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Effects of Liquid Detergent Plant Effluent on the Rotating Biological Contactor

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EFFECTS OF LIQUID DETERGENT PLANT EFFLUENT ON THE ROTATING BIOLOGICAL CONTACTOR

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report concerns itself with the "Effects of Liquid Detergent Plant Effluent on the Rotating Biological Contactor" and the possible presence of toxic chemicals in a plant's liquid waste. Results of the study will prove of interest to those persons who may find a need for on-site primary and secondary treatment of plant effluent but have insufficient available land to construct an aerated lagoon system or other conventional treatment facility. The reader's attention will be focused on the efficiency of the rotating biological contactor as compared to an aerated lagoon system and problems that may be encountered in design and operation of this newly developed technique. Additional information on the results of the report may be obtained by contacting:

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ABSTRACT

A pilot-scale investigation to determine the efficiency of the rotating biological contactor (RBC) on raw wastewater from a liquid detergent manufacturing plant has been undertaken. Efficiency of the RBC was compared with a presently operating, extended aeration lagoon system, each receiving identical waste.

Selected parameters were chosen for measurement, including chemical oxygen demand (COD), biochemical oxygen demand (BOD), methylene blue active substance (MBAS), and dissolved oxygen (DO). The effects of temperature, loading, and sudden changes in concentration of MBAS were monitored for effects on the biomass adhering to the disc. In some cases, studies were also conducted to determine the efficiency of each of the three operating stages.

Even under the best operating conditions, the RBC performance was essentially equivalent to that of the (operating) extended aeration lagoon. At other times, especially when the temperature dropped to 15°C or below, the RBC was inefficient compared to extended aeration. The temperature of the air above the discs needed to be kept approximately the same as that of the wastewater feed to avoid inhibiting bacterial growth on the discs. Furthermore, the biomass was found to be highly sensitive to sudden changes in MBAS concentration and development of foam. Within hours after contact with an increase in MBAS or excessive foaming, the mass would be stripped from the disc, rendering degradation efficiency nearly zero.

A second phase of the study was to determine qualitatively and quantitatively the presence of toxic inorganic and organic compounds in the raw and treated waste.

No toxic inorganics or organics were found in liquid detergent manufacturing waste except zinc, which was traced to the municipal water supply as received by the company. The quantity of zinc present appeared to have little or no effect on the biological system, however, and the concentration remained consistent between the influent and effluent streams.

This report was submitted in fulfillment of Grant No. S-803892013 by Texize Chemicals Company under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period August 13, 1975 to June 30, 1977, and work was completed as of June 30, 1977.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

°C	-- Degrees centigrade.
BOD	-- Biochemical oxygen demand without time limits designated. Measured in milligrams per liter.
BOD_5	-- Biochemical oxygen demand measured in 5 days. Measured in milligrams per liter.
COD	-- Chemical oxygen demand. Measured in milligrams per liter.
DO	-- Dissolved oxygen. Measured in milligrams per liter.
EPA	-- U.S. Environmental Protection Agency.
Eff	-- Effluent.
gpm	-- Gallons per minute.
Hp	-- Horsepower.
Inf	-- Influent.
l/min	-- Liters per minute.
MBAS	-- Methylene blue active substance. Used to quantitatively determine sulfated and sulfonated products. Units are milligrams per liter.
mg	-- Milligrams.
mg/l	-- Milligrams per liter.
pH	-- The measurement of acidity or alkalinity. pH 0-7 represents acidity, pH 7 is neutral, and pH 7-14 represents alkalinity.
ppm	-- Parts per million.
µg/l	-- Micrograms per liter.
RBC	-- Rotating biological contactor.
rpm	-- Revolutions per minute.
SVI	-- Sludge volume index.

METRIC CONVERSION CHART

Multiply	By	To Get
Inches	2.54	Centimeters
Feet	0.3048	Meters
Square feet	0.0929	Square meters
Cubic feet	0.0283	Cubic meters
Pounds	0.454	Kilograms
Gallons	3.79	Liters
Gallons/minute	5.458	Cubic meters/day
Feet/second	0.305	Meters/second

ACKNOWLEDGMENTS

The authors desire hereby to acknowledge their indebtedness to the many persons and organizations for their advice and efforts towards making this paper a contribution to the field of methods of wastewater treatment.

Especially we wish to commend the following for their guidance in developing the proposed plan of study: Mr. Fred Ellerbusch, former Project Officer who monitored the project until February 1977, Colin A. Houston & Associates, Inc., Mamaroneck, New York 10543.

Acknowledgment is also made of the use of published papers and textbooks as a source of material and/or test methods used to develop data noted in this study.

SECTION 1

INTRODUCTION

The research described in this report consists of two distinct phases:

- -- Evaluation of the rotating biological contactor (RBC) as a means of treating liquid detergent plant wastes, and

- -- Analysis of raw wastes and biologically treated wastes to determine the presence and treatability of selected chemicals or chemical families designated by the U.S. Environmental Protection Agency (EPA).

ROTATING BIOLOGICAL CONTACTOR PILOT STUDY

The RBC concept of treating waste streams biologically has been known for many years, but it was not until strong, lightweight plastics became available that significant interest in the technique began to develop. The treatment technique is to grow biologically active masses on a series of discs that slowly rotate, alternately exposing the biomass to the wastewater stream and the air above it. In early models, the discs were made of metal and were heavy, cumbersome, and subject to corrosion. Recent models have discs fabricated of polyethylene or polystyrene. Many investigators have found advantages for the RBC over activated sludge or other conventional treatment systems based on specialized circumstances. General advantages for the RBC system are described as follows.

Space

Biomass is concentrated on disc surfaces rather than dispersed throughout the wastewater.

Efficiency of Oxygen Transfer

Power requirements to achieve oxygen transfer are significantly lower than systems requiring aeration of the waste stream as the biomass absorbs oxygen from the air.

Acclimatization

Because the biomass is fixed on the disc surfaces rather than flushed through the system, it can become acclimated to a greater variety of waste streams, resulting in greater efficiency overall.

Ease of Operation

Food-to-mass ratios need not be controlled as in activated sludge systems. The system requires little expertise and minimum testing for smooth operation in routine installations.

In addition, the RBC unit can be installed in existing facilities such as clarifiers to upgrade marginal plant performance at minimum cost.

The Texize Chemicals Company is primarily interested in the RBC concept because of the space requirements and the simplicity of operation. Requests for information revealed that there was virtually none available on the operation of an RBC unit on the raw waste stream from a liquid detergent plant. To provide meaningful data, a pilot RBC unit was operated on the Texize wastewater stream and its performance compared to that obtained with the extended aeration lagoon system currently in operation.

ANALYSIS AND TREATABILITY OF RAW WASTES FOR TOXIC CHEMICALS

The analytical phase of the study arose from the EPA need to characterize the waste from a liquid detergent manufacturing plant with regard to its toxic constituents. The study consisted of a survey to determine the possible presence of specific toxic chemicals that could possibly be present in the raw wastewater stream and the treated wastewater from a liquid detergent manufacturing plant. Qualitative and quantitative analyses were conducted on the untreated and treated streams to confirm the presence or absence of the materials thought to be present. In addition, data were collected on the fate of those chemicals found to be present and their effects on biological action. The study was conducted using analytical techniques specified or approved by EPA when feasible.

SECTION 2

CONCLUSIONS

ROTATING BIOLOGICAL CONTACTOR PILOT STUDY

Data obtained in a pilot study on the performance of the RBC on a liquid detergent plant effluent indicate that satisfactory performance can be obtained only when operating under optimal conditions. Under the best conditions, degradation of wastes was approximately equivalent to that obtained in the extended aeration lagoon system currently being operated, but was considerably inferior at other times.

High levels of surfactant, measured as methylene blue active substance (MBAS), in the waste stream were found to have an inhibitory or toxic effect on the biomass affixed to the rotating discs. In addition, die-offs of biomass occurred when they were subjected to rapid decreases in wastewater temperature. Degradation levels achieved when waste stream temperatures were below 20^{o}C were also considered unsatisfactory.

Though problems were encountered in obtaining satisfactory levels of improvement in wastewater characteristics, the RBC concept is still considered viable where special problems must be overcome. The system requires relatively little space, and operation is simple and virtually maintenance free. Where space is limited and waste streams are relatively small, it may be possible to overcome the system deficiencies when operating at temperatures below 20^{o}C by preheating the waste stream before pumping it to the RBC unit. MBAS concentrations could be maintained at acceptable levels by recycling RBC effluent into the influent stream. Studies should be made to determine the feasibility of such control where space is a problem and/or a relatively small waste stream must be treated.

ANALYSIS AND TREATABILITY OF RAW WASTES FOR TOXIC CHEMICALS

Samples of raw, untreated plant effluent, effluent after secondary treatment, and effluent from the RBC were submitted to atomic absorption analysis for detection and measurement of inorganics appearing on the list of toxic substances. In addition, samples taken from identical locations were submitted to gas chromatographic analysis for organic compounds appearing on the list.

Zinc was present in all samples in measurable quantities (0.25 mg/1). The source of zinc was traced to incoming municipal water. Its concentration did not interfere with biological activity, however.

All other inorganics appearing on the toxic list were detectable but below minimum measurable limits.

Of the 18 organic compounds subjected to gas chromatographic analysis, all proved to be below the minimum detectable limits.

SECTION 3

RECOMMENDATIONS

Though the information and conclusions reported here are based on a 2-year study of the RBC, the operating phase was limited in scope to an actual operating year of only four calendar seasons. If duplicate seasons data were available for comparison, some deviations would possibly occur as a result of climate and raw influent stock variations. The concept of the RBC appears sound for certain uses and should not be discarded based upon a 1-year test.

The RBC should be operated long enough to gain an overall view of the effects of climatic conditions. Data for several summers, winters, springs, and autumns should be compared.

The influent temperature should be maintained at 23°C to 25°C during times of low temperature to determine the RBC's effectiveness under controlled temperature conditions.

The above two suggestions should be conducted at an operating facility where there is a problem of space (land area). The outfall from the plant should have comparable waste, both qualitatively and quantitatively, to correlate results obtained in this study.

SECTION 4

EXPERIMENTAL PROCEDURES AND DISCUSSION

BACKGROUND

The Mauldin, South Carolina Plant of Texize Chemicals Company, Division of Morton-Norwich Products, Inc., manufactures liquid detergent products for use in the home. Currently, the product line includes hard surface cleaners, light duty dishwashing liquids, laundry softeners, laundry soil and stain remover and a disinfectant containing pine oil. In addition, alkyl benzene is sulfonated and alcohol ethoxylates are sulfated by a AIR/SO_3 batch process to produce anionic surfactants for use in formulating the products eventually distributed to the consumer.

The major raw material types used in formulating Texize products include nonionic surfactants, anionic surfactants and coupling agents, quaternary ammonium compounds, pine oil, caustic soda, sodium silicates, and various oxygenated solvents.

The waste treatment system at Mauldin has evolved over the years from a series of holding ponds and grease pits to an extended aeration lagoon system which is highly efficient in BOD and MBAS reduction. The waste streams discharged to the lagoons include product and raw material losses through spillage and washouts, and sanitary wastes from approximately 500 employees. There are no by-products waste streams generated at this site. The various components of the waste treatment system are described as follows:

Equalization Chamber

All waste streams from the plant enter a concrete box with a nominal 4 to 6 hour residence time. The waste streams are mixed using an 8 rpm paddle blade mixer. The pH of the mixed waste in the chamber is monitored but not controlled. pH can vary from approximately 2 to 12 depending on activities in the Plant. The equalization chamber functions to "smooth out" waste flow into the lagoon system and prevent "slugs" of concentrated waste from possibly flowing through the system.

Equalization Lagoon

The equalization lagoon has a capacity of approximately 4,000,000 liters (1 million gallons) and a nominal retention time of 40 days. The equalization lagoon has two high speed 5 hp surface aerators which are there to provide complete mixing and prevent anaerobic decomposition, with the associated odors, from occurring on the lagoon bottom. In addition to providing mixing to the lagoon, oxygen is introduced and biological degradation does occur. The dissolved oxygen content of the lagoon effluent is normally zero.

Grease Trap

Effluent from the equalization lagoon flows through a grease trap and weir into the aerated lagoon. Separated oils and other floatable materials are removed from the waste stream. pH of the stream and volume flow are automatically monitored.

