Module 16:

The Activated Sludge Process - Part II

Instructor Guide – Answer Key

Unit 1 – Process Control Strategies

Exercise

1. What are the six key monitoring points within the activated sludge process?

Ans: Plant influent, primary clarifier effluent, aeration tank, secondary clarifier, internal plant recycles and plant effluent.

2. For each of the monitoring points listed above, explain what key characteristics a TPO should look for.

Ans: Plant influent – check for flow increase and influent solids increase

primary clarifier effluent – check BOD/COD, TSS and nutrients

aeration tank – check MLSS/MLVSS, residual DO, pH and total alkalinity, SOUR, color and the biomass

secondary clarifier – check sludge blanket level, sludge return rate and floating solids on clarifier surface

internal plant recycles – check digester or sludge holding tank supernatant and sludge dewatering or thickening process recycle

plant effluent – check turbidity and NPDES permit requirements

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Exercise

Calculate the pounds of solids under aeration for a plant with the following information:

Plant Flow: 400,000 gallons per day
MLSS: 2,000 mg/L

Pounds of solids under aeration = (MLSS, mg/L) x (aeration tank volume, Mgal) x 8.34
= (2,000 mg/L) x (0.4 Mgal) x 8.34
= 6672 lbs of solids

Calculation

Calculate the MCRT assuming the following:

- Total system flow is 5 MGD
- Aeration Tank Volume is 4 million gallons
- MLSS = 3,000 mg/l
- Effluent suspended solids concentration: 3.5 mg/L
- Sludge wasting rate (WAS flow) = 0.1 MGD
- Waste activated sludge suspended solids (WASSS) = 8,000 mg/L

$$\text{MCRT} = \frac{3{,}000 \text{ mg/l} \times 4 \text{ MG} \times 8.34}{3.5 \text{ mg/l} \times 5 \text{ MGD} \times 8.34 + 8{,}000 \text{ mg/l} \times 0.1 \text{ mgd} \times 8.34}$$

$$\text{MCRT} = \frac{100{,}080 \text{ lbs}}{145.95 \text{ lbs/day} + 6672 \text{ lbs/day}}$$

MCRT = 14.68 days

Calculation

Calculate the F/M ratio given the following:

Aeration tank volume is 500,000 gal
Aeration tank influent BOD = 200 mg/L
Influent flow = 1.0 MGD
MLVSS = 2,000 mg/l

$$\text{F/M} = \frac{\text{Influent BOD (or COD) lbs/day}}{\text{MLVSS in aeration, lbs-day}}$$

$$= \frac{200 \text{ mg/L} \times 1.0 \text{ mgd} \times 8.34}{0.5 \text{ mg} \times 2{,}000 \text{ mg/l} \times 8.34}$$

$$= \frac{1{,}668 \text{ lbs/day BOD}}{8{,}340 \text{ lbs MLVSS-day}}$$

F/M = 0.2

Calculation

Calculate the SVI for an activated sludge sample given the following:

30-minute settleable solids volume = 200 mL
MLSS = 2,000 mg/L

% settleable solids = (200/1000) x 100 = 20

$$SVI = \frac{20 \times 10{,}000}{2{,}000} = 100 \text{ mL/g}$$

Calculation

Calculate the required WAS rate given the following:

Volume of aeration tank = 1.7 Million gallons
MLSS = 1,600 mg/L
Plant flow = 10 MGD
Effluent suspended solids = 10 mg/L
WAS suspended solids = 8,000 mg/L
Target MCRT = 5 days

$$5 \text{ days} = \frac{(1600 \text{mg/L} \times 1.7 \text{ mgal} \times 8.34)}{(10 \text{ mg/L} \times 10.0 \text{ mgd} \times 8.34) + (8000 \text{ mg/L} \times \text{WAS} \times 8.34)}$$

$$(10 \text{ mg/L} \times 4.0 \text{ mgd} \times 8.34) + (8000 \text{ mg/L} \times \text{WAS} \times 8.34) = \frac{22{,}684.4 \text{ lbs}}{5 \text{ days}}$$

