Wastewater Treatment Plant Operator Certification Training Instructor Guide

Module 16: The Activated Sludge Process Part II

Revised June 2014

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

A Note to the Instructor

Dear Instructor:

The primary purpose of this course, *Module 16: The Activated Sludge Process – Part II*, is to provide an overview of the activated sludge process control strategies, typical operational problems encountered during the process and the microbiology of the activated sludge process. This module has been designed to be completed in approximately 5 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topically outline. You may need to adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by DEP.

Web site URLs and other references are subject to change, and it is the training sponsor's responsibility to keep such references up to date.

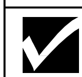
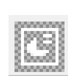
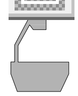
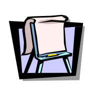
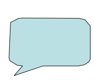
Delivery methods to be used for this course include:

- Lecture
- Exercises
- Calculations

To present this module, you will need the following materials:

- One workbook per participant
- Extra pencils
- Laptop (loaded with PowerPoint) and an LCD projector **or** overheads of presentation and an overhead projector
- Screen
- Flip Chart
- Markers

Icons to become familiar with include:

 Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.
 Case Study	Ans: Answer to exercise, case study, discussion, question, etc.
 Discussion Question	 PowerPoint Slide
 Calculation(s)	 Overhead
 Quiz	 Flip Chart
 Key Definition(s)	 Suggested "Script"
 Key Point(s)	

Instructor text that is meant to be general instructions for the instructor are designated by being written in script font and enclosed in brackets. For example:

[*Ask participants if they have any questions on how to read the table. Answer any questions participants may have about how to read the table.]*

If your module includes the use of a PowerPoint presentation, below are some helpful controls that you may use within the Slide Show.

PowerPoint Slide Show Controls

You can use the following shortcuts while running your slide show in full-screen mode.

To	**Press**
Advance to the next slide	N, ENTER, or the SPACEBAR (or click the mouse)
Return to the previous slide	P or BACKSPACE
Go to slide <number>	<number>+ENTER
Display a black screen, or return to the slide show from a black screen	B
Display a white screen, or return to the slide show from a white screen	W
Stop or restart an automatic slide show	S
End a slide show	ESC
Return to the first slide	Both mouse buttons for 2 seconds
Change the pointer to a pen	CTRL+P
Change the pen to a pointer	CTRL+A
Hide the pointer and button temporarily	CTRL+H
Hide the pointer and button always	CTRL+L
Display the shortcut menu	SHIFT+F10 (or right-click)
Erase on-screen annotations	E
Go to next hidden slide	H
Set new timings while rehearsing	T
Use original timings while rehearsing	O
Use mouse-click to advance while rehearsing	M

INTRODUCTION OF MODULE: 5 minutes

[Display Slide x—Module 16: The Activated Sludge Process – Part II.

Welcome participants to "Module16 – The Activated Sludge Process – Part II." Indicate the primary purpose of this course is to provide an overview of activated sludge process control strategies, typical operational problems encountered during the process and the microbiology of the activated sludge process.

Introduce yourself.

Provide a brief overview of the module.]

This module contains 3 units. On page i, you will see the topical outline for Unit 1 – Process Control Strategies and Unit 2 – Typical Operational Parameters.

[Briefly review outline.]

On this page, you will see the outline for the remainder of Unit 2 as well as the outline for Unit 3 – Microbiology of the Activated Sludge Process.

[Continue to briefly review outline.]

On this page, you will see the outline for the remainder of Unit 3.

[Continue to briefly review outline.]

[This page was intentionally left blank.]

UNIT 1: 130 minutes

[Display Slide x—Unit 1: Process Control Strategies.]

At the end of this unit, you should be able to:

- List the key monitoring points within the activated sludge process and explain what to look for at those points.
- List five key process control parameters and for each parameter, explain what it is, why it is used and how it is calculated.
- List the daily process control tasks that need to be accomplished and explain how to do them.

KEY MONITORING LOCATIONS: 50 minutes

We will start this unit by reviewing the key monitoring locations within the activated sludge process. Specifically, we will talk about monitoring the plant influent, the primary clarifier effluent, the aeration tank, the secondary clarifier, the internal plant recycles and the plant effluent.

Plant Influent

In order to effectively manage the operation of an activated sludge treatment plant, it is essential to know what is actually entering the plant. This is known as the plant influent. Monitoring influent characteristics and treatment plant capacity will enable you to manage the operation of the plant.

Effect of Influent Characteristics

[Review the information in the workbook.]

Large Flow Increase

[Review the information in the workbook.]

Large Influent Solids Increase

[Review the information in the workbook.

Be sure to review the definitions of mixed liquor volatile suspended solids and biochemical oxygen demand.]

[Review the definition of mixed liquor suspended solids in the workbook.

Continue to review information in the workbook.]

Monitor Treatment Plant Capacity

Major process upsets and NPDES permit violations can result when the plant is overloaded. The only way to determine when you are headed for an overload condition is to monitor the influent loadings and compare them to the plant's design capacity.

[Review the information in the workbook.]

Primary Clarifier

Monitoring the primary clarifier effluent characteristics and comparing it to the plant influent characteristics will enable you to determine the clarifier's efficiency and forecast potential upsets to the aeration tank. The parameters we will discuss are BOD/COD, TSS and nutrients.

Biological Oxygen Demand (BOD)/Chemical Oxygen Demand (COD)

[Review the first bullet item, and then share the following:]

Poor clarifier performance may be the result of several factors, such as excessive hydraulic loads, changes in the characteristics of the influent, and malfunctioning or improperly operated sludge removal equipment.

[Review the remaining information in the workbook.

Be sure to review the definition of flocculants in the workbook.]

Total Suspended Solids (TSS)

[Review the information in the workbook.]

Nutrients

[Review the information in the workbook.]

Aeration Tank

The heart of the activated sludge treatment plant is in the aeration tank. The goal of the activated sludge treatment process is for microorganisms in the aeration tank oxidize carbonaceous compounds and/or ammonia. These microorganisms will either thrive or struggle to stay alive based on the conditions in the aeration tank.

Operational Control Parameters

There are four operational control parameters that should be monitored to ensure the treatment process is optimized: the MLSS/MLVSS, the residual DO, pH and total alkalinity and the SOUR. We will begin with the MLSS/MLVSS.

