization. A wastewater characterization study was conducted for the CAMBL manufacturing facilities. Samples of the wastewaters were collected and analyzed during the evaluation of a prototype CAMBL manufacturing line. These data were compiled, and the expected characterization of the full-scale facilities were determined. The quantity of water requiring treatment from the CAMBL facility was determined to be approximately 200 m^3/d. This wastewater will contain acetone, ethanol, NG, nitroguanidine (NGu), other propellant ingredients, and inorganic nitrates.

Laboratory treatment studies. Laboratory-scale treatment studies were conducted to determine the feasibility of selected treatment methods and to define the design parameters for pilot plant studies. These studies showed that NGu alone is not biodegradable, but when mixed with a readily-biodegradable compound NGu is biodegradable.

Studies conducted by Wendt (ref. 4) showed that NG is biodegradable, but it does exert a toxic effect on the biological metabolism.

The biodegradability of NG and NGu was further studied using a laboratory-scale RBC unit. During the first ten days of the study, the RBC influent contained a COD concentration ranging from 500 to 1000 mg/l, a NGu concentration varying from 30 to 70 mg/l, and a NG concentration of approximately 5 mg/l. During this period, the COD removal was approximately 90 percent; the NGu removal ranged between 50 to 90 percent while achieving 100 percent NG removal.

During the latter part of this study, the NG concentration was increased to 30 mg/l. This increase in the NG concentration caused a slight reduction in the COD and NG removal; however, the NGu removal greatly decreased, dropping to almost zero 24 hours after increasing the NG concentration. From this laboratory-scale RBC study, it appeared that both NG and NGu were biodegradable; however, the removal of NGu is affected by the NG concentration.

Based on the wastewater characterization and laboratory studies, two design concepts were considered for this proposed wastewater treatment facility: (1) design a completely new chemical-physical treatment facility for the treatment of this wastewater alone, or (2) expand on the aerobic RBC treatment plant presently under construction at RAAP for the treatment of the wastewater from the existing manufacturing facilities.

Alternative (2) was selected for the pilot plant evaluation, based on the estimated savings of over $800,000 in capital costs and an annual savings of about $160,000 in operating costs. The characterization of the wastewaters from the existing manufacturing facilities, the proposed CAMBL facility, and the combined facilities are shown in Table 1.

TABLE 1

Characterization of wastewaters of existing and proposed facilities

Parameter	Existing facility	Continuous facility	Combined facilities	Increase due to continuous facility
Flow, m^3/d	4712	220	4932	4.6%
COD, kg/d (mg/l)	2145	857	3002 (607)	40.0%
BOD, kg/d (mg/l)	858	343	1201 (243)	40.0%
NO_3, kg/d (mg/l)	1375	65	1440 (304)	4.7%
NG, kg/d (mg/l)	--	6.5	6.5 (1.50)	
NGu, kg/d (mg/l)	--	26	26 (5.28	

The permit issued by the EPA and Commonwealth of Virginia for the wastewater discharge from the aerobic RBC treatment plant was based on the present manufacturing facilities only. Thus, any new manufacturing facility constructed at RAAP must provide facilities for treatment of the wastewater generated by that facility to ensure the effluent quality is not degraded.

The hydraulic capacity of the RBC plant, as designed, will be adequate for the combined facilities wastewater, but additional treatment facilities will be required for the removal of the increases in the BOD, COD, NG, and NGu. The removal of the additional inorganic nitrates can best be accomplished by a biological denitrification system. Therefore, the decision was made to evaluate on a pilot plant-scale the use of submerged RBC units for the biodenitrification process.

Pilot plant evaluation. To develop the design criteria for the treatment of the combined RAAP wastewaters, a new one-half meter RBC unit capable of independent operation of each stage as aerobic or anaerobic was purchased from Autotrol Inc. This RBC unit contained a total of 23.2 m^2 of surface area. The discs and tank were divided into four stages, separated by removable bulkheads. Each bulkhead consisted of a top and bottom section, whereby, each stage could be operated either completely or 40 percent sugmerged.

The first phase of evaluation of this unit was conducted with all four stages completely submerged to determine the feasibility of the decomposition of organic solvents, NG, and NGu under anaerobic conditions and to determine the rate of nitrate reduction in a biological denitrification system. The system was operated during this period at average organic loadings of 30 kg COD and 12 kg BOD per day per 1000 m^2 of surface area. The NG and NGu concentrations were both maintained between one and five mg/l to simulate the concentration expected in the full-scale facility and to prevent NG-NGu interreactions. During this phase of the evaluation the unit averaged 84 percent COD, 90 percent BOD, 94 percent NGu, and 100 percent NG removal. The nitrate removal rate was calculated to be 66 kg/1000 m^2 of surface area. The laboratory and preliminary pilot plant data indicated that a biological denitrification RBC system, followed by aerobic units, was a feasible treatment method for the removal of the organics, NG, NGu, and inorganic nitrates from the CAMBL manufacturing facility.

