OPTIMIZING A 60 MIGD BIOLOGICAL WASTEWATER TREATMENT PLANT.

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ABSTRACT

This is a report on a unique application of waste treatment process fundamentals to the solution of a practical problem. It involves diagnosis of the problems using:
bench-scale devices,
development of design parameters and operating criteria,
pilot plant and full-scale verification of test program results, and
long-term operational follow-up.

At the same time as the process performance of all components was improved, significant reductions were made in annual operating costs. In addition a reassignment of staff positions and responsibilities resulted in a net decrease of operating staff.

BACKGROUND INFORMATION

The Woodward Avenue Sewage Treatment Plant in The Regional Municipality of Hamilton-Wentworth was expanded to a 3.15 m3/sec (60 MIGD) secondary plant in 1972. In mid 1979 additional biological capacity to bring it up to 4.73 m3/sec (90 MIGD) was brought on-stream in response to concerns regarding deteriorated effluent quality and limited hydraulic capacity of the plant. Additionally expansion plans were approaching the tendering stage for increased hydraulic capacity in the primary clarifiers and the grit chambers. This would provide an additional 50 percent capacity in the front end works.

The Woodward Avenue Plant is made up of the following process components:

1. lift station having a maximum capacity of 13.15 m3/sec (250 MIGD),
2. four mechanically raked bar screens,
3. four square grit chambers 113.8 m2 each (1225 ft2),
4. eight rectangular primary clarifiers each 953 m2 (10,250 ft2) by 3.35 m (1 I feet) deep,
5. eight aeration tanks each, having a capacity of 71 1 0 m3 (1.88 MG)in the original plant, with six 45 kw (60 hp) aerators per tank,
6. four aeration tanks each of 4542 m2 (1.2 MG) in the new plant with four 45 kw (60 hp) aerators in each tank,
7. eight squarex final clarifiers 1338 M2 (14,400 ft2) with a 3 m (10 ft) side wall depth in the original plant,
8. four rectangular final clarifiers each 1204 m2 (12,960 ft2) by 3 m (10 ft) in the new expansion,
9. effluent chlorination providing a residence time of 30 minutes at 3.15 m3/sec (60 MIGD),
10. four dissolved air flotation units for thickening waste activated sludge, each with 37.2 m2

(400 f t2) of surface area,

11. eight anaerobic digester tanks (4 primary, 4 secondary) each 30.5 m (100 ft) in diameter with conical bottoms and having a capacity of 11,590 m3 (1.75 MG) each,
12. four vacuum coil filters each having 46.5 M2 (500 ft2) surface area, and
13. two multiple hearth incinerators 13.7 m (45 ft) in diameter with 9 hearths (3 firing hearths).

THE PROBLEM

The problems initially identified at the plant concerned the continued failure of the final effluent to meet the Ministry of Environment discharge requirements, and these problems persisted over a period of several years. Operation was reported to fluctuate in that good results could be obtained for a period of time and then upsets would occur which were not controllable with the existing facilities and procedures.

The symptom of the problem as reported by operations staff was that they could not keep biological sludge from welling up unexpectedly, and without apparent cause. This resulted in poor settling in the final clarifiers and severe deterioration of effluent quality. The observation was characterized by operation results reporting sludge volume indexes which were consistently over 200.

Many of the upsets seemed to be related to surges in hydraulic flow, sometimes related to wet weather conditions since the system contains many combined sewers. In an attempt to regulate this problem, bypassing of raw waste upstream of the wet well, and or primary effluent was being practiced frequently as flows increased.

Many causes were postulated for the problem including:

1. excess quantities of ammonia, cyanide, chrome, phenol and oil and grease in the raw waste because of local industries,
2. various toxic compounds presumably from "night haulers" since many of the problems seem to coincide with the closing of the landfill site to the discharge of liquid industrial wastes, and
3. rapid changes in influent feed concentrations resulting from dilution by . storm waters in the old city combined sewers, which contributed to the uncontrolled settling of the biological solids.

