Wastewater Operator Certification Training
Instructor Guide

Module 1:
Introduction to Wastewater Treatment

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 1: Introduction to Wastewater Treatment* is to provide participants with an introduction to basic concepts of wastewater collection and conveyance systems, the wastewater treatment process, the role of the treatment plant operator and the regulations that govern wastewater treatment plant operations. This module has been designed to be completed in 3 hours, 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 the 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.

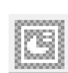
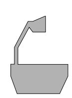
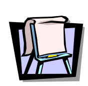
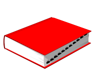
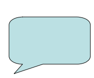
Delivery methods to be used for this course include:

- Lecture
- Small group and full group discussion
- Exercises
- Questioning

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

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

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: 5 minutes

Display Slide 1—Module 1: Introduction to Wastewater Treatment

[Welcome participants to "Module 1 – Introduction to Wastewater Treatment." Indicate the primary purpose of this course is to provide participants with an introduction to basic concepts of wastewater collection and conveyance systems, the wastewater treatment process, the role of the treatment plant operator and the regulations that govern wastewater treatment plant operations.]

[Introduce yourself.]

[Provide a brief overview of the module.]

This module contains four units. On page i, you will see the topical outline for Unit 1 – Role of the Treatment Plant Operator and Unit 2 – Characteristics of Wastewater.

[Briefly review outline.]

On page, you will see the topical outline for Unit 3 – Basic Wastewater Treatment Processes and Unit 4 – State and Federal Regulations.

[Continue to briefly review outline.]

The topical outline for Unit 4 continues on page iii.

[Continue to briefly review outline.]

UNIT 1: 20 minutes

Display Slide 2—Unit 1: Role of the Treatment Plant Operator.

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

- List the roles of the Treatment Plant Operator and describe the responsibilities of each.

DUTIES AND RESPONSIBILITIES OF THE TREATMENT PLANT OPERATOR: 20 minutes

We will begin this module by discussing responsibilities of a Treatment Plant Operator.

[Ask participants what duties and responsibilities they associate with a Treatment Plant Operator and record them on a flipchart. Keep the discussion brief. Combine similar answers and make the connection between participants' responses and the roles covered in this module (planning, design, and construction of new facilities; administration; public relations; operations and maintenance; safety; and education).]

Let's take a closer look at the six basic duties and responsibilities of a Treatment Plant Operator.

Planning, Design, and Construction of New Facilities

[Review information in workbook.]

[*Point out that the Treatment Plant Operator plays a critical role in the planning and design of new facilities and should be a member of the design team.]*

[Indicate that the Treatment Plant Operator should visit the site during construction so that he or she has the opportunity to relate the plant drawings to the actual facilities being constructed.]

Administration

There are three basic parts to the administration of a treatment plant. These include supervision of people, record keeping, and financial administration.

[Review each item in workbook on the administration of treatment plants.]

Public Relations

You will be required to maintain good relations with the public. This involves not only how you deal with complaints but also how you operate and maintain the plant. A well-maintained facility that appears clean and orderly adds credibility, which makes your dealings with the public easier. Good PR also requires you to educate the public on how the plant operates. Offer plant tours or an annual "open house" where anyone can visit and tour the facility. This should be coordinated with security personnel.

Remember to remain mindful of the downstream users' interests when communicating with anyone.

What are some examples of different interests various audiences may have?

Ans: Officials of regulatory agencies or other operators would want to be provided with detailed information on the operation of the plant. School classes would want to know only very basic information. Public tours or tours of the news media may be interested in water quality, which will help contribute to acceptance and support.

Wastewater Treatment Plant Operations and Maintenance

[Review importance of lab procedures and knowledge of mechanical principles in the workbook. Indicate lab analysis is critical for the operation of the plant but also necessary to show that the plant meets discharge permit criteria. Plant Operators must understand and follow lab procedures and take on somewhat of a "chemist" role.]

For instance, a Plant Operator must understand pH. pH is the expression of intensity of the basic or acid condition of a liquid. The pH may range from 0 to 14 where 0 is most acid, 14 most basic and 7.0 is neutral. Natural waters usually have a pH between 6.5 and 8.5. It is also vital for a Plant Operator to understand Biochemical Oxygen Demand or BOD. BOD is the rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. BOD testing is the best method for determining the organic strength of a wastewater.

Safety

[Read safety information in the workbook.]

What are some typical safety issues in a plant?

Ans: Some typical safety issues include:

- Chlorine Safety (potentially toxic atmosphere)
- Confined space entry – Most common cause of death from an on-the job accident for collection system operators is through asphyxiation.
- Explosions hazards – anaerobic digester producing methane gas
- Fall hazards
- Electrical Hazards

[Emphasize the importance of safety and how training and continued education are keystones in plant safety by using the following examples.]

- Operators, trained in the operation and maintenance of plant equipment, are less likely to have or cause an accident.
- Regular safety training is important to remind workers of proper use of equipment and proper work procedures.
- Plant Operators should develop and implement Stand Operating Procedures (SOP) relative to safe work procedures.

Continuing Education

You need to be aware of the existing resources for continuing education and how to obtain this information. Training materials and reference materials are available on a variety of topics through the Internet and various organizations, including those listed.

Private training providers may include;

- Colleges
- Universities
- Consulting firms
- Equipment manufacturers
- Internet training providers, or
- Environmental training companies.

[Review existing resources for Training Courses and Seminars and Training Reference Materials. (Verify websites are still correct prior to the training session. In addition, be aware of any new materials to reference that have been developed since this Module was printed.)]

[Continue reviewing existing resources for Training Reference Materials.]

[Review Key Points]

By now you should all realize that being a treatment plant operator involves more than opening valves and greasing pumps. As an operator, you have many responsibilities ranging from administration to maintenance to public relations to supervision. You are an important member of the design team during the planning and design of improvements to your treatment plant and a key player in the construction and start-up of new facilities.

You also have a responsibility not only to the community but to yourself to continue to expand your knowledge of wastewater treatment through continuing education. Attend technical conferences. Take advantage of any opportunities to visit other plants and to speak with other operators. Join a professional operator's association and become active in the association. More information about local and regional operator's organizations can be found at the web site of the Pennsylvania Water Environment Association.

UNIT 2: <u>60 minutes</u>

Display Slide 3—Unit 2: Characteristics of Wastewater.

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

- Describe the typical composition of raw wastewater.
- Explain the effects of wastewater discharges on the receiving stream.
- Identify how treatment plant discharge impacts natural cycles.

WASTEWATER CHARACTERISTICS: 15 minutes

In this module, we will be discussing some of the basics of wastewater treatment. First, let's examine the characteristics of wastewater and the potential impact of raw or inadequately treated wastewater discharges on the receiving stream.

[Read the first sentence on the page.]

Pure Water

Review the defintion for **Pure Water** that appears in the workbook.

[Review the information in the workbook about pure water and dissolved substances.]

Contaminants Typically Found in Untreated Wastewater

[Indicate that impurities may be referred to as contaminants.]

Contaminants typically found in wastewater are shown in Table 2.1 on page 2-3 of your workbook. The importance or potential impact of each contaminant on the environment is also covered in Table 2.1. If we look carefully at these contaminants, we will see that we can categorize them in one of four broad classes:

- Organic contaminants;
- Inorganic contaminants;
- Pathogens, and
- Other contaminants.

[Provide a brief summary for Table 2.1:]

- Suspended solids could lead to development of sludge deposits and anaerobic conditions.
- Biodegradable organics could lead to the depletion of natural oxygen.
- Pathogens could transmit diseases.
- Nutrients could lead to the growth of undesirable aquatic life and could lead to groundwater pollution.
- Priority pollutants, refractory organics, heavy metals, and dissolved inorganics could negatively affect public health.

We'll talk more about the classes of contaminants in a minute. But first, let's talk about another important wastewater characteristic—contaminant concentrations.

Contaminant concentrations are often used to describe the "strength" of the wastewater. Table 2.2 lists a range in concentrations for contaminants typically found in untreated wastewater. The strength, or concentration, will vary depending on the volume of diluting water and the types of users discharging to the plant. For example, a sewer system containing significant amounts of infiltration/inflow (clean water entering the sewer system from rain storms or groundwater) will tend to have contaminants of relatively low concentrations, whereas a system with high-strength industrial dischargers will contain some contaminants with higher concentrations. While the concentrations shown in Table 2.2 are typical of domestic strength wastewater, your system may be different depending on the types of users present. It is your job as the Plant Operator to characterize the wastewater entering your plant.

Now, let's take a closer look at each of the classes of contaminants.

Organic Contaminants

[Review key concept. Indicate that some priority pollutants (in addition to biodegradable and refractory organics) could also be organic contaminants.]

[State that organic contaminants can be discharged from domestic contributors or from various industries. Ask the class the discussion question.]

What are some examples of organic impurities from industrial contributors?

