The city of Orlando has implementated full-scale pilot studies at its Iron Bridge Regional Water Reclamation Facility to determine the maximum capacity of the Bardenpho process trains while maintaining reliable, permit-quality plant effluent. By modifying and rerating the Bardenpho trains, staff intends to remove the facility's "ailing" Rotating Biological Contactor (RBC) train from service.

The Iron Bridge facility is currently permitted for a treatment capacity of 40 mgd…16 mgd in the aging Rotating Biological Contactor (RBC) process and 24 mgd in the Bardenpho process. Each of the four Bardenpho-process trains were initially designed to treat 6 mgd average daily flow (ADF). Each Bardenpho train is outfitted with two 150-hp mechanical aerators recently upgraded with VFD units for speed control. The RBC facility equipment is reaching the end of its useful life, and its capacity must be replaced in some manner.

A paper study was performed to evaluate the cost of rehabilitating the mechanical RBC components; this cost was estimated at more than $25 million, not including delivery and installation. The cost was considered excessive to rehabilitate a process that staff members had grown to "hate" because of extensive preventive-maintenance requirements, difficult access to equipment, high humidity, odorous work areas, and a constant battle with a never-ending snail population. The decision was made to evaluate the potential for re-rating the Bardenpho facilities.

### Bench-Scale Pilot Study

The staff first performed a bench-scale pilot study to identify the microbiological activity and settleability characteristics of the MLSS in the Bardenpho process when treating the Iron Bridge influent wastewater, including the solids-handling sidestream flows. Staff members were unsure of the potential impact on the Bardenpho process if solids-handling sidestreams, which had been treated by the RBC trains, were combined with influent flow streams to the Bardenpho process.

The main objective of the bench-scale pilot project was to study the mixed-liquor quality to determine if the settling efficiency would be adversely influenced by a dominance of filamentous microorganisms (as strongly believed by the consulting engineer). The premise was that if the bench-scale pilot operated successfully, it would be reasonable to assume the full-scale Bardenpho plants would do the same.

The bench-scale pilot was a single-tank unit with baffled clarifier. Air was supplied and dissolved with aeration equipment similar to that of a fish tank: diffuser stones and a small WisperJet air blower. Raw wastewater was pumped into the beginning of the aeration chamber, while Return Activated Sludge (RAS) was conveyed from the bottom of the clarifier to the aeration chamber from the drafting movement of the aeration pattern. Final effluent overflowed the surface weir of the clarifier and exited the bench-scale pilot by gravity.

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in 1999, involved installing diffused aeration in the originally designed first anoxic zone of the five-stage Bardenpho train. The objective was to develop an aerated anoxic environment in which the autotrophic bacteria would oxidize ammonia to nitrate (nitrification), but limit the air supply to maintain the majority of the carbon ($CBOD_5$) available for denitrification. A multi-vane centrifugal blower with a 200-hp motor provided supplemental aeration during this phase of the project.

The purpose of the aerated anoxic pilot study was to identify the maximum capacity of each Bardenpho train in regard to nitrification and denitrification. Each train was originally designed for 6 mgd ADF (Average Daily Flow) with a design peak of 9 mgd; this equals a total Bardenpho capacity of 24 mgd ADF with peak flows of 36 mgd. This study attempted to treat an average daily flow of 10 mgd in one train with peak flows of 15 mgd. If successful, the Bardenpho process (four trains) would be capable of treating 40 mgd ADF, with a peak flow of 60 mgd. Possibly, additional process structures and equipment may be required to achieve these flow rates, including new secondary clarifiers, RAS pumping, aeration blowers, and chemical phosphorus polishing.

The pilot study was designed to aerate the first anoxic tank to encourage the major portion of nitrification to take place in this zone. Also, the initial goal was to control the amount of air supplied to the aerated anoxic zone to maintain a deficit of oxygen (meaning all of the oxygen demand would not be satisfied). The anticipated result was to encourage a major portion of denitrification to take place in this aerated anoxic zone, allowing the internal recycle (IR) flow to be reduced or totally shut off. The nitrification and denitrification that occurs in the aerated anoxic zone would greatly reduce the demand for oxygen in the Carrousel tank, which should allow for an increased volume of influent flow to be applied to the train. Also, as IR flow is reduced or shut off, the effective detention time within the first anoxic and Carrousel tanks would be greatly increased.