[Review the information in the workbook.

Be sure to review the definition of nitrification and SOUR in the workbook.]

Color

Sometimes, a visual check of the mixed liquor can reveal operational problems.

[Review the information in the workbook.]

Microscopic Examination of Biomass (Mixed Liquor)

[Review the information in the workbook.]

Secondary Clarifier

In conventional activated sludge treatment plants without tertiary treatment, the secondary clarifier is often the final treatment unit used to remove Total Suspended Solids (TSS) from the wastewater before it is discharged to the receiving stream. Therefore, it is critical to monitor the performance of the secondary clarifier to ensure compliance with NPDES permit limitations.

Sludge Blanket Level

Monitoring the sludge blanket level is one way to determine the performance of the secondary clarifier.

[Review the information in the workbook.]

[Display Slide x—Manual Sludge Judge]

This is an example of a manual sludge judge. We will not discuss in detail, how the manual sludge judge operates; however, your workbook provides an overview of how to use a manual sludge judge.

[Display Slide x—Example 1 of an Ultrasonic Automated Sludge Blanket Monitor.]

This slide shows an example of an automatic sludge judge. Again, we will not review the details of how it operates, as there is an overview of the operational concepts in your workbook.

[Display Slide x— Example 2 of an Ultrasonic Automated Sludge Blanket Monitor.]

This slide simply shows another version of an automatic sludge judge.

Effect of Sludge Return Rate

Monitoring the effect of the sludge return rate is another indicator of the performance of the secondary clarifier.

[Review the information in the workbook.]

Floating Solids on Clarifier Surface

Another indicator of secondary clarifier performance is the presence of floating solids on the surface of the clarifier.

[Review the information in the workbook.]

Internal Plant Recycles

Internal plant recycles are another key monitoring location during the activated sludge process. There are potentially several areas within the activated sludge treatment plant where clarified water is recycled back to the primary clarifiers. It is important to monitor the solids levels in these recycled streams to avoid the buildup of excessive levels of inert solids in the secondary treatment system.

[Review the information in the workbook.]

[Display Slide x— Typical Internal Plant Recycles.]

This slide shows typical plant recycles. The recycles occur from the belt filter press, the anaerobic digester supernatant and the gravity thickener back to the primary clarifiers.

Plant Effluent

Monitoring what is leaving the plant, otherwise known as the plant effluent, is also an additional key monitoring point. It is our final monitoring point.

Turbidity

[Review the definition of turbidity in the workbook.

Review the information in the workbook.]

NPDES Permit Requirements

[Review the NPDES permit parameters in the workbook.]

Please remember that the parameters in Table 1.1 are “typical” and they may vary from one plant to another. They are not meant to indicate a specific requirement for all plants.

[Review the minimum standards table in the workbook.]

The concentration levels listed in this table cannot be exceeded; however, exceptions are permitted for treatment plants servicing combined sewers (sanitary and storm water), certain industrial categories and less-concentrated water from separate sewers.

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

KEY PROCESS CONTROL PARAMETERS: 55 minutes

Now that we have discussed where to monitor within the sludge process, we will move our discussion to parameters to control the activated sludge process. Parameters we will review include MCRT, F/M ratio, SVI, SOUR and sludge wasting.

THE TEXT IN RED WAS ADDED TO THE WB CONTENT.

Before we discuss process control parameters, there are four important math rules to discuss.

Basic Rules for Activated Sludge Math

Rule #1: milligrams per liter (mg/L) = parts per million (ppm)

These values are interchangeable in equations. If you are given a value in ppm, you can use that value in an equation that needs mg/L.

Sometimes you will be given percentage (%) rather than mg/L or ppm. However, understand that ppm is a form of percentage (%). To understand how, consider this: 0.6% = .006 = 6/1000 = 6000/1,000,000, or 6000 parts per million (ppm). Using this process, you can take the percentage you are given and convert it into a value you need in ppm. The value for ppm is interchangeable with the value for mg/L. For example: 6,000 ppm = 6,000 mg/L.

A rule of thumb to help you remember this relationship: 1% Solids in a waste stream = 10,000 mg/l. For example, if your digester TSS reading is 21,000 mg/l, that equals 2.1 % solids.

Rule #2: Generally, **when balancing solids in the aeration tank and in the clarifier**, the solids in the influent and in the effluent are negligible and may be eliminated in the balancing equation that we will discuss. The reason is that the influent and effluent solids loads are very small compared to the MLSS, Return Activated Sludge (RAS) and Waste Activated Sludge (WAS) loads. If you are given the information in a problem, you should include influent and effluent solids, however, if you are not given the information, they can be considered negligible.

Rule # 3: Loading Equations
For wastewater calculations, most of what needs to be done relates to converting loading (lbs, or lbs/day) to a concentration (mg/L or ppm) or vice versa. For purposes of learning the following equations, this training module uses '8.34' in the equations. Understand that 8.34 has units, but for your day to day calculations, it is more important that you understand that volume must be in million gallon units, flow must be in million gallons per day, and the concentration must be in mg/l or ppm.

Load equation (lbs) = conc. (mg/L) x volume (mil gal) x 8.34
and
Loading equation (lbs/day) = conc. (mg/L) x flow rate (mil gal/day) x 8.34

Note: The loading equation is provided to you during the Certification exam on the formula sheet.

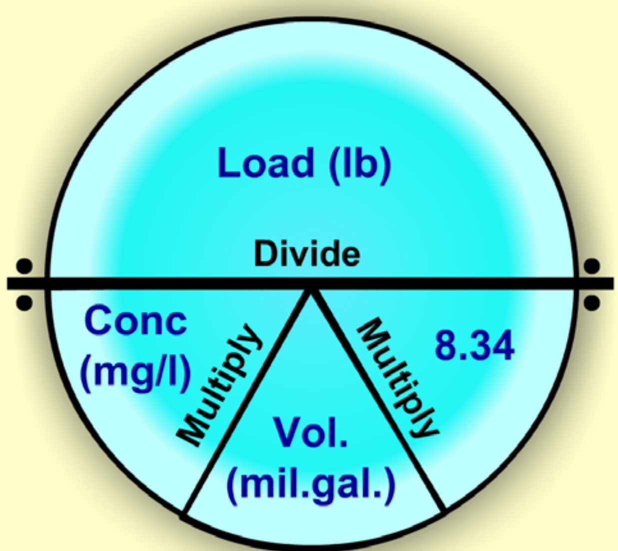
Using the first equation, for any concentration of a substance in a set volume (like a tank), you can find the lbs of that substance. For example, this equation is used to find solids in a tank (aeration tank, clarifier tank, etc.) for most of the activated sludge equations.

