GREASE REMOVAL BY A COMPLETELY MIXED ACTIVATED SLUDGE PLANT AND METHODS FOR ENHANCING GREASE REMOVAL

by

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Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment for the degree of

MASTER OF SCIENCE

in

Sanitary Engineering

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November, 1970

Blacksburg, Virginia

ACKNOWLEDGMENTS

This thesis and the graduate program undertaken by the author were supported by a United States Public Health Service Fellowship from the Department of Health, Education, and Welfare, and by Educational Benefits from the Veterans Administration. The author is grateful for these grants that made graduate work possible.

The author expresses his deep appreciation to for his suggestion of the topic and later guidance and help; to for his very able technical assistance; to for his assistance in preparing graphs; and to his wife, for her encouragement and very able assistance in the final preparation of this thesis.

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I. INTRODUCTION

Grease has long been a nuisance and deterrent to the effective operation of many wastewater treatment systems. Today's concern with the degradation of the environment, practically demands that more efficient wastewater treatment methods be developed. The development of an efficient, economical method to treat wastes high in grease content would be a step towards preventing further degradation of the nations' receiving waters. Grease causes problems not only at the treatment plants, but in the collection systems and receiving waters as well. Problems that are associated with grease at the treatment plant include: a) clogging of screens; b) formation of unsightly scums on sedimentation basins and receiving waters; c) formation of grease balls that prevent other materials from being broken down and protect pathogenic organisms; and d) severely affects anaerobic digesters in that it helps form scum blankets that reduce the digester capacity requiring frequent manual cleaning of the digesters.

In the past, grease has generally been removed either by grease traps at the source, or at the treatment plant by means of various aeration and skimming mechanisms with final disposal consisting of burial, incineration, or anaerobic digestion. The latter results in the formation of the scum blankets mentioned above. In general, grease in high concentrations (greater than 100 mg/1) has a detrimental effect on aerobic treatment units such as trickling filters and activated sludge tanks. Since reports indicate that most grease enters a sewage treatment plant in particulate form and is primarily composed of animal and vegetable fats and oils, it should in theory be available for metabolism by the organisms of activated sludge and not express inhibitory consequences.

The purpose of this research is to study the grease removal efficiency of a completely mixed, laboratory scale, activated sludge plant and methods for enhancing removal efficiencies at high concentrations. Bartsch (2) indicated that grease was readily metabolized by the organisms of activated sludge and high velocity blending of wastewaters prior to biological treatment should improve the removal efficiency. Blending should insure that the major portion of grease is in the colloidal, particulate form and thus provide more surface area for attack by the microorganisms. Emulsions of natural sewage grease were fed to the plant in varying concentrations and the efficiency of removal determined. The difference in grease removal of blended versus non-blended grease emulsions and blended versus non-blended raw sewage, and the effect of a surfactant (ABS), which also should provide more surface area for attack by the microorganisms, were also investigated.

Should blending, as is theorized, improve the removal efficiency, present day plants suffering under adverse grease loadings could modify their treatment units by the installation of blending units to obtain better grease removal. Thus, at proposed new treatment plants where grease is projected to be a problem, considerable savings could be realized by the construction of combination blending-activated sludge plants rather than other types that may require flotation and skimming devices.

II. LITERATURE REVIEW

Grease is a term that is defined by the solvent system used to extract it. Standard Methods for the Examination of Water and Wastewater (1) defines grease as the sum of all substances that are soluble in hexane. The Soxhlet extraction procedure for grease analysis as outlined in Standard Methods (1) was not used in this research because of the lengthy time required and difficulty in obtaining reproducible results. Instead, a modification of Loehr and Rohlich's wet analysis method (8) using chloroform as the grease extraction solvent was used. The term grease can be considered almost universal since an absolute quantity of a specific substance is not measured. Rather, depending upon the solvent used for extraction, groups of organic substances with similar characteristics are determined quantitatively. Included as grease are fats, waxes, oils, hydrocarbons, esters, high-molecular-weight fatty acids, and other non-volatile material extracted by the solvent used (1, 11). In the past, chloroform and similar solvents have been neglected because extraction of grease was accompanied by the dissolving of resin, waxes, dried paints, rubber, napthalene hydrocarbons, and other materials without the realization that these compounds contain materials that can be classified as lipids, or grease. The term lipid can be used synonymously with the term grease since they are defined in a similar manner (8).

The concentration of grease in sewage varies widely depending upon specific local conditions. Mahlie (9) reports values ranging from 16 to 200 mg/l in raw sewage, with Loehr and Rohlich (8) reporting average concentrations for municipalities ranging from 46 to 98 mg/1 when there is no industrial input. Grease in sewage originates from: a) fecal material, which contains about 225 mg of grease per gram; b) garbage, in which grease content ranges from 13.5 to 35.5 per cent (5), and household wastewaters; c) manufacturing wastes (refinery wastes, packinghouse wastes, and wool treating wastes contain heavy concentrations); and d) garages and automobile washing facilities (3, 4, 9). One factor that has increased the grease content of sewage tremendously is the increased use of garbage disposals. Watson et al (16) report a 35 per cent per capita increase in grease content in homes with garbage disposals while Bowerman and Dryden (3) indicate that in areas with grinders there is 50 per cent more grease than in areas without them.

Removal of the grease component in wastewaters is vital since its presence poses esthetic, economic, and treatment plant performance problems. Esthetically, grease results in the formation of unsightly scums on waterways. These scums also increase the biochemical oxygen demand and prevent the natural reaeration of waterways by acting as a barrier between the water surface and air limiting oxygen transfer. Such scums violate stream standards set forth by Federal and State agencies. These standards generally state that all waters shall at all times be free from all substances attributable to sewage, industrial wastes, or other wastes in concentrations which contravene established standards or interfere with beneficial uses of such waters. Its economic impact upon treatment plant performance is reflected in lower efficiency of grease removal per dollar and increased maintenance requirements. The economic aspect also pertains to some industries, such as the meat packing industry where tremendous savings could result from the recovery of grease. Fullen and Hill (4) report that not only is there a great savings in the recovery of grease but that there is considerably less treatment plant difficulties when it is recovered. Thus, there are savings effected in two ways, yield of a marketable product and less treatment plant operation difficulties.

The major incentive for the removal of grease is the detrimental effect it has on the treatment plant, especially the sludge digesters. In the conventional sewage treatment plant, grease is removed in the primary clarifier(s) via a scum baffle and trough, and thence pumped to the digesters. Mann (10) indicates that the grease mixes with screening and fibrous material to form a scum mat, which in some cases reaches a thickness of up to eight feet. This reduces the digester capacity, increases the cost of operation, and creates a situation where possible damage may occur to the digester if the scum layer prevents the normal overflow of supernatant or sludge. A thick scum layer necessitates opening the digester to manually break up the layer. Laboratory experiments have shown that grease readily digests at a temperature of 95 degrees Fahrenheit, if mixed to allow intimate contact between the grease and the microorganisms, but this is not the case in actual digester operation (10). Studies have shown that the digestion of sludge, grease, and screenings takes twice as long as sludge alone (10). This accumulation in the digester also decreases the pH, limiting the gas production. Other problems caused by grease throughout a sewage system are: a) accumulation of grease along the sides and crowns of sewers and inverted siphons resulting in a maintenance problem; b) accumulation of grease in force mains causing a reduction in capacity by increasing friction; c) clogging of fine screens; d) formation of unsightly scums on the walls of clarifiers; e) formation of grease balls that pass through the plant untreated, prevent other matter from breaking down, and protect pathogenic organisms; f) increased biochemical oxygen demand (BOD), although Fullen and Hill (4) doubt that grease contributes much to the 5-day BOD because the first breakdown yields highly insoluble fatty acids. Soluble glycerol represents just 9 to 10 per cent of the original fat; g) clogging of trickling filter ports; h) coats zoogleal growth on trickling filter media resulting in a larger volume of media required; i) inhibits oxygen transfer to biological cells during aerobic treatment; j) prevents natural reaeration; k) damages fish spawning areas; and l) imparts taste and odor to waters (the odors resulting from rancid fats that break down to the so-called "goat acids" of volatile nature such as acrylic, butyric, valeric, caproic and caprylic acids) (9, 12).

Hunter and Heukelekian (6) report that the main constituents of grease are the glyceride fatty acids, followed by the unsaponifiable matter and the free fatty acids. The saturated fatty acids represent about 85 per cent of the total glyceride and free fatty acids and consist mainly of stearic acid (50 per cent) with lesser amounts of palmitic and myristic acids. The unsaturated acids are about 95 per cent oleic acid, with only trace amounts of other unsaturated fatty acids. The unsaponifiable matter proved to be primarily aliphatic hydrocarbons with lesser amounts of aromatic and oxygenated material present.