## *Results of the Aerated Anoxic Pilot*

After an exhaustive trial period, the staff could not create a true aerated anoxic environment, where a large volume of air is supplied but a measurable D.O. content is not achieved. Maintaining a near zero D.O. in this aerated anoxic zone allowed high levels of ammonia to bleed through the tank. Increasing the air to improve nitrification, which reduced the ammonia values, resulted

| Process Area | Equipment/Component | # | Design Criteria |
|---|---|---|---|
| Bardenpho | Bardenpho Trains | 4 | 6 mgd Avg Capacity Each |
| | Fermentation Tanks | 4 | 606,000 Gallons per Tank<br>2,424,000 Total Gallons for All Fermentation Tanks |
| | Fermentation Mixers | 8 | Two Mixers per Tank<br>Low Speed Turbine Mixers |
| | First Anoxic Tanks | 4 | 606,000 Gallons per Tank<br>2,424,000 Total Gallons for All First Anoxic Tanks |
| | First Anoxic Mixers | 8 | Two Mixers per Tank<br>Low Speed Turbine Mixers |
| | Carrousel Aeration Tanks | 4 | 2,630,000 Gallons per Tank<br>10,520,000 Total Gallons for All Aeration Tanks |
| | Surface Mechanical Aerators | 8 | Two Aerators per Tank<br>Two-Speed Motors<br>150 HP Motor |
| | Second Anoxic Tanks | 4 | 890,000 Gallons per Tank<br>3,560,000 Total Gallons for All Second Anoxic Tanks |
| | Second Anoxic Mixers | 8 | Two Mixers per Tank<br>Low Speed Turbine Mixers |
| | Reaeration Tanks | 4 | Coarse Bubble Diffused Aeration<br>150,000 Gallons per Tank<br>600,000 Total Gallons for All Reaeration Tanks |
| | IR Pump Stations | 4 | 36 mgd Max per Train |
| | Total IR Pumps | 12 | Propeller Pumps<br>Float Controlled<br>6 mgd Capacity Each Pump |
| Secondary Clarifiers | Secondary Clarifiers | 8 | 100 Foot Diameter Tanks<br>3 mgd Avg Capacity Each<br>Draft Tube RAS Removal |
| RAS/WAS Stations | RAS/WAS Wet Wells | 2 | Each Station Serves Four Clarifiers<br>Telescopic Valve for Each Clarifier in the RAS/WAS Wet Well |
| | WAS Pumps per Wet Well | 3 | Two-Speed Motors<br>About 3,000 gpm Each<br>Discharges to Head of Fermentation Tanks |
| | Total RAS Pumps | 6 | |
| | WAS Pumps per Wet Well | 2 | Submersible Pumps |
| | Total WAS Pumps | 4 | Constant Speed<br>About 350 gpm Each |

Table 1 : Bardenpho Process Equipment Summary

in a D.O. content of 3 to 4 ppm. The elevated D.O. level was considered detrimental because it encouraged aerobic heterotrophic bacteria to consume carbon while using free dissolved oxygen, instead of allowing facultative heterotrophic bacteria to use nitrates as their source of oxygen as they consumed carbon. Carbon is a valuable commodity which becomes a limiting factor when attempting to maximize biological denitrification efficiency.

### Second Full-Scale Pilot Study: Supplemental Aeration in the First Aerobic Zone of the Carrousel

City staff relocated supplemental diffused aeration from the first anoxic zone to the first aerobic portion of the Carrousel aeration tank. In this study, traditional first anoxic (without aeration) was re-established. Supplemental aeration in the Carrousel tank was provided with the same multi-vane centrifugal blower with an upgraded 250 hp motor.

The second pilot phase has remained in service since July of 1999. The goal of this work is to identify the maximum flow rate that can be successfully applied to a single-train, optimum mixed-liquor concentration for nutrient removal performance, optimum RAS rate for maximum secondary clarifier performance, optimum internal recycle rate for enhanced bioactivity and optimum SRT for overall process performance.

### Results of the Supplemental Carrousel Aeration Pilot

The results of this second pilot study have been excellent. Additional aeration has allowed the flow treated to be increased from the original design of 6 mgd to 10 mgd. Nitrification has improved, and with traditional first anoxic in place, denitrification efficiency was deemed acceptable. This mode of operation continues to be successful, treating an average of at least 10 mgd with daily peaks of about 17 mgd while producing permit-quality effluent.

| Test Train Process Item | Units | Aerated 1st Anoxic 6-month Results | Aerated Carrousel 8-month Results |
|---|---|---|---|
| Average Daily Flow | mgd | 9.3 | 10.3 |
| Peak Flow Rate | mgd | 22.8 | 17.5 |
| Based on Daily Composite Samples | | | |
| Influent $CBOD_5$ | mg/L | 219 | 250 |
| Influent TSS | mg/L | 211 | 263 |
| Influent $NH_3$ | mg/L | 19.4 | 20.3 |
| Influent TKN | mg/L | 33.7 | 34.7 |
| Influent TN | mg/L | 35.6 | 35.4 |
| Influent TP | mg/L | 6.3 | 6.0 |
| Aeration MLSS | mg/L | 2450 | 2300 |
| RAS TSS | mg/L | 5700 | 4690 |
| Sec Clar Eff $NH_3$ | mg/L | 1.4 | 1.1 |
| Sec Clar Eff TN | mg/L | 3.78 | 3.8 |
| Sec Clar Eff TP | mg/L | 0.83 | 0.76 |
| Average ChemScan Data at Carrousel Weir | | | |
| $NH_3$ | mg/L | 3.52 | 3.5 |
| $NO_3$ | mg/L | 1.76 | 2.7 |
| $NO_2$ | mg/L | 1.91 | 0.5 |
| Based on Process Flow Meters | | | |
| QRAS | mgd | 6.1 | 8.9 |
| R:Q Ratio | % | 66 | 86 |
| QWAS | Kgpd | 306 | 385 |
| Calculated Process SRT | Days | 9.4 | 6.6 |
| Based On Daily Composite Samples of Flow Entering the Effluent Filters | | | |
| $CBOD_5$ | mg/L | 3.2 | 2.6 |
| TSS | mg/L | 4.6 | 4.5 |
| $NH_3$ | mg/L | 0.8 | 0.7 |
| $NO_x$ | mg/L | 0.7 | 0.3 |
| TKN | mg/L | 2.2 | 2.0 |
| TN | mg/L | 2.8 | 2.3 |
| TP (after alum trim) | mg/L | 0.5 | 0.4 |

