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Hydrogen Peroxide Cures Filamentous Growth In Activated Sludge

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HYDROGEN PEROXIDE CURES FILAMENTOUS GROWTH IN ACTIVATED SLUDGE

by

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ABSTRACT

Laboratory tests at the Dupont Experimental Station substantiated by tests at the EPA-DC Pilot Plant in Washington, D.C. revealed that H_2O_2 *offered a solution to filamentous bulking caused by Sphaerotilus growth. The addition of* H_2O_2 *eliminated the free-growing filaments while not deteriorating the spherical aerobic floc. The* H_2O_2 *also released oxygen which was beneficial in maintaining a purely aerobic environment. Bulking activated sludge units could be brought under control by doses of* H_2O *from 20-200 mg/l for less than one to several days. The sludge volume index of the systems was reduced substantially. The* H_2O_2 *treated aeration process could then be brought under control by maintaining proper plant operation.*

This report is submitted in partial fulfillment of Project 11010 FYM and Contract No. 14-12-818 by the Department of Environmental Services, Government of the District of Columbia under the sponsorship of the Office of Research and Monitoring, Environmental Protection Agency. Work was completed as of July 1971.

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FIGURES

ACKNOWLEDGMENTS

The pilot system was constructed, maintained and operated by the EPA-DC pilot plant staff under the direction of Robert A. Hallbrook, chief mechanic; Walter W. Schuk, head instrument technician; George D. Gray, chief operator; and Howard P. Warner, chief analytical chemist.

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SECTION I

CONCLUSIONS

1. The addition of H_2O_2 to the sludge recycle in filamentous bulking activated sludge processes reduced the SVI to controllable levels in laboratory tests on Penns Grove, New Jersey, wastewater and in pilot tests of step aeration and oxygen activated sludge processes on the District of Columbia wastewater. The filamentous organisms in the step aeration and oxygen system were identified as Sphaerotilus.

2. The effective dose of H_2O_2 was a function of time and concentration. The optimum dosage and time were not determined and may vary from plant to plant.

3. Once the SVI was below 200 and controllable settling was possible, continued addition of H_2O_2 was not required.

4. The H_2O_2 had no noticeable deleterious effect on the desirable spherical aerobic floc up to a concentration of 200 mg/l. At 400 mg/l, partial deflocculation of the spherical floc occurred.

5. While the addition of H_2O_2 eliminated the bulking condition, the plant must be operated to prevent re-establishment of the undesirable growth. Dissolved oxygen concentrations and the SRT in the process were important factors. If the SRT was maintained in a range where the filamentous metabolism was competitive with the spherical aerobic bacteria, the growth would persist or would reappear. The SRT for which filamentous bacteria growth was competitive is 3-5 days in the D.C. wastewater but may be unique for each wastewater.

6. Plant operation at high SRT (above 5 days) with minimum solids wasting prevented filamentous growth in D.C. operations.

SECTION II

RECOMMENDATIONS

The effectiveness of H_2O *for reducing bulking caused by filamentous organisms other than Sphaerotilus should be determined. Optimum dosage periods and concentrations of* H_2O_2 *to eliminate bulking should be determined for Sphaerotilus and other filamentous organisms.*

The product of the activated sludge effluent during treatment should be compared to other alternative methods of reducing bulking such as chlorine addition.

Accurate economic evaluations of all alternative solutions to bulking should be made.

The operational conditions and the influent substrates that cause the heavy propagation of the filamentous organism should be investigated.

SECTION III

INTRODUCTION

Bulking or nonsettling activated sludge has intermittently disrupted operation of sewage treatment plants for years. One of the most common causes of bulking is the proliferation of filamentous growth (1) (2) (3) (4). The establishment of filamentous growth is generally believed to be caused by conditions under which the filamentous organism propagates as fast or faster then the more desirable spherical aerobic (floc forming) bacteria. Since the free growing filamentous organisms have a higher area to volume ratio than spherical aerobic growth, Pipes (1) suggests that the filamentous organisms have the metabolic advantage in activated sludge reactors with high soluble organic substrates, low dissolved oxygen concentrations or low nutrient conditions.

Smith and Purdy (2) suggest that several types of filamentous organisms cause the bulking, but generally the Sphaerotilus species is the most common cause. Recently, Farquhar and Boyle (3) (4) verified the presence of filamentous organisms at various activated sludge plants. They developed techniques for identifying the various filamentous species and found that the Sphaerotalis and Thiothrix were most commonly associated with bulking.

The control of filamentous organisms and the prevention of bulking in the activated sludge process are important factors in achieving present and future water quality and effluent discharge requirements. The filamentous growth not only reduces product quality of the secondary effluent but also decreases the quality of subsequent tertiary treatment effluents (5) (6) (7) (8).

Imhoff and Fair (9) report that the treatments used to reduce the sludge volume index of the bulking sludge include reduction of the amount of return sludge and wasting more sludge in an attempt to build up a new microbiological population, increasing air supply, by-passing or diluting influent sewage to change the loading rate, addition of flocculating chemicals to improve the settling characteristics of the sludge, and chlorination of the return sludge to destroy the filamentous organisms. Chlorine, which is the most common treatment for elimination of filamentous organisms, has the disadvantage that it also destroys the desirable spherical bacteria.

These treatment techniques used to control bulking produce slow or poor response. A new method is clearly needed to eliminate the filamentous growth without extensive damage to the normal spherical aerobic population. In addition, operational procedures are needed to minimize reoccurrence of the filamentous condition in the activated sludge process.

