Wastewater Treatment Plant Operator Certification Training Instructor Guide

Module 6: Solids Handling and Disposal

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 *Module 6: Solids Handling and Disposal* is to provide an overview of the primary methods of solids digestion. This module has been designed to be completed in approximately 3 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
- Full group discussion

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

- One workbook per participant
- Operation of Wastewater Treatment Plants, Volume II
- Extra pens and pencils Flip Chart Markers
- Laptop (loaded with PowerPoint) and an LCD projector or Overheads of presentation and an overhead projector
- Screen
- Flip Chart

Icons to become familiar with include:

Participant Workbook	Instructor Guide
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 is 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: 10 minutes

[Display Slide 1, Wastewater Treatment Plant Operator Training. (This slide can also be displayed as the participants are entering the room to let them know they are in the correct location.)]

[Welcome participants to "Module 6: Solids Handling and Disposal." Indicate the primary purpose of this course is to provide participants with an overview of the primary methods of solids digestion.

Introduce yourself.

Ask the participants to introduce themselves, including job title and plant location. (Note: you may utilize another introductory activity if you desire.)]

The complete digestion and final disposal of sludge is an integral part of the wastewater treatment process. The digestion process reduces the volume (and hence weight) of the volatile portion of the sludge, and creates less volume to deal with for the processes that follow. These processes include dewatering, hauling, incineration, composting, disposal in a landfill or land application. In general, the less volume, the less expense is incurred.

During digestion pathogens are also reduced. Depending on the final disposal method, other reductions in viable pathogens may not be necessary. If the disposal method only requires a process to reduce pathogens, such as incineration, disposal in a landfill, and controlled land application, then the sludge can be disposed of directly from the digester. If the disposal method requires further reduction of pathogens, such as direct marketing, then other treatment must take place before the sludge can leave the plant. Either way, after digestion there is a lower volume of sludge.

Digestion also improves the ability of the solids to shed water when it is time to further reduce the volume to be handled. During dewatering, the higher the resulting solids content the better. The only time you may not want a high solids content is when land applying liquid sludge, or when high solids sludge is clogging your equipment.

There are two types of digestion: anaerobic and aerobic. Unit 1 will cover anaerobic digestion and Unit 2 will cover aerobic digestion.

[Review the topical outline for each unit.]

During Unit 1–Sludge Thickening, we will discuss the purpose of sludge thickening as well as the various methods used to thicken sludge.

In Unit 2—Anaerobic Digestion, we will review:

- Why solids are digested and how the anaerobic digestion process works.
- The main components of an anaerobic digester and gas system.
- The process of starting, feeding, and operating an anaerobic digester.
- The testing, troubleshooting, and cleaning requirements of a digester.

During Unit-3—Aerobic Digestion, we will discuss:

- How the aerobic digestion process works.
- The process of operating an aerobic digester.

During Unit-4—Solids Management Planning, we will discuss:

- Methods for dewatering and disposing of sludge.
- Regulations that govern the disposal of sludge.
- Items to review if involved in the construction of a wastewater treatment facility.

[The following questions are designed to encourage group participation, and to identify topic areas that the group will find most useful and interesting.]

To get a feel for what types of equipment everyone in the room is familiar with, please tell me what types of digesters are utilized at your facility.

[Record their responses on a flipchart, anaerobic digesters on one flipchart page, aerobic digesters on another flipchart page.]

Ans: Anaerobic digester: Rectangular, cylindrical, egg-shaped. You may also get responses as primary and secondary referring to the number of units in a treatment train and you may also get responses related to cover types.

Aerobic digester: Aerobic digesters do not have specific shapes like the anaerobic digesters in that any basin(s) with proper liquid transfer capabilities will do. For an aerobic digester to work properly, you just need a method to aerate the contents. It is easy to put a surface aerator in a lagoon or diffusers in a tank. You may sub list by the method of aeration: surface, course bubble, fine bubble.

[Indicate which digester types will be covered during the session. Acknowledge the types of digesters you have recorded and encourage participants to share their experiences when that particular digester type is reviewed.]

What problems have you or the facility you work for had with their digesters?

[Record their responses on a flipchart. Hang these on the wall. Indicate that these problems will be revisited throughout the course.]

UNIT 1—SLUDGE THICKENING. 45 minutes

[Display Slide 2, Unit 1—Anaerobic Digestion]

We will begin today by discussing sludge thickening. The learning objectives for Unit 1 are to: *[(briefly review the learning objectives)]*.

Does anyone have any questions before beginning Unit 1?

Purpose of Sludge Thickening

Prior to sending solids to a treatment unit, such as a digester, most wastewater treatment facilities will send the solids through a thickener. The purpose of thickening is to reduce the amount of water that is being sent to the treatment unit and subsequently being treated needlessly. During this unit we will briefly discuss the various thickening mechanisms to give you an understanding of the different units, what they consist of and some key points for each type of thickening device.

[Review the advantages to sludge thickening in the workbook.]

When thickening it is also important to remember to not thicken the sludge to greater than 10% because it may be difficult to pump the sludge when the solids content exceeds this amount.

Gravity Thickeners

The first type of thickener that we will be looking at will be the gravity thickener.

Display Slide

[Review the gravity thickener information in the workbook and refer to the identified parts on the slide.]

A picture of the gravity thickener can be found on page 1-3 in your workbook.

[Review the factors of gravity thickener operation in the workbook.]

Gravity thickeners are better suited for primary sludges, or sludges from a primary clarifier, than secondary sludges, or sludges from secondary clarifiers. Secondary sludges typically contain bound water which can cause the sludge to not settle since it is less less dense.

[Review the definition of ***bound water****.]*

There are several factors that control the performance of gravity thickeners including the speed of the sludge collection mechanism, the sludge withdrawal rate and the sludge blanket depth.

[Review the performance information in the workbook.]

As with any process, it is important to properly monitor the gravity thickening process, starting with visual observations based on the performance factors.

Dissolved Air Flotation Thickeners

We will now continue with dissolved air flotation thickeners. This process is the opposite of the gravity thickener, in that air is attached to the solids to make them float to the top. There are four methods that are used to attach the air to the solids. They include: *[Review the four methods of dissolved air flotation operation.]*
The dissolved air (pressure) flotation is the most common type of air flotation thickener.

[Review the performance factors in the workbook.]

Can someone tell us why primary sludges are not as well suited for dissolved air flotation thickeners?

Ans: Primary sludges are heavier and tend to settle.

If primary sludges are thickened in an air flotation thickener, typically some type of scraping mechanism is present to remove the sludge from the bottom of the thickener, as indicated in Figure 1.2.

As with the gravity thickener, troubleshooting starts with visual inspection.

Centrifuge Thickener

The next type of thickener that we will look at will be the centrifuge thickener. This type of thickener relies on both sedimentation and high centrifugal forces and is very similar to a centrifuge that may be used for final dewatering.

[Review the three basic types of centrifugal thickeners and the performance factors in the workbook.]

[Continue the review of the performance factors in the workbook.]

As with all of the thickeners, correct polymer usage may play a key role in thickening the sludge using the centrifugal thickener.

Gravity Belt Thickeners

The final thickening device that we will look at will be the gravity belt thickener, which is very similar to the belt filter press without the pressing function.
Basically chemically conditioned sludge is fed onto a porous belt where the water is allowed to drain and the sludge is fed to a pump to be sent for further processing, as demonstrated by Figure 1.4.

The main problem with gravity belt thickeners is call washout, where large amounts of water carry over with the sludge due to improper or lack of drainage.

[Review the items in the workbook that should be checked when washout occurs.]

[Have the participants review the Key Points for Unit 1 – Sludge Thickening.]