A preliminary design of a system for the treatment of the combined wastewaters consisted of four additional completely submerged RBC shafts preceeding the eight aerobic RBC shafts under construction. To evaluate the efficiency of this proposed system, the pilot plant RBC unit was converted to a four-stage system, the first stage anaerobic, followed by three aerobic stages (Fig. 5). The sample collection points for the evaluation were selected at the first stage influent and effluent, and the third stage effluent, therefore, simulating the results from the proposed full-scale facility.

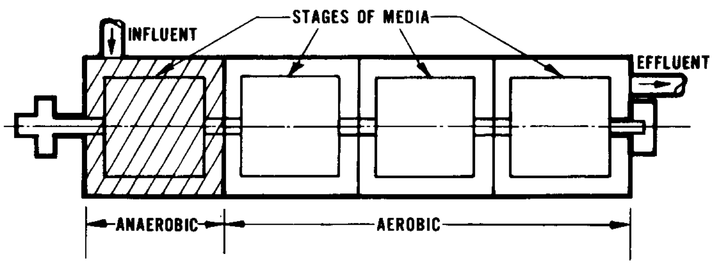

Fig. 5. RBC pilot unit anaerobic/aerobic system, RAAP

Studies were conducted during the last month of the evaluation to determine if this RBC system could operate effectively under the worst conditions expected in a full-scale facility and still produce an effluent meeting the required discharge standards. The system was operated at an average organic loading of 1.3 times the design loading, NG loading 3.5 times the design loading, and an NGu loading of twice the design loading. The system was operated at a low temperature of from 6 to 12°C during this period. See Figure 6 for the results of this evaluation. During this phase, the allowable daily average COD of 190 mg/l was exceeded on only two days; however, the maximum daily COD effluent concentration of 290 mg/1 was never exceeded. These adverse operating conditions reduced the average COD removal from 85 percent to 74 percent; however, the NG and NGu removals remained near 100 percent most of the time. Figure 7 shows the average BOD and COD remaining and the cumulative BOD and COD removal efficiency after each stage of treatment for this study.

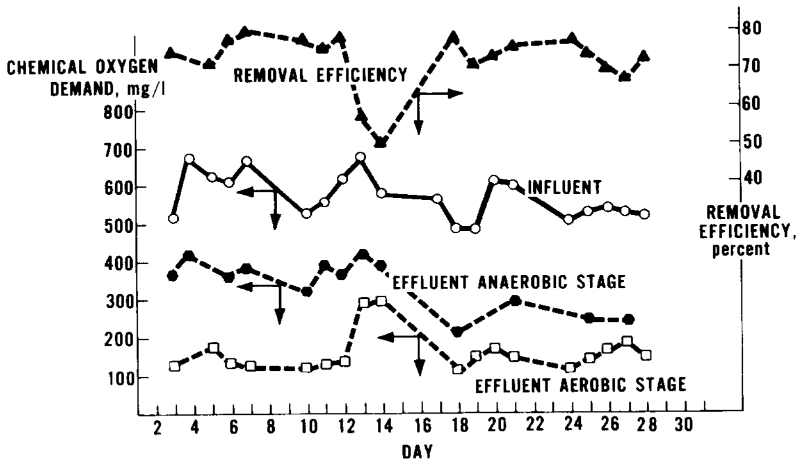

Fig. 6. RBC organic reduction, anaerobic/aerobic system, RAAP

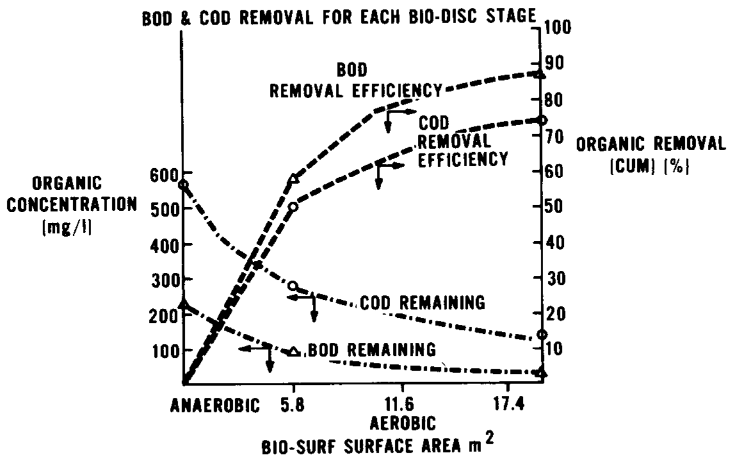

Fig. 7. RBC pilot plant operation average cumulative, anaerobic/aerobic system, RAAP

