South Carolina
Economy - Energy - Environment

WASTEWATER TREATMENT ENERGY CONSERVATION REPORT – SAMPLE RECOMMENDATION
REPLACE MECHANICAL MIXERS WITH FINE BUBBLE AERATORS

Recommended Action

Replace mechanical mixers used for aeration with more energy efficient technology like fine bubble aerators.

Background

Aeration is one of the largest energy consuming process in wastewater treatment plants. At this facility, wastewater flows to the aeration basin after passing through the primary sedimentation tank. In the aeration basin, the wastewater is aerated using mechanical mixers at the surface of the tank (surface aerators) which introduce oxygen into the water. The treatment process involves breaking down complex substrate by using bacteria. In order for the bacteria to break down the substrate, a terminal electron acceptor is needed. In this case, the electron acceptor is oxygen. Nitrate can also be used as a terminal electron acceptor decreasing the need for oxygen if an anoxic zone is present; however, this plant only has aerobic tanks. In the aeration tanks, nitrifying bacteria grow and convert ammonia to nitrate. This is an important process in wastewater treatment because ammonia in the effluent can deplete oxygen content of the effluent which enters rivers and lakes. It is recommended this plant switches to fine bubble air diffusers which are more efficient in terms of oxygen transfer and energy consumption than the current surface aerators.

Anticipated Savings

For the anticipated savings of this recommendation, the energy consumption of the mechanical surface aerators is calculated.

The plant has four mechanical surface aerators, each 125 HP. It is assumed the load factor is 70% and the efficiency is 80%. The energy required (E_R) to provide aeration using surface aerators is

$$E_R, Surface\ Aerators = \frac{N \times HP \times C \times LF \times UF \times OH}{EFF}$$

Where

N - Number of mechanical surface aerators
HP - Horse Power Rating of the Motor
C - Conversion Factor ($0.7457 \frac{kW}{HP}$)
LF - Load Factor
UF - Usage factor
EFF - Efficiency of the motor

$$E_R, Surface\ Aerators = \frac{4 \times 125\ HP \times 0.7457 \frac{kW}{HP} \times 0.70 \times 0.90 \times 8760 \frac{hours}{year}}{0.8}$$

$$E_R, Surface\ Aerators = 2.572 \times 10^6 \frac{kWh}{Year}$$

The next calculation depends on the additional aeration capacity of fine bubble aerators compared with mechanical surface aerators. The standard aeration efficiency (SAE) which is the amount of oxygen transferred per unit of energy consumed is the range of 1.1 and 1.4 kg O_2/kWh for mechanical surface aerators and it is in the range of 2 and 7 kg O_2/kWh for fine bubble aerators. Taking the average value of the range for surface aerators (1.25 kg O_2/kWh) and the average number for fine bubble aerators (4.5 kg O_2/kWh) gives an estimate that 3.25 extra kg of O_2 can be delivered for every kWh of energy if fine bubble aerators are installed.

As calculated above, last year the plant had an E_R for surface aerators of 2.572 x 10^6 kWh. Assuming SAE value (for mechanical surface aerators) of 1.25 kg O_2/kWh, the oxygen delivered (O_d) was

$$O_d, Surface\ Aerators = 2.572 \times 10^6 \frac{kWh}{Year} \times 1.25 \frac{kg\ O_2}{\text{kWh}}$$

$$O_d, Surface\ Aerators = 3.215 \times 10^6 \frac{kg\ O_2}{Year}$$

The oxygen required to treat the water is constant, so with fine bubble aerators the oxygen delivery will be the same (3.215 x 10^6 kg). The energy required by the fine bubble aerators to deliver the required oxygen is

$$E_R, Bubble\ Aerators = 3.215 \times 10^6 \frac{kg\ O_2}{Year} \times \frac{kWh}{4.5\ kg\ O_2}$$

$$E_R, Bubble\ Aerators = 714{,}444 \frac{kWh}{Year}$$

So, the *electricity consumption savings* (ECS) per year is

$$ECS = 2.572 \times 10^6 \frac{kWh}{Year} - 0.714 \times 10^6 \frac{kWh}{Year}$$

$$\boldsymbol{ECS = 1.857 \times 10^6 \frac{kWh}{year}}$$

At an electricity consumption rate (CR) of 0.075 \$/kWh, the estimated annual *electrical consumption cost savings* (*ECCS*) would be

$$ECCS = ECS \ \times CR$$

$$ECCS = 1.857 \times 10^6 \frac{kWh}{year} \times 0.075 \ \frac{\$}{kWh}$$

$$\boldsymbol{ECCS = \$139,275/year}$$

The *electricity demand savings* (EDS) is

$$EDS = \frac{1.857 \times 10^6 \ \frac{kWh}{year}}{8760 \ \frac{hrs}{year}} \times 12 \frac{months}{year}$$

$$\boldsymbol{EDS = 2543\ kW/year}$$

With a demand cost (DC) of $8.98 per kW-month/year, the *electricity demand cost savings* (EDCS) is

$$EDCS = EDS \times DC$$

$$EDCS = 2543\,\frac{kW}{year} \times \frac{\$8.98}{kW}$$

$$\boldsymbol{EDCS = \$22,843/year}$$

The total cost savings (TCS) is

$$TCS = ECCS + EDCS$$

$$TCS = \$139{,}275 + \$22{,}843$$

$$\boldsymbol{TCS = \$162,118}$$

Implementation Cost

It is estimated the fine air disc shaped diffusers for the plant's two aeration basins alone could cost about $100,000. Other installation equipment like pipes, air compressors, support structures, and labor cost for removing the existing mechanical surface aerators would be in the range of $150,000 to $250,000. The total cost is estimated to be around $350,000.

IC = $350,000

Simple Payback Period

Using the estimated $350,000 for implementation, the *simple payback period* (SPP) is calculated below by dividing the *total cost savings* (TCS) by the *implementation cost* (IC).

*SPP = IC / TCS * 12*

SPP = ($350,000/$162,118) 12 months/yr.*

SPP = 25.9 months

Note: The maintenance cost is high for fine bubble aerators, which is not considered in the calculation. This could affect the SPP by a small margin. This estimate can be recalculated as a more concrete implementation cost is determined if this recommendation is implemented.

References

SAE range for fine bubble aerators and mechanical surface aerators reference:

Mark Gehring and John Lindam "Energy-Efficiency Showdown: A Comparison of Aeration Technologies" (http://proddownloads.vertmarkets.com.s3.amazonaws.com/download/0e722a90/0e722a90-7cfb-49ca-a18e-38cf424f9852/original/27_vert_1213ezine_xylem.pdf)