$$\frac{834 \text{ lbs}}{\text{day}} + (8000 \text{ mg/L} \times \text{WAS} \times 8.34) = \frac{22{,}684.4 \text{ lbs}}{5 \text{ days}}$$

$$(8000 \text{ mg/L} \times \text{WAS} \times 8.34) = \frac{4536.88 \text{ lbs}}{\text{day}} - \frac{834 \text{ lbs}}{\text{day}}$$

$$8000 \text{ mg/L} \times \text{WAS} \times 8.34 = \frac{3702.88 \text{ lbs}}{\text{day}}$$

$$\text{WAS} = \frac{\frac{3702.88 \text{ lbs}}{\text{day}}}{8000 \text{ mg/L} \times 8.34}$$

WAS = 0.06 mgd

Exercise for Unit 1

1. If there is a large increase in influent plant solids, you may need to increase the _____ in the aeration tank.

    a. MLVSS
    b. BOD
    c. Total suspended solids
    d. Phosphorus

2. Typical wastewater parameters that are used to characterize influent loadings include (select all that apply):

    a. Flow
    b. BOD
    c. TSS
    d. Ammonia
    e. Phosphorus

3. T/F: Biochemical oxygen demand (BOD) can be used as a measure of the organic compounds in water or the "food" for microorganisms.

4. Well-designed primary clarifiers should remove _____ of BOD.

    a. 5-10%
    b. 10-20%
    c. 20-40%
    d. 40-60%

5. Well-designed primary clarifiers should remove _____ of TSS.

    a. 10-20%
    b. 20-30%
    c. 30-50%
    d. 50-70%

6. The _____ concentration is a measure of the total concentration of solids in the aeration tank.

    a. Dissolved oxygen
    b. pH

c. Mixed liquor suspended solids (MLSS)
d. Mixed liquor volatile suspended solids (MLVSS)

7. The MLVSS represents the concentration of the organisms in the aeration tank.

8. T/F: The return-sludge flow should be adjusted to maintain the sludge blanket as low as possible.

9. If the MCRT decreases, the solids move _____ through the aeration basin.

a. Faster
b. Slower

10. In general, increasing the sludge wasting rate (WAS) will _____ the MCRT.

a. increase
b. decrease
c. not change

11. When wasting sludge, the WAS rate should not be changed more than 10 to 15 percent from one day to the next.

12. The suspended solids concentration of the influent to a treatment plant is 285 mg/l. If the influent flow is 2.5 million gallons per day (MGD), how many lbs/day of suspended solids enter the treatment plant?

a. 872 lbs/day
b. 5942 lbs/day
c. 4530 lbs/day
d. 713 lbs/day

lbs/day = 285 mg/l x 2.5 mgd x 8.34 = 5942 lbs/day

13. Calculate the lbs of MLVSS given the following:
0.2 F/M ratio lbs BOD5/lbs MLVSS-day
Influent BOD5 = 200 mg/l
Influent flow 1.0 mgd
Aeration tank volume 500,000 gal

a. 8,340 lbs MLVSS
b. 1,820 lbs MLVSS

c. 6,550 lbs MLVSS
d. 4,190 lbs MLVSS

F/M = BOD loading to aeration (lbs/day)/lbs MLVSS in aeration

BOD loading = 200mg/l x 1.0 mgd x 8.34 = 1668 lbs/day

F/M = 0.2 Therefore, lbs MLVSS = BOD loading/F/M, 1668/0.2 = 8340 lbs

14. In the aeration tank, biological reactions _____ considerably below 5 °C.

    a. decrease
    b. increase

15. A DO concentration between __2__ to __4__ mg/L in the aeration tank is usually adequate to achieve a good quality effluent.

