Drinking Water Operator Certification Training
Instructor Guide

Module 23:
Organics Removal

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

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

A Note to the Instructor

Dear Instructor:

The primary purpose of this course, *Organics Removal* is to inform operators about the concerns involved with organics in drinking water and common methods for removing organics from water. This module has been designed to be completed in approximately 5.5 hours, but the actual course length will depend upon content and/or delivery modification and results of course dry runs performed by the DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topical outline. You may adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by DEP.

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

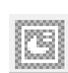
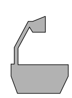
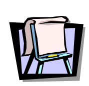
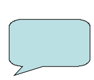
Delivery methods to be used for this course include:

- Lecture
- Exercises/Activities
- Calculations

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
	Exercise		Flip Chart
	Key Definition(s)		Suggested "Script"
	Key Point(s)		

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

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

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

PowerPoint Slide Show Controls

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

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

INTRODUCTION OF MODULE: 5 minutes

Display Slide 1—Module 23: Organics Removal.

[Welcome participants to "Module 3 – Organics Removal." Indicate the primary purpose of this course is to inform operators about the concerns involved with organics in drinking water and common methods for removing organics from water.]

[Introduce yourself.]

[Provide a brief overview of the module.]

This module contains 4 units. On page i, you will see the topical outline for **Unit 1 – Background and Overview of Organics**

[Briefly review outline.]

If you turn the page, you will see the topical outline for **Unit 2 – Source Control.**

[Continue to briefly review outline.]

If you turn the page, you will see the topical outline for **Unit 3 – Air Stripping.**

[Continue to briefly review outline.]

If you turn the page, you will see the topical outline for **Unit 4 – Adsorption.**

[Continue briefly to complete outline review.]

UNIT 1: <u>40 minutes</u>

As was referenced in the topical outline, we will begin Unit 1 with an overview of organics.

Display Slide 2—Unit 1: Background and Overview of Organics.

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

- List the four basic elements in organic chemicals.
- Name the four properties of organics that affect their ability to be treated.
- Name the three key methods of control and treatment.
- List other methods that can be used to remove organics from the water.

TERMS AND DEFINITIONS: <u>5 minutes</u>

Let's begin the unit by looking at some terms that you will need to know.

*[Review the definitions for **Molecular weight** and **Polartity** as presented in workbook.]*

Matter can be found in three states, solid, liquid and gas.

*[Review the definition for **Volatility** as presented in workbook.]*

Now let's take a look at terms that are specific to organics.

[Review the remaining definitions as presented in participant workbook.]

If you will turn the page, we will take a closer look at Organics Chemicals.

ORGANIC CHEMICALS: 15 minutes

Background

*[Review the key point of **organics** as presented in participant workbook.]*

In the past, organics were considered to be substances derived from living organisms; however, today many organic compounds are formed from sources other than living organisms. This is principally attributed to materials synthesized from the chemical industry.

Examples of Organics

[Review the examples of organics presented in the workbook and point out the combination of elements—Carbon plus one or more of the three organic elements: Hydrogen, Nitrogen and Oxygen.]

However in spite of having the Carbon and Hydrogen, Nitrogen, and/or Oxygen elements within their structure, there are a number of chemical compounds that are inorganic.

Exceptions

[Review the material on the exceptions—inorganic, as presented in the workbook. Point out the combination of elements—Carbon plus one or more of the three organic elements: Hydrogen, Nitrogen and Oxygen. Emphasize that these compounds are considered inorganic because of the type of bonding that occurs between the atoms. State that the key feature of organics is the presence of stable carbon to carbon bonds.]

Other Molecular Elements

While Carbon, Hydrogen, Nitrogen, and Oxygen are the most common elements found in organic chemicals, other elements can also be found in organic chemicals. Some natural organic chemicals have these elements, although more frequently they are found in synthetic organic substances. This list represents some of the other elements found in organic chemicals, especially manmade chemicals.

[Review the list of elements presented in the workbook.]

Examples of Common Synthetic Organic Substances

[Review the examples listed in workbook.]

Properties of Organic Compounds

The properties of organic compounds affect both the removal and treatment methods used. Different organic chemicals have different properties. This is important because organics with some properties are more easily removed by certain treatment methods while others are more easily removed in other ways. For example, volatile organics are relatively easily treated by aeration, but that method would not be effective for non-volatile organics.

[Review the properties as presented in the workbook.]

*[For **molecular size**, you may want to add:]*

The diameter of a strand of human hair is 100 times larger than a micrometer of organic compound.

[Continue to review the properties in the workbook.]

*[For **Polarity**, you may want to add:]*

A debye is 3.33 x 10^{-30} coulomb-meters, and is a measurement of "dipole moment," which basically is the product of the magnitude of the charge at either end of the dipole and the distance between the two charges.

Display Slide 3—Class of Organics (Table 1.1 of participant workbook).

This table illustrates a very simplistic method for categorizing organics known to exist in drinking water based on molecular weight, polarity, and volatility.

The size and complexity of organic molecules increases dramatically as a function of their molecular weight. Note the general relationship between volatility and molecular weight. As the molecular weight increases, the volatility decreases. Polarity, on the other hand, is unrelated to the molecular weight or volatility.

Now that we have a general understanding of what organics are, let's explore their importance in drinking water treatment.

Sources of Organics

[Review the material as presented in workbook.]

Problem Organics

[Review the material as presented in workbook.]

[For Synthetic Organic Chemicals, add:]

Some synthetic organic chemicals are hazardous to human health and others aren't. For most of them, it is unknown whether they are harmful to humans. Because more new chemicals are manufactured each year, it is impossible to know what the long-term effect of them will be in small doses, either alone or in combination with other chemicals.