The data from the pilot plant RBC evaluation were analyzed to determine the ratio of organic removal rates to the inorganic nitrate removal rates under various operating conditions. During the first phase of the evaluation the pilot plant cover was installed to provide a completely anaerobic system. This evaluation showed the nitrate removal rate to be 66.4 kg/1000 $m^2 \cdot d$ NO_3. During the later evaluations, the RBC cover was removed and the wastewater in the anaerobic stage was exposed to the atmosphere, allowing oxygen to diffuse into the wastewater, greatly reducing the nitrate removal rate (Fig. 8). Based on the results of this phase the nitrate removal rate was calculated to be 16.6 kg/1000 $m^2 \cdot d$ NO_3 The great differences in the nitrate removal rate between a covered and uncovered system can provide a method to control the nitrate utilization of the submerged RBC stage in the full-scale facility. The system can be designed with removable cover section to provide a flexibility to compensate for low or high nitrate concentrations in the facilities influent.

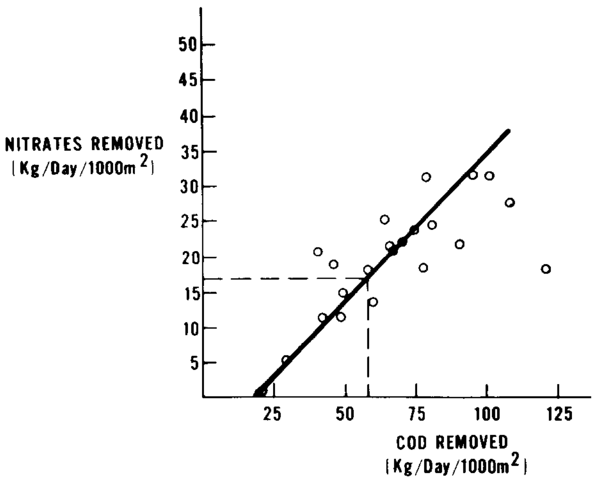

Fig. 8. RBC nitrate removal, anaerobic/aerobic system, RAAP

Design criteria

Based on the data from this evaluation, the design criteria for a rotating biological surface treatment facility were prepared. Figure 9 shows the flow diagram of the proposed RAAP facility for the treatment of the combined wastewater. These design criteria were submitted to the Corps of Engineers for the design of the facility. The final design has been completed and construction of the aerobic facility at RAAP is scheduled to be completed by November 1980. The construction of the anaerobic addition to the facility is scheduled to be initiated in 1981.

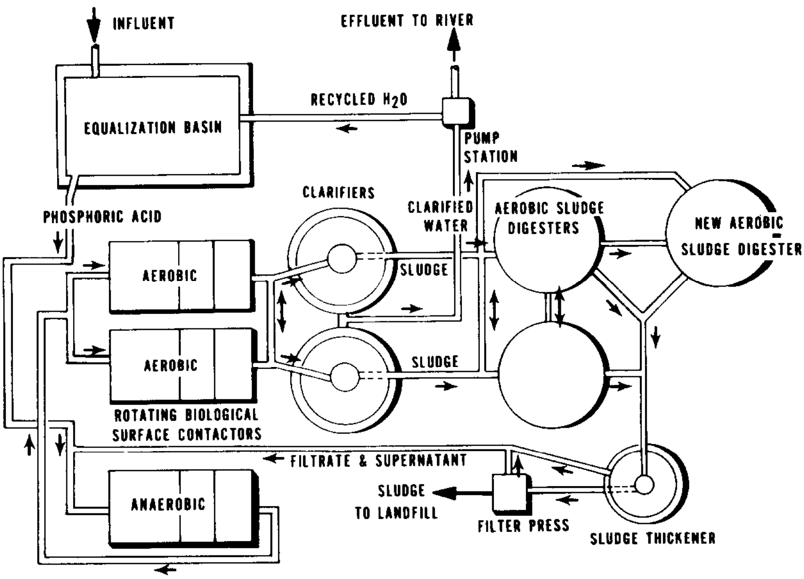

Fig. 9. Proposed wastewater treatment facility, RAAP, flow diagram

HOLSTON ARMY AMMUNITION PLANT STUDY

The major sources of water pollution at Holston Army Ammunition Plant (HAAP) result from acetic anhydrate production, acetic acid refinement and recovery, explosive recovery, nitric acid manufacture, and steam generation. The major pollutants are cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), trinitrotoluene (TNT), nitrate-nitrite nitrogen (NO_3NO_2-N), suspended solids, and miscellaneous organics.

