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ACTINOMYCETES OF SEWAGE-TREATMENT PLANTS

Municipal Environmental Research Laboratory
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ACTINOMYCETES OF SEWAGE-TREATMENT PLANTS

by

Hubert A. Lechevalier, Mary P. Lechevalier
Waksman Institute of Microbiology
Rutgers, the State University of New Jersey
Piscataway, New Jersey 08854

and

Paul E. Wyszkowski
Consulting Engineer
Warren, New Jersey 07060

Grant No. R803701

Project Officer

Ronald F. Lewis
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

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This report covers studies of attempts to control nuisance Nocardia foams in full scale activated sludge plants by adding anaerobic digester supernatant containing suspended solids that were toxic for the Nocardia. The results of tests at four full-scale plants are reported along with conclusions of the best method for the addition of the anaerobic digester supernatant.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

In some sewage-treatment plants of the activated sludge type, a thick foam rich in species of Nocardia may be formed at the surface of the secondary aeration and settling tanks. This report covers the work done on this problem between May 1975 and May 1976.

It had been observed previously that the supernatant from anaerobic digesters contained suspended solids which were toxic for Nocardia. In the present study we observed that this material is toxic for some bacteria and not for others.

In four sewage-treatment plants equipped with anaerobic digesters, attempts were made to control the foam by returning the supernatant from the digesters to the primary system. The nocardiotoxicity of the supernatant solids was tested to be sure that nocardiotoxic material was being returned into the system.

The amount of nocardia present was estimated visually and by measuring by gas chromatography the amount of nocardomycolic acids present in the suspended solids.

The results indicated that this method of control is difficult to use at the plant level and indicates that better results might be obtained if the toxic supernatant was added directly to the activated sludge aeration basins rather than added to the incoming sewage or the primary settling basins.

It is also concluded that a more rational approach to the method of control would be possible if the nature of the nocardiotoxic principle(s) of the anaerobic digested material was known.

This report was submitted in fulfillment of Grant No. R803701 by the Waksman Institute of Microbiology under the partial sponsorship of the Environmental Protection Agency. The reported work was completed as of May 1976.

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ACKNOWLEDGMENTS

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Mr. Robert Rogove, Superintendent, Township of Ocean Sewerage Authority.

Mr. Robert Buckingham, Plant Superintendent, Borough of Bernardsville.

Mr. Harris Layton, Superintendent, Bayshore Regional Sewerage Authority.

SECTION I

INTRODUCTION

GENERAL

We have previously reported on the presence and the role of different types of Nocardia in the thick foam which is formed at the surface of the secondary aeration and the settling tanks of some sewage-treatment plants of the activated sludge type. This work has been described in report EPA-600/2-75-031 of the Environmental Protection Technology Series, which was published in September 1975. We reported then that we had observed that the solids found in the supernatant of anaerobic digesters were toxic to Nocardia amarae (Lechevalier and Lechevalier, 1974), the organism most commonly associated with the production of foams. We recommended that the chemical nature of the nocardiotoxic principle should be elucidated and that attempts should be made to control foaming at the plant level by returning anaerobic digester supernatant into the system.

We are presently reporting on the work that we have carried out between May 1, 1975 and May 31, 1976 involving the addition of regulated amounts of supernatant from anaerobic digesters to the flow stream of plants known to have a nocardial foaming problem.

We selected four New Jersey wastewater treatment plants equipped with anaerobic digesters that were known to have actinomycetic foams during the summer. These were the plants at Ocean Township, Middletown Township, Bernardsville and the Somerset Raritan Valley Sewerage Authority in Bridgewater Township. As we were ready to start our study we were informed that the last plant had discontinued using anaerobic digesters. We dropped it from our study and replaced it with the Florham Park plant.

The plan of the study was to observe these plants until actinomycetic foam would occur. During that waiting period, supernatant return from the anaerobic digesters was to be kept to a minimum. After the development of a significant amount of actinomycetic foam had occurred, controlled amounts of nocardiotoxic anaerobic supernatant were to be returned into the system in an effort to control the actinomycetic foaming.

The field work was started in May 1975 and was terminated in November of the same year. It consisted in weekly monitoring the four wastewater treatment plants previously mentioned. During the weekly visits to each of these plants the physical appearance of the activated sludge was checked and a visual estimate of the foaming problem was made (Tables 1, 5 and 9). In addition, unusual operating conditions were noted and samples of the returned activated sludge and of the anaerobic digester supernatant were collected. Further, the plant operators supplied us with copies of their records containing information on flow, temperature, pH, suspended solids and BOD determinations (Tables 4, 8 and 12).

The weekly samples of return activated sludge collected at the plants were analyzed by us for pH, solid concentration and the presence of Nocardia amarae by two different methods (Tables 2, 6 and 10). One of the methods was qualitative, being the microscopic examination of the samples for the presence of nocardial hyphae. The other was quantitative, and involved the gas chromatographic determination of the nocardomycolic acids of N. amarae. This last method is based on the fact that N. amarae produces a unique type of lipid, a nocardomycolic acid whose α branch is mono-unsaturated. The rationale behind the utilization of this quantitative assay was that as the foam builds up with the warming of the weather, the hyphae of N. amarae become more abundant and the nocardomycolate content increases. The assumption was made that if the addition of anaerobic digester was reducing the nocardial growth, this would be accompanied with a reduction in the nocardomycolate content of the suspended solids.

The samples of anaerobic digester supernatants were checked for pH and nocardiotoxicity (Tables 3, 7 and 11). The pH of all supernatants tested were neutral. This assay was carried out since it was felt that there was no point returning a non-nocardiotoxic supernatant to a foaming plant.

OBJECTIVE

The purpose of this study was to determine if the addition of nocardiotoxic supernatant from anaerobic digesters to the raw sewage flowing into plants with nocardial foaming would control the foaming which is considered a nuisance in the operation of activated sludge sewage-treatment plants.

SECTION II

CONCLUSIONS

Attempts were made to control actinomycetic foaming in the secondary aeration and settling tanks of four activated sludge type sewage-treatment plants by adding controlled amounts of nocardiotoxic anaerobically digested material to the sewage flow.

In addition to the nocardiotoxicity of the anaerobically digested material, success seemed to depend on the plant design. Favorable design should permit the operator 1) to waste the Nocardia-infected foams to the anaerobic digester in order not to keep re-inoculating the secondary tanks with large biomasses of Nocardia, and 2) to add the nocardio-toxic material to the secondary flow into the activated sludge in order to prevent its partial removal by primary treatment system.

SECTION III

RECOMMENDATIONS

The production of actinomycetic foams should be prevented because the growth of nocardias in aeration tanks is a health hazard due to the formation of Nocardia-containing aerosols and, in addition, the production of thick foams in activated sludge type plants interferes with treatment efficiency and is a source of extra labor costs. In plants affected with nocardial foam, the foam should be skimmed off the secondary settling tanks and sent to the anaerobic digester. This should be done to reduce the amount of Nocardia in the secondary treatment system.

We feel that a pilot study should be run in properly equipped plants with anaerobic digesters to test the value of returning controlled amounts of nocardiotoxic anaerobic digester supernatant directly to the secondary flow stream.

It is also our recommendation that the chemical nature of the nocardiotoxic compound(s) be determined. If the nature of the nocardiotoxic material were known it might be possible to add small amounts of the active compound(s) which might be effective without applying an appreciable waste load to the system as is commonly experienced with supernatant returns. This last study would have the added benefit of increasing our knowledge of the chemical nature of anaerobically digested materials.

SECTION IV

METHODS

Isolation of Nocardia from sewage.

Method.

Samples of sewage sludge or foam were diluted in sterile distilled water to give final dilutions of 10^{-4}, 10^{-5} and 10^{-6}. A tenth of ml of these dilutions were spread on the surface of 6-10 plates containing Czapeks-Yeast Extract, Potato-Carrot, and Glycerol-Nutrient agars. After incubation of the plates at 28 °C for 10-14 days, actinomycete colonies were picked and streaked on fresh plates to determine morphology and freedom from contamination by other microorganisms. N. amarae strains grew as dry, beige, wrinkled colonies on all media. N. rhodochrous colonies were usually some shade of pink or orange (sometimes very light) and varied in consistency from very "runny" to quite dry.

Monitoring of Nocardia amarae chemical.

Monitor mycolate procedure.

Extraction.

Samples of activated sludge were autoclaved at 15 lb./sq. in. for 25 min, cooled, and the solids collected by centrifuging 250 ml aliquots at 5,000 rpm for 10 min in a Lourdes β-Fuge (4100 xg). The wet solids were air-dried to constant weight, and the dried solids ground to a fine powder in a Thomas-Wiley Intermediate Mill Model 3383-L40. Five gm of this powder were saponified in 75 ml 2% methanolic potassium hydroxide by boiling in a 250 cc Erlenmeyer over a steam cone for 7 min. The solids were separated from the supernatant by filtration through fluted Reese-Angel 802 filter paper. The filtrate was labelled "extract #1." The solids were rinsed with

hot methanol, replaced in the original flask and extracted by boiling in distilled methylene chloride for 2 min on the steam cone. The solvent was separated from the solids as before by filtering into a fresh flask, then the solids extracted once with fresh methylene chloride. Care was taken to "squeeze-dry" the solids to obtain all the extract. The two methylene chloride extracts were combined and labelled "extract 2" and taken to dryness in vacuo with mild heat (40 °C).

Purification.

Extract #1 was neutralized carefully to pH 7.0 with 6N hydrochloric acid and taken to dryness in a Buchi Rotovapor Model RE at 55 ° C under vacuum provided by a Buchler Water Booster #2-9000. Extract 2 was taken to dryness similarly without pH adjustment. Extract #1 and extract #2 were each separately treated in the following way: The dry residue was dissolved in 5-10 ml of methylene chloride, 5-10 ml of distilled water added, the water adjusted to pH 2.0 with 2N HCl and the two phases thoroughly mixed for 1 min on a Vibromix. The two phases were completely separated by centrifuging at 3,000 RPM in an International Clinical Centrifuge (1200 xg), and the aqueous (upper) phase discarded. The methylene chloride of the lower phase was removed under vacuum in a tared tube and the tube placed for complete drying in a vacuum oven (National Appliance Co. Model No. 5851) using concentrated technical sulfuric acid as desiccant.

Methylation.

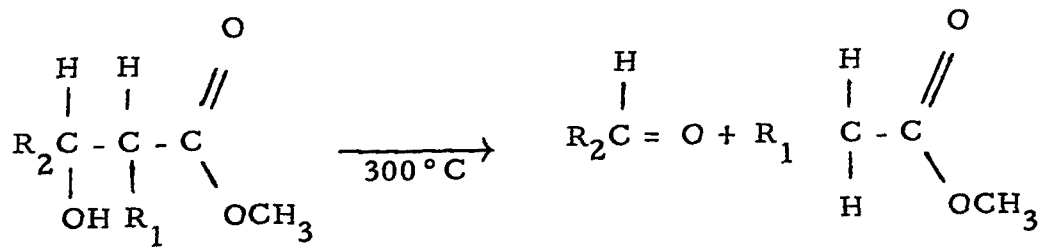
The dried extracts #1 and #2 were weighed, then methylated by boiling with 10% boron trichloride-methanol (Applied Science, State College, Pa.) (3 ml of reagent for 200 mg of residue) until the reagent went to dryness. The dry methylated material was dissolved in methylene chloride and washed three times with distilled water by mixing on a vibrator-mixer and centrifuging to break any emulsion as described above. The aqueous washes were discarded. The last wash had a pH 5.0-6.0. If the pH of the final wash was too low, the washing was continued. The organic (lower) layer of each extract was taken to dryness under vacuum in a tared tube.

Preparative thin-layer chromatography (PTLC).

Each methylated extract was weighed and the weight recorded. Each was dissolved in methylene chloride and fifty mg or less were spotted as a band 2 cm from the bottom of a 20 x 10 cm PF_{254} silica gel plate (Brinkmann Instruments, Westbury, N. Y.) containing 10 g of silica per plate. The bands were dried under warm air, then developed in a solvent system containing petroleum ether:diethyl ether in proportions of 8:2 (b.p. >40). When the solvent front had reached the top of the plate, the plate was air-dried under a hood, then sprayed with Rhodamine B (0.1% ethanolic Rhodamine B diluted 1:10 with 0.25 M KH_2PO_4). The band(s) migrating at an Rf corresponding to the methyl nocardomycolates from Nocardia amarae were carefully scraped off, and dried overnight at room temperature. The silica of the bands was eluted by 10X by volume distilled methylene chloride, and the eluate reduced in volume by heating at ∿40°C on a hot plate under a stream of compressed filtered air. The samples were transferred to tared tubes, the solvent driven off and the residues taken to dryness in vacuo and weighed.

