Wastewater Treatment Plant Operator Certification Training Instructor Guide

Module 8: Overview of Advanced Wastewater Treatment Processes

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 8:Overview of Advanced Wastewater Treatment Processes* is to provide participants with an introduction to the basic concepts of some common advanced wastewater treatment processes and systems. The purpose of advanced treatment, also known as tertiary treatment, is to further clean the effluent from the secondary processes. Since these tertiary processes generally follow secondary treatment, they are considered to be advanced processes. While not all wastewater treatment plants use the advanced processes discussed in this module, the national trend is toward treatment beyond basic secondary treatment to produce more environmentally friendly effluent. Therefore, it is important for wastewater treatment operators to become familiar with advanced wastewater treatment processes and systems.

This module covers a range of advanced wastewater treatment processes, from odor control to solids removal to nutrient removal. The time required to complete all the material in this module will be approximately 4 to 6 hours, depending on the scope and depth allowed for the class discussions and activities. This module may be divided into two shorter sessions designed to be completed in 3 hours each. If this approach is taken, it is suggested that Units 1 and 2 comprise one 3-hour session, and Units 3 and 4 comprise another session, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the Pa. DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the Pa. 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 topical 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 Pa. 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
- Small group and full group discussion
- Quiz
- Questioning

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

- One workbook per participant
- *Advanced Waste Treatment*, 3rd Edition
- 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:

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 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: <u>5 minutes</u>

Display Slide 1—Module 8: Overview of Advanced Wastewater Treatment Processes

[Welcome participants to "Module 8 – Overview of Advanced Wastewater Treatment Processes." Indicate the primary purpose of this course is to introduce operators to the basic concepts of some common advanced wastewater treatment processes and systems. The purpose of advanced treatment, also known as tertiary treatment, is to further clean the effluent from the secondary processes. Since these tertiary processes generally follow secondary treatment, they are considered to be advanced processes. While not all wastewater treatment plants use the advanced processes discussed in this module, the national trend is toward treatment beyond basic secondary treatment to produce more environmentally friendly effluent. Therefore, it is important for wastewater treatment operators to become familiar with advanced wastewater treatment processes and systems.]

[Introduce yourself.]

[Provide a brief overview of the module.]

This module contains four units. On pages i and ii, you will see the topical outline for Unit 1 – Odor Control and Unit 2 – Effluent Polishing. If you turn the page, you will see the topical outline for Unit 3 – Phosphorus Removal and Unit 4—Nitrogen Removal.

[Continue to review the Topical Outline.]

[Continue to review the Topical Outline.]

[This page was intentionally left blank.]

UNIT 1: 50 minutes

Display Slide 2—Unit 1: Odor Control

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

- Identify the source and general types of wastewater odors.
- List three potential impacts of odors.
- List three factors affecting the existence of odors.
- Name a commonly used method to reduce odors from wastewater.
- Describe three methods for solving odor problems in air.

SOURCES AND TYPES OF ODORS: 20 MINUTES

Odor Generation

We will begin this unit by discussing odor generation.

[Point out that odor control is an important aspect of the Treatment Plant Operators job.]

Ask participants why they think odor control is such an important task. Record participant answers on a flipchart. Discussion should be brief. Review participant answers and highlight any of the following points that are not mentioned by participants:

- odors create problems for plant personnel
- odors create problems for plant equipment
- odors can create problems for the community
- odor control can strain the resources of the treatment plant

As you can see, odor control is an important task for a Treatment Plant Operator. But let's talk about how odors are generated in the first place. Typically, odors are generated either through the biological degradation of wastes or through the discharge of odiferous materials. Let's discuss each of these further.

Biological Degradation of Wastes

[Review information in workbook.]

Discharge of Odiferous Materials

[Review information in workbook.]

Now that we have an understanding of how odors are generated, lets discuss the impacts odors have.

Impacts of Odors

Odors impact three important areas: safety, aesthetics and maintenance. We will discuss each of these in further detail, beginning with safety.

Safety Hazards

[Review information in workbook.]

In addition to impacting safety, odors impact aesthetics as well.

Aesthetic Problems

[Review information in workbook.]

Not only do odors have an impact on safety and aesthetics, as we have just discussed, but they also impact various maintenance issues.

Maintenance Issues

[Review information in workbook.]

So far, we have discussed how odors are generated and the impacts they have. Next, we will discuss organic and inorganic vapors and how they contribute to creating odors.

Organic Vapors

[Review the defintion for Organic Vapors that appears in the workbook.]

Now we will discuss how organic vapors may be produced.

Anaerobic Decomposition of Nitrogen & Sulfur Bearing Organic Compounds

[Review information in workbook.]

Examples of Organic Vapors

[Review examples presented in the workbook.]

[Review the defintion for Thiols that appears in the workbook. Note that alcohols and phenols contain an OH group (methanol is CH_3OH, phenol [C_6H_5OH] is a benzene ring with an OH group in place of one of the six H atoms). A thiol is formed when a sulfur atom (S) replaces the oxygen atom in the OH group.]

Now that we have discussed organic vapors, it is time to move on to inorganic vapors.

Inorganic Vapors

[Review the defintion for Inorganic Vapors that appears in the workbook.]

Examples of Inorganic Vapors

[Review the examples presented in the workbook.]

Next we will discuss how the characteristics of the wastewater can affect odor production.

Factors Affecting the Existence of Odors

There are several wastewater characteristics that impact the existence of odors. Can anyone tell me what one of those characteristics is?

Record participant answers on flip chart.

Ans: *[Temperature, pH, and dissolved oxygen concentration.]*

[Review information in workbook.]

Odor Detection

Another key factor in controlling odors is the ability to detect odors in the first place. Although it is common to rely on the human nose for odor detection, technology also plays an important role in detecting odors. We will discuss both of these options in this section.

[Review information in workbook.]

Odor Thresholds

[Review information in workbook.]

Display Slide 3—Odor Characteristics (Table 1.1)

Note that the concentration of these substances necessary to produce a detectable odor is very low. For most of the substances listed here, concentrations of a few parts per billion or even a few parts per trillion is all that is needed to produce a detectable odor.

Gas Detecting Devices

As I mentioned at the beginning of this section, modern technology plays a role in detecting odors.

[Review information in workbook.]

What kind of gas-detecting devices are used in your treatment plant?

Ans: *[Commonly used devices may include a combustible gas indicator/oxygen analyzer (CGI/O_2) which provides a non-specific lower explosive limit in percent and oxygen concentration in percent; a photoionization detector (PID) or Flame ionization detector (FID) which both provide non-specific gas concentrations; and direct reading instruments which can measure the concentration of a specific gas, such as carbon monoxide and hydrogen sulfide.]*

Managing Odor Complaints

As mentioned at the beginning of this unit, odors can create problems for the community. This can easily result in complaints from members of the public, so it is important for treatment plant operators to be aware of their role in managing odor complaints.

[Review the information in the workbook.]

SOLUTIONS TO ODOR PROBLEMS: 30 MINUTES

Now that we have identified sources and types of odors, we need to discuss how to solve odor problems. This will be the focus of the remainder of this unit.

The Odor Detective

Your job in solving odor problems is much like that of a detective. You will need to distinguish between odors and determine the probable cause or source of an odor. The ability to track down an odor will come with experience, but knowledge about odor types and potential causes will get you off to a good start.

Classification of Odors

Your first task is to describe the odor. This should enable you to classify it into a particular category, which in turn can help you to identify the source of the odor. If you look at Figure 1.1 in your participant workbook, you will see a list of common odor classifications. The common classifications are: garlic, medicinal, skunk, decayed cabbage, ammonia, fecal, fishy, rotten egg and decayed fish.

Source Detection

Once you have classified the odor, your role as odor detective has begun. You can now begin to determine the source of the odor.

[Review the bulleted items in the workbook.]

[For the instructor's information, amines are compounds that contain one or more of the following nitrogen groups:

NH_2, NH, or N]

Systematic Approach to Odor Detection

To be a successful odor detective, you will need to utilize a systematic approach to solve odor problems. The preferred approach is one that eliminates sources one at a time. To identify problem areas, you should evaluate housekeeping schedules and plant operations and review plant performance.

What kinds of odor problems have you experienced at your treatment plant? How were they resolved?

