On and Off

The alternate cycling process can be a cost-effective way to reach nutrient removal goals

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One of the current concerns in the field of wastewater treatment is how to meet new effluent nitrogen limits in a cost-effective manner. The application of oxic and anoxic cycles in a wastewater treatment bioreactor is one effective way.

An on/off strategy applied to aeration makes it possible to maintain nitrification and denitrification in a single aeration reactor. Reducing the time of oxygenation to include anoxic periods, and the possible need to increase solids to provide a longer retention time for autotrophic bacteria, lead to high oxygen-transfer rates in the reactor.

Using high-purity oxygen (HPO) enables an oxygen transfer rate increase of up to five times greater than the air-based systems' maximum. And using mechanical oxygen injection avoids the reduction of the alpha factor when higher solids concentrations must be maintained in the process, thus maintaining the highest efficiency. With HPO, the biological process becomes a compact and powerful solution for high-strength industrial wastewater treatment.

This strategy of operating with alternating cycles (AC) was tested at a full-scale industrial facility. The AC process has been optimized to obtain the required effluent limits at minimal operation costs. An online sensor for NH_4-N and NO_3-N has been installed at the full-scale facility to monitor performance. Model-based simulation tools were used to design the required cyclic pattern and evaluate an automatic control loop that has also been applied in the real facility and successfully validated.

Truck-cleaning facility description

The full-scale water resource recovery facility (WRRF), which treats wastewater resulting from truck cleaning, consists of a membrane bioreactor (MBR) aerated with HPO. Oxygenation is carried out using a mechanically agitated contacting system called the In-Situ Oxygenation (I-SO™ aerator) developed by Praxair, Inc. (Danbury, Conn.). The plant treats 50 to 100 m^3/d of flow intermittently in a 500-m^3 volume reactor. Tubular ceramic membranes with 300 kD of membrane pore size are used for solids separation (see Figure 1). An equalization tank stores the effluent and feeds the MBR for about 10 hours on working days. Considering both the heterogeneous origins of the wastewater and the discontinuous feeding pattern, the biological model has a highly variable inflow.

Figure 1. The biological reactor with the mechanical HPO injection aeration tank (left), equalization tank (center) and the membrane system (right).

The wastewater characteristics depend on the number of trucks to be cleaned and the goods they transport. The facility will use an oxic/anoxic cycling strategy at intervals of 160 minutes on, 45 minutes off. Only the NH_4-N content of the effluent was tracked.

A remote monitoring tool, AqScan, recorded and displayed all the online measurements generated by the multiple probes (measuring dissolved oxygen [DO], pH, redox, NH_4-N, NO_3-N, temperature, and flow) and actuators. In addition, AqScan automatically estimates the oxygen uptake rate (OUR), oxygen transfer coefficient (K_La), and oxygen transfer efficiency.

A mathematical biological model-based simulator was developed using the WEST® modeling platform. The biological model is a modified ASM1 model extended to include inorganic particulate compounds and temperature variation prediction, which is crucial for industrial compact treatment solutions. The model would help aid design enhancements to the existing basic DO control scheme to incorporate other process variables such as NH_4-N and NO_3 -N concentrations and the inflow rate.

Promising results

Figure 2 shows the influent characteristics and the reactor's mixed liquor total and volatile suspended solids measured during the study. The results suggested reducing mixed liquor total suspended solids in the bioreactor to around 6000 mg/L.