This work describes the use of H_2O_2 in laboratory and pilot activated sludge systems to eliminate filamentous growth. The laboratory studies were performed at the Dupont Experimental Station in Wilmington, Delaware. The pilot studies with step aeration and pure oxygen activated sludge were performed at the EPA-DC Pilot Plant in Washington, D.C. Operating conditions to prevent the reestablishing of the bulking sludge in the D.C. wastewater were also evaluated.

SECTION IV

LABORATORY TESTS

The bench scale tests were performed in an activated sludge system in the laboratory. The completely mixed aerator and the clarifier had detention times of 3.34 hrs. and 2.0 hrs., respectively, based on a feed rate of 12.5 cc/min. The sludge recycle rate was 100% of the feed flow.

The feed used for the experiment was a settled primary domestic sewage from Penns Grove, New Jersey. Both diffused and mechanical aeration were used to maintain the dissolved oxygen concentration above 5 mg/l.

Typical parameters were used for evaluation of waste treatment efficiency including a modified sludge volume index which was termed "sludge concentration index". The sludge concentration index was determined by using a 25 ml graduated cylinder for the settling tests rather than the standard liter cylinder. The small volume was necessary because of the scale of the laboratory experiments. The sludge concentration index, however, was calculated as a SVI and reported as the volume in milliliters occupied by 1 gram of dry suspended solids. The sludge concentration index obtained for the bench scale experimental work in the 25 ml cylinder were not comparable with the conventional SVI probably because of wall effects and the increase in the ratio of the diameter of the floc to the diameter of the cylinder. The sludge concentration index, however, was useful as a relative indicator of bulking conditions for the laboratory experiments.

SECTION V

EXPERIMENTAL PLAN AND RESULTS

After seeding the laboratory unit, the activated sludge unit was operated for approximately one week before data for analysis were recorded. After start-up, the sludge concentration index increased steadily. The food to micro-organism ratio increased from 0.3 to 0.7 lb of BOD_5/lb of MLSS and the sludge concentration index (Figure 1) increased to near 1000. Microscopic examination of the sludge revealed the presence of numerous free-growing filamentous organisms.

The effluent quality deteriorated from a turbidity of 3 Jackson Turbidity Units (JTU) and 2 mg/l of suspended solids to 13 JTU and 24 mg/l of suspended solids just prior to the addition of H_2O_2 on the eleventh day.

H_2O_2 at a concentration of 200 mg/l was added in the recycle line for a 24-hour period. The sludge concentration index immediately decreased from 1000 to 400-500. The sludge depth (Figures 2 and 3) in the clarifier also decreased after H_2O_2 treatment. This reduction of concentration index was observed to correspond to nearly complete elimination of the free-filamentous growth. The effluent quality improved to 3 JTU and to about 1 mg/l of suspended solids.

Operating at the same retention time and food to micro-organism ratio, filamentous growth reestablished within ten days after termination of H_2O_2 addition. The sludge concentration index increased again to near 1000 within five days even with the continuous addition of 10 mg/l of H_2O_2 in the recycle stream. The effluent quality deteriorated to 33 JTU and 52 mg/l of suspended solids. However, when the H_2O_2 dosage was increased to 40 mg/l, the sludge concentration index again decreased to below 400 within two days. The effluent quality improved to 4 JTU and 1 mg/l of suspended solids. Continued application of H_2O_2 for an additional four days did not lower the concentration index further. The studies on controlling filamentous bulking with H_2O_2 were then continued at the EPA-DC Pilot Plant in Washington, D.C.