Ans: *[Possible sources of odors may be headworks, primary clarifiers, anaerobic digestors, and effluent discharge. Associated odors may include hydrogen sulfide, skatoles, mercaptans, and in the effluent: chlorine and possibly ammonia.]*

Chemical Treatment Alternatives for Wastewater Sources

Preventing or eliminating anaerobic conditions often solves an odor problem. Odors can be mitigated or eliminated through the use of chemicals and by manipulating chemical equilibria. The next part of our discussion will focus on chlorination, aeration, pH control and other methods of chemical treatment alternatives for wastewater.

Chlorination

Chlorine is a commonly-used chemical at wastewater treatment plants, so it is often available.

[Review information in workbook.]

Another successful method for preventing odor problems is aeration.

Aeration

[Review information in workbook.]

pH control is another method used to prevent odors.

pH Control

[Review information in workbook.]

Other Chemicals

In addition to the three methods we just discussed, there are other methods of available for use to control odors. Hydrogen peroxide and ozone are two options. Other options include chromate and zinc, which may be used to bind the energy sources used by microorganisms and/or to create a toxic environment for the microorganisms. This will prevent the odor-causing compound from being generated.

Treating Air Containing Odors

Another important aspect of solving odor problems is actually managing the collection and treatment of odors in air. This could be more economical that treating wastewater. There are a variety of means available to treat air containing odors, which we will discuss for the next few minutes.

Chemical Absorbers

The chemical absorption process, in which odiferous compounds become dissolved in an absorbing solution, is one such method.

[Review the definition of Absorption which is in the workbook.]

[Ensure the following key points about chemical absorption are covered:

- *In order for odiferous compounds to become dissolved in an absorbing solution, the air stream containing the odor must be brought into contact with the absorbing compound.*
- *The greater the opportunity for contact between the odiferous air and the absorber, the better the treatment. Scrubbing is when the air containing the odiferous compound is washed by a liquid stream that is the absorbing solution. The absorbing solution is selected and customized based on the particular odor-causing compound.]*

On this page and the next page, there are examples of chemical absorption systems.

Display Slide 4—Electrolytic Chemical Scrubber Using a Brine Solution (Figure 1.2)

Note that this equipment sprays an absorbing liquid onto a media bed to provide the contacting surface through which the air stream must flow. As noted previously, intimate contact between the absorbing liquid and the air is required for an effective scrubber. The unique thing about this process is that electricity is used to transform the brine (an electrolytic solution) into hyprochlorite, which oxidizes the odors. Other oxidizing agents, such as ozone and peroxide, are also formed by the electrical reactions.

[Be sure to review definition of Electrolytic covered in workbook.]

Display Slide 5–Chemical Mist Odor Control System (Figure 1.3)

In this system, the absorbing solution is pumped to the contact medium. The combination of the medium, the pumping action, and the introduction of compressed air into the absorbing solution atomizes the liquid (creates very tiny liquid particles). The air stream is pumped into the system and must pass through the wetted medium in order to discharge through the top of the system. A mist eliminator is required near the top of the system to remove residual atomized liquid.

Packed Tower Scrubbers

Another means of treating air containing odors is through a treatment system known as a packed tower scrubber.

[Review the information on packed tower scrubbers.]

[Refer participants to Figure 1.4 in their workbook.]

Display Slide 6–Packed Tower Scrubber with Countercurrent Air Flow (Figure 1.4)

The basic concept here is similar to a chemical mist scrubber, except no attempt to atomize the liquid is made, and the liquid stream is generally recycled to the scrubber. However, the absorbing liquid is pumped to the packed media and the air stream must pass through the media as in the mist system.

Display Slide 7–A Packed Tower Scrubber with Cross Air Flow (Figure 1.5)

An alternative to using a countercurrent air flow is the use of a cross air flow, as illustrated in Figure 1.5 in your workbook.

This system works the same as the countercurrent flow system except that the liquid is sprayed down onto the media while the air flows through the media at a 90° angle to the liquid flow direction.

Regardless of which configuration is used, the odor-carrying air passes through the packed bed where it intimately contacts the absorbing solution. The odor is removed from the air stream, which continues through the scrubber's mist eliminator and is discharged.

Activated Carbon Adsorption

Another method of treating air containing odors is through activated carbon adsorption. In this process, the odiferous compounds are contacted with and adhere to the surface of a solid phase.

[Review the information on the adsorption process.]

[Refer participants to Figure 1.6 in their workbook.]

Display Slide 8–An Activated Carbon System (Figure 1.6)

This slide shows a very large activated carbon system. Each vessel is filled with activated carbon. The vessels are typically valued so that a variety of flow configurations can be achieved and so that some vessels can be removed from service as needed.

Other Options

In addition to chemical absorbers, packed tower scrubbers and activated carbon adsorption, there are a few other odor control options for odors. They include biological odor removal towers, masking agents, combustion of the odiferous gases, and ozonation.

[Review defininition of Ozonation provided in workbook.]

For additional information on these process options, refer to pages 32 and 33 of *Advanced Waste Treatment*, 3rd Edition.

Which of these methods for treating air containing odors are used at your treatment plant? How do they work?

Ans: [*There are no set answers for this question.]*

An Ounce of Prevention

The final solution to odor problems that we need to review is good housekeeping. The most effective way to solve odor problems is to prevent them from happening in the first place. This can be accomplished by adhering to a comprehensive, well-designed maintenance schedule that reduces the probability that odors will develop into problems.

[Review list of maintenance ideas in workbook.]

[Have the participants review the Key Points for Unit 1 – Odor Control.]

Exercise for Unit 1 – Odor Control

1. Describe some of the maintenance schedules used at your treatment plant:

Ans: *[If class participation is minimal, ask specifically about different wastewater processes such as the maintenance done at the headworks, the primary clarifiers, the anaerobic digesters, or the disinfection system.*

For headworks: is there a chemical addition schedule; is aeration employed routinely?

For primary clarifiers: are chemicals or air added routinely; are sludge levels checked routinely; are tanks covered?

For anaerobic digesters: is the cover seal checked routinely; is the tank checked for leaks; is the gas burner status automatically checked?

For disinfection systems: is the operation of the chlorinator checked routinely; is the dosage matched to the plant effluent flow rate; is the system checked routinely for leaks; is sludge removed routinely from the contact chamber?]

This completes our overview of the basics of odor generation and odor control methods for wastewater treatment plants. You should review the learning objectives presented at the beginning of this presentation to make sure that you have a basic understanding of the key concepts that were presented in this section of the module. If there are any additional questions we should go over, now is a good time to bring them up. If not, we will move on to the next section of this module, which is Effluent Polishing.

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UNIT 2: 150 minutes

Display Slide 9 and 10—Unit 2: Effluent Polishing

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

- Identify two distinct technologies for polishing effluent wastewater.
- Describe the three main steps for chemical precipitation.
- Describe a typical jar test procedure.
- Identify the major components of a physical-chemical treatment system.
- For each of the following filtration systems, explain how they work, and identify the major system components and operational considerations:
  - Gravity Filtration
  - Pressure Filtration
  - Continuous Backwash, Upflow, Deep-Bed Granular Media Filtration
  - Cross Flow Membrane Filtration

REMOVING SOLIDS FROM SECONDARY EFFLUENTS: 10 minutes

Why is Additional Treatment Necessary?

[Review information in workbook.]

Alternatives for Effluent Polishing

[Review information in workbook.]

Physical - Chemical Treatment

[Review three-step process in workbook.]

Filtration

[Review definition of Filtration provided in workbook.]

[Review list of filtration technologies provided in workbook.]

CHEMICAL PRECIPITATION: 50 minutes

In the next hour, we will discuss chemical precipitation in more detail.

Chemicals Used to Improve Settling

Chemicals are used to treat secondary effluent in order to create larger, denser particles that will readily separate from the secondary effluent. Without the use of these chemicals, the physical separation of wastewater particulates from secondary effluents would not be effective.

Coagulation/Flocculation Basics

[Review defintion of Coagulant Aids provided in workbook.]

[Review material in workbook.]

Display Slide 11—Coagulation-Flocculation Process (Figure 2.1)

[Note that the wastewater particles are negatively charged, so they attract positively charged particles. A cationic polymer is positively charged and is also attracted to the negatively charged particles. The long chain of the polymer gathers many particles together forming a settleable floc.]

Chemical Coagulants

Review list of common chemical coagulants in workbook.