PROCESS PERFORMANCE DATA

Initial Conditions

For the two years proceeding this tune-up program the following are the performance data for various components of the treatment plant and the final effluent as reported in the 1978 and 1979 Annual Reports on the operation of the Woodward Avenue Treatment Plant:

Influent Strength:

Characteristic	Year 1	Year 2
BOD (mg/L)	161	138
SS (mg/L)	256	268

Influent Flow:

Characteristic	Year 1	Year 2
m3/sec	2.78	2.89
MIGD	53	55
Bypassing (hours)	900	1552

Final effluent quality:

Characteristic	**Year 1**	**Year 2**
BOD5 (mg/L)	41	44
SS (mg/L)	45	78
Total P (mg/L)	2.1	2.8
Soluble P (mg/L)	1.3	1.4

During and Following the Tune-up Program

For the four year period, including the intensive on-site period by Pollutech staff, the effluent quality and performance data, as reported in the Annual Reports was as follows:

Characteristic	**Year 3**	**Year 4**	**Year 5**	**Year 6**
BOD (mg/L)	25	13	11	15
SS (mg/L)	27	17	17	13
Total P (mg/L)	1.6	1.6	1.1	1.1
Soluble P (mg/L)	1.1	1.1	0.7	0.8
Bypass (hours)	195	124	0	0

Cost Savings

The reductions in electrical power and organic polymer consumption, coupled with increased production of digester gas and the reallocation of staffing positions, has resulted in a fiscal benefit package worth over $900,000 per year. A summary of these costs is provided in the following table:

Component	Dollar Value
Electricity	$254,000
Natural Gas	300,000
Polymers	187,000
Manpower	162,000
Total Benefit	$903,000

DETAILS OF REMEDIAL PROGRAM

The tune-up program consisted of three distinct steps. The information which follows will describe the procedures applied to the optimization of the biological reactors and associated final clarifiers only (i.e. this discussion will be limited only to the biological section) since the efforts involved with the grit chambers, primary clarifiers, sludge flotation, vacuum filtration, anaerobic digestion, chlorination, and scum removal, are reported separately.

Step 1: Process Problem Diagnosis For Biological Reactors

Approach:

In order to diagnose the problem with the failure of the biological reactors, bench scale units were set up on the plant site in order to simulate a number of conditions of biological treatment as related to potential problems.

In response to the various opinions which had been expressed with respect to suspected causes of the problem, a total of 5 of the treatment process simulators were required in order to determine which if any of the following were causes of the problem:

> The first unit was set up to simulate the operation of the existing treatment plant.
>
> The second unit was set up to simulate the existing treatment plant without the industrial waste contributions which contributed to the high ammonia, phenol, chrome, cyanide and oil and grease in the raw waste.
>
> The remaining three units were set up to simulate various modifications to the operating parameters for the biological section, but using actual plant influent.

Results

The first unit which was set up to simulate the existing operating conditions at the treatment plant used operational parameters and flow variations similar to these achieved at the plant. When the simulator unit reproduced the problem observed at the full-scale plant it demonstrated its suitability as a basis for comparison to the other modified operations.

The second process unit which simulated the existing operating conditions at the plant, but without the industrial waste constituents, was operated under the same process parameters as the existing plant. The waste feed used for this portion of the study was collected from a residential area of the city. Lab analyses confirmed that none of the suspected problem industrial wastes were present. This unit demonstrated that it behaved virtually the same as the unit which was simulating conditions at the treatment plant.

The remaining three process units which were operated with the actual waste and the actual hydraulic surges, but with modifications to operating parameters, each showed significant improvement over the "control unit" under all conditions of feed. These units were kept in operation for a period of 7 weeks in order to cover a wide range of influent conditions. Process parameters were adjusted on these units in order to optimize growth rate control. Chemical analyses were made on the effluent from each of these units.