Using the second equation, for a given concentration of a substance and a flow rate (*not volume*) associated with that concentration; you can find the lbs/day loading of that substance. Notice that now we have a time associated with the load. This is because influent flows are constantly coming into the plant, so how many pounds of a substance comes in depends on what time frame you are looking at. Intuitively, the pounds of solids in 4 hours of influent flow would be less than the pounds of solids in 8 hours of influent flow. The preferred time unit for activated sludge calculations is 'day'.

> Example: For an influent flow of 3.4 MGD and an influent concentration of 250 mg/l. What is the solids loading to the treatment plant?
>
> Solution: The first clue is that we are dealing with flow (mgd), so the lbs/day equation is what we want to use.
> Solids (lbs/day) = 250 mg/L x 3.4 MGD x 8.34 = 7,089 lbs/day

Rule #4: If you need to find volume or concentration you can rearrange the equation using the following:

Load Equation: Load (lb) = Conc.(mg/l) x Vol (mil.gal.) x 8.34



Cover what you are missing (vol, conc, load). The answer for what you are missing is found by placing the remaining items in an equation as shown.

$$\text{Conc (mg/L)} = \frac{\text{Load (lb)}}{\text{Vol (mil gal)} \times 8.34}$$

$$\text{Vol (mil gal)} = \frac{\text{Load (lb)}}{\text{Conc (mg/L)} \times 8.34}$$

Tank Volume

Finally, sometimes you have to calculate a tank's volume so that it can be used in the loading equation. Volume equations are provided to you in the Operator Certification formula sheet during the exam. After the volume is determine in cubic feet, it must be converted to million gallons to be used in the loading equation.

Example: An aeration tank is 45 feet long and 25 feet wide. It is filled to a depth of 9 feet. What is the volume of the tank?

Based on the dimensions given, we can assume the tank is rectangular.

Volume = 55 ft x 35 ft x 10 ft = 19,250 ft^3

To convert this to gallons, we know that there are 7.49 gallons in 1 ft^3. So:

$$\frac{19{,}250\ ft^3 \times 7.49\ \text{gallons}}{1\ ft^3} = 144{,}182\ \text{gallons or } \mathbf{0.144\ million\ gallons.}$$

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

Mean Cell Residence Time (MCRT)

What Is MCRT?

The Mean Cell Residence Time (MCRT) or solids retention time is an average measure of how long the microorganisms remain in contact with the substrate (food source). MCRT is also known as solids retention time (SRT).

MCRT is not a mass balance, but rather a measure of how many days microorganisms are kept in the activated sludge process before being wasted. Activated sludge treatment systems are constantly generating new solids. In fact, as a rule of thumb, you will produce about 0.5 lbs of new solids per pound of BOD removed. So if you remove 100 pounds of BOD you will produce about 50 pounds of new solids. If you fail to remove the new solids produced, your treatment system will suffer deteriorated performance.

The amount of solids needed in your aeration system depends on a number of factors including design, weather and NPDES permit limits. Typically, any system with ammonia-nitrogen limits will require a higher MCRT, more air, and a corresponding higher MLSS concentration in the aeration basin.

NOTE: A longer sludge age (MCRT) yields less sludge production than a younger sludge age (MCRT). This is because BOD (food) is used for both maintenance energy (staying alive) and growth (using excess food beyond that needed for maintenance requirements)

$$\text{MCRT} = \frac{\text{Solids in the aeration system (lbs)}}{\text{Solids leaving the system, (lbs/day)}}$$

Let's look at each part of the equation.

'Solids in the aeration system' refers to solids in both the aeration tank and the clarifier.

There are two primary methods used to determine solids in the activated sludge system. The simplest method is to ignore the clarifier (for solving math problems, you may not be give information about the clarifier). The second method is to determine the volume of the aeration tank, as well as the volume of the clarifier, and use MLSS as the concentration in both tanks.

Depending on the information you are given, either of the following equations can be used to characterize solids in the activated sludge system. Please note: These are both "loading equations" discussed earlier.

Solids in aeration tank only = MLSS (mg/l) x aeration tank volume (MG) x 8.34

Solids in aeration and clarifier tanks =
MLSS (mg/l) x (aeration + clarifier tanks volumes) MG x 8.34

(This method assumes that MLSS is the concentration in the aeration tank as well as the concentration in the clarifier, if you mixed up the contents).

Now let's look at the denominator of the MCRT equation.

'Solids leaving the system' refers to the solids lost to waste activated sludge (WAS) and the solids leaving the clarifier through the effluent. Note again: These are the loading equations discussed previously.

Solids leaving as WAS lbs/day = WASSS mg/l x WAS flow MGD x 8.34

Solids leaving the clarifier as ESS lbs/day = ESS mg/l x discharge flow, MGD x 8.34

Putting the parts of the MCRT equation together:

$$\text{MCRT} = \frac{\text{solids in the aeration system, lbs}}{\text{solids in the effluent lbs/day + solids wasted lbs/day}}$$

Note: This formula is included in the sheet you receive during the certification exam.

Example: Calculate the MCRT given the following information:

- MLSS = 2,500 mg/l
- Aeration tank volume = 1.3 MG
- Effluent suspended solids (ESS) = 12 mg/l
- Flow (Q) = 3.3 MGD
- Waste activated sludge suspended solids (WASSS) = 5200 mg/l
- WAS flow = 0.4 MGD
- Optimal MCRT = 4 days

Since you are not given information regarding the clarifier, you can use the aeration tank only to find solids in the aeration system. Substituting into the above equation:

$$\text{MCRT} = \frac{\text{2,500 mg/l x 1.3 MG x 8.34}}{\text{12 mg/l x 3.3 MGD x 8.34 + 5,200 mg/l x 0.4 mgd x 8.34}}$$

$$\text{MCRT} = \frac{\text{27,105 lbs}}{\text{330.3 lbs/day + 17347.2 lbs/day}}$$

MCRT = 1.53 days

Why Is It Used?