☑ Exercise for Unit 1 – Solids Handling

Matching – Match the gravity thickener parts (A-E) with their proper description (1-5):

_C___ 1. Collects and removes effluent or thickener overflow.

_D___ 2. Slowly rotates to move the settled solids to the middle of the tank.

_A___ 3. Introduces the sludge into the thickener.

_B___ 4. Collects and removes floating debris.

_E___ 5. Provides gentle stirring or flocculation of the settled sludge and releases trapped gas to prevent rising sludge.

A. Inlet and distribution assembly
B. Scum removal equipment
C. Effluent/Overflow weir
D. Sludge rake to move the sludge to a hopper
E. Pickets or vertical steel members

Multiple Choice – Choose the best answer unless otherwise noted:

6. Which of the following are advantages of sludge thickening? (*Choose all that apply*)

   a. <u>Cost savings in the construction of new digestion facilities</u>
   b. Increased anaerobic digestion heating requirements, since more water has to be heated.
   c. <u>Improved digester performance due to a lower volume of sludge</u>

7. The type of sludge that is commonly thickened using a centrifugal thickener is: (*Choose one*)
   a. primary sludge
   b. <u>secondary sludge</u>
   c. tertiary sludge

8. Sludge that is to be thickened using a gravity belt thickener is first preconditioned, typically using what? (*Choose one*)
   a. chlorine
   b. lime
   c. <u>polymer</u>
   d. soda ash

9. The sludge thickener diagrams that were viewed in this unit include which of the following? (*Choose all that apply*)
   a. <u>air floatation thickener</u>
   b. <u>scroll centrifuge thickener</u>
   c. <u>gravity belt thickener</u>
   d. basket centrifuge thickener

UNIT 2—ANAEROBIC DIGESTION. 1 hour and 40 minutes

[Display Slide 2, Unit 1—Anaerobic Digestion]

We will continue our discussion on solids handling by discussing anaerobic digestion. The learning objectives for Unit 2 are to: (briefly review the learning objectives).

Does anyone have any questions before beginning Unit 2?

PURPOSE OF DIGESTION: 15 minutes

General Overview

Anaerobic digesters have several advantages over aerobic digesters. Anaerobic digesters produce methane gas that is a viable fuel source, thus reducing energy costs within the facility. In addition, anaerobic digesters produce a lower volume of sludge and require less space than aerobic digesters.

[Review the definition of ***anaerobic digestion****.*

Review the purposes of the anaerobic digestion process in the workbook.

Display Slide 3, General Overview.

Review the ***diagram of solids reduction****. The diagram is an example of how digestion reduces 100 pounds of sludge to 50 pounds of sludge and 50 pounds of gas and water.]*

Fixed solids can never be reduced, only volatile solids. Therefore, if you have 100 pounds of total solids, with 75 pounds being volatile solids and 25 pounds being fixed solids, the reduction will only affect the volatile solids.

75 pounds of volatile solids X 0.65 (65% reduction) = 50 pounds of volatile solids reduced

Therefore, after 65% volatile solids reduction, you have the 25 pounds of fixed solids still present and 25 pounds of volatile solids remaining. This gives you 50 pounds of total solids.

[Review the definition of ***dewaterable****.]*

So how does digestion reduce the volume of solids in the sludge?

Ans: The answer is on the next page of the workbook. (This question is a way to lead into the next page.)

How Digestion Works

The waste streams that are fed to the digester are either slightly heavier (they have been settled out of the flow stream in a clarifier) or slightly lighter (scum) than the rest of the flow. This combination tends to provide a wide range of food for organisms.

Certain organisms do well in this environment and produce simpler substances. Some of what they produce is acidic. They also give off gas products and water. The waste from these organisms can be used as food by other microorganisms. This second set of microorganisms produce a host of by-products. These by-products include more water, methane, carbon dioxide and other residuals. The water (most of it anyway) will be returned to the treatment process prior to discharge, the gases will be used or vented, and the residuals will have to be disposed in a legal manner.

[Display Slide 4, How Digestion Works.

Explain the ***diagram of reactions in a digester*** *by starting at the top left with Raw Sludge and then move to the right. The top line describes the Acid Formers digestion process. Continue your explanation beginning with Organic Acids at the bottom left and move to the right. The bottom line describes the Methane Formers digestion process.]*

Digesters are somewhat like the three bears' porridge in that they can be found in three different temperature ranges – cold, warm and hot.

[Introduce pyschrophilic, mesophilic, and thermophilic bacteria. (Note: pyschrophilic, mesophilic, and thermophilic bacteria are classifications for both acid formers and methane formers.)]

[Display Slide 5, Temperature Ranges and Days for Digestion.

While reviewing the **temperature ranges** *chart, include the following information:]*

- The three types of bacteria do the same thing but as with most biological processes, the more energy (heat) that is available, the quicker the process. This is one of the trade offs in the design of a facility. The time required to "digest" the solids has an impact on the volume of sludge that must be handled during digestion. If you had a digester operating in the psychrophilic (cold) range you might need to store over half a year's worth of sludge on your plant site in the digesters because of the long digestion time.
- If utilizing the thermophilic (hot) range, then only about two weeks of solids generation would need to be stored. The volumes will have to be doubled if you want the ability to take a unit out of service for cleaning and maintenance. However, most folks do not want to heat their digesters to the thermophilic range, nor do they want to have enough storage to operate in the psychrophilic range. Therefore, about 90% of anaerobic digesters are operated in the mesophilic (medium) range.

[If anyone wants an example of psychrophilic range digester, give the example of an Imhoff tank. (Yes, there are still some of these units being operated.)]

Acid Forming Reactions

[Display Slide 6, Bacteria Growth Rates.]

The acid forming microorganisms are quite hardy. They have high reproductive rates in slightly acidic conditions. They can tolerate a wider temperature range than methane forming organisms. Since acid forming microorganisms can tolerate a wider range of environmental conditions, can breed faster than methane formers, and can produce material that is toxic to the methane formers, you do not have to tailor your operation to these organisms. In fact, you sometimes have to alter the environment so that they do not proliferate as quickly. This is done so that the methane formers can operate at their peak.

[Review the definition for ***saprophytic organisms****.]*

Methane Fermentation Reactions

Since most facilities use the methane produced by the methane forming bacteria to heat the digester, it is in the interest of the facility to optimize the environment for the methane formers and maximize the production of methane. To maintain a favorable environment for the methane formers, you should check the digester temperature regularly, adjust feed and withdrawal rates, and monitor the tank's alkalinity and volatile acids. If these delicate organisms have a negative population trend for an extended period of time, the digester will need a long time to recover.

The **diagram of bacteria growth rates** provides a pictorial representation of where acid formers and methane formers grow best. While this depiction is general in nature, it indicates that the acid formers and methane formers do not share an environment that is optimal to both. However, if you have to choose, most of the time you will choose an environment that is beneficial to the methane formers. The reason is that if you have extra methane you can flare it off or vent it. However, if your methane production drops, you lose a source of fuel and you loose the reduction in volatile solids or pathogens. While the loss of fuel can be made up with alternate fuels, this may increase your operating costs and you may have sludge that is not treated sufficiently enough to dewater properly. You may also have nowhere to put the sludges that are being generated upstream in the treatment works.

We have just covered how the digestion process works; now let's take a look at the digester itself. The first item we will discuss is the shape of an anaerobic digester tank. Digester tanks come in three shapes: rectangular, cylindrical, and egg-shaped.

COMPONENTS OF AN ANAEROBIC DIGESTER SYSTEM: 25 minutes

Anaerobic Digester

Tank Shapes

Rectangular tanks are easy to build. Straight forms for concrete work are plentiful. The wall support columns and roofs are easy to erect. However, even with multiple mixers, there are areas of the tank that are difficult to mix. The majority of the sludges come from the primary and secondary clarifiers. Since the sludges have settled out in the primary and secondary clarifiers, you know the sludge is heavier than water and will settle out again unless it is kept mixed. This is important because solids that settle or are not mixed well do not digest properly.