Step 2: Translation of Process Simulator Data to Larger Scale

Approach

As a result of the information obtained from the bench scale study, a recommendation was made to the municipality that a portion of the biological reactors and final clarifiers be isolated from the rest of the plant and used as a large scale pilot plant in order to demonstrate that the operating parameters determined from the bench scale program would indeed make significant changes to the full-scale plant. The owners were fully appraised of the potential savings in power costs (and possible future chemical costs) as well as with the target expected for effluent quality, if this approach could be demonstrated successfully.

Due to physical limitations with the piping, pumping and channeling systems involving the returned biological solids system, it was not possible to isolate a single aeration tank and a single clarifier in order to demonstrate our program. Thus instead of having a relative small pilot plant it evolved that the test system would be a 1.32 m3/sec (25 MIGD) plant, utilizing half of the original biological treatment plant. The "new" section of the biological plant would be utilized for the other 1.58 m3/sec (30 MIGD)as well as other excesses. The test section of the plant could then be operated under controlled conditions and limited to some 1.32 m3/sec (25 MIGD).

The operating control parameters evolved from the bench scale program were applied to implement a biological solids growth rate controlled program in the operation of the full-scale pilot plant.

Results

Within 3 weeks the full-scale pilot plant was beginning to show signs of improvement. Over a 7 week period a steady improvement of effluent quality was observed and the results are as follows:

Time Period	Effluent BOD (mg/L)	Effluent SS (mg/L)
Start-Up	68	58
Week 1	56	88
Week 4	20	50
Week 7	7	7

During the bench-scale test period all of the units maintained a soluble effluent BOD5 Of less than 5 mg/L. The unit with the highest growth rate always had a total effluent BOD5 of less than 10 mg/L. The test unit simulating the actual plant operation experienced significant nitrification, loss of alkalinity, effluent turbidity and a pH of less than 6.

None of the test units experienced any difficulty with the nutrient balance, and a mixed liquor level of 2300 mg/L proved to be most suitable.

When the effluent quality was demonstrated to be superior to anything previously produced, it was confirmed that this pilot plant could be operated more efficiently and produce steady operating results. During this demonstration less than one-half of the aeration tank capacity previously utilized was in service.

Under "research grade" operating conditions we found that the pilot plant could be kept under control biologically, and consistently produce a very good effluent. However, we also found that primary effluent quality fluctuations were such that deterioration in influent quality could rapidly occur if constant attention was not being paid to solids growth rate control.

A further detailed study around the plant to trace down the cause of the fluctuations in primary effluent quality indicated that virtually all of these sources were due to upset conditions occurring at some other part of the treatment plant itself. Various bottlenecks resulted from breakdowns in other components of the treatment plant or in outages for maintenance, or other malfunctions. For example, problems involving incinerator shutdown usually resulted in a bottlenecking and backing up from the vacuum filters to the digesters. This sometimes put a strain on sludge pumping from the primary clarifiers and resulted in excess solids carry-over from the primaries. On other occasions problems with the supernatant discharges from the digesters caused severe deterioration of primary clarifier effluent quality.

Once it had been demonstrated that the biological treatment plant could be controlled to produce an acceptable effluent, plans were made to expand the program to full-scale operation. This also involved the beginning of a program to systematically "tune-up" all of the other components in the system which could adversely affect the operation of the biological section of the plant.

The full effect of the full-scale pilot plant program could not be demonstrated in terms of effluent quality until the final clarifiers were optimized in order to achieve best possible effluent quality. It was also necessary to make a number of changes to the primary clarifier operation in order to minimize the solids carry-over from the primaries to the biological side and hence optimize the procedures for biological solids growth rate controls.

Step 3: Full-scale Demonstration

After 8 weeks of operation of the full-scale pilot plant, and demonstrating to the municipality that an effluent quality of less than 15 mg/L BOD5 and suspended solids could be consistently produced, the experimental program was expanded to include the entire plant. Flow at this time normally ranged between 2.63 m3/sec to 3.15 m3/sec (5060 MIGD) with peak loads to the secondary plant during wet weather conditions up to 5.5 m3/sec (105 MIGD). This upper limit was controlled by primary bypassing in order not to exceed some of the channel capacity near the front-end of the plant.