Ans: Examples of organic impurities include:

- Chloroform from leather tanning operations and pharmaceuticals manufacturing
- Trichloroethylene from textile mills and adhesive manufacturing
- Phenols from pesticide manufacturing and from iron and steel manufacturing
- BOD and fats, oils, and greases from food processing industries

Inorganic Contaminants

Inorganic contaminants are not biodegradable, but may be nutrients necessary for microorganisms to live. From Table 2.1, inorganic contaminants might include suspended solids, nutrients such as phosphorus and nitrogen, some priority pollutants, heavy metals such as copper (which can be dissolved into the wastewater from household plumbing), and dissolved inorganics such as street cinders, road salt, and the by-product of the water softening process.

Pathogens

Pathogens are disease-causing organisms that find their way into wastewater from human and animal waste products. These pathogens can be bacteria or viruses. Examples of diseases caused by these organisms include typhoid, cholera, dysentery, polio, and hepatitis. Proper hygiene is extremely important when working around wastewater.

Because the potential for disease is so great, it is important that wastewater be treated and disinfected to inactivate the pathogens prior to discharge to the receiving stream. It is particularly important if the receiving stream is used for recreational purposes (e.g., boating, swimming, and fishing) or as a drinking water source.

Other Impurities

Examples of other types of contaminants include thermal wastes and radioactive wastes. A typical source of thermal waste is non-contact cooling water. Depending on the use of the stream, limits on the temperature of the wastewater may be established to prevent elevating the temperature of the stream and impacting use.

A stream used for trout stocking is one example of a thermal sensitive stream where the stream temperature needs to be regulated. Can anyone think of any other reasons to regulate the temperature of discharges to the receiving stream?

Ans: Additional reasons to regulate the temperature of discharges are:

- To prevent loss of dissolved oxygen (DO)—the amount of DO that can be dissolved into water decreases as the temperature of the water increases, and
- To control undesirable aquatic growth such as algae, which grows faster at higher temperatures.

Radioactive wastes might come from nuclear power plants, hospitals, or laboratories. Generally, it is good practice not to allow the discharge radioactive wastes into sewer system. EPA lists this as a suggested prohibited waste in their general pretreatment program guidelines.

SOLIDS IN WATER: 15 minutes

Types of Solids

Display Slide 4—Typical Composition of Solids in Raw Wastewater.

Solids are a part of the composition of wastewater. Solids in wastewater are made up of several types of solids: total solids, suspended solids, dissolved solids, settleable solids, and non-settleable solids. In a typical wastewater treatment plant, total solids, settleable solids, and suspended solids are monitored routinely. The total solids and suspended solids are typically used in calculations for process control. The settleable solids of the wastewater and effluent might be monitored for information purposes, but have little meaning for process control. Let's talk about the solid types and how to determine solid concentration levels.

Total Solids

[Refer to Figure 2.1 found in the workbook as you review total solids.]

The solids found in untreated wastewater consist of organic and inorganic particles, some suspended and some dissolved in the wastewater. Figure 2.1 represents the general categories of solids typically found in wastewater.

The sum of all of the solids present in the wastewater is represented by the total solids content. In Figure 2.1, the total solids content is shown as 720 mg/L.

Next, we can break the total solids content down into two distinct sub-categories:

- Dissolved Solids, and
- Suspended Solids.

In Figure 2.1, the dissolved solids content is shown as 500 mg/L and the suspended solids content is shown as 220 mg/L. Note that the sum of the dissolved and suspended solids concentrations is 720 mg/L, which is the concentration of total solids in the wastewater.

Dissolved Solids

[Continue to refer to Figure 2.1 as you review dissolved solids.]

The total solids and suspended solids concentrations are typically identified through actual laboratory analysis. Dissolved solids concentrations can be estimated by subtracting the concentration of suspended solids from the concentration of total solids.

Dissolved solids cannot be removed by physical means. If you want to measure the dissolved solids content directly, you first have to filter the sample of wastewater to remove all of the suspended solids. To isolate dissolved solids from the wastewater, you have to evaporate the filtered water (filtrate), leaving behind (as residue) the dissolved solids.

Suspended Solids

[Continue to refer to Figure 2.1 as you review suspended solids.]

As the category name might suggest, the suspended solids are particles that are suspended or floating in the wastewater and can be removed by settling or by filtration.

We can further break the suspended solids sub-category down into two additional categories:

- Settleable Solids; and
- Colloidal Solids.

As shown in the figure, the sum of the colloidal solids and the settleable solids is 220 mg/L, which is the concentration of the suspended solids.

Settleable

[Continue to refer to Figure 2.1 as you review settleable solids.]

The settleable solids are particles large enough to settle out on their own. Typically, the settleable solids are the solids removed in a primary clarifier. Settleable solids content is usually measured in an Imhoff cone in units of ml/L. The ml/L unit is not the same as a mg/L unit, and cannot be subtracted directly from a concentration in mg/L units.

Nonsettleable

[Continue to refer to Figure 2.1 as you review nonsettleable solids.]

The colloidal solids will not settle on their own, but will remain in suspension after the settleable solids have settled out. Usually, the removal of colloidal solids requires the addition of a chemical flocculating agent, or filtration. The nonsettleable solids concentration in mg/L, can be measured by analyzing a portion of the supernatant from a settled sample of wastewater for the weight of residue retained on a filter pad in much the same manner as a regular suspended solids analysis is performed.

Floatable Solids

Floatable solids are typically nonsettleable solids that make their way to the surface of a tank or stream. Floating solids are usually made up of grease and other fatty substances and typically make up the scum. Scum is most easily removed by surface skimming equipment on Primary and Secondary clarifiers. This equipment is further discussed in the section on Wastewater Treatment Processes.

[Review information on Floatable Solids.]

To conclude the topic of solids, remember that solids are identified by their characteristics and method of removal.

EFFECTS OF WASTEWATER DISCHARGES: 15 minutes

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

Untreated or inadequately treated wastewater can cause a variety of unsightly and undesirable conditions in the receiving stream including oxygen depletion, negative effects on human health, and unsightly accumulations of sludge and scum. Let's talk about the effects and treatment objectives of raw wastewater next.

Oxygen Depletion and Odor Production

Oxygen Levels for Aquatic Life

Oxygen levels in the stream are impacted by the natural effects of temperature and turbulence. Cold water will retain a higher dissolved oxygen content than warm water. Turbulent flow will add dissolved oxygen into the water by absorbing oxygen from the air. The more turbulent the flow, the more surface area is exposed to the air and the more oxygen will be absorbed.

Dissolved oxygen is necessary for many aquatic organisms to survive. It is desirable to maintain at least 5 mg/L of dissolved oxygen in the stream at all times to sustain life.

Oxygen levels in the stream will be depleted during decomposition of biodegradable organics discharged to the stream. Let's look at the processes involved during decomposition and the potential impacts to the stream and its aquatic populations.

Effects of Organic Waste Discharge

There are two main effects of organic waste discharge: oxygen utilization by aerobic bacteria and odor production by anaerobic bacteria.

[*Read the definitions for* ***Aerobic Bacteria*** *and* ***Anaerobic Bacteria***.]

[Refer participants to Figure 2.2 on the next page and provide the explanation that follows.]

Display Slide 5—Oxygen Utilization by Aerobic Microorganisms.

When improperly treated or untreated wastewater containing organic contaminants is introduced to a receiving stream, aerobic microorganisms (including aerobic bacteria) will use the organic contaminants as food.

In metabolizing the organics, these organisms will use oxygen dissolved in the stream. The oxygen required to support these organisms is called the "oxygen demand" and is directly proportional to the amount of organics discharged to the stream (i.e., the greater the amount of organics discharged, the greater the oxygen demand).

If the organic material discharged to the stream creates an "oxygen demand" greater than the amount of oxygen available in the stream, then the stream will become oxygen deficient.

When a stream becomes oxygen deficient, other organisms requiring oxygen to live can't survive and must relocate downstream where the oxygen levels are better, or die off from lack of oxygen.

When a stream becomes oxygen deficient, and if there is still organic contaminants and nutrients available, anaerobic organisms will become dominant in the stream. Anaerobic organisms live in areas where there is no dissolved oxygen present.

Hydrogen sulfide, the odor of rotten eggs, is generated by anaerobic activity. Certain bacteria can use oxygen bound chemically to such compounds as sulfate. When the oxygen molecule is removed from sulfate, the sulfate becomes sulfide. The sulfide will react with hydrogen molecules in the water to form hydrogen sulfide. Hydrogen sulfide not only is an odorous gas, it is also a toxic gas that is heavier than air, which means it will settle to the bottom of confined spaces like manholes and displace the oxygen. Anyone entering such a space without a self-contained breathing apparatus can be overcome and may die from even a short exposure to the gas.

Treatment Objective—Stabilization

Because of the potential damage to aquatic organisms, oxygen-demanding material must be prevented from entering the water.

[*Read the definition for* ***Stabilization*** *that appears in the workbook*.]