16. The typical optimum MLVSS-to-MLSS ratio in activated sludge plants is between 0.7 and 0.8.

17. Typically the F/M ratio is changed by:

    a. Changing the alkalinity of the aeration basin
    b. Changing the sludge wasting rate
    c. Changing the influent BOD
    d. Changing the filter media

18. Do lower or higher SVI values indicate better sludge settleability?

    a. Lower
    b. Higher

19. Calculate the SVI given the following:

    MLSS = 3,900 mg/L
    30 minute settleability volume = 300 mL

    300 mL/L x 1,000 mg = 76.9
    3,900 mg/L 1 g

20. Calculate the MCRT assuming the following:

    Total system flow is 5 MGD
    Aeration Tank Volume is 3 million gallons
    MLSS = 3,000 mg/l
    Total Pounds wasted from the system = 4,700 lbs/day

    $$\frac{(5\ MGD)(3{,}000\ mg/L)(8.34)}{4{,}700\ lbs/day} = 26.6\ days$$

21. An operator wants to decrease the MLSS and the MCRT in the aeration tank. This can be done by:

    a. Increasing the RAS rate and keeping the WAS rate the same
    b. Decreasing the WAS rate and increasing RAS rate
    c. Decreasing the WAS rate and keeping the RAS rate constant
    d. Increasing the WAS rate and keeping the RAS rate the same

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Exercise for Unit 2

1. List six process operational problems.

Ans: plant changes, sludge bulking, septic sludge, rising sludge, foaming/frothing or toxic substances.

2. What is sludge bulking?

Ans: A condition in which activated sludge has poor settling characteristics and poor compactability. This causes the sludge blanket in the secondary clarifiers to rise until solids eventually escape the clarifiers and are discharged from the plant.

3. What is septic sludge?

Ans: It is sludge that has become anaerobic and has a foul odor. The anaerobic conditions generate gases, which causes the sludge to rise to the surface of vessels.

4. List five classifications of toxic substances.

Ans: heavy metals, inorganic compounds, organic compounds, halogenated compounds, and pesticides, herbicides and insecticides.

Exercise for Unit 2

1. You notice that the MLSS concentrations differ significantly from one aeration basin to another. What is the potential cause(s) of this and how would you solve it?

Ans: One cause could be unequal flow distribution to the aeration tanks. The solution to this is to adjust the valves and/or inlet gates to equally distribute the flow.

Another cause could be the return sludge distribution is unequal to the aeration basins. In this case, you would check the return sludge flows and discharge points.

2. The sludge concentration in the return sludge is low. What are the four possible causes of this? For each cause, identify what you should check or monitor.

Ans:

Probable Causes	Check/Monitor
Sludge return rate too high	Return sludge concentration, solids level around final clarifier and settleability test.
Filamentous growth	Microscopic examination, DO, pH, nitrogen concentration.
Actinomycetes predominate	Microscopic examination, dissolved iron content
Collector mechanism speed Inadequate	Collector mechanism

3. There are thick billows of white, sudsy foam on the aeration tank. It has been determined that the reason for this is because the MLSS is too low. What should you do to resolve this problem?

Ans: Decrease sludge wasting to increase MLSS and MCRT.

Exercise for Unit 2 – Typical Operational Problems

1. If the shaft coupling on the surface aerator makes an unusual noise and vibration, what are the possible causes and how would you fix the problem?

Ans: The possible cause is a lack of proper location. Solutions include repair or replacement of oil pump and an oil change or removing an obstruction from the oil line.

2. Explain the monthly maintenance requirements for air headers/diffusers.

Ans: Exercise all regulating/isolation valves to prevent seizing for coarse bubble diffusers but not for porous media filters.

Apply grease to the upper pivot swing joint O-ring cavity.

Check for loose fittings, nuts and bolts and tighten them if necessary.

Increase air flow to the diffusers to 2-3 times the normal flow to blow out biological growths.

3. Describe the typical operational problems associated with air filters.

Ans: Cleanliness of the filter and pressure drops across the air filter.

4. If sludge is present in the pipe of the air distribution system, what is the possible cause and how would you resolve the issue?

Ans: A possible cause is vacuum action caused by the blower operating in reverse. Solutions include flushing the pipe, installing a check valve on the blower and/or repairing the check valve.

Exercise for Unit 2

1. An operator decides to increase the sludge wasting rate based on an observed increase in MLSS due to digester supernatant solids and worsens the situation. Explain briefly why this may be deleterious.