Rectangular tanks have a high surface area to volume ratio. The result is high heat loss. Digesters are usually big, and it takes a lot of heat to raise the temperature even a few degrees. Therefore, it makes economic sense to reduce heat loss as much as possible.

Cylindrical tanks are more complicated to build. Construction requires the forming of a curved concrete wall (steel tanks can be used but concrete holds up better with less maintenance and hassle). Cylindrical tanks usually have a conical bottom to help in circulation and sludge draw-off. These tanks can be mixed with a single draft tube/mixer. Large cylindrical tanks that are not very high can have some of the same problems as a rectangular tank when it comes to mixing. An advantage of a cylindrical tank is the surface area-to-volume ratio of a cylindrical tank is lower than for rectangular tanks, which leads to less heat loss.

Cylindrical tanks are sometimes called pancake tanks. You can envision this when thinking about a tank that has a large diameter but a small height. This terminology may have come into vogue with the introduction of the egg-shaped digester (before the egg-shaped digesters came along, a large diameter, low height tank was described as squatty or low).

[Display Slide 7, Cross-Section of an Egg-Shaped Digester.]

Egg-shaped tanks are more expensive to construct because they have complex forms. Curves have to be formed in both directions. Egg-shaped digesters have the best heat retention, the most efficient mixing, and the best separation of supernatant from the solids (important during draw-off).

*[Review the **Cross-Section of an Egg-Shaped Digester** diagram.]*

Fixed Cover Digesters

In addition to the shape of digester, another distinguishing characteristic is the type of cover a digester utilizes. There are two types: floating and fixed. More care has to be taken with fixed covers. The pressure inside the tank must be monitored and an adequate gas reserve must be maintained to keep the unit from imploding or exploding. Rectangular digesters usually have a fixed cover. Cylindrical digesters will usually have a fixed and floating cover if paired. A single stage digester can have either a fixed or floating cover. Egg-shaped digesters have fixed covers. The steep slopes of the egg-shaped digester overcome the heat retention and mixing challenges of the rectangular tanks. The gas domes are at the high point of the cover, but the gas systems are often located on the ground near the digester. Therefore, gas storage systems on the egg-shaped units are more complicated when they have to be placed on the sloping sides of the units.

[Refer the participants to pages 157 - 158 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Review items 1–11 on Table 12.1 and Figure 12.3. Items 1–11 on Table 12.1 are components of a fixed cover digester. The items are shown on Figure 12.3. Read the descriptions and move back and forth between Table 12.1 and Figure 12.3.]

Floating Cover Digesters

[Review the Floating Cover Digesters section in the workbook. Include the following information:]

✓ The formwork to outfit a rectangular basin with a floating cover would be difficult, and the sealing of a rectangular basin would be difficult. Therefore, floating covers are normally used on cylindrical tanks. They can be used on single and multiple stage units. If a facility only has two tanks and one of them is a fixed cover and the other is a floating cover, then the fixed cover is normally the primary digester and the floating cover is the secondary digester. More flexibility is achieved when both tanks (if there are only two) are equipped with floating covers and piped so that either can be heated—this allows either one to be the primary digester.

The utilization of a floating cover allows a larger latitude in the operation of the digester because the floating cover acts as a gas well. This allows the addition and removal of tank contents in larger volumes as compared to a fixed cover tank. The floating cover provides a larger gas reservoir and reduces the chance of outside air mixing with digester gases (outside air mixed with digester gases can be explosive).

[Refer the participants to page 184 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. The list in the workbook describes several parts of the floating cover that are highlighted in the diagram.]

Corbel is a term used in building that describes a support cornice or arch. In the case of a digester, the corbels are used as a landing area or minimum elevation support for the floating cover. The cover can be thought of as an arch in that most of the covers are domed/arched to provide structural stability and a trap for the digester gas. Once the cover is resting on the corbels, watch that a positive pressure is maintained inside the digester.

The **roller guides** can be either straight or helical. They stabilize the cover as it moves in response to the tank contents. The helical guides require more complicated connections to the gas system—they require a number of flexible connections. However, with the helical guides the total distance from the moving cover to the fixed point can remain the same. With straight guides the flexible joints have to compensate for a fluctuation in total distance between the two points.

The **access hatches** are only for maintenance operations. During normal operation these would not be opened. Remember, it may be explosive if methane gas inside the digester mixes with oxygen in the air from outside the digester.

The cover is heavy. This part of the digester literally floats on the digester contents. The **floatation chambers** are watertight compartments to keep the cover afloat. The cover also rides on the pressurized gases under the dome, but those pressures have to be kept below what would be required to lift the complete cover. The edges of the cover, or skirt, should be submerged in the digester liquid to keep air from entering or gases from escaping the digester.

Skirts help to control foaming by keeping the sludge and foam inside the tank. They also help contain the gases of the digester.

It would be inconvenient and dangerous to climb up on the digester to record the location of the cover relative to the range of allowable movement. But you need to know where the cover is floating. If it is at the bottom of its range, you need to watch for negative pressures and if it is at the top of its range you need to be aware of the potential for over pressurization. A functional **cover indicator dial** provides a way of seeing the location of the cover without climbing to the top of the tank.

As mentioned before, the **gas piping** needs to be flexible or have ways to accommodate the movement of the cover. The gas dome is on the floating cover (the floating cover moves), the waste flare, heating unit(s), and auxiliary generator are mounted on fixed (non-moving) structures. So to move the gas from the gas dome to points of use, there needs to be some flexibility in the piping—hose or flex joints (most use flex joints).

Water Seal

[Review the Water Seal section in the workbook. Include the following information:]

- ✓ The water seal on a fixed cover is in the area of the gas collection. The seal for a floating cover is around the perimeter of the cover.

[Refer the participants to pages 157 and 159 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Review items 12–18 on Table 12.1 and Figure 12.4. Items 12–18 on Table 12.1 are components of a water seal. The items are shown on Figure 12.4. Read the descriptions and move back and forth between Table 12.1 and Figure 12.4.]

Digester Mixing

[When discussing **gas mixing***, refer to page 158, Figure 12.3 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Include the following information:]*

✓ The draft tube is in the center of the digester and the gas injectors go down to the mid point of the tank. When the compressible gas is forced under the surface it reduces in volume. When the gas is released from the pipe and is allowed to rise its volume increases as it rises to the surface. As the gas bubble rises and gets bigger, it forces the sludge above to move upwards also.

✓ The tubes used in gas mixing are sometimes called draft tubes and sometimes called air lances. They function the same way an airlift pump functions but instead of using air, the gas from the digester is used—this keeps oxygen from entering the tank. With cylindrical tanks a center lift point is used. The theory is to get a rolling action from the bottom center of the tank, up the tube, out the top of the tube, out to the side of the tank, down the sidewall, and back to the bottom center of the tank.

[When discussing **mechanical mixing***, refer to pages 181 - 182, Figures 12.21 and 12.22 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Include the following information:]*

✓ Mechanical mixers usually have one or more propellers on a shaft connected to an electric motor. The propeller(s) are located in the draft tube. The motor is usually located outside of the cover, hence the shaft has to penetrate the cover and be sealed to exclude air from entering the digester. Placing the motor inside the cover presents a safety issue. The motor housing must be explosion proof.

Digester Heating

[Review the Digester Heating section in the workbook. Include the following information:]

✓ For each 18 to 20 degrees that the environment is heated, the biological process of digestion will double.

Sampling Well

[Review the Sampling Well section of the workbook. Include the following information:]

✓ These small hatches not only furnish access points to several locations of the digester, but they allow access while the inside of the digester is under a positive pressure.