Biodegradable organic material is stabilized when bacteria convert the organic material to new growth, carbon dioxide, and water.

Human Health

Disease Causing Bacteria

Human health can also be impacted by the discharge of untreated wastewater. A primary concern is the threat of communicable diseases.

[*Review the definition for* **Communicable** *that appears in the workbook*.]

[Add that a communicable disease is one that can be easily transmitted to humans and that disease causing organisms can be transmitted by contact with contaminated water.]

What are some communicable diseases that could be transmitted via untreated wastewater?

Ans: Typhoid, cholera, dysentery, polio, hepatitis.

[Review Key Point: To date no one working in wastewater collection or treatment has been infected with the AIDS virus from job conditions. The best defense against infections and diseases is good personal hygiene.]

Treatment Objective—Disinfection

[Review the treatment objective of disinfection.]

Scum and Sludge Accumulation

When sludge is discharged to the stream, it can accumulate along stream banks and on the stream bottoms. Non-settleable scum will tend to float on the surface of the stream and be trapped in poor flow areas. As this material will contain biodegradable organics, stream bacteria and other organisms will attempt to metabolize the organics, using oxygen from the stream. If the oxygen cannot be replenished quickly enough, the stream will become oxygen deficient and the sludge and scum accumulations will turn the stream septic. Other aquatic populations that need oxygen will not be able to survive and will have to migrate or die. Further decomposition of the sludge and scum under oxygen deficient conditions will lead to undesirable odors in the stream.

Therefore, the treatment objective is to remove the sludge and scum before it can enter the receiving stream.

Other Effects

Finally, there are a number of other effects to keep in mind, all of which are not desirable.

[Review and summarize the list of effects located in the workbook. Read the definitions for photosynthesis and respiration when discussing eutrophication leading to oxygen deficits.]

NATURAL CYCLES IN THE RECEIVING WATER: <u>15 minutes</u>

Impact of Discharge on Natural Cycles

Earlier we discussed the potential effects of inadequately treated or untreated discharge of wastewater to a receiving stream. The degree to which such discharges will impact the stream actually depend on a number of factors. Let's take a few minutes to review these factors.

[Review the seven factors listed in the workbook.]

Nutrient Cycles

There are processes that occur naturally in the stream. These natural processes are the way that the streams "purify" themselves of biodegradable organic matter that enters the stream from nature such as animal waste products, leaves, and other organic debris. Let's review a typical nutrient cycle that occurs naturally in the stream. The Nitrogen Cycle is just one example of a nutrient cycle. Other nutrients, such as phosphorus, have their own cycles.

[Review Figure 2.3 Simplified Nitrogen Cycle found in the workbook.]

In a wastewater treatment plant, nitrifying organisms convert ammonia in the wastewater to nitrite and then to nitrate. If the treatment plant does not denitrify (convert the nitrate into nitrogen gas), then nitrate will be discharged in the effluent into the receiving stream.

In the receiving stream, algae will uptake nitrate and use it as an energy source to produce new algal cells.

Fish will eat the algae and convert the algae to amino acids, urea, and other organic residues.

If the fish die and settle to the bottom, the fish will decay and the residual nitrogen compounds will be converted to ammonium ion (NH_4).

The same kind of bacteria that converted the ammonium ion in the treatment plant to nitrite and then to nitrate will, in the presence of oxygen in the stream, convert the ammonium ion generated from the decaying fish to nitrite, and then to nitrate.

{Review Key Points}

We have discussed the characteristics and effects of wastewater discharges and the solid types and concentration levels, as well as the natural cycles that occur in the receiving water. Let's now move on to how the wastewater is collected, conveyed, and treated.

UNIT 3: 60 minutes

Display Slide 6—Unit 3: Wastewater Treatment Processes.

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

- Describe how wastewater is collected and transported to a treatment plant.
- Indicate the function of each treatment process.
- Describe two methods of effluent disposal.

COLLECTION AND CONVEYANCE OF WASTEWATER: 20 minutes

This unit will cover three major components of a Wastewater System. The first component is Collection and Conveyance.

General Information

Collection and Conveyance

[Review the factors that affect the operation of the collection system and impact treatment plant performance. Incorporate the following:]

- Food processing facilities often have seasonal production schedules. Production and consequently discharge flows may increase before a holiday or during a specific time of the year when specific products are processed.
- Plant Operators needs to be familiar with all non-residential users in the service area. Plant Operators should know which manufacturing processes use chemicals that could impact the operation of the plant or collection system before a problem occurs.
- Hydrogen sulfide is produced by biological activity in the absence of dissolved oxygen. Biological activity occurs in scum layer that forms on the interior pipe wall. H_2S combines with moisture to form Sulfuric Acid, which can cause concrete to deteriorate.

[*Review the definition for* ***Septicity*** *that appears in the workbook*.]

[*Review the definition for* ***Influent*** *that appears in the workbook*.]

Types of Collection Systems

There are three main types of collection systems, each collecting different wastes.

[Review the three types of systems from the workbook.]

Why should the operator be familiar with the wastewater collection and conveyance network?

Ans: The operator should know the origin of wastes reaching the plant, the time it takes, and how the wastes are transported (flow by gravity or by gravity and pumped). Such knowledge will help you spot troubles and take corrective action.

Wastewater Conveyance Systems

Once the wastewater has been collected, it needs to be transported to the treatment plant. The following conveyance system components are typically utilized—gravity sewer, pumping station, and force main.

Display Slide 7—Wastewater Collection and Conveyance System.

[Review gravity sewers, pumping stations, and force mains using Figure 3.1. Incorporate the following:]

A typical wastewater collection and conveyance system is shown in Figure 3.1. Wastewater generated in the service area is usually discharged from the homes or businesses into a gravity sewer. It's called a gravity sewer because the wastewater flows downhill from the force gravity acting on the wastewater.

As the wastewater flows along in its gravity sewer, it will occasionally pass through a "manhole". A manhole is simply a structure that allows workers to gain access to the sewer to perform maintenance, e.g., cleaning, flushing, or just observing the flow. Manholes also provide access to the system for sampling and monitoring. This is useful for evaluating infiltration/inflow or for tracking the discharger of unwanted pollutants. Manholes should be placed at intervals not exceeding 400 feet.

It is not always possible for the wastewater to reach the plant just by gravity flow. Because water can't flow uphill by itself, it may be necessary to lift the wastewater to a higher elevation from which it can again flow by gravity to the plant. A lift station, or pumping station, is used to lift the wastewater to the higher elevation. The wastewater is discharged from the pumps into a "force main" also known as a pressure sewer, which carries the wastewater from the pumping station to its point of discharge, usually a manhole on another gravity sewer. From there, the journey continues by gravity.

WASTEWATER TREATMENT PROCESSES AND THEIR FUNCTIONS: 30 minutes

Now that the water has been collected and has reached the plant, it must be treated. The second component of a Wastewater System is Treatment.
The ultimate goal for wastewater treatment is to remove biodegradable organics, organic and inorganic solids, and kill pathogenic organisms through disinfection.

Display Slide 8—Wastewater Treatment Process.

[Review Table 3.1 found in the workbook.]

Wastewater is treated using a variety of physical, chemical, and biological processes. These processes are arranged in sequence, removing the coarse and easily settled materials first, then removing the dissolved nutrients and organics, and finally disinfecting the treated wastewater prior to discharge to the receiving stream.

The initial phase of treatment is referred to on Table 3.1 as Preliminary Treatment. During this phase, the larger, coarser materials are screened and settled out. Screening protects the pumping equipment from sticks, rags, and other materials that could cause damage or blockages.

The degritting process settles out and removes the inorganic grit and sand that enters the sewer system through the manholes or through breaks in the piping. It is important to remove grit early on in the treatment plant because otherwise it will take up valuable space in the solids handling processes, effectively decreasing the treatment and storage capacities of these process units. Excessive grit can also be damaging to equipment such as pumps.

Pre-aeration is sometimes used to “freshen” the wastewater by adding oxygen and encouraging aerobic activity. An oxygenated wastewater will generate less odors than a wastewater that has become septic.

Flow metering and influent sampling are important for measuring the quantity and characteristics of the influent wastewater. Such information is important not only for process control, but for planning purposes as well. Historical flow and loading data can be used to compare against plant capacity and to project when an expansion or upgrading may be required.

The next phase of the treatment process is the Primary Treatment phase. Here, the wastewater flows through settling tanks (primary clarifiers) where the remaining settleable solids and floating debris (grease) are removed. This process is not always provided in an activated sludge treatment plant. However, it is an absolute necessity for trickling filter plants to prevent clogging of the trickling filter media. Primary treatment usually lowers the organic and suspended solids loadings to the secondary treatment phase.