Extended Aerated Lagoon

The aerated lagoon has a capacity of approximately 6,000,000 liters (1.5 million gallons) and a nominal retention time of 60 days. The lagoon has a maximum depth of approximately 2 meters (6 feet). Aeration of the lagoon is accomplished through the use of four 10 hp floating aerators. The lagoon is completely mixed. Dissolved oxygen levels are normally in the range of 2 to 6 mg/liter (2 - 6 ppm). During the summer months a heavy growth of green algae develops. Because the manufacturing plant only operates 5 days/week, flow through the lagoons is negligible on weekends with the result that biological activity is severely reduced on the weekends. To correct this situation, wastewater is pumped from the aerated lagoon back into the equalization lagoon on weekends at the rate of approximately 400 l/min (100 gal/min). This in turn creates a flow from the equalization lagoon back to the aerated lagoon. Increases in efficiency have been dramatic since this change. Normal results are reductions in BOD of 90+ percent, COD of 85+ percent and MBAS of 95+ percent.

The major problems with the current system are foam generation during cool, high humidity periods, and the large amount of valuable land space required by the lagoons. Foam is objectionable because it can be blown by wind out of the lagoon. To date no effective defoamer has been found which would reduce the problem. When foam buildup occurs aerators are turned off until foam subsides. The land occupied by the lagoons at the present time is directly adjacent to the manufacturing plant and warehouse. Further expansion of these facilities is not possible unless the treatment system is moved.

Discharge from the treatment system is into the Western Carolina Regional Sewer Authority system. No clarification or disinfection steps are taken to reduce suspended solids or fecal coliform.

ROTATING BIOLOGICAL CONTACTOR PILOT STUDY

Initial interest was generated at Texize Chemicals Company by a paper, "Application of the Bio-disc System for Industrial Wastewater Treatment", presented at the Tenth Annual Seminar on Air and Water Pollution Control at Clemson University by Larry G. Blackwell.

The paper cited characteristics such as improved refractory and oil waste removals, gentle mixing action, and smaller space requirements which had appeal to Texize as possibly being an answer to some of the shortcomings in the operating treatment system. Excessive foam generation and the use of valuable land space are viewed as the two main problems in the current system, and improved reductions in COD and oil and grease would be desirable.

Objectives of the Project

A project was proposed to operate a pilot RBC unit on the effluent from a liquid detergent manufacturing plant. The major objectives of the project were to answer the following questions:

Are waste streams from a liquid detergent manufacturing process amenable to treatment by the RBC to the same, lesser, or greater extent than extended aeration?

Are the more refractory organic materials present in a liquid detergent manufacturing process effluent more adequately treated in a RBC system due to development of harder to maintain bacterial strains?

Are RBC systems more adaptable to varying waste loads than activated sludge or extended aeration lagoon systems?

Are RBC systems more efficient than the extended aeration lagoon system at lower operating temperatures (waste stream temperatures from 5°C to 15°C)?

Approach

The project proposed was to install and operate a pilot RBC unit for approximately 8 months. During that time major emphasis would be placed on evaluating the following variables:

Determination of optimum loadings range.

Determination of maximum loadings.

Determination of the effect of rapid changes in loadings on quality of effluent.

Determination of the effect of temperature on performance.

Determination of whether acclimated bacterial growths could be developed to degrade the more resistant organic constituents in the waste stream.

The major parameters for determining performance were BOD_5 reduction, COD reduction, and MBAS reduction. Measurements of other parameters would include oil and grease reduction, settleable and suspended solids of effluent, nitrogen concentration in effluent, and phosphorus concentration in effluent.

Description of Pilot Installation

The pilot RBC operation consists of the RBC unit itself, a variable capacity pump to provide constant feed to the unit, and a building to house the unit providing protection from the elements (Figure 1).

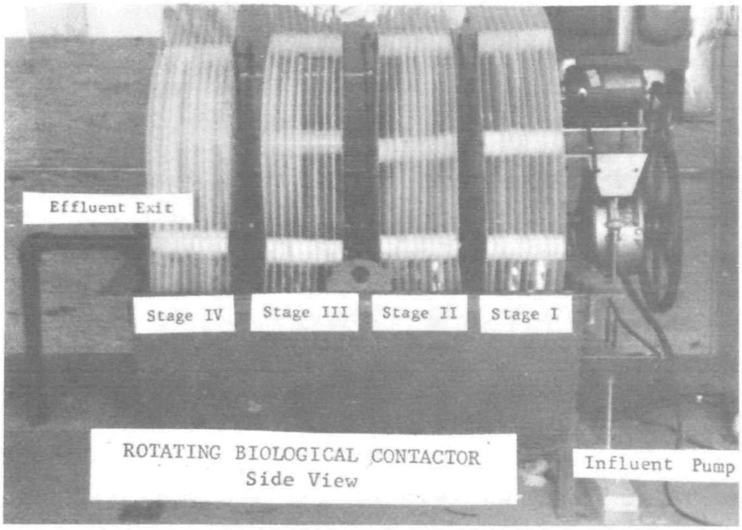

Figure 1. Rotating Biological Contactor, Side View

The RBC unit is a commercially available unit of conventional design. The rotating discs are 1.2 meters in diameter and fabricated of flat polyethylene. The discs are grouped to give four stage operation with 10 discs in each stage. The stages are separated by baffle plates so arranged that flow of wastewater occurs along the outside edges of the unit (Figure 2). Total surface area available for biological growth is approximately 11.69 square meters per stage, and 46.76 square meters for the unit overall. The discs are suspended in a carbon steel tank with a total liquid capacity of approximately 660 liters (175 gallons). The discs are powered by a 1/3 hp totally enclosed motor. Speed of rotation is controlled by the size of the wheels on the belt drive. The discs were operated at 2 speeds during the course of the project, either 8 rpm or 10 rpm.

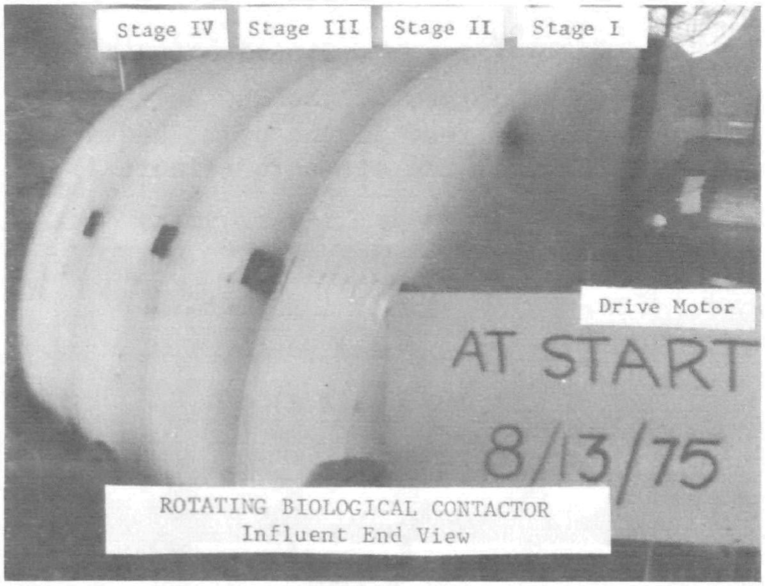

Figure 2. Rotating Biological Contactor, Influent End View

Feed to the RBC unit of wastewater was accomplished by means of a variable capacity centrifugal pump. The pump was so designed that flows could be regulated over the range of 0 - 30 liters/per minute. The intake line was in every case below the surface of the wastewater to avoid floating matter and provided with a screen to prevent suspended matter from fouling the pump. Wastewater feed to the RBC was to the end of the unit.

The RBC unit and the pump were both housed in an insulated metal building to protect them from the weather. The building was completely closed so that the RBC unit was operated in the dark. Provision was made to heat the building during winter months to prevent the equipment from freezing and to ventilate it during the summer to prevent temperatures from getting too high.

Experimental Conditions and Results

Initial Startup--

The RBC unit was put into operation on August 13, 1975.

The initial charge to the unit was made up of 50 percent wastewater from the equalization lagoon, and 50 percent wastewater from the extended aeration lagoon. The extended aeration lagoon had a significant population of bacteria which were acclimated to the type waste to be fed to the system.

The initial feed to the system was from the equalization lagoon. Feed was taken from the lagoon rather than from the equalization chamber for the major part of the study. There were two reasons for this:

> pH in the equalization chamber varied from 2.0 to 12.0 whereas in the equalization lagoon it varied between 6.5 and 8.5 requiring no control.
>
> In the equalization chamber, concentrated slugs of wastewater would wash through periodically as a result of spills and washouts. Wastewater in the equalization lagoon was more typical of the average wastewater being discharged. In addition it had the advantage of being more consistent enabling data taken at different times to be more easily compared.

The intake to the pump was placed inside a screened box below the surface of the lagoon. The screen prevented insoluble material from fouling the pump. The subsurface intake prevented intake of floating materials which would not be typical of the waste stream.

The initial feed rate was approximately 1.9 liters (0.5 gal) per minute. Detention time in the unit was approximately 6 hours (1.5 hours/stage). The BOD_5 loading on the unit (average concentration 250 - 300 mg/l) was 0.0146 to 0.0175 kg per square meter per day. This rate was selected as an estimate of approximately 50 percent of the maximum loading for the unit.

Rotational speed of the discs during startup was 10 revolutions per minute.

For approximately 6 weeks before the beginning of the RBC pilot operation, samples of the wastewater from the equalization lagoon were obtained and analyzed to characterize the nature of the waste feed to the unit (Table 1). The values in Table 1 are typical of those obtained during the period.

TABLE 1. TYPICAL CHARACTERISTICS OF WASTEWATER IN EQUALIZATION LAGOON

Parameter	Concentration in Wastewater	Parameter	Concentration in Wastewater
Temperature °C	27	Aluminum, μg/l	600
pH	6.8 - 7.9	Cadmium, μg/l	70
BOD_5, mg/l	200	Chromium, μg/l	30
COD, mg/l	1000	Copper, μg/l	40
Suspended Solids, mg/l	97	Iron, μg/l	4800
MBAS, mg/l	2.8	Lead, μg/l	100
Dissolved Oxygen, mg/l	0	Mercury, μg/l	0.6
Oil and Grease, mg/l	22	Nickel, μg/l	50
Kjeldahl Nitrogen, mg/l	32	Phosphorus, mg/l	1.2
		Zinc, μg/l	20

Operation at "Standard" Conditions

Initial startup conditions were selected on the basis of providing "base case" data on the performance of the RBC unit. Within 2 days growth of a slime on the discs became noticeable. Bacterial accumulation on the discs could be observed in the first stage in 4 to 6 days. Growth continued to accumulate on all four stages until it was an estimated one-fourth inch thick (Figure 3).

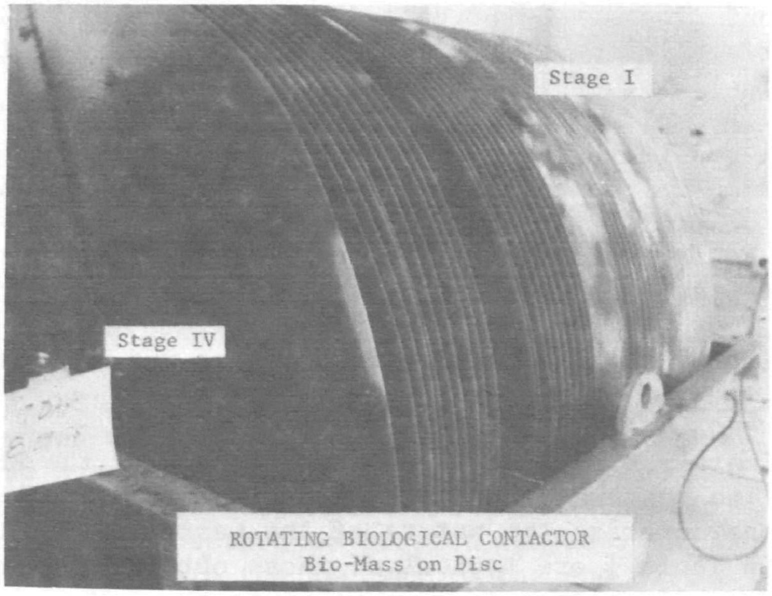

Figure 3. Rotating Biological Contactor, Biomass on Disc

At that point sloughing began to occur on large areas of the discs, beginning in the first stage and successively progressing through the fourth stage.