Analysis by gas chromatography.

Ten mcg of the samples to be analyzed were injected in 0.5 λ of methylene chloride into a Varian Gas Chromatograph Model 2800 equipped with a flame-ionization detector. Conditions were: injector port 300°C, detector 300°, column temperature programmed at 6°/min from 185° to 285°. Columns 6' x 1/8" of 10% OV-1 on Chromosorb W, AW-DMCS, 100-120 mesh were used. Under these conditions the mycolates in the sample pyrolyzed to give rise to a straight chain fatty acid methyl ester according to the following reaction:



Mycolic acid Methyl ester

Meroaldehyde

Fatty acid methyl ester

The fatty acid peak corresponding to the fatty methyl ester (methyl octadecenoate) from the pyrolysis of the nocardomycolic acids of N. amarae (amaraemycolate) was identified on the basis of retention time compared to that from an authentic sample of amaraemycolate isolated from a laboratory strain of N. amarae. An internal standard (methyl eicosanoate) injected at the same time, aided in this comparison. To verify the identity of the putative mycolate-derived peak, the sample was run again with the injector port at 235° C. Under these conditions no pyrolysis of mycolates takes place; thus, the disappearance of the fatty acid methyl ester peak confirms its derivation from the pyrolysis of nocardomycolates of N. amarae.

The volume under the peak was calculated by multiplying the height of the peak by its width at half height and the calculation of the original weight of amarae-mycolate in the starting sample was calculated as follows:

The volume under the peak of a known amount of methyl vaccenate ($C_{18}1=$) injected under the same conditions was calculated to give a peak volume to weight ratio. This, under the conditions of analysis used was 0.7 nanograms/mm^2. (A).

The peak volume from the unknown sample (B) was multiplied by (A) to give the amount by weight in the unknown sample expressed as micrograms of $C_{18}1=$ (G). The total weight of the unknown sample (C) was divided by the mcl of solvent (D) in which it was dissolved to give the concentration of the injected solution in mcg/mcl (E). (E) was multiplied by the amount (usually 0.8 mcl) actually injected to yield the total solids injected (F). $C \div F \times G \times 3^*$ gave the uncorrected total of amaraemycolate per 5 gm of dry sludge solids. Corrections to this last figure were made if the original sample before PTLC contained more than 50 mg (the maximum purified for GLC analysis).

The methods used in the assay of the mycolates were modified from those of Lechevalier et al. 1971 and 1973.

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* Assuming a molecular weight of amaraemycolate of about 900.

Microscopic monitoring of N. amarae.

The hyphae of Nocardia amarae were also monitored in each sewage sludge sample by microscopy. Without exception, where foaming occurred and the amaraemycolate levels were appreciable, the hyphae of the actinomycete were visible in the samples. An actual quantitation of the amount of the nocardia present was difficult by microscopic means.

The results are shown in Tables 2, 6 and 10.

Testing anaerobic digester supernatant for nocardiotoxicity.

Samples of supernatants from anaerobic digesters to be tested for nocardiotoxicity were autoclaved for 20 min at 15 lb/sq. in. pressure prior to testing. If the samples were received at the end of the day, they were stored at 4 C overnight prior to sterilization. Previous experiments showed that autoclaving did not destroy the toxic substance(s) which is associated with the solids present in the supernatant (Lechevalier, 1975).

The test organism was Nocardia amarae Se 6/ (ATCC 27808). It was inoculated in yeast-extract glucose broth dispensed at the rate of 50 ml per 250 cc Erlenmeyer flask and was incubated at 28 C on a rotary shaking machine (New Brunswick Scientific Co. Model G 10) operated at 200 RPM. Yeast-extract glucose medium (YD) is composed of 1% Bacto yeast extract and 1% glucose in water with a pH after sterilization of 6.8.

One ml aliquots of the culture of the test organism prepared as described above were used to inoculate a series of 250 cc flasks containing 50 ml Czapek's broth (Waksman, 1950) to which 0.2% yeast extract had been added (YCZ medium). The series of flasks received 0, 0.05, 0.5, 1.0 and 5.0 ml of the autoclaved anaerobic digest to be assayed. Assays were run in duplicate.

The assay flasks were incubated for 48 hr as described above at which time the growth was measured by the packed cell volume assay method.

The packed cell volume assay consisted in centrifuging 5 ml of each culture at 1,200 g for 3 min in graduated conical centrifuge tubes.

The volume of the packed cells was read off directly.

These readings were plotted on arithmetic paper and the 50% inhibition concentration was determined as mg of anaerobic supernatant solids per ml of YCz broth required to reduce growth of N. amarae Se 6 to 50% of that found in the untreated control.

To determine the dry weight of the solids per ml of anaerobic supernatant, 5 ml of well-mixed autoclaved material was placed into a tared weighing dish and taken to constant weight at 60 C.

SECTION V

SPECTRUM OF ANTIMICROBIAL ACTIVITY OF ANAEROBIC DIGESTER SUPERNATANT SOLIDS

Before we started this study we knew that the solids present in anaerobic supernatant were toxic to strains of Nocardia amarae. We felt that it would be useful to know if this material is also toxic for fecal bacteria likely to be found in domestic sewage. Using a modification of the assay method that we used for the determination of toxicity to N. amarae Se 6, we also tested the sensitivity of Streptococcus faecalis LL-B, Enterobacter cloacae LL-B and Escherichia coli 54.

The organisms to be tested were grown in nutrient broth for 24 hr at 28 °C by shaking at 200 RPM in 250 cc Erlenmeyer flasks containing 50 cc of medium. These were used to inoculate (2% inoculum) similar flasks of nutrient broth containing 3.3, 0.3 and 0.03 mg/ml of supernatant solids (determined as dry weight) from the Middletown plant sample of 6/10/75).[1] These cultures were incubated as described above for 24 hr and then centrifuged at 300 G for 1 min to settle the supernatant solids, leaving the bacteria in suspension.

Bacterial growth was estimated from the optical density of the bacterial suspensions which were measured with a Klett-Summerson colorimeter using a No. 66 filter. Control flasks included: a) nutrient broth containing only bacteria and no supernatant solids and b) nutrient broth containing only supernatant solids and no bacteria. Both types of controls were shaken 24 hr at 28 C and centrifuged as in the case of the experimental flasks.

The results were that at 3.3 mg/ml the growth of E. cloacae was reduced to 12% of that found in the positive control cultures and that of E. coli to 40%. These results were observed after 24 hr incubation but remained unchanged when the cultures were incubated for a total of 5 days. In the case of S. faecalis, no inhibition was

[1] 1.65 mg/ml, of this sample were required to give 50% inhibition of Nocardia amarae Se 6.

observed.

We can thus conclude that the solids present in anaerobic digester supernatant are not toxic to the same level for all types of bacteria and may even be non-toxic for some. These solids thus must play a selective role in the control of the microbial population of the activated sludge when they are returned into the system.

SECTION VI

THE BERNARDSVILLE PLANT

The Bernardsville Wastewater Treatment Plant in the Borough of Bernardsville, Somerset County, N. J. was constructed in 1933. When we started our studies in 1971, the 1,893 m^3/d (0.5 mgd) plant consisted of preliminary treatment (comminutor), primary sedimentation (rectangular clarifier), conventional diffused air activated sludge treatment with rectangular final settling tanks (without scum baffles), effluent disinfection (chlorination) and anaerobic digestion (conventional). The digested sludge was dewatered by centrifugation and the anaerobic supernatant was returned to the primary treatment system. Dewatered sludge was used for landfill.

As far back as the operators of the plant could recall the Bernardsville facility had been free of heavy foaming and we were unable to see or isolate nocardia from the Bernardsville suspended solids during the period of April 1971 to May 1974.

Later in 1974, the Bernardsville plant was modified in such a way that the anaerobic digester was no longer used. In spring 1975, the aeration tanks of the plant were covered with a thick foam in which actinomycetic hyphae could be seen and a number of strains of N. amarae and N. rhodochrous were isolated from it. We thought that the Bernardsville facilities would be ideal for the testing of our hypothesis because it was a plant which had operated for a long time without nocardial foam and which had started to foam only after the anaerobic digesters had been abandoned.

We asked the operator of the plant to reactivate the anaerobic digesters in order to be able to return their supernatant into the system, as it was done previously. During the period of this study (May 1975 to May 1976) he was unable to get satisfactory digestion, the pH remaining always on the acidic side (pH 4 to 5). We eventually had to abandon the hope of being able to use this plant for this study.

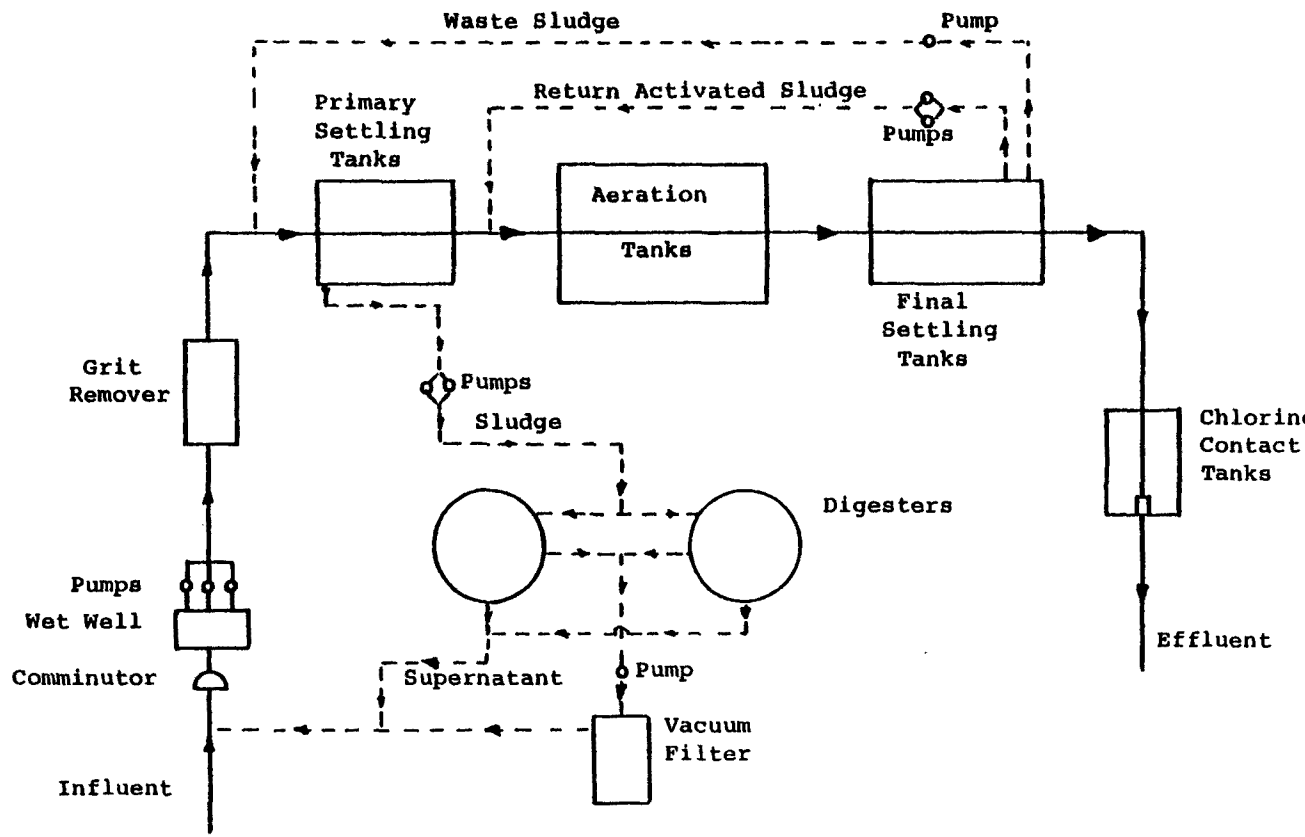
SECTION VII

THE FLORHAM PARK PLANT

The Florham Park Sewage treatment plant located in the Borough of Florham Park, Morris County, New Jersey was constructed in December 1966. The plant has a capacity of 3,785 m^3/d (1.0 mgd) and consists of preliminary treatment (comminutor and grit remover), rectangular primary sedimentation tanks with scum and sludge conveyed to the digesters, conventional secondary activated sludge (diffused air) and secondary sedimentation in rectangular units, effluent disinfection (chlorination); digested sludge is dewatered by vacuum filtration and disposed as land fill. The anaerobic supernatant is returned to the preliminary treatment units as illustrated in the flow diagram (Figure 1). The foam and scum collected on the surface of the secondary clarifiers is periodically manually removed and disposed as landfill.