Following the primary treatment phase are the Secondary Treatment processes. Here is where the bulk of the dissolved organics and nutrients are removed from the wastewater. Biological treatment processes can be broadly characterized as suspended growth and fixed growth processes. The suspended growth processes are the activated sludge processes that consist of biomass suspended in an aeration tank into which oxygen is added to maintain aerobic conditions. An example of a fixed-film process is a trickling filter. A trickling filter is a tank filled with rock or plastic media upon which microorganisms attach themselves. The wastewater trickles over and through the media, contacting the organisms as it passes among the media.

Sedimentation is usually considered a part of the secondary treatment phase because it is needed to separate the biological process biomass from the treated wastewater. These clarifiers often have mechanisms to remove floating scum similar to the primary clarifiers.

Tertiary or Advanced Treatment is usually used where exceptionally stringent treatment is required to protect the receiving stream. Advanced treatment can take place after biological treatment, or it can be a part of the overall biological treatment process. It can be a chemical precipitation process or a biological process. For example, phosphorus (a nutrient) can be removed by adding a chemical such as aluminum sulfate or ferric chloride to the wastewater as it exits the biological reactor before entering the secondary clarifier. This is called a chemical precipitation process. The phosphorus combines with the aluminum or iron and forms a precipitate, which is a particle large enough to settle out in the clarifier. The precipitate settles out in the secondary clarifier and is disposed with the rest of the biomass.

Phosphorus can also be removed biologically in a process generally called Biological Nutrient Removal. Given the proper environment, specialized microorganisms can remove both nitrogen and phosphorus from the wastewater. The removal of nitrogen is usually referred to as denitrification. Denitrification can also be accomplished in separate treatment units located after the secondary clarifiers prior to disinfection.

Filtration is another tertiary treatment process; it involves the removal of suspended solids beyond that which can be routinely achieved just with simple settling. Multimedia filters trap the suspended solids particles within the tiny spaces between the media. As a result, exceptionally clear effluent is produced. Filtration is also helpful in meeting particularly low effluent limits for phosphorus where a chemical precipitation process is used.

Disinfection is the next step in the treatment process. After the organics and nutrients have been removed and the biomass separated from the treated wastewater in the secondary clarifiers, the wastewater is disinfected to kill pathogenic organisms before discharging the effluent to the receiving stream. Disinfection can be accomplished by adding a disinfectant such as chlorine, or it can be accomplished by bombarding the effluent with ultraviolet light. Either way, the efficiency of the disinfection process is measured by the number of fecal coliform organisms remaining. The degree of treatment is usually defined by the plant's NPDES discharge permit.

A consequence of the removal of pollutants from the wastewater is the generation of waste products. Solids Treatment processes typically consist of digestion, where the remaining volatile organic material is reduced, and ultimate disposal. Well-stabilized solids meeting state and federal requirements can be recycled to farmland or to land reclamation sites. Solids containing excessive quantities of undesirable pollutants such as heavy metals are usually disposed of in landfills.

Preliminary Treatment

Display Slide 9—Wastewater Treatment Process.

The first treatment process is Preliminary Treatment. Preliminary Treatment includes several processes—screening and comminution, grit removal, pre-aeration, and flow metering.

Screening and Comminution

[Review the purpose and process description of screening and comminution from the workbook.]

[Point out that the major difference between screens and comminuters is that screens physically trap and remove debris from the wastewater, where as comminuters cut or grind the debris into smaller pieces, but the debris remains in the wastewater.]

[Review Figure 3.2 Screening.]

Screening and comminution perform similar tasks, even though they differ considerably in design and function. Screens trap debris on parallel bars or inside rotating perforated drums. The trapped debris is then either manually or mechanically removed from the screen and deposited in a container for disposal.

[Ask participants to turn the page.]

[Review Figure 3.3 Comminuter.]

A comminuter, on the other hand, grinds or cuts debris into smaller pieces with these smaller pieces then passing through the unit and continuing on to other downstream treatment processes. The ground-up debris from a comminuter usually winds up in the waste sludge. While this may not be a problem when the waste sludge is landfilled, the debris can make a well-stabilized sludge less appealing for farmland application.

Grit Removal

[Review the purpose and process description of grit removal as it appears in the workbook.]

Grit removal equipment comes in a variety of shapes and sizes. However, all grit removal equipment must have at least 2 components: a basin or channel into which the grit settles and equipment to remove the grit from the basin or channel. There are a number of technologies used for grit removal. These include the simple grit channel, the aerated grit chamber, and centrifugal grit separators.

In a grit channel, the velocity of the flow is controlled to remain at 1 to 2 feet/minute to allow grit to settle out, while keeping the lighter organic suspended solids in suspension. These channels work satisfactorily most of the time. However, high flows often generate high flow velocities which can scour the channel of the settled grit, depositing the grit into the next downstream treatment unit.

Aerated grit chambers and centrifugal separators are not as impacted by flow rates, up to the design capacity of the unit. Figure 3.4 illustrates an aerated grit chamber. An aerated chamber uses diffused air to gently agitate the wastewater just enough to keep the organics in suspension while allowing the grit to settle out.

Centrifugal separators keep the organics in suspension by centrifugal forces, while allowing the heavier grit to settle out.

Settled grit can be removed from these processes by bucket elevators, by special pumps, or by airlifts. The removed grit is usually run through a "classifier" that further separates the grit from the wastewater and deposits the grit in a container.

What is typically done with grit once it is removed from wastewater?

Ans: Grit is usually taken to an approved sanitary landfill.

Pre-aeration

The purpose of the pre-aeration step is to introduce oxygen into the wastewater to prevent the wastewater from undergoing anaerobic activity and becoming septic. Keeping the wastewater "fresh" will prevent odors that often accompany septicity from forming.

Flow Metering

[Review purpose and process description of flow metering. Incorporate the following:]

Flow data is important to the plant operator for calculating loadings used for making process control decisions and for tracking the remaining capacity in the treatment plant. Flow metering technologies are broadly classified as either open-channel flow or closed-conduit.

Open Channel Flow

Open-channel flow technologies are typically used for monitoring influent flows when the flow into the plant is by gravity and for monitoring effluent from the plant, again where the effluent flow is by gravity, not pumped. Open-channel flow metering facilities consist of a primary flow control element and a sensor.

Display Slide 10—Flow Metering.

The primary control element (parshall flume, weir, or Kennison nozzle) controls the depth of flow based on the geometry or shape of the device. Figure 3.5 shows two types of control elements, a flume and a weir.

The intent is to relate the depth of flow to the velocity of flow through the control section. Knowing the depth of flow and the particular geometry of the control section, a specific formula (each primary control element has its own flow equation) can be applied to calculate flow rate based on the depth of flow at a specific point in the channel.

Sensors used to measure the flow depth are usually either ultrasonic level sensors, or mechanical devices which use a float to track with the surface elevation of the flow. The ultrasonic sensor devices are preferred because there is nothing actually touching the wastewater that can capture rags and other debris that will cause the flow meter reading to be inaccurate.

Redisplay Slide 10—Flow Metering.

[Indicate that the participants should look back at Figure 3.5 to help them answer the following question.]

Why is the Parshall Flume widely used for measuring wastewater flow? Why is the Weir not used very frequently to measure influent?

Ans: The parshall flume is widely used for measuring untreated wastewater flow because it creates no obstructions to the flow of wastewater, which minimizes the chance for blockages or accumulations that might affect the depth of flow and subsequently, the measured flow rate.

The weir is not used as frequently because solids may collect behind the weir, which could result in inaccurate flow measurements. This collection of solids could also cause odors.

Closed Conduit

Sometimes, the wastewater is pumped into the treatment plant. In that case, there may not be an open channel available to measure flow using one of the open channel devices. So where the wastewater is pumped through a force main, metering requires a different approach. Common metering technologies for measuring closed conduit flow include mag meters and Doppler meters. Mag meters are placed in the force main so that the wastewater flows through the unit. Flow velocity is measured based on the amount of induced current produced by the flow passing though a magnetic field set up by the meter. In order for the flow measurement to be accurate, the mag meter can only be used where full-pipe flow is achieved. Otherwise, the flow measurement will be inaccurate. A Doppler meter is strapped to the outside of the force main. It sends a sonic pulse through the pipe wall into the flow stream and measures the time it takes for the signal to bounce back. Both technologies are fairly precise. Dopplers are popular for retrofitting because no repiping is necessary. Also, since there are no intrusions into the waste flow stream, the potential for blockages is minimized.

Primary Treatment

Display Slide 11—Wastewater Treatment Process.

The next part of the treatment process is Primary Treatment. Primary treatment removes settleable solids prior to secondary treatment.

[Discuss the purpose and process description of primary treatment from the workbook.]

[*Review the definition for* **Sludge** *that appears in the workbook*.]

Display Slide 12—Primary Clarifier.

[Review Figure 3.6 Primary Clarifier found in the workbook.]