Laboratory studies were conducted at Purdue University to determine feasible treatment methods for the HAAP wastewater (ref. 5). The concept design process developed from this study included the following: preliminary neutralization, biodenitrification, aerobic biological treatment, filtration, and re-aeration.

The investigation revealed that activated sludge systems were not suitable for use at HAAP due to the development of filamentous growth. Biological fixed-film denitrification (submerged anoxic filters) and aerobic fixed-film reactors (trickling filters) were recommended for the treatment of HAAP wastewater.

A pilot plant evaluation of certain phases of the treatment processes was conducted by the Holston Defense Corporation, operating contractor of HAAP (ref. 6)

It became apparent early in the study that a trickling filter alone would not sufficiently remove organics from HAAP wastewater; therefore, it was necessary to modify the pilot plant operations to include activated sludge processes.

Pilot plant evaluations of two treatment processes were conducted on the HAAP wastewater (Fig. 10).

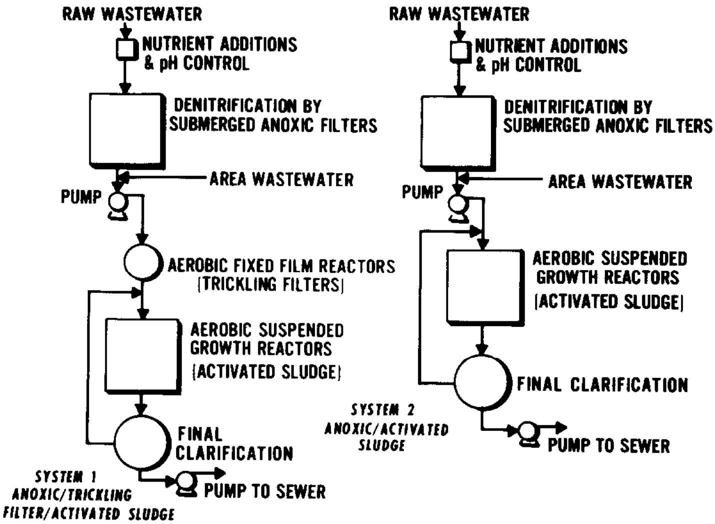

Fig. 10. Schematic diagrams of pilot plant, HAAP

Anoxic filter operation

In both of the pilot plant configurations the first treatment step was an anoxic filter for the removal of inorganic nitrates. An upflow anoxic tower, using a polyvinyl chloride media, 0.36 m in diameter and a media height of 4.88 m, which contained sample ports every 0.61 m, was used for the study.

The filter was operated at a flow rate of 8.15 x 10^{-4} $m^3/s/m^2$. It was found that most of the nitrate removal occurred in the first 1.8 m and that the average nitrate concentration was reduced from 30 mg/l to 1.5 mg/l in the lower 3.1 m of media.

Activated sludge evaluation

Two bench-scale activated sludge units were constructed from 38 liter glass aquariums. One unit was evaluated as an independent activated sludge system and the second as a trickling filter/activated sludge process.

The independent activated sludge system was evaluated to determine if sludge bulking would occur and the appropriate methods of control. An equally important goal, however, was to determine the minimum aeration time necessary to produce the required effluent BOD_5 and COD. The solids residence time (sludge age) was maintained at eight days for this system. Other sludge ages were not evaluated because of limited time for the project.

During the first month the system operated at a nine-hour aeration period at which time the aeration time was increased to 12 hours to determine whether a lower effluent BOD_5 and COD was achievable.

During the time the system was operating at a nine-hour aeration period the average COD and BOD_5 reductions were 80 and 91 percent, respectively.

The COD data for the 12-hour aeration period are presented in Figure 11. During this evaluation a COD and BOD_5 reduction of 85 and 96 percent, respectively, was obtained, producing an average effluent of 20 mg/l BOD_5 and 71 mg/l COD.