At a wastewater treatment plant, generally polymers are only added in the secondary clarifiers, typically in winter, to enhance settling characteristics. Also, when ferric chloride is used, polymers are not added on a regular basis.

Chemical Flocculants

[Review information in workbook.]

Display Slide 12—A Polymer Map (Figure 2.2)

The map shows what type of polymer might be effective for different applications based on its molecular weight and charge density. The outlined areas represent potential application areas on the map.

Selecting the Right Chemical and Dosage

[Review information in workbook.]

Jar Testing

[Review defintion of Jar Test provided in workbook.]

Display Slide 13—Jar Testing Equipment (Figure 2.3)

The top photo shows a jar test machine. It has six stations with a mixer for each station. Sample jars are placed at each station and mixed. The bottom photo shows a jar testing setup using magnetic stirs inserted into glass beakers.

[Cover the bulleted items provided in the workbook.]

Evaluating Results

[Cover the following key points:

Rigorous evaluation would involve:

- *Recording the chemicals and dosages used in each reactor*
- *Recording the characteristics of the floc formed*
- *The speed at which the floc settled*
- *The volume of the sludge generated*
- *The characteristics of the supernatant]*

Scaling the Test

[Review the information in the workbook.]

Performance Optimization

[Review the information in the workbook].

Physical-Chemical Treatment Process Equipment

So far, we have discussed the different types of chemicals used for chemical precipitation and we have discussed how to select the right chemical and dosage. Our discussion will now move on to the equipment used for physical-chemical processes, starting with the equipment needed for chemical storage and mixing.

Chemical Storage and Mixing Equipment

The type of equipment used for storage and mixing will depend on whether the coagulants and flocculants are in either solid or liquid form.

[If solids are used, they need to be dissolved in water first. Special equipment is required to properly meter the solid, wet the solid and mix it into a useable solution.]

Display Slide 14—Dry Chemical Feed System (Figure 2.4)

[Cover the remaining items on solid chemicals that appear on the next page.]

As mentioned previously, solids and liquids require different types of equipment. Liquids are often received in a concentrated form and require dilution before use. As a result, a day tank may be used to mix the liquid chemical to the appropriate concentration and hold it for metering to the point of application. Figure 2.5 in your workbook shows an example of a liquid chemical feed system.

Display Slide 15—Liquid Chemical Feed System (Figure 2.5)

Chemical Feed Equipment

Another important equipment consideration involves the chemical feed equipment.

[Review first bulleted item and its 2 sub-bullets.]

Like the storage and mixing equipment, chemical feed equipment varies depending on whether the chemicals to be fed are liquid or solid. For liquid chemicals, positive displacement pumps are used. These pumps use either a plunger or diaphragm. Figure 2.6 in your workbook shows examples.

Display Slide 16—Positive Displacement Pumps (Figure 2.6)

When solid chemicals are used, a screw feeder is commonly used to meter them to the solution tanks or the point of application.

Display Slide 17—Screw Feeder (Figure 2.7)

The slide depicts graphically what the workbook presents.

Coagulant Mixing Units

Another piece of equipment used in chemical precipitation processes is the coagulant mixing unit.

[Review the bullet points in the workbook.]

Flocculators

Flocculators are yet another type of equipment that plays an important role in chemical precipitation.

[Review bullet items in workbook.]

Display Slide 18—Mechanical Flocculators (Figure 2.8)

Clarifiers

Clarifiers are generally used for solids separation. The design of the clarifier can be rectangular or circular. The rectangular design uses a chain and flight or a traveling bridge for solids collection.

Display Slide 19—Rectangular Sedimentation Clarifiers (Figure 2.9)

[Point out the chain and flight and the traveling bridge on the graphic.]

[Briefly discuss the common elements of the chain and flight and the traveling bridge and how they work by covering the following key points:

- *Note the influent and effluent locations, the adjustable weirs that control the liquid level in the clarifier, the scum trough, and the sludge hopper.*
- *Influent enters at the sludge hopper end and effluent discharges from the scum collecting end. As the wastewater flows through the clarifier, solids settle to the bottom and scum rises to the top.]*

[Next point out the principle difference between the two:

- *The chain and flight collector uses a gear mechanism to rotate a chain around the clarifier. The chain has flights (scrapers) mounted on it that move the sludge from the bottom of the clarifier to the sludge hopper.*
- *The traveling bridge collector moves back and forth along the clarifier. While moving in one direction it positions a scraper to collect solids from the bottom of the clarifier and deposit them in the sludge hopper. While moving in the opposite direction, the bottom scraper is idle but a skimmer blade is activated to propel scum to the scum trough.]*

In the circular design, solids may be scraped to the center of the tank into a collection well.

[Next present the slide showing the circular clarifiers. Briefly discuss how they work.]

Display Slide 20—Circular Clarifiers (Figure 2.10)

In a) the influent enters at the bottom center and discharges into the clarifier at the center top. A circular baffle forces the flow toward the bottom of the clarifier. Effluent flows over a weir to a collection trough. Scraper arms move sludge from the bottom of the clarifier to the center sludge trough.

In b) the influent enters via the perimeter of the clarifier, is directed downward by a perimeter baffle, then flows up to the effluent collection troughs. A counterbalanced suction arm collects sludge from the bottom of the clarifier using a vacuum.

In c) influent again enters at the perimeter but in this case flows down and around back to the perimeter to the effluent trough. As in a, scraper arms move sludge from the bottom of the clarifier to the center sludge trough.

Tube settlers are another option. They reduce the distance solids are required to travel before they are removed from the solution.

Display Slide 21—Tube Settler Module (Figure 2.11)

Sludge Management

When talking about physical-chemical treatment process equipment, it is important to consider sludge management.

[Review bullet items in workbook.]

Operation and Maintenance Considerations

[Review items on operational practices and considerations and on maintenance considerations provided in workbook.]

☑ Exercise

[Give participants ten minutes to answer the following questions in their workbook, then review the correct answers with them.]

1. What is the importance of mixing in the coagulation process?

Ans: *[Vigorous mixing during coagulation is important to ensure that the coagulants are thoroughly mixed into the waste stream and that the solids particles make physical contact with each other.]*

2. What is flocculation?

Ans: *[Flocculation is the actual gathering together of smaller suspended particles into flocs, thus forming a readily settleable mass.]*

3. Briefly describe the jar test procedure.

Ans: [*Various types of chemicals or different doses of a single chemical are added to sample portions of wastewater in a jar test unit and all portions of the samples are rapidly mixed. After rapid mixing, the samples are slowly mixed to approximate the conditions in the plant. Mixing is stopped and the floc formed is allowed to settle. The appearance of the floc, the time required to form a floc, and the settling conditions are recorded. The supernatant is analyzed for turbidity, suspended solids, and pH. With this information the operator selects the best chemistry or best dosage to feed on the basis of clarity of effluent and minimum cost of chemicals.]*

GRAVITY FILTRATION: 30 minutes

Gravity Filtration Basics

As mentioned at the start of this unit, filtration is one of two methods for effluent polishing. We will now focus on gravity filtration for the next portion of our discussion. Gravity filtration involves the removal of suspended solids from wastewater through the application of the wastewater to a medium that allows water to pass through while retaining the solids. A key point to remember is that no forces, other than gravity, are at work to effect the separation.

The Filtration Process

[Review information as it appears in the workbook.]

[Review the steps presented in the workbook:

- *Influent Distribution to the Top of the Media.*
- *Solids Capture on the Media.*
- *Collection of Effluent in the Underdrain System.]*

[Finish covering the steps presented in the workbook.]

The Backwash Process

[Read the paragraph on the backwash process.]

Monitoring Head Loss to Avoid Breakthrough

[Review bullet item in workbook.]

Display Slide 22—Differential Pressure Through a Sand Filter (Figure 2.12)

In this graphic, a differential pressure sensor is used with one input from a point above the filter media and another input from a point beneath the underdrain. As solids accumulate on or in the filter medium, the differential pressure will increase. At a pre-determined differential pressure, backwash should be initiated.

Backwash Water Applied Through Underdrain System

[Review bullet item in workbook.]

Upward (Reverse) Flow of Backwash Water Fluidizes the Media

[Review bullet item in workbook.]

Solids are Carried Out with Wash Water to Discharge

[Review bullet item in workbook.]