A significant reduction in BOD_5, COD and MBAS was being obtained after 7 days of operation (Table 2).

Because neither the effluent from the RBC unit, nor the aerated lagoon were being clarified to remove suspended solids, samples tested for BOD_5 were filtered to remove suspended solids. This was done to provide a better basis for comparing data.

TABLE 2. SEVEN-DAY REDUCTION OF BOD, COD, AND MBAS

Parameter	Influent	Effluent	Percent Reduction
BOD_5, mg/l	150*	30*	80
COD, mg/l	630	473	25
MBAS, mg/l	3.5	0.86	75

*BOD_5 determined on filtered samples.

The RBC was operated under the initial conditions for approximately 5 weeks. Slight improvement in effluent quality occurred for the first 3 weeks, then appeared to level off. At that time effluent from the RBC was approximately equivalent to effluent from the extended aeration lagoon in characteristics (Table 3). Average waste reductions achieved for each of the major parameters of interest for the period 9/2/75 to 9/18/75 are shown in Table 4.

TABLE 3. RBC EFFLUENT AND EXTENDED AERATION EFFLUENT COMPARISONS

Parameter	Influent	RBC Effluent	Aerated Lagoon Effluent
pH	7.5 - 8.2	7.4 - 7.5	--
BOD_5, mg/l	80 - 290	25 - 40	25 - 50
COD, mg/l	675 - 1300	340 - 650	220 - 470
MBAS, mg/l	2.3 - 6.8	0.15 - 0.40	0.15 - 0.35
Suspended Solids, mg/l	--	40 - 80	30 - 90

TABLE 4. PERCENT WASTE REDUCTION ACHIEVED BY THE RBC SYSTEM AND EXTENDED AERATION

Parameter	Percent Reduction Achieved	
	RBC Effluent mg/l	Aerated Lagoons Effluent mg/l
BOD_5	83	78
COD	46	65
MBAS	96	96

The next phase of the experimental program was to determine the maximum feed rate at which satisfactory results would be obtained.

The RBC unit was run at "standard" conditions on several occasions during the course of the project. All data obtained when running the RBC under these conditions are compiled in Appendix, Table A-1 to provide easy comparison of results. The performance of the RBC was not as good at any time as was found with the September-October, 1975 experiments. For example, all startups after failure of the system required longer times, the degree of degradation obtained was not as complete, and the length of time until failure of the system was shorter.

Operation at Increased Loading

With the results obtained at "standard" conditions as a target, operation at increased feed rates was conducted to determine if possible the maximum loadings under which the RBC unit would give comparable results (Table A-2).

With the advent of a period of cold weather and rain in mid-September, 1975, a failure of the RBC system occurred. All bacterial growth on the discs died and sloughed from the discs. The same die-off was experienced in the aerated lagoon system. Die-off appeared to be associated with a rapid drop in wastewater temperature from 24°C to 19°C in 2 days. The temperature continued to drop to a low of 17°C before warming slightly by the end of the month. Attempts to reestablish growth on the discs were unsuccessful until the RBC was flushed and recharged with a 50/50 mixture of materials from the equalization lagoon and the extended aeration lagoons as in the initial startup.

After recharging the unit, slime began to develop on the discs but at a considerably slower rate than when the experiment was begun. This was attributed to lower wastewater feed temperatures (approximately 20°C versus 27°C). After 3 weeks it was felt that effluent quality from the RBC unit was approaching the quality obtained before the failure of the unit.

The flow rate of the wastewater feed was then increased from 1.9 liters/minute to 2.85 liters/minute (0.75 gpm). Dentention time in the unit was reduced to 4 hours (1 hour per stage). The increase in feed rate did not materially affect the quality of the effluent measured by BOD_5, COD, or MBAS. After operating approximately 2 weeks at wastewater feed rates of 2.85 liters/minute, the feed rate was increased to 3.8 liters/minute (1.0 gal/min). Thus increase in feed rate did not appear to seriously affect quality of the effluent when measured by BOD_5, COD, or MBAS. However, data are difficult to interpret in this case because the waste concentrations in the wastewater feed were considerably lower than earlier when feed rates were lower. The net effect was that although the hydraulic rates were increased and residence times shortened, the waste load measured as contaminant/square foot of disc/day did not increase. The wastewater feed rates were increased to 7.8 liters/minute in early December, however, by this time wastewater feed temperatures had dropped to below 15°C and data were not representative of what might have occurred during warmer weather and could not provide a valid comparison to quality at lower feed rates.

Table 5 shows typical data obtained with changing wastewater feed rates.

TABLE 5. EFFECT OF INCREASING FLOW ON EFFLUENT QUALITY UNDER AMBIENT CONDITIONS

Date	Flow (l/Min)	Parameter					
		BOD_5 (mg/l)		COD (mg/l)		MBAS (mg/l)	
		Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
10/15/75	1.9	150	43	1090	560	8.8	1.3
10/23/75	2.85	150	20	1300	570	4.9	0.9
11/4/75	2.85	77	20	800	400	3.1	0.6
11/11/75	3.8	135	20	940	300	0.6	0.2
11/20/75	3.8	77	6	825	330	0.2	0.1
12/16/75	7.6	157	34	1370	680	7.6	4.5

Further studies at feed rates above 1.9 liters/minute were not conducted since it was not possible to obtain consistent performance of the RBC at that low feed rate thus to yield meaningful data.

Operation at Different Feed Temperatures

A major factor in RBC performance on liquid detergent plant waste streams is the temperature of the wastewater feed. As noted earlier in the report, a rapid drop in temperature from 24°C to 19°C in mid-September, 1975 resulted in a die-off of the biomass on the discs and the concurrent failure of the unit. A similar drop occurred in late November, 1975, which resulted in severely decreased biological activity. Further, it was not possible to generate or maintain a heavy growth of biomass on the discs until wastewater temperatures increased to above 20°C. Although bacteria were present in the system, no significant degradation of waste occurred even at wastewater feed rates of 0.95 l/minute (0.25 gpm) which was the lowest rate at which our equipment would operate (Table A-3). However, when waste flow to the unit was stopped and the discs were allowed to continue to rotate, degradation did occur as shown in Table 6.

TABLE 6. DEGRADATION OF WASTEWATER AT LOW TEMPERATURES

Parameter	Test 1 Influent 12/30/75	Test 1 Effluent 12/30/75 (1.81 l/min.)	Test 1 Effluent 1/6/75 (no flow)	Test 2 Influent 1/15/76	Test 2 Effluent 1/15/76 (0.95 l/min.)	Test 2 Effluent 1/27/76 (3.8 l/min.)
BOD_5, mg/l	50	26	8	114	50	11
COD, mg/l	1125	893	580	1850	1500	420
MBAS, mg/l	8.2	7.8	0.2	18	8.7	0.55
Temperature °C	8	11	10	8	11	10

These tests clearly indicate that the waste streams were amenable to biological action and that biological activity was occurring; however at a very low rate.

The rate of degradation which occurred under "no flow" conditions was observed during July 1975 and September 1975 when wastewater temperatures were above 20°C. Based on the earlier experiences where failure of the system occurred when MBAS levels were high, it was of interest to see whether a high MBAS waste could be degraded if residence times were longer as in a "no flow" situation. A trial run was made in July 1976 (Table 7) where there was little or no biomass on the discs. Over a period of 96 hours, MBAS levels dropped from 33 mg/l to 5.8 mg/l. A second trial was conducted in early September 1976 (Table 7), when approximately 50 percent of the discs were covered with biomass. In this case, the MBAS concentration in the unit decreased from 8.1 mg/l to 2.0 mg/l in 48 hours. At the same time, the COD dropped from approximately 1500 mg/l to 1000 mg/l. A third run was made in September 1976 (Table 7), when approximately 80 percent of the discs were covered with biomass. MBAS concentrations in the unit decreased from 0.60 mg/l to 0.16 mg/l.

It would appear that a "batch" type operation has some feasibility with high MBAS wastes particularly where daily flows are not too high.

TABLE 7. BATCH TEST: BIOMASS, TIME, AND WASTE REDUCTION RELATIONSHIP

Parameter	MBAS (mg/l)			COD (mg/l)
Date:	7/2/76	9/1/76	9/13/76	9/1/76
Biomass Coverage	0%	50%	80%	50%
Initial	33	8.1	0.60	--
After 2 hours	--	7.6	0.32	1485
After 6 hours	--	6.9	0.23	--
After 24 hours	--	4.0	0.18	--
After 30 hours	--	3.4	--	1100
After 48 hours	--	2.0	0.16	1020
After 96 hours	5.8	--	--	--
Removal Efficiency	82%	75%	73%	75%

During the period from early November, 1975 to late January, 1976, the temperature in the building in which the RBC unit was housed was kept at a minimum of 15°C in accordance with the originally proposed program. However, from late November on, no appreciable growth was generated on the rotating discs under a variety of wastewater feed rates and conditions. It was then thought that growth on the discs might be inhibited through "shocking" the bacteria by exposing them to significantly different temperatures in the water and the air. The temperature in the building was adjusted to keep it in the range of 8°C to 10°C, more nearly the temperature of the wastewater in the unit. After approximately 10 days with a wastewater feed rate of 1.9 l/minute a significant reduction in COD and MBAS occurred. It appears that it would be necessary to keep the temperature of the air above the discs at approximately the same temperature as the wastewater feed to keep from inhibiting bacterial growth on the discs. However, although the biomass exists, the reduced rate of activity at the lower temperatures occurring during the winter months would make the usefulness of the RBC system minimal.

The problem of low wastewater temperatures can be overcome in situations where wastewater flows are relatively small as they are at the Texize Chemicals Company. Capital investments and operating costs to install heat exchangers making use of waste steam as a heating mechanism would not be prohibitive. If other factors would favor the adoption of an RBC system then heating the waste stream should be considered as a means of overcoming the shortcomings encountered in operating at low wastewater temperatures.

Relative Degradation in the Various Stages of the RBC

A number of times during the study, all four stages of the RBC unit were sampled to determine the degree of degradation that was taking place in each stage (Table A-4). Invariably it was found that the great majority of BOD_5, COD and MBAS reduction occurred in the first stage. At the same time, virtually no change in concentrations occurred between the third and fourth stages (Table 8). No additional reduction in COD concentration was obtained as a result of the second stage treatment. These findings can be illustrated using analytical data obtained during sampling of the several stages.

TABLE 8. PERCENTAGE EFFICIENCY OF EACH RBC STAGE

	Parameter		
	BOD_5 mg/l	COD mg/l	MBAS mg/l
Influent	180	1280	5.0
First Stage	90	1040	2.0
Second Stage	-	480	1.1
Third Stage	70	480	0.85
Fourth Stage	40	480	0.40

Because so much of the degradation was occurring in the first stage an experiment was conducted in which the baffle plate between the first and second stage was removed, effectively doubling the surface area of the discs in the first stage. The RBC unit would then operate as a three stage unit with the first stage having 23.4 square meters of disc surface and the second and third stages 11.7 square meters each. It was considered that possibly a greater total degradation would be achieved in this manner. As the data shown in Table 9 indicate no significant advantage in overall waste reduction was obtained.

TABLE 9. EFFECT OF INCREASING SURFACE AREA IN FIRST STAGE

Parameter	Before Removing Baffle		After Removing Baffle			
	MBAS	COD	MBAS		COD	
Sample Date	7/23/76 mg/1	7/23/76 mg/1	7/26/76 mg/1	8/5/76 mg/1	7/26/76 mb/1	8/5/76 mg/1
Influent	5.4	1240	2.8	13.0	1100	1240
First Stage	3.0	1150	1.4	7.8	700	1070
Second Stage	3.0	990	1.2	-	-	1030
Third Stage	2.8	990	1.2	7.2	700	1030
Fourth Stage	2.6	990	-	-	-	-

Although this experiment did not indicate any advantage in increasing the surface area of the first stage, the experiment was run at a time when the RBC unit was not operating at optimum. It would be of interest to repeat the experiment when the unit was operating better. It may be found that there is no real advantage in having stages.

