ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT

EPA-330/2-79-005

Evaluation Of The Hopewell Regional Wastewater Treatment Facility Hopewell, Virginia

NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
DENVER, COLORADO
AND
REGION III, PHILADELPHIA, PENNSYLVANIA

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EVALUATION OF THE HOPEWELL REGIONAL WASTEWATER TREATMENT FACILITY
HOPEWELL, VIRGINIA

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National Enforcement Investigations Center - Denver, Colorado
and
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I. INTRODUCTION

EPA Region III requested the National Enforcement Investigations Center (NEIC) to determine the reasons for the "consistent and severe" violations of NPDES* permit limitations reported by the Hopewell, Virginia Regional Wastewater Treatment Facility (HRWTF). The Discharge Monitoring Reports (DMR) submitted by the plant showed that they had been in compliance with their effluent limitations only once since the beginning of operations in August 1977. From October 1977 through November 1978, the monthly average effluent biochemical oxygen demand (BOD) concentrations had averaged 135 mg/l and the weekly average BOD concentrations had averaged 266 mg/l. The respective effluent limitations are 30 and 45 mg/l.

In the same time period, the monthly average effluent total suspended solids (TSS) concentrations had averaged 180 mg/l and the weekly average TSS concentrations had averaged 625 mg/l. The respective effluent limitations for TSS are 50 and 75 mg/l.

NEIC engineers reviewed the Regional Office and plant files and inspected the Hopewell facility in October 1978. Plant contacts were Mr. Thomas Kirtley and Mr. Joseph Joseph.

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* National Pollutant Discharge Elimination System

II. SUMMARY AND CONCLUSIONS

SUMMARY

Operator's data sheets and logs, pilot plant records, design drawings, Discharge Monitoring Reports and correspondence among the City, vendors and regulatory agencies were studied in an effort to determine the reasons for the plant's inability to meet its permit limitations. A detailed plant inspection was made, the laboratory procedures were evaluated and standard samples for BOD and TSS were left with the laboratory staff to determine the accuracy of their results.

The suppliers of some of the major pieces of equipment that were found to be inoperative were contacted and asked what was being done to make their equipment perform as expected.

NEIC engineers concentrated their efforts on evaluation of the plant's solids handling system, the plant design, the influent characteristics, the operating and maintenance procedures and the laboratory methodology.

CONCLUSIONS

Solids Handling System

The inability to remove suspended solids effectively before discharge is the major cause of the very high BOD and TSS levels reported in the effluent. Statistical analysis of the effluent BOD and TSS data showed that most of the BOD in the effluent was associated with suspended solids.

A high solids recycle load to the aeration basins and secondary settling tanks is one of the principal causes of the high suspended solids in the final effluent. The recycle stream from the gravity sludge thickeners to the aeration basins was reported to contain as much as 453,000 kg (1,000,000 lb)/day of suspended solids, almost 100 times the design load of 4,940 kg (10,906 lb)/day.

This high solids load in the supernatant from the gravity sludge thickener is caused by several factors. One is the failure of the dissolved air flotation (DAF) thickeners to concentrate the waste activated sludge. Because of this, the waste activated sludge must be concentrated in the gravity sludge thickeners which were designed to thicken only the primary sludge.

In addition, the sludge disposal system, consisting of a heat treatment system, vacuum filters and a multiple hearth incinerator is not functioning at full effectiveness because of large and frequent leaks in the heat treatment system. Because of this, solids cannot be removed from the gravity sludge thickeners at the design rate.

The high solids load in the feed to the gravity sludge thickeners and the inability to remove solids from these thickeners at the design rate combine to increase the solids in the supernatant return to the aeration basins.

Plant Design

Frequent shutdowns of one or more of the final settling tanks result in an overload on the operating tanks and cause an increase in the suspended solids content of the final effluent. The majority of the shutdowns are a result of the failure of the sludge return pumps that have been experienced. Two of the eight secondary settling tanks were out of service at the time of the NEIC inspection because of pump failure and the plant staff stated that this is a frequent occurrence.