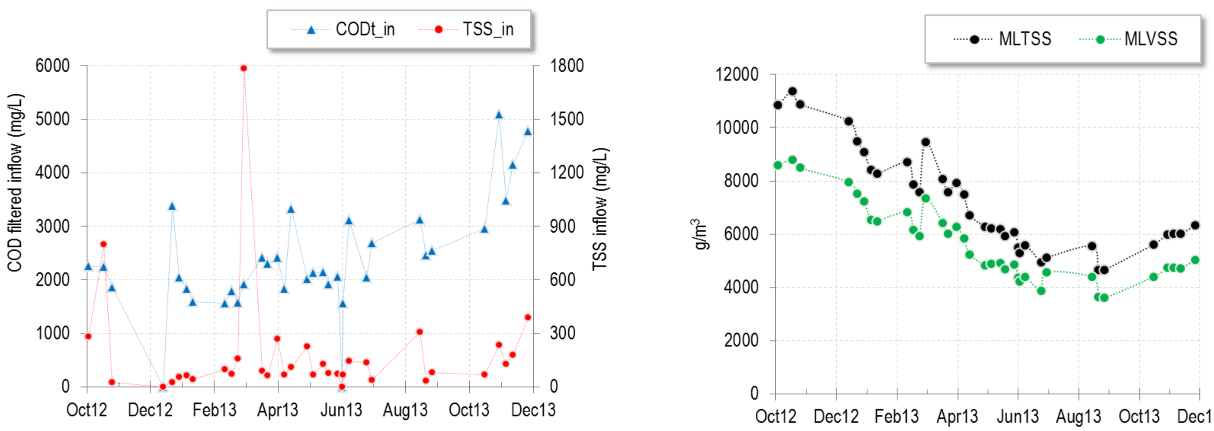

Figure 2. Influent characteristics and reactor solids states

The first 2 months were dedicated to trial runs at the plant to observe the immediate response of the process to a variation in critical process parameters. By the third month, the automatic control strategy designed was applied and was maintained until the end.

The effect of the cyclic operating strategy was clear. Online OUR estimations indicated that OUR is maintained at 120–140 g/m^3•d throughout both the oxic and anoxic phases. The oxygen demand in the anoxic phase is ostensibly met by denitrification of nitrates.

Figure 3 shows the system's response during the study period.

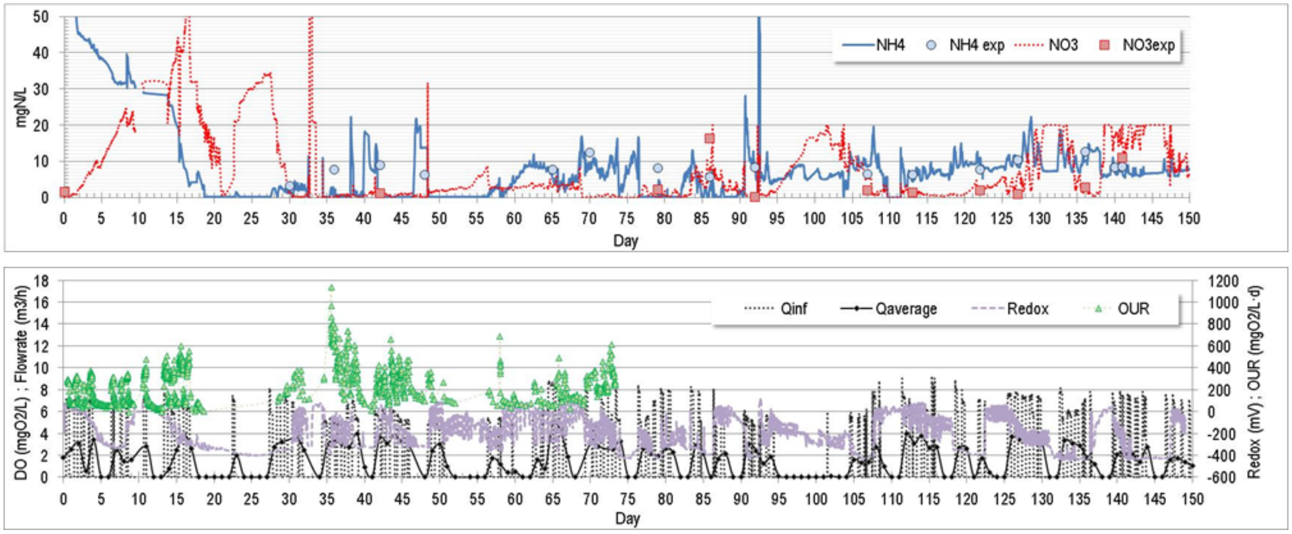

Figure 3. Online measurements compared to lab measurements and OUR

Figure 4 shows this effect in detail (during 3 days of operation).