Heukelekian and Balmat (5) indicated that grease arrives at the treatment plant with the major portion in the particulate form. Of this, 19.13 per cent was settleable, 23.85 per cent supracolloidal and 51.43 per cent colloidal particles. According to Bowerman and Dryden (3) 90 to 95 per cent of grease is in the form of saponified fatty acids or insoluble soaps. Therefore, it would seem logical to conclude that since most grease is in the colloidal form in which it can most readily be metabolized by microorganisms, and that since it is generally assumed that the saponifiable or fatty matter portion of grease is easily metabolized by microorganisms, the activated sludge process should be an efficient method for the removal of grease. However, the literature is somewhat contradictory on the successful aerobic treatment of grease. There has been considerable work on anaerobic degradation of grease (9) but little work done on aerobic degradation. Mahlie (9) reported that grease is a deterrent to the effective operation of an activated sludge treatment plant. Fullen and Hill (4) indicate that since grease is not very soluble, it would not be readily degraded. Viswanathan et al (13, 14, 15) indicated that the fatty matter portion of grease is degraded easily by the activated sludge process. Viswanathan et al (15) in studies of three treatment systems, septic tanks, biological filters, and activated sludge, reported an absence of grease in the effluent of the activated sludge system after 18 days while the other two systems contained considerable grease. Using natural domestic sewage and a batch activated sludge process, they reported an absence of grease in the effluent after 3 days. Bartsch (2) indicated that grease was readily metabolized by the organisms of activated sludge, but recommended that there be modifications eliminating primary sedimentation. Bartsch also indicated that high velocity blending of wastewaters prior to biological treatment should improve the removal efficiency. Loehr and deNavarra (7) in studies on a contact stabilization activated sludge plant reported an overall plant removal efficiency of 84 per cent with an influent of 147 mg/1 grease.

III. MATERIALS AND METHODS

A. Materials

1. Bio Cert Peptone, Fisher Scientific Co. Used in primary substrate.

2. Dextrose, Fisher Scientific Co., Anhydrous, A.S.C. Used in primary substrate.

3. Bio Cert Yeast Extract, Fisher Scientific Co. Used in primary substrate.

4. Alkyl Benzene Sulfonate, (ABS), Soap and Detergent Association. Used in primary substrate.

5. Ferric Chloride, ($FeCl_3 \cdot 6H_2O$), Fisher Scientific Co. Used in primary substrate.

6. Potassium Dihydrogen Phosphate, (KH_2PO_4), Fisher Scientific Co. Used in buffer for primary substrate.

7. Dipotassium Hydrogen Phosphate, (K_2HPO_4), Fisher Scientific Co. Used in buffer for primary substrate.

8. Disodium Hydrogen Phosphate Heptahydrate, ($Na_2HPO_4 \cdot 7H_2O$), Fisher Scientific Co. Used in buffer for primary substrate.

9. Ammonium Chloride, (NH_4Cl), Allied Chemical. Used in buffer for primary substrate.

10. Filter Paper, Whatman, No. 40. Used in determination of grease.

11. Filter Glass Fiber, Reeve Angel. Used in the determination of total suspended solids and volatile suspended solids.

12. Hydrochloric Acid, (HCl), Fisher Scientific Co. Used for the

acidification of grease samples.

13. Hexane, (C_6H_{12}), Fisher Scientific Co. Used for the initial extraction of grease.

14. Chloroform, ($CHCl_3$), Fisher Scientific Co. Used for the determination of grease.

15. Methanol, (CH_3OH), Fisher Scientific Co. Used to separate the grease and chloroform from the water of the samples when extracting the grease.

16. Blender, Waring. Used for blending the samples during grease analysis.

B. Methods

1. Source and Procedure for Obtaining Pure Grease

Grease in the crude form was obtained from the grease flotation unit from the Stroubles Creek Sewage Treatment Plant. This grease was acidified to pH 1 with concentrated hydrochloric acid, hexane was added and then mixed for two hours on an automatic shaker. The hexane was decanted, filtered through Whatman No. 40 filter paper and evaporated over a water bath at 85° C. Since chloroform is the solvent in this research, the grease was again extracted using the method described in Appendix A. After extraction the pure grease was stored at 10° C.

2. Completely Mixed Activated Sludge Unit

This unit (refer to Figure 1) consisted of an aeration tank, settling tank, sludge return pump, and substrate feed pump. The primary substrate was fed at the rate of 176 ml

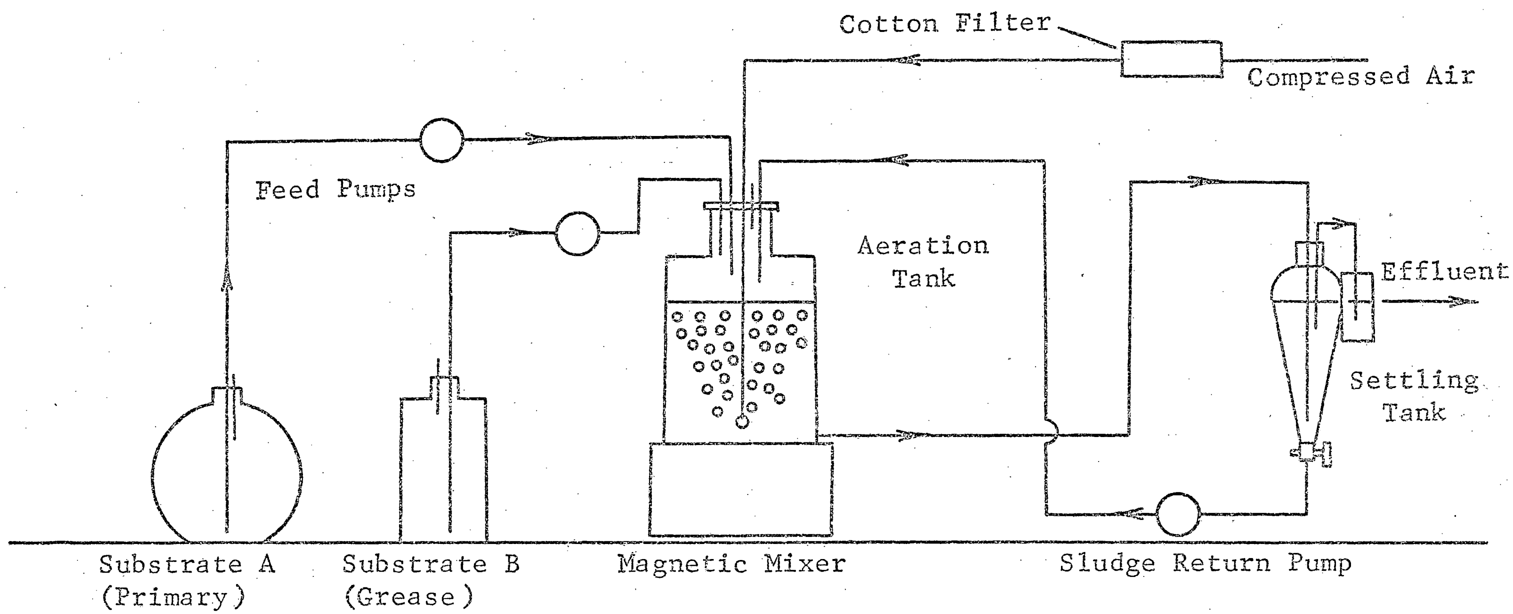

Figure 1. Completely Mixed Activated Sludge Bench Unit

per hour. Grease emulsion feed rates varied from 12 to 24 ml per hour. With an aeration tank working volume of 4 liters the combined substrates gave detention times ranging from 20.0 to 21.3 hours. When raw sewage alone was fed to the unit, the detention time was 22.7 hours. Mixing and aeration were accomplished by use of diffused air. The settling tank volume was 750 ml which provided a detention time ranging from 3.75 to 4.26 hours depending upon the substrate feed rates. Sludge return was at the rate of 330 ml per hour which gave a recirculation ratio ranging from 1.65 to 1.88 again depending upon the substrate feed rates. All volumes were kept constant by means of siphons. The unit was seeded with sludge obtained from the aeration tank of a package activated sludge plant owned and operated by the Corning Glass Works plant located between Christiansburg and Blacksburg, Virginia.

3. Substrates

The primary substrate was prepared every three days in a 12 liter pyrex bubble. The substrate was autoclaved immediately after preparation to prevent degradation by microbial action. Table I gives the composition of the primary substrate.

Grease emulsions were prepared when needed by the addition of the required amount of pure grease to distilled water to obtain the desired concentration. This mixture was then blended for two minutes to obtain the emulsion form.

4. Total Suspended Matter

Suspended solids were determined by the procedures outlined in the twelfth edition of Standard Methods for the Examination of Water and Wastewater (1) with two exceptions: A glass fiber filter was used in place of an asbestos mat filter and 10 ml samples were used instead of 30 ml samples.

5. Total Volatile Suspended Matter

Volatile suspended solids were determined by the procedures outlined in the twelfth edition of Standard Methods for the Examination of Water and Wastewater (1) with two exceptions: A glass fiber filter was used in place of an asbestos mat filter and 10 ml samples were used instead of 30 ml samples.

6. Sludge Volume Index

The sludge volume index was determined by the procedures outlined in the twelfth edition of Standard Methods for the Examination of Water and Wastewater (1).

7. Grease Extraction

Grease was extracted by a modification of Loehr and Rohlich's wet extraction method. A correlation was obtained between the two. See Appendix A for a detailed procedure. All test values are corrected for background grease content.