The primary clarifier is a treatment unit that is sized so that the flow can slow down as it passes through the tank. Because the flow velocities are so slow, settleable solids will settle out and be removed from the wastewater. These clarifiers can be either circular or rectangular in shape. However, all will have the following components:

- Inlet structure that controls the way the wastewater enters the tank (influent control gate—not shown);
- Bottom sludge rakes to transport the settles solids towards the sludge outlet area (sludge collector mechanism and blade and scraper squeegees);
- Effluent weirs that control exit velocities and prevent density currents from forming that could re-suspend already settled solids; and
- Surface scum scrapper to remove floating debris (skimmer arm).

Settled and floating solids removed from the wastewater must be regularly pumped out of the clarifier to the solids handling facilities for stabilization.

Secondary Treatment

Display Slide 13—Wastewater Treatment Process.

The next part of the treatment process is Secondary Treatment. The purpose of secondary treatment is to remove dissolved and suspended (nonsettleable) organic materials from the water being treated.

As we mentioned previously, biological secondary treatment processes can be broadly characterized as either fixed-film or suspended growth processes.

Fixed Film Process Descriptions

The fixed-film processes include the trickling filter (TF) and the rotating biological contactor (RBC). Both of these technologies use a fixed in place media upon which microorganisms attach themselves. The organisms acquire their “food” as the wastewater flows past them.

[Review definitions and fixed film process descriptions.]

Display Slide 14—Fixed Film Biological Treatment Process.

Figure 3.7 is a process schematic that can be used to represent either TF or RBC technology. The wastewater enters the TF or RBC after primary treatment. The wastewater flows over the media where the microorganisms adsorb and metabolize the organic matter. Following the TF or RBC, the flow then goes to the secondary clarifier where excess solids that "sloughed off" the biological process are separated and the treated wastewater goes on to disinfection.

You will notice that there is a recycle coming from the secondary clarifier that reenters the biological unit. This recycle line is there for one of two reasons:

1. To give the microorganisms another shot at removing residual organics, which will ultimately improve treatment efficiency; or
2. To keep the media from drying out during low flow periods.

Recirculation rates of 100 to 400% were needed to improve the BOD removal efficiencies of the old rock-media TFs. But that changed with the development of plastic media having a much higher specific surface area upon which microorganisms could grow. It was quickly discovered that recirculation did not improve treatment efficiencies beyond that which the new media offered. However, recirculation was still required to keep the media wet during low flow periods.

Suspended Growth Process Description

Display Slide 15—Suspended Growth Process Schematic.

[*Review the definition of* Suspended Growth Process*, the section on activated sludge, and Figure 3.8. Incorporate the following:]*

By suspended growth, we mean that the microorganisms are actually suspended in the wastewater, rather than being attached to any fixed surface. This process is more commonly referred to as the activated sludge process. Here, microorganisms accumulate on “floc” particles that are suspended in the aeration tank by agitation by diffused aeration or by mechanical aerators. The organisms are basically floating in their food. The total mass of floc particles is referred to as the Mixed Liquor Suspended Solids (MLSS), or just Mixed Liquor.

In Figure 3.8, we see a typical process schematic for a suspended growth process. The wastewater enters the activated sludge aeration basin and is maintained in the basin long enough for the organics to be fully adsorbed and metabolized. The MLSS and wastewater mixture then flows to the secondary clarifier where the MLSS settles out and the clear treated wastewater goes on to disinfection. A portion of the MLSS is returned to the aeration tank as seed for the continuing biological treatment process. This is the “Return Activated Sludge.” The excess biomass, or “Waste Activated Sludge,” is wasted to the digestion and solids handling processes.

There are a number of variations of the conventional activated sludge process, including the contact-stabilization and the extended aeration processes. Also, the activated sludge process serves as the basis for the advanced Biological Nutrient Removal processes, many of which are also suspended growth processes. The primary differences among these variations are the environments that are created for the specialized microorganisms to grow and function and the manner in which the systems are operated. These processes are discussed in more detail in later training courses.

Secondary Clarifiers

[Ask participants to recall the fixed film processes and the suspended growth process. Point out that secondary clarifiers are used with both types of technologies.]

Why is a secondary clarifier needed after a trickling filter, rotating biological contractor, or aeration tank?

Ans: To allow organisms in treated wastewater to be removed by settling.

Waste Treatment Ponds

Another type of secondary treatment is the Waste Treatment Pond, which achieves secondary treatment without the mechanics associated with the activated sludge process.

[Review the types of ponds and the process description of Facultative Ponds. Incorporate the following:]

Of the three types of ponds, most in use in Pennsylvania are of the Facultative type. The anaerobic ponds can be odorous and are not a good application for use in populated areas.

[*Review process description of aerated ponds.*]

Despite facultative ponds being most common, aerated ponds are considered better suited for application in Pennsylvania. They are relatively deep ponds (15 – 20 feet) equipped with mechanical aeration to foster aerobic activity in the upper reaches of the pond. Aerobic ponds are deep to allow for long-term storage of waste solids. These units are usually designed so that sludge removal need only occur every 10 years or so. The solids on the bottom of the pond undergo anaerobic decomposition. Very high volatile solids reductions are achievable because of the extended storage times.

Because the aerated pond is much deeper than the traditional shallow aerobic or facultative pond, the areas of the pond treating the wastewater cannot be maintained aerobic just from absorption and photosynthesis. Therefore, it is necessary to provide some means of mechanical aeration to supplement the natural oxygenation methods. Aeration can be provided by floating surface aerators or by diffused aeration. Of all the pond types, the aerated pond is more applicable to use in Pennsylvania than the other pond types. Process performance can be enhanced by adding clarifiers and return sludge pumping capabilities like the traditional extended aeration activated sludge process.

Advanced Treatment Processes

Display Slide 16—Wastewater Treatment Process.

Another part of the treatment process is Advanced Treatment Processes, which reduce the nutrient content of the wastewater. The three types of removal are biological, chemical, and physical.

[Discuss the purpose and process descriptions of advanced treatment processes.]

Biological Phosphorus Removal

Display Slide 17—Biological Phosphorus Removal Process Schematic.

Figure 3-9 is a process schematic for the biological phosphorus removal process. This process is incorporated into the activated sludge process by the addition of an anaerobic zone upstream of the aeration zones. In the anaerobic zone, the influent wastewater is mixed with the return activated sludge containing the specialized biomass that will accomplish phosphorus removal. These organisms are able to store and use organic phosphorus as an energy source for reproduction and other life functions when oxygen is not present. They use up their stored phosphorus in the anaerobic zone so that by the time they reach the aeration, or oxic zones, they need to replenish their depleted phosphorus levels so they absorb phosphorus from the wastewater. The efficiency of this process depends on the ability to keep oxygen out of the anaerobic zone, and on the amount of phosphorus and BOD in the untreated wastewater. These systems usually incorporate a standard chemical precipitation process as a back-up process for phosphorus removal to insure permit compliance.

Chemical Precipitation of Phosphorus

Display Slide 18—Chemical Precipitation Process Schematic.

Figure 3-10 shows a typical chemical addition process for phosphorus removal. This process is easily added to an existing secondary treatment process and only requires chemical storage and pumping equipment. A chemical containing a metal ion such as aluminum sulfate, ferric chloride, or ferrous sulfate is added to the wastewater prior to the secondary clarifier. The metal ion combines with the phosphorus to form a stable, settleable precipitate that will settle out in the final clarifiers with the rest of the waste sludge.

Denitrification

Display Slide 19—Denitrification Process Schematic.

Figure 3-11 shows a typical process schematic for a biological denitrification process. The process appears similar to the biological phosphorus removal process in that a special zone is added prior to the standard aeration zones of an activated sludge plant. However, this zone is an anoxic zone. An anoxic zone is one that contains oxygen bound to other elements such as nitrogen, but no free residual dissolved oxygen. Under these conditions, certain types of organisms can use the bound oxygen for energy when free residual dissolved oxygen is not present. This is how it works: the return activated sludge along with an internal recycle flow from the effluent end of the aeration tanks is mixed with the influent wastewater in the anoxic zone. The return and recycle flows contain nitrate, (NO_3), produced in the aeration zones from the conversion of ammonia present in the untreated wastewater. Since there is no free oxygen present in the anoxic zone, the organisms must use the oxygen bound to the nitrate for energy, thereby releasing nitrogen into the wastewater. The nitrogen gasses off, thereby reducing the total amount of nitrogen originally present in the untreated wastewater. This process is called "denitrification."

The important things to remember about this process are:

- It requires anoxic conditions, so no residual DO can be present in the anoxic zone;
- The process requires a carbon source as part of the overall biochemical reaction. There is carbon in the untreated wastewater that can be used to satisfy this demand.
- The process requires nitrate to work. Nitrogen in the influent is usually in the form of ammonia, which must be converted to nitrate before the denitrification process will take place. This requires that the activated sludge process be operated to achieve this conversion, called nitrification, in the aeration zones.

Disinfection

Display Slide 20—Wastewater Treatment Process.

The final part of the treatment process itself is Disinfection. Refer to Table 3.1 on page 3-5.

