Drinking Water Operator Certification Training Instructor Guide

Module: 4
Water Quality and Characteristics

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 4: Water Quality and Characteristics* is to introduce water quality classifications, water quality parameters for treatment, and water quality sampling and analysis. It also provides an historical perspective of water quality issues and standards in the U.S. This module has been designed to be completed in approximately 3 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the 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 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.

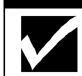
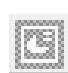
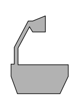
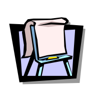
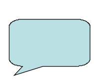
Delivery methods to be used for this course include:

- Lecture
- Class Discussion
- Quizzes
- Class Exercises

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

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

Icons to become familiar with include:

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

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

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

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

PowerPoint Slide Show Controls

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

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

INTRODUCTION OF MODULE: <u>5 MINUTES</u>

Display Slide 1—Module 4: Water Quality and Characteristics.

[Welcome participants to "Module 4: Water Quality and Characteristics." Indicate that the primary purpose of this course is to introduce:]

- Water quality classifications
- Water quality parameters for treatment
- Water quality sampling and analysis
- The historical development of water quality issues and standards in the U.S.

[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: General Overview* and *Unit 2: Drinking Water Standards*.

[Briefly review the outline.]

If you turn the page, you will see the topical outline for *Unit 3: Water Quality Classifications*.

[Briefly review the outline.]

On page iii you will see the topical outline for *Unit 4: Water Quality Parameter Sampling and Monitoring for Treatment Process Optimization and Control*.

[Briefly review the outline.]

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UNIT 1: <u>5 minutes</u>

Display Slide 2—Unit 1: General Overview.

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

- Outline a historical perspective of major water quality concerns and disease outbreaks.
- Name three common sources of water quality contaminants.
- List the general water quality contaminant classifications.

HISTORICAL WATER QUALITY ISSUES: 3 minutes

We begin Module 4 and this unit with a brief historical perspective of water quality issues and an overview of the sources and classifications of water quality contaminants. We will look first at water clarity.

Water Clarity

[Review the material in the workbook.]

Association of Water Quality with Disease

Water quality is a larger issue than that of the aesthetic water clarity. Let's look at the earliest association of water quality with disease.

[Review the material in the workbook.]

Waterborne Disease Epidemics

Let's look at some examples of life threatening water borne disease epidemics.

[Review the material in the workbook. Emphasize the most recent epidemic in 1993.]

At the time of the Milwaukee outbreak, the USEPA had not developed a standard for *Cryptosporidium*. This large outbreak of waterborne disease drew attention to the importance of safe drinking water and had a significant influence on the United States Environmental Protection Agency (USEPA) and the U.S. Congress.

GENERAL SOURCES AND CLASSIFICATIONS OF WATER QUALITY CONTAMINENTS: 2 minutes

Sources of Contaminants

Review the definition of contaminant in the workbook.

The sources of contaminants can be divided into three major categories. We will explore the source categories in depth later in this module. At this point, let's review the categories and a few examples of each.

[Review the material in the workbook.]

General Water Quality Contaminant Classifications

The general water quality contaminant classifications will also be presented in greater detail later in this module. Here I would simply like to introduce the five classifications of water quality contaminants established by the EPA.

[Review the classifications listed in the workbook.]

Identifying and classifying water quality contaminants set the stage for developing standards which is covered in Unit 2.

Key points for Unit 1 – General Overview

- Filtration was used in the 18th century to clarify water and helped to improve taste, smell, and appearance.
- In 1855, Dr. John Snow proved that cholera was a waterborne disease.
- In recent times, 400,000 people got sick in Milwaukee in 1993 due to waterborne disease.
- Water contaminants include physical, chemical, biological, and radiological substances.
- Contamination can occur because of both natural and man-made causes.
- Disinfectants like chlorine are very effective in eliminating biological pathogens, but care must be taken so that harmful disinfection by-products (DBPs) such as TTHMs are not formed.