Alternative Processes

There are other backwashing schemes available in addition to the one we just reviewed in detail.

[Review the 2 bulleted items in the workbook that cover the alternative processes.]

Gravity Filtration Alternatives

We have just learned about gravity filtration basics, the filtration process and the backwash process. It is important to note that there are numerous alternatives to consider when discussing gravity filtration. However, these alternatives fall into two general categories of filtration – surface straining type and depth filtration type. We will now briefly review these two filter types and examples of each.

Surface Straining Type

[Review bulleted information from workbook.]

The solids mat that accumulates on the face of the filter may be difficult to remove, so this needs to be considered in determining the length of the filter run. A longer running time may make removal of the mat more difficult. Generally, the amount of backwash water required for this type of filter is less than that required for a depth filter.

Rapid Sand Filters

Display Slide 23—Rapid Sand Filter (Figure 2.13)

Rapid sand filters are a surface straining filter and are often used in wastewater treatment plants.

Depth Filtration Type

The second gravity filtration type is the depth filter.

[Review bulleted item in workbook.]

Two examples of depth filters are dual media filters and multi-media filters.

Dual Media Filters

[Review information in workbook.]

Multi-Media Filters

[Review information in workbook.]

Display Slide 24—Filter Configurations (Figure 2.14)

[In all the downflow filter figures, the density of the different media is selected so that after backwashing the filter (which fluidizes the filter bed), the media will settle back into the designated configuration. The denser media will settle quicker than the lighter media, so the denser media will end up as the bottom layer of the filter.]

Take this opportunity to quiz the participants on the graphic by asking them to answer the following question about each figure (a), (b), (c) and (d) on the slide:

On each figure, is a surface straining filter or a depth filter being used?

Ans: *[Figure (a) is a surface straining filter*

Figure (b) is a depth filter

Figure (C) is a depth filter

Figure (d) is a depth filter]

[Be sure to cover these remaining key points regarding Slide 24 (Figure 2.14):

- *In figure (a), the conventional downflow filter is a surface straining filter. The fine sand is the filter medium, the coarse medium is used only to support the sand and keep it from washing out of the filter system.*
- *In figure (b), the upflow filter is a depth filter in which the larger solids are captured in the coal (coarse medium) and the fine sand surface strains the smaller solids.*
- *In figure (c), the coal is the depth filter, the silica sand is the surface straining layer.*
- *In figure (d), the coal again is the depth filter, the silica sand could act as a finer depth filter, depending on the application, with the garnet sand acting as a surface straining layer. Garnet sand is denser than silica sand and will settle first to the bottom of the filter system after backwashing is completed.]*

Major Parts of a Gravity Filter

Now that we have finished our discussion on gravity filtration alternatives, we will talk about the major parts of a gravity filter. Specifically, we will talk about the inlet distribution system, the filter media, the underdrain system, the media scouring system, the influent rate control valve and the backwash system

Inlet Distribution System

[Review information in workbook.]

Filter Media

[Review information in workbook.]

Underdrain System

[Review information in workbook.]

Display Slide 25—Underdrain System (Figure 2.15)

The slide shows details of the blocks commonly used as underdrain support. These blocks have replaced natural materials, such as rocks, which were used prior to the development of modern plastic underdrain systems.

Media Scouring System

[Review information in workbook.]

[Cover definition of Mudballs in workbook.]

Effluent Rate Control Valve

[Review information in workbook.]

Backwash System

[Review information in workbook.]

Operational Considerations

The next area of emphasis will be key operational considerations for gravity filtration systems. Specifically, we will talk about filter loading rate, head loss, chemical feed management, backwash effectiveness and backwash water management.

Filter Loading Rate

[Review information in workbook.]

Head Loss

[Review information in workbook.]

Backwash Effectiveness

[Review information in workbook.]

Loss of Media

[Review information in workbook.]

Exercise

[Give participants ten minutes to answer the following questions in their workbook. Then, review the correct answers with participants.]

1. When should a gravity filer be cleaned?

Ans: *[A gravity filter should be cleaned when the solids capacity of the media has nearly been reached but before solids break through into the effluent.]*

2. How is head loss through the filter media determined?

Ans: [*The head loss through the filter media is determined by measuring the water pressure above and below the filter media. When water flows through the media, the pressure below the media will be less than the pressure above the media (when the pressure levels are measured or read at the same elevation). The difference between the two readings is the head loss.]*

3. What can happen if the filter media is not thoroughly cleaned during each backwashing?

Ans: *[If the filter media is not thoroughly cleaned during each backwashing, a buildup of solids will occur. The end result of incomplete cleaning is the formation of mudballs within the bed].*

PRESSURE FILTRATION: 20 minutes

Pressure Filtration Basics

The next filtration method we will cover is pressure filtration. Pressure filters operate similarly to the gravity filters we just learned about. The biggest difference is that in a pressure filter, closed vessels are used so that pressure can be applied to force the wastewater through the filter media.

[Cover the key points regarding the method of controlling the flow through the filter.]

Major Parts of a Pressure Filter

A pressure filter has several major parts, most of which are very similar to the gravity filter. The differences between the two relate to the use of pressure versus gravity to affect the separation of solids from the wastewater.

Influent Holding Tank

[Review information in workbook.]

Filter Feed Pumps

[Review information in workbook.]

Chemical Feed Systems

[Review information in workbook.]

Filter

[Review information in workbook.]

Continue to review information on filter.

Backwash System

[Review first bullet item in workbook.]

Typically, pressure filters are designed to run approximately 6 to 8 hours under peak conditions. This is equivalent to a run of approximately 24 hours based on average load conditions.

[Review next three bullets in workbook.]

A typical backwash cycle may consist of the following steps:

- Valves close to stop flow into and out of the filter
- Backwash influent and effluent valves open
- Surface washing arms begin scouring the surface mat
- Backwash pumps start and valves regulate the gradual increase of backwash to the filter
- The filter bed fluidizes (expands) and mechanical scouring of the media occurs (due to the rolling action of the fluidized bed and the continued action of the spray nozzles on the washing arms. Because the bed has expanded, the spray washer effectively acts on the top portion of the filter media (not just the surface).
- The water flow to the spray wash arms is stopped to allow the filter media to stratify
- After the requisite amount to backwashing time, valves gradually close to reduce and stop the backwash flow
- The backwash valve close
- The wastewater influent valves open and filtration is resumed

Backwash Decant Tank

[Review information in workbook.]

Operational Considerations

Just as there are operational considerations for gravity filters, there are operational considerations for pressure filters. Key operational considerations include filter loading rate, head loss, chemical feed management, backwash effectiveness and backwash water management.

Filter Loading Rate

[Review information in workbook.]

Head Loss

[Review information in workbook.]

Chemical Feed Management

[Review information in workbook.]

Backwash Effectiveness

[Review information in workbook.]

Backwash Water Management

[Review information in workbook.]

Exercise

[Give participants ten minutes to answer the following questions in their workbook. Then, for each question, ask participants if one of them would share their answer with the group. Correct answers are listed below and should be reviewed with participants if volunteers do not give correct answers.]

1. List the major components of a pressure filter system.

Ans: *[The major components of a pressure filter system include: a holding tank or wet well; filter feed pumps; chemical coagulant feed pump system; filters; filter backwash wet well; filter backwash pumps; and decant tank.]*

2. What is the purpose of the holding tank located just ahead of a pressure filter?

Ans: *[The purpose of the holding tank is to store water and to allow additional settling of the suspended solids before the water is applied to the filter.]*

3. What could cause high operating filter differential pressures?

Ans: *[High operating differential pressures could occur if either (1) the media is filled with suspended material; and/or (2) excessive chemical feed is blinding the media].*

CONTINUOUS BACKWASH, UPFLOW, DEEP-BED GRANULAR MEDIA FILTRATION: 25 minutes

Benefits of Continuous Backwash, Upflow, Deep-Bed Granular Media Filters

The next type of filtration system we will examine is the continuous backwash, upflow, deep-bed granular media filter.

[Review information in workbook. Cover these key points:

- *These filters continue to operate while being backwashed*
- *Because they run continuously, less standby filter capacity is required (because a filter does not need to be taken out of service to be cleaned).]*

Filter System Components

Filter system components may be housed within a factory-provided tank or the components may be installed in a concrete tank constructed on-site.