- Control of the plant using the MCRT is accomplished by adjusting the sludge wasting and return rates to achieve the desired MCRT.
- Let's look at the equation again:

$$\text{MCRT} = \frac{\text{Solids in the aeration system (lbs)}}{\text{Solids leaving the system, (lbs/day)}}$$

You can see that increasing the "solids leaving the system" (wasting), will decrease the MCRT (or shorten the solids retention time).

In general:

- o Increasing the wasting rate will decrease the MCRT
- o Decreasing the wasting rate will increase the MCRT.

- NOTE: A longer sludge age (MCRT) yields less sludge production than a younger sludge age (MCRT). This is because BOD (food) is used for both maintenance energy (staying alive) and growth (using excess food beyond that needed for maintenance requirements)

Typical Values

- MCRTs ranging from 3 to 15 days are typical for conventional activated sludge plants. MCRTs less than 3 days will produce a sludge that is young and slow settling and produce a turbid effluent.

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

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

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

$$\text{MCRT} = 14.68 \text{ days}$$

Food/Microorganism Ratio (F/M Ratio)

What Is F/M Ratio?

[Review the definition of F/M ratio in the workbook.]

Why Is It Used?

[Review the first and last bullet item in this section.]

How Is It Calculated?

Let's take a look at the formula used for calculating the F/M.

[Review the elements of the formula as listed.]

Sample Calculation

Now that we have been introduced to the formula, let's take a look at a sample calculation. In this calculation we will be determining F/M ratio at this treatment plant.

[Review the steps of the sample calculation in the workbook.]

Typical Values

[Review the typical F/M ratios in the workbook.]

Calculation

Now that we have reviewed a sample calculation and the typical F/M ratios, do the calculation in the workbook on your own.

[Allow 3-5 minutes for participants to do the calculation and then review the answer with them.]

- Step 1: Calculate the influent BOD_5
  - Influent BOD_5 = (200 mg/l) x (1.0 mgd) x 8.34

    = 1668 lbs/day
- Step 2: Calculate the lbs of MLVSS in aeration
  - MLVSS in aeration = (0.5 mgd) x (2000 mg/l) x 8.34

    = 8340 lbs MLVSS
- Step 3: Calculate F/M ratio

$$\frac{1668 \text{ lbs/day } BOD_5}{8340 \text{ lbs MLVSS-day}} = 0.2$$

Sludge Volume Index (SVI)

Our next process control parameter is the sludge volume index.

What Is SVI?

[Review the definition of SVI in the workbook.]

Why Is It Used?

[Review the information in the workbook.]

How Is It Calculated?

[Review the information in the workbook.]

Calculation

[Allow participants 3-5 minutes to perform the calculation in the workbook and then review the solution with them, using a flipchart.]

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

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

Typical Values

[Review the information in the workbook.]

Specific Oxygen Uptake Rate (SOUR)

The SOUR is our next process control parameter.

What Is Sour?

[Review the definition of SOUR in the workbook.]

Why Is It Used?

[Review the information in the workbook.]

How Is It Calculated?

We will not perform any actual SOUR calculations in this module; however, your workbook highlights how the SOUR is calculated and provides a reference you can consult for further details on SOUR calculations.

Typical Values

[Review the information in the workbook.]

Sludge Wasting

Our final process control parameter is sludge wasting.

[Review the information in the workbook.]

Remember, the goal in activated sludge treatment is to maintain a healthy population of microorganisms in the aeration tank in just the right concentration to achieve effluent quality standards. When your plant is achieving treatment objectives and operating steadily, you want to discard biomass at a rate roughly equal to the rate of new cell growth.

Why Is Sludge Wasted?

[Review the information in the workbook.]

How Is Sludge Wasted?

[Review the information in the workbook.]

[Display Slide x— Solids Wasting.]

Given the large volume of water in this waste stream, WAS is typically wasted from the return activated sludge (RAS) line to either the primary clarifier or a solids thickener to reduce the water content prior to anaerobic digestion, as shown in this slide.

[Review the information in the workbook.]

Two means of wasting sludge are through the primary clarifier or through a solids thickener.

Primary Clarifier

[Review the information in the workbook.]

Solids Thickeners

[Review the information in the workbook and refer to Figure 1.8.]

- Calculating the Sludge Wasting Rate – This section has been modified to include only the WAS rate calculation using the MCRT parameter and the MCRT formula as discussed previously. We are leaving in the examples on WB pages 1-X and 1-X for reference only. We will use the same example problem from WB 1-X but this time we will give them the MCRT and they must solve for the WAS rate.

VERIFY THE PAGE NUMBERS ABOVE.

As mentioned previously, the F/M ratio or the MCRT parameters are typically used to control the activated sludge process. How the sludge wasting rate is calculated depends on which of the two parameters you use to control the process. Examples are given in your WB for using both parameters for your reference. We will use the target MCRT parameter and associated data to calculate the sludge wasting rate. Take a look at the example in your workbook on page 1-X to see how you would use the data provided to solve the problem.

Ask the students if they have any questions before having them solve the next problem on page 1-30. Give them 5-10 min. to work on the problem and then go over the calculation.

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

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

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

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

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

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

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

$$\text{WAS} = 0.06 \text{ mgd}$$

DAILY PROCESS CONTROL TASKS: 30 minutes

In this section of the unit, we will discuss daily process control tasks such as recordkeeping, reviewing the log book and reviewing lab data. By keeping accurate and complete daily records of process parameters, meter readings and calculations, and visual observations, you will develop an understanding of the activated sludge process and will be able to determine the optimal ranges for process parameters. Maintaining consistent records will also enable you to identify potential plant upset conditions before they impact the plant's effluent quality.

Recordkeeping

[Review the information in the workbook.

Display Slide x— Example 1 of Monthly Data Sheet.]

This slide is one example of what a lab data sheet would look like. You will see listed across the top of the data sheet the various process parameters we just discussed. The data table is used to monitor and control activated sludge plants. It is an effective means to summarize, in a concise manner, the process parameters that you need to control the operation of the plant. Note that this is only an example and that you should tailor your monthly data sheets to include those process parameters that you need to control the plant.

[Display Slide x— Example 2 of Monthly Data Sheet.]

This slide shows an additional example of another type of monthly data sheet. It contains much of the same information you see on the first example, with a few minor differences. For example, this monthly data sheet contains additional information such as weather (third column) and cost data (lower right quadrant of sheet).