At the beginning of our study, as can be seen in Table 1, the plant had little or no foam accumulation. Toward the end of June the foam and scum, which was shown to contain nocardias (Table 2) and from which strains of N. amarae were isolated, was sufficiently developed to attempt control by the return of digester supernatant, the solids of which were toxic to Nocardia amarae (Table 3). Plant operating records during the study period are given in Table 4. Figure 2 gives the nocardiotoxicity of the supernatant solids and the nocardiomycolate levels of the sludge solids.

On July 1, a control program was instituted consisting of the return of approximately 6.4 m^3 (1,700 gal) of anaerobic digester supernatant per day to the plant headworks. This quantity of return represented about a ratio of 1 volume of supernatant to 500 of plant flow and was based on a preliminary experiment run at the Middletown plant in 1974. The supernatant was returned to the primary flowstream over an average 4 hr time period.



FLOW DIAGRAM

SEWAGE TREATMENT PLANT
FLORHAM PARK SEWERAGE AUTHORITY

Figure 1

Table 1. FIELD OBSERVATIONS

FLORHAM PARK PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam conditions	Miscellaneous observations and recommendations
May 6, 1975	Darkish	Normal. Some channel scum	Color dark	Low amount	To keep supernatant return to a minimum
12	Some foam	Some channel scum	Color dark	Low amount	To try to lower RAS rate
20	Some foam	More channel scum	Color darkish	Low amount	Reducing RAS rate
27	Some foam	Some channel scum	Color darkish	Low amount	
June 2, 1975	Some foam	More channel scum	Color dark	Medium amount	
10	Low foam	Low channel scum	Color dark	Low amount	Returned large amount of supernatant RAS valve problem
17	Some foam	Some channel scum	Color good darkish	Low amount	Temperature of sewage 17° C
24	Good foam development	Good scum amount in channel	Color good darkish	Good development	Foam in primary channel too

Table 1 (continued). FIELD OBSERVATIONS

FLORHAM PARK PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam conditions	Miscellaneous observations and recommendations
July 1, 1975	Plenty of foam	Plenty of scum in channel bulking	Color dark	Good development	Started supernatant control: 10.2 cm/day (4"/day) RAS problem and wasting problem
8	Somewhat less foam	Less scum in channels	Color dark	Somewhat reduced	ML high; wasting problem; supernatant return cut to 7.6 cm/day (3"/day)
15	Less foam	Less scum dark color	Very dark color	Reduced	Rain; heavy flow washed out ML
22	Good foaming	Good scum in channels	Color dark	Good development	ML washed out due to heavy rain flows
29	Good foam	Good scum in channels	Color very dark	Good development	ML high; wasting problem
August 1, 1975	Less foam	Less scum in channels	Color good	Reduced	Wasting problem
12	Plenty foam	Plenty channel scum	Color dark	Good development	
19	Plenty foam	Plenty scum in channel	Color dark	Good development	By pass out; 1 final out; wasting problem
26	Less foam	Less scum in channel	Color dark	Reduced	Heavy rain; ML washed out; flow change wasting

Table 1 (continued). FIELD OBSERVATIONS

FLORHAM PARK PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam conditions	Miscellaneous observations and recommendations
August 27, 1975	Less foam	Less scum; very good clarity	Color dark	Reduced	Started new wasting ML 1800 ± mg/l
Sept. 2	Plenty of foam	Plenty of foam in channel; good clarity	Color dark-ish	Good development	Supernatant from primary digestor
4	Plenty of foam	Clarity good; plenty of scum	Color dark	Good development	Wasting problem
9	Plenty of foam	Plenty of scum in channels	Color dark	Good development	Go back to secondary digestor supernatant
12					Less foaming during day, more at night
16	Plenty of foam	Lot of light scum in channels	Dark color	Good development	Will lower aeration at night; wasting problem
23	Some foam	Lot of scum in channel, little in primary channel; #1 bulking	Dark color	Good development	Heavy rain last night; wasting problem

Table 1 (continued). FIELD OBSERVATIONS

FLORHAM PARK PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam conditions	Miscellaneous observations and recommendations
Sept. 30, 1975	Less foam	Good scum in channel	Color very dark	Reduced?	Heavy rain and flow washed out ML; changing RAS well
Oct. 7	Lots of foam	Plenty of scum in channels	Color very dark	Good development	Change RAS method
14	Less foam	Somewhat less scum; tanks bulking; clarity poor	Color very dark	Reduced	RAS clogged 12 and 13th. Problems with wasting and RAS. Stopped supernatant control on 10th
21	Some foam	More scum in channels; good clarity; #1 some bulking	Color better but still darkish	Increasing development	Will keep no supernatant feed until next week, then drop slug amount
28	Less foam	Less scum in channel; bulking in afternoon	Color good darkish	Reduced?	
31	Some foam	Some scum in channels #1 bulking	Color very good	Reduced (same as 28th)	To drop slug of supernatant 25.4 cm (10")

Table 1 (continued). FIELD OBSERVATIONS

FLORHAM PARK PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam conditions	Miscellaneous observations and recommendations
Nov. 4, 1975	Lots of dark foam	Lots of dark scum #1 bulking	Color very dark	Increased development	Dropped 99 cm (3 ft. 3 inches) of digester on 31st. Much problems with clogging pumps and etc.
6	Less foam	Slightly less scum #1 bulking	Color good, darkish	Reduced	
10	Plenty of foam	Plenty of scum in channels but lighter than in past	Color darkish	Increased development	Wasting problems
18	Somewhat less foam	Somewhat less scum	Color good	About same as 10th	Dropped 30.5 cm (12") of super-natant wasting problem
25	Less foam	Plenty of scum in channels	Color darkish	Increased development	Wasting problem
Dec. 2	Plenty of foam	Plenty of foam in channels; #2 bulking	Color darkish	Good development	End control attempts

RAS = activated sludge return.

ML = mixed liquor of aeration tanks.

Table 2. ANALYSIS OF RETURN ACTIVATED SLUDGE

FLORHAM PARK PLANT

Date	Suspended solids mg/l	Microscopic estimation of nocardial hyphae	Mycolate content µg/5 gm dry sludge solids
5-6-75	6,400	+---	6.3
5-12	7,200	+--	34.2
5-20	6,600	+--	30.9
5-27	8,800	+	199
6-2	8,200	+	188
6-10	14,400	+	141
6-17	10,600	+	130
6-24	10,600	+	286
7-1	8,400	+	453
7-8	9,000	+	433
7-15	9,000	+	142
7-22	8,400	+	153
7-29	8,200	+	281
8-1	8,000	+	444
8-12	9,600	+	575
8-19	4,200	+	391
8-26	9,800	+	481

Table 2 (continued). ANALYSIS OF RETURN ACTIVATED SLUDGE

FLORHAM PARK PLANT

Date	Suspended solids mg/l	Microscopic estimation of nocardial hyphae	Mycolate content µg/5 gm dry sludge solids
9-2-75	7,200	+	310
9-9	7,200	+	570
9-16	7,800	+	402
9-23	8,800	+	418
9-30	9,200	+	242
10-7	11,600	+	1,169
10-14	10,600	+	353
10-21	8,400	+	413
10-28	8,000	+	1,051
11-4	9,800	+	623
11-10	8,800		
11-18	9,280		
11-25	6,800		

Table 3. ANALYSIS OF DIGESTER SUPERNATANT

FLORHAM PARK PLANT

Date	Suspended solids mg/l	mg/ml for 50% inhibition of N. amarae
6-24-75	15,300	
7/1-8	22,400	1.2
7/9-14	16,100	1.1
7/15-21	20,800	1.3
7/22-29	26,000	1.1
7/30-8/12	10,600	0.7
8/13-19	8,300	0.8
8/20-26	4,500	2.7
8/27-9/2	3,900	>3.0
9/3-9	12,600	0.9
9/10-16	25,700	1.3
9/17-23	20,400	0.9
9/24-30	24,300	1.1
10/1-7	33,700	1.1
10/8-14	28,100	0.4
10/31	13,800	
11/18	8,500	
		Av. 1.3

Table 4. PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

FLORHAM PARK PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	$m^3/d \times 10^3$	M.G.D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
5/1-6	2.80	(.740)	13	7.9	7.1	160	40	75	140	-	16	89
1-13	2.89	(.763)	14	7.6	7.1	143	6	96	320	-	11	97
14-20	2.98	(.788)	15	7.8	7.1	125	20	84	145	-	12	92
21-27	2.66	(.703)	16	7.9	7.0	146	21	86	130	-	5	96
28-6/3	2.75	(.727)	16	7.8	7.1	210	11	95	137	-	5	96
4-10	2.98	(.787)	17	7.8	7.1	180	19	89	140	-	5	96
11-17	3.09	(.816)	17	7.5	7.1	155	15	90	160	-	10	94
18-24	2.71	(.716)	18	7.6	7.1	135	10	93	250	-	8	97
25-30	2.49	(.659)	18	7.7	7.0	160	9	95	130	-	8	94
7/1-8	2.41	(.636)	19	7.6	7.1	180	25	86	150		30	80
9-14	3.25	(.858)	19	7.6	6.9	165	30	82	130		22	83

Table 4 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

FLORHAM PARK PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M.G.D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
15/21	3.12	(.823)	20	7.2	6.9	120	13	89	130		20	85
22-29	2.78	(.736)	20	7.4	7.0	130	21	84	115		20	83
30 8/12	2.39	(.631)	20	7.4	7.0	175	10	94	125		10	92
13-19	2.15	(.568)	21	7.6	7.0	120	16	87	140		15	89
20-26	2.82	(.745)	21	7.5	6.8	170	20	88	150		8	95
27-9/2	2.46	(.650)	21	7.6	6.8	130	15	88	120		13	89
3-9	2.43	(.641)	20	7.8	7.0	140	10	93	170		5	97
10-16	2.38	(.629)	20	7.7	7.0	140	15	89	120		7	94
17-23	2.85	(.752)	20	7.8	7.2	130	5	96	150		10	93
24-30	4.78	(1.264)	19	7.6	7.1	-	-		-		-	
10/1-7	2.71	(.716)	19	7.7	7.1	110	12	89	130		14	89

Table 4 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

FLORHAM PARK PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M. G. D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
8-14	2.64	(.697)	19	7.8	7.1	145	15	90	180		15	87
15-21	3.30	(.873)	19	7.7	7.0	145	15	90	170		5	97
22-28	2.81	(.743)	18	7.6	7.0	112	12	89	156		8	95
29-11/4	2.65	(.699)	18	7.8	7.0	170	12	93	120		16	87
5-10	2.79	(.738)	18	7.8	7.1	165	15	91	150		8	95
11-18	2.83	(.749)	17	7.8	6.9	120	25	79	130		12	91
19-25	2.82	(.745)	17	7.8	6.9	138	13	91	147		8	95
26-12/2	2.66	(.703)	16	8.0	7.0	-	-	-	-		-	-

Sew = Sewage

Infl = Influent

Effl = Effluent

REM = removal

BOD/5 = 5 day biochemical oxygen demand

TABLE 4 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

FLORHAM PARK PLANT

Date	Aeration Tanks				Ret. sludge		Digesters		Misc.
	MLSS mg/l	ML Set S ml/l	SVI	DO mg/l	% R	SS mg/l	Sup'n Gal	Sup'n % TS	
5/1-6	2150	520	245	2.6					
7-13	2371	470	194	2.7					
14-20	2643	440	156	2.6	← Estimated 60 to 100% →	Not Determined	9690	Not Determined	
21-27	2100	250	116	3.2			3960		
28-6/3	2129	240	111	3.5			7490		
4-10	2157	220	104	3.0			4840		
11-17	2486	240	98	3.1			5280		
18-24	2757	280	100	2.9			7490		
25-30	2567	290	110	2.5			14090		
7/1-8	3175	340	104	2.2			7930		
9-14	2750	320	117	1.7			11450		

TABLE 4 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

FLORHAM PARK PLANT

Date	Aeration Tanks				Ret. sludge		Digesters		Misc.
	MLSS mg/l	ML Set S ml/l	SVI	DO mg/l	% R	SS mg/l	Sup'n Gal	% TS	
15-21	2488	220	91	2.2			11010		
22-29	2963	310	102	2.0			18500		
30-8/12	3464	370	104	2.0			9250		
13-19	3385	310	94	2.0	↑ Estimated 60 to 100% ↓	Not Determined	9250	Not Determined	
20-26	2757	270	93	2.1			9250		
27-7/2	2850	290	95	2.1			9250		
3-9	2657	250	94	2.0			9250		
10-16	2671	340	124	2.1			9250		
17-23	3000	370	129	2.0			9250		
24-30	2100	180	91	2.2			9250		
10/1-7	2986	290	94	2.2			9250		