Display Slide 26—Bottom Feed Concrete Filter (Figure 2.16)

This is a continuous backwash, upflow, deep-bed granular media filter installed in a concrete basin. Except for the concrete containment, this system is identical to a factory-provided filter that uses steel containment. Our discussion of the filter system components will be based on the next slide you see, which is a factory-built unit.

Display Slide 27—Bottom Feed Cylindrical Filter.

This is a factory supplied continuous backwash, upflow, deep-bed granular media filter. We will use this slide now to briefly describe how this filter works.

Wastewater to be treated enters the bottom of the filter and flows to the inlet tubes that carry the wastewater to the distribution ring located within the sand filter. Wastewater flows along and around the ring and is introduced into the sand filter. From there it flows upward through the sand and solids are removed along the way. Clean water exits the sand bed and continues flowing upward. Some flows to the effluent weir and is collected and discharged. Some flows up through the gravity sand washer carrying washed solids to the reject compartment and out to the dirty water discharge. Meanwhile, the sand bed is continuously moving downward because the air lift at the bottom of the filter is continuously pumping dirty sand up to the sand/water separator at the top of the filter. As sand moves downward, a clean sand interface is continuously presented to the wastewater entering the sand bed.

Chemical Feed Systems

[Mention that chemical treatment is normally provided to assist the performance of this filter.]

The chemical feed systems and the discussion of them is identical to our previous discussion from Unit 2 on Chemical Precipitation. Therefore, we will skip over these details in this unit.

Flocculation Tank

[Review information in workbook.]

Influent Distribution System

[Review information in workbook.]

Influent and Effluent Turbidity Monitoring

[Review information in workbook.]

Influent and Effluent Flow Metering

[Review information in workbook.]

Continuous Backwash System

Display Slide 28—Continuous Backwash System (Figure 2.18)

This is a slide of the continuous backwash system. Refer to this slide as we quickly go over the operation of the continuous backwash system.

Plate A is a detail of the influent feed tube that discharges to the inlet hood, which distributes the wastewater across the face of the filter medium. We discussed this just a few minutes ago – it is not part of the backwash system. Plate B shows how the air lift works to carry dirty sand to the top of the filter. A steady stream of compressed air is used to create the pumping action. Plate C shows the air lift discharge point in the sand/water separator. Referring to Plate C, dirty sand falls back down through the baffled wash tube where it is contacted by uprising filtered water, which acts to clean the dirty sand. After passing through the baffled area, the clean sand is deposited on the top of the sand bed. The uprising water carries the solids dislodged from the sand up to the sand/water separator, where the solids are carried out of the filter in the reject water.

[Review bulleted information in workbook.]

Backwash Water Sump

[Review information in workbook.]

Operational Considerations

[Review the first paragraph. Indicate that they will focus on the air lift pump and controlling reject water flow rate.]

Air Lift Pump

[Review the information on air lift pump.]

Controlling Reject Water Flow Rate

[Review information in workbook.]

☑ Exercise

[Give participants ten minutes to answer the following questions in their workbook. Then, for each question, ask participants if one of them would share their answer with the group. Correct answers are listed below and should be reviewed with participants if volunteers do not give correct answers.]

1. What happens if the air lift is allowed to operate without wastewater flowing to the filter?

Ans: *[Dirty sand will be carried to the top of the filter and deposited at the top of the sand bed. This dirty sand will slough off solids into the filter effluent when the filter is restarted for normal operation.]*

2. What are the advantages of continuous backwash, upflow, deep-bed silica sand media filters over other types of granular media filters?

Ans: *[They do not need to be shut down to clean the filter media, consequently they can be run continuously. Therefore, they can provide the same filtration capacity using fewer or smaller filter systems. Also, they provide excellent quality effluent with very low turbidity because of the deep-bed media design.]*

3. How is silica sand media cleaned in a continuous backwash, upflow, deep-bed silica sand media filter?

Ans: *[Dirty sand is carried to the top of the filter by an air lift pump. Sand and dirty water are separated there and the dirty sand falls through a baffled launder where it is contacted with upflowing filtered water. This water helps to clean the sand as it passes through the launder and it carries the sloughed solids to the reject compartment where they are discharged over a weir. The clean sand falls out of the launder onto the top of the sand bed, replenishing the sand bed with clean sand.]*

CROSS FLOW MEMBRANE FILTRATION: <u>15 minutes</u>

The Basics of Membrane Filtration

[Instructor Note: If time considerations require the deletion of some material from the Module presentation, this section on cross-flow membrane filtration may be shortened or deleted because this process is not commonly used for municipal wastewater treatment in Pennsylvania. This is, however, a commonly used industrial wastewater pretreatment process.]

[Review information in workbook.]

Display Slide 29—Ultrafiltration Wastewater Treatment Flow Schematic (Figure 2.19)

In this figure, the ultrafiltration system is pressurized by the recirculating pump, which forces water to cross the membrane while solids are retained on the influent side of the membrane. The UF permeate is the treated water that has crossed the membrane. The bleed line returns wastewater to the feed tank. This wastewater has a higher solids concentration than the influent because water has been removed. In the feed tank the recycled wastewater mixes with the incoming wastewater and is returned to the ultrafiltration system.

Types of Membrane Filters

[Review information in workbook.]

Reverse Osmosis

[Review information in workbook.]

Display Slide 30—Cross Flow Membrane Filtration (Figure 2.20)

This graphic presents relative sizes for various membranes. A Dalton is an indirect measure of the size of the pores. A Dalton is a unit of mass designated as one-sixteenth the mass of oxygen-16, the most common oxygen molecule. Therefore, a pore size of 16 would allow the passage of an oxygen molecule. As the graphic shows, ultrafiltration membrane pores are rated for 1,000 to over 100,000 Daltons, which can be related to microns based on our earlier discussion that ultrafiltration pore sizes range from 0.005 to 0.1 microns.

What experiences have you had with any of the membrane filters listed above?

Ans: *[There are no "correct" answers to this question since it is a subjective question.]*

Membrane System Configurations

Membranes are made of durable polymers, such as polysulfone, polyamide, and polyvinylidene fluoride. They must be durable enough to withstand cleaning and use in a variety of environments. A life expectancy of one to five years is common.

Tubular Membranes

Display Slide 31—FEG One-inch Tube (Figure 2.21)

As shown in the graphic, membranes can be applied to plastic and steel piping so that the membrane covers the inside diameter and length of the piping. This is a rugged arrangement that allows the solids to travel along the length of the pipe as water permeates through the membrane and exits through the side of the pipe.

Hollow Fiber Membranes

Display Slide 32—Hollow Fiber Cartridge (Figure 2.22)

[Review information in workbook.]

Spiral Membranes

Display Slide 33—Spiral Wound Module (Figure 2.23)

[Review information in workbook.]

The Membrane Filtration Process

[Review information and definitions.]

Display Slide 34—Tubular Arrangement (Figure 2.24)

This shows a simple basic membrane filtration system using tubular membranes.

Display Slide 35—Batch Process (Figure 2.24)

This shows a simple basic membrane filtration system using an unspecified membranes. Just another way of showing the same thing.

Display Slide 36—Modified Batch Process (Figure 2.25)

This shows a continuous wastewater feed to the feed tank – not a true batch process now.

Display Slide 37—Stages in Series Process (Figure 2.25)

This shows membranes installed in series for better performance and longer runs with the secondary membrane.

Basic Calculations

[Review information in workbook.]

Operational Considerations

[Review the first paragraph. Indicate that the parameters include the following: temperature, flux, transmembrane pressure, differential pressure of the recirculation flow, membrane fouling, and cleaning options.]

[Review information in workbook.]

[Continue to review information in workbook.]

[Have the participants review the Key Points for Unit 2 – Effluent Polishing.]

☑ Exercise

[Allow participants 10 minutes to answer the quiz questions in their workbook, then review the following correct answers with them.]

