Design and Start-up of an Advanced Treatment System for High Strength Wastewater from a Chemical Plant

By

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Introduction

Expansion at a chemical plant would produce additional wastewater, including some low-volume, high strength (130,000 mg COD/L), process wastewater. At full production capacity, the organic loading from the additional 15,700 gallons of process wastewater (three waste streams A, B, and C) would be 17,000 pounds chemical oxygen demand (COD) per day (maximum capacity is 20,000 gpd and 24,000 pounds COD per day). Current total organic loading at the local publicly owned treatment works (POTW) is 1,000 to 2,000 pounds COD per day. The new wastewater would also be high in dissolved solids, averaging 80,000 mg/L non-volatile dissolved solids (NVDS). Pretreatment requirements for the local POTW are provided in Table 1. The additional wastewater would require extensive pretreatment and discharge to a local POTW or hauling to an off-site treatment and disposal facility (at considerable expense).

This paper presents the results of the bench and pilot testing performed on the process wastewater, design of the treatment system, and the start-up and initial performance of the treatment system. Descriptions are provided for unique features of the design, the chemical treatment system and the bioseeder. The paper also includes a discussion of the salt management strategy used during start-up.

Bench and Pilot Testing

Bench and pilot testing performed using a proprietary, thermophilic treatment process (AFC_{SM}) showed that the additional wastewater was biodegradable and the AFC process could achieve the necessary effluent quality for discharge to the local POTW. Results of initial bench testing and respirometry using unacclimated AFC seed and the concentrated waste streams showed that a thermophilic biomass could degrade the waste streams. AFC also appeared to be a cost-effective alternative to off-site waste treatment and disposal.

The AFC Technology is a unique patented and proprietary technology which treats organic waste streams and sludges with little ancillary sludge production. AFC is a combination of thermophilic aerobic biological treatment and ancillary chemical treatment of thermophilic biomass. Waste materials are fed to a self-heating, thermophilic bioreactor for treatment. Effluent from this reactor is conveyed to a solids separator. A portion of the separated solids is returned directly to the thermophilic reactor, while the remaining portion goes to chemical treatment. The chemical treatment step partially solubilizes the biosolids before they are returned to the thermophilic reactor for further digestion and destruction.

Bench-scale testing was conducted over a nine-month period that encompassed various testing objectives (acclimation, design, and maximum target load testing). A 7.5 liter (L) plastic reactor was seeded with 5 L of thermophilic biomass from two existing full-scale AFC systems. An air pump was used to aerate the bioreactor and maintain a dissolved oxygen (DO) concentration greater than 1 mg/L. The reactor was heated in a water bath designed to maintain the reactor temperature between 45 and 48ºC. The bench-scale reactor was setup with continuous feed of the three waste streams. Nitrogen and phosphorous were added in excess to prevent nutrient limitation.

Pilot-scale testing was conducted concurrently with the bench-scale testing. The purpose of the pilot-scale testing was to demonstrate the effectiveness of the ultrafiltration step and evaluate other key parameters for the full-scale AFC technology. The goal of the pilot testing was to provide performance data at a larger scale. Pilot testing on the three waste streams was conducted over a nine-month period using a 1000-gallon steel tank. The pilot testing was initiated with seed from two existing full-scale AFC facilities.

The AFC system demonstrated during bench- and pilot-testing that it could function operationally for wastewater with NVDS levels at 8% (80,000 mg/L) during both design (200 mg/L-hr COD) and maximum target (300 mg/L-hr COD) loadings. The bench reactor COD removal efficiency was 85% during the period it was fed the design and maximum target COD loadings. This removal efficiency was obtained without the use of an ultrafilter. The full-scale AFC system, with daily use of an ultrafilter, will achieve greater than 90% COD removal efficiency. The AFC system was also shown to be capable of meeting the toluene pretreatment standard of 0.028 mg/L. Influent toluene levels of up to 500 mg/L were reduced to below detection levels during testing. Toluene emissions to the atmosphere from the AFC reactor were calculated to be within acceptable limits for the facility. A decision was made to proceed with full-scale design and construction of an AFC pretreatment system. The AFC system was to be completed and operational to coincide with the start-up of the additional production capacity.