[Review the bullet item in the workbook.

Display Slide x— Example 1 of Process Parameter Plot.]

This slide as well as the next, show examples of process parameter plots for several parameters, such as influent solids loading, flow, waste sludge rate, aerator air flow rate, and SVI.
Notice that these plots are "stacked" on top of a common time axis. This allows you to see how the process parameters are affected when changes to the system are made.
In Figure 1.11, a storm occurring during days 3 through 5 resulted in a spike in influent flow to the plant.

[Display Slide x— Example 2 of Process Parameter Plot.]

In Figure 1.12, the plot shows that the influent flow spike caused a washout of volatile suspended solids from the aeration system and a decrease in % aerator volatile solids. In response to this process upset, the operator slowly decreased the sludge wasting rate to build the mass of MLVSS and the % volatile solids back up to design values.

Process Parameters

There are several process parameters that should be monitored daily and recorded. They include: TSS and VSS; BOD, COD or TOC; DO; settleable solids/SVI; temperature; pH; clarity; chlorine demand and coliform group bacteria. We will not discuss each of these parameters in detail, however, your workbook provides important information about each of these parameters that you can read about.

TSS and VSS

Note that the TSS and VSS are monitored at different locations.

BOD, COD, or TOC

[Review the information in the workbook.

When discussing the third bullet, in regards to the comparison of COD and BOD, write the following example on a flipchart and discuss.]

For example, a treatment plant has historical primary clarifier effluent COD and BOD data, and has determined that for every 1 mg/l of COD there is 0.8 mg/l of BOD.
Therefore, if checking the effluent from the primary clarifier and a COD test is conducted, the operator can estimate the BOD by multiplying the result by 0.8.

If the a sample was taken and analyzed for COD and the result was 210 mg/l then:

210 X 0.8 = 168 mg/l BOD
Based on this calculation you can estimate that the BOD for the primary clarifier effluent is 168 mg/l. This is only an estimate of the BOD. If an actual value is needed then the BOD test will have to be conducted.

DO

[Only review the first bullet item in the workbook.]

Settleable Solids/SVI

[Only review the first bullet item in the workbook.]

Temperature

[Review the bulleted items in the workbook.

Display Slide x—Typical Ranges in Influent Wastewater Temperature.]

pH

[Review the first bullet item in the workbook.]

Clarity

[Review the first bullet item in the workbook.]

Chlorine Demand

[Review the first bullet item in the workbook.]

Coliform Group Bacteria

[Review the first bullet item in the workbook.]

Meter Reading & Calculations

Meter readings and calculations are also helpful for monitoring plant performance.

[Review the meter readings listed in the workbook.]

Your workbook shows you how the meter readings are used to determine various process control parameters. We will not discuss this in detail during this training module; however, the information is there for your use.

Observations

In addition to process parameters and meter readings and calculations, simple observations can provide important information about your plant performance.

[Review the bolded bullet items only and not the detailed information provided for each bullet.]

Review Log Book

In addition to daily recordkeeping, the treatment plant operators should also review the plant log book as part of their daily process control tasks.

[Review the information in the workbook.]

Review Lab Data

Reviewing the lab data is the final task that should be completed daily.

[Review the information in the workbook.]

[Review the Key Points for Unit 1 – Process Control Strategies.]

Exercise for Unit 1 – Process Control Strategies

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

    $\frac{300\ mL/L}{3,900} \times \frac{1,000\ mg}{1\ g} = 76.9$

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**

[Indicate that references are listed on this page.]

We have now completed the first unit of this module. You should now be familiar with the key monitoring locations within the plant, the key process control parameters and daily process control tasks. In the next unit we will learn about typical operational problems you may encounter in the plant.

[This page was intentionally left blank.]

UNIT 2: 75 minutes

[Display Slides—Unit 2: Typical Operational Problems.]

At the end of this unit, you should be able to:

- List six common process operational problems.
- List and explain possible plant changes that may result in process operational problems.
- Define sludge bulking, explain what causes it and identify possible solutions.
- Define septic sludge, explain what cause it and explain possible solutions.
- List five classifications of toxic substances and explain their effects on biological treatment systems.
- List and explain institutional, design and process controls that can be used to control toxic substances.
- Define rising sludge, explain what causes it and identify possible solutions.
- Explain what causes foaming/frothing and possible solutions.
- Explain the significance of the Process Troubleshooting Guide.
- List and explain seven common equipment operational problems.
- Describe the maintenance required for surface aerators, air filters, blowers, the air distribution system and the air header/diffuser.

PROCESS OPERATIONAL CHANGES: 40 minutes

In this unit, we are going to discuss operational problems you may encounter during the activated sludge process. Specifically, we will discuss typical problems you will encounter and how to resolve them. We will also look at a troubleshooting guide that will be a useful tool when you encounter problems. Finally, we will discuss some typical problems you may encounter with the equipment used at the plant.

Plant Changes

Making plant changes is one area that can cause process problems. Before making any adjustments or corrective actions to resolve an upset condition, review the process data for the past several weeks. Usually, the cause for an upset condition occurs at least a week before any symptoms are noticeable. Often plant upset conditions are caused by changes in digester supernatant solids concentrations, plant influent flow and strength, ambient and influent temperature and internal sampling programs. Let’s begin with the digester supernatant solids concentrations.

High Digester Supernatant Solids

[Review the information in the workbook.]

Plant Influent Flow and Waste Characteristic Changes (BOD/COD, TSS)

Toxic dumps, accidental discharges, seasonal industrial discharges, and storms affect the flow and strength of the influent wastewater. These occurrences can’t be controlled by the operator, so the best thing to do is to keep good monitoring records and be alert for the first signs of a rapidly changing plant influent.

[Review the information in the workbook.]

Temperature Changes

[Review the information in the workbook.]

Sampling Program Changes

[Review the information in the workbook.]

Sludge Bulking

The next area that can cause process problems is sludge bulking.

[Review the definition of sludge bulking in the workbook.]

Causes

[Review the information in the workbook.]

Solutions

There are five potential solutions to sludge bulking: increase the MCRT, increase the DO, increase hydraulic detention time in the aeration basin, chlorinate the return sludge or add a flocculant such as alum, ferric chloride or ferric sulfate. Let’s briefly discuss each of these solutions.