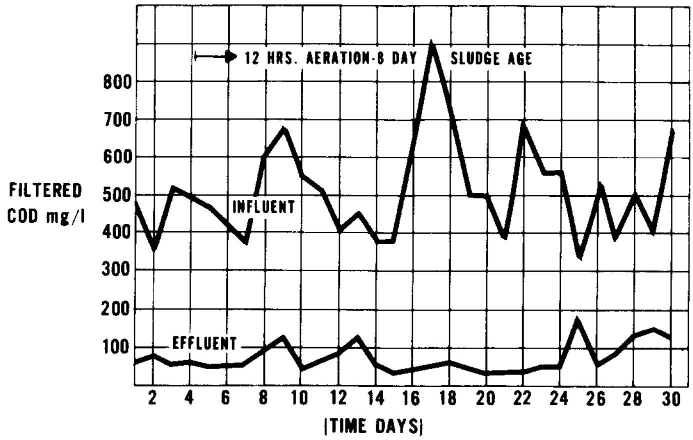

Fig. 11. HAAP activated sludge system, effluent COD versus time

The sludge characteristics for the 12-hour aeration period are presented in Figure 12.

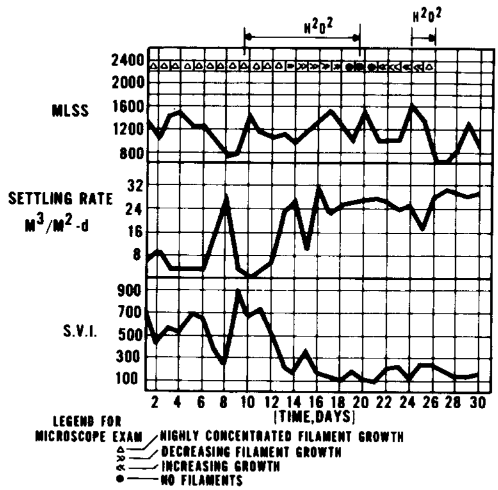

Fig. 12. HAAP activated sludge system, SVI, MLSS versus time

The average sludge volume index (SVI) for the 12-hour aeration period was 319 mg/l. If only the data between the sixteenth to thirtieth day are considered (this is the period following peroxide treatment for the bulking sludge), the average SVI was 171 ml/g. During periods where the sludge bulking was kept under control, the 12-hour aeration resulted in better sludge settling characteristics than the nine-hour aeration. During the study, hydrogen peroxide was effective in temporarily eliminating the filamentous organisms.

Trickling filter activated sludge evaluation

The main purpose of the biological system evaluation was to study the organic removal rate in the trickling filter process. However, the need for alternate removal systems became obvious when pilot plant data showed reduction rates substantially less than predicted by the earlier laboratory aerobic biological studies conducted by Purdue University (ref. 5).

There were two objectives in evaluating the trickling filter/activated sludge system; the first was to determine if bulking would occur, and the second was to determine the reaction rate coefficient and the minimum required aeration time. The sludge age in the activated sludge system was first maintained at eight days. When bulking was noted, the sludge age was reduced to three days in an attempt to wash the filamentous organisms from the system. The COD data for this system are presented in Figure 13.

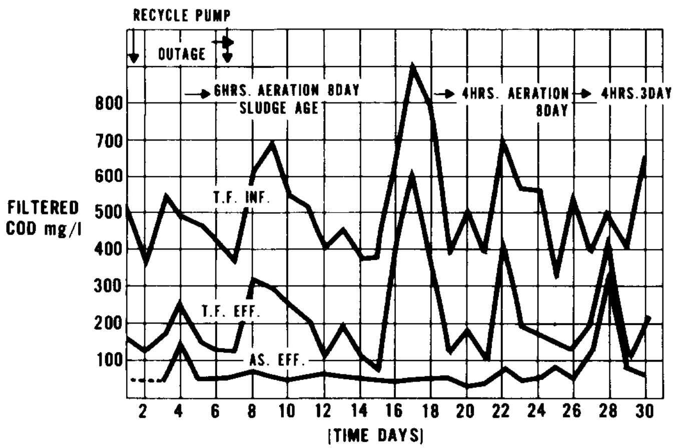

Fig. 13. HAAP trickling filter/activated sludge system, effluent filtered BOD versus time

The system was operated at six hours aeration time with an eight-day sludge age for the first two weeks. During the third week the aeration period was reduced to four hours and the sludge age maintained at eight days. During the fourth week the sludge age was reduced to three days with the aeration period being maintained at four hours.