[For "Precursors," add:]

A Precursor is an organic found in water that would normally not be a problem by **itself**, but becomes one when it reacts with the disinfectant (chlorine), forming disinfection by-products (DBPs). DBPs are a problem because they are carcinogens.

[Remind participants of the definition of THM.]

So you not only have to be concerned about precursors but the actual disinfection by-products that they form.

[Complete the review of Problem Organics with Disinfection By-Products.]

CONTROL AND TREATMENT METHODS: 10 minutes

Most of the attention on treatment of organics is focused on disinfection by-products and organics from commercial activities. While these categories make up little of the total organic loading in drinking water, they are the organics that generally have the greatest threat to human health.

Let's briefly review how the control and treatment of organics in drinking water can be achieved. Any one of the following methods or a combination can be used.

Source Control

[Review information in workbook.]

There are many different methods of source control aimed at preventing various types of problematic organics. These methods are discussed further in Unit 2.

Air Striping

[Review information in workbook.]

Adsorption

[Review information in workbook.]

Precipitation and Filtration

[Review information in workbook.]

Enhanced coagulation is a method promoted in the Stage 1 Disinfection By-product Rule to improve removal of disinfection by-product precursors during treatment. In this technique, the dose of the coagulant and the pH of the water during coagulation are optimized to improve the amount of organic matter removed during the coagulation and precipitation stage of treatment. Module 14: Conventional Filtration covers coagulation and precipitation more thoroughly.

Direct Filtration

[Review information in workbook.]

Module 15 covers Direct Filtration treatment more thoroughly.

Combination of Oxidation and Adsorption

[Review information in workbook.]

Reverse Osmosis

[Review information in workbook.]

While reverse osmosis is effective in removing many of the problematic organics, it is an expensive technique for treating water. Other methods of removing organics are generally less expensive while still effective.

Ion Exchange

[Review information in workbook.]

Boiling

[Review information in workbook.]

All of these methods have some degree of effectiveness at controlling or removing organics. However, adsorption and air stripping are the most common methods of removing volatile organic compounds (VOCs), taste and odor, and many SOCs. Source Control is the most common method used for prevention of disinfection by-products, although it can often be used effectively for other types of organics. Each of these three methods has an entire unit dedicated to its review.

[Ask participants if they have any questions on the material covered in Unit 1.]

[Answer questions as necessary.]

EXERCISE UNIT 1: <u>10 minutes</u>

Use the Word Box above to complete questions. Words used twice are indicated with a (2).

Word Box

Air Stripping (2)	Adsorption (2)	Boiling	Carbon
Direct Filtration	Hydrogen	Ion Exchange	Molecular Size
Molecular Weight	Nitrogen	Oxidation & Adsorption	Oxygen
Polarity	Precipitation & Filtration	Reverse Osmosis	Source Control (2)
Volatility			

1. List the four basic elements in organic chemicals in the space provided.

Ans: Carbon
Hydrogen
Oxygen
Nitrogen

2. Write the names of the four properties of organics that affect their ability to be treated.

Ans: Molecular Size
Molecular Weight
Polarity
Volatility

3. List methods that can be used to remove organics from the water.

Ans: (In any order)

Source Control
Air Stripping
Adsorption
Precipitation and Filtration
Direct Filtration
Combination of Oxidation and Adsorption
Reverse Osmosis
Ion Exchange
Boiling

4. Name the three key methods of control and treatment.

Ans: Source Control
Air Stripping
Adsorption

UNIT 1 RESOURCES

This is the end of Unit 1.

[Ask participants if they have any questions on any of the material covered thus far. Answer questions as necessary.]

Over the next three Units we will be exploring the three most cost effective and efficient treatments used in organics removal and treatment. Let's turn to Unit 2 where we will focus on Source Control.

UNIT 2: <u>65 minutes</u>

Display Slide 4—Unit 2: Source Control.

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

- Identify and explain each of the five components of source control.

SOURCE CONTROL OVERVIEW: 4 minutes

As we learned in Unit 1, source control and management of organic contaminants at their source is often considered to be the first barrier in eliminating or reducing the organic contaminant level prior to treatment.

Definition

[*Review definition.]*

Five Components

There are five major components of source control.

[Review material in workbook.]

Please note that the primary focus for many of these components will be control of surface water (lakes and reservoirs).

Rivers and streams are very difficult to exert source water control on, because there is nowhere the water can be under the operator's control before it reaches the plant. Generally, any source water control for flowing water will be implemented by a state or local government attempting to protect its water rather than by a water treatment plant. Overall, legislation seems to be the best way to protect flowing water sources, including those that may flow into lakes or reservoirs. While recent regulatory emphasis has been on treatment of the organics and prevention of disinfection by-products, elimination or reduction of point-source contamination has been a focus of public health regulations for years.

In addition, while treatment plant staff can use source water controls on well water, well water rarely has high concentrations of natural organic matter unless the well is under the influence of surface water. If an organic problem exists, it is usually a manmade organic that contaminates the well; therefore, we will focus on well water in Limiting Contaminants Originating from Commercial Activities.

MONITORING WATER QUALITY: <u>11 minutes</u>

Source Water Monitoring

Monitoring is the first step in source control. By tracking raw water quality, assessments can be made about what control strategy is necessary. Monitoring should be utilized for any organic contaminant.

Water Quality Parameters and Testing

[Review material in workbook.]

[Continue to review materials on Water Quality Parameters and Testing. When reviewing pH-Algal Activity, indicate that Algal means of, or relating to, algae.]

Predicting Changes

As data is collected over a period of time, it will become possible to better predict what weather conditions and upstream activities are likely to precede or coincide with heightened organic problems. With experience, an operator will be able to know when to expect problems with organics and react more quickly to the changes, minimizing the chance of poor quality water.