Septic Sludge

Septic sludge is another potential problem you may encounter in an activated sludge plant.

[Review the definition of septic sludge in the workbook.]

Causes

[Review the information in the workbook.]

Solutions

[Review the information in the workbook.]

Rising Sludge

Rising sludge is yet another operational problem you may encounter.

[Review the definition of rising sludge in the workbook.]

Causes

[Review the information in the workbook.]

Denitrification occurs when bacteria convert nitrite and nitrate to nitrogen gas in an anoxic environment. The nitrogen gas produced by the bacteria clings to the sludge and raises it to the surface.

Solutions

[Review the information in the workbook.]

Foaming/Frothing

Foaming or frothing on the surface of the aeration tank is another operational problem.

[Review the definition of foaming/frothing in the workbook.]

Causes

There are many theories for the causes of foam accumulation in aeration tanks—we will review two of them.

[Review the information in the workbook.]

Solutions

[Review the information in the workbook]

Toxic Substances

Toxic substances present unique process operational challenges because the operator has little control over what enters the plant and toxic substances have the potential to severely impact the activated sludge process. Basically, there are three methods of controlling or addressing the discharge of toxic substances to your plant: institutional controls, design controls, and process controls. These control methods will be discussed later.

[Review the information in the workbook.]

Classifications

Toxic substances are categorized as heavy metals, inorganic compounds, organic compounds, halogenated compounds or as pesticides, herbicides and insecticides.

[Review the information in the workbook on heavy metals, with the exception of the list of examples. Be sure to point out to participants that examples are listed in their workbook for their reference.

Review the information in the workbook on inorganic compounds.]

[Review the information in the workbook on organic compounds.

Review the definition of VOC in the workbook.

Review the information in the workbook on halogenated compounds.

Review the definition of halogenated compounds in the workbook.]

[Review the information in the workbook on pesticides, herbicides and insecticides.]

Effects on Biological Treatment Systems

[Review the information in the workbook.]

Since toxic substances pose such a danger, it is necessary to have controls in place to manage their presence. We will discuss three categories of controls: institutional controls, design controls and process controls.

Institutional Controls

[Review the definition of institutional controls in the workbook.]

There are two types of institutional controls: prohibited discharge standards and categorical standards. We will not spend time discussing the difference between the two, but your workbook contains information explaining how they differ.

Design Controls

[Review the definition of design controls in the workbook.

Review the information in the workbook.]

Process Controls

[Review the information in the workbook.]

Exercise

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.

PROCESS TROUBLESHOOTING GUIDE: 20 minutes

Process Troubleshooting Guide

This section presents comprehensive process troubleshooting guidelines for activated sludge treatment plants. This guide lists most of the common process operational problems encountered in municipal wastewater treatment plants and provides probable causes, suggested monitoring activities as well as potential solutions.

[Review the information in the workbook.]

This is the first page of the Troubleshooting Guide. We will not do an in depth review of the content of the guide, but let's take a look at how it is organized and what type of information is included. The guide has four columns. The first column lists the indicator or observation, in other words, the problem the plant is experiencing. The second column lists probable causes of the problem. The third column tells you what you should check or monitor and the fourth column lists potential solutions. The Troubleshooting Guide lists a total of twelve indicators or observations. We will not review them, but just to give you an idea, here are a few of the indicators/observations listed in the guide: sludge concentration in return sludge is low, sludge blanket overflowing secondary clarifier weirs uniformly and thick billows of white sudsy foam on the aeration tank. During the next ten minutes, review the guide and complete the exercise on page 2-17.

[Indicate that this is the second page of the Troubleshooting Guide.]

[Indicate that this is the third page of the Troubleshooting Guide.]

☑ Exercise

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.

EQUIPMENT OPERATIONAL PROBLEMS AND MAINTENANCE: 15 minutes

Surface Aerators

The troubleshooting guide we just reviewed will assist you with process problems; however, other problems, in the form of equipment problems can occur at the plant as well. We are going to discuss some of the common operational problems and maintenance issues associated with the equipment in the plant.

Operational Problems

Table 2.2 indicates some of the problems associated with the surface aerator. As you can see, there are a number of places where problems can occur – the motor, the gear reducer, the shaft coupling and the impeller. This table also lists abnormal conditions, possible causes of the problem and what the operator should do to correct the problem.

Maintenance

There are some general maintenance guidelines that should be followed with the surface aerator. Let's review them.

[Review the information in the workbook.]

Air Filters

The aeration system may experience operational problems, if using diffused air to aerate the activated sludge. The air filter is one piece of equipment that may experience problems.

Operational Problems

[Review the information in the workbook.]

Maintenance

[Review the information in the workbook.]

Blowers

Malfunctioning blowers are another possible operational problem at the plant.

[Review the information in the workbook.]

Operational Problems

Table 2.3 lists some common operational problems associated with the blowers. Some of those problems include unusual noises or vibration, air flow problems, motor problems or oil temperature problems. As with table 2.2, this table also includes information about abnormal conditions, possible causes and operator responses.

Maintenance

[Review the information in the workbook.]

Air Distribution System

The next area where operational problems may occur is in the air distribution system.

[Review the information in the workbook.]

Operational Problems

Here is another table like the previous two. It has the same type of information we saw in tables 2.2 and 2.3, so we will not review it in detail at this time.

Maintenance

[Review the information in the workbook.]

Air Header/Diffusers

Another source of potential problems in the plant is the air header/diffusers.

[Review the information in the workbook.]

Operational Problems

Again, your workbook contains a table indicating potential operational problems associated with the air header/diffusers. Table 2.5 refers to the air header while table 2.6 refers to the air diffuser. Since these two tables are organized like the previous tables, we will not review them at length. Like the previous tables, these are a good reference for you to use back at your plant.

[Review the information in the workbook.]

On this page you will find the table for the diffusers.

Maintenance

[Review the information in the workbook.]

Motors

As you can imagine, problems with motors can occur as well.

Operational Problems

[Indicate that motor operational problems were already covered in the review of the surface aerator.]

Gear Reducers

The final source of potential equipment problems you should be aware of is the gear reducers.

Operational Problems

[Indicate that gear reducer operational problems were also covered in the review of the surface aerator.]

[Review the Key Points for Unit 2 – Typical Operational Problems.]