TABLE 4 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

FLORHAM PARK PLANT

Date	Aeration Tanks				Ret. sludge		Digesters		Misc.
	MLSS mg/l	ML Set S ml/l	SVI	DO mg/l	% R	SS mg/l	Sup'n Gal	Sup'n % TS	
8-14	2564	270	97	2.3			3960		No super 10th →
15-21	2244	270	103	2.4			0		
22-28	2616	310	112	2.1			0		
29-11/4	2767	320	111	2.3	← 30% ± →	Not Determined	17170	Not Determined	
5-10	2883	320	113	2.4			0		
11-18	3031	360	114	2.9			5280		
19-25	2586	340	114	2.4			-		
26-12/2	2217	310	136	2.2			-		

MLSS = Mixed Liquor Suspended Solids
ML Set S = Mixed Liquor Settleable Solids
SVI = Sludge Volume Index
DO = Dissolved Oxygen

SS = Suspended Solids
Sup'n. = Supernatant
TS = Total Solids

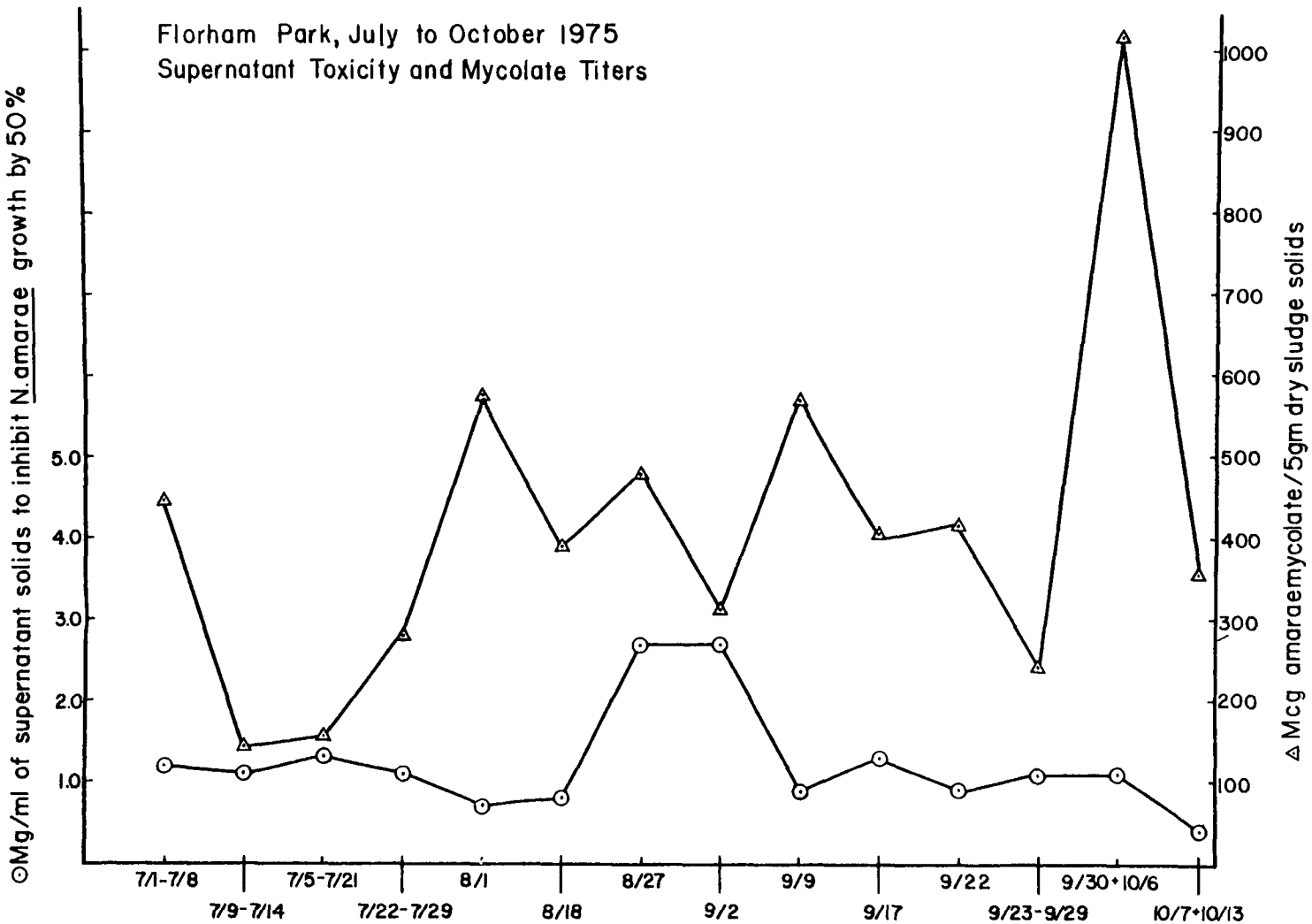


Figure 2. Nocardiotoxicity of the Supernatant from the Anaerobic Digester and Nocardiomycolate Contents of Sludge Solids at the Florham Park Plant from July 1 to October 13, 1975

Throughout the study period, the return of anaerobic supernatant did not appear to affect the development of actinomycetic foam. Periodically, the foam was reduced but it was not clear if this effect was not due to excessive flow and the washout of aeration tanks due to infiltration or inflow from occasional heavy rainfalls.

An additional source of problems were the many operational difficulties the Florham Park plant experienced throughout the study period.

Two major problems were the control of the return activated sludge system and the removal of excessive activated sludge from the process to maintain a proper concentration of suspended solids under aeration.

Throughout the study period, it was felt that the mixed liquor suspended solids content in the aeration system was too high for the attempted control to be effective. Although a comparison of the data on suspended solids in Table 4 does not show high solid contents, the high aeration solids retention time or "sludge age" at this plant (Table 13) shows that the concentration of suspended solids in the aeration tanks was about twice that in the two other plants studied. Various attempts at revision of the plant system were made to permit a proper control of the wasting from the aeration system but none were successful in reducing the excess level of mixed liquor suspended solids under aeration.

On the 10th of October the daily return of supernatant was discontinued and instead, a control method of returning large amounts of supernatant (17 m^3/d = 4500 gal/d) to the system at selected intervals was instituted. This was referred to as "slugging" the system. The reasoning behind this procedure was that the nocardial population might have become adapted to the presence of small amounts of toxic material. It was felt that the periodic slugging of the system with larger doses might be more beneficial. The results, as indicated in Table 1, did not show any significant reduction in foaming. In fact, the first attempt at slugging the system resulted in an upset of the plant system because of the accidental addition of too large a volume (65 m^3 = 17,170 gal). The second attempt at slugging the system was better controlled and did not affect the plant system; however, no significant reduction of the foam or scum formation was noted.

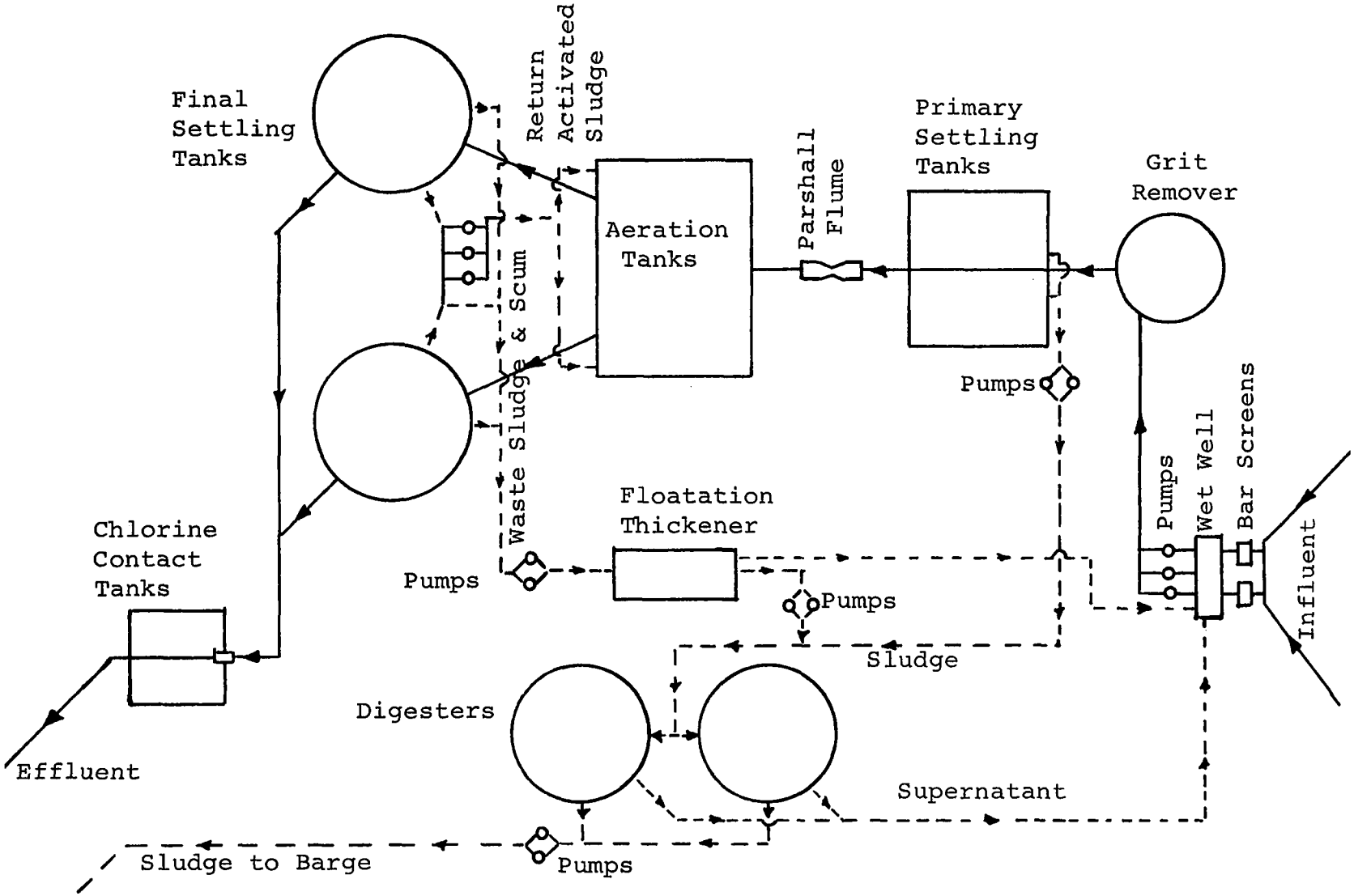
Since the addition of anaerobic supernatant had no apparent effect on the actinomycetic foam at Florham Park, the question was asked if this was due to an increase in resistance of the nocardial flora of the sludge. In order to answer this question, the foam was plated out as previously described (Lechevalier, 1975) and two strains of Nocardia amarae were isolated (strains Se 351 and Se 355). These were tested for sensitivity to anaerobic digester supernatant solids as previously described at the same time as our standard assay strain Se 6. The freshly isolated strains turned out to be more sensitive to the supernatant solids than our assay strain. Their growth was inhibited 50% by 1.8 mg of solids per ml as compared to 4.9 mg/ml in the case of Se 6. It was then concluded that the lack of control of the foam was not due to an increase of resistance of the nocardial population.

SECTION VIII

THE MIDDLETOWN PLANT

The Middletown Waste treatment plant began operation in July, 1971. It is a 24,600 m^3/d (6.5 mgd) facility which provides for preliminary treatment (mechanical bar screen and grid remover); primary treatment in rectangular clarifiers with the sludge and scum sent to anaerobic digesters; secondary treatment of the conventional activated sludge type with aeration by mechanical turbines; circular final clarifiers in which the wasted sludge and collected surface scum are sent to the anaerobic digesters; effluent chlorination and anaerobic sludge digestion. Digested sludge is disposed by barging to an ocean disposal site. The supernatant from the anaerobic digestion system is returned to the primary treatment facilities at the wet well (see flow diagram, Figure 3).

As can be seen in Table 5, supernatant return was kept to a minimum and good development of foam was noted starting July 15. On July 28, a control program consisting in returning approximately 6 inches (15.2 cm = 12,400 gal) of anaerobic supernatant per day to the primary flow stream was instituted (Table 5). This amount of supernatant was returned in approximately 1/2 h. It was felt that this rapid procedure would minimize removal of supernatant solids in the primary sedimentation units. By the end of August, the reduction in foaming was obvious and reached a low level on September 30. At this point it was felt that the control method had succeeded and that the foam nuisance was eliminated. Throughout the remaining portion of the study period, an increase in the actinomycetic foam was noted at the plant which was attributed to the variation in supernatant control feeding, a decrease in the supernatant toxicity (Table 7), and difficulties with various plant units.