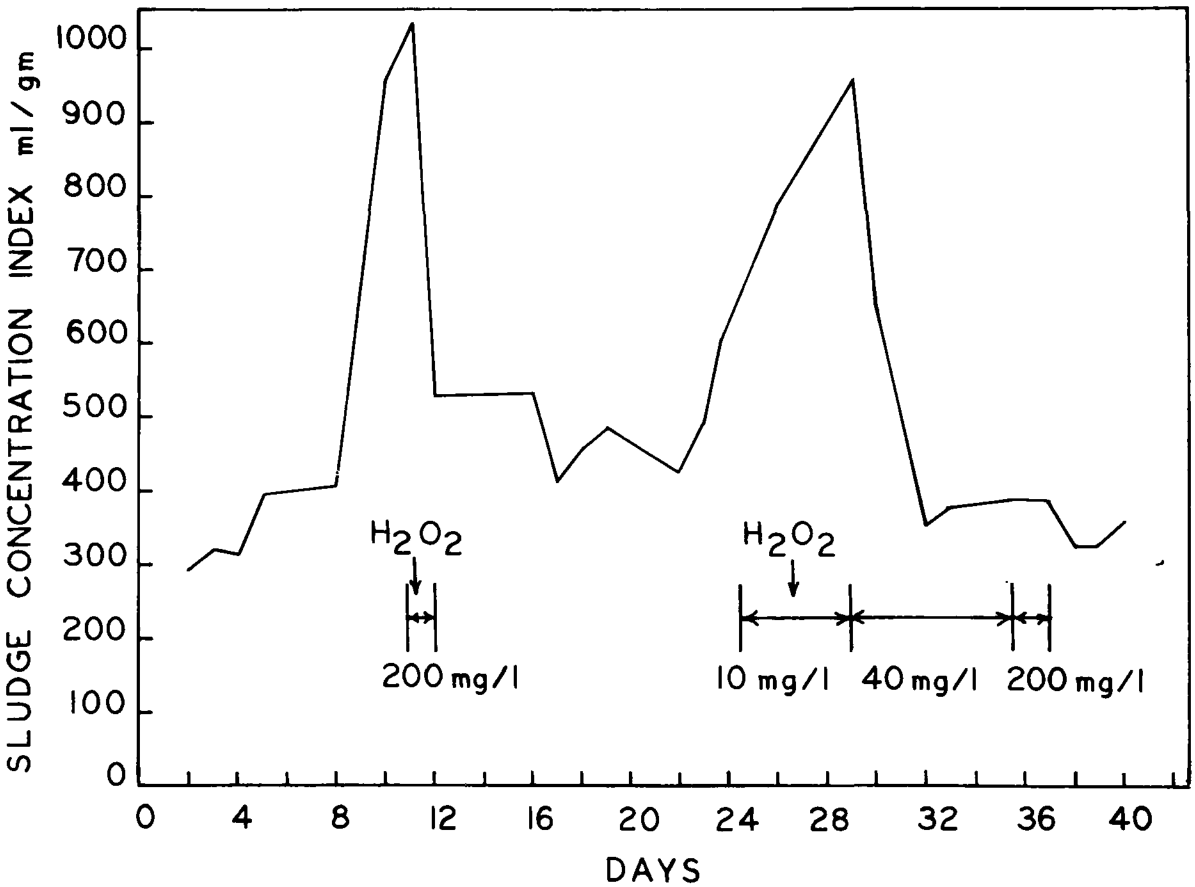

FIGURE 1 - Sludge concentration indexes observed in the bench scale tests

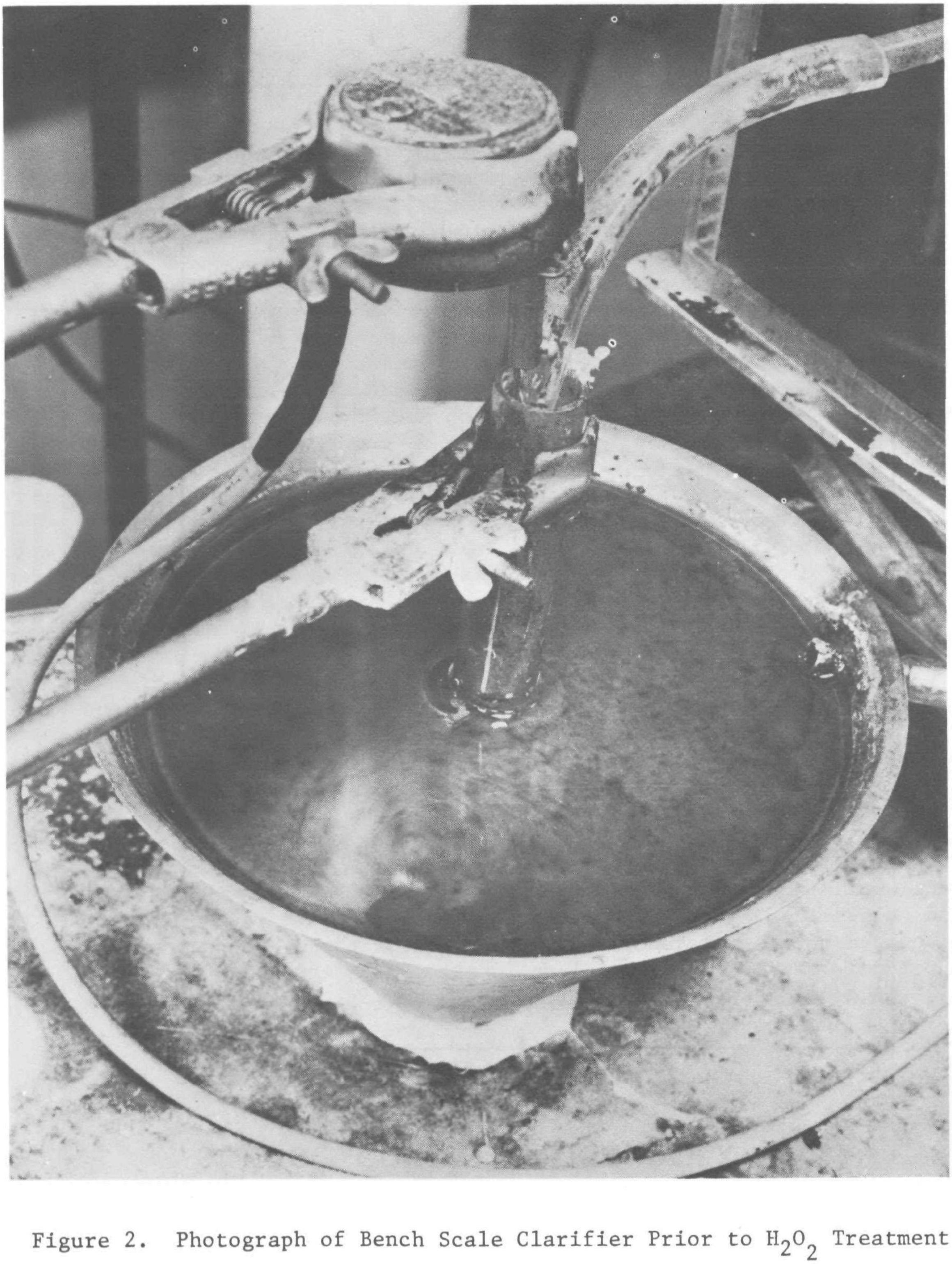

Figure 2. Photograph of Bench Scale Clarifier Prior to H_2O_2 Treatment

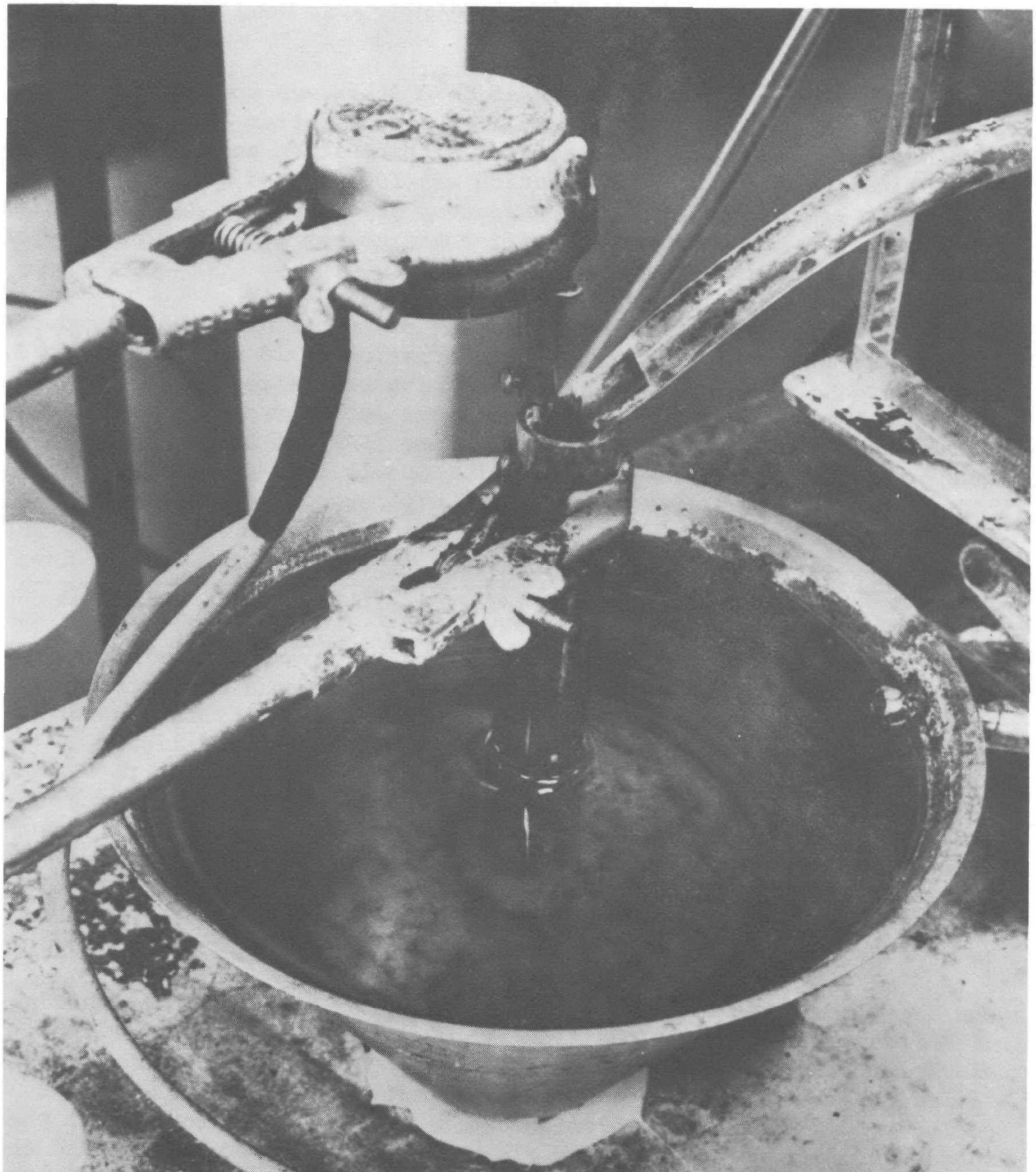

Figure 3. Photograph of Bench Scale Clarifier After the Addition of 200 mg/l of H_2O_2

SECTION VI

PILOT PLANT AERATION

At the EPA-DC Pilot Plant, the aeration process was operated as step aeration or contact stabilization. The step aeration effluent was fed to subsequent treatment stages of nitrification and denitrification. The nominal capacity of step aeration was 100,000 gpd with a 2.3:1 maximum to minimum diurnal flow variation at an average detention time of 3.6 hours. The secondary clarifier had an average overflow rate of 650 gpd/ft^2 with daily peaks of 975 gpd/ft^2.

In the summer of 1970, the step aeration plant performed well producing an effluent and suspended solids concentration of 16 mg/l and 25 mg/l, respectively. The system was operated with high mixed liquor concentrations (over 2500 mg/l) and with minimum solids wasting. The operation produced a solids retention time (SRT) of between 8 and 12 days at a loading of less than 0.3 lb. BOD_5/lb. of MLVSS. The high SRTs indicate the process was operated with endogenous metabolism (Equation 1).

$$SRT = \frac{\text{(lb. vol. solids under aeration)}}{\text{(lb. vol. solids wasted/day) + (lb. eff. vol. solids/day)}} \qquad (1)$$

In October of 1970, high solids wasting was programmed to minimize nitrification in order to provide the maximum ammonia concentration for the subsequent independent nitrification system. This mode of operating the step aeration process produced lower mixed liquor concentrations. less endogenous respiration and an SRT of 3 to 5 days at a loading of approximately 0.5 lb. BOD_5/lb. of MLVSS. As with earlier operation on D.C. wastewater in the 3-5 SRT range (10), heavy filamentous growth developed in the aeration tank. The organisms were identified (11) as Sphaerotilus. The effluent quality deteriorated to 32 mg/l of BOD and 48 mg/l of suspended solids and the SVI increased to over 300.