Amenability of RBC Effluent to Clarification

Of interest in this study was whether any significant difference existed between RBC effluent and aerated lagoon effluent with respect to attempts at clarification. Accordingly laboratory jar tests were run to compare the quality of the supernatent liquid from the two sources after treatment with alum.

A stock solution of alum was prepared with the proper amount to give the desired dosage and added to slowly stirred samples of wastewater. After addition of alum was completed, the sample was mixed vigorously for one minute, then at a more moderate speed for 15 minutes to allow the floc to form. Mixing was then discontinued and the sample allowed to stand for 60 minutes while the floc settled. The sludge volume index (SVI) was determined after 30 minutes of settling. After 60 minutes the supernatent liquid was sampled and analyzed for the various parameters.

There was no significant difference in the effluent's response to clarification attempts. Trials were run in February and August of 1976 (Table 10).

TABLE 10. CLARIFICATION OF EFFLUENT STREAMS

Effluent Source	RBC				Aerated Lagoon			
Date	2/76		8/76		2/76		8/76	
Dosage	300 mg/1		1000 mg/1		300 mg/1		1000 mg/1	
Parameter	Before	After	Before	After	Before	After	Before	After
BOD_5, mg/1	--	--	140	60	--	--	121	7
COD, mg/1	--	--	1800	400	--	--	630	130
MBAS, mg/1	2.8	1.1	26	3.4	0.9	0.5	0.3	0.3
TSS, mg/1	44	28	72	24	108	28	44	12
SVI (30 min)	86		145		90		120	

Although a much higher concentration of alum was required in the studies conducted during August, in both experiments Total Suspended Solids of the clarified effluent were in the acceptable range. A factor of interest is the significant reductions of both MBAS and COD obtained during clarification. If suitable disposition of the sludge could be arranged, an attractive treatment route could be the clarification of the raw waste before biological treatment.

During the latter part of the research study, the possibility of using the RBC unit as a polishing step after secondary treatment was investigated. Additional reduction in MBAS and COD concentrations was achieved in doing this; however, clarification of the two effluents resulted in similar final effluent concentrations (Table 11). Thus use of the RBC as a polishing step did not benefit final effluent after clarification.

The results of a comprehensive study conducted on the aerated lagoon effluent by AWARE, Nashville, Tennessee, can be compared to current results by referring to the report issued which is included as part of this report as Appendix Table A-5.

TABLE 11. ALUM TEST

	10/27/76 pH mg/l	MBAS mg/l	COD mg/l	Flow to RBC from #2
Extended Aerated Lagoon (Initial 10/27)	7.4	0.94	598	
(750 mg)	5.3	0.51	341	
Rotating Biological Contactor (Initial 10/27)	7.6	0.58	488	3.785 l/min
(750 mg)	5.5	0.52	323	

Incidence of Foaming in the RBC Unit

One of the major problems which occurs in the present aerated lagoon treatment system is the generation of foam when temperatures are below 20°C and humidity is high. If at the same time the wind was blowing, it would be necessary to shut down the aerators to keep foam from blowing out of the lagoon. Because of the relatively slow speed at which the RBC discs were rotating it was felt that significant foam would not be generated in the system. Alternatively if foam was generated it would be easier to cope with in the relatively small area occupied by the RBC units.

Contrary to expectations, small amounts of foam were generated in the first stage of the RBC even at relatively low concentrations of MBAS (less than 10 mg/l) and warm temperatures (above 20°C). This did not appear deleterious to the functioning of the unit. However, during the winter months when the wastewater feed temperatures were below 15°C and MBAS levels in the wastewater were above 5.0 mg/l copious amounts of foam were generated in all four stages of the unit (Figure 4). Foam would spill out of the unit tank onto the floor and adhere to and completely cover the rotating discs. During these periods it would take only a short time for the biomass to be completely stripped from the discs.

If the other conditions are met for satisfactory performance of the RBC (wastewater temperatures above 20°C and MBAS less than 10 mg/l) it is not believed that foam would be a significant problem with the RBC unit.

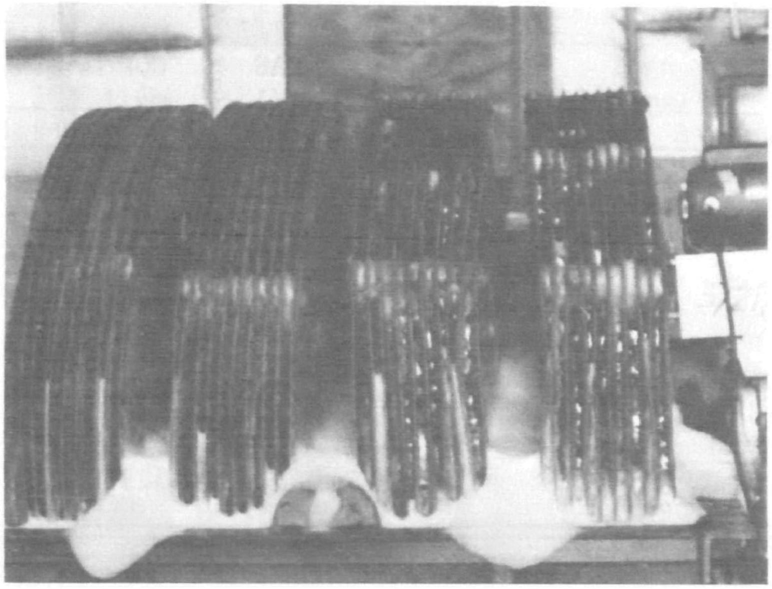

Figure 4. Foam Generation by the Rotating Biological Contactor

Characterization of Bacteria in the System

There were no significant differences in types of bacteria growing in the two treatment systems. Bacteria found were gram negative rods typical of those associated with organic degradation. In one sampling a small population of mold similar to a yeast was identified. The mold represented less than 1 percent of the total growth found in any one sample.

Operation and Maintenance of the RBC Unit

A prime advantage claimed for the RBC unit is the simplicity of operation and low maintenance requirements. Based on the experience obtained in this study it would appear the claim is well founded. Mechanically very little problem was encountered with any of the equipment. The only problem encountered was that the polyvinyl chloride baffle plates fractured where they were attached to the sidewall of the unit. Additional clamps were placed on the plates and the unit functioned very well. The manufacturer has indicated that later models of this unit have been strengthened in this area.

The unit required no operators care. After the initial charge was made on startup the only operator time involved was to check the feed rate to the unit, record the wastewater temperature, and collect samples for testing.

Review of Operational Data by Colin A. Houston & Associates, Inc.

Upon completion of data collection and evaluation, a draft report concerning the operation of the RBC was presented to Colin A. Houston & Associates, Inc.[9] for review and comments on the conclusions reached by the Texize Chemicals Company personnel. In private correspondence dated January 12, 1978, with the Effluent Guidelines Division (WH-552) of the United States Environmental Protection Agency, comments were made and are extracted below.

> "All in all, it would appear that the RBC is not applicable to the successful treatment of wastewater containing high concentrations of surfactants unless at least all the following things are done.
>
> (a) The unit is preceeded by a large equalization tank in which the wastewater is mixed thoroughly to prevent step changes in feed composition.
>
> (b) The temperature of the feed is adjusted to and controlled in a narrow range.
>
> (c) The feed is diluted to maintain a uniformly low concentration of detergent measured as MBAS - this could be done by recirculating the effluent from the unit.
>
> (d) The effluent from the RBC is subjected to coagulation and settling treatment to remove suspended solids.
>
> Unfortunately, if all the foregoing are done then the advantages of using the RBC equipment are largely negated and alternative methods are more attractive."

ANALYSIS AND TREATABILITY OF RAW WASTES FOR TOXIC CHEMICALS

Objectives

Upon completion of the operational phase of the RBC study a program was planned in order to determine the presence of toxic materials that may appear in effluent from a liquid detergent plant. Ions and compounds of interest were published in "Toxic Materials News", April 15, 1976, a copy which was forwarded to these laboratories by the EPA Project Officer.

In that the existing waste treatment facility is an earthen aerated lagoon system the plan called for qualitative and quantitative determinations of all inorganics appearing on the list, it being conceivable that leaching of these elements from the earth may have been possible. Further consideration was given to the fact that some of the inorganics could have possibly been used by a raw material manufacturer as a catalyst, the catalyst then only partially removed would possibly be shipped in the raw material creating problems of which the detergent formulator may be unaware.

A decision was made in the case of organic compounds appearing on the list of toxic materials that only those compounds that could be considered as a likely candidate in effluent from a liquid detergent plant would be determined both qualitatively and quantitatively. The presence of many of the compounds appearing on the list are candidates only to very specific types of chemical industry and any likelyhood that such compounds could or would appear in a detergent plant even as a raw material contaminant would be remote. Certain of the listed compounds are used as laboratory reagents, e.g., chloroform and could conceivably be detected in the waste treatment basin should careless handling of reagents occur in the laboratories. None of the listed organics are either maintained in the Company's raw material inventory or have ever been knowingly used in a manufacturing process within the last 8 to 10 years. Further, the synthesis procedures of raw materials used in detergent manufacturing do not lend themselves to the use of these organics even as a medium for reactions.

On this basis, in agreement with the project officer a total of 16 compounds were chosen for analysis, those being 16 that could possibly either be shipped as contaminants or find their way into the treatment system through an improper discard from a laboratory. Inorganics and organics chosen for the study were

Inorganics	Organics	Organics
1. Antimony	14. Benzene	22. Dichloroethylene
2. Arsenic	15. Carbon Tetrachloride	23. 2,4-dimethylphenol
3. Beryllium	16. Chlorinated benzene	24. Ethylbenzene
4. Cadmium	17. Chlorinated ethane	25. Pentachlorophenol
5. Chromium	18. Chlorinated phenol	26. Phenol
6. Copper	19. Chloroform	27. Tetrachloroethylene
7. Lead	20. 2-Chlorophenol	28. Toluene
8. Mercury	21. Dichlorobenzene	29. Trichloroethylene
9. Nickel		
10. Selenium		
11. Silver		
12. Thallium		
13. Zinc		

The plan for study required that raw plant effluent be sampled and analyzed for each element and compound. Should the analysis indicate that any of the toxic materials be identified in an accurately measurable quantity then production records would be consulted to determine products manufactured during the analysis period. From these records raw materials used could be established. Each raw material involved then would be checked for contamination. In addition samples of waste obtained from sumps leading from an operating department would be analyzed in order to establish the source of the unwanted material. Additionally, the fate of each identified and measured compound or element would be determined.

<u>Analysis for Inorganic Ions</u>

On November 3, 1976, a complete inorganic characterization of effluent took place to not only include those elements appearing on the toxic list but also to include others that could possibly influence biological action in either the RBC or the extended aeration system. The results of the atomic absorption analysis indicated all elements classed as toxic were detectable with very few in the measurable range. There appeared to be no element in the system classed as toxic or non-toxic in a concentration that may interfere with biological oxidation (Table 12).

TABLE 12. TYPICAL ATOMIC ABSORPTION ANALYSIS OF TREATED WASTEWATER FOR INORGANIC IONS

Element	Maximum Concentration	Element	Maximum Concentration
Aluminum	< 500 μg/l	Iron	2.35 mg/l
Antimony	< 0.02 mg/l	Lead	50 μg/l
Arsenic	0.001 mg/l	Magnesium	1.45 mg/l
Barium	< 100 μg/l	Mercury	< 0.001 mg/l
Beryllium	< 0.006 mg/l	Nickel	< 20 mg/l
Boron	< 50 mg/l	Potassium	13.8 mg/l
Cadmium	< 2 μg/l	Selenium	< 0.001 mg/l
Calcium	2.73 mg/l	Silver	< 0.01 mg/l
Chromium	< 20 μg/l	Sodium	410 mg/l
Copper	< 10 μg/l	Thallium	< 0.06 mg/l
		Zinc	70 μg/l

On April 14, 1977 and July 1, 1977, analysis was again completed for elements listed as toxic. At this time samples were analyzed to include raw untreated waste (which served as influent to both the RBC and the extended aeration system), effluent from the RBC, and effluent collected from the secondary treatment lagoon. In all but one case it was found the elements were detectable but generally below accurate quantitative measurement. The exception was zinc. In each case this element was definitely present (Figures 5, 6, and 7).