FLOW DIAGRAM
SEWAGE TREATMENT PLANT
TOWNSHIP OF MIDDLETOWN SEWERAGE AUTHORITY Figure 3

Table 5. FIELD OBSERVATIONS

MIDDLETOWN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
May 5, 75	Normal	Normal		None	To keep supernatant return to minimum
13	Normal	Minor scum	Color good		Sewage temperature 14.5° C
21	Normal	Some scum on #2		Minor	
27	Normal	Very slight scum	Color good	Minor	Sewage temperature 17° C
June 2	Some foam	Some scum	Color good	Slight	Dropped back 61 cm (2') of digester #2
10	Normal	Some scum	Color good	Minor	Barged sludge
19	Moderate foam	Scum on #2 slight on #1	Color good	Slight	Sewage temperature 20° C
24	Minor foam	Normal	Color good but darkish	Minor	Dropped back some digester #2

Table 5 (continued). FIELD OBSERVATIONS

MIDDLETOWN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
July 1, 75	Normal	Minor scum	Color good	Minor	
8	Normal	Some scum	Color good but darkish	Minor	
15	Full of foam	Lot of scum	Good color	Good development	
22	Foaming	Lot of scum	Good color	Good development	Sewage temperature 21° C
29	Foaming	Lot of scum	Good color	Good development	Started supernatant control 7/28/75 15.2 cm (6")/day
Aug. 1	Foaming	Lot of scum loss in center well	Good color somewhat dark	Good development	
12	Good foam development	Good scum layer	Good color but dark	Good development	Stopped supernatant control but will restart No supernatant 9, 10, 11 and 12

Table 5 (continued). FIELD OBSERVATIONS

MIDDLETOWN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Aug. 19, 75	Less foam	Less foam	Color good slightly dark	Somewhat reduced	Restarted control on August 14 7.6 cm (3")/day
26	Some foam	Less scum	Color good darkish	Reduced	No supernatant 23 and 24
Sept. 2	Lots of light froth foam	Some scum None in center-wells	Normal	Reduced	Detergent spill August 29? Increase supernatant to 15.4 cm (6")/day. No supernatant 30, 31 and 1. Primary down Sunday.
9	Lots of light foam	Very little to no scum	Color good	Reduced to low level	No supernatant 3 and 7. Barged sludge.
16	Good foam	Very light scum. Some in center-wells.	Normal	Reduced	No supernatant 10, 12, 13, 14, and 15th.

Table 5 (continued). FIELD OBSERVATIONS

MIDDLETOWN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Sept. 23, 75	Less foam	Very little scum. Minor in center-wells.	Good color	Reduced	No supernatant 17, 18 and 20.
30	No foam	Minor scum particles	Color very dark	Very low level - minor	Problem with 1 primary
Oct. 7	No foam	Minor scum particles. None in centerwell	Color good darkish	None	Primary down on 30th. No supernatant 30 and 1st. Barged sludge.
14	Some minor foam	Minor scum. None in center-well.	Color good	Minor	No supernatant 11, 12 and 13th
21	Some foam darkish	Very little scum. None in center-wells.	Color darkish - heavy	Low level	1 Final tank down and recycle low.

Table 5 (continued). FIELD OBSERVATIONS

MIDDLETOWN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Oct. 28, 75	Some foam. Light color	Good scum. 1/3 of tank and center-well.	Good color, light	Moderate development	No supernatant 24, 25, and 27th
Nov. 4	Foaming	Minor scum	Good color	Reduced	No supernatant 1 and 2nd
10	Heavy foam	Some scum. 1/4 tank; heavy in center-well.	Good color, dark	Moderate, increased	
18	Good foam develop-ment	Some scum to minor good in center-well. Looks like breaking up.	Good color dark	Reduced	No supernatant 17 and 18? Barged on 13th.
25	Lots of foam. MLSS very low	Lots of dark scum	Darkish	Increased?	Recycle was off some-time. May be reason for scum in finals. End control attempts.

Table 6. ANALYSIS OF RETURN ACTIVATED SLUDGE

MIDDLETOWN PLANT

Date	Suspended solids mg/l	Microscopic estimation of nocardial hyphae	Mycolate content µg/5 gm dry sludge solids
5-5-75	4,400	-	0
5-13	7,800	-	0
5-21	8,800	-	3
5-27	8,000	+--	0
6-2	8,800	+--	12
6-10	11,000	+--	11
6-19	9,200		
6-24	10,600	+--	10
7-1	12,000		
7-8	15,200	-	0
7-15	9,800	+	23.7
7-22	11,400	+	46
7-28	14,600	+	34
7-29	8,600	+	57
8-1	9,600	+	81
8-12	13,200	+	88
8-19	11,200	+	85

Table 6 (continued). ANALYSIS OF RETURN ACTIVATED SLUDGE

MIDDLETOWN PLANT

Date	Suspended solids mg/l	Microscopic estimation of nocardial hyphae	Mycolate content µg/5 gm dry sludge solids
8-26	8,200	+	47
9-2	8,400	+	78
9-9	9,000	+	202
9-16	8,400	+	103
9-23	11,600	+	33
9-30	8,800	+	29
10-7	9,000	+	26
10-14	11,400	+	45
10-21	12,800	+	73
10-28	8,800	+	150
11-4	13,200	+	186
11-10	13,200		
11-18	12,000		
11-25	15,800		

Table 7. ANALYSIS OF DIGESTER SUPERNATANT

MIDDLETOWN PLANT

Date	Suspended solids mg/l	mg/ml for 50% inhibition of N. amarae
7/15-21	29,900	1.6
7/30-8/12	34,000	1.4
8/13-19	36,800	2.5
8/20-26	37,000	2.3
8/27-9/2	33,900	2.9
9/3-9/9	34,500	4.9
9/10-16	36,500	2.5
9/17-23	13,200	1.5
9/24-30	23,600	0.9
10/1-7	36,100	1.1
10/8-14	23,000	3.7
10/15-21	28,000	4.4
10/22-28	26,000	1.8
10/29-11/4	32,500	2.0
11/5-10	30,100	1.6
11/11-18	33,200	1.9
11/19-25	20,100	
		Av. 2.3

Table 8. PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

MIDDLETOWN PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M. G. D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
5/1-6	17.75	(4.69)	13.6	7.1	7.1	144	13	91	175		7	96
7-13	18.96	(5.01)	14.6	7.1	7.2	169	6	96	181	138	9	95
14-20	18.77	(4.96)	16.1	7.1	7.0	202	10	95	160		10	94
21-27	17.83	(4.71)	16.3	7.1	7.2	141	16	87	166		8	95
28-6/3	17.98	(4.75)	16.9	7.2	7.2	164	7	96	150		5	97
4-10	17.98	(4.75)	16.8	7.1	7.2	149	13	91	178		13	93
11-17	18.85	(4.98)	17.4	7.2	7.1	138	10	93	151		5	97
18-24	19.30	(5.10)	17.9	7.2	7.0	163	18	89	220		7	97
25-30	17.52	(4.63)	18.6	7.2	6.9	199	13	93	-		-	
7/1-8	17.18	(4.54)	19	7.1	6.8	190	15	92	146		8	95
9-14	18.58	(4.91)	19	7.1	6.8	167	17	90	173	128	7	96

Table 8 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

MIDDLETOWN PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M. G. D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
15-21	19.38	(5.12)	20.0	7.2	6.8	205	23	89	177	147	12	93
22-29	19.30	(5.10)	20.8	7.3	6.8	206	22	89	191	143	14	93
30-8/12	17.90	(4.73)	21	7.1	6.8	173	19	89	140	140	6	96
13-19	18.21	(4.81)	20.9	7.2	6.8	237	41	83	169		46	73
20-26	18.36	(4.85)	20.7	7.2	6.8	213	14	93	150		4	97
27-7/2	18.05	(4.77)	20.4	7.1	6.8	190	38	80	160	231	14	91
3-9	17.45	(4.61)	20.0	7.1	6.9	218	76	65	137		33	76
10-16	17.41	(4.60)	19.1	7.1	6.7	152	38	75	177		51	71
17-23	17.22	(4.55)	19	7.1	6.7	152	14	91	183		11	94
24-30	20.74	(5.48)	18.6	7.1	6.8	150	16	89	188		25	87

Table 8 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

MIDDLETOWN PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M.G.D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
10/1-7	19.98	(5.28)	19	7.1	6.9	112	12	89	180		35	81
8-14	19.11	(5.05)	18			160	14	91	182		14	92
15-21	19.38	(5.12)	18.5			137	14	90	186		11	94
22-28	19.98	(5.28)	18			151	15	89	179		17	91
29-11/4	18.74	(4.95)	17.5	7.0	6.9	117	11	91	178		7	96
5-10	18.66	(4.93)	18	7.0	6.5	165	12	93	221		10	95
11-18	18.36	(4.85)	18	7.0	6.8	133	48	64	166		10	94
19-25	18.81	(4.97)	18	7.0	6.8	142	17	88	194		12	94
26-12/2	19.91	(5.26)	17	7.1	6.9	194	43	78	198		56	72

Sew = Sewage
Infl = Influent
Effl = Effluent

REM = Removal
BOD/5 = 5 day Biochemical Oxygen Demand

Table 8 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

MIDDLETOWN PLANT

Date	Aeration Tanks				Ret. sludge		Digesters	
	MLSS mg/l	ML Set S. ml/l	SVI	DO mg/l	% R	SS mg/l	Sup'n Gal	% TS
5/1-6	2173	240	110		39	8283		
7-13	2345	340	143		44	7530		
14-20	2238	310	136		41	8027		
21-27	2644	430	163	Not Recorded	40	8355		
28-6/3	2220	300	135		40	7985	49,600	
4-10	2239	400	175		42	8615		
11-17	2600	370	141		41	9956		
18-24	2508	270	108		42	9034		
25-30	2730	370	136		41	9115		

Table 8 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

MIDDLETOWN PLANT

Date	Aeration Tanks				Ret. sludge		Digesters	
	MLSS mg/l	ML Set S ml/l	SVI	DO mg/l	% R	SS mg/l	Sup'n Gal	% TS
7/1-8	2846	340	117		36	10,555		
9-14	3526	540	151		49	11,885		
15-21	3164	430	134		44	9,627		
22-29	3114	390	122	Not Recorded	45	10,003	74,460	3.4
30-8/12	2912	440	144		44	10,830	200,000	
13-19	3682	660	177		42	12,115	24,820	
20-26	2987	440	145		40	9,773	33,090	
27-9/2	2813	560	201		40	8,540	33,090	
3-9	2839	700	243		38	9,156	82,120	3.15
10-16	2831	650	220		45	8,486	24,820	1.52

Table 8 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

MIDDLETOWN PLANT

Date	Aeration Tanks				Ret. sludge		Digesters	
	MLSS mg/l	ML Set S ml/l	SVI	DO mg/l	% R	SS mg/l	Sup'n Gal	% TS
17-23	2259	570	244		31	10,337	62,050	2.01
24-30	2252	500	210		30	9,482	74,460	2.22
10/1-7	2184	360	161		31	9,257	86,250	
8-14	2312	520	210		30	7,171	39,300	
15-21	1782	340	179		21	7,996	62,050	
22-28	2824	570	195		32	8,640	49,640	
29-11/4	2114	360	161	Not Recorded	28	7,622	68,260	
5-10	2237	380	164		28	8,432	78,600	
11-18	2731	580	202		34	9,639	82,180	
19-25	2299	510	203		36	12,401	62,050	
26-12/2	2673	-	-		32	8,810		

See legend at end of Table 4.