[Review the definition for ***Supernatant****.]*

Supernatant Tubes

[Refer the participants to page 160 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

The supernatant tubes allow the draw-off of liquid from different levels of the digester. The arrangement shown on page 160 is one method of selecting the depth from which to draw-off supernatant. The flow will be produced out of the tube with the lowest top provided that the bottom of the tube is submerged and that the pressure (static head of the liquid + the gas pressure) is enough to push the flow out. Instead of using adjustment rings, the tubes may be equipped with valves (gate or ball), or telescoping valves which serve the same function as adjustment rings. The longer a digester is in service, the more settling and scum reduce the amount of "working volume" inside the digester. As this happens, the window of proper draw-off becomes smaller.

Sludge Draw-Off Lines

A digester reduces but does not eliminate the volume of sludge. Therefore, sludge volume gradually accumulates in the digester and must be removed and processed further or disposed of. Sludge is removed from the digester through the draw-off lines for use “as-is” for land application, or for further processing through a drying bed, centrifuge, plate press or belt filter press.

Gas System

[Read the first paragraph in the Gas System section of the workbook.]

How many have a gas system?
[(Note: everyone with an anaerobic digester should have a gas system.)

Record the number of responses on a flipchart.]

How many use the gas for heat?
[(Note: everyone with an anaerobic digester should use the gas for heat.)

Record the number of responses on a flipchart.]

What kinds of problems do you have with your gas systems?
Ans: *[Expect moisture problems, clogs, low methane content, leaks, corrosion, etc.*

Record their responses on a flipchart. Hang on the wall and refer to the problems as appropriate throughout the session.]

Gas Dome

[Review the Gas Dome section in the workbook.

Refer the participants to page 159, Figure 12.4 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Incorporate the following information into your discussion of Figure 12.4:]

✓ The gases produced will be collected at a high point in the cover. This high point will assist in keeping some of the moisture and foam out of the gas system. Because the gas pressure and volume fluctuate, it is very beneficial to have a collection point that can change in volume. To accomplish this, the collection point needs to have a seal so that air will not enter the digester and digester gases will not escape.

Relief Valve

[Review the Relief Valve section in the workbook.

Refer the participants to items 13 and 17 on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Indicate that item 13 is the relief valve and that item 17 is the relief and flame trap assembly.]

Flame Arrester

[Review the Flame Arrester section in the workbook.

Refer the participants to item 1 (flame arrester) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Thermal Valve

[Review the Thermal Valve section in the workbook.

Refer the participants to item 19 (thermal valve) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Indicate the name of the item is different in the diagram.]

Flame Trap Assembly

[Review the Flame Trap Assembly in the workbook.

Refer the participants to item 12 (flame trap assembly) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Drip Trap

[Review the Drip Trap section in the workbook.

Refer the participants to items 8 and 16 (low pressure and high pressure drip traps) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Sediment Trap

[Review the Sediment Trap section in the workbook.

Refer the participants to item 6 (sediment trap) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Gas (Flow) Meters

[Review the Gas Meters section in the workbook.

Refer the participants to item 10 (gas meter) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Indicate the name of the item is different in the diagram.]

What type of meters do people in the class use?

Ans: *[These responses could be brands (Trident, Neptune, Ford, WT, Watts) or working types (displacement, turbine, propeller).]*

Which types of meters have worked the best?

Ans: *[It is common for the ones that have worked the best to be the ones that were installed with the proper upstream protections. Expect responses of blockage and corrosion to be the items that downgraded the performance of the meters.]*

Pressure Regulators

[Review the Pressure Regulator section of the workbook.

Refer the participants to item 21 (pressure regulator) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Indicate the name of the item is different in the diagram.]

Waste Gas Burner

[Review the Waste Gas Burner of the workbook.

Refer the participants to item 18 (waste gas burner) on page 163, Figure 12.6 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

How do you check your waste gas burners?

Ans: Visual observation from the ground is probably the most common method of checking the burner. A better way is close visual observation of the burner. Once you are close you can also see if fasteners are loose, material is being eaten away, the auxiliary flame source is still lit, or obstructions are developing in the airways.

Does anyone have any tips for checking waste gas burners?

Ans: Access is a big concern. Therefore, methods of getting to the burner, ladders, platforms, mirrors, closed circuit TV, are important.

We have discussed how digestion works and covered the physical components of a digester. Now let's move on to how to start and feed a digester. But before we do, has anyone started a digester? If so, could you please describe your experience? (Transition to next section.)

OPERATIONS OVERVIEW OF ANAEROBIC DIGESTION. 35 minutes

Starting and Feeding a Digester

Starting the Digester

[Display Slide 8, Starting and Feeding a Digester.

Review the Starting the Digester section of the workbook.

Review the definitions of ***inoculate****,* ***seed sludge****, and* ***acid regression stage****.]*

Seed sludge is best taken from a nearby facility so that the organisms do not have to acclimate to a totally new environment. The amount to add does not have to be precise. Between 10% to 50% of the tank volume has been used successfully in the past. Another source of seed may already be coming to your plant but being placed elsewhere in the flow scheme. If your facility accepts septic tank waste for example, you already have a source of anaerobic digestion material.

Feeding the Digester

[Incorporate the following information in your review of the Feeding the Digester section of the workbook:]

✓ Just about all waste streams but the grit and screenings go to the digester. The digester should be fed on a regular and frequent basis. If there is a large influx of food to the digester, such as only sending sludge to it weekly, the acid producers will have a feast on the new food. This could drive the pH down below the level at which the methane formers can function. In addition, a weekly feeding will probably be a large volume of sludge that will create a pressure differential in the tank as well as an impact on the interface levels of the scum-supernatant-sludge mix. (A week is extreme because the clarifier operation would also degrade without more frequent sludge removal.)

[Review the page in the workbook. Include the following information:]

✓ If you have a separate sludge concentrator or thickener, you should use it. By feeding the digester a thick (higher percent solids) sludge mixture, you can you reap the following benefits: lower heat requirements, denser food source, less supernatant.

Considering all the waste streams arriving at the digester, which one gives your plant the most problems in transport and why?

Ans: Scum is probably on the top of the list because the grease and oils foul the pipes. It is also the most difficult to pump. Hopefully, most of the grit and stringy material has been removed from the flow stream. The sludges may have gas entrained in them that hinders efficient pumping, but the gas is less of a problem than plugged piping.

Mixing Tank Contents

Earlier we discussed the methods of mixing tank contents. With the exception of supernatant withdrawal, the tank should be kept in a completely mixed and heated state. Complete mixing breaks up the scum blanket and moves the food to the organisms.

[Review the Mixing Tank Contents section of the workbook.]

Gas Production

[Review the Gas Production section of the workbook.

Refer the participants to page 164 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. These pictures show the explosive potential of an anaerobic digester.]

Not only is methane used as fuel, but the gas production is an indication of the health of the digester. If the methane formers get into trouble, methane production will decrease.

Removing Tank Contents

[Review the definitions for Positive Pressure*.]*

The gas is removed from the tank based on the pressure inside the tank and the utilization of the methane throughout the plant.

The supernatant should be drawn off on a regular basis. This could be three times a day or once a week, preferably some frequency in between. Once a week is probably too long because the amount removed will be too large and will have an adverse impact on the receiving process unit and the digester. Three times a day is probably too frequent because the digester should be brought to a rest before pulling off supernatant. Stopping the mixing three times a day is probably too frequent.

The sludge can be drawn off while the mixing is in operation but it is better to pull it out of the tank after the tank has had some time to settle the solids. This provides a higher percentage of solids in the sludge to be pumped.

Another reason to pull off clarified liquid and sludge on a routine basis is to match the inflows and outflows of the digester. Matching the inflows and outflows maintains a positive pressure in the digester and avoids large and sudden movements of the cover.