TABLE I

COMPOSITION OF PRIMARY SUBSTRATE

Constituent	Quantity
Peptone	200 mg/1
Dextrose	50 mg/1
Yeast Extract	40 mg/1
ABS	2 mg/1*
Phosphate Buffer	25 ml/1
Ferric Chloride	1 ml/1
Tap Water	200 ml/1
Distilled Water	To Volume

*Increased to 10 mg/1 when checking for the effect of a surfactant.

IV. EXPERIMENTAL RESULTS

Experiment I. The Removal Efficiency of the Plant When Fed Varied Concentrations of Blended Grease Emulsions.

The object of this experiment was to determine the removal efficiency of the laboratory completely mixed activated sludge plant when fed varied concentrations of blended natural sewage grease emulsions. Concentrations of 100 mg/l and 200 mg/l total grease influent were fed to the unit for 7 days each and the removal efficiency determined in each case. Samples in triplicate were taken every 24 hours. Testing was according to the procedure outlined in Appendix A.

Activated Sludge

The activated sludge was acclimated to the primary substrate and a background grease concentration of 10 to 15 mg/l for a period of four weeks. Total suspended solids were maintained at approximately 2000 mg/l by wasting sludge at periodic intervals. Ninety per cent of the suspended solids were volatile suspended solids. Other sludge characteristics were: sludge volume index, 80; color, golden brown; population, large number of sludge worms, rotifers and stalked ciliates.

Grease Emulsion Substrates

Grease emulsions were prepared in the desired concentrations by adding the proper amount of pure sewage grease to the required amount of distilled water and blending for two minutes in a Waring blender. This emulsion was then tested for grease content as outlined in Appendix A. Additions of grease or dilution with distilled water were employed to obtain the desired concentration. The primary substrate contained a background grease concentration of 53 mg/l. Allowance for this background was made when calculating the grease emulsion concentration required to obtain the desired total influent concentration.

Results

Figures 2, 3, 4 and 5 indicate good uptake of grease by the organisms of activated sludge with removal efficiencies ranging from 68 per cent for an influent grease content of 200 mg/l to 76 per cent for an influent grease content of 100 mg/l. An acclimation period of three days was required at each concentration as evidenced by the peaks in Figures 2 and 4. Also, both concentrations required 5 to 6 days before maximum removal efficiency was reached.