Over a period of 14 months the grit chambers, primary clarifiers, final clarifiers, dissolved air flotation, sludge digesters, vacuum filters and chlorination process were all tuned-up to increase efficiency and determine the limiting capacity of each of these components. This entire program was carried out without affecting normal operations by utilizing progressive incremental improvements in operating parameters, control chemical dosages where applicable, and control of pumping rates.

As a result of this program the following features were achieved:

1. Grit chambers were adjusted for optimum velocity control and optimum organic washing with the result that only 2 grit chambers were required to be in service at flows of less than 3.15 M3/sec (60 MIGD.) This increased utilization of the existing capacity resulted in postponing indefinitely the existing plans for expansion for the addition of two more grit chambers.
2. Primary clarification was improved by a program of primary solids inventory control and in this manner maximum capacity was determined to be in excess of 8.42 m3/sec (160 MIGD) without affecting effluent quality to the point where the biological process would be upset. As a result of this increase in practical working capacity of the primary clarifiers, a proposed expansion program to increase primary clarification capacity was postponed indefinitely.
3. Final clarification capacity was evaluated under optimum conditions of biological solids control and hydraulics control, resulting in determination of the limiting capacity of the 8 original final clarifiers at almost 6.31 m3/sec (120 MIGD) without serious deterioration to final effluent quality.
4. The dissolved air flotation system was optimized with a combination of relatively simple mechanical changes and process fine-tuning to increase the total available capacity to 34,500 kg/day (38 tons/day) from the existing I 1,800 kg/day (1 3 tons/day).
5. Vacuum filters were adjusted with respect to both operating parameters and chemical dosage, with the result that an increase throughput to 136,000 kg/day (150 ton/day) from 36,300 kg/day (40 tons/day) was attained with a substantial reduction in chemical use.
6. Both the primary and secondary digesters were cleaned out as well as tuned-up in order to increase mixing efficiency in the primaries and settling efficiency in the secondaries. The net result of this was substantial increase in g@s production from 5600 m3/day (200,000 ft-5/day) to 32,500 m3/day (1,150,000 ft3/day) which resulted in substantial cost savings to the Region.

The following table shows effluent quality data during the period of intensive tune-up of all treatment plant components.

Parameter	March	May - June	July - Sept	Oct - Dec
BOD (mg/L)	17	16	11	11
SS (mg/L)	23	20	10	10
Total P (mg/L)	1.0	1.6	1.2	1.9

The effluent quality attained at the Woodward Avenue Treatment Plant as presented in the Region's Annual Reports from 1979 to 1983, covering prior to and after the study program is noted as follows:

Parameter	Year 1	Year 2	Year 3	Year 4	Year 5
BOD (mg/L)	44	25	13	11	15
SS (mg/L)	78	37	23	17	13
Total P (mg/L)	2.8	1.6	1.6	1.1	1.1

SUMMARY

As a result of a study of process fundamentals, followed by a program of full-scale demonstration and fine-tuning of components at the Woodward Avenue Treatment Plant, effluent quality has been greatly improved while operational costs and capital costs have been greatly reduced. While the fundamental operations involved in the diagnosing of problems with each of the components, and with the optimizing of each of the components were essentially a research quality of operation, the end result was practical. The operating staff have had their positions redefined and have modified many of their procedures in order to be able to keep the plant operating in the way that the study program showed was the best operating conditions.

The principles established during the study on process fundamentals have provided simple practical techniques by which the operations staff can maintain a similar quality of productivity from each of the process components and minimize plant upsets. Bypassing of the screened waste or primary effluent has not been practiced for more than 2-1/2 years. Chemical costs have been greatly reduced, digester gas production has been increased, and operations and maintenance staff total numbers have been decreased.

This project has clearly demonstrated over a period of more than 4 years that process fundamentals and research techniques involving processes in waste treatment plants can be effectively utilized to provide practical operating parameters, to increase operating efficiency and to decrease costs.

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