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

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UNIT 2: <u>45 minutes</u>

Display Slides 3 and 4 – Unit 2: Drinking Water Standards

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

- Outline the history of drinking water standards
- List the three step process in the development of the United States Environmental Protection Agency (USEPA) Safe Drinking Water Act
- Define the following regulatory standard classifications:
  - ✓ Primary Maximum Contaminant Level (PMCL)
  - ✓ Primary Maximum Contaminant Level Goal (PMCLG)
  - ✓ Secondary Maximum Contaminant Level (SMCL)
  - ✓ Maximum Disinfectant Residual Level (MDRL)
  - ✓ Maximum Disinfectant Residual Level Goal (MDRLG)
  - ✓ Treatment Technique (TT)
- List the major groups of water quality parameters regulated by the United States Environmental Protection Agency (USEPA)
- Identify the commonly used units of measurement for the major groups of water quality parameters

[Instructor: *This unit covers background information on the drinking water regulations. It is good for the operator to know, but do not get bogged down in the details.]*

HISTORY, DEVELOPMENT, AND BASIS OF DRINKING WATER STANDARDS: 20 minutes

In this unit we will discuss the history of drinking water standards and explore the evolution of the United States Environmental Protection Agency Safe Drinking Water Act, various regulatory standard classifications, and water quality parameters. Let's begin with the history of drinking water standards.

History of Drinking Water Standards

[The following item can be used to cover bullet one in the workbook. It contains the bulleted text plus additional information:]

For the most part, standards for drinking water quality were nonexistent up through and including much of the 19th century. However, this changed after people began to realize that various epidemics (cholera, typhoid fever, etc.) had been caused and/or spread by water contamination and that drinking water safety could not be accurately judged by the senses (appearance, taste, and smell).

- *[Review bullet two in the workbook.]*

[The following item can be used to cover bullet three in the workbook. It contains the bulleted text plus additional information:]

By the year 1900, the number of municipal water systems in the United States had increased to over 3,000, although only approximately 10 systems filtered their supplies (slow sand filter plants). While municipal water supplies were growing, development of drinking water standards lagged behind. Major disease outbreaks occurred due to the efficient distribution of contaminated water through pumped and piped supplies. As a result, it was not long before treatment producing safe drinking water became a priority.

- *[Review bullet four in the workbook.]*

We've looked briefly at the history; now let's look at how the development of drinking water standards progressed.

Development of Drinking Water Standards

[Review the material in the workbook.]

[Continue reviewing the material in the workbook. Be sure to place special emphasis on the "1986" bullet including the five classifications of contaminants and the descriptions of the measurement units of each.]

[Continue reviewing the material in the workbook.]

In the next section we'll review the six types of studies and evaluations used to determine which contaminants should be regulated.

Basis for Drinking Water Standards

[Review the material in the workbook.

- *Highlight the definitions of "Toxicology," "Carcinogenic," and "Mutagenic."*

Toxicology can be described as the study of the impact of chemical substances on health.]

[Continue to review the information in the workbook. Reinforce that epidemiological studies are the studies or evaluations that support scientific and technical assessments.

Provide some additional information on the following items. Specifically address how "Treatment technologies and costs" and "Analytical methods and monitoring" fit in with the overall list.]

- **Occurrence and human exposure** - Occurrence of disease relative to the population exposed.

- **Public perception** - The public needs to be educated on what is in their water and why drinking water standards are being developed.

- **Treatment technologies and costs** - EPA is mandated by law to take into consideration costs when developing new drinking water standards, as per the SDWA amendments of 1996. There has to be treatment technologies available that can remove contaminants below the levels of the proposed standards at a cost affordable to the water providers.

- **Analytical methods and monitoring** - There has to be analytical methods available to water testing laboratories that can reliably measure concentrations below the proposed contaminant standards and whose results are readily reproducible.

MAJOR COMPONENTS OF THE USEPA SAFE DRINKING WATER ACT: 15 minutes

While the United States Environmental Protection Agency Safe Drinking Water Act continues to evolve today, the major components were developed in an initial three-step process.

The USEPA Safe Drinking Water Act (SDWA): A Three-Step Process

[Review the material in the workbook.]

The next section lists and describes the terminology used by the SDWA to describe contaminant levels.

Terminology Used for Drinking Water Regulations

[Review the material in the workbook.]

***[Instructor:** Be sure to focus on MCLs. Tell operators that their main concern will be meeting MCLs for various contaminants.]*

[Continue reviewing the material in the workbook.]

Now try the matching exercise on 2-7 to practice these important terms.

Exercise:

Try this exercise to test your knowledge of the regulatory terms we just reviewed. Place the letter of the definition before the correct term.