The inability to control the sludge level in the secondary settling tanks is an additional cause of high suspended solids in the final effluent. The sludge level finder installed on the secondary settling tanks was ineffective because it was installed in the zone of influence of the sludge return pumps. In addition, the plant as designed and installed did not include a flow measuring device on the return sludge line from each pump. Thus, it is not possible to measure the sludge removal rate from the individual tanks. These two factors prevented stable operation of the secondary settling tanks.

Surge loads of TSS and BOD resulting from upsets in the sludge handling system contribute to uneven operation of the biological treatment system and to a high solids concentration in the final effluent. The return of all of the supernatant from the gravity thickeners directly to the aeration tanks imposes an unnecessarily high and variable load of BOD and TSS on the biological system. The supernatant from these thickeners includes the water removed from the primary and secondary waste activated sludges, incinerator scrubber water, filtrate from the vacuum filters, decant tank overflow and the flow from all floor drains in the solids handling area. The thickener supernatant could be returned to the plant influent, allowing the primary settling tanks to equalize these flows and remove some of the TSS and BOD.

Influent Characteristcs

Rapid, large variations in the temperature of the wastewater entering the plant cause unstable operating conditions in the plant and prevent effective bio-oxidation of the influent organics. An influent temperature variation as high as 10°C (18°F) in one 24-hour period was noted.

Sudden surges in the BOD load to the plant also prevented the development of a stable bio-mass and thus the effective removal of BOD and TSS on a continuous basis. The analysis of daily composite samples of influent did not show daily BOD loads over 150% of the design load but the operators stated that surge loads as high as 600 to 700% of the design BOD load were fed to the plant for periods up to six hours.

No data are available on the presence of biologically inhibitory materials but samples of the influent and effluent have been taken and are being analyzed for complex organic materials and heavy metals. A subsequent report will discuss the findings of these analyses.

Operation and Maintenance

Operation of only three of the four parallel aeration systems contributed to overloaded operating conditions and deterioration of effluent quality. Only three of the aeration tanks were kept in service to prevent underloaded operating conditions which could result in endogenous respiration and impaired sludge settling characteristics. This practice, however, resulted in extreme overloads to the operating systems during surge loads.

Efficient operation of the activated sludge plant is hampered by the inability to measure the activated sludge waste rate. The flow measuring devices in the sludge waste lines were inoperable at the time of the inspection and, according to the plant staff, had not been operable for some time.

The lack of control of the addition of nutrients (nitrogen and phosphorus) to the system may be limiting the biological oxidation of organic materials. The influent wastewater contains some nitrogen but very little phosphorous. Phosphorous, as phosphoric acid, is added but it is not paced with the influent organic load as it should be. Nitrogen was not being added at the time of the visit.

Unequal distribution of flow to the final settling tanks results in inferior effluent quality from the overloaded tanks. The flow over the weirs of the final settling tanks varied enough from one tank to another that it was immediately obvious visually.

Laboratory Methodology

The HRWTF was using correct analytical methods for the permit parameters. Standard samples for BOD analysis were left with the laboratory and the results received were within acceptable accuracy. A standard sample for TSS was also left with HRWTF but it was later discovered that this sample had been prepared incorrectly by the supplier so the TSS accuracy could not be checked.

III. PROCESS DESCRIPTION

Figure 1 is a flow diagram of the 189,000 m^3/day (50 mgd) Hopewell Regional Wastewater Treatment Facility provided by plant personnel. The figure contains information on equipment design, flow rates and design loadings for BOD and TSS.

The treatment sequence at the HRWTF includes screening, grit removal, primary sedimentation, activated sludge aeration using the UNOX* pure oxygen process and final sedimentation. Primary sludge is passed through a Hydrogritter (not in original design) for additional grit removal and pumped to gravity thickeners. Waste activated sludge was to be thickened in dissolved air flotation (DAF) units and mixed with the thickened primary sludge. However, the DAF units are not working so the waste activated sludge is pumped directly to the gravity thickeners, bypassing the DAF units.

The thickened sludge (primary and waste activated) is treated in Porteous heat treatment units which break down the cell structure and make sludge dewatering easier. The heat treated sludge is then decanted, dewatered on vacuum filters and burned in a multiple hearth furnace.