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Metal	Units	Concentration
Aluminum	μg/l	< 500
Antimony	mg/l	< 0.02
Arsenic	mg/l	0.001
Barium	μg/l	< 100
Beryllium	mg/l	< 0.006
Boron	mg/l	< 50
Cadmium	μg/l	< 2
Calcium	mg/l	2.73
Chromium	μg/l	< 20
Copper	μg/l	< 10
Iron	mg/l	2.35
Lead	μg/l	50
Magnesium	mg/l	1.45
Mercury	mg/l	< 0.001
Nickel	μg/l	< 20
Potassium	mg/l	13.8
Selenium	mg/l	< 0.001
Silver	mg/l	< 0.01
Sodium	mg/l	410
Thallium	mg/l	< 0.06
Zinc	μg/l	70

Figure 5. General inorganic analysis for background characteristics of waste treatment system.

WATER ANALYSIS DATA

Parameter	Units	Primary Treatment Lagoon	Aeration Lagoon	RBC Effluent
Cadmium	mg/l	<0.002	<0.002	<0.002
Chromium	mg/l	<0.02	<0.02	<0.02
Copper	mg/l	<0.05	<0.05	<0.05
Lead	mg/l	<0.1	<0.1	<0.1
Nickel	mg/l	<0.05	<0.05	<0.05
Silver	mg/l	<0.1	<0.1	<0.1
Zinc	mg/l	0.25	0.20	0.25
Antimony	mg/l	<0.2	<0.2	<0.2
Arsenic	mg/l	<0.001	<0.001	<0.001
Beryllium	mg/l	<0.005	<0.005	<0.005
Mercury	mg/l	<0.001	<0.001	<0.001
Selenium	mg/l	<0.001	<0.001	<0.001
Thallium	mg/l	<0.05	<0.05	<0.05

Figure 6. Inorganic analysis of waste for toxic substances April 14, 1977.

WATER ANALYSIS DATA

Parameter	Units	Primary Treatment Lagoon	Aeration Lagoon	RBC Effluent	Tap Water
Antimony	mg/l	<0.02	<0.02	<0.02	
Arsenic	mg/l	<0.001	<0.001	<0.001	
Beryllium	mg/l	<0.007	<0.005	<0.007	
Cadmium	mg/l	<0.002	<0.002	<0.002	
Chromium	mg/l	<0.05	<0.02	<0.05	
Copper	mg/l	<0.04	<0.01	0.08	
Lead	mg/l	<0.05	<0.05	<0.05	
Mercury	mg/l	<0.001	<0.001	<0.001	
Nickel	mg/l	<0.02	0.03	0.04	
Selenium	mg/l	<0.001	<0.001	<0.001	
* Silver	mg/l	0.80	2.11	1.32	
Thallium	mg/l	<0.07	<0.05	<0.07	
Zinc	mg/l	0.095	<0.047	0.115	0.02

Figure 7. Inorganic analysis of waste for toxic substances July 1, 1977.
*Results declared invalid due to an erratic atomic adsorption lamp.

Upon examination of samples for the purpose of locating the zinc source it was found that incoming water from the municipal supply contained a measurable quantity of this ion. It was later confirmed that a trace quantity of zinc salts is added to the municipal water for the purpose of corrosion control. This being the primary source of the metal, no further effort was expended in the identity of other sources as the quantity added exceeded the quantity found in the wastewater (Table 13).

TABLE 13. WATER ANALYSIS BY ATOMIC ABSORPTION FOR ZINC

	Sample Source and Concentration			
Date	Raw Plant Effluent	Aerated Treatment Effluent	RBC Effluent	Municipal Supply
11/3/76		70 μg/l		
4/14/77	0.025 mg/l	0.20 mg/l	0.25 mg/l	
7/1/77	0.95 mg/l	0.47 mg/l	0.115 mg/l	0.20 mg/l

Analysis for Organic Compounds

Analysis for organic compounds were performed with a commercial gas chromatograph equipped with a flame ionization detector. The gas of choice was helium. Purchased pre-packed columns as indicated in the Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF or American Society for Testing Materials D-3328-74 were obtained for use to minimize the possibility of void spaces or improper packing.

Detector signals were fed to a data interface connected with a Spectra-Physics SP-4000 central processing unit capable of data reduction using internal standards methods. The actual trace was produced on a printer-plotter followed by calculated data from the central processing unit.

Solutions of analytical grade standards were prepared in distilled water for each chemical with which the study was concerned up to the limit of solubility for the chemical. In some cases it proved difficult to obtain good solubility above 10 mg/l at room temperature. Prepared known concentration standards were then used to determine the detector sensitivity, retention time, plus the minimum qualitative and quantitative limits of the instrument. The detectable limits of the organic compounds for analysis can be found in Table 14.

TABLE 14. DETECTABLE LIMITS FOR ORGANIC COMPOUNDS WITH FLAME IONIZATION DETECTOR ON BARBER COLEMAN (DRAWING NO. A4070) GAS CHROMATOGRAPH

Compound	Minimum Qualitative Limit mg/1	Minimum Quantitative Limit mg/1
Benzene	0.25	0.57
Carbon tetrachloride	0.5	0.83
Chlorinated benzene	0.8	1.7
Chlorinated ethane	0.8	1.42
Chlorinated phenol (2,4-di)	0.1	0.20
Chloroform	0.06	0.17
2-Chlorophenol	0.10	0.20
Dichlorobenzene	0.8	1.7
Dichloroethylene	0.5	1.09
2,4-Dimethylphenol	1.0	1.92
Ethyl benzene	1.2	1.82
Pentachlorophenol	3.0	4.43
Phenol	0.2	0.44
Tetrachloroethylene	1.5	3.16
Toluene	0.6	1.14
Trichloroethylene	0.8	1.25

Upon completion of the determination of detector response samples of raw plant effluent, RBC effluent, and aerated lagoon effluent were injected under the same parameters of temperature and flow rates as were the prepared analytical standards. In all cases there was no detectable quantity of materials found (Tables B-4 and B-5).

In order to confirm the absence of these organic compounds of interest preparations were made using analytical grade chemicals and raw wastewater taken from the manufacturing plants effluent. Sufficient numbers of these preparations were made to confirm that probable detection would have been possible should the organic compounds of interest have been present.

As was suggested in the discussion of the plan of analysis it was unlikely that the chemicals listed as toxic would be found in a liquid detergent plants effluent unless there had been mishandling within a laboratory. On the basis of inability to detect the compounds it is assumed raw materials are free of any contamination of chemicals for which this analysis was designed and that laboratories are following safety disposal procedures. In addition these analyses suggest that in the process of biological degradation of waste there is no formation of toxic organic chemicals appearing on the list of toxic substances as by-products due to either oxidation in an aerobic system or fermentation during an anaerobic state.

Organic analyses to include instrument calibration may be found in Appendices Figures B-1 thru B-7 inclusive and Tables B-4, B-5 and B-6.

REFERENCES

1. Application of the Bio-disc System for Industrial Wastewater Treatment, L. G. Blackwell, Tenth Annual Seminar on Air and Wastewater Control, Clemson University, 1974.

2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, New York, 1976.

3. Methods for Chemical Analysis of Water and Wastes, EPA, 1971.

4. Toxic Materials News, April 15, 1976.

5. Gas-Liquid Chromatography, Stephen Dal Nogare and Richard S. Juvet, Jr., Interscience Publishers, 1962.

6. Gas Chromatograph Instruction Manual, Barber Coleman Company for Drawing A-4070.

7. SP-4000 Microprocessor Instruction Manual, Spectra Physics, Inc., 1977.

8. American Society for Testing Materials, Methods D-3328-74 aT and D-3257-73, USA.

9. Letter, Colin A. Houston & Associates, Inc., Mamaroneck, New York, 10543 to Effluent Guidelines Division (WH-552) U.S. Environmental Protection Agency, Washington, D.C., dated January 12, 1978.

APPENDICES

APPENDIX A. ROTATING BIOLOGICAL CONTACTOR PILOT STUDY, ANALYTICAL METHODS

Routine grab sample laboratory determinations during the RBC pilot operation study were carried out by the procedures described in:

American Public Health Association, American Waterworks Association, and Water Pollution Control Federation, "Standard Methods for the Examination of Water and Wastewater", 14th Edition, American Public Health Association, Inc., New York, 1976.

The methods used were:

Biochemical Oxygen Demand--p. 543

Chemical Oxygen Demand--p. 550

Oil and Grease--p. 518

pH--p. 460

Suspended Solids--p. 94

Total Solids--p. 91

Total Kjeldahl Nitrogen--p. 437

Environmental Protection Agency, National Environmental Research Center, Analytical Quality Control, "Methods for Chemical Analysis of Water and Wastes", 1971.

Method used:

Ammonia--p. 134

APPENDIX B. DETAILED DATA FOR ANALYSIS OF TOXIC SUBSTANCES

Specific tests for the detection and measurement of toxic substances were performed on grab samples by atomic absorption spectrophotometry and/or gas chromatographic techniques. Methods for determination of these parameters may be found in:

American Public Health Association, American Waterworks Association, and Water Pollution Control Federation, "Standard Methods for the Examination of Water and Wastewater", 14th Edition, American Public Health Association, Inc., New York, 1976.

American Society for Testing Materials, Methods ASTM D-3328-74 aT and ASTM D-3257-73.

Inorganic Analysis by Atomic Absorption Spectrophotometry was performed by R. S. Noonan of South Carolina, Inc.

TABLE A-1. DATA OBTAINED DURING OPERATION AT FEED RATE OF 1.9 LITERS/MIN. (STANDARD)

Sample Date	Temp. °C Inf.	Temp. °C Eff.	pH Inf.	pH Eff.	BOD5* - mg/l Inf.	BOD5* - mg/l Eff.	COD - mg/l Inf.	COD - mg/l Eff.	MBAS - mg/l Inf.	MBAS - mg/l Eff.
A. Initial Startup										
8/13/75	-	-	-	-	-	-	-	-	-	-
8/20/75	27	24	7.2	7.3	150	30	630	473	3.5	0.86
8/22/75	27	24	8.1	7.5	340	30	1090	470	6.2	0.50
8/26/75	28	25	7.8	7.1	-	-	1280	480	16.9	0.40
8/28/75	28	25	7.6	7.3	300	30	1090	580	17.9	0.23
9/2/75	25	23	8.0	7.5	250	30	850	580	4.6	0.15
9/4/75	25	23	7.9	7.5	290	30	1010	650	6.7	0.42
9/9/75	25	23	8.2	7.5	150	30	960	550	2.3	0.15
9/11/75	24	22	7.8	7.5	180	40	1280	480	5.0	0.37
9/16/75	19	17	7.6	7.5	80	20	730	340	1.0	0.13
B. Second Trial										
9/29/75	-	-	-	-	-	-	-	-	-	-
9/30/75	20	19	7.1	7.4	150	50	1140	1090	4.8	4.2
10/1/75	-	-	6.9	7.0	-	-	-	-	4.0	3.7
10/2/75	20	19	6.9	7.0	150	60	1330	1160	6.1	2.5
10/3/75	-	-	6.8	7.0	-	-	-	-	6.0	4.2
10/6/75	-	-	6.9	7.0	-	-	-	-	5.8	4.7
10/7/75	19	21	7.0	7.1	140	100	1320	1290	6.5	6.0
10/9/75	19	18	7.8	7.5	-	-	1620	1050	18.6	9.1
10/10/75	23	21	7.2	7.5	-	-	-	-	24.8	13.8
10/14/75	21	22	7.2	7.3	150	40	1090	560	8.8	1.3
10/15/75	22	22	7.4	7.4	-	-	-	-	8.3	2.0
10/16/75	22	22	7.5	7.4	150	40	1700	730	9.4	2.0
10/21/75	20	19	7.3	7.5	270	35	1050	820	6.5	4.0
10/22/75	-	-	7.1	7.2	-	-	-	-	7.3	3.6

TABLE A-1. DATA OBTAINED DURING OPERATION AT FEED RATE OF 1.9 LITERS/MIN. (STANDARD)