During the six-hour aeration period there was no evidence of sludge bulking. A COD and BOD_5 reduction in the activated sludge system of 76 and 85 percent, respectively, was achieved, producing an average effluent of 19 mg/l BOD_5 and 55 mg/l COD. The COD and BOD_5 removals for the four-hour aeration periods were approximately the same as for the six-hour aeration periods, the COD and BOD_5 reduction in the activated sludge system being 70 and 90 percent, respectively. The sludge characteristics for this study are presented in Figure 14.

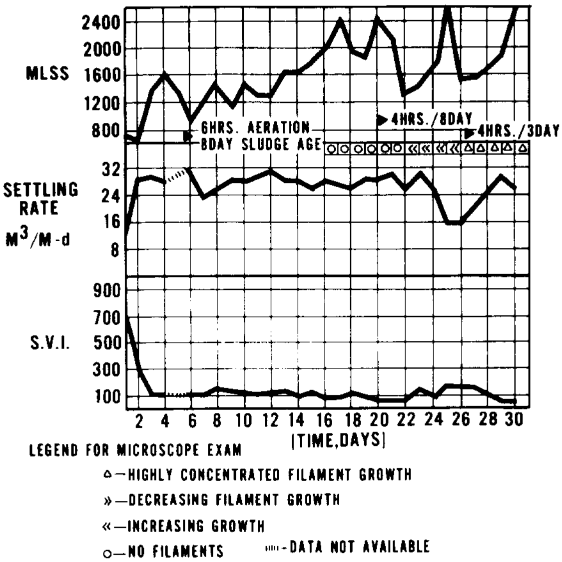

Fig. 14. HAAP trickling filter/activated sludge system, SVI, settling rate, MLSS versus time

The average SVI at four hours aeration time was slightly higher and the average settling rate was slightly lower than at the six-hour aeration. This was due to the bulking from the filamentous growth which started during this period of the study. To combat the filamentous growth, the sludge age was reduced to three days. The sludge bulking continued and the sludge characteristics deteriorated for the next 21 days. The system then recovered from the bulking condition without the use of chemicals. This suggests that bulking may be controlled, but not eliminated, during the three-day sludge age period.

Based on performance predicted from these pilot plant results, a wastewater treatment facility consisting of an anoxic tower, trickling filter, and a six-hour aeration activated sludge system will provide an effluent quality which will meet the NPDES standards. The schematic diagram of the HAAP proposed waste treatment system is presented in Figure 15.

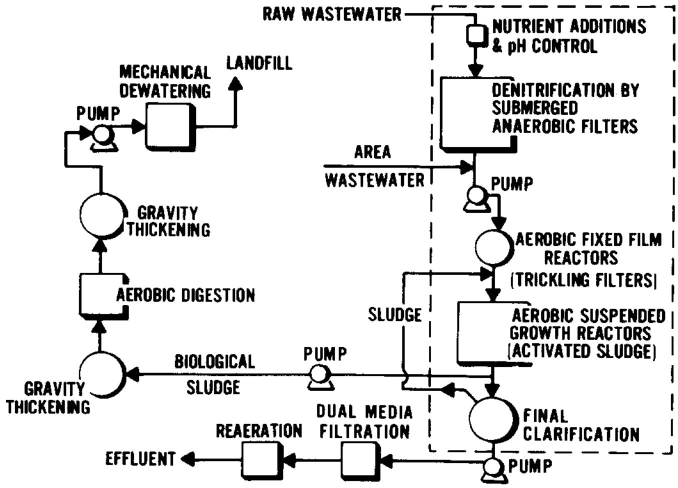

Fig. 15. Schematic diagram of HAAP proposed waste treatment system

PILOT SCALE EVALUATION OF THE TREATABILITY OF RDX/HMX SITE "X" FACILITY WASTEWATER

The U.S. Army is designing a new facility for manufacture of RDX and HMX. This facility, RDX/HMX Site "X", will incorporate not only the explosive production but all the ancillary processes necessary to manufacture and blend these explosives. These ancillary processes will include nitric acid plants, acetic acid dehydration, acetic anhydride production, explosives formulation and blending operations, and wastewater treatment facilities. Preliminary cost studies indicated that the RBC would be preferred technology for treatment of "X" facility wastewaters, provided technical feasibility could be demonstrated.

The "X" facility wastewaters contain the same pollutants as found at HAAP. However, the quantity and quality of the projected "X" facility wastewaters are significantly different from that found at HAAP. The expected volumes of wastewater are less than at HAAP due to new manufacturing methods coupled with extensive at-source pollution control. Because the wastewater volume has been substantially reduced, the concentrations of many of the individual components in the "X" facility wastewater exceed that in evidence at HAAP. In particular, high concentrations of formaldehyde appeared to be a potential problem since this chemical is inhibitory to many microorganisms.