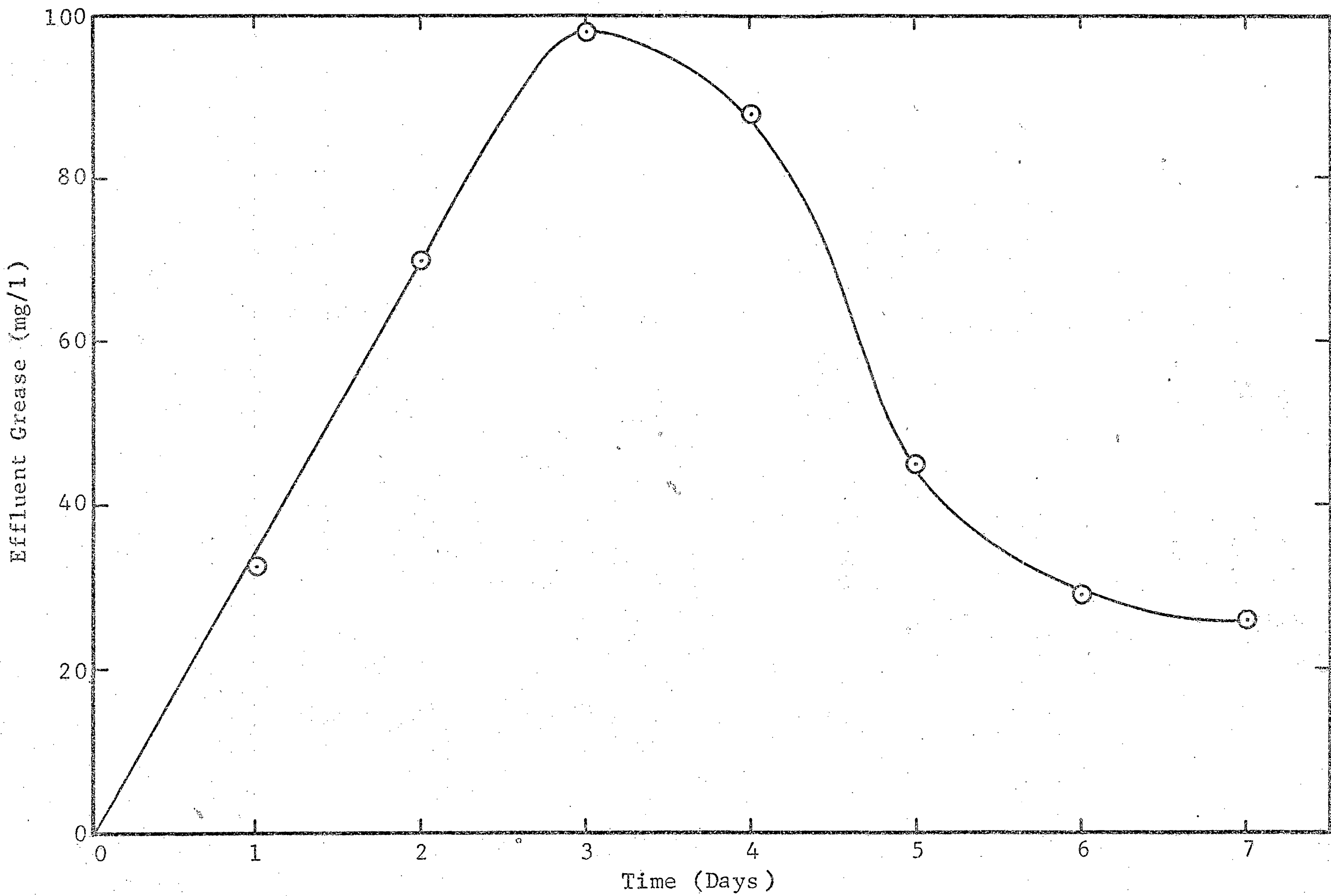

Figure 2. Effluent Concentration vs. Time - 100 mg/1 Grease

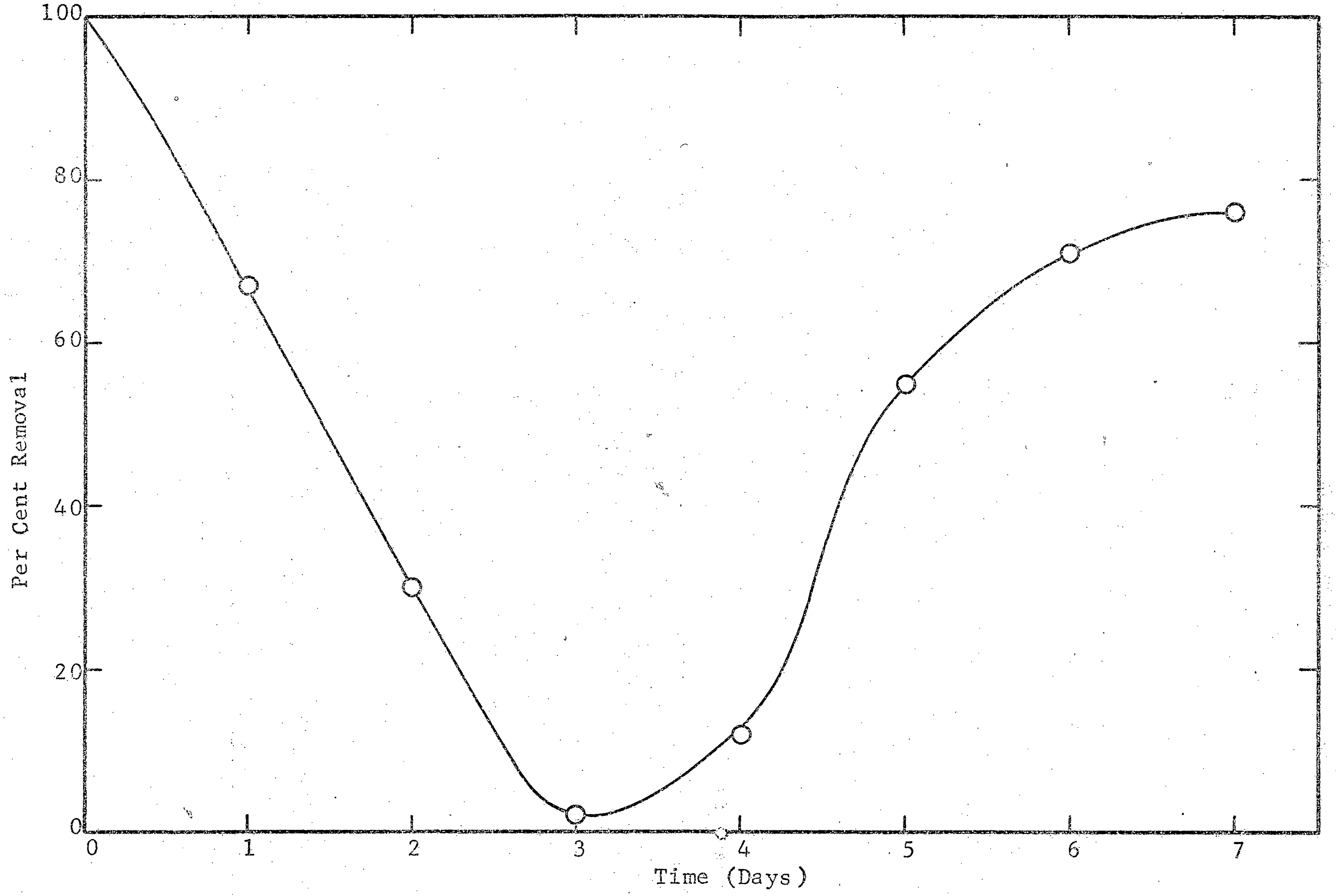

Figure 3. Per Cent Removal vs. Time - 100 mg/1 Grease

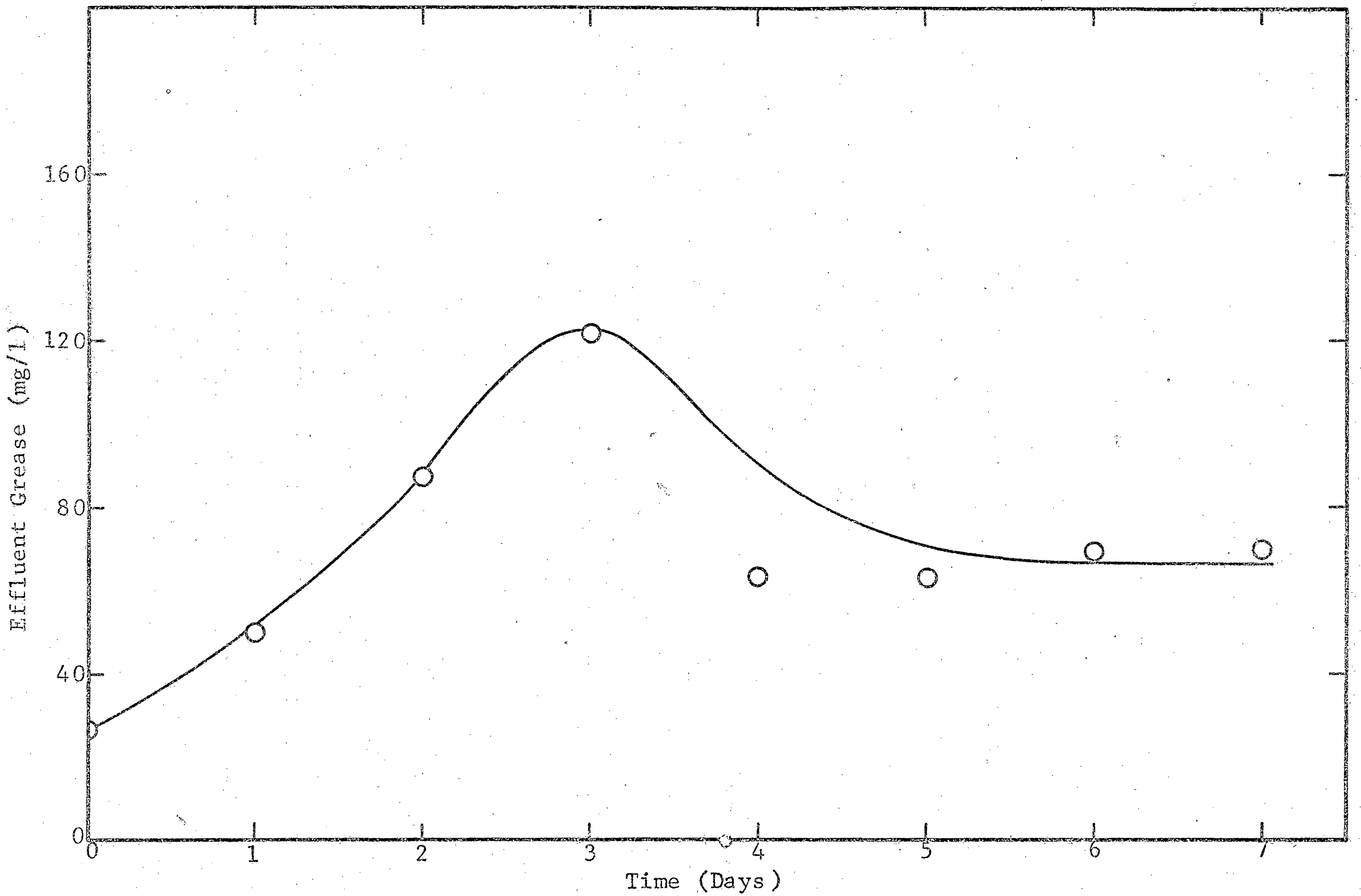

Figure 4. Effluent Concentration vs. Time - 200 mg/l Grease

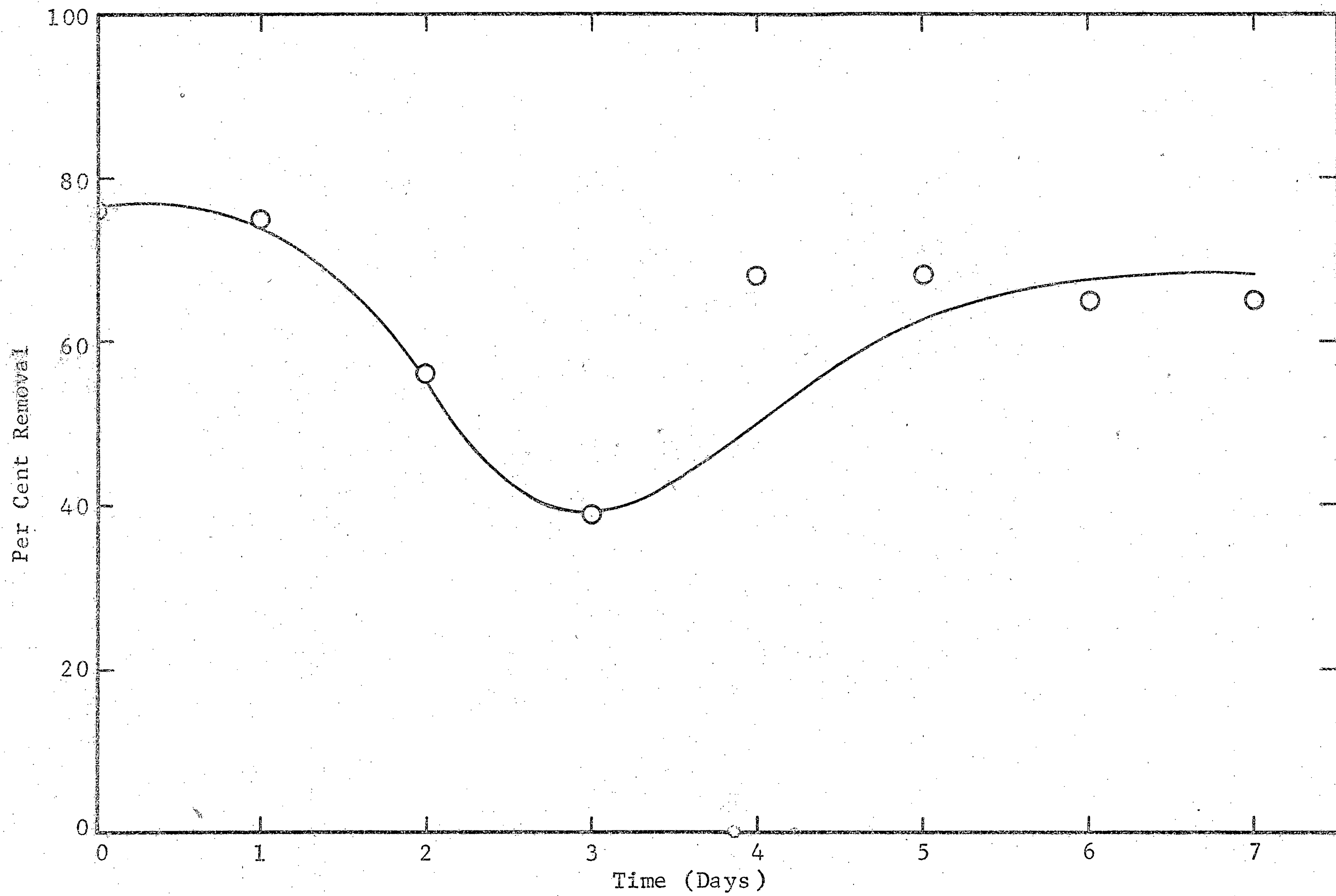

Figure 5. Per Cent Removal vs. Time - 200 mg/1 Grease

Experiment II. The Effect of a Surfactant (ABS) on the Removal Efficiency.

Addition of surface-active agents or surfactants should increase the amount of surface area available for attack by microorganisms and; consequently, better removal efficiencies should be obtained. The alkyl benzene sulfonate (ABS) content was increased from 2 mg/l to 10 mg/l in the primary substrate and its effect noted. Sampling was in triplicate every 24 hours for four days. Testing was in accordance with the procedure outlined in Appendix A.

Activated Sludge

The activated sludge had the same characteristics as in Experiment I.