Sample Date	Parameter									
	Temp. °C		pH		BOD_5* - mg/l		COD - mg/l		MBAS - mg/l	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
C. Third Trial										
12/15/75	-	-	-	-	-	-	-	-	-	-
12/15/75	11	15	7.2	7.2	-	-	-	-	7.6	3.8
12/16/75	13	16	7.2	7.2	160	34	1370	680	7.6	4.5
12/17/75	11	13	7.2	7.2	-	-	-	-	10.0	5.5
12/29/75	10	12	8.7	7.5	-	-	-	-	10.0	10.0
12/30/75	8	10	-	-	50	26	1120	890	8.2	7.8
D. Fourth Trial										
1/28/76	-	-	-	-	-	-	-	-	-	-
1/29/76	7	10	7.2	7.2	110	50	1180	1180	5.65	2.8
1/30/76	8	9	7.2	7.3	-	-	-	-	7.6	3.1
2/2/76	8	9	7.1	7.2	-	-	-	-	-	6.0
2/3/76	7	8	7.0	7.3	-	-	1510	1410	5.3	3.0
2/4/76	8	9	7.2	7.3	-	-	-	-	11.8	3.8
2/5/76	8	9	-	-	-	-	1660	1620	11.2	3.6
2/6/76	-	-	6.8	7.0	-	-	-	-	8.2	4.3
2/9/76	-	-	6.9	7.0	-	-	-	-	20.0	8.0
2/10/76	9	10	7.0	7.1	-	-	2030	1930	-	-
2/11/76	11	13	6.8	6.9	-	-	-	-	15.0	7.7
2/12/76	11	11	8.0	7.4	-	-	2180	2010	16.8	9.0
2/16/76	13	14	7.1	7.2	-	-	-	-	3.0	4.0
2/17/76	12	12	-	7.3	-	-	1810	1500	-	6.5

TABLE A-1. DATA OBTAINED DURING OPERATION AT FEED RATE OF 1.9 LITERS/MIN. (STANDARD)

Sample Date	Temp. °C		pH		BOD_5* - mg/l		COD - mg/l		MBAS - mg/l	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
E. Fifth Trial										
2/26/76	-	-	-	-	-	-	-	-	1.6	3.0
2/27/76	-	-	-	-	-	-	-	-	1.9	2.8
3/1/76	15	15	-	-	-	-	-	-	1.3	1.1
3/2/76	17	17	6.1	6.5	-	-	-	-	1.6	1.5
3/3/76	18	18	7.4	7.6	-	-	-	-	-	-
3/4/76	18	18	7.0	7.2	-	-	1350	980	4.2	4.2
3/8/76	14	14	7.2	7.2	-	-	-	-	2.0	3.0
3/10/76	12	12	6.9	7.1	-	-	1070	920	4.0	4.7
3/11/76	15	15	6.8	7.1	-	-	-	-	-	-
3/12/76	-	-	-	-	-	-	-	-	3.6	3.6
3/16/76	-	-	8.0	7.5	-	-	-	-	1.8	3.2
3/18/76	12	12	6.5	6.9	-	-	2250	1960	16.0	40.0
3/19/76	12	12	6.4	6.9	-	-	-	-	18.2	45.0
3/22/76	14	14	6.8	7.1	-	-	-	-	36.0	45.0
3/23/76	14	14	9.3	7.8	-	-	-	-	-	-
3/24/76	-	-	7.7	7.5	-	-	-	-	-	-
F. Sixth Trial										
3/26/76	-	-	-	-	-	-	-	-	-	-
3/29/76	16	16	6.8	7.0	-	-	-	-	28	30
3/30/76	17	17	6.8	7.0	-	-	-	-	22	24
4/1/76	-	-	6.4	7.1	-	-	2670	2350	20	19.5
4/5/76	18	15	7.0	6.9	-	-	-	-	9.4	9.4
4/6/76	17	17	7.2	7.4	-	-	-	-	12.3	9.0
4/8/76	16	15	7.1	7.2	-	-	-	-	12	-

TABLE A-1. DATA OBTAINED DURING OPERATION AT FEED RATE OF 1.9 LITERS/MIN. (STANDARD)

Sample Date	Temp. °C Inf.	Temp. °C Eff.	pH Inf.	pH Eff.	BOD_5* - mg/l Inf.	BOD_5* - mg/l Eff.	COD - mg/l Inf.	COD - mg/l Eff.	MBAS - mg/l Inf.	MBAS - mg/l Eff.
G. Seventh Trial										
4/23/76	-	-	-	-	-	-	-	-	-	-
4/26/76	-	-	-	-	-	-	-	-	5.4	3.0
4/28/76	17	16	9.4	7.3	-	-	1680	810	-	1.8
5/4/76	-	-	8.7	8.0	-	-	-	-	15.0	4.5
5/5/76	20	18	-	8.0	-	-	-	-	25.0	3.5
5/6/76	19	19	-	-	-	-	1935	1050	15	5.0
H. Eighth Trial										
5/14/76	-	-	-	-	-	-	-	-	-	-
5/17/76	22	23	8.2	8.2	-	-	-	-	12.6	0.3
5/18/76	-	-	7.7	-	-	-	-	-	18	6.7
5/19/76	17	18	7.6	-	370	300	1440	840	12.6	7.5
5/20/76	19	19	9.2	7.8	-	-	-	-	70	50
I. Ninth Trial										
7/16/76	-	-	-	-	-	-	-	-	-	-
7/19/76	24	23	-	-	-	-	-	-	4.4	2.8
7/20/76	25	25	-	-	-	-	-	-	5.7	2.5
7/21/76	-	-	7.2	7.4	-	380	1570	1030	7.0	2.9
7/23/76	26	25	7.2	7.4	-	-	1240	990	5.4	2.6
7/26/76	-	-	-	-	-	-	1100	700	2.8	1.2
7/27/76	25	25	7.3	7.4	-	-	-	-	2.9	1.3
7/29/76	27	27	7.2	7.3	900	375	1700	830	7.8	1.3

*All BOD_5 samples filtered before testing. BOD_5 measured is soluble BOD.

TABLE A-2. DATA OBTAINED AT FEED RATES GREATER THAN 1.9 LITERS/MIN. (STANDARD)

Sample Date	Temp. °C		pH		BOD_5* - mg/l		COD - mg/l		MBAS - mg/l	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
A. Feed Rate at 2.85 l/min.										
10/22/75	18	19	7.1	7.2	150	20	1300	570	4.9	0.92
10/27/75	-	-	7.0	7.2	-	-	-	-	4.6	0.82
10/28/75	16	18	6.5	7.0	-	-	1360	670	4.4	0.88
10/30/75	17	19	7.0	7.2	-	-	1800	800	7.0	2.0
11/3/75	16	18	7.0	7.5	-	-	-	-	4.8	0.62
11/4/75	18	20	7.0	7.5	75	20	790	400	3.1	0.58
11/6/75	19	22	7.0	7.2	75	15	960	400	4.2	0.88
B. Feed Rate at 3.8 l/min.										
11/6/75	-	-	-	-	-	-	-	-	-	-
11/10/75	20	22	6.9	7.1	-	-	-	-	0.88	0.64
11/11/75	19	20	6.9	7.1	135	20	940	300	0.60	0.21
11/13/75	15	16	6.9	7.1	70	30	690	300	0.60	0.38
11/14/75	10	13	-	-	-	-	-	-	0.84	0.45
11/17/75	12	15	7.0	7.2	-	-	-	-	0.13	0.16
11/18/75	12	14	7.2	7.5	30	20	620	290	0.08	0.01
11/20/75	15	17	8.0	7.3	80	10	820	330	0.23	0.01
11/25/75	9	11	7.2	7.3	30	10	490	490	0.21	0.21
11/26/75	7	10	7.2	7.3	-	-	-	-	0.20	0.18
12/1/75	-	-	7.5	7.6	-	-	-	-	0.10	0.09
12/2/75	9	10	7.5	7.6	36	15	-	-	1.39	0.09
12/3/75	10	13	7.7	7.8	-	-	-	-	1.00	0.18

TABLE A-2. DATA OBTAINED AT FEED RATES GREATER THAN 1.9 LITERS/MIN. (STANDARD)

Sample	Temp. °C		pH		BOD5* - mg/l		COD - mg/l		MBAS - mg/l	
Date	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
C. Feed Rate at 76 l/min.										
12/3/75	-	-	-	-	-	-	-	-	-	-
12/4/75	10	12	7.0	7.5	30	20	1370	860	1.9	0.65
12/5/75	11	14	7.1	7.5	-	-	-	-	2.3	1.3
12/9/75	9	10	6.8	7.1	100	15	1180	900	3.8	1.3
12/10/75	9	11	-	-	-	-	-	-	6.0	1.8
12/11/75	9	11	7.2	7.3	65	20	1320	1030	15.6	2.8

*All BOD5 samples filtered before testing. BOD5 measured is soluble BOD.

TABLE A-3. DATA OBTAINED AT FEED RATES LESS THAN 1.9 LITERS/MIN. (STANDARD)

Sample Date	Temp. °C Inf.	Temp. °C Eff.	pH Inf.	pH Eff.	BOD_5* - mg/1 Inf.	BOD_5* - mg/1 Eff.	COD - mg/1 Inf.	COD - mg/1 Eff.	MBAS - mg/1 Inf.	MBAS - mg/1 Eff.
A. Feed Rates of 0.9 1/min. Initial Startup										
1/12/76	-	-	-	-	-	-	-	-	-	-
1/13/76	9	13	7.5	7.1	75	30	1660	990	15.4	4.5
1/14/76	9	13	-	-	-	-	-	-	16.4	5.5
1/15/76	8	11	7.1	7.2	115	50	1850	1500	17.8	8.7
B. Second Trial										
4/8/76	-	-	-	-	-	-	-	-	-	-
4/9/76	16	14	-	-	-	-	-	-	8.7	7.2
4/13/76	18	16	7.0	7.1	-	-	1070	900	7.9	4.5
4/15/76	21	21	7.3	7.5	-	-	-	-	8.2	2.2
4/19/76	-	21	7.0	7.2	-	-	-	-	4.4	1.4
4/21/76	20	21	7.0	7.2	-	-	1060	480	4.0	1.2
C. Third Trial										
5/6/76	-	-	-	-	-	-	-	-	-	-
5/7/76	-	-	9.9	8.6	-	-	-	-	26.1	4.0
5/10/76	20	20	10.0	8.4	-	-	-	-	17.4	0.28
5/11/76	20	20	9.6	8.4	-	-	-	-	6.0	0.10
5/12/76	21	21	8.9	7.6	-	340	1610	1050	12.0	0.12
5/14/76	21	21	8.4	8.4	-	-	-	-	9.4	0.15

TABLE A-3. DATA OBTAINED AT FEED RATES LESS THAN 1.9 LITERS/MIN. (STANDARD)

Sample Date	Temp. °C Inf.	Temp. °C Eff.	pH Inf.	pH Eff.	BOD5* - mg/l Inf.	BOD5* - mg/l Eff.	COD - mg/l Inf.	COD - mg/l Eff.	MBAS - mg/l Inf.	MBAS - mg/l Eff.
D. **Fourth Trial**										
5/21/76	-	-	-	-	-	-	-	-	-	-
5/24/76	20	19	8.0	8.2	-	-	-	1570	28.8	23.3
5/26/76	-	-	7.9	8.4	-	-	-	-	33.6	22.7
5/27/76	-	-	-	-	450	375	2100	1640	22.4	10.4
6/1/76	22	22	7.8	8.0	-	-	-	-	13.2	9.0
6/2/76	-	-	-	-	-	-	-	-	15.0	8.0
6/3/76	21	21	7.6	7.8	-	-	1240	730	11.3	9.2
6/4/76	-	-	-	-	-	-	-	780	12.6	8.5
6/9/76	24	23	7.6	7.9	-	-	-	-	20.0	8.0
6/10/76	24	23	7.7	7.9	-	-	2030	780	16.3	3.0
6/11/76	24	24	7.8	7.8	-	-	-	-	22.0	7.7
6/14/76	25	25	7.7	7.9	-	-	-	-	8.5	5.8
6/16/76	24	23	7.7	7.8	-	-	1540	1010	10.0	5.0
6/21/76	23	24	8.1	8.1	-	-	-	-	8.1	4.2
6/22/76	22	21	7.8	8.0	-	-	-	-	5.3	3.8
6/23/76	24	23	7.6	7.9	-	-	1160	1100	5.4	1.8
6/25/76	24	24	7.8	8.0	-	-	-	-	6.6	3.5
6/30/76	23	22	-	-	-	-	1120	960	8.4	3.8
7/2/76	23	23	-	-	-	-	-	-	33.0	16.0
E. **Fifth Trial**										
9/3/76	-	-	-	-	-	-	-	-	-	-
9/7/76	22	22	-	-	-	-	-	-	9.0	3.4
9/9/76	25	25	7.5	7.6	275	180	950	475	5.0	1.4
9/10/76	24	24	7.6	7.7	-	-	-	-	3.5	0.8
9/17/76	21	21	7.4	7.6	-	-	-	-	39.0	28.0

*All BOD5 samples filtered before testing. BOD5 measured is soluble BOD.