[Review the purpose and process descriptions of Disinfection. Incorporate the following:]

The disinfection process is an important final treatment step in the treatment of wastewater. This is the step that kills the pathogens in the wastewater that could transmit diseases to other downstream users of the receiving stream. The two most common disinfection processes in wastewater treatment are chlorination and ultraviolet light radiation. Chlorination can be accomplished using either chlorine gas or a commercially available solution such as sodium hypochlorite. When chlorine gas is used, the gas is drawn from a cylinder or tank under a vacuum and injected into water to make a hypochlorite solution. The water used is often recycled plant water that has already been through the disinfection process. Because of the risks associated with storage of large quantities of chlorine gas onsite, many treatment plants have opted to switch over to commercially available hypochlorite solutions. The chlorination chemistry is the same, since the solution created by injecting chlorine gas into the plant water is hypochlorite.

The most important aspects of the chlorination process are:

- Good initial mixing of the chlorine solution with the clarifier effluent is important to process performance.
- Adequate contact time after initial mixing insures that the chorine solution will contact and inactivate the pathogens in the treated water.
- Adequate kill must be achieved before dechlorination, if the plant has a limit on the amount of residual chlorine it can discharge to the receiving stream.

As an alternative to chlorination, many plants are using ultraviolet light (UV) radiation for disinfection. UV radiation does not require a large contact tank like the chlorination process does, and there is no chlorine residual to be removed if the plant has a total chlorine residual limitation. UV systems have gained in popularity since DEP has been limiting the amount of chlorine residual that can be discharged into the receiving stream. One of the features of UV disinfection is that since it is not a chemical addition process, there are no potentially harmful residual chemicals remaining after disinfection, recently, there are concerns regarding the potential carcinogenicity of chlorinated hydrocarbons and other chlorinated products left over from the chlorination process.

UV radiation uses ultraviolet light from a mercury vapor lamp that produces a wavelength of around 254 nm (nanometers). This wavelength falls within the 250 – 270 nm wavelengths found to be germicidal. The lamps of a UV system are typically housed in quartz outer tubes and submerged into the water. The lamps are arranged such that all of the water must pass around or near a tube, thereby preventing any particles of water from escaping the UV light. Experience has shown that the quartz tubes must be cleaned routinely to remove any deposits that might interfere with UV transmittance. The lamps typically last about a year, depending on the usage.

Solids Handling and Disposal

Display Slide 21—Solids Treatment.

Stabilization Process Descriptions

[Review the purpose and process descriptions of stabilization.]

The waste sludge removed from the primary and secondary treatment processes must be treated or “stabilized” before disposal to reduce the volatile organics remaining and to reduce the number of pathogenic organisms in the sludge. There are a number of treatment technologies available to accomplish the stabilization process. These include digestion, incineration, and wet oxidation. We’ll discuss the digestion process first.

Digestion

When we think of *digestion*, we typically think of two types: aerobic digestion and anaerobic digestion. The major difference between these processes is that the aerobic process, as the name would imply, is accomplished under aerobic conditions. Oxygen is added to the sludge in an unheated tank to maintain aerobic conditions and to accomplish volatile solids reduction. On the other hand, the anaerobic process is performed in a heated tank under anaerobic conditions. The by-products of the aerobic digestion process are primarily carbon dioxide and water, while the primary by-product of the anaerobic digestion process is methane gas. The methane gas generated by the anaerobic digestion process is often reused as fuel for the heat exchanger to keep the anaerobic digester contents heated to 95º F.

Both processes are referred to in the state and federal regulations as Processes to Significantly Reduce Pathogens, or PSRP processes. That means that the processes will achieve a significant reduction in numbers of pathogens, but will not completely eradicate the organisms. Both processes will achieve reductions in the volatile solids content of the feed sludge of 40-60%, depending on detention time and temperature.

Incineration

Incineration is another stabilization process. Here, sludge after being dewatered is actually combusted to burn off virtually all of the volatile organics. Incinerators are typically multiple hearth furnaces where the sludge is moved from hearth to hearth where drying and burning takes place. The end-product of incineration is typically an inorganic ash residue that retains little or no remaining organic material. While this process achieves a tremendous reduction in volume of residue for ultimate disposal, the cost to operate these facilities is fairly high. Supplemental fuel is usually required during portions of the burning cycle when the combustion process is not self-sustaining. This process is referred to as a PFRP process, or a “process to further reduce pathogens”. With the temperatures achieved during combustion of the sludge, virtually no microorganisms survive. The remaining ash residue is usually landfilled because any metals present in the feed sludge will be concentrated in the ash.

Wet Oxidation

Wet Oxidation, sometimes called wet-air oxidation, is a stabilization process where the untreated sludge is mixed with compressed air and pumped through a series of heat exchangers to bring the temperature to 350 – 600º F. The air-sludge mixture enters a pressurized vessel where volatile organics are oxidized. The reactor vessel is pressurized to keep the sludge in a liquid phase while oxidation takes place. The remaining ash and residue is conveyed to a settling tank where the solids settle out and the liquid is returned to the treatment process. A major disadvantage of this process is the strength of the liquid recycle. There are not many wet-oxidation processes in use today.

Lime Stabilization

Lime Stabilization is a stabilization process that uses lime addition to increase the pH of the sludge to 12.0 or higher. This creates an environment not conducive to the survival of microorganisms in the sludge. The process adds lime, as a slurry, to the sludge in a flash-mixing tank. The lime-amended sludge proceeds to a mixed holding tank for storage until disposal. To meet the state and federal requirements for lime stabilization, the sludge must attain a pH of 12.0 or greater and maintain that pH for 2 hours. The pH must remain above 11.5 for another 22 hours without supplemental addition of lime. This stabilization method is not as energy intensive as the other stabilization processes. The product tends to settle rapidly and thicken without the addition of flocculant aids to 6 – 8% total solids content. A disadvantage is that, if the pH were to drop to below 9 over time, bacterial regrowth can occur, and the sludge can become unstable. Another disadvantage is that the lime slurry has a tendency to produce scaling in piping and maintaining the process can be labor-intensive.

Post-Lime Stabilization

Post-Lime Stabilization is a variation of the lime stabilization process whereby quick-lime, or calcium oxide, is blended with dewatered sludge cake immediately following a dewatering process such as a belt filter press or centrifuge. The quicklime reacts with the moisture remaining in the cake to form calcium hydroxide, the same product we just discussed for the traditional lime stabilization process. The lime-amended sludge cake is considered lime stabilized when the pH is raised and maintained at 12.0 or greater for a period of 2 hours, and then remains at a pH of at least 11.5 for an additional 22 hours without supplemental lime addition. Experience has shown that the pH of a post-lime treated cake will remain at or above 12.0 for weeks or months, which lends itself to long-term storage without concern for regrowth of bacteria.

Dewatering Technologies

The primary purpose of dewatering is to remove water from the sludge. Dewatering a liquid sludge such that the total solids content increases from 2% to 15% will reduce the total volume of sludge to be stored by approximately 87%. Dewatering is a necessary step ahead of incineration, and the post-lime treatment processes.

There are a number of technologies available to accomplish dewatering. There are mechanical processes such as filter presses and centrifuges that can dewater sludge at a rate of over 100 gpm and achieving total solids contents of 15 to 30%, depending on the sludge characteristics. These mechanized processes require that the sludge be pre-conditioned to help with the release of “free water” from the sludge. Free water is the “carrier” water content of the sludge that is not bound up in the sludge particle. The mechanical processes obviously require some mechanical energy input.

On the other hand, a sludge drying bed is a non-mechanized drying process where sludge is pumped out onto a flat, permeable surface made up of sand or some other permeable material. Dewatering takes place by gravity draining of water from the sludge through the permeable surface and by evaporation. While this technology can eventually achieve 50% total solids content or greater, it requires a larger land area and can take months to achieve dryness. This technology is suited for small facilities where land requirements are minimal.

There are mechanized versions of the sludge drying bed that use a solid, but permeable surface through which a vacuum is generated to speed up the gravity drainage process. While this process is faster than the traditional sand drying bed, the land area requirement is still larger than for the belt press or centrifuge.

EFFLUENT DISPOSAL: 5 minutes

The third and final component of the Wastewater System is Disposal.

Stream Discharge

[Review stream discharge.]

Stream discharge is the most widely used method of treated effluent disposal, mostly because of it's simplicity and ease of operation. Most plants flow by gravity to the receiving stream, although there are instances where effluent has to be pumped to the stream. An example might be where the discharge criteria or the assimilative capacity of a larger stream located some distance from the plant makes it more cost effective to pump to the larger stream than discharge by gravity to a smaller stream closer to the plant where the treatment requirements may be much more difficult and expensive to meet.

Land Disposal

[Review land disposal.]