1. How do cross flow filtration processes differ from conventional filtration?

Ans: *[In cross flow filtration, wastewater flows across the surface of a membrane rather than through a bed of granular media. The membrane permits water to pass through but blocks the passage of particles. Other differences include the length of the filter run and the ease of cleaning the membranes.]*

2. The amount of flux across a membrane is dependent on what factors?

Ans: *[The amount of flux across a membrane is dependent upon transmembrane pressure (driving force), flow rate across the membrane surface (turbulence on the membrane), concentration of waste material, temperature, viscosity and cleanliness of the membrane surface.]*

3. List the steps for cleaning (washing) a membrane.

Ans: *[The steps are as follows:*

1. Displacement of waste from the system with water.

2. Washing the membranes with a caustic and surfactant to remove oils and grease.

3. Flushing the surfactant from the membrane with warm water.

4. Washing the membrane with an acid cleaner to remove salt buildup.

5. Flushing the acid from the membrane with warm water.

6. Recording clean water flux as a check on cleaning effectiveness.]

[Ask participants if they have any questions about Unit 2. Respond accordingly.]

UNIT 3: <u> 80 minutes</u>

Display Slide 38—Unit 3: Phosphorus Removal

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

- Identify two distinct technology options for removing phosphorus from wastewater.
- Describe each of the following processes, list the equipment required for each process and identify some operational considerations for each:
  - Biological Phosphorus Removal
  - Phosphorus Removal by Lime Precipitation
  - Phosphorus Removal by Alum Flocculation

PHOSPHORUS REMOVAL BASICS: 5 MINUTES

Why Remove Phosphorus

[Review the first paragraph.]

Technology Options for Phosphorus Removal

[Emphasize that for the purposes of this module, the two main technology options that will be covered are biological removal and chemical precipitation.]

Biological Phosphorus Removal

[Review information in workbook.]

Chemical Phosphorus Removal

[Be sure to point out that the two most common chemical processes are lime precipitation and alum flocculation.]

[Review information in workbook.]

BIOLOGICAL PHOSPHORUS REMOVAL: 35 MINUTES

Now that we understand why phosphorus needs to be removed from wastewater, let's turn our attention to biological phosphorus removal and how that process works.

How the Process Works

[Review information in workbook. Be sure to emphasize the use of two treatment tanks during biological phosphorus removal.]

Luxury Uptake of Phosphorus

[Review information in workbook.]

Display Slide 39—Microorganism Cell Reactions (Figure 3.1)

[Use this slide as a visual aid during discussion of the anaerobic selector and aerobic reactor sections.]

Anaerobic Selector

[Refer to Slide 39:]

The phosphorus is stored in the cell mass of the microorganisms as polyphosphate (compounds containing many phosphate molecules). When little food and no oxygen are available, the microorganisms must use their cell mass for food and energy. By breaking down the polyphosphates, the microorganisms obtain energy that they use to metabolize the food (COD) in the wastewater into carbon sources they store in their bodies. As the polyphosphates are broken down, phosphate is released into the wastewater.

[Review information in workbook.]

Aerobic Reactor

Continue to Display Slide 39—Microorganism Cell Reactions.

The carbon sources stored in the cell while the microorganisms are in the anaerobic selector are used as food and energy sources by the microorganisms while in the aerobic reactor. The energy available from the breakdown of the carbon sources is used by the cell in the synthesis of new cell mass. Phosphate from the wastewater is absorbed by the microorganisms and used to build the new cell mass by synthesizing polyphosphates. The microorganisms use oxygen dissolved in the wastewater to metabolize the carbon sources, creating carbon dioxide and water as by-products.

[Review information in workbook.]

Equipment Requirements

To further our understanding of biological phosphorus removal, we need to talk about the equipment required for the process.

[Review information in workbook.]

Display Slide 40—Biological Phosphorus Removal Process (Figure 3.2)

Typical process layouts for biological phosphorus removal are shown in slide 40 and Figure 3.2 in your workbook. The mainstream process relies on a sedimentation tank to remove microorganisms that have absorbed the phosphorus from the wastewater. The sidestream process adds chemical treatment to enhance the removal of phosphorus from the anaerobic selector effluent stream.

[Review information in workbook.]

Display Slide 41—Luxury Uptake of Phosphorus (Figure 3.3)

Note the lime mix tank, in which the phosphorus in the anaerobic tank effluent is chemically removed by precipitation with calcium hydroxide (lime). Phosphorus is also removed in the secondary clarifier by sedimentation of the microorganisms from the aerobic tank that have absorbed excess phosphorus.

Operational Considerations

[Read the first paragraph.]

[Cover the bullet items provided in the workbook for each of the key operational considerations:

- *Anaerobic Selector Cell Residence Time.*
- *Maintenance of Anaerobic Conditions in the Anaerobic Selector.*
- *Maintenance of Sufficient Dissolved Oxygen in the Aerobic Reactor.]*

[Continue to cover the bullet items provided in the workbook for each of the key operational considerations:

- *All Considerations Associated with the Chemical Phosphorus Removal System]*

[Before moving on, conduct an oral review with the class by posing the following questions to the class, one at a time.]

Now, before moving on, we will briefly review the content in this section with a few discussion questions.

REVIEW QUESTIONS:

1. What is the luxury uptake of phosphorus?

Ans: *[It is a microbiological process in which the wastewater environment is manipulated to encourage the microorganisms to absorb more phosphorus into their cell mass then they would normally absorb.]*

2. The phosphorus stripping process using luxury uptake is similar to an activated sludge plant with the exception of what tanks?

Ans: *[Anaerobic selector tank]*

3. Why is it important to closely control the detention time in the anaerobic phosphorus stripping tank?

Ans: *[Because if the microorganisms are kept in the tank too long, they will die. If they are not kept in there long enough, they will not be forced to release phosphorus from their cell mass.]*

CHEMICAL PHOSPHORUS REMOVAL: 40 MINUTES

Phosphorus Removal by Lime Precipitation

As I mentioned at the start of this unit, there are two types of phosphorus removal – biological and chemical. We have completed our discussion on biological phosphorus removal and are now going to talk about chemical phosphorus removal. Specifically, we will talk about phosphorus removal by lime precipitation and phosphorus removal by alum flocculation.

[Review introductory information in workbook.]

How the Process Works

When lime is added to wastewater, the calcium in the lime reacts with the natural bicarbonate alkalinity to precipitate CaCO3 (calcium carbonate):

[Write the following equation on a flipchart for participants to see.

$Ca(OH)_2 + H_2CO_3 \Leftrightarrow CaCO_3 \downarrow + 2H_2O$*]*

With the addition of excess lime, a high pH will be produced in the wastewater so unreacted calcium ions will be available to react with the phosphates in the wastewater. This is the reaction shown in your workbook.

[Review bulleted items in workbook.]

Equipment Requirements

The equipment required for the lime precipitation process includes lime preparation and feeding systems, mixing and flocculation chambers, chemical clarifiers and associated pumps and piping. There may also be equipment required for sludge thickening, neutralization of the treated wastewater prior to discharge, recovery of the lime from the sludge and sludge management. We will review key equipment components in more detail.

Display Slide 42—Single Stage Lime Recarbonation Process (Figure 3.4)

[As you review each bulleted item in the workbook, point out its location on Slide 42.]

[Continue reviewing each bulleted item in the workbook, pointing out its location on Slide 42.]

[When covering Sludge Dewatering, provide the following information:]

The referenced figure presents a sludge thickening tank, a centrifuge to further dewater the lime sludge, and a calciner (a heat-treating process) to recover lime from the sludge (by removing water and carbon dioxide).

[When covering the Recarbonation tank, be sure to provide the following information:]

In larger treatment plants, carbon dioxide is much more economical than acid solutions.

Operational Considerations

As with all processes we have been discussion, there are operational considerations when talking about phosphorus removal by lime precipitation. Our discussion will focus on target pH level, effectiveness of flocculation, recarbonation control and lime handling safety procedures.

[Review workbook information on target pH level.]

[Review workbook information on remaining three operational considerations.]

[When reviewing lime handling safety procedures, be sure to cover the following:]

Treatment Plants typically have standard operating procedures for many work situations, including working with strong caustics.

[Before moving on, conduct an oral review with the class by posing the following questions to the class, one at a time.]

Now, before moving on, we will briefly review the content in this section with a few discussion questions.

REVIEW QUESTIONS:

1. What is a typical pH range for operation of a lime precipitation system for phosphorus removal?

Ans: *[pH of 10 to 11]*

2. Why would you perform a jar test when removing phosphorus by the lime precipitation process?

Ans: *[Jar tests can be used to determine what pH levels and polymer dosages form the largest floc possible and allow the fastest settling of the floc formed.]*

3. When removing phosphorus by the lime precipitation process, the phosphorus concentration normally does not control the lime dosage required, what does?