TABLE A-4. DATA OBTAINED BY SAMPLING INDIVIDUAL STAGES OF THE RBC

	Date	Source	Temp. °C Inf.	Feed Rate Liters/Min.	BOD5* mg/l	COD mg/l	MBAS mg/l	Dissolved Oxygen, mg/l
1.	8/18/75	Influent to Stage I	27	1.9	-	-	-	0
		Stage I			-	-	-	3.7
		Stage IV (Effluent)			-	-	-	4.1
2.	8/26/75	Stage I	25	1.9	-	-	-	1.0
		Stage IV (Effluent)			-	-	-	1.8
3.	9/8/75	Stage I	-	1.9	-	-	-	1.5
		Stage IV (Effluent)			-	-	-	1.8
4.	9/11/75	Influent to Stage I	24	1.9	180	1280	5.0	-
		Stage I			90	1040	2.0	-
		Stage II			-	480	1.1	-
		Stage III			70	480	0.85	-
		Stage IV (Effluent)			40	480	0.37	-
5.	9/25/75	Stage I	17	1.9	-	-	-	0.2
		Stage IV (Effluent)						0.2
6.	10/1/75	Influent to Stage I	-	1.9	-	-	4.0	.0
		Stage I			-	-	-	1.0
		Stage IV (Effluent)			-	-	3.7	0.5
7.	10/10/75	Influent to Stage I	23	1.9	-	-	24.8	0
		Stage I			-	-	-	0.7
		Stage IV (Effluent)			-	-	13.8	1.2
8.	10/16/75	Influent to Stage I	22	1.9	150	1700	9.4	-
		Stage I			-	-	4.5	-
		Stage II			-	-	3.8	-
		Stage III			-	-	2.5	-
		Stage IV (Effluent)			40	730	2.0	-

TABLE A-4. DATA OBTAINED BY SAMPLING INDIVIDUAL STAGES OF THE RBC

	Date	Source	Temp. °C Inf.	Feed Rate Liters/Min.	BOD5* mg/l	COD mg/l	MBAS mg/l	Dissolved Oxygen, mg/l
9.	10/20/75	Influent to Stage I	16	1.9	-	-	-	0.0
		Stage I			-	-	-	0.6
		Stage IV (Effluent)			-	-	-	2.1
10.	10/29/75	Stage I	-	2.85	-	-	-	0
		Stage IV (Effluent)			-	-	-	1.9
11.	11/6/75	Influent to Stage I	19	2.85	80	960	4.2	0
		Stage I			-	-	-	0.2
		Stage IV (Effluent)			15	400	0.88	2.4
12.	11/13/75	Influent to Stage I	15	3.8	70	690	0.60	0
		Stage I			-	-	-	0.1
		Stage IV (Effluent)			30	300	0.38	1.9
13.	11/20/75	Influent to Stage I	15	3.8	80	820	0.23	-
		Stage I			35	665	0.06	-
		Stage II			25	330	0.01	-
		Stage III			10	400	0.01	-
		Stage IV (Effluent)			10	330	0.01	-
14.	12/5/75	Influent to Stage I	11	7.6	-	-	-	0
		Stage I			-	-	-	4.65
		Stage IV (Effluent)			-	-	-	4.70
15.	2/9/76	Influent to Stage I	-	1.9	-	-	20	0
		Stage I			-	-	-	7.9
		Stage IV (Effluent)			-	-	8.0	8.0

TABLE A-4. DATA OBTAINED BY SAMPLING INDIVIDUAL STAGES OF THE RBC

	Date	Source	Temp. °C Inf.	Feed Rate Liters/Min.	BOD5* mg/l	COD mg/l	MBAS mg/l	Dissolved Oxygen, mg/l
16.	3/4/76	Influent to Stage I	18	1.9	-	1350	4.2	-
		Stage I			-	1200	4.2	-
		Stage II			-	980	4.2	-
		Stage III			-	980	4.2	-
		Stage IV (Effluent)			-	980	4.2	-
17.	3/10/76	Influent to Stage I	13	1.9	-	1070	4.0	-
		Stage I			-	910	4.8	-
		Stage II			-	-	5.0	-
		Stage III			-	-	4.7	-
		Stage IV (Effluent)			-	910	4.7	-
18.	3/11/76	Influent to Stage I	15	1.9	-	-	-	0
		Stage I			-	-	-	3.1
		Stage IV (Effluent)			-	-	-	4.2
19.	3/18/76	Influent to Stage I	12	1.9	-	2250	16	0
		Stage I			-	2100	-	3.4
		Stage II			-	2000	-	-
		Stage III			-	2000	-	4.6
		Stage IV (Effluent)			-	1950	40	-
20.	4/13/76	Influent to Stage I	18	0.95	-	1070	7.9	-
		Stage I			-	900	4.5	-
		Stage IV (Effluent)			-	900	4.5	-
21.	4/19/76	Influent to Stage I	-	0.95	-	-	4.4	-
		Stage I			-	-	2.1	-
		Stage IV (Effluent)			-	-	1.4	-

TABLE A-4. DATA OBTAINED BY SAMPLING INDIVIDUAL STAGES OF THE RBC

	Date	Source	Temp. °C Inf.	Feed Rate Liters/Min.	BOD_5* mg/l	COD mg/l	MBAS mg/l	Dissolved Oxygen, mg/l
22.	4/21/76	Influent to Stage I	20	0.95	-	1060	4.0	-
		Stage I			-	650	2.0	-
		Stage II			-	480	1.2	-
		Stage III			-	480	1.2	-
		Stage IV (Effluent)			-	480	1.2	-
23.	4/28/76	Influent to Stage I	17	1.9	-	1680	-	-
		Stage I			-	890	2.1	-
		Stage II			-	810	-	-
		Stage III			-	810	-	-
		Stage IV (Effluent)			-	810	1.8	-
24.	5/6/76	Influent to Stage I	19	1.9	-	1930	15.2	-
		Stage I			-	1050	-	-
		Stage II			-	1050	-	-
		Stage III			-	1050	-	-
		Stage IV (Effluent)			-	1050	5.0	-
25.	5/12/76	Influent to Stage I	21	0.95	-	1610	12	-
		Stage I			-	1150	0.7	-
		Stage II			-	1050	0.18	-
		Stage III			-	1050	0.12	-
		Stage IV (Effluent)			-	1050	0.12	-
26.	5/14/76	Influent to Stage I	21	0.95	-	-	9.4	0
		Stage I			-	-	-	0
		Stage IV (Effluent)			-	-	0.15	2.6

TABLE A-4. DATA OBTAINED BY SAMPLING INDIVIDUAL STAGES OF THE RBC

	Date	Source	Temp. °C Inf.	Feed Rate Liters/Min.	BOD5* mg/l	COD mg/l	MBAS mg/l	Dissolved Oxygen, mg/l
27.	5/19/76	Influent to Stage I	17	1.9	370	1440	12.6	0
		Stage I			-	840	9.9	1.0
		Stage II			-	840	-	-
		Stage III			-	840	-	-
		Stage IV (Effluent)			300	840	7.5	2.8
28.	6/18/76	Influent to Stage I	-	0.95	-	-	-	0
		Stage I			-	-	-	2.5
		Stage IV (Effluent)			-	-	-	3.3
29.	7/2/76	Influent to Stage I	23	0.95	-	-	33	0
		Stage I			-	-	-	0.3
		Stage II			-	-	-	0.5
		Stage III			-	-	-	1.7
		Stage IV (Effluent)			-	-	16	2.0
30.	7/23/76	Influent to Stage I	26	1.9	-	1240	5.4	0
		Stage I			-	1150	3.0	0.5
		Stage II			-	990	3.0	1.3
		Stage III			-	990	2.8	2.0
		Stage IV (Effluent)			-	990	2.6	2.4
31	7/26/76	Influent to Stage I		1.9	-	1100	2.8	-
		Stages I & II (Combined)**			-	700	1.4	-
		Stage III			-	-	1.2	-
		Stage IV (Effluent)			-	700	1.2	-
32.	7/27/76	Influent to Stage I	25	1.9	-	-	2.9	0
		Stages I & II (Combined)			-	-	1.8	0.1
		Stage III			-	-	1.3	0.2
		Stage IV (Effluent)			-	-	1.3	0.5

TABLE A-4. DATA OBTAINED BY SAMPLING INDIVIDUAL STAGES OF THE RBC

	Date	Source	Temp. °C Inf.	Feed Rate Liters/Min.	BOD_5* mg/l	COD mg/l	MBAS mg/l	Dissolved Oxygen, mg/l
33.	7/29/76	Influent to Stage I	27	1.9	900	1700	7.8	-
		Stages I & II (Combined)			-	830	1.9	-
		Stage III			-	830	1.4	-
		Stage IV (Effluent)			375	830	1.3	-
34.	8/4/76	Influent to Stage I	24	1.9	-	-	8.1	-
		Stages I & II (Combined)			-	-	7.0	-
		Stage III			-	-	6.5	-
		Stage IV (Effluent)			-	-	6.0	-
35.	8/5/76	Influent to Stage I	25		-	1240	13	-
		Stages I & II (Combined)			-	1070	7.8	-
		Stage III			-	1030	-	-
		Stage IV (Effluent)			-	1030	7.2	-
36.	8/12/76	Influent to Stage I	25	1.9	-	-	10	0
		Stages I & II (Combined)			-	-	-	1.7
		Stage III			-	-	-	2.8
		Stage IV (Effluent)			-	-	9.4	3.3

*All BOD_5 samples filtered before testing. BOD_5 measured is soluble BOD_5.

**Baffle plate between first and second stages removed doubling surface area in the first stage making three stages.

TABLE A-5. DATA OBTAINED ON SUSPENDED SOLIDS, NITROGEN, PHOSPHORUS, AND OIL & GREASE UNDER VARIOUS OPERATING CONDITIONS

Sample Date	Wastewater Feed Rate, l/min.	Wastewater Feed Temp. °C	Total Suspended Solids, mg/l Inf.	Total Suspended Solids, mg/l Eff.	Nitrogen, mg/l Inf.	Nitrogen, mg/l Eff.	Phosphorus, mg/l Inf.	Phosphorus, mg/l Eff.	Oil & Grease, mg/l Inf.	Oil & Grease, mg/l Eff.
8/20/75	1.9	27	104	104	-	-	1.44	1.40	-	-
8/22/75	1.9	27	84	116	-	-	-	-	-	-
8/26/75	1.9	28	32	160	-	-	-	-	14.1	6.4
8/28/75	1.9	28	28	40	-	-	3.08	2.78	-	-
9/2/75	1.9	25	76	72	-	-	-	-	48.7	13.9
9/4/75	1.9	25	108	80	-	-	-	-	-	-
9/9/75	1.9	25	136	60	-	-	-	-	-	-
9/16/75	1.9	19	88	52	-	-	6.63	5.75	6.1	19.2
9/23/75	3.8	23	44	48	-	-	3.00	3.00	-	-
9/25/75	3.8	17	30	32	-	-	-	-	-	-
9/30/75	1.9	20	-	-	-	-	3.01	2.50	-	-
10/7/75	1.9	19	-	-	-	-	2.05	2.50	34.5	21.0
10/14/75	1.9	21	32	48	-	21.6	5.10	2.70	16.1	12.7
10/16/75	1.9	22	76	48	-	-	5.10	2.70	16.1	12.7
10/21/75	1.9	20	36	44	41.2	24.6	4.00	3.00	16.2	19.2
10/23/75	2.85	18	68	56	-	-	-	-	-	-
10/28/75	2.85	16	36	36	40.0	38.4	6.93	4.50	21.8	47.1
10/30/75	2.85	17	56	48	-	-	-	-	-	-
11/4/75	2.85	18	36	80	-	-	5.75	5.50	-	-
11/6/75	2.85	19	72	68	-	-	-	-	-	-
11/11/75	3.8	19	120	60	14.6	12.0	4.50	2.63	22.0	19.1
11/13/75	3.8	15	116	40	-	-	-	-	-	-
11/18/75	3.8	12	124	40	7.8	6.0	3.93	3.38	14.7	13.0
11/20/75	3.8	15	156	60	-	-	-	-	-	-
11/25/75	3.8	9	100	92	4.2	0.84	3.20	2.80	21.8	14.4
12/2/75	3.8	9	84	132	8.7	6.5	3.20	3.20	5.9	5.9