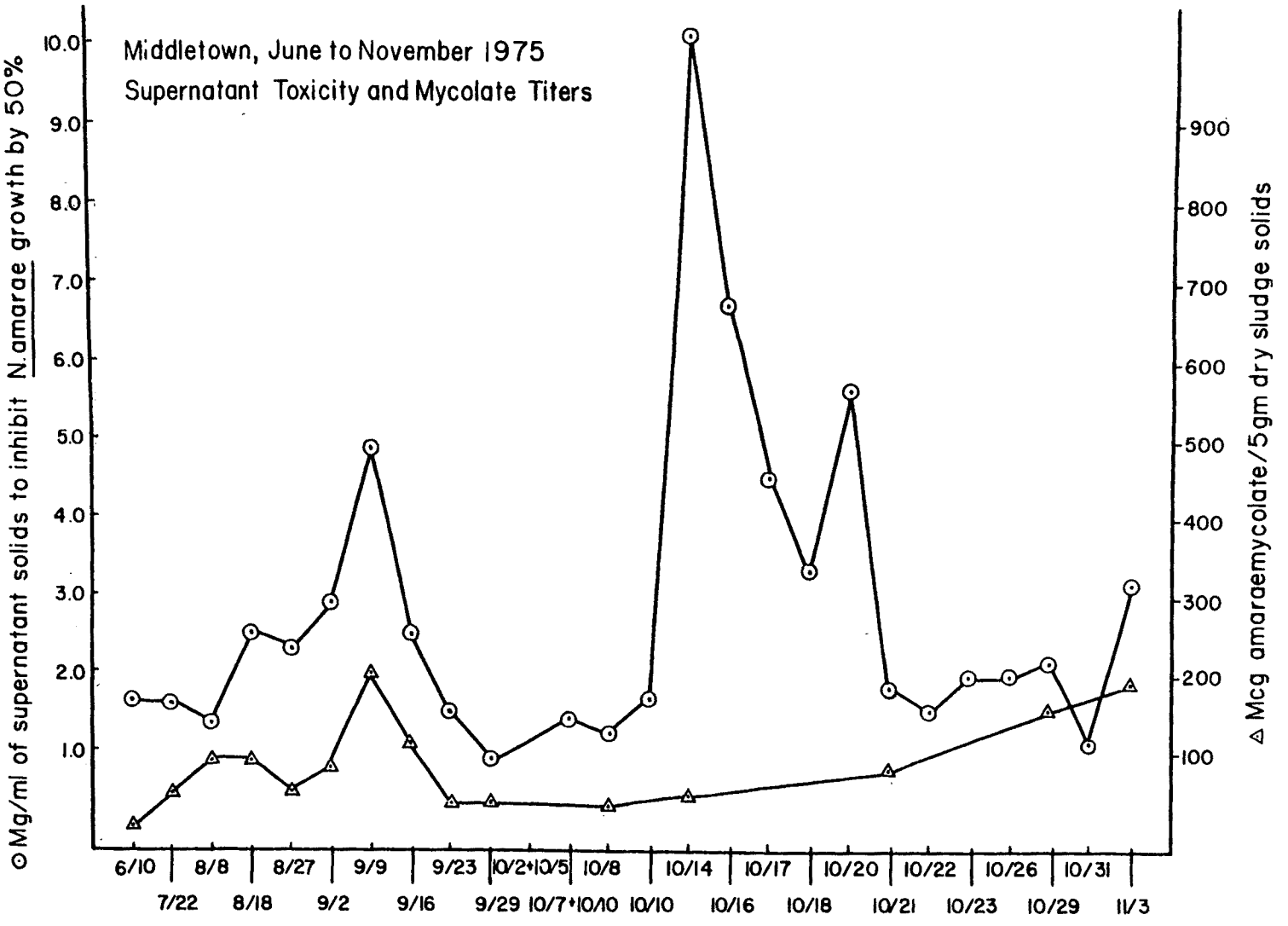


Figure 4. Nocardiotoxicity of the Supernatant from the Anaerobic Digester and Nocardiomycolate Contents of Sludge Solids at the Middletown Township Plant from June 10 to November 3, 1976.

SECTION IX

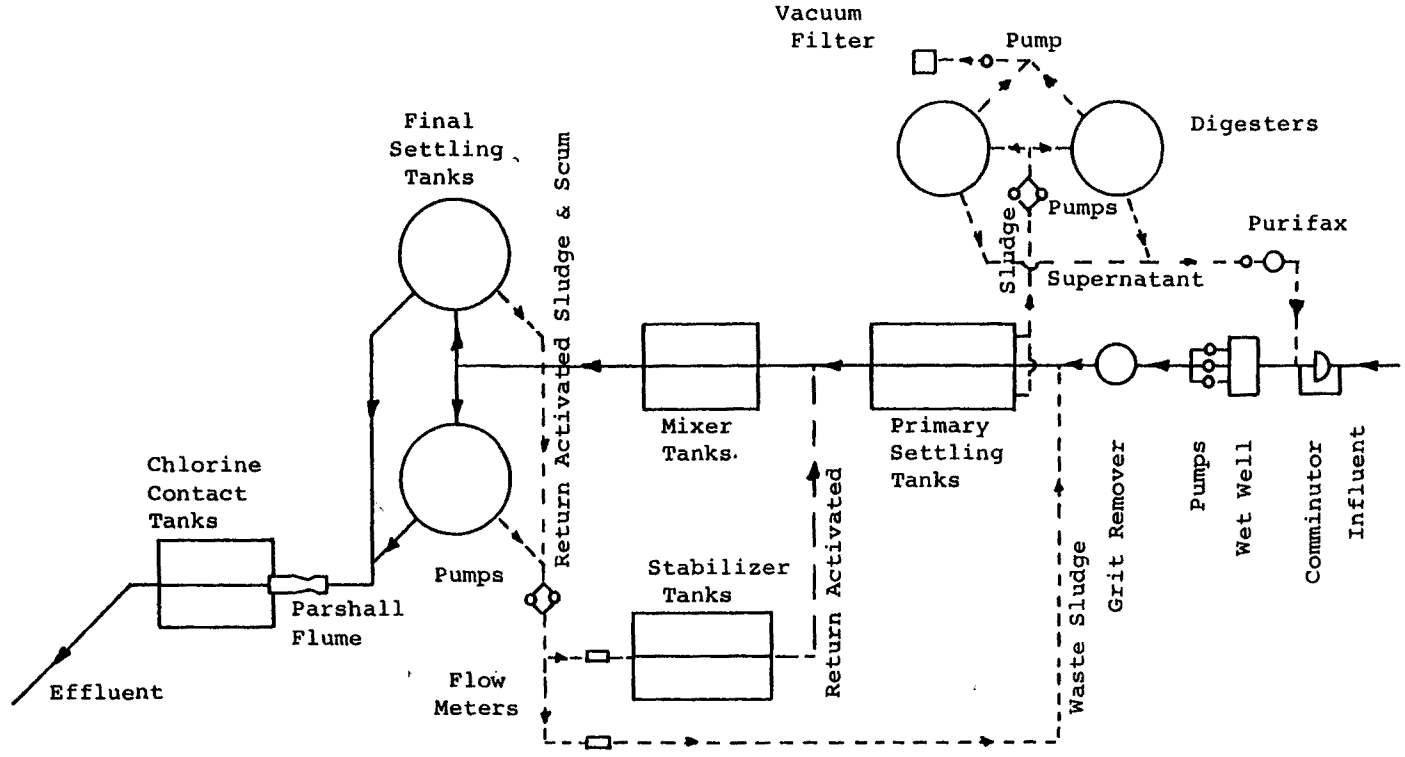
THE OCEAN TOWNSHIP PLANT

The Ocean Township Wastewater Treatment Plant began operation in October 1968. The 11,355 m^3/d (3.1 mgd) facility consists in preliminary treatment (comminutor and grit remover) with addition of hydrogen peroxide; primary treatment in rectangular clarifiers, the sludge and the scum being disposed of in anaerobic digesters; secondary treatment of the activated sludge type (sludge reaeration-contact stabilization), with mechanical turbine aeration; circular final clarifiers with waste sludge disposal to the primary clarifiers and the secondary scum being returned to the sludge reaeration tanks; effluent chlorination and anaerobic sludge digestion. The supernatant from the anaerobic digesters is returned to the primary system at the wet well after having been chlorinated by Purifax treatment. The digested sludge is vacuum filtered and used as land-fill (see Flow diagram, Figure 5).

Foam development started at the plant around August 1, 1976 when control measures were initiated as indicated in Table 5 by returning to the primary tanks 28.39 m^3/d (7,500 gal/d) anaerobic digester supernatant which was not Purifaxed. This foam development coincided with a marked increase in amaraemycolate (Table 10). This was later changed to the use of chlorinated supernatants.

Throughout the study period there was some fluctuation in the amount of actinomycetic foam produced but foaming reduction, when it occurred, could not be correlated with the control technique which did not appear to be effective.

The initial return of unchlorinated anaerobic supernatant created an odor problem but the use of chlorinated material should still have been effective since it had equivalent nocardiotoxicity as shown in our assays (Table 11).



FLOW DIAGRAM

SEWAGE TREATMENT PLANT
TOWNSHIP OF OCEAN SEWERAGE AUTHORITY

Figure 5

Table 9. FIELD OBSERVATIONS

OCEAN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
May 5, 75	Normal	Normal		None	To keep normal Purifax supernatant treatment
13	Normal	Some slight scum in center-wells	Color good	Minor	Using H_2O_2 for odor control
21	Normal	Some scum	Color good	Minor	H_2O_2 in use
27	Normal	Some scum	Color good	Slight	H_2O_2 in use
June 2	Some foam in re-air	No scum	Color good darkish	Minor	Rain past few days
10	Slight foam	Minor scum	Color good	Minor	
19	Slight foam	Very minor scum	Color good	Minor	Sewage temperature 21°C
24	Minor foam	Some scum in center-wells	Good color ML low	Minor	

Table 9 (continued). FIELD OBSERVATIONS

OCEAN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
July 1, 75	Minor foam	Minor scum, clarity fair	Color good darkish	Minor	
8	Some foam	Very minor scum	Color dark	Minor	
15	No foam	Slight scum, clarity good	Color dark	Minor to none	ML lower
22	Some foam	Slight scum in broken pieces	Color good darkish	Slight	Sewage temperature 23.9°C. Still using H_2O_2
29	Some foam	Some scum	Color dark-ish	Slight	Purifax feed 149.3-186.6 kg (4-500 lb)/day Cl_2

Table 9 (continued). FIELD OBSERVATIONS

OCEAN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Aug. 1, 75	Full of foam	Full of scum	Color good darkish	Good development	Started control 28.4 m^3d (7500 gal/day) = 15.2 cm (6")/day. Foam built up 2 days ago. Sewage temperature 24.4° C.
12	Plenty of foam	Plenty of scum	Color dark	Good development	Odor problem - stopped control on 8th. Less foam then more now.
19	Less foam	Less scum	Color very dark	Reduced?	MLSS reduced to keep Purifax feed low
26	Some foam	Less scum	Color very dark	Reduced	Continue low. Purifax Cl_2 feed.
Sept. 2	Heavy dark foam in re-air	No center-well scum. Surface scum - 1/2 tanks.	Color dark	Medium amount	Purifax feed increased 279.9 kg (750 lb) day odors.
9	Plenty foam	Some scum in centerwell. Less on surface.	Color very dark	Medium amount	Purifax 279.9 kg (750 lb)/day. 6 hr ± run.

Table 9 (continued). FIELD OBSERVATIONS

OCEAN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Sept. 16, 75	Plenty foam	More surface scum - low in center-well	Color very dark	Good development	ML low
23	Less foam	Less scum	Color very dark	Reduced	Returned supernatant with no Purifax 17-23; Rain.
30	Less foam	Some scum - breaking up	Color very dark	Reduced	Still not using Cl_2 in Purifax - Trying to slug with supernatant.
Oct. 7	Plenty foam	Plenty scum	Color dark	Good development	Using no Cl_2 in Purifax - will try 2 day w/o Cl_2 and 5 day with Cl_2
14	Plenty foam	Plenty scum, open weir	Color dark	Good development	Using 2 day no Cl_2 in Purifax supernatant return
21	Less foam	Plenty scum	Color dark-ish	Good development	Dropped 56.8 m^3 (15,000 gallons) supernatant on 20. Sewage temperature 19.4°C.
28	More foam	Less scum	Color good	Reduced?	Using no Cl_2 in Purifax on 2 days

Table 9 (continued). FIELD OBSERVATIONS

OCEAN PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Nov. 4, 75	Plenty foam	Some scum	Color good	Reduced?	Still using no Cl_2 2 days in Purifax
10	Less foam	Some scum breaking up	Color dark-ish	Reduced?	End controlling attempts.