Weather Related Changes

The weather plays an important role in source water quality, particularly in surface water sources. It is important to be aware of the changes that rain, sun, heat, and cold can bring.

[Review material in workbook.]

Upstream Activities

Knowing what potential sources of organics are upstream of the water intake can help to prevent organic loading or to alert the water treatment plant so treatment can be adjusted.

Treatment plant operators need to communicate with upstream commercial and agricultural entities, provide them with information on how to minimize organics in the water, and ask them to alert the treatment plant if any problems occur.

Upstream activities are more likely to affect surface water sources than ground water, due to the easy access to surface water.

[Review material in workbook.]

TREATING NATURALLY OCCURRING ORGANIC MATERIAL: <u>20 minutes</u>

The next method of controlling source water to be covered is the treatment of naturally occurring organic material before it enters the water treatment plant. Typically, this treatment will occur in lakes or reservoirs that act as the treatment plant's source water.

The vast majority of organic material present in surface waters is comprised of naturally occurring humus material. Other sources of naturally occurring organics in water include microorganisms and petroleum residues.

As was mentioned in Unit 1, natural organic matter (NOM), while rarely dangerous to human health, can be a problem because it will cause unpleasant coloration of the water or an unpleasant odor. In addition, high concentrations of NOM are largely a concern from a health standpoint because they are precursors to the halogenated organics formed when the water is disinfected with chlorine, chlorine dioxide, or chloramines. Therefore, removing NOM before it reaches the plant will help to reduce the THMFP and the final concentrations of HAA (haloacetic acids) and TTHM, both of which are regulated groups of DBPs.

In addition, reduction of naturally occurring organics can aid in the treatment of the water. By reducing NOM, it will reduce the dose of chemicals needed to treat the water and it will improve the treatment effectiveness by allowing more odor and color to be removed and by preventing some of the DBPs from forming.

[Review the paragraph at the top of the page.]

Removal of the organic matter can only be effectively used if there is an area before the treatment plant where the water can be treated. For surface water sources, lakes and reservoirs make good locations. In flowing water sources such as rivers or streams, it is usually not possible to remove the natural organic matter before the treatment plant. Ground water sources do not usually have problems with natural organic matter, but removal of NOM from ground water prior to the treatment plant would be difficult.

Destratification

The first approach to reduce the concentration of natural organics in source water is destratification. Destratification removes NOM from the water before it enters the treatment plant.

[Review material in workbook.]

Algaecide

The second approach to reduce NOM in source water is algaecide. This approach also reduces NOM from the water prior to it entering the treatment plant.

[Review material in workbook.]

[Continue to review material on Algaecide.]

Intake Placement

The third approach for reducing NOM is intake placement. This method employs selecting water with less organic matter in it.

[Review material in workbook. Note that this method applies to all types of surface water sources, not just lakes and reservoirs.]

Multiple Sources

The fourth and last approach for reducing NOM is multiple sources. Like intake placement, this method employs choosing where source water is obtained.

The use of multiple sources is another way to reduce source water NOM. Note that this not only applies to lakes and reservoirs, but to all types of water sources. It is especially useful if one of the possible sources is ground water and the other is surface water. When NOM is especially high in the surface water source, it may be possible to use the ground water source more heavily.

When adjusting source proportions, care should be taken in adjusting treatment chemicals for the differences in the water quality of the sources. The organics concentration may not be the only difference between them.

[Review material in workbook.]

MINIMIZING FORMATION OF COMPOUNDS DURING WATER TREATMENT: 4 minutes

A third method for source water control involves minimizing the formation of DBPs during water treatment.

Chlorine Application Point

[Review material in workbook.]

If possible, chlorine, chloramine, or chlorine dioxide should be used as late as possible in the treatment process, after most of the natural organic matter is removed. This is because most of the precursors for disinfection by-products come from the natural organic matter.

Before changing where the disinfectant is applied, it should be ensured that adequate disinfection will still be provided.

Alternative Disinfectants

[Review material in workbook.]

CONTROLLING CHEMICAL REACTIONS WITHIN TRANSMISSION SYSTEMS: <u>3 minutes</u>

The fourth method for controlling source water is to control the chemical reactions that take place within the transmission system.

[Review material in workbook.]

LIMITING CONTAMINANTS ORIGINATING FROM COMMERCIAL ACTIVITIES: 8 minutes

The last method for source water control is to limit contaminants that originate from commercial activity.

[Review first paragraph in workbook.]

Industrial

Some form of government intervention is typically needed to place direct limitations on organics pollution from sources.

Synthetic organics from industries are more likely to be a problem in ground water than surface water. In ground water, the organic cannot escape once it has made its way into the ground water, so it does not dissipate. Typically SOCs in ground water come from one source. In surface water, however, while there may be many sources of SOCs, most will vaporize from the water because it is well aerated.

[Review material in workbook.]

Wastewater Treatment

[Review material in workbook.]

Non-Point Sources

[Review material in workbook.]

This brings us to the end of our Unit on Source Control. Before we go on to the exercise, are there any questions?

[Answer questions as necessary then move on to the exercise on the next page.]

UNIT 2 EXERCISE: <u>15 minutes</u>

1. Source Control of organics involves two facets. Circle the statement that is correct.
   a. Minimize the level of organics in the influent and control the formation of toxic inorganics during treatment and distribution.
   b. Minimize the level of organics in the effluent and control the formation of toxic organics during treatment.
   c. Minimize the level of organics in the influent and control the formation of toxic organics during treatment and distribution.
   d. Maximize the level of organics in the influent and control the formation of organics in the effluent.

Ans: C. Minimize the level of organics in the influent and control the formation of toxic organics during treatment and distribution.

