What every operator should know about activated sludge

Dave Flowers

Knowledge	Principle	A practical consideration
Activated sludge	Microorganisms are brought into contact with wastewater containing “food” (measured as biochemical oxygen demand [BOD]) and oxygen. Under good conditions, the food (our waste) is consumed by the microorganisms. We then separate the microorganisms, leaving behind clean water (effluent).	Microorganisms thrive under the right environmental conditions. Of particular importance are • population (number of microorganisms), • pH, • temperature, • mixing, • contact time, • oxygen, and • presence of life-sustaining nutrients.
Conventional activated sludge system	This process is typically an aeration tank followed by solids–liquid separation and, if needed, a return activated sludge pump. There also has to be a method of air or pure-oxygen addition and a method of removing excess microorganisms, which are called waste activated sludge (WAS).	Conditions needed for this type of system include • 8 to 12 hours of detention time in the aeration tank (more for extended air), • 1500 to 3500 mg/L of mixed liquor suspended solids (MLSS), • adequate mixing, • a dissolved-oxygen (DO) concentration of about 2 mg/L, and • a good food-to-microorganism ratio (F:M).
MLSS (population) control using F:M	To balance the waste load of food (lb of BOD_5 per day) to the population of microorganisms, you need a F:M of 0.2 to 0.5.	WAS is removed, or wasted, from the secondary system to maintain the proper F:M. To calculate F:M, divide the food by the biological mass in the entire secondary system. • Food = flow (mgd) × 8.34 lb/gal × BOD_5 mg/L. • Microorganisms = [aeration tank volume (million gal) × 8.34 lb/gal × mixed liquor volatile suspended solids (MLVSS) mg/L] + [clarifier tank volume (million gal) × 8.34 lb/gal × clarifier coretaker[1] total volatile suspended solids (TVSS) (mg/L). • So, F:M = food ÷ microorganisms.

[1] A coretaker device is used to take a sample of clarifier water that reaches from the floor to the water’s surface. This sample is run into a bucket then mixed well and analyzed for total volatile suspended solids (TVSS) (mg/L). In this case TVSS and MLVSS both are a measure of microorganisms present in the total activated sludge system.

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MLSS (population) control using mean cell retention time (MCRT)	Another way to balance the waste load of food (pounds of BOD_5 per day) to the population of microorganisms is to maintain an MCRT of 5 to 15 days.	To calculate MCRT, measure the pounds of biomass in the entire secondary system and divide by the pounds of biomass wasted each day. Typically, a target MCRT is maintained. For example, if you had a 10-day MCRT, you would waste 10% of the biomass each day. If the effluent is low in TVSS, this loss of microorganisms is typically ignored in the MCRT calculation.
pH	The pH should be between 6.5 and 8.5.	Microorganisms do not grow well in pH outside this range. Be especially mindful of pH if the water supply is soft, such as from a lake.
Temperature	Operators can't control influent temperature; however, a common range is between 10°C and 38°C (50°F and 100°F).	Understand that microorganisms can have difficulty growing at temperatures higher than 38°C (100°F). Cooling may be necessary. For every 10°C rise in temperature, microorganism respiration doubles. During cold temperatures a higher population will be needed to achieve the same treatment results – that means a lower F:M or higher MCRT.
Mixing	Regardless of the aeration tank configuration, the tank should be well-mixed.	Good mixing will ensure that the microorganisms are in good contact with the food, the oxygen, and each other. Check for this by measuring DO, MLSS, or total suspended solids at several locations within the tank – the results should be similar at each location.
Contact time or hydraulic retention time	The hydraulic retention time (HRT) within the aeration tank must be long enough for the microorganisms to consume all the freely available food.	HRT is calculated by dividing the aeration tank volume by the volume of flow per day, then multiplying by 24 hours per day to get a result of hours. An easy method of checking if the HRT is long enough is to check the oxygen uptake rate (OUR) leaving the aeration tank (before solids–liquid separation). If the rate is endogenous – meaning the microorganisms have consumed all freely available food and are burning their reserves and consuming each other – the HRT is long enough for the flow, load, and MLSS concentration.

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Oxygen	Maintain a DO residual concentration of at least 2 mg/L anywhere in the aeration tank.	This is a rule of thumb. One can run at a lower DO. A higher DO may be necessary if low DO filaments are present and DO is not penetrating to the inner floc. Approximately 0.45 kg (1 lb) of oxygen is needed to consume 0.45 kg (1 lb) of BOD_5. Approximately 2.0 kg (4.3 lb) of oxygen is needed to convert 0.45 kg (1 lb) of ammonia.
Life-sustaining nutrients	As a rule of thumb, microorganisms need, pound for pound, 100:5:1:0.5 for BOD_5:N:P:Fe. That means for every 100 lb of BOD_5, they need 5 lb of nitrogen, 1 lb of phosphorus, and 0.5 lb of iron.	The phosphorus must be available to the microorganisms and is generally referred to as orthophosphate. It passes through a 10-µm filter. Nitrogen here is generally referring to ammonia–nitrogen.
Oxygen uptake rate	OUR is the "breathing rate" of the microorganisms, sometimes referred to as "respiration rate." OUR = mg of oxygen consumed per L per h.	There is a correlation that the respiration rate of the MLSS is higher when freely available food is present. Monitor OUR at the points where flow is entering and exiting the aeration tank. The exit point should show an endogenous respiration rate. Respiration rate also will vary in relation to the concentration of microorganisms.
Solids–liquid separation	After culturing microorganisms in an aeration tank under excellent environmental conditions, the "quality biomass" will settle well in a clarifier or separate well in a membrane. The sidewater depth is typically between 3.7 and 4.6 m (12 and 15 ft). The surface overflow rate of the clarifiers is typically less than 24,450 L/m²•d (600 gal/ft²•d) at average flow and less than 48,900 L/m²•d (1200 gal/ft²•d) during the peak hourly flow. Return activated sludge (RAS) rate is typically 50% to 150% of the plant flow. However, the upper range will be lower for large plants.	A quality biomass will flocculate (come together or "stick" together) under mild agitation. This agitation often occurs as MLSS leaves the aeration tank and flows to the clarifier. Many clarifiers have inlet baffles that serve this purpose. RAS pumps (if required) must remove an adequate quantity of activated sludge to maintain a reasonable sludge depth – depth of blanket – 0.15 to 0.6 m (0.5 to 2 ft) is typical. Avoid a higher than necessary RAS rate to maintain a low sludge blanket.
Settleometer testing	Using a settleometer, conduct a settling test. Five- and 30-minute test results should be placed on a trend chart at the testing frequency, which is often daily.	After experiencing long periods of excellent performance, these trends will allow observation of impending settling problems. Follow-up may be microscopic examination for filaments, adjustments to the WAS rate.
Sludge volume index (SVI)	SVI is the volume occupied by 1 g of MLSS after 30 minutes of settling. SVI = ([30-minute settling volumes as mL/L] ÷ [MLSS concentration as mg/L]) × 1000 mg/g = mL/g.	• SVI of less than 80 mL/g = generally very good settling. • SVI between 80 and 150 mL/g = good settling. • SVI greater than 150 mL/g = generally poor settling and requires corrective action. *Microscopic examination is a good start. Look for filaments, microorganism diversity, and nutrient deficiency for starters.*

***Dave Flowers** is president and operator at Natural Water Solutions LLC (Cedarburg, Wis.).*