STRATEGIES FOR MAINTAINING AN ANAEROBIC DIGESTION SYSTEM. 25 minutes

Test Interpretation and Controls

We have been talking about how the digester works, now we will talk about testing and controlling the operation of the digester for optimal performance.

Because methane formers are the weak link in the process, steps must be taken to help them prosper. To maintain a healthy environment for the methane formers, the following items are monitored and adjusted.

Temperature

[Incorporate the following information in your review of the Temperature section of the workbook:]

✓ The majority of digesters operate in the mesophilic range. The temperature of the environment provides some of the energy for biological activity. Consequently, the hotter the environment, the more the biological activity.

Acid-Alkalinity Relationship

The acid-alkalinity ratio is one of your best friends. With a large amount of alkalinity in the digester, sudden changes to the pH in the digester usually cannot happen. Alkalinity can be thought of as the buffering capacity of the liquid. The buffering keeps the pH from moving to the acid range. The methane formers like a slightly alkaline environment so you do not want the acid formers to get to far ahead in their production to make the digester inhospitable to the methane formers. For the acid formers to depress the pH (move it to the acid side of the scale), their by-products would first have to neutralize the available alkalinity. Since the process of neutralization can be time consuming, the ratio (or available alkalinity) should be watched to give an early warning of a digester in need of attention.

[Display Slide 9, Acid-Alkalinity Relationship.

Review the volatile acids to alkalinity ratio chart.]

Digester Gas

[Incorporate the following information in your review of the Digester Gas section of the workbook:]

✓ If you use the waste flare to determine if the digester is working, you might often be in trouble. If you wait until methane is no longer being produced, the digester is close to being dead.

pH

[Incorporate the following information in your review of the pH section of the workbook:]

✓ If the pH is dropping, this is a sign the digester is in trouble. For the pH to be become more acidic, most of the alkalinity has been consumed and the methane formers are now dying off in large numbers. If the pH drops below neutral (7.0), the digester is in trouble because the methane formers are about to stop producing. This is mostly a confirmation of trouble, not a warning sign.

Solids Tests

You have to guess what is in the digester. Testing the feed sludge, circulated sludge, discharged sludge and supernatant can give a better estimate of what is going on in the digester. From the feed sludge you can get an idea of the amount of sludge that will be reduced (part of the volatile content) and how much will be passed on to the next process. By testing the circulation sludge you can estimate how far the digestion has to process. Testing the supernatant provides data on how much solids is being recycled back to the plant. By knowing the volume of sludge pumped and the concentration of solids in that sludge you can calculate the amount of solids that should be in the digester and how long they have been retained. This is important because the sludge needs to be retained for a certain amount of time for it to stabilize.

Records

[Review the Records section of the workbook. Incorporate the following:]

A system of records must be maintained to make informed process decisions, provide proper data for reporting, and satisfy state and federal regulations. Many of the records are compilations of data from laboratory tests, while some records are measurements taken in the field (on-site around the plant). The data is used to determine:

- The length of time the sludge has been digesting (hydraulic detention time).
- The amount of volatile compounds remaining (volatile solids).
- The amount of sludge to process in the next step of treatment (i.e. the solids inventory of the digester). This includes calculating the total solids remaining and the amount of volatile solids remaining, and the amount of sludge pumped in and out of the digester.
- The health of the digester (pH, alkalinity).
- Gas production.
- The size of the gas fractions.

[Review this page in the workbook.

Refer participants to the sample digestion bench sheet on the next page.]

Bench sheets are plant specific. They are tailored to each plant and the operators that run the plant. When using a bench sheet you need to ensure that the remarks column is utilized as it should be. For important data, an omission should be explained. What is important data? In order of importance it would be described as:

❶ Data used to prepare regulatory reports.

❷ Data used to make a decision on plant operation.

❸ Trend data that indirectly has an impact on plant operation.

❹ Other data such as detention time, pounds of solids, and ratios of volatile solids to incoming flow.

Knowing how much sludge is being placed in the digester and the working volume provides the elements to calculate the detention time. This is a function of how stable the product is. There is a minimum detention time requirement. The percent volatile solids provides an estimate of the reduction to expect, while the pH is an indication of adjustments that may have to be made to put the tank contents in the proper range for methane production.

The items in the “Recirculated Sludge” area provide the environmental conditions in the tank.

The three “Gas” columns indicate the production both of total gases and a ratio of the incoming flow. The percent CO_2 allows the calculation of available methane as well as a direct indicator of the digester health.

The next six columns (Sludge Disposal) indicate that sludge was not wasted in the month of July because nothing was sent to the drying beds.

The bench sheet provides the basis for calculating the sludge inventory. It also provides sludge volume information for the next process.

The graph (Figure 2.13) of Total Feed Sludge and Percent Volatile Solids is a trend chart of two items. The dashed line shows a variation of feeding volumes to the digester and the solid line shows the percentage of the solids that are volatile. The dashed line is read off of the left axis, the solid line is read off of the right axis.

Using both the top and bottom graphs, you can track the Volatile Acid to Alkalinity Ratio against the feed sludge. In the beginning of the month the ratio was a little high, so the feed rate was cut back. The digester responded with an improving ratio. This can be seen again in the later part of the month—around the 22^{nd}. The digester did not make the same response around the 10^{th} when there was another dip in feed rate. The percent volatile is fairly consistent—varying only 8 percentage points.

Other trend parameters could probably be plotted which would coincide with some of the other movements of the volatile acid to alkalinity ratio graph. These may include:

- Temperature
- Sludge withdrawal
- Other chemical additions

Volume of Sludge

To track the amount of solids being moved throughout the plant you have to calculate the volume indirectly because there is not a method of direct measurement. The volume of solids is calculated using the volume of suspended solids and the percent solids in the suspension. In rough numbers you can create for your facility an approximation of how much biomass will be created by removing a specified amount of BOD and Total Solids Suspension (TSS). The TSS would be a rougher estimate than the calculation of volume times the percent solids.

[Review page 196, Example 4 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Raw Sludge

To track how much material is being fed to the digester, the amount of sludge and scum has to be added together. This is a three-part number. Scum is the least important component of the number. The other two components are the fixed and volatile solids. The scum takes up digester volume but should be decomposed and processed out of the digester. The scum volume should be small in relation to the sludge volume. The sludge numbers provide an indication of gas production (the volatile fraction) and the volume of solids that will be remaining in the digester. These numbers have an impact on the retention time in the digester as well as the operating level in the tank.

[Review page 197, Example 5 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Computing Digester Loadings

The return of supernatant to the wet side of the plant can cause disturbances in those processes if the treatment load is too high. Therefore, the amount of solids being returned should be tracked. This also serves as a guide as to when to adjust the withdrawal tubes so that the most clarified supernatant is being removed from the digester. The sight glass that is sometimes built into the side of the digester might help, but laboratory conformation is often needed to determine the optimum draw-off point.

[Review page 198, "J. Digester Supernatant" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

The amount of sludge to feed the digester depends on how much material is already in the tank. There are several factors to consider when wasting sludge:

- Is there enough volume available in the tank for more material?
- Do you have to get rid of some liquid or solids to have room for the new material?
- Will there be enough viable material in the digester to work on (eat) the new incoming food?

The first step in the process is to figure out how much good stuff you are sending to the unit. This is the food feeding ratio, or the amount of Volatile Matter to the current content volume of the tank.

[Review page 198, "K. Computing Digester Loadings" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

continued

Computing Gas Production

The gas production is not really computed but is directly read from the meter. Unfortunately, that number by itself does not help in operating the facility. However, if it is related to other factors such as the amount of volatile matter destroyed or the amount fed, then it can be a reliable number. Consider this, if the methane formers start to be come stressed, (not that they are working too hard but their environment is no longer conducive to growth) and begin to produce less gas, one of the reasons might be that there is not enough food being introduced to the digester to maintain the past levels of production. If however the gas production has stayed constant as per the type of calculation we will see in Section L, then other causes need to be investigated.