2. Which two of the water quality parameters and testing performed (below) are not commonly done at the plant but by an outside laboratory?

Total Organic Carbon (TOC)	Dissolved Organic Carbon (DOC)
Ultraviolet 254	Specific Ultraviolet Absorbance (SUVA)
Algae Counts	Analysis for Synthetic Organic Chemicals (SOCs)
Turbidity	pH – Algal Activity
True Color	Apparent Color
Volatile Organic Compounds (VOCs)	

Ans: Analysis for Synthetic Organic Chemicals (SOCs) and Volatile Organic Compounds (VOCs)

3. Which state is not correct about predicting changes?
   a. Storm events will wash degraded organic materials into the surface water sources.
   b. Warm weather followed by a cold snap may kill algae, resulting in degradation products that cause taste and odor.
   c. Releases for dams or reservoirs will not change water quality.
   d. Industrial activities may add to TOC, SOC or VOC to raw water.

Ans: C. Releases for dams or reservoirs <u>may</u> change water quality.

4. Reduction of natural organic matter in the treatment plant's raw water can occur in one of two ways. What are they?
   a. Remove the natural organic matter from the water before it enters the treatment plant.
   b. Select a water source with less organic matter in it.
   c. Natural organic matter can only be removed in the treatment process so selection is not a viable option.
   d. Ground water sources are very high in natural organic matter and should be avoided.

Ans: A & B Remove the natural organic matter from the water before it enters the treatment plant and Select a water source with less organic matter in it.

5. Destratification, Algaecide and Multiple Sources are three or the four methods used to reduce the concentration of naturally occurring organics. Which is the fourth?
   a. Oxidization
   b. Chlorination
   c. Intake Placement
   d. Mixing

Ans: C. Intake Placement

6. Which disinfectant(s) that can be used as an alternative to chlorine? Circle best answer.
   a. Ozone and Ultraviolet (UV) radiation
   b. Chloramines and Chlorine dioxide
   c. Both a. and b.
   d. None of the above

Ans: C. Both a. and b.

7. Industrial, wastewater treatment and non-point sources are three major sources in which contaminants originate. Which statement is correct?
   a. SOC discharges from an industry may remain in the groundwater source long after the discharge is eliminated.
   b. VOC will remain in high concentrations because they do not volatize in water.
   c. Since operators cannot control upstream non-point sources, the do not need to be aware of them.
   d. Wastewater treatment facilities will contact the water supplier when the have a abnormal discharge.

Ans: A. SOC discharges from an industry may remain in the groundwater source long after the discharge is eliminated.

UNIT 2 RESOURCES

This is the end of Unit 2—Source Control.

[Ask participants if they have any questions before moving on to the next unit. Answer questions that may arise.]

There are many occasions where source control will not be adequate to handle problems with organics, especially SOCs and NOM. NOM can often be reduced to an acceptable level during conventional treatment. However, if SOCs are a problem in the source water, additional treatment will often be needed. Two technologies for removing SOCs from water, air stripping and adsorption, are discussed in the next two units.

UNIT 3 – AIR STRIPPING: 65 minutes

Display Slide 5—Unit 3: Air Stripping.

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

- Describe the air stripping process.
- Identify different types of aeration equipment and aeration system components found in the air stripping process.
- Explain the causes and solutions to common operating problems in the air stripping processes.
- Specify safety issues pertaining to air stripping.

INTRODUCTION: <u>3 minutes</u>

Description of the Air Stripping Process

*[Review definition of **Air stripping** (**Aeration**) in workbook.]*

Constituents Removed by Aeration

[Review the key point of volatile organics removal in workbook.]

AERATION EQUIPMENT: 17 minutes

Now that we reviewed the basic process of aeration and what constituents it can remove, let's take a look at the equipment used for air stripping.

Packed Tower Aerators

The first type of aerator we will look at is a packed tower aerator.

Conventional Countercurrent System

Display Slide 6—Conventional Packed Tower Aerator (Figure 3.1 of participant workbook).

These systems are used primarily for stripping of VOCs and dissolved gases. It is the more effective is removing VOC than other types of aeration because of the large surface area, which creates more liquid-gas transfer. A packed tower consists of a column filled with a packing material that is designed to increase the air/water contact surface area.

[Point to the packing material throughout the tower.]

In a conventional countercurrent system like the one we see here, water is pumped to the top of the column and distributed along the surface of the packing.

[Point to the water inlet indicated by "Liquid in" (top left) and then point to "Liquid out" (bottom right).]

The water then flows down through the packing by gravity and is collected at the bottom of the tower.

[Point to the inlet for the air and indicate its movement with an upward motion.]

Air is introduced at the bottom of the tower and bubbles up through the wetted packing material.

[Point to the very top of the tower "gas out."]

The contaminated air is either exhausted to the atmosphere or collected for treatment.

A demister "de-mister" is a device for removing vapor from a gas. It will "catch" small droplets of liquid.

Other Packed Tower Systems

The cross flow and cascade systems introduce air differently. These systems allow for larger air flow rates with lower head loss and are used primarily when treating semi-volatile or non-volatile contaminants which require a high air-to-water ratio.

[Review material as presented in workbook.]

Bubble Diffusers

Another type of aerator is a bubble diffuser.

[Review paragraph at top of page in workbook.]

Display Slide 7—Bubble Diffuser Systems (Figure 3.2 of participant workbook).

Figure (a) uses porous plates at the bottom of the tank to distribute the air. This bubble diffuser works in a similar manner as the air stones used in fish tanks. Porous plates are usually a ceramic material with holes small enough to allow tiny air bubbles through.