C______ Maximum Contaminant Level

A______ Treatment Technique

B______ Maximum Disinfectant Residual Level

A. This is a regulatory standard that is used in place of the MCL when it is not feasible to determine the level of the contaminant.

B. The highest level of a disinfectant allowed in drinking water

C. The highest level of a contaminant that is allowed in drinking water

We've looked at terminology used for regulations. Now in table 2-1 let's look at a few of the more significant drinking water regulations and their requirements.

Establishment of Drinking Water Rules

[Review the material in the workbook. Focus on the "Surface Water Treatment Rule (Pennsylvania Filtration Rule)."]

For folks with groundwater systems, you don't have to worry about the surface water treatment rule.

[Review the material in the workbook. Focus on "Stage 1-Disinfectant/Disinfection Byproduct Rule."]

[Continue reviewing the material in Table 2-1.]

We will refer back to these rules in Unit 4 when we discuss water quality parameters and monitoring.

UNIT 2 EXERCISE

[Have the class take five minutes to complete the quiz. They can complete it individually or with a partner. Once completed, take five minutes to review the answers.]

1. How did the increase in the number of municipal water systems in the U.S. contribute to major disease outbreaks in the early part of the 20th century?

   A: By the year 1900, the number of municipal water systems in the US had increased to over 3,000, although only approximately 10 systems filtered their suppliers (slow sand filter plants). The result of this explosion of water systems contributed to major disease outbreaks due to the distribution of contaminated water through pumped and piped supplies.

2. Match the following terms with their definitions (place the letter of the term in the line in front of the definition):

Answer	Term	Definition
C	Toxicology	A. Causing heritable alteration to genetic material
A	Mutagenic	B. Long term, low dose exposure to a contaminant
D	Acute	C. The study of adverse effects of chemicals on living things
B	Chronic	D. Short term, high does exposure to a contaminant
E	Genotoxic	E. Causing alteration or damage to genetic material

3. **True or False:** Maximum Contaminant Levels (MCL) are non-enforceable levels that relate to the taste and odor (aesthetic quality) of the water.

Key points for Unit 2 – Drinking Water Standards

- In 1900 there were 3000 municipal drinking water systems but only 10 were filtering the water.
- Drinking water regulations date from the 1893 Interstate Quarantine Act to the 1974 Safe Drinking Water Act (SDWA) and major amendments to the SDWA in 1986 and 1996.
- Primary Maximum Contaminant Levels (PMCL or MCL) are enforceable water quality standards.
- Secondary Maximum Contaminant Levels (SMCL) are non-enforceable guidelines for contaminants that affect the aesthetic quality of drinking water.
- Maximum Disinfectant Residual Level (MDRL) is the highest level of a disinfectant allowed in drinking water.
- A 2-log removal of Giardia cysts means that 99% of the cysts are removed from the drinking water.
- A 4-log inactivation of enteric viruses means that 99.99% of the virus is inactivated.
- The Total Coliform Rule requires that finished drinking water in the distribution system can have zero total and fecal coliform and zero *E. coli*.

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

UNIT 3: <u>105 minutes</u>

Display Slides 5 and 6 – Unit 3: Water Quality Classifications.

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

Physical Characteristics

- List the four physical characteristics of water

Microorganisms

- List three currently regulated waterborne pathogenic microorganisms (pathogens)
- Name the three of the six common sources of pathogens
- List three indicators of microbiological contamination

Inorganic Constituents

- Name three regulated inorganic constituents that occur in drinking water supplies
- Name at least three common sources of inorganic constituents

Organic Compounds

- Name at least two common sources of SOCs
- Describe one BAT for treatment

Radionuclides

- List two regulated radionuclides
- Name two common sources of radionuclides

Disinfectants and Disinfection Byproducts (D/DBP)

- List three regulated disinfectants and disinfection byproducts
- Name a common precursor of disinfectant byproducts
- Describe two BATS for treatment

PHYSICAL CHARACTERISTICS OF WATER: 5 MINUTES

There are four characteristics of water that are commonly used to define the physical properties. These include:

[Review the information on the physical characteristics in the workbook.]

MICROORGANISMS: 40 minutes

In Unit 3 we will discuss, in depth, the five major classifications of EPA regulated water quality parameters that were identified in Unit 2. We begin with Microorganisms.