Grease Emulsion Substrate

The grease emulsion was prepared as in Experiment I. Since the unit was already acclimated to an influent grease concentration of 200 mg/l, this concentration was employed to evaluate the effect of increased surfactant. The ABS increased the grease content of the primary substrate slightly (approximately 5 mg/l) and the overall grease concentration of the influent even less. Dilution was undertaken to obtain an influent of 200 mg/l grease.

Results

Figure 6 indicates that there was an increase in the quantity of grease in the effluent, from 66 mg/l to 91 mg/l or a decrease of some 12.5 per cent in removal efficiency with the increased ABS concentration indicating that increases in surfactant (ABS) concentration has no net beneficial influence upon grease degradation in an activated sludge system.

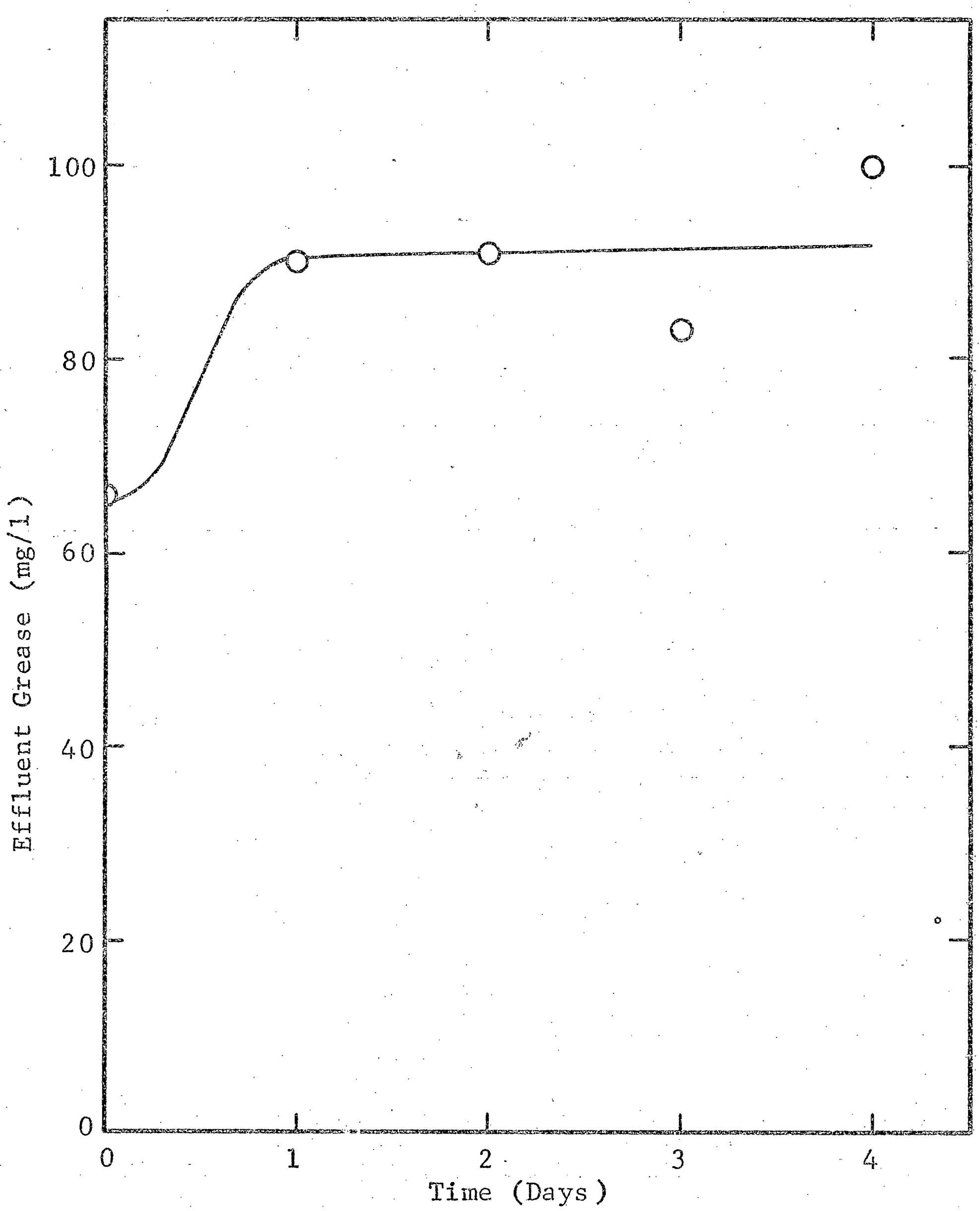

Figure 6. Effluent Concentration vs. Time - 200 mg/1 Grease - 10 mg/1 ABS

Experiment III. The Removal Efficiency of the Plant When Fed an Unblended Grease Solution.

The objective of this experiment was to determine the efficiency of grease removal when unblended grease solutions were fed to the unit. The ABS concentration was reduced to the original experimental condition of 2 mg/1. Samples were taken in triplicate every 24 hours for four days. Testing was in accordance with the procedure outlined in Appendix A.

Activated Sludge

The activated sludge had the same characteristics as in Experiment I.

Grease Substrate

The grease substrate was prepared by diluting pure grease with heated distilled water to enhance the solutioning of the grease. The resulting solution was placed upon a shaker operating at 130 cycles per minute to simulate conditions present at the influent point of a sewage treatment plant. Since the unit was already acclimated to an influent grease content of 200 mg/1, this concentration was employed.

Results

Figure 7 indicates an effluent concentration of 92 mg/1 which corresponds to a removal efficiency of 54 per cent. Difficulties were experienced in working with unblended grease substrates. Fast operation of the shaker resulted in formation of an emulsion. Slow shaking produced grease balls when the substrate cooled. Grease also adhered to the side of the feed lines duplicating a problem common in sewage lines. A noticeable decrease in grease removal efficiency was observed with the introduction of unblended grease to the unit. The effluent concentration and the removal efficiency at zero days were identical to the concentration and removal efficiency present at the completion of Experiment I.

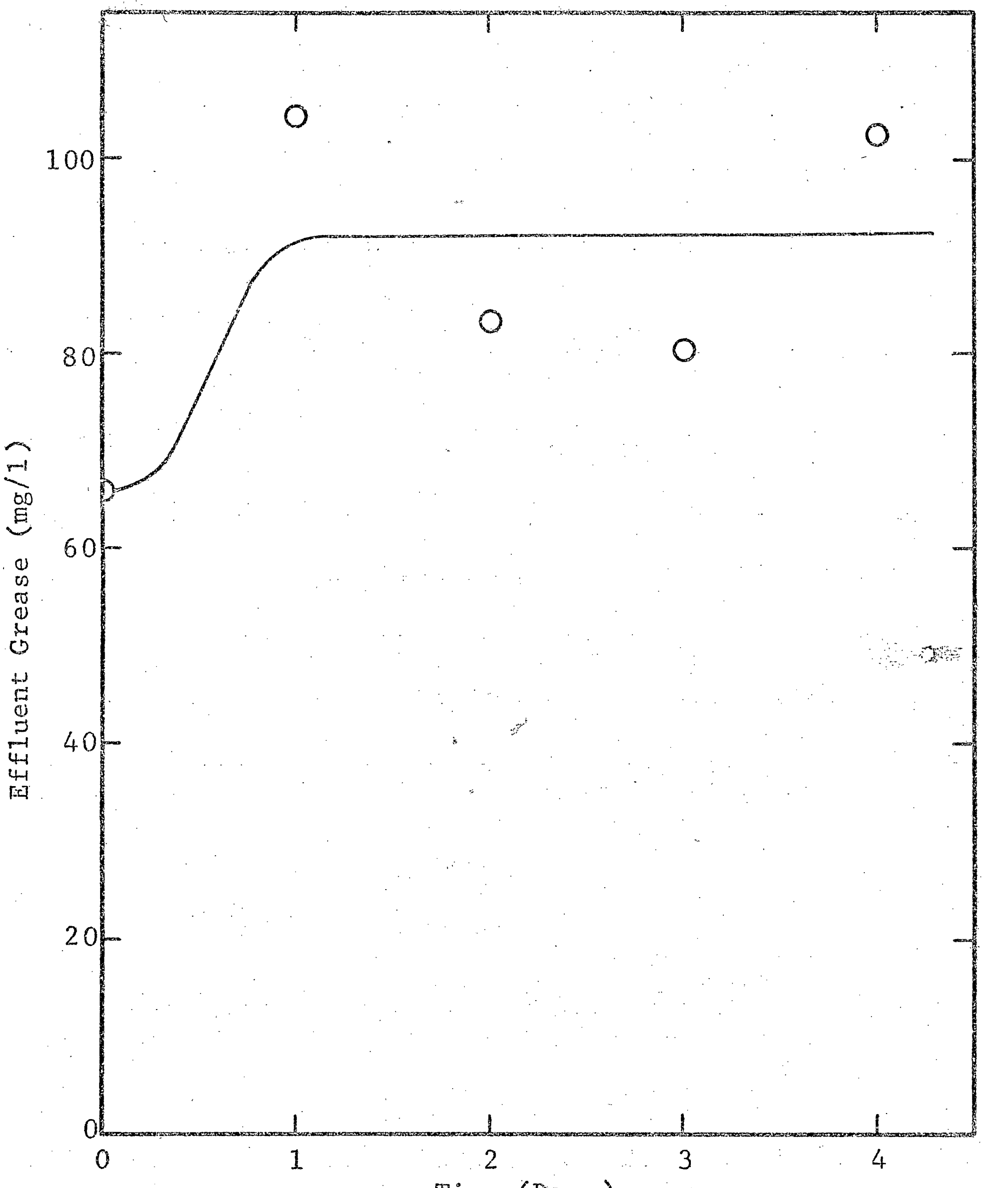

Figure 7. Effluent Concentration vs. Time - 200 mg/1 Grease - Unblended

Experiment IV. The Removal Efficiency of the Plant When Fed Unblended Raw Sewage.