Figure (b) uses a jet aerator. Jet aerators recirculate a portion of the water in the tank at a high velocity, introducing air into the water inside the aerator. It serves both to mix and aerate the water.

[Review the last bullet on the page.]

Tray, Cascade, and Cone Aerators

Some other types of aerators include tray, cascade, and cone aerators.

Tray Aerator

[Review material presented in workbook. Indicate that Figure 3.3 is an illustration of a tray aerator.]

Display Slide 8—Tray Aerator (Figure 3.3 of participant workbook).

Cascade Aerators

[Review material as presented in workbook. State that Figures 3.4 and 3.5 are two examples of cascade aerators.]

Display Slide 9—Stairway Cascade Aerator (Figure 3.4 of participant workbook) and Ring-type Cascade Aerator (Figure 3.5 of participant workbook).

Cone Aerators

[Review material presented in workbook. Indicate that Figure 3.6 shows an example of a cone-type cascade aerator.]

Display Slide 10—Cone-type Cascade Aerator (Figure 3.6 of participant workbook).

Spray Aerators

The last type of aerators we will take a look at is a spray aerator.

[Review material presented in workbook. Refer to slide for illustration.]

Display Slide 11—Spray Tower (Figure 3.7 of participant workbook).

Uncovered spray aerators are often placed in a part of the water treatment plant where they can be viewed by the public since they have a nice decorative effect.

Process Operation and Monitoring: <u>10 minutes</u>

Now that we have an understanding of the purpose of aeration and the equipment used, we will look at Process Operation and Monitoring.

Gas to Liquid Ratio in Packed Tower

Balanced Gas to Liquid Flow Ratio

[Review material presented in workbook.]

If the gas flow rate is too high, this condition is known as "flooding."

Maintaining Proper Air Flow for Balanced Gas to Liquid Ratio

[Review material presented in workbook. Mention the following:]

Since high levels of VOCs are more commonly found in ground water, this is the source water for most packed tower operations. Water flow from wells is typically very consistent, so generally the blower speed will be constant, with the air flow designed to create the proper gas to liquid ratio with the well production.

Inspection

Aerators

[Review material presented in workbook.]

Pumps and Compressors

[Review material presented in workbook.]

Top of Tower and Demister System

[Review material presented in workbook.]

Inlet

[Review material presented in workbook.]

Cleaning

Foulant

[Review material presented in workbook.]

Air Diffusers

[Review material presented in workbook.]

Air Filtering System

[Review material presented in workbook.]

COMMON OPERATING PROBLEMS: 12 minutes

We've taken a look at issues concerning the operation and monitoring of aeration equipment. Now let's look at some common operating problems.

Fouling

*[Review material presented in workbook on **Carbonate Scaling**, **Iron Oxidation**, and **Bio-Fouling**.]*

Problems Resulting from Fouling

*[Review material presented in workbook on **Loss of Air Flow Due to Fowling** and **Flooding/Channeling Due to Fouling**.]*

Excess Aeration

Over-aeration can cause problems with the treatment processes that follow the aerator.

[Review the first paragraph on the page.]

[State that increased corrosion, floating flocs, and false clogging filters are three problems that can occur due to excess aeration.]

*[Review material presented on **Increased Corrosion**, **Floating Flocs**, and **False Clogging Filters** in workbook.]*

[Indicate that the obvious solution for any of these three problems is to avoid over-aeration by decreasing the amount of aeration.]

Packed Tower Incorrect Design Assumptions

When an aeration system is designed, certain operating conditions are used to determine the best design. If the conditions change, the aerator may not meet the treatment requirements. In some cases, adjustments to the aeration system will be able to compensate for the change in operating conditions.

*[Review material presented on **Temperature**.]*

*[Review material presented on **Contaminant Concentration** and on **Water Flow**.]*

Monitoring: 4 minutes

When using air stripping to remove organics, three things that need to be monitored on a regular basis include organic concentration, flow rates, and exhaust emissions.

Organic Concentration

Measure Concentration of Contaminant

[Review material presented in workbook.]

Flow Rates

*[Review material presented on **Packed Towers and Bubble Diffusers** and on **Other Aerators**.]*

Exhaust Emissions

[Review material presented in workbook.]

SAFETY AND AERATION: 4 minutes

Before concluding this section on aeration, it is important for us to take a look at safety and aeration.

Hazards

*[Review material presented on **Gases** and **VOCs** in workbook.]*

Preventions & Remedies

*[Review material presented on **Proper Ventilation** and **Removal of Contaminants** in workbook.]*

UNIT 3 EXERCISE: **15 minutes**

True (T) or False (F)

1.____ When the packing of a packed tower is coated with a slimy layer wash the column with a chlorine solution.

Ans. True

2.____ Increase the air flow rate in the column when the water flow rate through the column is very low and the column is starting to flood.

Ans: False. Decrease the air flow rate in the column.

3.____ Clean rust deposited on the packing material in a packed tower with potassium permanganate or chlorine.

Ans: False. Clean with an acid to remove the iron. Potassium permanganate or chlorine can be added in the water to avoid metals oxidizing.

4.____ When bubbles attach themselves to the flocs and cause them to float rather than settle, decrease amount of air flow—do not over-aerate.

Ans: True

5.____ Excess aeration has caused metal parts to corrode. To minimize this effect increase amount of air flow—over-aerate. In addition, adding a protective coating on exposed metals to minimize corrosion.

Ans: False. Decrease amount of air flow—do not over-aerate.

6.____ To decrease risk to personnel proper ventilation and routine inspections of air handling systems is essential.

Ans: True

UNIT 3 RESOURCES

This is the end of Unit 3—Air Stripping.

Ask participants if they have any questions before moving on to the next unit. Answer questions that may arise.