Definitions

Before we proceed, there are a number of definitions relevant to microorganisms and their impact on drinking water quality that are useful for us to know.

[Review the material in the workbook. Focus on the definition of "Waterborne pathogenic microorganisms."]

Disease Outbreaks

Waterborne pathogenic microorganisms cause disease. There were 691 reported waterborne disease outbreaks in the U.S. from 1972 to 1998.

[Review the material in the workbook.]

Current List of Regulated Waterborne Pathogenic Microorganisms and Indicators

A pathogenic microorganism is capable of causing disease. Table 3-1 is the list of currently regulated pathogenic microorganisms with associated goals and regulations. We will discuss regulation treatment techniques later in this module.

[Table 3-1 is provided as a reference.]

Common Sources of Waterborne Pathogenic Microorganisms

There are six groups of common sources of waterborne pathogenic microorganisms.

[Review the material in the workbook.]

Three Categories of Microorganism Agents of Waterborne Disease

Pathogenic microorganisms can be divided into three categories: bacteria, protozoa, and viruses. Let's first look at the category of bacteria.

Bacteria

[Review the material in the workbook. Include that:]

- Survival in water is hours up to days.
- Conventional filtration offers some removal capability. Disinfection easily inactivates bacteria.

[Refer the class to Table 3-2.]

In this table we can see sample organisms and the associated disease along with the infectious dose estimate. The dose is measured in colony forming units per mL.

[Ask the students to note Figures 3-1 to 3-4. These are sample pictures of bacteria.]

Protozoa

The second category is protozoa.

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

- Reproduction requires a human or animal host.
- Filtration provides good removal. Protozoa is resistant to highly resistant to most disinfectants.

[Refer the class to Table 3-3 to review sample organisms in this group and the diseases they cause. Include the following information:]

- Infectious dose is measured in number of cysts per mL. Size is measured in microns (μm), one thousandth of a millimeter.

[Refer the class to the pictures of sample protozoa.]

[Ask the participants to look at the additional sample pictures of protozoa.]

Viruses

The last category, viruses, can be defined as intracellular parasites that are assembled from components (not grown or cell divided), lack metabolic machinery required for cellular activity, and must borrow such machinery from a host cell.

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

- Viruses cannot reproduce in water. They require a human or animal host.
- Filtration provides poor removal; disinfection has mixed results. Some viruses are resistant to disinfection, some are not. Hepatitis A is somewhat more resistant to chlorine.

[Refer the class to Table 3-4 Virus Disease Examples for a reference.

Refer the class to Figure 3-11.]

Now that we've discussed the three categories of microbiological waterborne pathogens, we will explore the topic of microbial indicators used in testing for these categories.

Microbial Indicators

[Review the material in the workbook. Refer the class back to the definition of an "Indicator" on workbook page 3-2.]

Indicator – Surrogate microorganisms and other water quality parameters used as a sign of a water system's vulnerability to the presence of pathogenic microorganisms. For example, the presence of coliform bacteria indicates that pathogenic bacteria may be present.

Can you think of any reasons for this procedure?

[Request any ideas from the class.]

Ans: Waterborne pathogens generally occur in such low numbers relative to other waterborne microorganisms that they are difficult to test and would not provide real time data for process control. Therefore, testing for indicators that are present when the pathogen is present is an expedient alternative.

Let's review the characteristics an indicator should have to be effective.

[Review the material in the workbook.]

[Refer the class to Table 3-5 in the workbook]

This table shows us some samples of microbial indicators, their characteristics, and shortcomings. We'll review a few you may be familiar with and use the rest of the table as a reference.

[Review "total coliforms" and "fecal coliforms."]

On the next page, let's look at the indicator "Particle Counts."

[Review "Particle Counts" in the workbook.

Suggest the class review the remaining indicators outside of class.]

Although we often think of illness as the negative result of pathogenic microorganisms, there are certain microorganisms which create nothing more than nuisance concerns. In the next section we will explore the "Nuisance Microorganisms."

General Groups of Nuisance Microorganisms and Aesthetic Concerns

Some microorganisms create aesthetic unpleasantries rather than disease. Table 3-6 shows a few sample nuisance microorganisms and their impact on the water supply.

[Review "Algae blooms" and "Sulfur bacteria."

Suggest that the other samples be reviewed outside of class.]

[Refer the class to the sample pictures of various nuisance bacteria.]