Design

The pretreatment system was designed to take advantage of the rapid biodegradation rates associated with aerobic systems and the low sludge yields of thermophilic systems. The final, full-scale thermophilic system is designed to treat an average load of 17,000 lbs/day of COD. The plant capacity is 24,000 lbs/day COD (at a maximum daily flow of 20,000 gpd). The AFC plant is a multi-process biological and physical-chemical treatment system.

The treatment system consists of equalization, thermophilic aerobic treatment, ultrafiltration, bioseeder, and chemical sludge treatment. Figure 1 is a process schematic of the AFC treatment system. The three process wastewaters, A, B, and C, are combined in the equalization tank to reach target COD and NVDS concentrations. The target concentrations are 130,000 mg/L COD and 80,000 mg/L NVDS. From the equalization tank, the wastewater is pumped to the thermophilic reactor for thermophilic, biological destruction of the organic contaminants in the wastewater. The mixed liquor in the reactor is continuously recirculated through the ultrafiltration system. This system separates the treated wastewater from the mixed liquor. The treated water, or permeate, is stored in effluent storage tanks and tested. If it meets the effluent requirements, the permeate is discharged to a local POTW.

Conductivity of the influent wastewater is monitored in the equalization tank. Conductivity data was correlated with NVDS data to develop a relationship curve. The influent NVDS concentration can be adjusted by adding more of one of the three waste streams to the equalization tank. pH control with sulfuric acid and sodium hydroxide is used on both the equalization tank and the thermophilic reactor to maintain the pH between 7.5 and 8.5 standard units (s.u.). The reactor dissolved oxygen (DO) level is monitored, and depending on the reading, the aeration blowers can be adjusted to add more or less air to the reactor. Ammonium hydroxide is also added to the thermophilic reactor to elevate the nitrogen level to the required concentration necessary for sustaining biological growth in the reactor. Antifoam is added, as required, to control buildup of foam at the reactor surface. In addition, the foam abatement pump can be used to control reactor foaming. This pump recirculates reactor mixed liquor through a spray nozzle system inside the reactor and above the liquid surface. This spray helps maintain foam at safe levels and prevents reactor foam-overs.

The reactor mixed liquor is pumped through the ceramic membrane (ultrafiltration) system for separation of the solids from the treated liquid. The permeate stream will be discharged to the effluent storage tanks, and eventually a local POTW. The solids-laden stream is primarily directed back to the reactor. A portion of the solids-laden stream will be directed to the chemical treatment tank. The ceramic membrane system can also be used to concentrate biomass for the bioseeder. Should non-biodegradable solids need to be discharged from the system, they can be directed from the solids-laden stream.

The AFC system is designed to treat sludge on a regular basis to reduce the requirement for off-site disposal and to reduce foaming. A slipstream (2 to 5 percent of the thermophilic reactor volume) of mixed liquor is treated in batches in the Chemical Treatment Tank. In the tank, the pH is dropped to 5.0 with the addition of sulfuric acid, and then the biomass is hydrolyzed by the addition of hydrogen peroxide and ferrous sulfate. After treatment, the sludge is slowly pumped back to the reactor. Chemical treatment of the sludge provides the following:

- Organic sludge control
- Partial inorganic sludge control
- Foam control

- Partial recalcitrant organic control (make more biodegradable)
- Recycle/reuse of nitrogen and phosphorous

A separate inventory of biomass is kept in the covered, aerated bio-seeder tank. Biomass from the thermophilic reactor is concentrated using the ultrafilter and transferred to this tank. In the event of a problem with the thermophilic reactor, this biomass will be utilized to speed the recovery of the process. This inventory of biomass will be acclimated to 8% NVDS, providing an available supply of salt tolerant, thermophilic biomass. Seed from other sources would not be acclimated to thermophilic temperatures and 8% NVDS.