As was mentioned at the end of Unit 2, if SOCs are a problem in the source water, additional treatment will often be needed. We just covered one of the two technologies for removing SOCs from water (air stripping). We will now take a look at the second technology—adsorption.

UNIT 4: 160 minutes

Display Slide 12—Unit 4: Adsorption.

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

- Describe the adsorption process.
- Identify the characteristics and types of activated carbon.
- Describe considerations for locating PAC feed point.
- Indicate the main pieces of equipment used in PAC and GAC adsorption facilities.

Display Slide 13—Unit 4: Adsorption.

- Identify four design considerations for a GAC adsorption bed.
- List seven common operating problems with adsorption processes.
- Name three operation control tests used in adsorption process.
- Specify safety issues pertaining to adsorption.

INTRODUCTION: 15 minutes

Description of Adsorption Process

[Review definition of ***Adsorption****.]*

Conditions that Affect Adsorption Process

As some bonds between the adsorbent and the organic compound are formed, other ones are broken. When the number of bonds that form is equal to the number of bonds broken, the system is at equilibrium and no more net adsorption is possible, unless the adsorption conditions change. The following are some conditions that will affect the adsorption process.

[Review material presented in workbook and add the following:]

- Strength of the chemical bonds

Polarity affects how well a compound bonds—the less polar, the more easily adsorbed. Changes in pH will change the polarity of a compound.

- Molecular size of the adsorbate and Range of pore sizes in the adsorbent

Smaller molecules are more easily adsorbed, especially when the adsorbent has many micropores (pores with a diameter less than 2 nm). Keep in mind, however, that larger molecules are better adsorbed when there are large pores available—large molecules do not fit into small pores.

- Available surface area on the adsorbent

More surface area means more places for molecules to bond and more adsorption.

- Temperature

Molecules move faster at higher temperatures. This makes it more difficult for molecules to bond, resulting in less adsorption.

- Adsorbate concentration

A higher adsorbate concentration in the water will result in a larger amount of adsorbate being adsorbed. However, keep in mind that this does not mean that the ***percentage*** removed will increase. For example, if the influent concentration increases by 50 percent, the amount adsorbed may only increase by 10 percent.

- Competing chemicals

If there are chemicals other than the adsorbate, these other chemicals may also bind to the adsorbent, reducing the space available for the adsorbate and reducing the amount of adsorbate adsorbed.

Activated Carbon

Characteristics/Properties of Activated Carbon

[Review information as presented in the workbook.]

*[Finish **Characteristics/Properties** with a review of particle size.]*

Forms of Activated Carbon

[Review information as presented in the workbook.]

We will be taking a closer look at these two forms of activated carbon over the next two sections. We will begin with Powdered Activated Carbon.

POWDERED ACTIVATED CARBON (PAC): 45 minutes

As I just mentioned, PAC will be covered in this section. We will focus on a number of key topics, including Point of Application, Dose, Feed Equipment, Carbon Contactors, Operation and Monitoring, and Common Operating Problems.

Point of Application

*[Review **Common Application Points** and **Considerations for Placement**.]*

Table 4.1 summarizes the advantages and disadvantages of several application points. Take a minute to review the table.

[Ask if there are any questions. Respond accordingly.]

Dose

Once an appropriate point of application is determined, it is important to consider the PAC dose.

*[Review **Influencing Factors**. Note that all of these factors can change throughout the day or seasonally so the PAC dose will have to be adjusted as these conditions change to prevent under or over dosing. Indicate that under dosing would result in high concentrations of the organic contaminant remaining in the water; over dosing would result in waste of PAC, greater volumes of solids to remove and dispose of, and possibly in more difficulty with pretreatment or greater amounts of PAC remaining in the filtered water. Also include the following information in your review:]*

- Concentration of organic contaminant – As the concentration of the organic contaminant increases, more PAC will be needed.
- The nature of the organic contaminant – If more than one organic is a problem, some will be more difficult to remove than others and will need more PAC.
- The contact time available – Even if the same application point is used at all times, the contact time will vary as the plant flow rate changes. At higher flow rates, there will be less contact time and the required PAC dose is likely to increase.
- The concentrations of chemicals that interfere with the adsorption process – This includes those interfering chemicals found in the source water; such as natural organic matter (NOM), and those added during water treatment; such as coagulant or oxidants. As the concentration of these interfering chemicals increases, the adsorbate will become more difficult to adsorb and so more PAC will be needed.

*[Review **Common Dosages** and **Determining Dosages**.]*

Display Slide 14—HSDM-fit (Figure 4.1 of participant workbook).

Figure 4.1 is one example of what the results of a series of tests may look like. The y-axis represents the percent of MIB remaining after the test. Note the effect of the contact time and organic concentration on the required dose. If the effluent concentration of MIB desired was 10 ppm and the influent concentration was 50, then 80% would need to be removed. Using these curves, a dose of 20 mg/L would be needed with 1 hour of contact time, or a dose of 44 mg/L would be needed with 7.5 minutes of contact time. On the other hand, if the influent MIB concentration was only 20 ppm, then only 50% would need to be removed. With 1 hour of contact time, a dose of 9 mg/L would be needed, and with 7.5 minutes of contact time, approximately 21 mg/L would be needed.

Calculating Feed Rate

So how much PAC would we add in a day if are dose was set at 20 mg/L

Calculate the pounds per day of PAC to treat 3.5 MGD of water. Assume we want to feed 20 mg/L of PAC.

Ans: We calculate pounds per day by multiplying the concentration by the flow in Million gallons per day by 8.34.
X lbs/lday = 20 mg/L x 3.5 MGD x 8.34
X lbs/day + 583.8 lbs/day of PAC fed

[Ask if everyone understood, writing on a board may be helpful.]