All of the recycle streams (heat treatment decant overflow, filtrate, furnace scrubber water) flow to the gravity thickener. The thickener supernatant is pumped to the aeration tanks.

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* Mention of commercial products, processes or equipment does not imply endorsement by the Environmental Protection Agency.

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IV. STUDY FINDINGS

SOLIDS HANDLING SYSTEM

Linear regression analysis of the effluent BOD and TSS data showed a good correlation (correlation coefficient = 0.83) between these two parameters. A similar analysis of the relationship between effluent TSS and that part of the BOD not passing a laboratory filter (BOD contributed by suspended solids) showed a correlation coefficient of 0.97. These results indicate that one of the reasons for the high BOD in the effluent is the inability to remove solids from the wastewater before discharge. Much of this problem is believed to be the result of problems in the solids handling system.

The plant design [Figure 1] indicated that the recycle of solids to the aeration tanks from the gravity sludge thickeners would amount to 4,530 kg (10,000 lb)/day. The data evaluated show solids recycle loads from this source of up to 85,600 kg (189,000 lb)/day and it has been reported[1] that the solids concentration in this stream gets up to 2% in a flow of 6 mgd (453,000 kg/day-1,000,000 lb/day).

There are two main reasons for this high load of solids leaving the gravity thickeners. The first of these is that the gravity thickeners are being used to thicken the waste activated sludge as well as the primary sludge. They were designed to thicken only the primary sludge. Dissolved air flotation units were installed to thicken the waste activated sludge but they have not been effective in accomplishing this and have been bypassed. The units supplier (Komline-Sanderson) was contacted to determine the reasons for this failure to perform as anticipated. Research work by Komline-Sanderson and others[2] has indicated that the source of the problem is the anti-foaming agent added to the aeration tanks. This agent is necessary to prevent the formation of massive amounts of foam in the aeration tanks and release of this foam in the settling tanks.

Another cause of the high solids in the gravity sludge thickener supernatant return to the aeration tanks is the inability to remove solids from the thickeners at the design rate. If solids are not removed at as high a rate as necessary, they build up in the thickeners and eventually overflow in the supernatant.

The normal flow path for sludge from the gravity sludge thickeners is to a sludge holding tank, then through a heat exchanger to the heated reactor, and back through the heat exchanger to a decant tank. The decant liquor flows to the gravity thickener and the separated heat-treated solids are dewatered on a vacuum filter and burned in a multiple hearth furnace. There are three heat exchanger-reactor systems installed at the HRWTF but only one of these was operational at the time of the NEIC inspection. The plant staff said that two of the units are down for repair most of the time. The major problem is that the head gaskets in the heat exchangers leak badly and the units cannot be operated under these conditions.

These heat treatment units, known as the Porteous Process, were supplied by the Envirotech Corporation. The Envirotech engineers contacted[3] said that the problem was the result of improper design by the supplier of the heat exchangers. Envirotech is now welding the head gaskets shut and believes that this will enable continuous operation of the heat treatment system.

Proper operation of both the dissolved air flotation units and the heat treatment system should result in a decrease in the amount of solids being recycled to the aeration tanks from the gravity sludge thickeners. This will decrease the solids load in the aeration tanks and secondary settling tanks and decrease the suspended solids content of the final effluent.

PLANT DESIGN

Frequent maintenance requirements on the sludge return pumps in the final settling tanks cause frequent shutdown of these tanks with the resultant overload of the tanks remaining in operation. The drive shaft between the motor and the sludge return pump is over 16 ft long and frequent bearing trouble has necessitated shutdown and maintenance. More conventional design would have the motor and pump located in pipe galleries below the settling tanks and would include a piping system so that failure of one pump would not force shutdown of a settling tank.

Sludge level finders were installed to enable the maintenance of a constant sludge level and stable conditions in the settling tanks but these sludge finders were installed in the zone of influence of the sludge return pump. Therefore, they do not give a correct measure of the depth of sludge in the settling tanks and have not promoted stable operation.

The sludge return pumps are variable speeds but the design did not include flow monitoring devices on the individual pump discharge lines. Without a flow monitoring device, the sludge return rate cannot be controlled to the degree necessary to maintain stable operation of either the final settling tanks or the aeration tanks.

