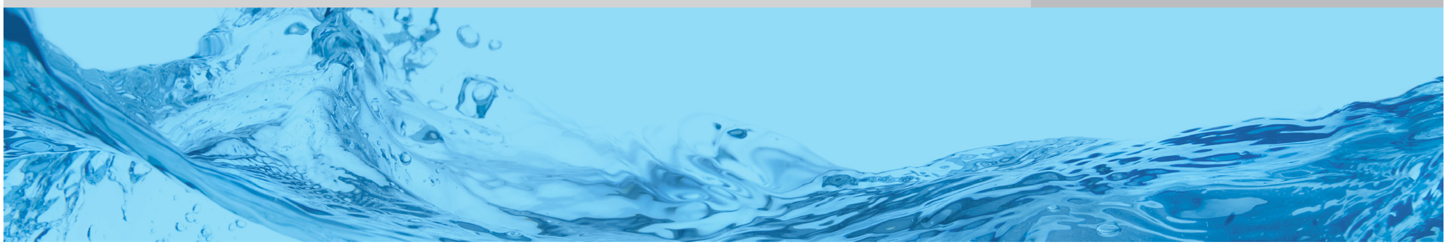
U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

BERKELEY LAB



Optimize Dissolved Oxygen-Based Control Strategy for Aeration Process

Principle

The activated sludge process is a common wastewater treatment step in which the influent wastewater is injected with air or oxygen, referred to as "aeration." Aeration promotes the growth of aerobic microorganisms that can then digest the organic matter in the wastewater. The microorganisms clump together and settle to the bottom of the settling tank (clarifier), prior to disinfection. The settled material, or sludge, is removed from the bottom of the tank before some material is recycled back into the activated sludge process and the remainder is sent for further processing.

The aeration process is commonly the most energy-intensive in activated sludge plants, often accounting for more than half of the plant's energy[1]. Therefore, any improvements that can be made to the aeration process are key to reducing energy consumption. Most of this energy consumption is from the blowers that deliver air or pure oxygen to the wastewater. These blowers are essentially low pressure, high volume air compressors that both agitate the wastewater and produce air bubbles to "feed" the aerobic microorganisms. The most common measurement of aeration effectiveness is Dissolved Oxygen (DO) concentrations. Recommended DO concentrations vary by facility but typically range from 1.0 to 2.0 milligrams per liter. Under-aerated systems can "starve" the aerobic microorganisms leading to underperformance of the activated sludge process, among other problems. Over-aeration, besides wasting energy and money, leads to poor sludge settling, increased foaming, and negative impacts on the anoxic zone of nitrogen removal systems, when present[2]. Thus, proper control of the aeration process is critical to an operationally and energy efficient wastewater treatment plant.

Suggested Actions

- Determine the amount of energy used by the blowers as a percentage of full flow.
- Install dissolved oxygen sensors in aeration tanks and VFDs on blowers.
- Vary the speed of the aeration blowers to match the required oxygen as determined by the dissolved oxygen automated sensors.

[1] Pabi, S, et al. 2013. "Electricity Use and Management in the Municipal Water Supply and Wastewater Industries." Electric Power Research Institute: 194.

[2] US EPA. 2010. "Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities." United States Environmental Protection Agency: 4-7.

Commonly, these blowers are fitted with variable frequency drives (VFDs) which allow them to vary their speed. This variation can be controlled either manually based on user input or automatically based on sensor input. An example of manual manipulation of aeration tank blowers would be if a plant operator measured the DO in the aeration tanks once every few hours and altered the speed of the blowers based on that reading. Since DO levels change rapidly, blowers may then be running at an inappropriate level of aeration and energy usage for hours until the next reading. Therefore, a better method of controlling aeration tank blowers is to have automatic DO sensors vary the speed of the blowers via the VFDs to maintain proper aeration and energy usage continuously.

Example

A hypothetical wastewater treatment plant will be used to demonstrate the energy saving benefits of employing an automated-DO control strategy. This plant utilizes an activated sludge process with a 150-hp centrifugal blower, appropriately sized for aerating and mixing wastewater at peak treatment loads. In a worst-case scenario, the 150-hp blower (with a nominal efficiency of 92%) would be running at full speed day and night in order to meet the highest loading, thereby inadvertently over-aerating at lower loads, especially overnight. Ignoring inevitable inefficiencies in piping, the energy consumption would be calculated as follows:

Baseline Annual Energy Consumption =

$$\frac{\text{Blower Size (hp)}}{\eta_{\text{Blower}}} \times 0.746\ \frac{\text{kW}}{\text{hp}} \times \text{Operating Hours} =$$

$$\frac{150\ \text{hp}}{0.92} \times 0.746\ \frac{\text{kW}}{\text{hp}} \times 8{,}760\ \frac{\text{hrs}}{\text{yr}} = \mathbf{1{,}065{,}482}\ \frac{\textbf{kWh}}{\textbf{yr}}$$

Which, at an estimated $0.10 per kWh, would cost about $106,548 per year.

Compare the baseline energy consumption and costs to the facility utilizing an automated DO sensor to control a blower using a VFD (97% efficiency) for appropriate aeration. This facility only requires full power from the blowers for 25% of the time (2,190 hours per year) and for the rest of the time it requires 75% output (6,570 hours per year). Assuming that the change in blower efficiency between these states is negligible[3], the energy consumption and cost of the DO-controlled facility would be calculated as follows:

DO Controlled Annual Energy Consumption =

$$\frac{\text{Blower Size (hp)}}{\eta_{\text{Blower}} \times \eta_{\text{VFD}}} \times 0.746\ \frac{\text{kW}}{\text{hp}} \times \sum \left((\text{\% of Full Flow}) \times \text{Operating Hours} \right) =$$

$$\frac{150\ \text{hp}}{0.92 \times 0.97} \times 0.746\ \frac{\text{kW}}{\text{hp}} \times \left[\left((1.0) \times 2{,}190\ \frac{\text{hrs}}{\text{yr}} \right) + \left((0.75) \times 6{,}570\ \frac{\text{hrs}}{\text{yr}} \right) \right] = \mathbf{892{,}479}\ \frac{\textbf{kWh}}{\textbf{yr}}$$

[3] This equation assumes that the static head dominates other sources of head loss and that fan affinity laws do not apply. See p. 8-15 of US DOE's Continuous Energy Improvement in Motor Driven Systems for more information: https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_guidebook_web.pdf.

Which, at an estimated $0.10 per kWh, would cost about $89,248 per year. Therefore, there is substantial energy and cost savings possible in upgrading from an uncontrolled aeration system to an automated DO-controlled system. The automated system requires multiple automated sensors, a control system, and a VFD on the blower which will vary in cost depending on the size of the facility. According to multiple case studies from the U.S. EPA, the simple payback for similar projects range from eighteen to thirty months[4].

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[4] US EPA. 2010. "Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities." United States Environmental Protection Agency: Appendix A.

Resources

See the Sustainable Wastewater Infrastructure of the Future (SWIFt) website for more information on wastewater energy solutions at betterbuildingssolutioncenter.energy.gov/accelerators/wastewater-infrastructure

To view more Energy Tip Sheets visit energy.gov/eere/amo/tip-sheets-system

To access these and many other industrial efficiency resources and information on training, visit the Advanced Manufacturing Office Website at manufacturing.energy.gov