The dissolved oxygen was then maintained above 1 mg/l and the wasting of solids was reduced to the minimum level which would prevent the clarifier blanket from overflowing. This combination of techniques failed to substantially reduce the SVI below 300 through the winter period to mid-February. Chlorine addition was avoided to protect the subsequent nitrifying activated sludge from both free chlorine and the long-term heavy organic (BOD) loading stress caused by the deterioration of secondary effluent during chlorination. The H_2O_2 was then employed based on the success of the laboratory studies at the Dupont Laboratories.

The addition of H_2O_2 in moderate dosages was applied in mid-February. The H_2O_2 was added to the sludge recycle (50% of the influent flow) *at a dose equal to 20 mg/l of the influent flow for 2 days. The dosage was then increased to 40 mg/l for 12 additional days. As seen in Figure 4, the addition of H_2O_2 quickly reduced the SVI from the 300-400 range to less than 200. Solids wasting was reduced as the settling qualities of the mixed liquor improved. The SVI then steadily improved to 60 and remained at that level. As shown in the photo-micrographs (Figures 5 and 6), the long free growing filamentous strands were quickly reduced and eventually eliminated as the SVI improved.*

The improved settling properties permitted continuous operation at higher solids concentrations and an SRT above 5 days. During the H_2O_2 addition, the poor effluent quality (80 mg/l of BOD_5 and 90 mg/l of SS) did not deteriorate further but steadily improved to 25 mg/l BOD_5 and 20 mg/l SS.

In late April, equipment tank modifications required the step aeration process to be transferred to temporary tankage. The available temporary aeration tank was too large and wooden baffles were used to section the tank to the desired size. However, the baffles had uncontrollable leaks. The leakage of mixed liquor out of the aeration tank was sufficient to lower the SRT to the point where filamentous growth was reestablished. The SVI rapidly increased to well over 300. H_2O_2 was again added to the recycle but this time at a high dosage (equivalent to 200 mg/l in the influent flow) for a 1 day period. An immediate reduction in SVI to less than 150 occurred (Figure 7). The effluent BOD_5 of 67 mg/l before treatment improved to less than 40 mg/l for several days immediately after the addition of H_2O_2.

Normally with the improvement in settling characteristics, the bulking condition could be permanently controlled in D.C. wastewater by building solids and operating at a higher mixed liquor solids concentration and a higher SRT. With the uncontrolled mixed liquor wasting through the wooded baffles, however, the SRT and mixed liquor concentrations could not be increased. Thus the filamentous growth gradually reappeared and the effluent BOD_5 deteriorated to its previous levels.