All of the recycle streams from the solids handling system are returned to the main stream just before the aeration tanks. This arrangement maximizes BOD and TSS load and the effect of upsets in the sludge handling system on the biological system. More conventional design would divert these recycle streams to the head of the plant, thus taking advantage of the BOD and TSS removal and equalization capabilities of the primary settling tanks.

INFLUENT CHARACTERISTICS

The plant was designed to treat an influent to which industry contributes over 80% of the hydraulic load, 90% of the BOD load and 70% of the TSS load [Table 1].

Table 1 also shows the maximum temperature reached by several of the contributors to the HRWTF during August 1978, the hottest month for the individual contributors. In July 1978, the wastewater temperature at the plant influent ranged from 40 to 54°C (104-129°F). Efficient biological systems can be operated at temperatures in this range but high variations in temperatures will decrease the efficiency.[4,5,6] The inlet temperature at HRWTF changed as much as 10°C (18°F) from one day to the next.

Between June 1 and October 10, 1978, the hydraulic flow to the plant exceeded 50 mgd only three times, the maximum flow being 10,200 m^3/day (62.7 mgd). The BOD design influent load was exceeded 29 times during this period, the highest daily load being 95,700 kg (211,000 lb)/day. With only three of the four aeration tanks on stream, this is equivalent to a BOD load of 127,500 kg (281,000 lb)/day - twice the design BOD load. The influent TSS exceeded the design load four times in this time period, with the maximum daily load being over 227,000 kg (500,000 lb)/day. This high load was reported to be a result of backwashing wastes from the Virginia American Water Co.[7]

The only information available to the investigators on BOD loads to the plant was the daily average values which, as stated above, reached 95,700 kg (211,000 lb)/day. However, the operators stated[8] that BOD loads to the plant got as high as 600 to 700% of design for periods of up to six hours. These loads were reported to be caused by spills and upset conditions at the contributing industries.

Table 1*

Design Flows and Loads to Hopewell
Regional Wastewater Treatment Facility

Source	Flow m^3/day	(mgd)	BOD kg/day	(lb/day)	TSS kg/day	(lb/day)	High Temp Aug 78 °C	(°F)
Industrial								
Firestone	2,600	(0.7)	1,100	(2,418)	50	(116)	40	(104)
Hercules	38,200	(10.0)	28,700	(63,327)	8,300	(18,332)	42	(108)
Allied Chemical	17,000	(4.5)	6,800	(15,000)	1,100	(2,330)	49	(120)
Continental Forest Industries	81,400	(21.6)	17,100	(37,800)	27,000	(59,500)	60	(140)
Domestic								
Fort Lee	9,500	(2.5)	1,700	(3,850)	2,500	(5,410)	-	-
Hopewell	15,100	(4.0)	2,800	(6,160)	3,900	(8,658)	30	(86)
Old Dominion	4,900	(1.3)	-	-	6,800	(15,000)	-	-
Totals	168,700	(44.6)	58,200	(128,555)	49,650	(109,346)	-	-
Reserve	20,300	(5.4)	5,800	(12,808)	6,000	(13,252)	-	-
Totals	189,000	(50.0)	64,000	(141,363)	55,650	(122,598)	-	-

* Taken from "Hopewell Regional Wastewater Treatment Facility Agreement," July 1, 1975.

In July 1978, the industries contributing to the HRWTF, conducted a statistical study[9] indicating a calculated BOD range from 37,000 to 89,200 kg (82,000 to 197,000 lb)/day in the influent (ratio of 2.4:1) and a TSS range from 18,500 to 75,200 kg (40,800 to 166,000 lb)/day (ratio of 4.1:1). These ranges could be reduced by revised operating procedures at the contributing industries. For example, Hercules has an 83,200 m^3 ($22x10^6$g) holding basin at their plant, 56,800 m^3 ($15x10^6$g) of this being available for surge capacity. Hercules also has a "chemical cotton" process which, because of market conditions, is on stream for 10 days and off for 4 days on a regular cycle. The effluent stream from the chemical cotton process, which enters the holding basin, averages 22,700 m^3/day (6 mgd) and has an average BOD of 800 mg/l. All other waste streams entering the holding basin average 15,100 m^3/day (4 mgd) and have an average BOD of 1,600 mg/l. When the chemical cotton process shuts down after 10 days of operation, the flow from the holding pond to the HRWTF is reduced to a lower level for 4 days. During this time period, the BOD concentration in the holding pond is increasing because the lower strength chemical cotton wastes are not entering the pond. At the end of the four day "off period" for the chemical cotton process, this process is started up and the volume into the holding pond is increased. At this time, the holding pond is at its maximum BOD concentration. Also at this time, the flow rate to the HRWTF is increased, causing the maximum possible load from Hercules to the HRWTF and unstable slug loading to the HRWTF.