H_2O_2 = Hydrogen Peroxide

ML = Mixed Liquor of Aeration Tanks

Cl_2 Chlorine

MLSS = Mixed Liquor Suspended Solids

Table 10. ANALYSIS OF RETURN ACTIVATED SLUDGE

OCEAN PLANT

Date	Suspended solids mg/l	Microscopic estimation of nocardial hyphae	Mycolate content µg/5 gm dry sludge solids
5-5-75	4,400	-	0
5-13	4,600	-	0
5-21	4,000	-	0
5-27	7,600	-	19
6-2	4,200	-	16
6-10	5,600	-	18
6-19	3,800	-	9
6-24	2,600	-	6
7-1	4,600	-	17
7-8	5,200	+	111
7-15	4,800	+	31
7-22	5,400	+	37
7-29	7,800	+	87
8-1	4,800	+	140
8-12	5,800	+	248
8-19	5,600	+	150
8-26	4,606	+	92

Table 10 (continued). ANALYSIS OF RETURN ACTIVATED SLUDGE

OCEAN PLANT

Date	Suspended solids mg/l	Microscopic estimation of nocardial hyphae	Mycolate content µg/5 gm dry sludge solids
9-2	4,000	+	169
9-9	4,800	+	117
9-16	3,400	+	111
9-23	4,400	+	345
9-30	5,200	+	188
10-7	5,000	+	102
10-14	4,000	+	222
10-21	3,800	+	156
10-28	3,400	+	202
11-4	4,400	+	277
11-10	3,800		
11-18	4,200		

Table 11. ANALYSIS OF DIGESTER SUPERNATANT

OCEAN PLANT

Date	Suspended solids mg/l	mg/ml for 50% inhibition of N. amarae	Comments
8-1-75	30,100	1.5	
8-8	20,400	0.9	
8/12-19	26,100	1.3	
8/20-26	30,500	1.5	
8/27-9/2	25,500	1.7	
9/10-16	34,800	1.2	
9/17-23	27,800	1.2	
9/24-30	22,100	1.1	
10/1-10/7	42,500	0.7	
10/8-14	27,700	0.4	
10/15-21	23,100	0.8	
10/22-28	30,800	1.1	
11/4	29,300	0.5	No chlorine
11/4	25,900	0.5	279.9 kg (750 lb/day) chlorine Purifax
11/5-10	24,000		
		Av. 1.1	

Table 12. PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

OCEAN PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M.G.D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
5/1-6	14.42	(3.81)	14.4	7.1	7.3	80	8	90	83	43	3.5	95
7-13	13.17	(3.48)	14.4	7.0	7.1	90	10	89	107	39	6.3	94
14-20	12.83	(3.39)	16.7	7.0	7.1	-	-	-	117	42	9.3	92
21-27	11.39	(3.01)	12.8	7.0	7.0	100	10	90	73	29	8.3	89
28-6/3	10.79	(2.85)	18.9	6.9	6.9	80	10	88	102	34	21	79
4-10	10.75	(2.84)	19.4	6.9	7.0	100	5	95	147	93	9	94
11-17	12.98	(3.43)	19.4	6.9	6.9	100	10	90	88	51	8	91
18-24	11.66	(3.08)	20.6	6.9	6.9	110	5	95	118	76	16	86
25-30	10.67	(2.82)	21.1	6.8	6.8	100	10	90	106	39	6	94
7/1-8	10.60	(2.80)	21.7	-	-	100	5	95	128	84	18	86
9-14	10.94	(2.89)	22.8	6.8	6.9	-	-	-	122	88	13	89

Table 12 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

OCEAN PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M.G.D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
15-21	10.90	(2.88)	23.3	7.0	7.0	100	5	95	110	66	18	84
22-29	10.41	(2.75)	24.4	6.8	7.3	90	5	94	132	76	20	85
30-8/12	10.71	(2.83)	23.9	6.7	7.0	137	9.3	93	125	73	17	86
13-19	10.41	(2.75)	23.9	7.1	7.3	95	5	95	142	111	26	82
20-26	10.83	(2.86)	23.9	7.3	7.3	200	10	95	108	66	20	81
27-9/2	10.64	(2.81)	24.4	6.7	7.0	-	-	-	125	67	20	84
3-9	10.86	(2.87)	23.9	-	-	125	10	92	134	61	16	88
10-16	10.14	(2.68)	22.2	7.4	7.3	125	5	96	153	101	14	91
17-23	10.60	(2.80)	22.2	7.8	7.1	110	10	91	183	101	19	90
24-30	12.98	(3.43)	21.1	7.2	7.0	-	-	-	85	45	27	68
10/1-7	10.94	(2.89)	20.6	7.0	7.2	110	20	82	123	51	22	82

Table 12 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

OCEAN PLANT

Date	Flow		Sew. Temp.	pH		Suspended Solids			BOD/5			
	m^3/d x 10^3	M.G.D.	Infl. °C	Infl.	Effl.	Infl. mg/l	Effl. mg/l	% REM.	Infl. mg/l	Pri. effl. mg/l	Effl. mg/l	% REM.
8-14	11.77	(3.11)	21.1	7.2	7.1	-			117	47	13	89
15-21	13.17	(3.48)	21.1	7.6	7.0	100	10	90	93	59	12	87
22-28	13.21	(3.49)	20.0	7.2	7.1	105	13	88	89	54	16	82
29-11/4	12.60	(3.33)	20.6	7.2	7.1	-	-	-	83	53	9.3	89
5-10	12.11	(3.20)	20.6	7.1	7.0	100	10	90	92	54	16	83
11-18	12.64	(3.34)	18.9	7.0	6.9	110	15	86	88	45	15	83
19-25	12.57	(3.32)	17.2	7.1	6.9	83	10	88	78	40	15	81

Sew = Sewage

Infl = Influent

Effl = Effluent

REM = Removal

BOD/5 = 5 day Biochemical Oxygen Demand

Table 12 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

OCEAN PLANT

Date	Aeration Tanks					Ret. sludge		Digester	
		MLSS* mg/l	ML Set. S ml/l	SVI	DO* mg/l	% R	SS mg/l	Sup'n Gal	% TS
5/1-6	1070	4390	180	168	2.5/.8	44			
7-13	1260	4570	190	151	3.6/1.4	44	Reported Same as Reaeration Tank	Reported Normal - 18,000 gpd through Purifax	Not Determined
14-20	1180	4200	180	157	1.8/.8	48			
21-27	1140	3800	390	209	1.8/.9	49			
28-6/3	1260	3440	260	206	1.6/1.0	48			
4-10	1720	4600	400	229	1.3/.2	50			
11-17	1870	4700	290	190	2.6/.9	43			
18-24	1420	4090	190	134	2.6/1.0	49			
25-30	1380	3940	230	162	1.1/2.4	50			
7/1-8	1470	4220	320	217	2.0/1.4	49			

Table 12 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

OCEAN PLANT

Date	Aeration Tanks					Ret. sludge		Digester	
		MLSS* mg/l	ML Set. S ml/l	SVI	DO* mg/l	% R	SS mg/l	Sup'n Gal	% TS
9-14	1390	3980	340	244	1.6/.4	50			
15-21	1690	4990	570	334	2.0/1.0	50			
22-29	1670	4280	270	158	1.2/1.2	52			
30-9/12	1940	4430	320	163	1.8/1.1	51		45,000	
13-19	1840	4420	280	153	1.9/2.6	50			
20-26	1700	4180	200	122	3.4/2.2	43			
27-9/2	1520	3800	200	130	2.7/2.6	51			
3-9	1280	3460	200	161	1.6/1.6	50			
10-16	1320	3700	240	175	1.6/2.3	46			
17-23	1210	3040	190	166	1.1/1.7	57			

Reported Normal - 18,000 gpd

Not Determined

Table 12 (continued). PLANT OPERATING RECORDS

(WEEKLY AVERAGES)

OCEAN PLANT

Date	Aeration Tanks					Ret. sludge		Digester	
		MLSS* mg/l	ML Set. S ml/l	SVI	DO* mg/l	% R	SS mg/l	Sup'n Gal	% TS
24-30	1010	3410	170	170	1.8/.6	45			
10/1-7	1200	3640	190	160	2.0/1.1	54			
8-14	1540	3800	240	155	1.0/.8	48			
15-21	1090	3080	150	139	1.6/1.2	43			
22-28	860	2720	120	138	2.0/1.4	45			
29-11/4	1100	3310	110	110	1.6/1.0	45			
5-10	1540	3680	130	85	1.2/.8	46			
11-18	1160	2810	110	95	1.0/.6	47			
19-25	1240	3000	110	89	1.0/.8	45			

Reported Normal - 18,000 gpd

Not Determined

* Mixer and reaeration tanks.

See legend at the end of Table 4.

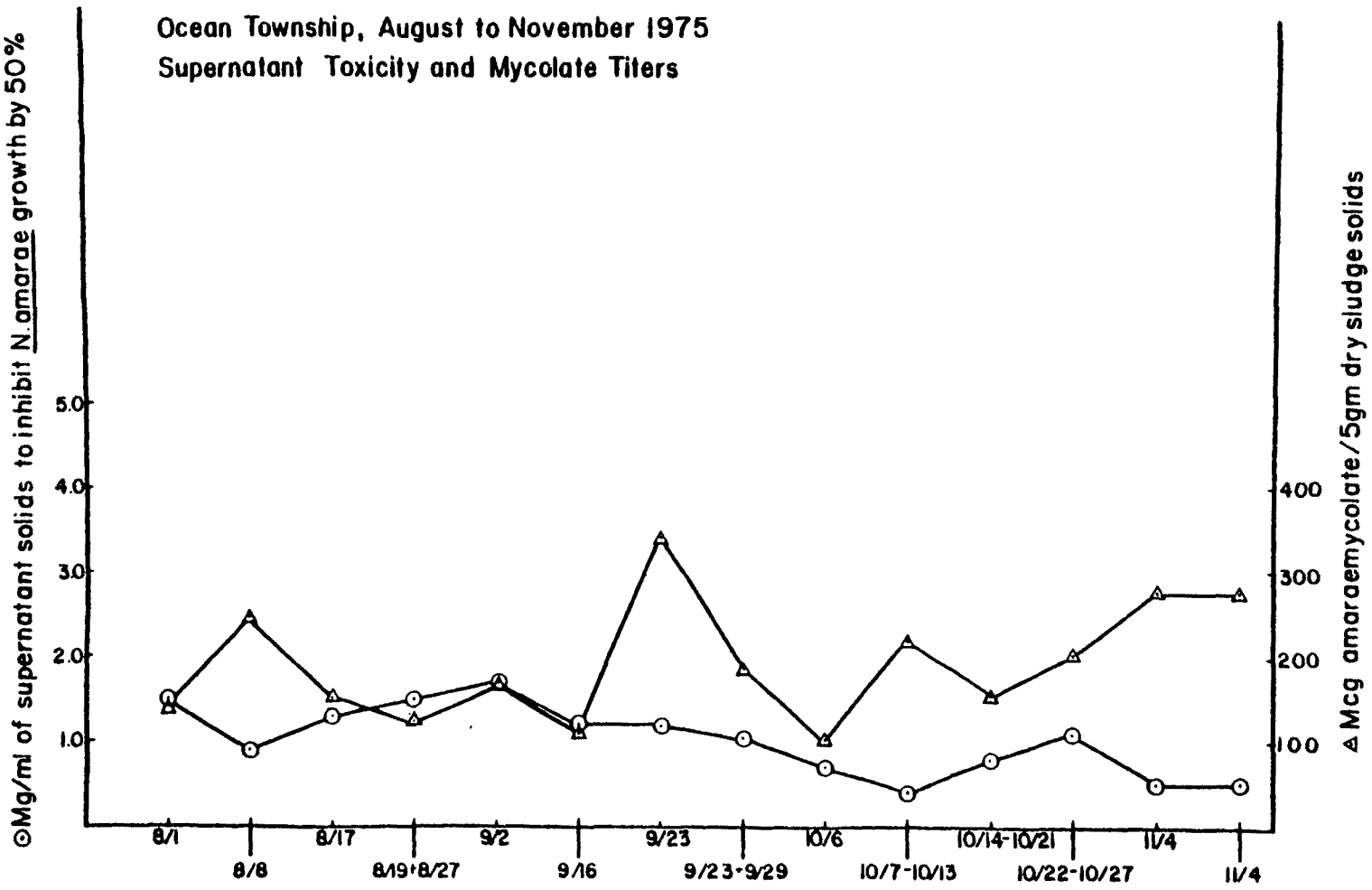


Figure 6. Nocardotoxicity of the Supernatant from the Anaerobic Digester and Nocardiomycolate Contents of Sludge Solids at the Ocean Township Plant from August 1 to November 4, 1976

The ineffectiveness of the control technique at the Ocean plant might be attributed to the method of supernatant return which is controlled by plant personnel through the operation of a 3.2 l/s (50 gal/min) pump for an average of 6 hours during the latter part of the day. It is quite likely that at this low rate of return a substantial amount of the anaerobic solids were removed in the primary sedimentation tanks with the raw sewage solids. In addition, plant records are not kept on this operation and disruptions of the duties of plant personnel might have resulted in alteration of the schedule of supernatant return.

More important, however in explaining the lack of control observed, is the design of the plant which is such that foam and scum from the secondary clarifiers are returned to the secondary aeration tanks. Since the foam is composed almost exclusively of air and filaments of nocardia, the design of the plants is such that the secondary system is constantly reinoculated with a heavy dose of the nocardias.