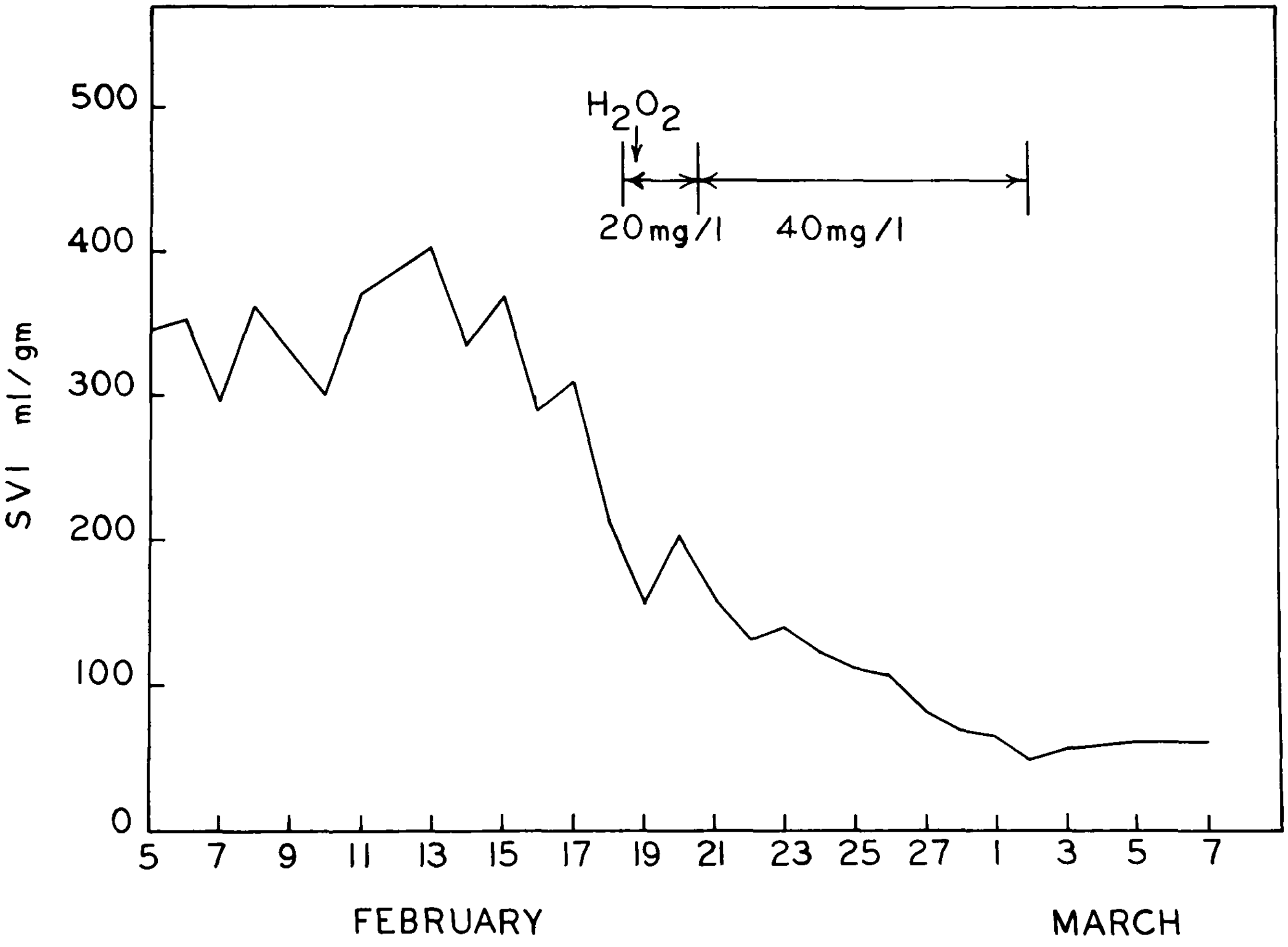

FIGURE 4 - Sludge volume indexes observed during February H_2O_2 treatment in the pilot plant step aeration process

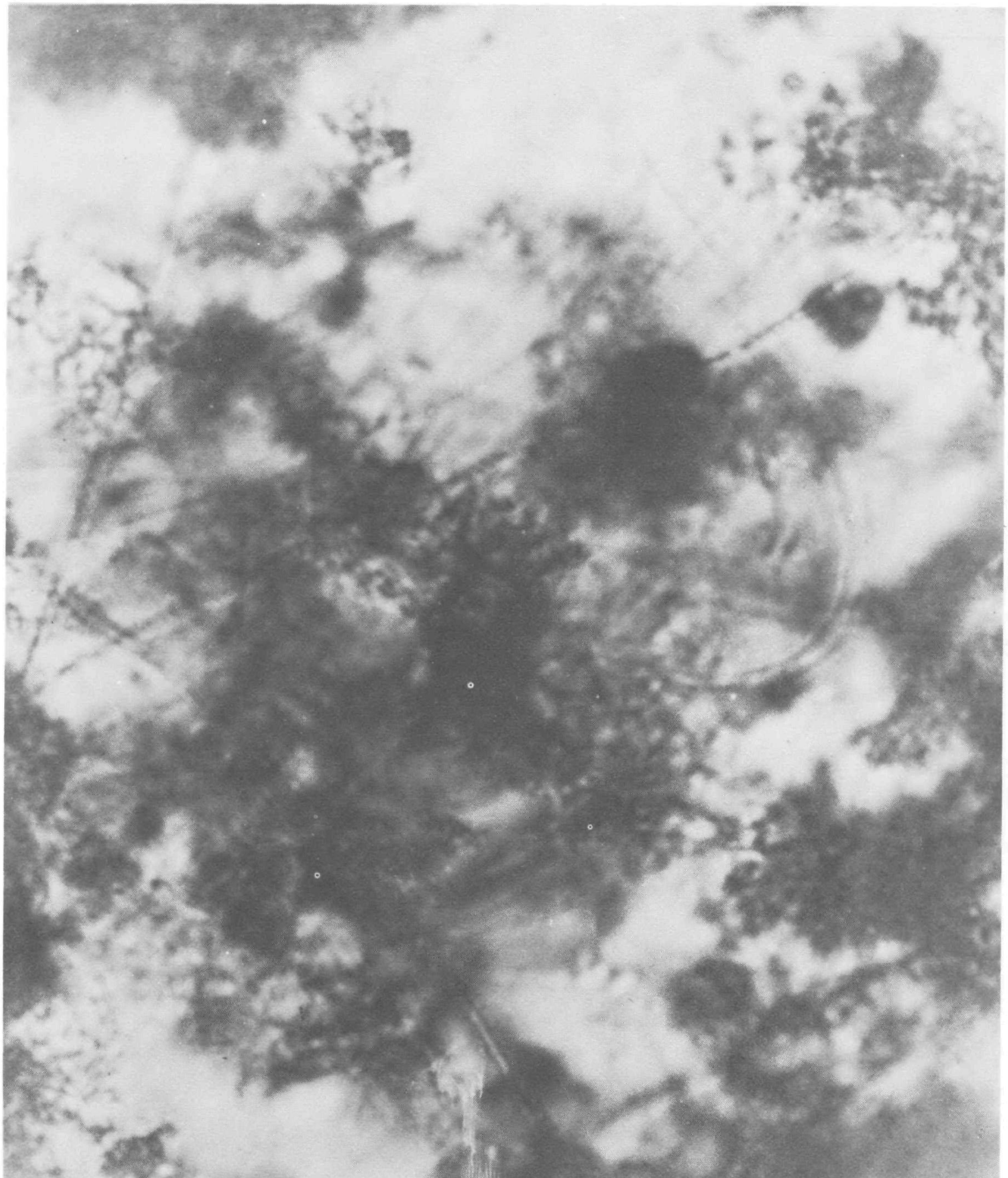

Figure 5. Photo-Micrograph of Free-Growing Filamentous Growth (Sphaerotilus) in the Pilot Plant Step Aeration Process