Raw Sewage

Raw sewage was used to more closely approximate the influent conditions at sewage treatment plants and to study removal efficiencies by microorganisms not acclimated to a synthetic substrate. The objective of this experiment was to determine the grease removal efficiency when unblended raw sewage was fed to the plant. Raw sewage was obtained from the Stroubles Creek Sewage Treatment Plant at a point prior to the grease chamber. The laboratory unit was acclimated to this new substrate for two days before testing was renewed. Samples were taken in triplicate every 24 hours for four days. Testing of these samples was in accordance with the procedure outlined in Appendix A.

Activated Sludge

With the exception of a color change to a dirty brown, the activated sludge had the same characteristics as in the previous experiments.

Substrate

The raw sewage was refrigerated to prevent decomposition prior to being fed to the laboratory unit, and was taken from the refrigerator in small amounts several times a day to replenish the container for the laboratory unit. A magnetic stirrer was used to insure a uniform substrate. Heavy rains resulted in a lower-than-normal grease concentration (60 mg/l) in the raw sewage.

Results

Figures 8 and 9 indicate an eventual effluent concentration of 20 mg/l resulting in a removal efficiency of 67 per cent. The effluent concentration at zero days is taken as the influent value.

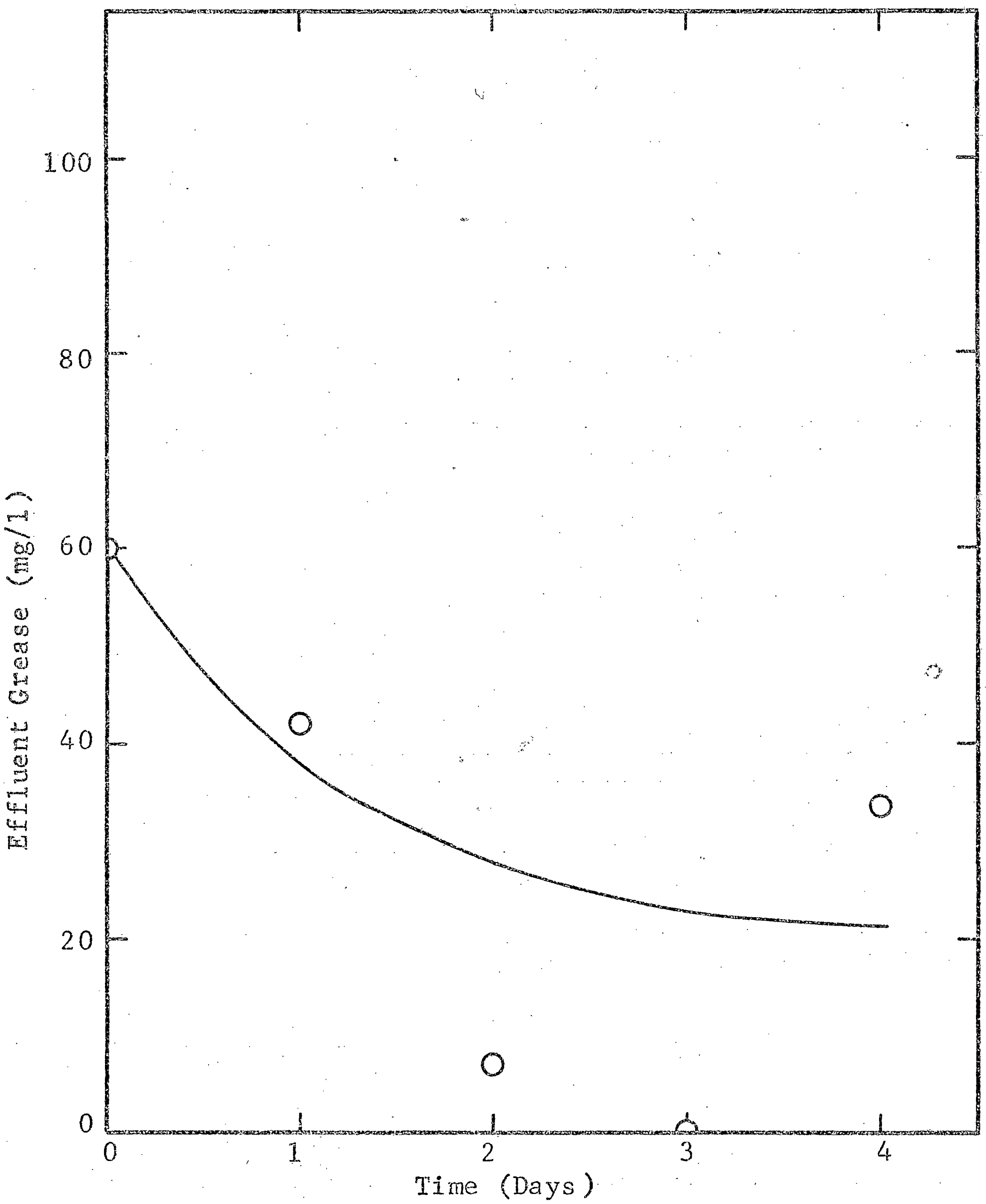

Figure 8. Effluent Concentration vs. Time - Unblended Raw Sewage

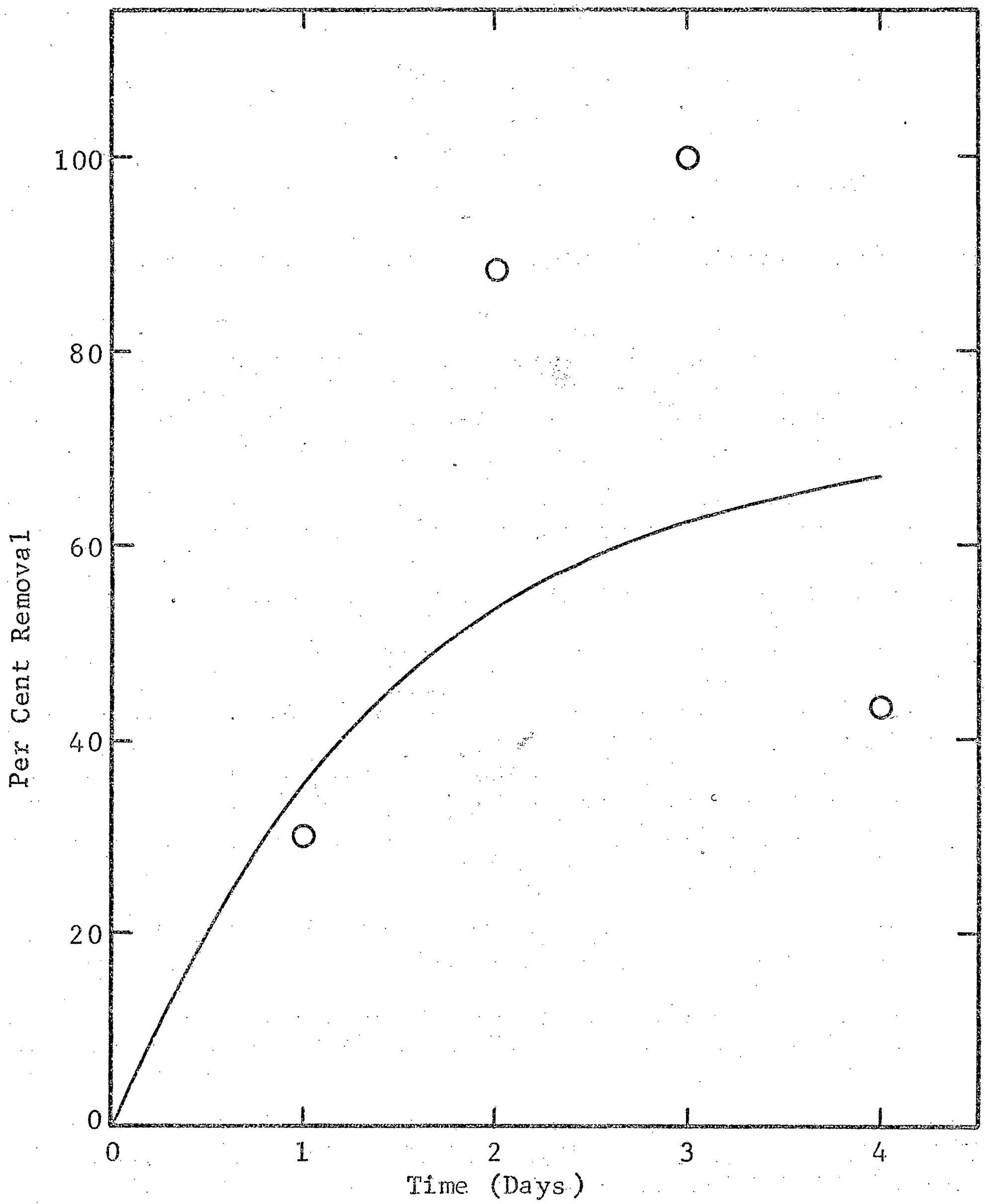

Figure 9. Per Cent Removal vs. Time - Unblended Raw Sewage

Experiment V. The Removal Efficiency of the Plant When Fed Blended Raw Sewage

Raw Sewage

The objective of this experiment was to determine the efficiency of grease removal when blended raw sewage was the substrate. Raw sewage was obtained from the same source as in Experiment IV. Feeding was begun immediately upon completion of Experiment IV. Samples were taken in triplicate every 24 hours for four days. Testing of these samples was in accordance with the procedure outlined in Appendix A.