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 is 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 is 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

[Point out that references are listed on this page.]

We have now finished this unit of the training module. You should be familiar with common process operational problems and equipment operational problems and you should be able to locate information that will assist you in identifying potential solutions. In our next unit, we will discuss the microbiology of the activated sludge process.

UNIT 3: 85 minutes

[Display Slide x—Unit 3: Microbiology of the Activated Sludge Process.]

At the end of this unit, you should be able to:

- Explain why microbiology is important to the activated sludge process.
- List and identify four typical microorganisms found in activated sludge.
- List the equipment required during sample collection.

[Display Slide x—Unit 3: Microbiology of the Activated Sludge Process.]

- Identify four sampling locations for various treatment plant processes.
- Explain two methods of sample preparation.
- Identify the components of a microscope typically used at Wastewater Treatment Plants.

[Display Slide x—Unit 3: Microbiology of the Activated Sludge Process.]

- Explain three common observations that are recorded.
- List and explain three means of interpreting results of microscopic observations
- Explain how to decide when to make a process change.

[Display Slide x—Unit 3: Microbiology of the Activated Sludge Process.]

- List possible process changes that can be made and explain what the purpose of each process change is.
- Explain how frequently processes should be monitored during good operations, poor operations and following a process change.

WHY IS MICROBIOLOGY IMPORTANT IN ACTIVATED SLUDGE?: 5 minutes

So far we have talked about strategies for controlling the activated sludge process as well as problems you may encounter in the process. Now we need to spend some time talking about microbiology and its role in the activated sludge process.

Activated Sludge is a Biological Process

[Review the information in the workbook.]

Tools for Process Control

Microbiology is essentially a tool that is used to control the activated sludge process and to forecast potential problems at the plant. You can read your workbook for more information about using microbiology as a tool.

MICROORGANISMS IN ACTIVATED SLUDGE: 15 minutes

As we already mentioned, there are many different types of microorganisms used to treat wastewater. You should be familiar with some of these organisms, so we will spend the next section of our training discussing the microorganisms typically found in activated sludge: bacteria, protozoa, rotifers, worms, fungi and algae.

Bacteria

Bacteria are single-celled organisms and they are the most predominate microorganism found in activated sludge. Most bacteria are approximately 0.5 to 1.0 microns (1 micron = 10^{-6} meters = 1/25,400 inch) wide by 2.0 to 5.0 microns long. Their small size makes individual bacteria difficult to see using microscopes typically used in activated sludge plants. You can see, however, clumps of bacteria, or flocs, under the microscope. Your workbook contains additional information about bacteria, but we will not review it here.

[Display Slide x—Typical Growth Cycle for Bacteria.]

This slide shows the growth cycle for bacteria.

[Review the information in the workbook and be sure to point out each phase on the slide as you review it]

Filaments are a special type of bacteria and are either classified as long or short. There are many different types of long filaments, which makes identifying them difficult and time consuming. Therefore, you shouldn't be concerned with identifying the type of long filaments. Rather, you should focus on learning how to identify increasing trends in long filament growth. Your workbook goes into more detail about long and short filaments, but due to time constraints, we will not review that information now.

[Display Slide x—Filamentous Bacteria Found in Sludge Bulking.]

This slide shows examples of different types of filamentous bacteria.

[Point out to participants that additional information about short filaments is included on this page.]

Protozoan

The next type of microorganism we will discuss is protozoa.

[Review the definition of protozoa in the workbook.

Review the second bullet item in the workbook.

Display Slide x—Protozoa.]

This slide shows the five different types of protozoa. Notice how they all differ in shape, yet the one thing they all share in common is that they are single celled organisms.

Rotifers

The next type of microorganism you will encounter in activated sludge are rotifers.

[Review the definition of rotifers in the workbook.

Review the information in the workbook.]

Worms

Worms are another type of microorganism found in activated sludge.

[Review the information in the workbook.]

SAMPLE COLLECTION AND PREPARATION: <u>20 minutes</u>

In order to observe the various types of microorganisms we have just discussed, it is necessary to collect a sample of the activated sludge. For the next several minutes, we will review some key information about collecting and preparing samples, beginning with a discussion of the equipment used for sample collection.

Equipment

Sample Collection

[Review the information in the workbook.

Display Slide x—Dipper Pole and Bottle Holder.]

This slide shows what a dipper pole and bottle holder looks like.

[Review the information in the workbook.]

Sampling Locations for Various Treatment Processes

As in all types of sampling, it is important to collect a sample that is representative of actual conditions. You should collect your sample from the same spot in the aeration tank at the same time each day and preferably at the same time you collect your SVI sample. This way, you'll be able to correlate microscopic observations with sludge settling characteristics.

[Review the information in the workbook.

Display Slide x—Sampling Locations.]

This slide shows where samples should be collected in conventional, step-feed, contact stabilization and extended aeration plants. The appropriate sampling location is indicated by the circle with the "x" in it. The P.E. represents the "Primary Effluent" entry point and the RAS represents the "Return Activated Sludge" entry point into the activated sludge process.

Conventional Activated Sludge Plant

[Continue to display Slide x—Sampling Locations.

Review the information in the workbook and indicate the sampling location for conventional on the slide.]

Step Feed

[Continue to display Slide x—Sampling Locations.

Review the information in the workbook and indicate the sampling location for step-feed on the slide.]

Contact Stabilization

[Continue to display Slide x—Sampling Locations.

Review the information in the workbook and indicate the sampling location for contact stabilization on the slide.]

Extended Aeration

[Continue to display Slide x—Sampling Locations.

Review the information in the workbook and indicate the sampling location for extended aeration on the slide.]

Sample Preparation

Now that the sample has been collected, it needs to be prepared. This is accomplished with either a wet mount slide when observing live organisms or with a stained dry slide when observing stained filamentous bacteria. Your workbook contains additional information regarding the supplies you need to prepare your sample.

MICROSCOPIC OBSERVATIONS: 20 minutes

At this point, our sample has been collected and is prepared. Now it is time for us to observe the sample. Since the organisms we need to observe are not visible to the naked eye, a microscope is used to observe the sample. There are several categories of microscopes, as you can see in your workbook. Since the most common microscope found in an activated sludge plant is the basic compound light microscope, that is the type we will discuss in detail.

The Microscope

Component Parts

[Display Slide x—Compound Microscope.]