The speculative nature of the preliminary design led ARRADCOM to contract Mobility Equipment Research and Development Command (MERADCOM) and Atlantic Research Corporation (ARC) to perform bench-scale and pilot-scale studies to evaluate the treatability of the "X" facility wastewaters with RDX. These contracts were for six-month experimental studies aimed mainly at determining feasibility and obtaining a data base for design criteria for the "X" facility wastewater treatment plant.

A pilot-scale evaluation of aerobic RBC treatment of synthetic "X" facility wastewaters was conducted by Atlantic Research Corporation (ref. 7).

The principal objective of the program was to evaluate the ability of the RBC aerobic system to remove organic material from the wastewater generated by the RDX/HMX Site"X" facility.

A four-stage aerobic RBC pilot plant, manufactured by the Environmental Systems Division of Geo. A. Hormel and Company, was used in this evaluation. This unit has four stages which can be arranged in series, parallel, or any combination thereof. Each stage has twelve 1.2 m diameter polyethylene discs packaged together and attached to a central shaft. The area of each stage is 39 m^2. The total disc area of the pilot unit is 156 m^2. The speed of rotation could be varied from 0 to 20 rpm.

After review of the wastewater flow and contaminant levels, ARC was instructed to evaluate two synthetic wastewaters. Condition "A" is the total dry weather wastewater with a total flow of 5846 m^3/d. For condition "B", 2067 m^3/d from the heat exchanger condensate are eliminated from waters entering the wastewater treatment facility. The resulting stream has a flow of 3779 m^3/d and except for the sulfate concentrations, the concentrations of the contaminants are $\sim$1.55 times condition "A".

Start-up of RBC unit

The initial inoculum consisted of 4 liters of primary effluent from Arlington Sewage Treatment Plant, 50 ml of formaldehyde, and 50 gm of nutrient broth per chamber. The RBC was allowed to grow in a static mode for 10 days with daily feeding of 50 ml formaldehyde and 10 ml corn steep liquor per chamber. Significant growth on the discs was observed.

Pilot unit operations on the "A" wastewater

The "A" stream was introduced into the pilot RBC one week after biological growth in the unit was established. The initial feed was made according to the concentrations given for the maximum "A" stream values; however, no explosives were added. This solution was neutralized to $\sim$pH 7 with ammonium hydroxide and sodium hydroxide. The ammonium hydroxide was added to supply a nitrogen source for the microbial growth. The hydraulic loading to the RBC was an influent flow rate of 1500 l/d. The RBC was operated in a series mode, i.e., influent → chamber 1 → chamber 2 → chamber 3 → chamber 4 → effluent.

The results obtained from the pilot RBC operation during the second week of operations were very erratic. During this period of operation, COD reduction varied between 60 and 80 percent. However, good formaldehyde reductions were obtained. The initial growth, that was observed uniformly throughout the chambers before the "A" stream operation, sloughed off. This growth was replaced by a cream colored fungus in chamber 1. Chambers 2, 3, and 4 had no significant biological growth on the discs.

The daily analyses for the RBC operation on the "A" stream are presented in Figure 16.

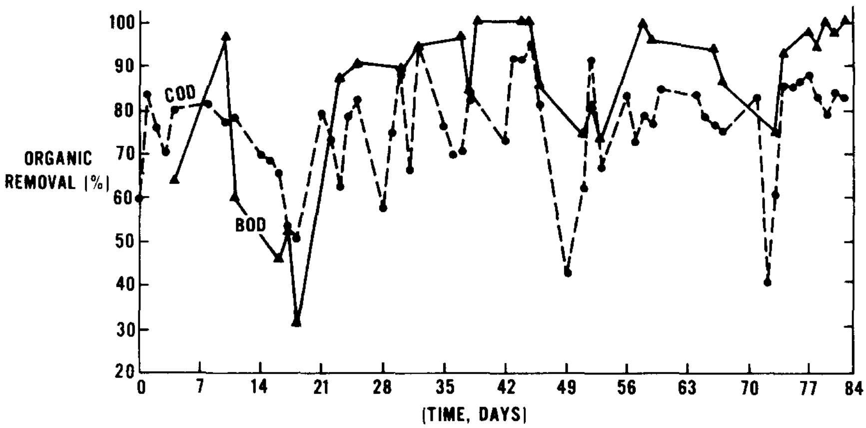

Fig. 16. Operational results X facility wastewater treatment evaluation "A"

On the twenty-third day the explosives, RDX, HMX, and TNT, were added to the "A" stream. The RDX and HMX explosives flowed through the pilot unit essentially unchanged. The TNT photolyzed in the influent tank. The only effect this explosive had on the RBC operations was to color the growth on the first disc pink.