Ans: *[The amount of alkalinity present controls the lime dosage.]*

Phosphorus Removal by Alum Flocculation

We will now move on to a second type of chemical phosphorus removal, which is phosphorus removal by alum flocculation.

[Review definition of Alum provided in workbook.]

How the Process Works

[Review information in workbook.]

[Write the following information from the participant workbook on a flip chart and refer to it when discussing it:

$Al_2(SO4)_3 + 2PO_4^{-3} \Leftrightarrow AlPO_4 \downarrow$
alum phosphate aluminum phosphate

$Al_2(SO4)_3 + 6HCO_3^{-} \Leftrightarrow 2Al(OH)_3 \downarrow + 3SO_4^{-2} + CO_2$
alum alkalinity aluminum hydroxide carbon dioxide]

Equipment Requirements

[Review information in workbook.]

Operational Considerations

The operational considerations for alum precipitation are generally similar to those for lime precipitation with a few minor differences. Those differences are highlighted in your workbook.

[Review the operational considerations listed in the workbook.]

[Continue to review the operational considerations listed in the workbook.]

[Have the participants review the Key Points for Unit 3 – Phosphorous Removal.]

☑ Exercise for Unit 3 – Phosphorous Removal

1. How would you determine the optimum alum dosage for phosphorus removal?

Ans: *[Conduct a jar test to find the dosage that produces the best clarification with the least amount of alum. Confirm the removal by testing the supernatant for phosphorus.]*

2. What would you do first if you observed a cloudy appearance in the effluent from a filtration unit in a phosphorus removal system that uses alum?

Ans: *[Check to make sure that the alum feed system is not overdosing because the cloudy condition of the effluent is indicative of an alum overdose.]*

3. What safety hazard might operators encounter in areas where aluminum sulfate is mixed with water?

Ans: *[Slippery surfaces, especially slippery floors.]*

4. Two chemical processes are commonly used to remove phosphorus from wastewater are __lime__ precipitation and __alum__ flocculation and precipitation.

5. A polymer is often used as a flocculation aid with alum, because the aluminum phosphate precipitate is not dense enough to provide adequate removal.
   a. __X__ True b. ____ False

6. Luxury uptake is a term used to describe a reaction of microorganisms after they have been depleted of _phosphorous_.

7. Aerobic is a condition in which atmospheric or dissolved molecular _oxygen_ is present in the aquatic environment.

8. A strict anaerobic environment is necessary in the anaerobic selector to force the microorganisms to utilize the polyphosphates in their cell mass for energy to survive their stay in the anaerobic selector.

   a. _X_ True b. ____ False

9. Typically, the pH of the wastewater will be raised to the range of _10_ to _11_ with the addition of lime to properly precipitate the phosphorus present.

10. When alum is mixed with wastewater, it acts as an acid, reducing the pH of the wastewater (by reducing alkalinity). Optimum phosphorus removal is generally achieved at a pH range of approximately _6.0_ to _7.0_.

11. _pH_ testing is recommended to optimize the alum dosage and to avoid overdosing.

[There is no need to discuss the references on this page.]

[This page was intentionally left blank.]

UNIT 4: 85 minutes

Display Slide 43 and 44—Unit 4: Nitrogen Removal

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

- Identify three distinct technology options for removing nitrogen from wastewater.
- Explain the purpose and process of Nitrification.
- Explain the purpose and process of Denitrification.
- Explain the difference between suspended and attached growth reactors.
- Describe each of the following processes, list the equipment required for each process and identify the operational considerations for each:
  - Ammonia Stripping
  - Breakpoint Chlorination

NITROGEN REMOVAL BASICS 10 minutes

Why Remove Nitrogen from Wastewater

[Review information in workbook.]

Technology Options for Nitrogen Removal

Nitrogen removal from wastewater can be accomplished by a variety of biological, physical and chemical processes.

Display Slide 45—Types of Nitrogen Removal Systems (Table 4.1)

Several biological, chemical, and physical nitrogen removal processes are presented in Table 4.1 in your workbook. As you can see, physical and chemical processes tend to be more expensive, in part because of the chemical demand required to remove nitrogen. Equipment cost considerations also come into play for sedimentation, stripping, and ion exchange. Biological processes are more commonly used, but capital and operating costs are also required to build and maintain biological nitrogen removal facilities. The rest of this unit will be devoted to a brief exploration of technologies to biologically, chemically, and physically remove nitrogen from wastewater.

[Review information in workbook.]

BIOLOGICAL NITROGEN REMOVAL <u>30 minutes</u>

Nitrification/Denitrification Process

[Review information in workbook.]

Goal of Process

[Read the goal as it appears in the workbook.]

Chemical Conversions during Nitrification

[Review information in workbook.]

[Review definition of Autotrophic that is in workbook.]

Use flipchart to write the 2 chemical equations.

[Review information in workbook.]

Chemical Conversions during Denitrification

[Review information in workbook.]

[Review definition of Heterotrphic that is in workbook.]

[Continue to review information in workbook.]

[Use flipchart to write the chemical equation.]

Nitrification Reactors

[Review first paragraph under Nitrification.]

Suspended Growth Reactors

[Review information in workbook.]

Process Modes Suitable for Nitrification

[Review information in workbook.]

Factors Impacting Performance

[Review information in workbook.]

Attached Growth Reactors

[Review information in workbook.]

Commonly Used Process Modes

[Review information in workbook.]

Display Slide 46—Trickling Filter Plastic Media (Figure 4.1)

This is an example of modern trickling filter media; corrugated plastic plates have replaced the stone beds formerly used for trickling filter media.

Display Slide 47—Packed Tower for Nitrification (Figure 4.2)

This is an example of a very large packed tower for nitrification. The tower is packed with bundles of plastic media.

Factors Impacting Performance

[Review information in workbook.]

Denitrification Reactors

[Review information in workbook.]

Suspended Growth Reactor

[Review information in workbook.]

Factors Impacting Performance

[Review information in workbook.]

Attached Growth Reactor

[Review information in workbook.]

Factors Impacting Performance

[Review information in workbook.]

Process Configurations Based on Sludge Management Options

[Review information in workbook.]

Display Slide 48—Nitrification & Denitrification Using Suspended Growth Reactors (Figure 4.3)

[Review the following key information about the slide with the participants:

- *Discuss the alternative process schemes for denitrification. In your discussion note that nitrification/detrification can be configured with the denitrification tank preceding the nitrification tank or following the nitrification tank, depending on how the sludge is managed.*
- *In the first example, post denitrification using separate sludges, a dedicated clarifier is provided for both nitrification and denitrification so that the sludges can be managed individually. This gives the process greater flexibility.*
- *In the next two examples, a common sludge is produced and the order of the processes differs. The post denitrification process, the second example, has denitrification following nitrification. In the third example, denitrification precedes nitrification.*
- *Note that when denitrification follows nitrification, it is necessary to aerate the effluent from denitrification prior to settling the sludge. This is because denitrification is an anaerobic process and 1) anaerobic wastewater may not settle well, and 2) the final effluent from the plant must contain dissolved oxygen to avoid adversely impacting the receiving stream.*
- *A final note should be made regarding the pre-denitrification process scheme. When nitrification follows denitrification, the nitrates produced in the nitrification tank do not get completely removed from the wastewater. Only the portion of the nitrified wastewater that is recycled back to the denitrification tank will be denitrified. Also, this process relies on the raw influent to provide the carbon source for denitrification.]*

Review of Biological Nitrogen Control Reactions

[Review information in workbook.]

Display Slide 49—Biological Nitrogen Control Reactions

[Briefly, discuss a few of the rules of thumb in this table to show the participants how to use the table and how it is useful in control or monitoring the nitrification and denitrification processes. For example, to achieve nitrification, 4.6 milligrams of oxygen will be required for every milligram of nitrogen oxidized. This information helps the operator understand what the oxygen demand will be based on the concentration of nitrogen in his wastewater. For successful denitrification, sufficient methanol must be added. The rule of thumb is 1.9 milligrams of methanol per milligram of oxidized nitrogen removed, but a safety factor of up to 50% excess should be considered to account for extraneous demand.]