Figure 6. Photo-Micrograph After the Elimination of Filamentous Growth by H_2O_2 Addition in the Step Aeration Process

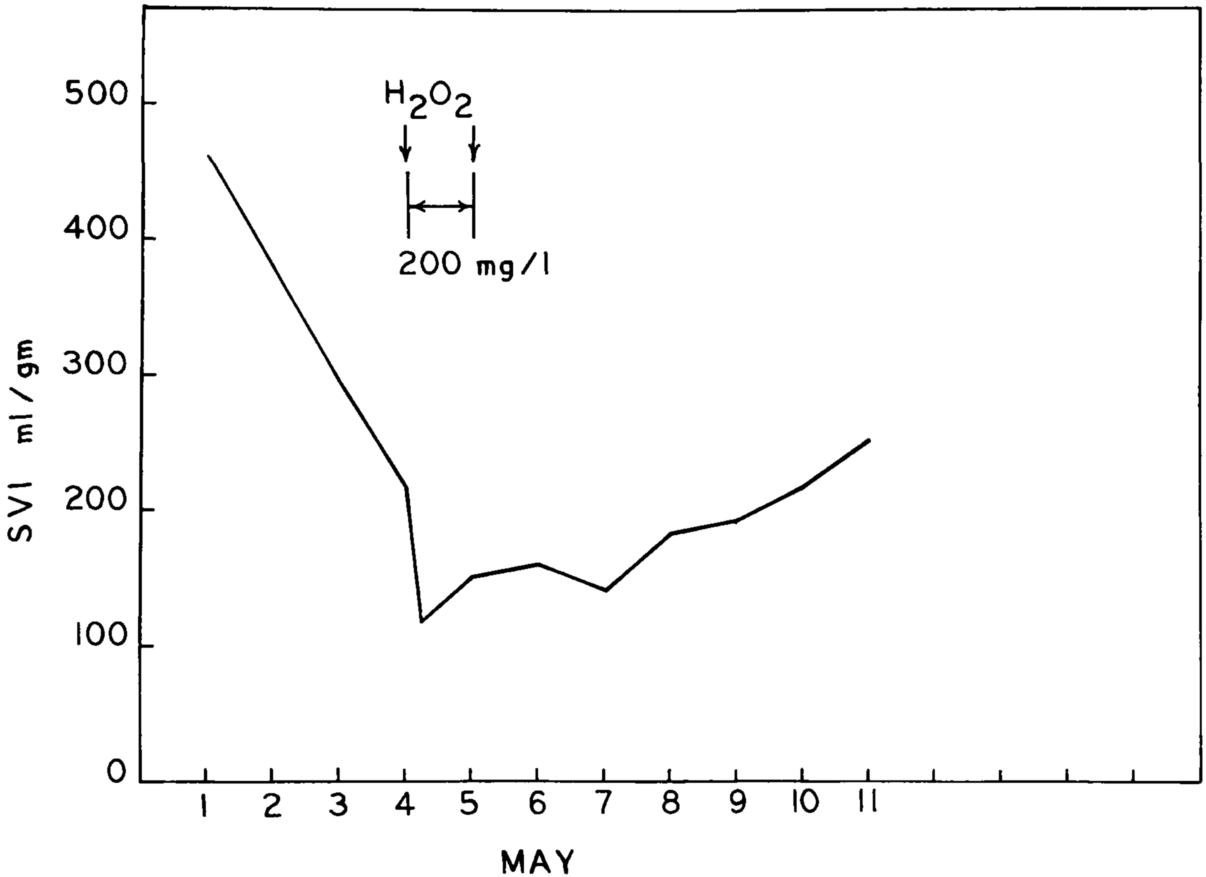

FIGURE 7 - Sludge volume indexes observed during April and May H_2O_2 treatment in the pilot plant step aeration process.

SECTION VII

OXYGEN ACTIVATED SLUDGE

The oxygen ("UNOX") activated sludge process at the EPA-DC Pilot Plant during the study had a nominal capacity of 100,000 gpd and operated with an average reactor time of 1.5 hours and a clarifier overflow rate of 650 gpd/ft^2. The reactor dissolved oxygen was maintained between 6 and 10 mg/l.

The system developed filamentous growth during a period of reactor modification where the operating conditions produced an SRT of less than 5 days and where periods of low dissolved oxygen occurred. Once the filamentous growth was established and SRT was maintained below 5 days (0.6 lb. BOD_5/lb. of MLVSS), the growth continued to propagate in the high dissolved oxygen concentrations. As in step aeration systems, the SVI ranged between 300 and 500. The growth was also identified as Sphaerotilus (12). Initially the flow was decreased from 100,000 gpd to 45,000 gpd to lower the loading and overflow rate in an attempt to increase the SRT. However, improvement in SVI was only slight for the four days prior to H_2O_2 treatment (Figure 8).

H_2O_2 treatment was then employed. The initial treatment consisted of adding 200 mg/l (based on the influent flow) to the recycle (70%)for 24 hours followed by four hours of an increased dose of 400 mg/l. The reduction of free growing filaments occurred but not as drastically as in step aeration, perhaps because the organism was acclimated to a high oxygen environment where the relative change in oxidation-reduction potential with the H_2O_2 addition was less. During the high dosage period (400 mg/l), deflocculation of the spherical aerobic mass also was noticed. The SVI, however, decreased to nearly 200 after the H_2O_2 treatment.