Initially, the pH in the influent tank was adjusted to between 7.0 and 8.0 with ammonium hydroxide and sodium hydroxide. However, the pH of the synthetic influent dropped to ∿5.0 in one to two days after its preparation. In order to maintain a relatively constant influent pH, sodium hydroxide was added to the tank on a daily basis. This method of pH adjustment did not provide a constant pH to the RBC. A large amount of biological growth was also observed in the feed tanks.

In order to remedy this situation, a pH adjustment tank was placed in the feed line to the RBC. This set-up provided a more constant pH influent to the RBC. In addition, the pH in the main feed tank could be maintained below 5 to discourage microbial growth.

The problem of pH variations in the influent was further compounded by a drop in pH in the first RBC stage. When a biological system is metabolizing a neutral organic compound such as formaldehyde, the pattern of metabolism results in the formation of organic acids which, in the absence of a buffering agent, causes a drop in pH in the wastewater. In an attempt to control the pH in the first stage of the RBC unit, sodium hydroxide was added to the RBC unit on a continuous basis. Since the formaldehyde concentration in the influent varied from day to day, the hydroxide demand also varied, causing wide pH fluctions. Because of this varied pH, the biological growth on the RBC media was predominantly fungi. Only during the period between the fifty-sixth and seventy-first days of the evaluation was the influent and first stage pH maintained in the 6.5 to 9 range. This is the same period where the most consistent COD and BOD reduction occurred.

Pilot unit operations on the "B" wastewater

During the last three months of the study the "B" wastewater was fed to the RBC pilot unit. The influent flow rate was reduced to 760 l/d in order to maintain the BOD loading less than 13.2 kg/1000 $m^2 \cdot d$. The sequence of events and observed COD and BOD reductions for ∿2 months of pilot operations on the "B" wastewater are presented in Figure 17.

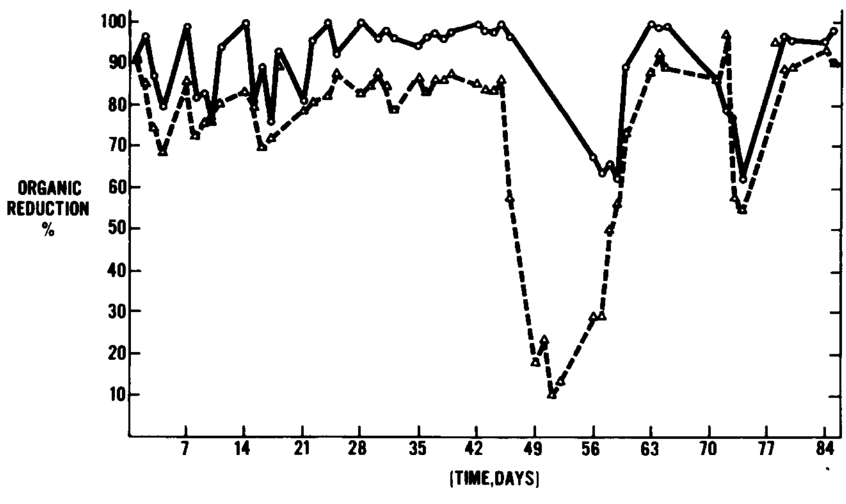

Fig. 17. Operational results X facility wastewater treatment evaluation "B"

After a period of flow adjustments and pH control problems, steady state operation was obtained during the period between the eighteenth and forty-sixth days. Both the influent and first stage pH was maintained between 6.5 to 8 during this period. The COD reductions averaged between 80 and 86 percent, and the BOD reductions between 95 and 100 percent. On the forty-seventh day, the temperature fell below 10°C, and remained low for several days. Problems were also encountered with the pH control again. As a result of the pH variations and colder temperature, the BOD and COD reduction efficiency dropped severely. The pilot plant was moved indoors on the fifty-eighth day. The organism recovered within seven days and the percentage COD and BOD reductions returned to the 80-85 percent and 95-100 percent levels, respectively, until pH problems occurred on the seventy-second day.

The results of this RBC study are presently being evaluated and a determination will be made whether to use an RBC system or a combination system such as is being constructed at HAAP for the new "X" facility wastewater.

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