Activated Sludge

The activated sludge had the same characteristics as in Experiment IV.

Substrate

The raw sewage had a grease concentration of 236 mg/1 and was handled in the same manner as Experiment IV. Blending was undertaken immediately prior to placing in the influent container.

Results

Figures 10 and 11 indicate an eventual effluent concentration of 13 mg/1 grease with a removal efficiency of 94.5 per cent. The peaks in the graphs indicate that, due to the very large increase in grease concentration (60 to 236 mg/1), an acclimation period of two days was required.

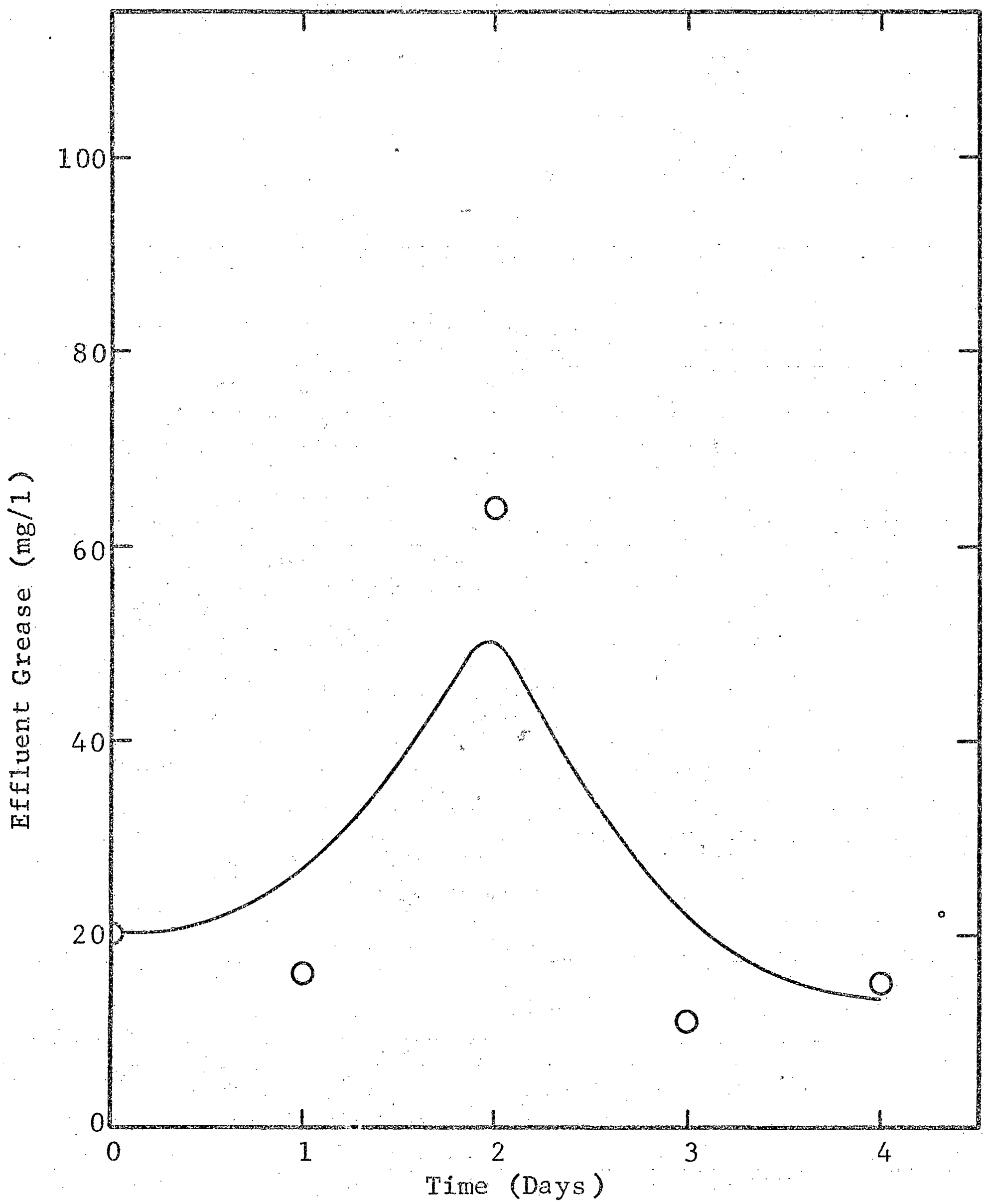

Figure 10. Effluent Concentration vs. Time - Blended Raw Sewage

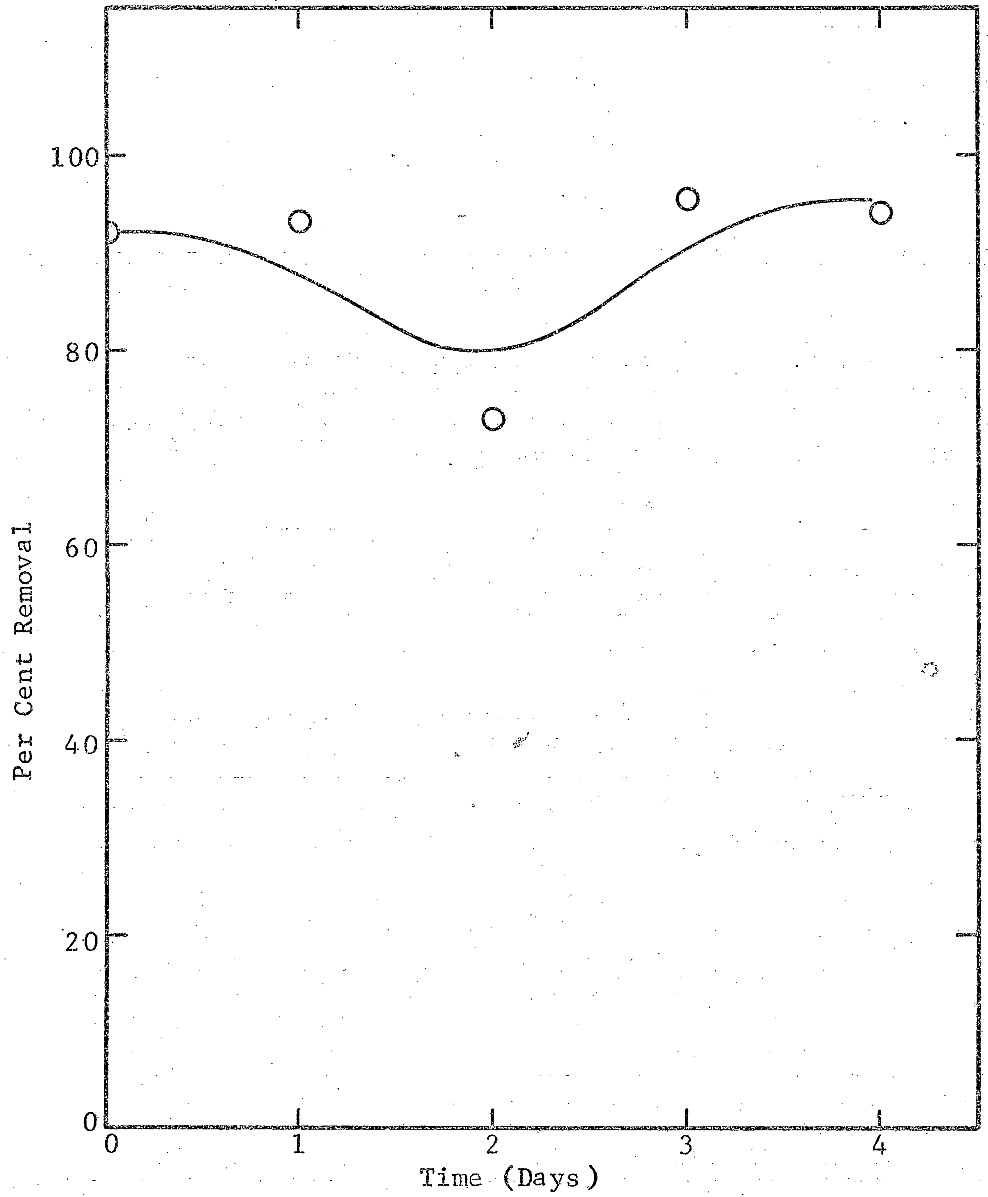

Figure 11. Per Cent Removal vs. Time - Blended Raw Sewage

V. DISCUSSION OF RESULTS

The effluent grease concentration versus time graphs clearly indicate that grease was readily metabolized by the organisms of activated sludge. The amount metabolized varied dependent on such factors as influent grease concentration, concentration of surfactant, and feed blending. A characteristic "lag" period ranging up to three days was exhibited in each experiment before removal to any great extent. Associated with these "lag" periods was either an increased concentration of grease feed or a change in the type of substrate fed to the laboratory units; i.e. blended or unblended substrates. The occurrence of the "lag" periods indicates that a period of acclimation is required by the microorganisms present. At sewage treatment plants undergoing large changes in influent grease concentration, an accompanying decrease in removal efficiency should correspond to the observed lag time.