More about calculating feed rates can be found in the Drinking Water Module 21: Chemical Feed.

Feed Equipment

PAC is typically fed using either a dry feed system or a slurry system.

[Review information as presented in the workbook.]

Carbon Contactors

Many times, PAC is to be added to an existing plant. In these cases, there is rarely an ideal location for a PAC application point—early in the treatment process there are chemicals that interfere with adsorption and later in the treatment process there is little contact time or the PAC may break through the filters.

One way to provide a better application point that reduces the amount of PAC that needs to be used, either as an addition to an existing plant or as a part of a new treatment plant, is to use a carbon contactor. This is a process that is designed to provide contact time for the PAC without chemical interference.

[Review the first paragraph on the page.]

Carbon Contact Basin

[Review material in workbook.]

Slurry Recirculation Tank

Another option is a slurry recirculation tank upstream of chemical addition. This tank is designed to concentrate solids by recirculating them within the basin.

Display Slide 15—Slurry Recirculation Tank (Figure 4.2 of participant workbook).

Continue Displaying Slide 15—Slurry Recirculation Tank (Figure 4.2 of participant workbook).

*[Review material in workbook. Use the slide to point out the process described and the components listed under equipment (third main bullet under **Slurry Recirculation Tank**).]*

Operation and Monitoring

Monitoring

To operate a PAC system efficiently, monitoring must be conducted for the organics of interest. Since PAC systems are frequently used only intermittently when a problem with organics arises, monitoring for the organic will indicate when the PAC should be used and when use should end.

[*Review the material on Before PAC System Use in workbook.]*

Once the PAC is being used, the organic concentration should be measured before and after contact with the carbon. This will provide feedback about whether the selected PAC dose is effectively removing the contaminant. The PAC dose can be adjusted based on these results.

[Review the material on During PAC System Use and After PAC System Use in workbook.]

Operation

[Review material in workbook.]

Maintenance

[Review the key point.]

[Review the material in workbook.]

Common Operating Problems

There are six common operating problems when using PAC.

[Briefly review material in workbook.]

*[For **Carbon Dust**, indicate that Activated carbon dust is regulated under Occupational Safety and Health Administration (OSHA) regulations as a nuisance dust. State that in the long term, inhaling dust can lead to respiratory problems and in the short run, it will cause mild irritation to the respiratory tract and can aggravate existing problems.]*

*[For **Improper Selection of Application Point**, stress the "if possible"—a lot of treatment plants do not have the option to add chlorine or oxidants later in the process.]*

[Indicate that before changing chlorine feed points, they should ensure that adequate disinfection will still be attained through the rest of the treatment process.]

*[Continue to review **Common Operating Problems**.]*

[Ask participants if they use PAC at their treatment plant and if so, have they experienced any of these problems. Discuss.]

GRANULAR ACTIVATED CARBON (GAC): 75 minutes

Now that we have finished our review of PAC, let's take a look at the second form of activated carbon—granular activated carbon (GAC). We will focus on a number of key topics within GAC, including GAC Properties, Equipment, Retrofitting Existing Conventional Filters, Operation and Monitoring, Maintenance, Carbon Regeneration, Operating Problems, and Biological GAC (BAC).

GAC Properties

If you use GAC at your treatment plant, you need to be aware of the following terms.

[Review the definitions.]

Equipment Types

Driving Force - Gravity vs. Pressure

The first characteristic is driving force. There are two types—gravity or pressure.

[Review material as presented in workbook.]

Flow Direction - Downflow vs. Upflow

The next characteristic is flow direction. Here again, there are two types—downflow or upflow.

[Review material as presented in workbook.]

Configuration – Parallel vs. Series

The third characteristic is configuration of contactors. When more than one GAC contactor is required, they can be operated in parallel or in series. Operating in either of these modes can help reduce carbon usage, since one of the contactors can be operating until the effluent contaminant concentration is higher than the treatment goal.

Display Slide 16—Series System and Parallel System (Figure 4.3 of participant workbook).

When operating in parallel, the flow is split evenly amongst all the contactors. By contrast, when operating in series, the entire flow passes through each contactor in succession.

[Review material as presented in workbook.]

Placement – Pre-Filtration vs. Filter/Adsorber vs. Post-Filtration

The last characteristic we will look at is placement. The GAC contactor could be located before or after the filtration step or the contactor could be used as part of a filter.

[Review material as presented in workbook.]

Equipment Properties

[Review material as presented in workbook.]

Retrofitting Existing Conventional Filters

One way to add GAC treatment to a plant is the retrofitting of existing conventional filters.

[Review material as presented in workbook.]

Figure 4.4 illustrates the conversion of split-cell filters.

Display Slide 17—Retrofitted Split-Cell Filters (Figure 4.4 of participant workbook).

[Indicate the upflow in Compartment C1 and the downflow in Compartment C2.]

Operation and Monitoring

In order for a GAC system to operate efficiently, certain operation and monitoring functions need to be performed.

[Review material as presented in workbook.]

An illustration of a mass transfer zone is shown in Figure 4.5.

Display Slide 18—Mass Transfer Zone (Figure 4.5 of participant workbook).

[Review remaining bullet on page.]

Review the first bullet on the page.

Display Slide 19—Typical Breakthrough Curve (Figure 4.6 of participant workbook).

Figure 4.6 shows a typical breakthrough curve with exhaustion of the carbon occurring when the effluent concentration of the contaminant is equal to the concentration in the influent. The point of breakthrough would occur when the effluent concentration is equal to the maximum desired concentration in the effluent.

[Illustrate that the length of time before breakthrough depends on what the allowable concentration is by showing a couple of concentrations and what the corresponding time to breakthrough would be.]