CFI and Firestone also have holding ponds but their sizes and methods of operation were not determined.

Little information is available on the presence of heavy metals or complex organics in the plant influent. If present, these materials could inhibit the biological process. A pilot plant study of the UNOX process conducted by a consulting engineering firm found that the Firestone and City of Hopewell discharges contained chemicals that inhibited biological activity.[10] Inhibitory materials were found later when conducting a BOD study.[11] However, in the latter study it was reported that the bacteria could be acclimated to degrade all of the chemicals in the influent. Samples of the influent and effluent were taken by the EPA (Region III) and are being analyzed for complex organic chemicals and heavy metals. The results of these analyses and the effect of the influent characteristics on the biological system will be discussed in a subsequent report.

OPERATION AND MAINTENANCE

During the inspection, only three of the four aeration tanks were on stream. The fourth was not on stream because it was believed that, during normal operation, the organic content of the wastes would not be high enough to prevent endogenous respiration and the formation of solids that would not settle. This practice served to amplify the overload conditions when sudden surges in the influent BOD were received from the industrial contributors. Since the inspection, all four aeration tanks have been put in service and the effluent quality has improved.

The flow monitoring devices on the activated sludge waste lines were not working at the time of the NEIC visit and, according to the operating staff, had not been working for some time. Control of the activated sludge waste rate is one of the most important activities available for maximizing the performance of an activated sludge system. The inability to measure this waste rate makes efficient operation difficult, if not impossible.

Biological treatment systems require the presence of nitrogen and phosphorous as nutrients for growth of the organisms. Facilities for adding both of these nutrients to the wastewater were provided at HRWTF. However, nitrogen was not being added at Hopewell and phosphorous is being added but no information was available on whether or not either nutrient was present in sufficient quantity. Conventional practice calls for adding nutrients so as to maintain fixed ratios between BOD and nitrogen and BOD and phosphorous.

The inspection revealed unequal distribution of mixed liquor into the final settling tanks. The flow over the weirs was obviously different between tanks. No correlation was noted between effluent quality and the rate of flow over the weirs but unequal distribution would undoubtedly degrade effluent quality during periods of high hydraulic load.

LABORATORY METHODOLOGY

The BOD and TSS procedures used and the associated laboratory equipment were judged as satisfactory. Standard samples for BOD analyses having true BOD concentrations of 28.7 and 264 mg/l were left with the HRWTF for analysis. The laboratory reported values of 30 and 295 mg/l, respectively. Both of these values are within acceptable limits.

Standard samples for TSS analyses were also left with HRWTF but it was later determined that the samples had been incorrectly prepared by the supplier so no accuracy check of the HRWTP TSS analyses was possible.

REFERENCES

1. Private communication

2. Record of telephone conversation with Komline-Sanderson, December 7, 1978

3. Record of telephone conversation with Envirotech Corporation, December 5, 1978.

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5. Record of telephone conversation with Dr. A.A. Friedman, Syracuse University, December 5, 1978.

6. Record of telephone conversation with Dr. Lin, University of New Brunswick, December 5, 1978.

7. "Plant Influent Sheet" August, 1978.

8. Telephone conversation with Hopewell plant, December 1978.

9. "Basis for Statistical Analyses," July 26, 1978.

10. "Wastewater Treatment - Pilot Plant Report for the City of Hopewell - Hopewell, Virginia," February 1974, Union Carbide Corporation.

11. "Management Study for the Hopewell Regional Wastewater Commission," Arthur Beard Engineers Inc., June 1978.