The facility has an on-site lab capabilities to monitor key process performance parameters such as pH, oxygen uptake rate (OUR), chemical oxygen demand (COD), nutrients (nitrogen and phosphorous), total and volatile suspended solids (TSS and VSS, respectively), dissolved solids, and a gas chromatograph (GC) for toluene analysis. Analyses required by permit are performed by an outside, certified laboratory. The AFC system is controlled by a distributed control system (DCS) that is monitored by a full-time wastewater treatment plant operator who is also in-charge of system maintenance. The plant production personnel, via a remote display screen monitor the DCS system during off-hours.

System Start-up and Performance

The AFC wastewater pretreatment system is undergoing a gradual start-up. A plan was developed to provide the procedures and benchmarks for start-up. The start-up plan outlines a twelve week program to get the AFC system operating at design loading conditions (17,000 lbs COD/day and 8% NVDS). This paper describes the start-up plan for the AFC system and will report on the progress of the start-up, which is scheduled for April 11, 2000.

The AFC reactor will be seeded with a mixture of biomass from two separate systems. Thermophilic biomass (40,000 gallons) will be obtained from an existing AFC system. This plant receives waste at approximately 2.5 % non-volatile dissolved solids. In addition, waste activated sludge (WAS) will be obtained (40,000 gallons) from a local POTW. The POTW biomass has a low NVDS concentration. The reactor seed concentration will be adjusted to 3 percent NVDS by the addition of 12,000 lbs of sodium sulfate. An additional seeding of AFC thermophilic sludge (40,000 gallons) will occur during the second week of start-up. The second seeding will be performed to speed-up the establishment of an active thermophilic biomass in the reactor.

The initial batches of feed wastewater will be mixed to produce NVDS concentrations that will not shock the reactor. Subsequent batches of feed wastewater will increase in NVDS concentrations; thus gradually increasing the NVDS levels in the reactor and allowing the reactor biomass to slowly acclimate to higher NVDS concentrations. The NVDS level of the reactor will be limited to changes of less than 1,000 mg/L for 3 consecutive days and/or 0.5 percent (5,000 mg/L) per week. The reactor will be gradually brought to the design NVDS loading of 8 percent. Table 2 shows the COD and NVDS loading schedule for the initial 12-week start-up and acclimation period for the AFC treatment system. Fed and unfed OUR's will be performed to quantify the biological activity to verify that the biomass can handle the selected COD and NVDS loading rates.

The reactor is scheduled to be at design loading conditions, 200 mg COD/L/hour at 8 percent NVDS, twelve weeks after start-up. The ultrafilter will be started during the ninth week and produce an effluent that will be discharged to a local POTW. Once reactor solids levels reach 40,000 mg/L TSS (or 30,000 mg/L VSS), chemical treatment will be activated to stabilize solids growth. Chemical treatment could begin earlier if reactor operations warrant. Excessive foaming or accumulation of organics (as measured by COD levels) could result in chemical treatment being initiated prior to reaching the above benchmarks. The goal of the chemical treatment system is to hydrolyze the sludge solids and non-readily biodegradable organics, making them more amenable to biodegradation in the thermophilic aerobic reactor.

Summary

Expansion at a chemical plant in a small town would produce a high strength (130,000 mg COD/L), high salt (80,000 mg NVDS/L) wastewater. This wastewater would have to be treated on-site to meet pretreatment requirements or be hauled off-site for treatment (at considerable expense). A review of treatment and disposal technologies showed that an AFC treatment system could cost effectively pretreat this wastewater. Based on successful bench and pilot testing results, design of an AFC system to treat the new production wastewater was initiated and completed. Construction of the AFC system commenced late in 1998 and was completed by winter 2000. The AFC system start-up was commenced in April 2000. The system is scheduled to treat 17,000 lbs. COD/day, with a NVDS content of eight percent within three months of start-up. Start-up of the AFC solids chemical treatment process is expected during the third month of operation. This process will minimize buildup of solids within the AFC system with the goal of eliminating excess solids production so that no organic sludge will need to be removed from the plant. The AFC system can be ramped up in the future to maximum design conditions, 24,000 lbs. COD/day at 8 percent NVDS, when production capacity at the chemical plant is increased.