[Continue to review material in workbook.]

*[Continue reviewing material on **Operation and Monitoring**.]*

Display Slide 20—Proper Backwash Rate (Figure 4.7 of participant workbook).

Figure 4.7 illustrates the different backwash rates needed at different temperatures to achieve various percent bed expansion levels. The percent expansion that is most effective can be determined through operating experience, or may be provided by the GAC supplier. As temperature changes, the backwash rate will have to be adjusted to maintain the ideal bed expansion. For example, if the desired bed expansion rate was 20% for a Grade I GAC, then when the water temperature increased from 55°F to 65°F, the backwash rate would increase from 12 gpm/sf to 14 gpm/sf. For a 20 ft x 20 ft GAC contactor, this is equivalent to a change from 4,800 gpm to 5,600 gpm. The difference would be even larger when considering that winter water temperatures may approach 32°F.

It is important during operation to recognize the effect of temperature, or GAC may be lost by using too high of a backwash flow rate when water temperatures decrease.

Control Tests

When using GAC, a number of things need to be monitored. Let's take a look at several control tests that need to be performed on a regular basis.

[Review material as presented in workbook.]

[Add the following after reviewing the second bullet on effluent turbidity.]

Bacteria that grows on the GAC may be dangerous to human health, so turbidity is an important indicator of the water quality. However do not rely on the turbidity, carbon does not always register on turbidimeter, the carbon may absorb rather than reflect the light.

*[Review remaining bullets on **Control Tests**.]*

Maintenance

Another key factor to the efficient operation of a GAC system is routine maintenance.

[Review materials as presented in workbook.]

Carbon Regeneration

[Review material as presented in workbook.]

Furnace Types Commonly Used for Regeneration.

There are four furnace types commonly used for regeneration.

- Electric Infrared Oven

Display Slide 21—Cross Section of Infrared Tunnel Furnace (Figure 4.8 (a) of participant workbook).

[Use the slide to point out the process described.]

- Fluidized Bed Furnace

Display Slide 22—Cross Section of Two-Stage Fluidized Bed Furnace (Figure 4.8 (b) of participant workbook).

[Use the slide to point out the process described.]

- Multiple-Hearth Furnace and Rotary Kiln

Display Slide 23—Cross Section of Multihearth and Rotary Kiln Furnaces (Figure 4.8 (c) and (d) of participant workbook).

[Use the slide to point out the processes described.]

Operating Problems

There are four common operating problems when using GAC.

[Briefly review material in workbook.]

*[Continue to review **Operating Problems**.]*

[Ask participants if they use GAC at their treatment plant and if so, have they experienced any of these problems. Discuss.]

Biological GAC (BAC)

[Review first bullet.]

[Indicate that the reason some treatment plants opt to use BAC is that it is cost effective—don't need to constantly replace the GAC.]

[Review remaining bullets.]

SAFETY: 5 minutes

Before concluding this unit on adsorption, let's take a look at safety issues concerning PAC and GAC.

[Review material as presented in workbook.]

UNIT 4 EXERCISE: 20 minutes

Fill in the Blank

1. Adsorption is the process of ________________ a substance located in a gas or liquid at the surface of a solid.

Ans: concentrating

2. Activate carbon removes _________________________ and ___________________ through the absorption process

Ans: taste and odor

3. Four considerations for the placement of an application point for Powered Activated Carbon are:
Adequate contact time between the PAC and the ___________,
Coagulant will coat the surface of the PAC and _________ its ability to adsorb the contaminants,
PAC will react with _____________, potassium permanganate, and other oxidants and
PAC is small enough to pass through a ______________ filter.

Ans: organics
reduce
chlorine
dual-media

True (T) or False (F)

4.____ The slurry system of PAC feed equipment will distribute better and prevent material from floating.

Ans: True

5. ____ A PAC uses much smaller carbon particles than a GAC.

Ans: False. The particle size of a PAC is much smaller than the larger particles of a GAC.

6. ____ A fire may start when activated carbon reacts with oxidizing agents

Ans: True

7 . ____ An operator doesn't need to wear air protection around activated carbon that has been wetted down.

Ans: False. Always wear proper air protection around activated carbon. Wetted carbon, such as in the slurries, will remove oxygen from the air.

8. ____ There are four common operating problems that can occur with the adsorption process.

Ans: False. GAC has four but PAC has seven.

PAC
Carbon Dust
Improper Selection of Application Point
PAC Pass Through
Taste and Odor Problems
Poor Pre-Treatment Performance
Loss of Adsorption Capacity
GAC
Bacterial Growth
Changing Bed Depth
Desorption of Adsorbed Organics
Backwashing and Loss of Carbon

9. ___ On a regular basis a number of operation control tests can be used in the adsorption process. Core samples and effluent turbidities are done every 6-months or twice a year.

Ans: False. Core samples of carbon bed for filter absorbers should be taken every 6-months, and post-filtration contactors every 3-months. Distance between top of the carbon and top of the wash-water trough should be measured ever 3 months. The remaining control test, including the effluent turbidities should be performed on a regular basis.

10. ____ Activated carbon will burn so the following safety precautions should be taken:

- Storage area and storage bins should be fireproof.
- Dust control equipment and ventilation should be used to minimize dust.
- Carbon should not be stored with gasoline, mineral oils, vegetable oils, or similar materials.
- Carbon should not be stored with strong oxidizers.
- Explosion-proof wiring and equipment should be used in carbon storage and feed areas.

Ans: All True.

UNIT 4 REFERENCES

This concludes Unit 4 as well as Module 23.

[Ask participants if they have any questions and respond accordingly. Thank them for their participation. Remind participants that this workbook has been designed not only for instructional purposes but as a reference resource.]