Table 2: Process Performance Data Comparisons - One, 6 mgd Test Train

### On-Line Nitrogen Analyzer

The staff recognized early on that they could not perform adequate manual sampling and nitrogen profile testing to identify the operational comparisons between the two supplemental aeration locations within the Bardenpho process. Sampling, analysis and control was developed utilizing an on-line nitrogen profile analyzer that receives MLSS samples drawn from the end of each pilot tank modified with supplemental aeration.

The analyzer filters the samples through ultra-filtration modules and performs a UV spectrum analysis to identify the nitrite, nitrate and ammonia concentrations. Average sample analysis requires four to five minutes per batch sample. The on-line nitrogen analyzer, which trends and records process performance in real time, allows the operators to make timely adjustments to the VFD on the mechanical aerators to optimize the nitrification and denitrification processes.

### Polymer Addition to Enhance MLSS Settleability

Due to the higher flow rates and possibly the high-rate biological activity rates, settleability of the mixed liquor has been adversely affected. Prior to the increased flow-rate pilot testing, sludge blankets were typically one foot or less. Fluff layers above the sludge blanket hardly ever existed. During the first pilot phase, aeration of the first anoxic zone, fluff above the sludge blanket in the secondary clarifiers started to become a problem. At times, the fluff layer was drafted over the weirs. To reduce the fluff layer in the clarifiers, the staff installed a polymer feed system that supplied a solution of cationic polymer into the clarifier mixed-liquor inlet splitter box. Within a few hours of activating the polymer feed system, clarifier sludge blanket fluff was greatly reduced.

During the second pilot phase, supple-

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mental aeration in the first aerobic zone of the Carrousel aeration tank, the fluff layer above the clarifier sludge blanket was significantly reduced. The polymer feed system was used only when MLSS settleability required chemical conditioning. Normal operation during the second pilot phase did not require polymer addition to realize successful performance in the secondary clarifiers.

## Conclusions

It is anticipated that the pilot studies will result in savings by modifying and rerating the existing Bardenpho trains as opposed to the more conventional method of building new tankage and support facilities. Supplemental air diffusers will be permanently installed in the Carrousel first aerobic zone, raw-flow equalization tanks will be constructed, and minor modifications will be made to clarifier flow splitting, RAS pumping, and IR pumping, resulting in a facility rerating from 24 mgd to more than 40 mgd. As a conservative estimate at $3 per gallon for design and construction of Bardenpho process units, the anticipated savings will exceed $48 million by attaining a 16-mgd increase in permitted treatment capacity.

| Process Performance Item | Units | Design 6 mgd Train | Pilot 10 mgd Train |
|---|---|---|---|
| Detention Times (without RAS) | | | |
| Fermentation | hours | 2.4 | 1.4 |
| 1st Anoxic | hours | 2.4 | 1.4 |
| Carrousel Aeration | hours | 10.5 | 6.3 |
| 2nd Anoxic | hours | 3.6 | 2.1 |
| Re-aeration | minutes | 36 | 22 |
| Secondary Clarifiers (2 of 4) | hours | 6.8 | 4.1 |
| Detention Times (with RAS) | | | |
| Fermentation | hours | 1.5 | 0.8 |
| 1st Anoxic | hours | 1.5 | 0.8 |
| Carrousel Aeration | hours | 6.6 | 3.3 |
| 2nd Anoxic | hours | 2.2 | 1.1 |
| Re-aeration | minutes | 22 | 11 |
| Secondary Clarifiers (2 of 4) | hours | 4.2 | 2.1 |
| Secondary Clarification Loading Rates (2 of 4 Clarifiers) | | | |
| Surface Settling Rate | gal/day/ft$^2$ | 382 | 637 |
| Weir Overflow Rate | gal/day/ft | 9,544 | 15,924 |
| Solids Loading Rate | lbs/day/ft$^2$ | 12.5 | 23.1 |

Table 3: Process Performance Data Comparisons - 6 mgd vs. 10 mgd