Ans: The situation will likely degrade because by increasing the sludge wasting rate, the operator is also wasting valuable VSS, which is needed to build the MLVSS-to-MLSS ratio back up. The operator should decrease or cease wasting until the desired MLVSS concentration is reached. The plant may need to be changed to a step feed aeration process to accommodate the solids buildup in the aeration tank.

2. Activated sludge plants require _less_ volatile suspended solids and _more_ air flow in the summer.

3. Rising sludge is caused by the process of denitrification in the secondary clarifiers.

4. Sludge bulking is typically caused by:

   a. Low F/M ratio
   b. High MCRT
   c. Filamentous organisms

d. High DO

5. Rising sludge may be differentiated from sludge bulking by the presence of gas bubbles on the surface of the clarifier.

6. Light, white foam on the surface of the aeration tank may be caused by:

   a. Filamentous bacteria
   b. Low MLSS
   c. Nocardia
   d. Toxic substances

7. A thick, dark brown foam on the surface of the aeration tank is usually caused by the filamentous bacteria _____.

   a. Nitrosomonas
   b. Pseudomonas
   c. Nocardia
   d. Acinetobacter

8. An operator needs to increase the F/M ratio at his plant. He would do this by:

   a. Keep the RAS pumping rate the same.
   b. Increase sludge wasting
   c. Increase the RAS pumping rate
   d. Decrease sludge wasting

9. When this occurs, the sludge blanket in the secondary clarifier rises and solids escape and are discharged in the effluent.

   a. Denitrification
   b. Rising sludge
   c. Bulking sludge
   d. Wasting

10. An operator notices the effluent is turbid and the DO in the aeration tank has increased dramatically even though the aeration rate has not changed. This may be a result of:

    a. An increase in BOD removal efficiency
    b. Increased nitrification rates
    c. Toxic influent
    d. Increased temperature

Exercise for Unit 3 – Microbiology of the Activated Sludge Process

1. Name four typical microorganisms found in activated sludge.

   a. bacteria
   b. protozoa
   c. rotifers
   d. worms

2. List three observations that are recorded in your activated sludge process.

   a. size and nature of floc particles
   b. microorganism counts
   c. filament index

3. List three possible process changes in an activated sludge process. Briefly explain the purpose of each change. Answers may vary. Here are some possible responses:

   a. Reducing the waste activated sludge (WAS) flow rate may remedy a decreasing MLSS problem.

   b. Increase the WAS rate if you see an increasing trend in rotifers.

   c. Increase air flow rate if the problem is rising sludge and the plant is not required to denitrify.

4. Bacterial growth occurs in four stages. The _____ phase is when cells begin to feed on themselves in the absence of another food supply and is an indicator of an older sludge with a low F/M ratio and a long MCRT.

   a. lag
   b. endogenous
   c. stationary
   d. log-growth

5. The _____ flow rate is used to control the mass of microorganisms in the aeration tank.

   a. influent
   b. RAS
   c. WAS
   d. nitrate recycle

6. _____ is caused by denitrification occurring in the secondary clarifier.

a. Bulking sludge
b. Rising sludge
c. Foaming
d. Frothing

7. The _____ should be temporarily increased to control a rising sludge blanket in the secondary clarifier.

a. WAS rate
b. RAS rate
c. influent flow
d. aeration rate

8. A certain amount of _____is essential in activated sludge because they are the "backbone" that holds bacterial flocs together, giving them good settling characteristics.

a. Short filaments
b. Long filaments
c. Rotifers
d. Nocardia

9. The most common short filament in activated sludge plants is called _____. They form short, web-like branches and can cause _____ and/or _____in the aeration tanks and excessive brown floating scum in secondary clarifiers.

a. Pseudomonas; foaming; frothing
b. Nocardia; denitrification; nitrification
c. Nocardia; foaming; frothing
d. Nitrosomonas; nitrification; denitrification

10. To promote conditions favorable for denitrification, reduce the air flow rate until the DO at the end of the aeration tank is in the range of _____ to _____ mg/L.

a. 0.0 to 0.2 mg/L
b. 0.2 to 0.5 mg/L
c. 2.0 to 4.0 mg/L
d. >4.0 mg/L