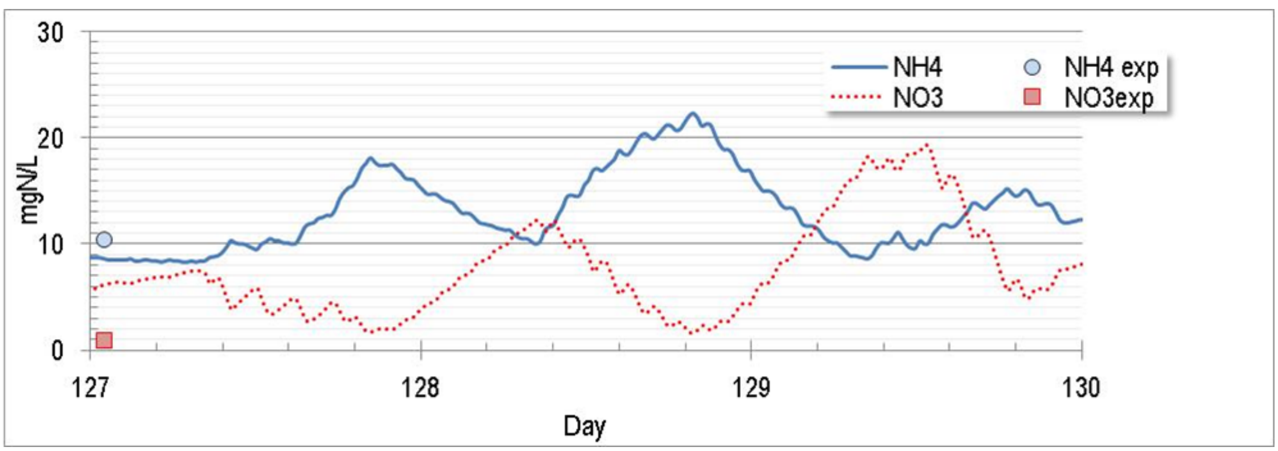

Figure 4. Nitrogen after 3 days of intermittent oxygenation

The table summarizes the different operational strategies applied to the full-scale plant.

Table. Summary of the results at the full-scale facility

Period	Days	Goal	Oxic/anoxic cycle (min)	Results
1	0–15	Reduce NH_4-N	120/60	Goal reached, but NO_3-N increased
2	15–35	Reduce NH_4-N and NO_3 -N	90/60	Both NH_4-N and NO_3-N removed efficiently
3	35–60	Trials	Variable	Different observations prior to control strategy application
4	60–70	Reduce oxic periods	60/60 Increase DO level	No clear conclusions due to inflow variability. To be analyzed in pilot plant.
5	70–125	Improve efficiency, apply first automatic control loop	Feeding	Good performance in terms of effluent quality and oxygen consumption
6	125–150	Improve NH_4-N oxidation	Increase oxic cycles for no feeding periods	No improvement in NH_4-N

\The HPO-MBR process was retrofitted for nitrogen removal using the oxic/anoxic cycles in the same compact reactor, providing more efficient nitrogen removal and energy savings.

The final strategy (validated at the full-scale plant) is as follows:

1. If the inflow rate is higher than 0: 120 minutes anoxic, 60 minutes oxic
2. If the inflow rate is 0 (no feeding): 60 minutes anoxic, 90 minutes oxic
3. If the inflow rate changes from 0 to another value: Switch directly to anoxic operation
4. If the inflow rate changes from a value to 0: Switch directly to oxic operation

This study demonstrated that the AC process requires only minimal, if any, additional capital or infrastructural upgrades, making it a cost-effective solution to reach nutrient removal goals. The development of robust, calibrated biological process model and the development of control strategies for optimizing the AC process will enable more robust and cost-effective implementation of the treatment process at this facility.