This slide shows a typical compound microscope. Let's review the major components, beginning with the eyepiece. This is the part of the microscope you look into. The eyepiece should have a magnification of 10X. The total magnification is equal to that of the eyepiece times the objective.

Moving clockwise, the next major component is the revolving nosepiece which is rotated to change the objective lens.

Beneath the nosepiece is the objective. The objective lenses are used in conjunction with the eyepiece to magnify the image. Typical objective magnifications are 43X, 97X and 100X. The 97X and 100X objectives require the use of immersion oil between the objective lens and cover glass, so you will be primarily using the 43X lens, which provides a total of 430X magnification.

Below the objective is the stage, which is where the cover glass is secured for viewing. Some microscopes have mechanical stages that allow you to adjust the slide forward, backward, left or right.

Under the stage is the condenser, which focuses the light from the illuminator so that adequate light reaches the objective.

Below the condenser, you will see the diaphragms, which is used to adjust the amount of light that reaches the objective. Close the diaphragm if image is too bright.

At the bottom of the microscope, resting on the base is the illuminator, which generates the light that focused by the condenser.

Moving up the left side of the microscope, you will find the fine and the coarse adjustments. These are used to focus the image.

Recording Observations

While observing a sample under the microscope, there are a number of things you will see. You will need to record some of your observations, which is what we will discuss now.

Size and Nature of Floc Particles

[Review the information in the workbook.]

Microorganism Counts

[Review the information in the workbook.

Display Slide x—Microorganism Counts on a Slide.]

This slide demonstrates how microorganisms are counted on a slide by dividing it into the 28 fields we just discussed.

[Review the bullet item in the workbook.

Display Slide x—Worksheet for Microorganism Counting.]

This is an example of a worksheet that can be used for counting microorganisms. Note the three process control parameters on the bottom of the worksheet – SVI, F/M ratio and MCRT. You can see from the worksheet that sludge with a high SVI, high F/M ratio and a low MCRT will likely have a predominance of amoeboids and large flagellates, while a sludge with a low SVI, low F/M ratio and high MCRT will likely have a predominance of rotifers and long filaments.

[Review the remaining bullet items in the workbook.]

Filament Index

[Review the definition of filament index in the workbook.

Display Slide x—Technique for Counting Filaments.]

This slide shows the technique in practice. As you can see, there are three fields, labeled #1, #2 and #3. In each field, you can see the etched diagonal line. This line is used to count the number of times a filament crosses it. In field #1, we see that a filament crosses the line 5 times, while in field #2, no filaments cross the line. In the final field, there are 4 filaments that cross the etched line. As the slide indicates, a total of 28 fields are counted and those 28 numbers are added together to give us the filament index. Based only on these three fields, our count currently stands at 9.

[Review remaining bullet item in the workbook.]

RESPONSE TO RESULTS: <u>20 minutes</u>

For the remainder of this unit, we will discuss how to respond to the results obtained from your sample collection and microscopic observation.

Indicators of Stable and Unstable Treatment Process

[Review the information in the workbook.

Display Slide x—Indicators of Stable and Unstable Treatment Processes.]

This slide demonstrates the indicators of stable and unstable processes. The arrow along the left side of the graphic indicates the predominance of the organisms, while along the bottom we see three process parameters: SVI, F/M and MCRT. If you look at the middle column of the graphic, you can visually see our initial point—a good settling floc, which is our goal, will primarily contain some rotifers and a large number of stalked and free-swimming ciliates. Some flagellates will be present as well and even few amoeboids. Your workbook includes some additional information about these indicators.

Microscopy vs. Process Data

[Review the information in the workbook.]

Changes in Microorganism Populations

[Review the information in the workbook.]

Deciding When to Make a Process Change

[Review the information in the workbook.

After the last bulleted question, share the following with the participants:]

Deciding when to make a process change is an important task. There are several questions you should ask yourself before making a process change—those questions are listed in your workbook for your review. It is important to remember not to rely on deteriorating effluent quality and process parameters (i.e., MCRT, SVI, F/M ratio) alone to make process changes because it may be too late. Try to base most of your process changes on microscopic observations. This should help you to maintain a good quality effluent for longer periods of time.

Which Process Changes to Make

In conventional activated sludge treatment plants, the process is changed by adjusting the process air flow rate, waste activated sludge (WAS) rate, return activated sludge (RAS) rate and number of tanks in service. We will now review these adjustments further.

Process Air Flow

Decreasing MLSS

[Review only the bulleted item in the workbook and then point out to participants that this point is further exemplified by the example in their workbook.]

Rising Sludge

[Review information in the workbook.]

[Continue to review bulleted items in the workbook regarding rising sludge.]

Waste Activated Sludge (WAS) Flow Rate

[Review the information in the workbook.]

Return Activated Sludge (RAS) Flow Rate

[Review the information in the workbook.]

Number of Tanks in Service or Plant Changes (Drastic Changes)

[Review the first bullet item in the workbook.]

Examples of drastic changes include: taking a primary clarifier out of service to increase the F/M ratio, taking an aeration basin out of service to decrease aeration detention time, changing to step feed or contact stabilization to reduce SVI and sludge blanket level or changing to conventional activated sludge to reduce *Nocardia*.

[Return to the workbook and continue to review the bulleted items.]

[Point out to participants that details regarding each of the drastic process changes are included on this page for their review.]

How Much Change to Make

In addition to knowing what kind of change to make or when to make a change, determining how much change to make is a crucial decision in the operation of the activated sludge plant.

[Review the information in the workbook.]

MONITORING PROCESSES: 5 minutes

Frequency of Monitoring

As a new plant operator, you should make microscopic observations daily for several months. Make observations at low flow and high flow if your influent flow rate varies significantly throughout the day. Once you become familiar with the operation and the microbiology of your plant, you can reduce the frequency of observations.

Good Operation

[Review the information in the workbook.]

Poor Operation

[Review the information in the workbook.]

Following Process Change

[Review the information in the workbook.]

[Review the Key Points for Unit 3 – Microbiology of the Activated Sludge Process.]

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

[Point out that references *are listed on this page.]*

We have now completed this module. You should have a good understanding of various strategies used to control the activated sludge process, the types of operational problems encountered at a wastewater treatment facility and the microbiology of the activated sludge process. Are there any questions about the material we have discussed?