[Review page 199, "L. Computing Gas Production" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Solids Balance

To some extent the digester is a magic act. Liquid sludge goes in, and solids, liquids and gases come out. The liquids go back to the treatment process, the solids (and their transport liquids) go to other plant processes or off site, and the gases are used as fuel or are vented. The gases are easy to transport although there are some concerns for safety. They are also fairly easy to measure accurately. The liquids don't really leave the treatment processes at this point. The solids are almost ready to leave the facility. However, you need to track where the solids are going. Some will remain as a solid (all of the fixed portion and some of the volatile), some will be converted to liquid and some will leave as a gas. If you can match up your total pounds in to the total pounds out of the digestion system you have a good handle on the operation of the system.

[Review page 197, "G. Raw Sludge" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

This is an example of the calculation for finding the "Percent Reduction of Volatile Solids".

[Review page 198, "I. Secondary Digester Sludge" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

This is an example of the calculations for finding the "Solids Balance". While it doesn't seem like a lot of information to start with (5 data points), with a few assumptions it builds to a fair assessment of the solids balance. The data points are the volume of flow to the unit (2,800 gal), and the solids content in and out of the digester for both the total and volatile fractions (in - total solids 6.5%, volatile 68%; out – total solids 4.5% volatile 54%). Some of the assumptions used in the calculation are:

- The density of the sludge is close to that of water (using 8.34 pounds per gallon).
- There are few losses in the system.
- That the volume in was about the same as the volume out.

One of the first things to be done is to get the mass (weight) of the various components. This is where the volume of flow and our assumption of density are used. This calculation gives total weight to the digester. Use the percentages to find the fraction of total solids and volatile solids. Some of the calculations are indirect in nature, such as finding the inorganic (fixed) fraction of the solids component by subtraction.

[Review page 199, "M. Solids Balance" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

continued

Other Calculations

[Review page 197, "H. Recirculated Sludge" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

In Section N, the first problem is a solids balance and reverse volume scenario. Before we were looking at pump run times and pumping rates to determine the amount of sludge coming to the digester. In this case, we are attempting to keep a steady sludge blanket depth in the primary clarifier. With a known solids removal and flow we find the amount that has to be removed. Using the percent solids and pump rate we find the length of time the pump should run. Since this is a primary clarifier, we can use the difference (Infl – Effl) in suspended solids (SS) to find the solids to be removed.

The next problem is blending two rates and two concentrations to find the resulting rate and concentration. You find the total solids and total flow to calculate the combined solids percentage.

The last problem is a digester loading problem.

[Review page 201, "N. Other Computations" of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II.]

Checklists

Checklists serve as reminders. They can and should be modified to reflect the conditions and situations at each plant. They can be combined with a logbook to track when the activities are accomplished. In this case, the logbook becomes one of the plant records. The checklist could also be used to populate an automated work order system for operation and maintenance activities.

For sampling and other data collection the bench sheets sometimes constitute the checklist or the checklist is used to develop the bench sheets.

[Instruct the participants to review pages 204 – 206 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Ask if they have items they would like to discuss, or items that they do differently.]

Troubleshooting

[Review the paragraph at the top of the Troubleshooting section in the workbook.

Refer the participants to pages 209 – 215 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II. Demonstrate how to use the troubleshooting tables by looking for solutions to digester problems that have come up throughout the session, by looking for solutions to problems you think are most important, or by asking participants which problems they would like to focus on.]

Foaming

Foaming is usually caused by the fast growth of organisms. Conditions that can exacerbate the situation are a heavy sludge/scum blanket and swings in digester environment (feeding too much, withdrawing too much, temperature swings). Corrective action involves stabilizing the environment. Preventative measures are to keep the contents mixed and to maintain the proper environment.

[Page 191, Section 12.25 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II has additional information on this topic. Participants can be referred to page 191 for future reference.]

Neutralizing a Sour Digester

Who has had a digester go bad? What was your experience?

The weak link in digester operation is usually the methane forming organisms. It could be their relative imbalance to the acid producers, or their growth in general. There are several indicators that should be tracked to determine the cause. Most cures involve getting the acid to alkalinity ratio back to the proper range. Temperature can also be a factor but it is an environmental condition that changes slowly.

Nothing comes free. One of the main purposes of a digester is the disposal of solids. One of the most used methods of adding alkalinity is to introduce lime to the unit. However, this increases the solids in the tank. The additional weight needs to be included in the solids balance calculations.

[Review the Neutralizing a Sour Digester section of the workbook.

✓ *For fun: In the section on curing a sour digester, you can joke about an additional cure: "Add Tums. Because of the expense, these are usually for the smaller digesters we carry with us."]*

[Review the list at the top of the workbook.]

Waste Gas Burner

[Incorporate the following information in your review of the Waste Gas Burner section of the workbook:]

- ✓ A waste gas burner should always have a flame, either the methane flame or the pilot light. If just the pilot light is burning and there is normal gas production and not an abnormal gas usage, check for blocked lines, leaks, or a high CO2 fraction in the gas.

Sludge Draw-Off Lines

[Incorporate the following information in your review of the Sludge Draw-Off Lines section of the workbook:]

- ✓ Sludge draw-off lines are difficult to access and clean. However, they must be working properly to move the sludge (biosolids) from one place to another. The sludge draw-off lines are usually connected to positive displacement pumps. Positive displacement pumps are used because centrifugal pumps may have a difficult time priming or moving the solids content of a digester. Positive displacement pumps usually have a higher head capacity and can handle a higher percentage of solids in what they are pumping.

Digester Cleaning

[Incorporate the following information in your review of the Digester Cleaning section of the workbook:]

- ✓ Unless your digester has a mechanism to move the material along the bottom of the tank to the sludge draw-off pipe, there will be a gradual build up of solids in the digester. The solids balance calculations can provide an idea of how fast this buildup is occurring. A symptom of a digester filling with inorganic/non degradable solids is that some environmental swings will happen at a faster rate. For example, pH, alkalinity, and volume of supernatant available changes will happen more quickly as the working volume of the tank decreases. As the working volume of the tank decreases and the digester becomes more sensitive to changes, the available reaction time for the operator diminishes.

Pre-Cleaning

Pre-cleaning involves laying out the game plan on how to accomplish the cleaning of the digester. Items to consider include what to do with the solids being generated, where are the digested solids going, and who is going to do the work. As the saying goes, if you fully plan the work, then work the plan, the operation should be a smooth one.

Remember to have some seed sludge available for the restart of the unit.

[Review the Pre-Cleaning section of the workbook.]

Cleaning Methods and Equipment

[Review the Cleaning Methods and Equipment section of the workbook. Include the following items in your discussion:]

- ✓ To regain digester volume that is being taken up with non-digestible material, the tank has to be emptied and the contents disposed of properly. In the days of cheap land, there may have been enough drying bed space to put the digester contents on the beds and still have dewatering capacity for normal operations. However, few places currently have that luxury, and only a few facilities are being designed that way. Now other methods of dewatering the sludge are needed. Often these services will be contracted out if there is a long time period between instances where the extra dewatering capacity is needed.
- ✓ The disposal of the solids removed from the digester might be the same as the disposal of regular process solids. But for a variety of reasons, such as they don't meet certain regulatory requirements for some disposal options, they may have to be disposed of in an alternative manner.

What have you found in your digesters when cleaning them?

Safety

[Review the Safety section of the workbook.]

What types of tests should be conducted before entering a digester that has been taken off-line?