A second treatment of H_2O_2 was tried 11 days later. The dosage was 200 mg/l for one day. The treatment initially produced a modest improvement, and the SVI dropped below 200. The SVI then steadily decreased to 60 as solids could be retained in the system without further H_2O_2 addition.

At low influent flow and low overflow rates, the effluent quality remained satisfactory. The effluent BOD_5 remained below 10 mg/l during the entire test period, even during H_2O_2 treatment.

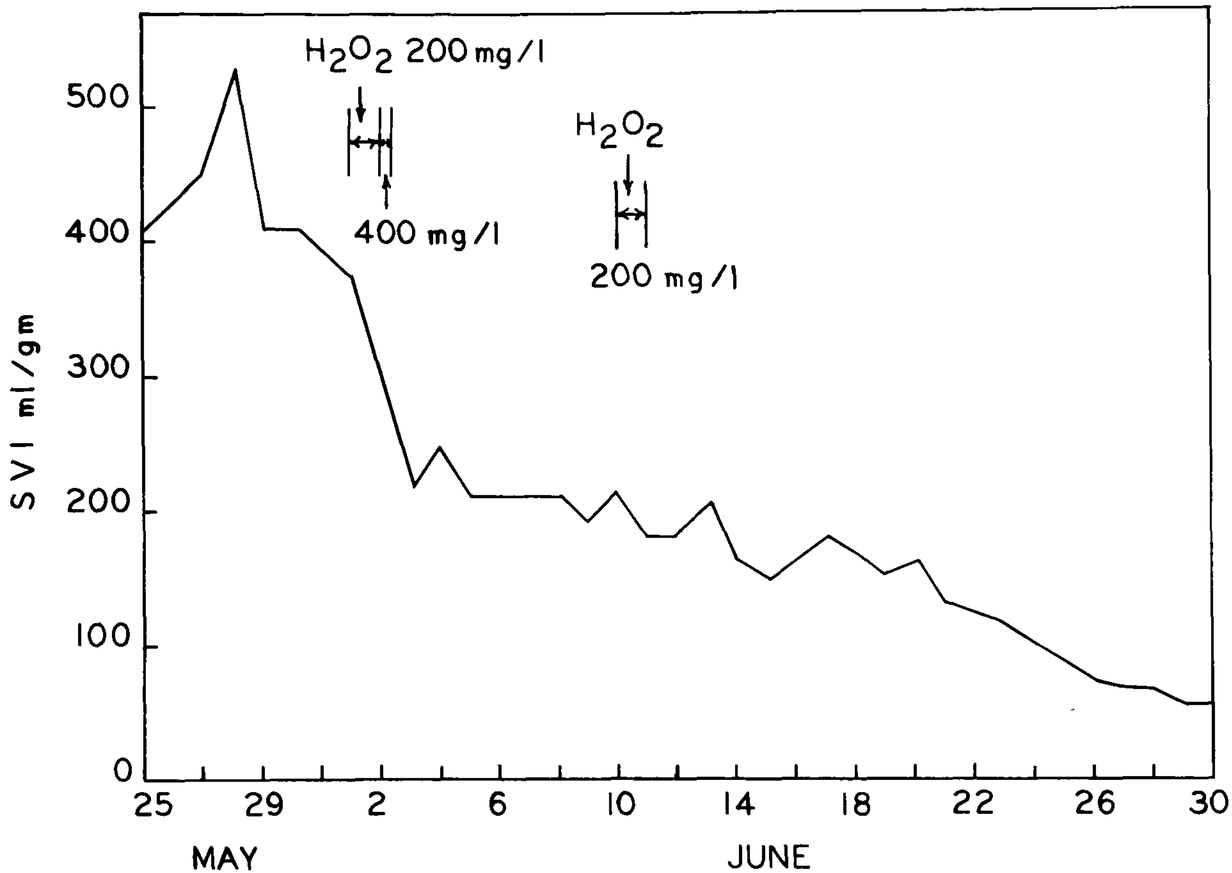

FIGURE 8 - Sludge volume indexes observed during H_2O_2 treatment in the pilot plant oxygen activated sludge process.

SECTION VIII

ECONOMICS

The chemical cost for treatment with H_2O_2 as employed in this study to eliminate filamentous bulking is estimated as $548.00 per million gallons of plant flow. This cost assumes treatment at a dosage of 200 mg/l based upon influent plant flow and applied to the recycled sludge for a 24-hour period. The cost for H_2O_2 (13) is $0.23 per pound of 70% by weight H_2O_2 ($0.33 per pound of pure H_2O_2) in tank truck lots FOB freight equalized to the nearest source of production.

This cost does not necessarily reflect optimum treatment requirements and costs but does indicate that continuous application of H_2O_2 even at low doses to control filamentous bulking is not likely to be economically practical. Thus H_2O_2, as an immediate cure for bulking conditions, requires subsequent operation of the treatment plant to prevent or to minimize the number of recurrences of the bulking filamentous condition.

Since other techniques to eliminate bulking have shown slow or poor response and continue to permit poor quality treatment for extended periods, these techniques and their costs are not comparable to H_2O_2 as an effective treatment approach for Sphaerotilus bulking.

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17a. Descriptors

Activated Sludge
* Sphaerotilus
Sedimentation

17b. Identifiers

* Hydrogen Peroxide
Bulking

17c. COWRR Field & Group 05D

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