Land disposal of treated effluent usually involves a lot more equipment to maintain. Spray irrigation systems have been used in Pennsylvania to return the treated water back to the groundwater. However, the spray systems are usually fairly complex systems of piping and pumps that have to be maintained. Also, the amount of water that can be applied to the land is restricted, and often depends on the weather conditions. Therefore, storage ponds must be constructed with the capacity to retain the treated water for months at a time, until the conditions are proper to allow spray application to begin again. There are also restrictions related to spray application in areas frequented by the public.

Spray irrigation systems are sometimes used to recycle treated wastewater to golf courses and resort areas. There are also several locations in Pennsylvania where the treated effluent is used by ski resorts for snowmaking. These uses are, as you would guess, stringently regulated to protect public health and have been successful.

There may be more uses for treated wastewater in the future, as pilot studies related to groundwater recharge are conducted.

UNIT 3 EXERCISE: 5 minutes

This unit covered the three components of a Wastewater System. To summarize the information and to ensure the objectives were met, please complete the Unit 3 Exercise independently without referring back to your workbook or notes. You have 5 minutes to complete the exercise.

Ans:

1. What are the three major components of a Wastewater System?
   1. Collection and Conveyance
   2. Treatment
   3. Disposal
2. Name the three types of collection systems and briefly describe.
   1. Sanitary Sewer- collects commercial and household wastes.
   2. Storm Sewer- Collects runoff from streets, land and roofs.
   3. Combined Sewer- Collects sanitary and storm water.
3. Match the Treatment Processes with the correct description.
   1. C
   2. F
   3. D and/or B
   4. A
   5. B and/or B
   6. G
   7. E
4. Describe two methods of effluent disposal.
   1. Stream Discharge
   2. Land Disposal

[*Review Key Points]*

Ask participants if they have any questions regarding the exercise or this unit. Respond accordingly before moving on to Unit 4.

UNIT 4: 35 minutes

Display Slide 22—Unit 4: State and Federal Regulations.

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

- Identify the classifications and sub-classifications for wastewater operator licenses under the Water/Wastewater Certification Act (Act 11 of 2002).
- List the responsibilities of a licensed operator under Act 11.
- Identify and locate state and federal regulations that govern wastewater treatment.

An introduction to wastewater treatment plant operation would not be complete without a discussion of the more important state and federal regulations affecting you as a certified operator, and the plant you operate. The following sections will introduce you to the Wastewater Certification Act, Act 11 of 2002, and other state and federal regulations governing the NPDES permit program, wastewater planning, secondary treatment, water quality, and biosolids management. Of these regulations, the one that will most directly affect you is the Operator Certification Act. It is important that you understand your duties and responsibilities as a certified operator under this legislation. Information on the other legislation is provided because you need to be aware that this legislation exists and where to locate it when you need to. However, it is not as important that you know all of the specifics of these rules. Therefore, we will quickly cover the general content and purpose of these other regulations. You may want to take some time later on to review this legislation in greater detail.

[*Ensure participants are aware of where to access the PA Operator Certification Act and other state regulations.*

- *On the DEP website at* www.dep.state.pa.us *choose "Subjects" and then "Biosolids."*
- *Can also access the biosolids link from DEP wastewater operator page.*
- *Other state legislation can be accessed from the DEP website, choose "Subjects," then "Regulations" and choose "Title 40-Protection of the Environment."]*

Pennsylvania Operator Certification Act: 10 minutes

Wastewater Treatment Plant Operator Licensing

Classifications and Sub-classifications

[Review Classifications and Sub-classifications as they appear in the workbook.]

Criminal Record Check

[Review information on Criminal Record Check. Focus on the tips for filing a request with the State Police.]

Training and Continuing Education

Required Hours per Renewal Cycle

[*Review hours required per cycle. Refer to Figure 4.1 Continuing education requirements and point out the following from the figure.]*

Figure 4.1 lists the continuing education requirements for certified operators. Note that the requirements for an operator's first 3-year cycle is half the requirement of subsequent cycles.

Examination Requirements

[Review the two parts of the Exam]

[Refer to Figure 4.2 Point out the following from the figure:]

Figure 4.2 lists the experience required to qualify to become a certified operator. Note that the amount of experience required depends upon your education. The education codes in the table are explained at the top of page 4-4. For example, if you have completed a DEP-approved certificate program in wastewater treatment, you would need 2 years of operating experience for a B class license. You must have worked at a treatment plant similar in nature to the one for which you wish to become licensed. The Certification Board will also consider experience at a plant that is no more than two classes lower.

Notice also on the top of page 4-4 that there is a table showing that a person with only a high school education may reduce experience requirements by taking DEP-approved training courses.

Certified Operator's Duties and Responsibilities Under the Regulations

Earlier we discussed the general Duties and Responsibilities of the Treatment Plant Operator. Now we will specifically discuss the responsibilities of a certified operator under state regulations.

Meet the Requirements for Recertification

[Review criteria needed to satisfy the requirements of the law for recertification.]

Report to the System Owner any Known Violations or Conditions that may Cause Violations

[Discuss the reporting of violations or conditions that may cause violations.]

What are examples of conditions that cause violations?

Ans: Conditions that cause violations:

- Overloading conditions that can lead to overflows, by-passes, or process upsets
- Mechanical equipment deficiencies
- Inadequate budget for maintenance or operation of the plant

Failure to report a violation such as an overflow, even if instructed by the owner not to report it, is a violation of the Act and enforceable on you, the certified operator. There are provisions in the Act to protect the operator under these circumstances. The so-called Whistleblower provisions will protect the security of your employment when you are required to report conditions that are contrary to the wishes of the owner.

Develop and Implement Operations and Maintenance Planning

[Tell participants what is included in developing and implementing an Operations and Maintenance Plan.]

- Preventive Maintenance Program:
  - Equipment inventory
  - Schedule of preventive maintenance tasks, as recommended by the manufacturer
  - Record of preventive and required maintenance for each piece of equipment
  - Spare parts inventory and tracking system

- Emergency Planning:
  - Need to develop plans for operating during unusual or adverse conditions such as flooding, personnel strikes, snow emergencies when it's difficult to get to the facility, etc., before the condition occurs.
  - Goal is to prevent unnecessary permit violations and to protect the stream by already having contingency plans in place for the emergency.

- Process control and monitoring strategies:
  - Need to develop good records regarding process performance under various operating conditions.
  - Based on the characteristics of the wastewater from your service area and your discharge permit requirements, you may need to make seasonal adjustments to the operation of the plant in order to maximize performance.
  - Good records will help you to know what process control settings have worked best for your facility.
  - Need to establish monitoring policies and procedures so that the data obtained is representative of actual operating conditions and reliable.
  - Monitoring locations should be carefully chosen to insure well-mixed representative samples are obtained. Usually, it is better not to randomly change monitoring locations without good reason.

Report to System Owner Actions Necessary to Prevent or Eliminate Violation of Regulations or Permit

Provide written reports to the owner outlining actions taken or recommend actions that can be taken to eliminate the violations. Remember, you as the certified operator are responsible for the operation of the plant. You must report all violations or make the owner aware of conditions which may lead to violations so that those conditions may be addressed. Written reports are the best way to convey this information. Be sure to keep copies of the reports for your own reference and protection.

Make Process Control Decisions, or Direct Actions Related to Process Control

Review the definition for Process Control that appears in the workbook.

[Review the examples of process control decisions. Ask the class for other examples.]

What are examples of tasks that would be candidates for a Standard Operating Procedure?

Ans: Examples of tasks would be:

- Field measurement of pH or DO
- Calibrating field montoring instrumentation
- Rotation of duplicate pumping equipment to equalize wear, without changing pumping rates

[Summarize discussion of process control decisions and standard operating procedures with the following:]

To summarize, the Operator Certification Act requires that only certified licensed operators can make process control decisions. As a certified operator in charge of a staff of operators and laborers, you are encouraged to develop Standard Operating Procedures to make some routine tasks more understandable and to make performance among operators more consistent. These procedures should not be applied to any task that requires an interpretation of data or operating situation, followed by a judgment as to the proper response. Rather, a SOP should deal with more routine tasks such as refilling a batch chemical tank. The Certification Act does not allow Standard Operating Procedures to take the place of an on-site certified operator.

Collection System Operator Licensing

[Review the classification and examination requirements for a licensed collection system operator as presented in the workbook.]

Classification

Classification E; no sub-classification for collection system operator license.

Penalties and Enforcement

Violations

[Review the three violations listed in the workbook.]

Penalties

[Review the penalties of summary offenses and civil penalties, and how they are determined, as presented in the workbook.]

[Point out when payments are due and discuss the appeal process as provided in the workbook.]

Role of the State Board for Certification

[Review the make-up of the Certification Board.]

[Review the duties of the State Board listed in the workbook.]

NPDES REGULATIONS: 10 minutes

Now that we have discussed the Pa. Operator Certification Act, the responsibilities under the law and violations and penalties associated with the regulations, let's move on to NPDES regulations.

[Ensure participants are aware of where to locate the regulations.]