Ans: Since this may be a confined space, the required tests for confined space entry should be completed: oxygen, explosive gases, hydrogen sulfide, carbon monoxide.

Cleaning Pipelines and Valves

[Review the Cleaning Pipelines and Valves section of the workbook. Include the following information:]

- ✓ Rodding is the forcing of a scraper or other cleaning tool through a pipe to break solids off the pipe walls.
- ✓ Pigging involves forcing a semi-rigid cleaning tool through the pipe using the normal contents of the pipe or some other fluid. This tool also cleans the pipe walls and moves debris down the pipeline.
- ✓ Flushing involves using velocity or solvents to clean the pipeline.
- ✓ When possible, the sludge piping system should be laid out so that it can be cleaned with rigid cleaning tools.

[Have the participants review the Key Points for Unit 2 – Anaerobic Digestion.]

Exercise for Unit 2 – Anaerobic Digestion

Multiple Choice – Choose the best answer unless otherwise noted:

1. Anaerobic digestion reduces pathogens by what percentage?
   a. 50-65%
   b. 70-84%
   c. 85-99%

2. Psychrophilic bacteria would be used in which kind of digester?
   a. Cold digester
   b. Warm digester
   c. Hot digester

3. A sour digester occurs when:
   a. The gas produced by the acid formers gets caught in surfactant
   b. Acid formers grow faster than methane formers
   c. Soap and detergent reduce the surface tension of liquids

4. Which V.A./ALK (volatile acids/alkalinity) ratios are within problem levels? *(Choose all that apply):*
   a. 0.08
   b. 0.1
   c. 0.8
   d. 1.0

5. An acidic (low pH) digester can be cured by adding alkalinity to the digester. Which one of the following compounds is the most cost effective in curing an acidic digester?
   a. Sodium Bicarbonate
   b. Anhydrous Ammonia
   c. Lime ($Ca(OH)_2$)
   d. Sulphuric Acid

Fill in the blank with a correct response:

6. A material is considered _dewaterable_ if water will readily drain from it.

7. An anaerobic digester will produce twelve to eighteen cubic feet of gas for every _pound_ of volatile matter destroyed.

8. Normally a digester should be fed often. This can be anywhere from two to _twenty_ times per day.

9. Anaerobic digesters produce methane gas and carbon dioxide gas. If the amount of CO_2 reaches 45 % or more, the gas mixture will not be burnable.

10. When a digester's working volume reaches _60_ % or less of its design volume, it is time to shut down and clean the digester.

References

This brings us to the conclusion of Unit 2.

Does anyone have any questions?

UNIT 3—AEROBIC DIGESTION. 30 minutes

[Display Slide 10, Unit 3—Aerobic Digestion.]

We've reviewed anaerobic digestion. Now let us turn our attention to aerobic digestion. On this page are the learning objectives for Unit 3—Aerobic Digestion.

[Briefly review the learning objectives.]

Does anyone have questions about the learning objectives or the unit?

AEROBIC DIGESTION. 30 minutes

Overview

[Review the definition of ***aerobic digestion****.]*

Since the aerobic microorganisms consume oxygen during cellular reproduction, they need dissolved oxygen in their environment. Maintaining a constant supply of dissolved oxygen is energy intensive and is therefore limited to small installations.

Aerobic digestion is good following an activated sludge process because there is usually a carryover of dissolved oxygen from that process.

[Review the Overview section of the workbook.]

Comparison Between Anaerobic and Aerobic Digestion

[Display Slide 11, Comparison Between Anaerobic and Aerobic Digestion.

Review the Comparison Between Anaerobic and Aerobic Digestion section of the workbook.]

Process Description

[Review the Process Description section of the workbook. Include the following information:]

✓ Air can be forced through the sludge, or, using a surface aerator, the sludge can be thrown into the air.

✓ Since there is no reason to collect the gases from these units, they do not need a top or cover.

Anyone using compressed air? How about surface aeration?

Ans: *[This is a question to survey the class to see the breakdown of diffused (submerged aeration) and surface aeration.]*

What maintenance problems have you encountered?

Ans: *[This will depend on what type of system they are using. Anyone with a fine bubble diffuser head will probably have clogging and plugging problems. All submerged systems may have had balance problems. Other items could be leaks in the piping system (corrosion), tearing of diffusers, solids accumulation and scum.]*

Operation

We will begin by discussing the startup of a three-cell train. The first step is the hydraulic filling of the first cell, followed by the establishment of the proper organisms. Next, the remaining cells are filled to achieve the proper total hydraulic detention time that will result in the desired reduction in volatile materials. Supernatant is removed from the last cell and returned to the front of the plant much like the supernatant from anaerobic digesters. Before removing the supernatant, the last cell is allowed to settle so that a high percentage of solids is not returned to the plant. The supernatant from the last cell is easier on the treatment process because it carries some dissolved oxygen.

[Review the Operation section in the workbook.]

[Review the top section of the workbook.]

Review the definition of endogenous respiration.

Records

Whether the sludge is digested anaerobic or aerobically, there will need to be records showing that it has been properly processed. It might be that digestion is all the processing the sludge needs, or it might be just one of the processes. As an operator or plant manager, you will need to have documentation that your solids were disposed of properly. This documentation should include the volume and characteristics of the solids.

[Review the Records section in the workbook.]

Problems

[Display Slide 12, Problems.

Review the Problems section in the workbook. Include the following information:]

✓ **Scum** should be a minimal problem. The scum produced should be more of a froth. If there is a heavy scum, it needs to be better treated. (The scum will need more frequent skimming or the digester operation will need to be altered to better break up the scum and have the organisms reduce it to more elemental components). Chemicals can be used to break up the sludge. These are usually surfactants to break up the scum, enzymes to break up the bulk of the blanket, or degreasers.

✓ **Odors** should not be a problem because there is constant aeration of the contents. There are two main reasons there are fewer odors. Airborne odors are diluted by the aeration process, and aerobic organisms produce fewer odors than anaerobic organisms. Areas in the tank that are not mixed properly may cause odor because these areas may develop anaerobic activity.

✓ Two forms of **floating sludge** will appear on the digester: 1. sludge that is still aerobic, 2. sludge that has come to the surface from anaerobic activity at the bottom of the tank. When the tank is under active aeration, the light sludge will continue to be mixed with the tank contents. However when the unit is being prepared for supernatant removal, the light sludge will collect on the surface. Since you only want to put clear supernatant back into the system, the supernatant draw-off lines need to be below the light sludge.

✓ **Diffusers** come in several shapes and styles. Examples include: sock, disk, plate, fine bubble, and course bubble. Most diffusers will produce a course bubble to reduce the possibility of clogging.

✓ **Aeration equipment** includes compressors and diffusers, propeller induction tubes, and surface aerators.

What type of diffusers do you have at the facility you work at and do you have any tips to keep them operable?

Ans: They may bump (send a burst of air) through the headers to blow off some of the accumulated buildup, they may have to drain the tanks to clean out rags and other debris, or they may have articulated drop pipes to access the diffusers.

[Have the Participants review the Key Points for Unit 3 – Aerobic Digestion.]

Exercise for Unit 3 – Aerobic Digestion

1. The target level of dissolved oxygen in an aerobic digestion tank is:

   a. 6 mg/L

   b. <u>1 mg/L</u>

   c. 0 mg/L

2. Sludge is usually kept in the aerobic digestion tank for:

   a. 1 day

   b. 5 days

   c. 10 days

   d. <u>20 days</u>

3. Aerobic digestion creates a waste that is better for disposal or beneficial use (reduced volume through dewatering, reduced pathogens and a more stabilized product through the reduction of volatile solids).

   a. <u>True</u> b. False

4. Scum is typically the biggest problem when using aerobic digesters.

   a. True b. <u>False</u>

5. Odors are not generally a problem with aerobic digesters. If odors occur, what are two remedies that may correct the odor problem?

   a. <u>Ensure that proper mixing is occurring in the tank.</u>

   b. <u>Ensure that proper dissolved oxygen levels are being maintained.</u>

References

This brings us to the conclusion of Unit 3.