In the next section we will move to the second water quality classification—inorganic constituents.

Exercise - Microorganisms

[Have the class take five minutes to complete the exercise. They can complete it individually or with a partner. Once completed, take five minutes to review the answers.]

1. List three examples of regulated waterborne microorganisms.
    - *a.* *Cryptosporidium*
    - *b.* *E. coli*
    - c. Fecal Coliforms

2. Waterfowl droppings, septic fields, and run-off from farm fields are some of the common sources of waterborne pathogenic microorganisms.
    - a. True
    - b. False

3. Protozoa can survive in water for up to
    - a. One hour
    - b. One day
    - c. One month
    - d. One year

4. Best Available Technologies for treating water with bacteria include conventional filtration and disinfection.
    - a. True
    - b. False

5. List three examples of microbial Indicators and give one shortcoming for each.

    {Instructor: See pages 3-11 and 3-12 for possible answers to this question]

    - a. ____
    - b. ____
    - c. ____

INORGANIC CONSTITUENTS: __25 minutes__

The second group of EPA regulated drinking water parameters is that of inorganic constituents. Table 3-7 lists the parameters and the PMCL, SMCL, and PMCLG of each.

Standards and BATS for Inorganic Constituents That May Occur in Drinking Water Supplies

Tables 3-7 and 3-8 (on next page) consists primarily of trace heavy metals not common in our water supplies. Some exceptions are lead and copper, byproducts of corrosion of pipe and plumbing materials. Iron and manganese are also common in water supplies due to their prevalence in geologic formations and their propensity to become dissolved when in contact with water. Nitrates are another common inorganic contaminant, found in groundwater supplies that are located in agricultural areas and are the result of fertilizer leaching into groundwater.

Prior to examining Table 3-7 let's review the definitions of the levels in Unit 2 (page 2-6).

Primary Maximum Contaminant Level Goal (PMCLG) – A regulatory standard established as part of the amendment in 1986 to strengthen the SDWA. The PMCLG is the level of a contaminant known to occur in drinking water below which there is no known or expected risk to health, based on toxicology reviews. PMCLGs allow for a margin of safety and are non-enforceable public health goals.

Primary Maximum Contaminant Level (PMCL) – The highest level of a contaminant that is allowed in drinking water. PMCLs are set as close to PMCLGs as feasible, using the Best Available Treatment technology (BAT), and taking cost into consideration. PMCLs are enforceable standards.

Secondary Maximum Contaminant Level (SMCL) – The non-enforceable guidelines for contaminants that may adversely affect the aesthetic quality of drinking water. States were encouraged to establish regulations based on these standards.

As we can see by a cursory review of Table 3-7, most of the PMCLs are set at the PMCLG level. One familiar constituent, arsenic, is regulated at a level greater than the PMCLG.

Table 3-8 lists inorganic constituents and the types of BATS appropriate to each. Let's examine the key at the bottom of the page and use a familiar parameter, Fluoride, as an example to review.

[Review the key at the bottom of the page and review Fluoride in the table. Also, make a note of the footnote on lead at the very bottom of the page.]

We've looked at an abbreviated list and BATs of inorganic constituents. Now we'll review the sources of inorganic constituents.

Common Sources of Inorganic Constituents

We can see in Table 3-9 a list of inorganic constituents and their common sources.

[Review 2 or 3 of the constituents of your choice.]

[If time allows, review one of the constituents on this page.]

General Inorganic Chemical and Treatment Terminology

When discussing inorganic chemicals and treatment techniques, much of the terminology may be new or unfamiliar. The definitions on the next few pages of your workbook will be very useful as a reference. Let's review just a few.

[Review "Buffer," "Buffer Capacity," "Catalyst", and “Colloidal”]

[Review the "Hardness" definitions. Point out that hardness is usually reported as Calcium Carbonate.]

[Review the final "Hardness" definition at the top of this page. Also review the definition of pH.]

[Review "Standard Solution" and suggest the class review the other definitions when needed.]

Acute and Chronic Health Affects

Table 3-10 lists both acute and chronic health effects of a number of waterborne inorganic constituents, most of which are quite serious and should give us pause to consider the importance of providing the best possible drinking water to our communities.

[Review "Arsenic" in Table 3-10.]