☑ Exercise

1. Nitrification can be accomplished by the use of what two types of biological growth reactors?

Ans: *[Nitrification can be accomplished by using suspended growth reactors or attached growth reactors.]*

2. What can an operator do to maintain sufficient alkalinity in a nitrification process?

Ans: *[Sufficient alkalinity can be maintained in a nitrification process by adding calcium oxide (lime) or soda ash.]*

3. What tests must be conducted to monitor nitrogen levels in the reactors during the nitrification process?

Ans: *[Nitrogen tests that must be performed at various key points along the reactors during the nitrification process include ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). A predominance of ammonia indicates inadequate nitrification. A predominance of nitrite indicates incomplete nitrification. A predominance of nitrate, with essentially no ammonia, indicates successful nitrification.]*

PHYSICAL NITROGEN REMOVAL BY AMMONIA STRIPPING: <u>25 minutes</u>

How Ammonia Stripping Works

[Review information in workbook.]

Equilibrium Equation

[Write this equation on flipchart:

NH_4^+	$\leftrightarrow$	NH_3	+	H^+
Ammonium ion		*ammonia gas*		*hydrogen ion]*

[Then review information in workbook.]

Process Considerations

[Review information in workbook.]

Display Slide 50—Effects of pH & Temperature on Equilibrium (Figure 4.4)

[Discuss with the class how to read the graphic & review these key points:

- *Select a particular operating temperature and follow the curve for that temperature.*
- *The left vertical axis shows the percentage of nitrogen present as ammonia gas (the right vertical axis shows the percentage of nitrogen present as ammonium ion). Their sum will always equal 100%.*
- *Therefore, as you follow the temperature curve from left to right, you are increasing the pH. As the pH increases the ratio of gas to ion increases, which means that more ammonium ion is being converted to ammonia gas.*
- *At a pH of approximately 11, at least 90% of the ammonia nitrogen is present as ammonia gas for all the temperatures shown in the graphic. Note also that temperature has an impact on the ratio of ammonia gas to ammonium ion.*
- *At any particular pH value, the amount of ammonia gas present compared to the amount of ammonium ion will be higher at the higher temperature.]*

☑ As a class exercise, select three operating points on the figure and ask the class to provide the correct answer to the question. Three suggested problems are:

1. At a temperature of 0°C and a pH of 11.0, what are the approximate percentages of ammonia gas and ammonium ion in solution?

Ans: *[90% ammonia gas, 10% ammonium ion.]*

2. At a pH of 9.0 and a temperature of 20°C, what are the approximate percentages of ammonia gas and ammonium ion in solution?

Ans: *[30% ammonia gas, 70% ammonium ion.]*

3. If the wastewater contains 60% ammonia gas and 40% ammonium ion, and the temperature of the wastewater is 40°C, what would be the approximate pH of the wastewater?

Ans: *[8.7 to 9.0]*

pH Sensitivity

[Review information in workbook.]

Temperature Sensitivity

[Review information in workbook.]

Ammonia Stripping Equipment

Display Slide 51—Ammonia Stripping Process with Lime Recovery (Figure 4.5)

Note that lime is mixed with the raw waste in a flash mixer followed by flocculation and precipitation (sedimentation). Sedimentation is necessary because the addition of lime will cause compounds to precipitate out of solution. The solids produced by lime addition must be removed before the stripper to avoid plugging the stripper. A pump will be required to transport the high pH liquid to the top of the stripper. Air is blown into the bottom of the stripper. Following stripping, the pH will need to be adjusted downward prior to discharge of effluent (recarbonation tank). Ammonia gas is shown discharging at the top of the stripper. The air discharge may require treatment is remove ammonia gas prior to discharge of the air.

The focus of the next part of our discussion will be on the key components of the ammonia stripper rather than the lime feed and recovery system.

[Review information on workbook regarding Packed Towers.]

[Review information in workbook on pumps and piping and instrumentation and controls.]

Operational Considerations

There are three key operational considerations to discuss. They are Air to Liquid Mass Flow Ratio, Scaling, and Freezing.

[Review the information in the workbook for each of the operational considerations.]

[Continue reviewing the information in the workbook for each of the operational considerations.]

[Take the opportunity to quiz participants before moving on to the next section of this unit.]

1. Why must the pH of the wastewater be increased to successfully strip ammonia from wastewater?

Ans: *[Because ammonia is present in the wastewater in equilibrium with ammonium ion and at alkaline pHs (9 and higher) most of the nitrogen will be present in the ammonia form. Ammonia is a gas that can be stripped from the wastewater.]*

2. What are the two most common operating problems for ammonia strippers?

Ans: *[Freezing and scaling.]*

3. How is scale (calcium carbonate) formed during the stripping process?

Ans: *[Lime (calcium oxide) is often used to increase the pH during ammonia stripping. When carbon dioxide from the atmosphere reacts with calcium in alkaline environment, calcium carbonate (scale) is formed. The scale coats the surfaces of the equipment it comes in contact with.]*

That completes our review of physical nitrogen removal via the ammonia stripping process. If there are no questions on that material, we will move on to chemical nitrogen removal, and specifically, breakpoint chlorination.

CHEMICAL NITROGEN REMOVAL BY BREAKPOINT CHLORINATION: <u>20 minutes</u>

How Breakpoint Chlorination Works

[Review information in workbook.]

[Review defintion of Chloramines from workbook.]

Chemical Reactions

[Write the following equations on flipchart and then refer to them when review information in workbook.

$NH_3 + HOCl \leftrightarrow NH_2Cl + H_2O$
monochloramine

$NH_2Cl + HOCl \leftrightarrow NHCl_2 + H_2O$
dichloramine

$NHCl_2 + HOCl \leftrightarrow NHCl_3\ (gas)\uparrow + H_2O$
trichloramine

$2NH_3 + 3HOCl \leftrightarrow N_2\ (gas)\uparrow + 3HCl + 3H_2O$*]*

Chlorine Demand

[Review information in workbook.]

Breakpoint Chlorination Curve

Display Slide 52—Breakpoint Chlorination Reaction Curve (Figure 4.6)

[Review the breakpoint chlorination curve with the class noting the following:

- *The breakpoint curve is actually the curve with the high hump followed by the low dip. The other lines and curves in the figure are for illustrative purposes.*
- *In Zone 1, the measured chlorine residual increases as the chlorine dosage increases. During this phase, the chlorine is reacting with ammonia and chloramines to form primarily monochloramine, dichloramine, and trichloramine, which are all residual forms of chlorine. Therefore, the chlorine residual increases as the chlorine dosage increases.*
- *In Zone 2, more chlorine has been added to the wastewater than is required to react with the ammonia, the chloramines, and the inorganic compounds. Therefore, some of the chlorine completely oxidizes the chloramines. When that happens, some of the residual chlorine (in the form of chloramines) is destroyed and nitrogen gas is produced. As the dosage of chlorine increases further in Zone 2, additional residual chlorine (in the form of chloramines) is destroyed.*
- *At the beginning of Zone 3, most of the residual chlorine in the form of chloramines and chlororganics has been destroyed so that when additional chlorine is added to the wastewater, it goes into solution as free residual chlorine because nothing is left to react with the chlorine. Therefore, as the chlorine dosage increases in Zone 3, the free residual chlorine concentration increases.*
- *The low point in the dip of the curve is referred to as the breakpoint. This is the point at which all the chlorine demand has been satisfied.]*

Equipment Considerations

[Review information in workbook.]

Operational Considerations

As with all processes we have discussed today, breakpoint chlorination has several operational considerations that should be discussed.

[Review information in workbook.]

[Continue reviewing the information in the workbook.]

[Have the participants review the Key Points for Unit 4 – Nitrogen Removal.]

[Review information in workbook.]

☑ Exercise

1. Explain how the breakpoint chlorination process works.

Ans: *[By adding sufficient quantities of chlorine to wastewater containing ammonia nitrogen, the complete oxidation of the ammonia nitrogen takes place at a level of chlorine addition normally referred to as the "breakpoint".]*

2. What is the appropriate application for breakpoint chlorination?

Ans: *[Secondary or filtered effluent is the appropriate application for breakpoint chlorination. Breakpoint chlorination also is frequently used as final cleanup following other nitrogen removal processes.]*

This concludes Module 8 – Overview of Advance Wastewater Treatment Processes.

[Ask participants to list what were key learning points. Record responses on a flip chart.]

[Ask for and respond to questions.]

[Thank attendees for their participation. Offer words of positive encouragement. Remind participants that the participant workbook from this class will serve as a good reference in preparation for the state test.]