SECTION X

COMPARISON OF THE RESULTS OBTAINED AT THE FLORHAM PARK, MIDDLETOWN AND OCEAN TOWNSHIP PLANTS

An examination of the records of the plants (Tables 4, 8 and 12) shows that the addition of anaerobic supernatant in the doses used did not reduce the quality of the effluent in any of the three plants studied. The only problem of this type observed was the upset of November 4, 1975 at the Florham Park plant caused by the accidental dropping of 3 to 4 times too much supernatant into the system.

A review of these operating records further indicates that each of the plants was operating in a generally normal manner throughout the study period and that there was a general similarity between the plants.

The data show that the three plants were very similar in sewage temperature, pH, influent suspended solids, and BOD levels. Likewise, the mixed liquor suspended solids in the aeration systems of the facilities appeared generally similar. The mixed liquor suspended solids and sludge volume indices varied within reasonable limits.

One major difference between the treatment facilities was the age of the sludge under aeration. As shown in Table 13, the sludge age at Middletown and Ocean was very similar, averaging 4.5 and 4.2 days respectively but was almost double (7.8) at the Florham Park plant. This long period of aeration may have caused trouble in controlling the actinomycetes by increasing the degradation of the nocardiotoxic material.

Table 13. SLUDGE AGE IN DAYS

Date	Middletown	Ocean	Florham Park*
5/1-6	4.4	4.7	7.2
7-13	3.8	4.9	8.8
14-20	3.1	4.6	10.8
21-27	5.5	4.3	8.2
28-6/3	3.9	5.3	5.6
4-10	4.4	5.7	6.1
11-17	5.2	4.9	7.9
18-24	4.2	4.2	11.5
25-30	4.1	4.9	9.8
7/1-8	4.6	5.2	11.1
9-14	5.9	4.8	7.8
15-21	4.2	6.0	10.1
22-29	4.1	6.2	12.4
30-8/12	4.9	4.2	12.6
13-19	4.5	6.1	19.9
20-26	4.0	2.6	8.7
27-9/2	4.3	2.8	13.5
3-9	3.9	3.4	11.9
10-16	5.6	3.9	12.1

Table 13 (continued). SLUDGE AGE IN DAYS

Date	Middletown	Ocean	Florham Park*
17-23	4.5	3.5	12.4
24-30	3.8	3.1	5.1
10/1-7	5.1	3.9	15.3
8-14	3.9	4.0	10.1
15-21	3.5	3.1	7.0
22-28	4.9	2.5	12.6
29-11/4	5.0	3.4	9.4
5-10	3.8	4.2	9.5
11-18	5.6	2.8	13.5
19-25	4.5	4.0	10.1
26-12/2			9.4
Average	4.5	4.2	7.8

* Based on assumed 20% removal in primaries.

Another difference between the three treatment plants was in the method of return of the scum and foam from the secondary clarifiers. These were periodically removed for landfill disposal at Florham Park, were sent to the anaerobic digesters at Middletown but were returned to the secondary aeration tanks at Ocean. This last practice is detrimental since it results in the constant reintroduction of the nocardia into the secondary system which is where trouble develops in the plant.

Conclusions.

In general, the nocardiotoxicities of the anaerobic supernatants of all three plants (Tables 3, 7 and 11) were equivalent, averaging (for 50% inhibition of N. amarae Se 6) 1.1 mg/ml at Ocean, 1.3 mg/ml at Florham Park and 2.3 mg/ml at Middletown. These averages were based on the 10 week period of August 1 to October 13 for which equivalent data for each plant are available.

In Middletown, the decreases in nocardiotoxicity of the anaerobic supernatant coincided with its removal by barging. In this plant, the decrease in nocardiotoxicity also preceded or coincided with an increase in amaraemycolate levels and foam formation. Furthermore, the two major foamouts (September and November) in this plant were probably enhanced at critical moments by the fact that there were periods when no supernatant was returned to the system because of operational problems.

The nocardiotoxic principle is also inhibitory to two fecal gram-negative bacteria tested, but not to a gram-positive one.

No evidence for increased resistance of N. amarae to the nocardiotoxic principle was found.

SECTION XI

THE BAYSHORE PLANT

Toward the end of July 1975 the Bayshore Regional Sewerage Authority Treatment Facility at Union Beach, N. J. was experiencing a severe foaming problem. The foam was tested and found to contain nocardias (N. amarae and N. rhodochrous). This plant is a 22,710 m^3/d (6 mgd) activated sludge plant and utilizes gravity thickeners and an incinerator for solids disposal. On checking the plant, a source of anaerobic material was found in the sludge from the bottom of the gravity thickeners. This material was septic and on testing was found to have a good nocardiotoxicity.

Utilizing this material, plant personnel set up a temporary means of feeding the thickened material directly into one of the aeration tanks. This toxic material was fed into the aeration system on a weekly basis at a rate of approximately 15.1 m^3 (4000 gal) per mgd per week. This control method was started on August 7 and by the first of September the foam had been greatly reduced (see Table 14). This low level of foam and the weekly dosing continued through to the middle of the month. At this time the incinerator had to be taken out of service and resulted in excessive solids accumulations in the thickeners leading to a constant overflow of septic material back through the plant system. During the time of this constant septic feed, the small amount of foam was further reduced until there was no foam on the final settling tanks by the end of September. The incinerator was started again in the beginning of October and operated periodically through to the end of October. During this period of time a slight foam buildup appeared in the final settling tanks; however, the operating personnel felt it was not significant enough to reinstitute the controlling measures at this time. The complete elimination of surface scum on the final settling tanks at the end of September may be a result of more than the controlling feed of septic material at the plant. The plant personnel report that on one day the mixed liquor solids were lost in the system and suspect that they may have received a slug of industrial waste that upset the system. It is possible that such an industrial waste may

have aided in the elimination of the minor amount of remaining foam at the plant at that time. In Table 15 will be found a summary of the operating records of the Bayshore plant during the study period.

It is felt, however, that the use of the septic feed as a controlling technique at the plant did reduce the large initial foam accumulation to a low level and that it did not present any nuisance in the plant operations.

Table 14. FIELD OBSERVATIONS

BAYSHORE REGIONAL PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
July 29, 1975	Full of light brown foam	Heavy 5 cm thick scum darkish	Color darkish	Very severe	Problem started 7/14 ±. Sampled scum and thickener sludge.
Aug. 1	Full of foam	Heavy 5 cm scum	Color darkish	Very severe	Operator to feed 2, 000 gal ± of toxic thickener sludge to aeration tanks as slug -
12	Less foam	Less scum	Color darkish	Reduced	Fed slug of thickener sludge 2 days 6 and 7th ± foam dropped to low level on 11th.
19	Plenty foam	Plenty scum	Color darkish	Increased	Fed thick sludge on 13th and 18th. No apparent reduction.
26	Same or somewhat less	Same or somewhat less	Color darkish	Reduced?	Will return sludge to day.
Sept. 2	Very little foam	Very little scum	Color dark	Reduced	Fed sludge on 26th and will today also. Heavy scum on 27 and 28.
9	Some foam	Some light scum 1/2 tank	Color dark	Minor to slight	Some scum buildup on 4th - dropped thickener sludge on 8th.
16	Some foam	Some light scum	Color dark	Slightly increased but minor	No sludge feed since 8th - was less scum yesterday.

Table 14 (continued). FIELD OBSERVATIONS

BAYSHORE REGIONAL PLANT

Date	Aeration tanks	Final settling tanks	Activated sludge	Scum/ foam condition	Miscellaneous
Sept. 23, 1975	Light foam	No scum	Color dark	Reduced	No sludge since 8th - have thickener heavy solids overflow - incinerator out 15th to 18th ±. Lost solids in air tanks.
30	Black foam	Very minor to none	Dark color	Reduced to low level	No sludge feed - heavy solids in thickener overflow.
Oct. 7	No foam	Slight scum particles #2 and #3	Color dark	Low level	
14	Light foam greyish	No scum	Color dark	Low level	Industrial waste problem? No sludge feed.
21	Light grey froth	No scum	Color dark	None to low level	No sludge feed. Toxic industrial slug?
28	Light foam	Slight scum on #3	Color dark	Low level	No sludge feed.
Nov. 11	Grey froth	None	Color dark	Low level to none	Received toxic industrial slug?
18	Grey froth	None	Color dark	Low level	

Table 15. OPERATING RECORDS

BAYSHORE REGIONAL PLANT

Date	Flow		Aeration MLSS	Thickener sludge feed	Thickener sludge feed	Thickener sludge susp. solids
	m^3/d x 10^3	M. G. D.	mg/l	m^3	gallons	%
July 29, 1975			2,200			
Aug. 6-7					Unknown	Unknown
13	16.65	(4.4)	2,400	37.8	10,000	3.9
18	17.0	(4.5)	2.600	56.8	15,000	3.8
26	16.65	(4.4)	2,900	39.7	10,500	4.1
Sept. 2	16.27	(4.3)	3,220	7.6	2,000	2.9
4			2,800			
8	16.65	(4.4)	3,380	7.6	2,000	3.6
16			3,500 ±			

SECTION XII

DISCUSSION

We have attempted to control actinomycetic foam in the secondary system of four sewage treatment plants of the activated sludge type by addition of anaerobically digested material. Control has been observed in two plants and failure in the two others. We should try to analyze the reasons for these successes and failures.

Good control was obtained at the Bayshore plant by adding septic thickener material with demonstrated nocardiotoxicity directly to the intake of the secondary aeration tanks. We feel that this is an important point. This was the only plant where it was possible to go directly to the secondary aeration tanks and we feel that, in other plants, during the passage through primary treatment, a part of the nocardiotoxic solid material was removed, making control in the secondary tanks difficult.

We feel that the poor results observed at the Ocean Township plant is due to the fact that we could not add the nocardiotoxic material directly to the secondary aeration tanks and that in addition, the nocardia-containing foam and scum from the secondary clarifier were returned into the secondary aeration tanks.

The poor results observed at the Florham Park plant were probably due to the removal of part of the nocardiotoxic material during primary treatment coupled with the long retention time of the sludge.

In the case of the Middletown plant, good results were observed but we feel that they would have been more spectacular if we could have added the nocardiotoxic material directly to the secondary aeration tanks. In the case of this plant, there was no other adverse factor to deal with. The foam and the scum, rich in nocardia were not returned into the system and the retention time was not long.

In general the nocardiotoxicity of the anaerobic digester supernatant solids of the three plants studied was equivalent. Through the study period, the 50% inhibition point of N. amarae Se 6 averaged 1.1 mg/ml at Ocean, 1.3 mg/ml at Florham Park and 2.3 mg/ml at Middletown.

At the Middletown plant, the decreases in nocardiotoxicity of the anaerobic digester supernatant coincided with the barging of the anaerobic sludge. In this plant, the decrease in nocardiotoxicity also preceded or coincided with an increase in the levels of the typical mycolate of Nocardia amarae and with foam formation. Furthermore, the two major foaming incidents which occurred in September and November at the Middletown plant were probably enhanced at critical moments by the fact that there were periods when no supernatant was returned into the system due to operational problems.

The amaraemycolate (AM) levels averaged from approximately 25 samples from each of three plants showed a direct relationship with the extent of foam observed. In the Middletown plant, AM levels averaged 56.5 mcg/5 gm of dry weight sludge solids. This plant had the least problem with foam. The Ocean Township plant had an average of 106 mcg AM/5 gm, with the principal increased AM levels encountered toward the end of the observation period when the major foam-out began. Florham Park, which showed an intractable foam throughout the period of study showed an average of 367 mcg AM/5 gm.

If we try to put together all the information we have on nocardial foaming we would suggest that control might best be achieved by wasting activated sludge to bring the mixed liquor suspended solids to 2,000-2,500 mg/l while adding anaerobic digester supernatant directly to the activated sludge. Our best estimate is that for an anaerobic digester producing supernatant with the type of nocardiotoxicity we observed, one should add 50-100 kg per day of anaerobic digester supernatant solids per 1000 kg mixed liquor suspended solids.

SECTION XIII

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16. ABSTRACT

In some activated sludge sewage treatment plants a thick foam rich in Nocardia may be formed at the surface of the secondary aeration and settling tanks. It had previously been observed that the supernatant from anaerobic digesters contained suspended solids which were toxic for Nocardia. In the present study attempts were made to control the foam by returning the supernatant from digesters in four plants to the primary system. The nocardiotoxicity of the supernatant solids was tested to be sure that toxic material was returned to the system. Laboratory studies showed that the material is toxic for some bacteria and not for others.

The results indicated that this method of control is difficult to use at full-scale plant level and indicates that better results might be obtained if the toxic supernatant was added directly to the activated sludge aeration basins rather than added to the incoming sewage or the primary settling basins.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Activated sludge process *Nocardia Waste treatment Microorganism control (sewage) Foam	Problem	13B

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