Arsenic has been found to be present in many groundwater supplies (mainly in the western states) at levels that exceed the new arsenic regulation promulgated in 2002. PA has some small groundwater systems that will be required to provide treatment to meet the new regulation. Treatment must be on-line by 2006.

[Review "Nitrate."]

Some water suppliers in PA are providing treatment (typically ion exchange) to remove nitrates. Typically this is in agricultural areas where groundwater becomes contaminated with fertilizer containing nitrates.

Aesthetic Concerns

Less threatening but often annoying are the many aesthetic concerns listed in Table 3-11.

[Review "Fluoride."]

[Review "Scale and sediments."]

[Refer class to Figures 3-17 and 3-18. These pictures show how scale and sediments can clog water pump impellers.]

Exercise - Inorganic Constituents

[Have the class take five minutes to complete the exercise. They can complete it individually or with a partner. Once completed, take five minutes to review the answers.]

1. Give the Maximum Contaminant Level (MCL) for the following inorganic constituents.
   a. Arsenic = 0.01 mg/L
   b. Fluoride = 4 mg/L
   c. Cadmium = 0.005 mg/L
   d. Mercury = 0.002 mg/L

2. List the Best Available Technologies (BATS) for treating water with the following inorganic constituents.
   a. Mercury GAC
   b. Cadmium Coagulation/Filtration
   c. Arsenic Coagulation/Filtration

3. List three common inorganic constituents and their sources. [*Instructor: See pages 3-18 and 3-19 to for many possible answers to this question*].
   a. ____________________
   b. ____________________
   c. ____________________

4. What could cause a metallic or salty taste in drinking water?

   A: Copper, iron, manganese, zinc, pH, total dissolved solids, sulfate or chloride

5. High levels of fluoride in drinking water could cause tooth discoloration.

6. Which of the following produce water with the highest hardness?
   a. Lake
   b. Well
   c. River
   d. Stream

7. **True or False:** Hard water is caused by iron in the water

ORGANIC COMPOUNDS: <u>15 minutes</u>

We will now look at organic compounds, the next water quality classification regulated by EPA.

General Categories of Organic Compounds

Organic compounds are divided into two main categories.

The first is Synthetic (man-made) Organic Chemicals (SOC). The SOCs are often a result of run-off, containing pesticides, from farm fields sprayed with pesticides.

The second, Natural Organic Matter (NOM), consists of decayed plant vegetation such as leaves and algae, of which breakdown products have become dissolved.

Regulations

Regulations are significantly different for each category.

[Review the material in the workbook.]

Standards and BATS for Volatile Organic Compounds (VOC)

Table 3-12 lists the current regulated standards and BATS for Volatile Organic Compounds (VOC) for your reference. We will not review this table in class. VOCs are almost exclusively a groundwater contaminant since they dissipate rapidly when exposed in surface water.

Standards and BATS for Non-Volatile Organic Compounds

Table 3-13 lists the non-volatile organics with their standards and BATS for your reference.

[Refer the class to the balance of the list on this page.]

Common Sources

Can you think of some common sources of Natural Organic Compounds (NOMs)?

[Encourage answers from the class.]

Ans: Many answers including: breakdown of plant debris including algae, aquatic plants, leaves, humic matter from wetlands in the watershed.

"Humic matter" can be defined as a substance derived from humus, a black or brown organic substance consisting of partially or wholly decayed vegetable matter.

Can you think of some common sources of Synthetic Organic Chemicals (SOCs)?

Ans: Many answers including: chemical industrial discharges, metal degreasing chemicals, wasted dry cleaning chemicals, leakage from old electrical transformers (PCB), agricultural runoff containing pesticides, drinking water chemicals, storm water runoff from developed areas.

Exercise - Organic Compounds

[Have the class take five minutes to complete the exercise. They can complete it individually or with a partner. Once completed, take five minutes to review the answers.]

1) SOC is an acronym for Synthetic Organic Chemicals

2) Synthetic Organic Chemicals can be further classified as Volatile Organic Compounds or Non-volatile Organic Compounds.

3) List the Maximum Contaminant Level (MCL) for the following volatile organic compounds.

   a) Benzene = 0.005 ppm

   b) Ethylbenzene = 0.7 ppm

   c) Vinyl Chloride = 0.002 ppm

4) List three non-volatile organic compounds.
   [Instructor: See page 3-27 for possible answers.]
   1. Atrazine ________________
   2. Diquat ________________
   3. Lindane ________________

5) List the best available technologies (BATS) for removing Benzene from drinking water.