- State regulations can be accessed through the DEP website at www.dep.state.pa.us, choose "Subjects," then "Regulations," then "Title 40 – Protection of the Environment."
- EPA regulations can be accessed through the EPA website at www.epa.gov, choose "Laws and Regulations," then "Code of Federal Regulations," then "CFR Title 40 – Protection of the Environment."
- Guidance documents and other fact sheets can also be accessed through the DEP and EPA websites.

EPA Regulations

40 CFR 122 – EPA Administrative Regulations for the NPDES Permit Program

[Review 40 CFR 122 various sections listed in the workbook.]

40 CFR 125 – Criteria and Standards for NPDES Permits

[Review 40 CFR 125, what it covers and point out various sections listed in the workbook.]

40 CFR 133 – Secondary Treatment Regulations

[Review the general content of 40 CFR 133, as presented in the workbook.]

40 CFR 136 – Guidelines Establishing Test Procedures for the Analysis of Pollutants

[Review the general content as presented in the workbook.]

Pennsylvania State Regulations

Title 25 Pa Code Chapter 92 – NPDES Regulations

[Review the general content of Title 25 Pa Code Chapter 92, as provided in the workbook.]

INDUSTRIAL PRETREATMENT REGULATIONS: 5 minutes

If your treatment plant has an average daily design flow capacity equal to 5 mgd or greater, or if you have industrial users in your service area that discharge industrial wastewater capable of impacting plant operation and performance, you will probably have to develop and implement an Industrial Pretreatment Program (IPP) to control the discharges from those contributors. It will be your responsibility to insure that no industrial wastewater is discharged that will cause damage to your plant or collection system, pass through your plant and damage the receiving stream, or impact on the end-use of your wastewater sludges. In Pennsylvania, the EPA makes the decisions regarding IPPs, although DEP has input and can request EPA to require a treatment plant to develop and implement a program.

[Ensure participants are aware of where to locate the regulations. Information is available at the EPA website described previously.]

EPA Regulations

[Review Key Point: DEP does not have primacy for the Industrial Pretreatment Program in PA. EPA is the Approving Authority.]

40 CFR 401 – The Federal Pretreatment Program

[Review the information presented in the workbook for 40 CFR 401.]

40 CFR 403 – General Pretreatment Regulations for Existing and New Sources

[Review information provided for 40 CFR 403]

BIOSOLIDS AND RESIDUALS MANAGEMENT REGULATIONS: 2 minutes

As a certified operator in Pennsylvania, you will need to be aware of both the federal and the state regulations and guidelines governing the handling of biosolids. The federal regulations are found under Title 40 of the Code of Federal Regulations, Part 503. The current Pennsylvania regulations relating to the permitting and disposal of biosolids are found under 25 Pa Code Section 271, Subchapter J. The good news is that there are a lot of similarities between the state and federal legislation. However, there are some differences in reporting and management requirements.

DEP currently offers a training course on Land Application of Biosolids that goes well beyond the scope of this introductory course. The Biosolids course is offered several times a year at several locations across the state. You should check with your DEP regional office to find out when it will be offered at a location near you.

[*Ensure participants are aware of where to locate the regulations.*

- *Additional information relating to Biosolids Management in Pennsylvania can be found on the DEP website at www.dep.state.pa.us, under "Subjects," choose "Biosolids" or choose "Biosolids" from the Wastewater Operators web page.]*

EPA Regulations

40 CFR 503 – Standards for the Use and Disposal of Sewage Sludge

[Review the highlights of 40 CFR 503 from the workbook.]

A particularly informative guidance document available from EPA titled "Control of Pathogens and Vector Attraction in Sewage Sludge," EPA/625/R-92/013, is available for downloading from the EPA website. This document should be in everyone's library.

Pennsylvania State Regulations

25 Pa Code Section 271 – Subchapter J – Beneficial Use of Sewage Sludge by Land Application (January, 1997)

[Review the highlights of 25 Pa Code Section 271 from the workbook.]

In addition to the training course offered by DEP, DEP also has several technical guidances for land application of biosolids. One of these documents is titled, "Guidelines for Agricultural Utilization of Sewage Sludge" and provides guidelines for determining application rates. Another titled, "Guide to Field Storage of Biosolids" discusses the requirements associated with the storage of biosolids at the application site. Both of these documents are available for downloading from DEP's website.

WASTEWATER PLANNING AND MANAGEMENT: 3 minutes

Wastewater planning in Pennsylvania is governed under Act 537 of 1966. This act requires that all municipalities in Pennsylvania provide for the wastewater needs of the residents and businesses in their communities. A lot of Act 537 relates to the management of on-lot septic disposal systems, which is something the certified operator usually doesn't become too involved with. However, Act 537 also establishes requirements related to the management of public sanitary sewer systems, specifically where it relates to sufficient capacity to address the wastewater needs of the community. As a certified operator, you are responsible for monitoring the remaining capacity of your plant and collection/conveyance facilities. When you become aware of any conditions of overloading, or if you are concerned that an overload will occur in the near future, it is your responsibility to advise the municipal officials of that concern, and to help them in planning to address the existing or projected overload. You may also be asked to provide capacity information for your plant and collection/conveyance system when a new development is going through the planning stages. Act 537 requires planning modules to be submitted that provide information about wastewater capacity. It also requires that the municipality certify that sufficient capacity exists for the proposed new development, and that no overloads will be created by the new growth. Your input in these situations will be very important.

As with many of the previous regulations we've discussed, it is not necessary that you memorize the content of Act 537. However, it is important that you are aware of how this legislation affects planning for your facility, and what your role as a certified operator is with respect to that planning.

Ensure participants are aware of where to locate the regulations.

- The text of Act 537 and a number of fact sheets and guidances are available for downloading from DEP's website. As before, choose "subjects," then "Act 537 Sewage Facilities Program" from the list.
- Links to the Act 537 are also available from the wastewater operator's web page, and from the municipal officials' page.

Overview of Act 537

[Review the highlights of Act 537 from the workbook.]

25 PA Code Chapter 94

Chapter 94 is closely related to Act 537 in that this regulation deals with the management of reserve capacity. Where Act 537 establishes the general requirements for wastewater planning, Chapter 94 provides the roadmap, particularly with respect to existing or potential hydraulic or organic overloading conditions. As a certified operator, you need to be aware of existing or potential problems and you need to keep your municipal officials aware of any capacity issues as soon as you become aware of them. Certain provisions of Chapter 94 are “self-implementing.” That is, these provisions are to be implemented automatically when an overloading condition occurs or when you become aware of a potential future overloading condition. One of these provisions requires that a “Corrective Action Plan” be prepared and submitted to DEP, which establishes the steps your municipality intends to take to address the overload. You will be an important member of the planning team should a CAP be required.

Chapter 94 tries to prevent the need to implement emergency planning criteria by requiring that the municipality prepare an annual “Wasteload Management Report.” This report is more commonly referred to as the “Chapter 94 Report.” The purpose of the report is to generate an estimate of the hydraulic and organic loadings 5 years in the future, based on historical loadings, to identify existing and future overloading conditions, and to report on the growth within the service area of the treatment plant. This also includes monitoring discharges from significant industrial users. The report also provides information on the condition of the plant and collection/conveyance system, and reports on efforts directed towards evaluating and mitigating infiltration/inflow, or any other condition that impacts system capacity. Here again, your knowledge of the plant and collection system can be important to the preparation of a useful report.

[Review the highlights of Chapter 94 from the workbook.]

WATER QUALITY REGULATIONS: 5 minutes

These next few regulations deal with the criteria upon which the discharge limits in your NPDES permit are based. EPA requires that the states examine and develop criteria necessary to protect their streams and other bodies of water. Chapters 93 and 16 establish the treatment goals and background water quality criteria for all of the streams in Pennsylvania. Chapter 93 presents regulations establishing water quality requirements based on stream usage. Chapter 16 presents Pennsylvania's Toxics Management Strategy, and regulates the discharge of potentially toxic materials into the state's streams and waterways.

It is important that you, as a certified operator, know where to find information about the water quality criteria for the stream or waterway into which your treatment plant discharges. These regulations directly impact your plant discharge requirements, and therefore they will impact on the way you need to operate your plant.

[Ensure participants are aware of where to locate the regulations.

- *As before, information on these regulations can be found on DEP's website at www.DEP.state.pa.us. There is also a lot of information available on watershed management.]*

25 Pa Code Chapter 93 – Pennsylvania Water Quality Standards

[Review the highlights of Chapter 93 from the workbook.]

25 Pa Code Chapter 16 – Water Quality Toxics Management Strategy

[Review the highlights of Chapter 16 from the workbook.]

[*Review Key Points]*

Today you were given an introduction to basic concepts of wastewater collection and conveyance systems, the wastewater treatment process, the role of the treatment plant operator, and the regulations that govern wastewater treatment plant operations. This concludes Module 1. Does anyone have any questions?

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