Does anyone have any questions?

UNIT 4—SOLIDS MANAGEMENT PLANNING. 35 minutes

[Display Slide 13, Unit 4—Solids Management Planning.]

Once sludge has been processed, it must be disposed of. We will now cover solids management planning, which deals with the handling and disposal of sludge. On this page are the learning objectives for Unit 4—Solids Management Planning.

[Briefly review the learning objectives.]

Does anyone have any questions about the learning objectives or the unit?

DIGESTED SLUDGE HANDLING. 10 minutes

Overview

Sludge-generating facilities in Pennsylvania have many options to choose from for sludge disposal. These options include: Agricultural Utilization, Land Reclamation, Composting, Distribution Programs, Landfills, and Incineration. All of these, with the possible exceptions of agricultural utilization, use dewatered sludge. By using dewatered material, hauling costs are reduced, fuel costs for incineration are reduced and less bulking agents are needed for composting.

There are several ways to dewater sludge. The choice is usually made during the design of the facility. The selection is based on available land, size of the facility, and desired solids content in the end product. A small facility next to suitable agricultural fields may only need a sludge concentrator and may not need to have the solids content above 7%– 9%. An operation with an incinerator will want feed sludge solids above 18% (higher is better) to reduce the amount of water that has to be driven off before burning the sludge. This is a balance between dewatering cost and fuel cost. Sometimes, the cost of polymers, coagulants and extensive dewatering is more expensive than fuel. Most landfills accept dewatered (no free water) sludge. The desired solids percentage is driven by the tipping charges and distance to the site.

Dewatering options include:

- ✓ Drying Beds
- ✓ Reed Beds
- ✓ Lagoons
- ✓ Vacuum Filters
- ✓ Belt Filters
- ✓ Plate and Frame Filter Press
- ✓ Centrifuge

Drying Beds

[Review the Drying Beds section in the workbook.]

[Continue to review the Drying Beds section in the workbook.

Refer to page 224 of Chapter 12 in Operation of Wastewater Treatment Plants, Volume II for a graphic of a drying bed.]

Do you think there is a fire risk when anaerobic digested sludge is applied on a drying bed?

Ans: Yes (see next question).

Why is anaerobic more dangerous then aerobic sludge?

Ans: Anaerobic sludge contains methane gas. Aerobic sludge should not contain methane gas.

For those drying beds not equipped with vehicle treads, what can be used to facilitate the use of wheelbarrows on the drying bed?

Ans: Planks, grating, plywood.

Reed Beds

[Review the Reed Beds section in the workbook.]

Lagoon

[Display Slide14, Lagoon.

Review the Lagoon section in the workbook.]

Lagoons can be both a dewatering method and a disposal method. As a dewatering method they are oversized clarifiers and have a very long time between cleanings. If the lagoon is a one-time use for dewatering then it becomes the disposal method also. This can be a viable option for some small remote facilities.

Mechanical Dewatering

[Display Slide 15, Mechanical Dewatering.

Review the Mechanical Dewatering—Vacuum Filter section in the workbook.]

Do any participants use vacuum filters?
[If anyone has a vacuum filter, find out if they have the drum type or the newer filament type. (The drum types work by having the sludge outside the drum and then pulling the liquid through a filter cloth with a vacuum. The drum may or may not have a scraper to clean the cloth. The filament type submerges hollow fibers in the solution and uses a vacuum in the hollow centers to withdraw liquid.)]

Belt filters usually start by allowing the sludge to rest on a porous belt for some drainage. This area of the filter may have plows to move the sludge around to allow more water to escape. The material is then moved to an area that will capture the sludge between two belts to make a sludge sandwich. The two belts are then moved between rollers with increasing contact (tighter squeezing) to force more water out of the sludge.

[Review the belt filter section in the workbook.]

[Review the Plate and Frame Filter section of the workbook. Include the following information in your discussion:]

✓ Plate and Frame Filters are also known as filter presses. The name filter press imparts visions that are not true. The press is equipped with fairly massive (usually hydraulic) pistons or screws, but these are just to keep the assembled plates together under pressure. The force that squeezes the water out of the sludge is the pump feeding the filter press. The pore size of the filter cloth that covers the plates also has an effect on the performance of the press. The filter fabrics sometimes have to be cleaned or replaced. If they are blinded by a batch of sludge they will not pass water properly and the middle of the cake may not be as dry as the parts near the plate. Most of these installations are mounted on the second floor with a live bottom or opening in the floor so that the emptied sludge can fall into an awaiting container or truck.

Centrifuges normally require a lot of energy. This is because the bowl must be spun at high speeds to force the separation of solids. While they are heavily built, they also require close tolerances between moving and non-moving parts. The sludge is abrasive and contains foreign objects, 3-6% solids to 18-25% solids range, therefore items may break and begin to ricochet around inside the centrifuge, or tolerances wear outside their optimal range. There is a continuous discharge of solids cake and filtrate.

SLUDGE DISPOSAL. <u>15 minutes</u>

Methods of Sludge Disposal

[Display Slide 16, Methods of Sludge Disposal.

Review the Methods of Sludge Disposal section in the workbook. Include the following information in your discussion:]

✓ As noted earlier there are several methods available: Agricultural Utilization, Land Reclamation, Composting, Distribution Programs, Landfills, and Incineration. The first two, Agricultural Utilization and Land Reclamation, are the most common types of land application.

✓ Incineration produces a very heavy solids residual. Sludge ash has to be monitored for heavy metal concentrations.

✓ The two types of incinerators are fluidized bed (less precise burn control) and multiple hearth (higher degree of burn control).

Regulations

Environmental Protection Agency (EPA)

[Display Slide 17, Regulations.]

The EPA regulations are often referred to as the 503 regulations because that is the part number in the Code of Federal Regulations (CFR) Chapter 40 containing the regulations.

[Review the EPA section of the workbook.]

Sewage Sludge Use and Disposal Regulation

[Review the Sewage Sludge Use and Disposal Regulation section in the workbook. (Prior to the training session, verify that the website and instructions for accessing the regulations are still correct.)]

Pennsylvania Code

The Pennsylvania code is in Title 25, Article VIII, Chapters 271 through 285.

[Review the Pennsylvania Code section in the workbook.]

REVIEW OF PLANS AND SPECIFICATIONS. 10 minutes

Items to Review

If an operator can review a set of plans before the facility is built, there is a lot of value added for the time expended. The operator may notice when there is not enough room for maneuvering equipment. They may also notice small but important things like the number and placement of lifting eyes, number and placement of electrical outlets, location of work platforms, and other items that would make operating the facility better.

[Review the Items to Review section in the workbook.]

[Continue to review the Items to Review section in the workbook.]

[Continue to review the Items to Review section in the workbook.]

[Have the participants review the Key Points for Unit 4 – Solids Management Planning.]

☑ Exercise for Unit 4 – Solids Management Planning

1. In a drying bed the typical sludge thickness is _ten_ to _twelve_ inches.

2. A drying bed requires about _14 to 20_ days of drying time.

3. Reed beds can last up to _10_ years.

4. Most sewage sludges are classified as:
   a. hazardous waste
   b. non-hazardous waste
   c. radioactive waste
   d. none of the above

5. Sludge dewatering methods include drying beds, reed beds, lagoons and mechanical dewatering systems.
   a. True   b. False

References

This brings us to the conclusion of Unit 4 and this module.

Does anyone have any questions?

[Thank attendees for their participation.]