   GAC and PTA

Let's move on to the next water quality classification, Radionuclides.

RADIONUCLIDES: <u>5 minutes</u>

Table 3-14 lists types and sources and Table 3-15 lists the standards and BATS for your reference.

*[Include the following information when reviewing the workbook sections **Types and Sources of Radionuclides** and **Standards and BATS for Radionuclides**:]*

- Radionuclides are almost exclusively a groundwater contaminant since the emissions from radioactive minerals in the underlying geology is what imparts the water with radioactive particles or gases. Radioactive emissions quickly dissipate in surface waters.
- Radioactive particle contamination, although regulated, is rare even in groundwater supplies. However, radon, a radioactive gas, is much more common. A regulatory standard will be proposed in the near future for radon, possibly in 2004.
- Treatment for radioactive particle contaminants is almost exclusively restricted to granular activated carbon (GAC), which absorbs the particulates. The BAT for radon is air stripping, which is a process whereby the flow stream is exposed to the maximum amount of air to strip it of the radioactive gas.

Acute and Chronic Health Affects

Table 3-16 lists types of Radionuclides and potential health affects.

[Review Table 3-16.]

DISINFECTANTS AND DISINFECTANT BYPRODUCTS: <u>20 minutes</u>

The last group, disinfectants and disinfectant byproducts will be addressed as two sub groups, beginning with disinfectants.

Disinfectants

Standards and BATS for Disinfectants

Table 3-17 lists regulated Disinfectants and BATS. In each case, the BAT is a Disinfection Control System.

Let's look at the parameters for monitoring each of these disinfectants, beginning with chlorine.

Parameters for Monitoring

[Review Bullet 1 and Sub Bullet 1.]

Detectable chlorine residual must be maintained throughout a distribution system for regulatory compliance and is generally measured at representative locations within a system using a chlorine residual field test kit.

[Review Bullet 1 Sub Bullet 2.]

Generally more than the required theoretical dose of chlorine is added for a particular contaminant to assure that the reaction goes to completion.

[Review Bullet 1 Sub Bullet 3.]

The downside of excess chlorination is that it can contribute to increased levels of disinfectant byproducts, many of which are regulated.

[Review Bullet 2 and Bullet 3

Review Bullet 4. Sub Bullets 1 and 2.]

Following the measurement of any of the disinfectant types mentioned above, if the levels vary from the operator's goal or objective (DEP regulation), the next step is to adjust the disinfectant feed after (some period for a downstream location to reflect the new dosage) which another sample would be analyzed. If the target disinfectant level is still not correct, another feed adjustment would be required.

Disinfectant Byproducts

Table 3-18 lists the disinfectant byproducts and their regulated levels and BATS.

[Briefly review Table 3-18.]

Now that the general classifications of water quality contaminants found in drinking water and their regulatory standards have been discussed, the next section presents how monitoring for these contaminants is used for their removal.

Exercise - Radionuclides and DBP

1. Besides alpha emitters, radium-226 and radium-228, what radionuclide must be monitored?

A: Uranium

2. T/F: The source of most radionuclides is the erosion of natural deposits

A: True

3. Which of the following are reasons a water system measures chloramine

a) Use the chloramine result to determine how well reactions of chlorine with ammonia are working
b) Determine if chlorine will react with hydrogen sulfide
c) Determine the concentration of Total Available Chlorine (TAC) residual in the distribution system
d) Determine the acidity of the water

A: a and c

4. List the Maximum Disinfectant Residual Levels (MDRLs) for the following disinfectants:

a. Chlorine (4 mg/L)
b. Chloramines (4 mg/L)
c. Chlorine dioxide (0.3 mg/L)

Key points for Unit 3 – Water Quality Classifications

- Waterborne pathogenic microorganisms present in drinking water can cause disease in humans.
- Drinking water disease outbreaks most often involve groundwater systems.
- Waterfowl droppings, septic fields, and farm run-off are common sources of waterborne pathogenic microorganisms.
- The three categories of microorganism agents of waterborne disease are bacteria, protozoa, and viruses.
- Microbial indicators are often used in place of testing for waterborne pathogenic microorganisms.
- A colloidal suspension of extremely small particles in water will not settle naturally and requires chemical additives or special techniques to remove the particles.
- The process of coagulation involves adding a chemical compound (like alum) to water to destabilize colloidal and suspended particles to form a floc that can be removed by settling and/or filtration.
- Colorimetric testing methods are used to measure a water sample's color adsorption after adding specific reagents to the water.
- A measurement of pH indicates the hydrogen ion activity which affects many chemical reactions.
- Organic compounds are classified as Synthetic Organic Chemicals (SOC) or Natural Organic Matter (NOM).
- Common chemical disinfectants are Chlorine, Chloramines, Chlorine Dioxide, and Ozone.