TABLE A-5. DATA OBTAINED ON SUSPENDED SOLIDS, NITROGEN, PHOSPHORUS, AND OIL & GREASE UNDER VARIOUS OPERATING CONDITIONS

Sample Date	Wastewater Feed Rate, l/min.	Wastewater Feed Temp. °C	Total Suspended Solids, mg/l Inf.	Total Suspended Solids, mg/l Eff.	Nitrogen, mg/l Inf.	Nitrogen, mg/l Eff.	Phosphorus, mg/l Inf.	Phosphorus, mg/l Eff.	Oil & Grease, mg/l Inf.	Oil & Grease, mg/l Eff.
12/4/75	7.6	10	84	84	-	-	-	-	-	-
12/9/75	7.6	9	44	68	22.0	14.6	3.25	3.50	32.6	31.1
12/11/75	7.6	9	52	32	-	-	-	-	-	-
12/16/75	1.9	13	44	85	17.6	16.5	3.38	3.25	66.4	66.2
1/6/76	No flow	10 (in unit)	-	124	-	25.8	-	5.38	-	2.1
1/13/76	0.95	9	12	112	38.6	38.4	3.25	4.13	8.6	8.6
1/20/76	No flow	11 (in unit)	-	-	-	-	2.38	4.50	-	-
1/26/76	No flow	20 (in unit)	-	20	-	21.8	-	4.50	-	12.6
1/29/76	1.9	7	28	32	-	-	-	-	-	-
2/3/76	1.9	7	24	12	33.0	28.6	2.50	4.50	29.8	45.0
2/10/76	1.9	9	36	72	38.0	25.0	2.38	4.50	4.7	42.0
2/17/76	1.9	12	52	60	26.6	21.6	-	-	12.9	51.0
3/4/76	1.9	18	36 (1st Stage)	52	-	17.4	-	-	-	-
3/10/76	1.9	13	52	40	24.4	17.4	3.38	3.25	12.7	12.0
3/18/76	1.9	12	28	20	17.9	14.0	2.38	2.00	63.5	26.1
4/13/76	0.95	18	68	16	-	-	3.93	3.40	7.6	1.8
4/21/76	0.95	20	88	100	12.6	10.9	3.93	3.00	13.7	13.0
4/28/76	1.9	17	364	132	28.8	7.3	4.25	4.00	16.7	50.0
5/6/76	1.9	19	96	64	22.1	11.8	3.80	3.00	24.7	42.3
5/12/76	0.95	21	124	48	10.4	6.2	3.75	1.25	34.9	25.2

TABLE A-5. DATA OBTAINED ON SUSPENDED SOLIDS, NITROGEN, PHOSPHORUS, AND OIL & GREASE UNDER VARIOUS OPERATING CONDITIONS

Sample Date	Wastewater Feed		Total Suspended Solids, mg/l		Nitrogen, mg/l		Phosphorus, mg/l		Oil & Grease, mg/l	
	Rate, l/min.	Temp. °C	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
5/19/76	1.9	17	28	92	9.4	5.6	-	-	14.6	-
5/27/76	0.95	-	88	84	22.4	10.4	3.50	3.75	14.3	35.6
6/3/76	0.95	21	76	72	33.0	10.9	3.00	3.50	10.7	28.1
6/10/76	0.95	24	76	24	39.5	8.1	-	-	28.1	26.0
6/16/76	0.95	24	124	80	27.4	-	4.13	3.25	29.4	-
6/23/76	0.95	24	108	60	47.6	6.7	3.00	2.90	34.9	21.5
6/30/76	0.95	23	68	68	21.3	20.4	4.13	3.40	23.7	13.7
7/21/76	1.9	-	92	56	68.3	8.1	3.50	3.00	20.3	28.4
7/29/76	1.9	27	84	72	45.9	6.5	4.13	4.10	36.1	27.2
8/5/76	1.9	25	92	44	78.9	12.3	4.25	4.00	-	-
8/10/76	1.9	24	92	100	66.9	3.4	4.10	4.60	69.4	-
8/17/76	1.9	27	44	72	12.0	4.8	4.10	3.75	-	-
9/19/76	0.95	25	68	60	32.5	4.8	-	-	60.0	17.8

TABLE B-1. ROTATING BIOLOGICAL CONTACTOR EFFLUENT INORGANIC ANALYSIS FOR TOXIC METALS

Element	Sample Date 4/14/77	7/1/77
Antimony µg/l	< 200	< 200
Arsenic µg/l	< 1	< 1
Beryllium µg/l	< 5	< 7
Cadmium µg/l	< 2	< 2
Chromium µg/l	< 20	< 50
Copper µg/l	< 50	< 80
Lead µg/l	< 100	< 50
Mercury µg/l	< 1	< 1
Nickel µg/l	< 50	< 40
Selenium µg/l	< 1	< 1
Silver µg/l	< 100	*1.32 mg/l
Thallium µg/l	< 50	< 70
Zinc µg/l	250	115

*Results declared invalid due to erratic atomic absorption lamp.

TABLE B-2. RAW PLANT WASTE INORGANIC ANALYSIS FOR TOXIC METALS

Element	Sample Date 4/14/77	7/1/77
Antimony µg/l	< 200	< 200
Arsenic µg/l	< 1	< 1
Beryllium µg/l	< 5	< 7
Cadmium µg/l	< 2	< 2
Chromium µg/l	< 20	< 5
Copper µg/l	< 50	< 40
Lead µg/l	< 100	< 50
Mercury µg/l	< 1	< 1
Nickel µg/l	< 50	< 20
Selenium µg/l	< 1	< 1
Silver µg/l	< 100	*0.8 mg/l
Thallium µg/l	< 50	< 70
Zinc µg/l	< 250	95

*Results declared invalid due to erratic atomic absorption lamp.

TABLE B-3. EXTENDED AERATED LAGOON EFFLUENT INORGANIC ANALYSIS FOR TOXIC METALS

Element	Sample Date 11/3/76	4/14/77	7/1/77
Antimony µg/l	< 20	< 200	< 200
Arsenic µg/l	1	< 1	< 1
Beryllium µg/l	< 6	< 5	< 5
Cadmium µg/l	< 2	< 2	< 2
Chromium µg/l	< 20	< 20	< 20
Copper µg/l	< 10	< 50	< 10
Lead µg/l	50	< 100	< 50
Mercury µg/l	< 1	< 1	< 1
Nickel µg/l	< 20	< 50	< 30
Selenium µg/l	< 1	< 1	< 1
Silver µg/l	< 10	< 100	*2.11 mg/l
Thallium µg/l	< 60	< 50	< 50
Zinc µg/l	70	< 200	< 47

*Results declared invalid due to erratic atomic absorption lamp.

TABLE B-4. ORGANIC ANALYSIS ON ROTATING BIOLOGICAL CONTACTOR EFFLUENT FOR TOXIC SUBSTANCES

Compound	Results of Analysis	Date of Analysis
Benzene	<0.25 mg/l	6/16/77
Carbon tetrachloride	<0.5 mg/l	6/20/77
Chlorinated benzene	<0.8 mg/l	6/17/77
Chlorinated ethane	<0.8 mg/l	6/20/77
Chlorinated phenol(2,4-di)	<0.1 mg/l	6/20/77
Chloroform	<0.06 mg/l	6/15/77
2-Chlorophenol	<0.10 mg/l	4/27/77
Dichlorobenzene	<0.8 mg/l	4/27/77
Dichloroethylene	<0.5 mg/l	4/27/77
2,4-Dimethylphenol	<1.0 mg/l	4/27/77
Ethyl benzene	<1.2 mg/l	4/27/77
Pentachlorophenol	<3.0 mg/l	4/27/77
Phenol	<0.2 mg/l	6/20/77
Tetrachloroethylene	<1.5 mg/l	6/20/77
Toluene	<0.6 mg/l	6/20/77
Trichloroethylene	<0.8 mg/l	4/27/77

TABLE B-5.- ORGANIC ANALYSIS ON RAW PLANT WASTE FOR TOXIC SUBSTANCES

Compound	Results of Analysis	Dates of Analysis	
Benzene	< 0.25 mg/l	6/16/77	6/20/77
Carbon tetrachloride	< 0.5 mg/l	6/20/77	
Chlorinated benzene	< 0.8 mg/l	6/17/77	6/20/77
Chlorinated ethane	< 0.8 mg/l	6/20/77	
Chlorinated phenol(2,4-di)	< 0.1 mg/l	6/20/77	
Chloroform	< 0.06 mg/l	6/15/77	6/20/77
2-Chlorophenol	< 0.10 mg/l	2/2/77	4/27/77
Dichlorobenzene	< 0.8 mg/l	3/28/77	6/17/77
Dichloroethylene	< 0.5 mg/l	3/28/77	4/27/77
2,4-Dimethylphenol	< 1.0 mg/l	3/28/77	4/27/77
Ethyl benzene	< 1.2 mg/l	3/24/77	4/27/77
Pentachlorophenol	< 3.0 mg/l	3/22/77	4/27/77
Phenol	< 0.2 mg/l	6/20/77	
Tetrachloroethylene	< 1.5 mg/l	6/20/77	
Toluene	< 0.6 mg/l	6/17/77	6/20/77
Trichloroethylene	< 0.8 mg/l	3/20/77 4/27/77	3/30/77 5/9/77

TABLE B-6. ORGANIC ANALYSIS ON AERATED LAGOON EFFLUENT FOR TOXIC SUBSTANCES

Compound	Results of Analysis	Dates of Analysis	
Benzene	< 0.25 mg/l	6/16/77	6/20/77
Carbon tetrachloride	< 0.5 mg/l	6/20/77	
Chlorinated benzene	< 0.8 mg/l	6/20/77	
Chlorinated ethane	< 0.8 mg/l	6/20/77	
Chlorinated phenol (2,4-di)	< 0.1 mg/l	6/15/77	6/20/77
Chloroform	< 0.06 mg/l	4/27/77	
2-Chlorophenol	< 0.10 mg/l	3/28/77	
Dichlorobenzene	< 0.8 mg/l	4/27/77	
Dichloroethylene	< 0.5 mg/l	4/27/77	
2,4-Dimethylphenol	< 1.0 mg/l	4/27/77	
Ethyl benzene	< 1.2 mg/l	4/27/77	
Pentachlorophenol	< 3.0 mg/l	4/27/77	
Phenol	< 0.2 mg/l	6/20/77	
Tetrachloroethylene	< 1.5 mg/l	6/20/77	
Toluene	< 0.6 mg/l	6/20/77	
Trichloroethylene	< 0.8 mg/l	4/27/77	

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

IERL-Ci Project Officer for this report is Ronald J. Turner, 513/684-4481

16. ABSTRACT

This report summarizes data on the treatment of wastewaters from a liquid detergent manufacturing plant by a rotating biological contactor and presents the findings of an analytical effort to determine the presence or absence of metals and organic compounds which were among those listed in the Consent Decree, Train vs NRDC, et al, June 1976. Even under the best operating conditions, the rotating biological contactor performance was essentially equivalent to that of the extended aeration lagoon. All metals except zinc (0.25 mg/l) were below minimum measurable limits. All organic compounds subjected to analysis by gas chromatograph were below minimum detectable limits.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Industrial Wastes Industrial Waste Treatment Detergents	Rotating Biological Contactor	68D 91A

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