Overall removal efficiencies of 76 per cent and 68 per cent were obtained with blended influent grease concentrations of 100 mg/l and 200 mg/l, respectively, as seen in Figures 2, 3, 4, and 5. Each concentration required an acclimation period of three days after which the amount of grease in the effluent tapered off to a steady value. These efficiencies do not quite approach the 84 per cent removal efficiency as reported by Loehr and de Navarra (7) on a contact stabilization activated sludge plant with an influent grease concentration of 147 mg/l. This is attributed somewhat to the fact that, as seen in a later experiment, better removal efficiencies can be obtained with organisms that are not acclimated to an artificial substrate, and to the fact that extracted grease is difficult to solutionize and, thus, does not really approximate natural conditions.

Surface active agents, or "surfactants", in theory, are supposed to increase the surface area available for biological action and make this surface more amenable for use by mircoorganisms. In an attempt to increase removal efficiencies, the alkyl benzene sulfonate (ABS) content of the primary substrate was increased from 2 mg/l to 10 mg/l. Blended grease emulsions provided a total grease influent concentration of 200 mg/l. The grease concentration in the effluent increased by 25 mg/l (the effluent concentration at day zero was the effluent value prior to increasing the ABS content) over that obtained with an ABS concentration of 2 mg/l. The possibility exists that ABS concentrations in this range resulted in an inhibitory environment for the microorganisms of activated sludge. As seen in Figure 6, it is conclusive that an increase in surfactant (ABS) content has no beneficial effect upon the removal of grease by the activated sludge process and may prove inhibitory. Of interest is the ABS effect of shortening the acclimation period to one day as opposed to the three plus days of Experiment I. This is, in all probability, due to the system being completely acclimated to an influent grease concentration of 200 mg/l prior to increasing the surfactant content.

Various difficulties were encountered when trying to work with unblended synthetic substrates; thus, the removal efficiencies determined when working with unblended grease solutions are not considered entirely accurate, although they do give an indication of a much lower percentage of removal than does the blending process. The best results were obtained by heating distilled water, adding pure grease in the desired amount, and placing the container on a shaker operating at approximately 130 cycles per minute to simulate treatment plant influent conditions. Problems experienced were the formation of grease balls if the shaker were operated too slowly, formation of an emulsion if operated too fastly, and grease adhering to the walls of the influent lines. Figure 7 indicates an eventual effluent grease concentration of 92 mg/l which gives a removal efficiency of 54 per cent, as compared to 68 per cent for the same concentration when blended. The difference in the removal efficiencies can be accounted for because of the much greater surface area available for biological action when blending is accomplished.

The study of removal efficiencies of substrates consisting of raw sewage only was undertaken to more closely simulate actual conditions at sewage treatment plants and to determine if differences exist in grease removal efficiencies between the organisms acclimated to a synthetic substrate and organisms naturally present in raw sewage. The efficiency of removal of grease in unblended raw sewage was 67 per cent with an influent of 60 mg/l as illustrated in Figures 8 and 9. This efficiency would have been higher with an increased influent concentration. With an influent concentration of 60 mg/l, a well-defined "lag" period was not noted, rather a gradual tapering to maximum removal was evident. The effluent value at day zero was taken to be the influent value of 60 mg/l.

A very high degree of grease removal was obtained when blended raw sewage was used as the substrate. Due to a tremendous increase in influent grease concentration (60 to 236 mg/l) a two-day "lag" period was observed before removal efficiencies improved to a final efficiency of 94.5 per cent and an effluent concentration of 13 mg/l grease. The effluent concentration at day zero was taken to be 20 mg/l which was the value upon completion of the unblended raw sewage tests. This high degree of grease removal can be explained by two facts: 1) Blending increases the surface area available for biological action, and 2) Organisms that are natural habitants of sewage apparently remove much more grease than do organisms that are acclimated to a synthetic substrate.

From the works of Heukelekian and Balmat (5) and others, and the above discussion, it can be logically concluded that the activated sludge process, with modifications to provide blending prior to biological treatment, is a method that should remove 90 plus per cent grease consistently.

VI. CONCLUSIONS

1. Grease was readily metabolized by the organisms of activated sludge.
2. The addition of a surfactant (ABS) decreased the removal efficiency, possibly a result of an inhibitory environment caused by the increased surfactant concentration.
3. Acclimation periods of up to three days were noted with sudden, large variations in the concentration of grease in the influent and with changes in the substrate composition (i.e. blended or unblended). Decreased efficiencies should be anticipated at treatment plants that receive large variations in grease content.
4. Blending of wastes containing grease will increase the removal efficiency considerably.
5. Much higher removal efficiencies were obtained when blended raw sewage was employed as the substrate indicating that the broad-spectrum organisms that are naturally present and are not acclimated to a particular, unchanging, substrate are more efficient.
6. Grease removal efficiencies should consistently be greater than 90 per cent at activated sludge treatment plants that are modified to provide blending prior to biological treatment.

VII. SUMMARY

Experimental data obtained in the study of the effect of various concentrations of grease on a completely mixed activated sludge laboratory plant indicated that grease is readily metabolized by the organisms of activated sludge. Methods for enhancing grease removal were blending prior to biological treatment and the addition of a surface active agent (ABS).

Grease removal efficiencies were determined by a modification of Loehr and Rohlich's wet analysis method using chloroform as the solvent.

Experimental evidence indicated that the addition of a surfactant will decrease the removal efficiency by providing an inhibiting environment and that blending of raw sewage will increase the removal efficiency to 90 plus per cent, even with very high concentrations (in the 200 mg/1 plus range). Removal efficiencies remained below 70 per cent when raw sewage was not blended.

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APPENDIX

APPENDIX A

Grease Extraction

Procedure:

1. Obtain sample and acidify to pH 3.0 with concentrated hydrochloric acid (HCl).
2. Blend for 10 seconds and return sample to the original container.
3. Add 100 ml of sample, 190 ml of chloroform, 180 ml of methanol, to separate blender (glass, because chloroform deteriorates plastic). By using the same graduate and adding in the above order, little, if any, grease will remain in the graduate.
4. Blend for two minutes.
5. Filter through Whatmen No. 40 filter paper by using Buchner funnel and a vacuum pump.
6. Transfer to separatory funnel.
7. Rinse previous containers with 20 ml of methanol filter, and transfer to separatory funnel.
8. Agitate for 30 seconds and after two systems phase (2-5 minutes) draw off the bottom (chloroform) layer into previously tared flask.
9. Add 10 ml of chloroform to separatory funnel and agitate 15 seconds. Again, after the phases break, draw off the bottom layer into the same flask.
10. Evaporate the solvent in a water bath at 80 degrees Centigrade.

11. Dry the flask to a constant weight in a 103-degree Centigrade oven and cool in a dessicator for 30 minutes and weigh. Grease is then determined as follows:

$$\text{mg/l grease} = \frac{\text{mg grease x 1000}}{\text{ml sample}}$$

12. Prior to another test, all glassware is rinsed with a quantity of chloroform followed by rinse with a quantity of methanol.

Only by taking extreme care and by following the above procedure exactly can reproducible results be obtained.

This method extracted approximately 30 per cent less grease than did Loehr and Rohlich's method. Loehr and Rohlich's correlation between their wet analysis method and the Soxhlet method was approximately 1.3, or 30 per cent more than the Soxhlet method.

GREASE REMOVAL BY A COMPLETELY MIXED ACTIVATED SLUDGE PLANT AND METHODS FOR ENHANCING GREASE REMOVAL

by

Larry Keith Owens

Abstract

Various concentrations of grease were fed to a completely mixed activated sludge laboratory plant and the effects of blending and the addition of a surfactant on removal efficiencies were determined. Blended and unblended raw sewage containing grease was studied to obtain a comparison between the removal efficiencies by organisms acclimated to a synthetic substrate and organisms naturally present in raw sewage.

Grease determinations were made by a modification of Loehr and Rohlich's wet analysis method using chloroform as the solvent.

The experimental results indicated that grease was readily metabolized by the organisms of activated sludge, that the addition of a surface active agent decreased the removal efficiency, and that blending of raw sewage prior to biological treatment should increase removal efficiencies to greater than 90 per cent.