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

[There is no need to discuss the additional resources listed on this page.]

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UNIT 4: <u>20 minutes</u>

Display Slide 7 – Unit 4: Water Quality Parameter Sampling and Monitoring for Treatment Process Optimization and Control.

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

- Explain grab sample and composite sample techniques
- Explain two characteristics of on-line monitoring which make it preferable to grab sampling
- Explain the primary forces driving water quality monitoring
- State why total coliform are routinely monitored

WATER QUALITY SAMPLING: <u>3 minutes</u>

In Unit 4 we will discuss general monitoring techniques and the various microbiological, organic, and inorganic compounds monitored as part of a water quality program. Let's begin by looking at water sampling.

Sampling Types

[Review grab sample, on-line sample, and composite sample in the workbook. Include the following information:]

- **Grab sampling** is typically used for routine, non-compliance monitoring; for non-health related parameters such as iron, manganese, taste and odor (aesthetic concerns); for compliance monitoring for water quality parameters that are more of a chronic health concern, such as disinfectant byproducts and volatile organic compounds; for distribution system parameters such as chlorine residual and total coliform, in which grab sampling is the most practical technique.
- **On-line sampling** is most commonly used when continuous monitoring/feedback is needed for timely treatment optimization and/or compliance, such as filtered turbidity and finished water chlorine residual.
- **Composite sampling** is used when an average water quality value is required for situations when the water quality parameter is varying significantly over relatively short periods of time, such as total suspended solids during a filter backwash, and metals concentrations from a periodic process wastewater NPDES discharge.

The type of sampling technique used will generally dictate the frequency of sampling, which is discussed on the next page.

Sampling Frequency

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

- Sampling frequency may be based on some of the following factors:
  - Compliance, such as the requirement of the Enhanced Surface Water Treatment Rule that filter effluent turbidity from each filter must be monitored at a minimum frequency of every 15 minutes, which essentially requires on-line monitoring.
  - Pacing (automatic control) of the coagulant feed pump, based on a feedback signal from an on-line water quality instrument such as a streaming current detector which is able to continuously update coagulant conditions.
  - Reservoir turnover due to seasonal affect, which may significantly impact water quality. Depth grab samples are often conducted near the raw water intake to provide advanced warning of reservoir turnover.

The type and frequency of sampling are both components that must be established based on the goals and objectives of water quality monitoring, which is presented in the next section.

INTRODUCTION TO WATER QUALITY MONITORING: 3 minutes

[Review the material in the workbook.

Elaborate on the items in the bulleted list:]

These factors will depend on the type of source water supply, the target contaminant(s) that are intended to be removed, the frequency of contaminant variation, and regulatory requirements.

Primary Driving Forces for Water Quality Monitoring

[Review the material in the workbook.]

Secondary Driving Forces for Water Quality Monitoring

We have reviewed the primary driving forces, now let's take a look at secondary driving forces.

[Review the material in the workbook.]

Now that that the general reasons and techniques for primary and secondary monitoring have been discussed, the next section will discuss monitoring as it pertains to waterborne microorganisms that are a concern either form a nuisance or public standpoint.

MICROBIOLOGICAL AND DISINFECTANT MONITORING: **5 minutes**

Water Quality Parameters and Monitoring for Disinfectants

This section will discuss water quality parameters and analytical equipment commonly used for the monitoring and control of disinfectants used for inactivation of pathogenic microorganisms.

[Review the material in the workbook.]

[Continue to review the material in the workbook.]

Water Quality Parameters and Monitoring for Bacteria

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

- Analyzing for fecal coliform and *E Coli* is often done as a follow-up to sample(s) analyzed as positive for total coliform, verifying that contamination of the water supply has occurred.

Analytical Tools

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

- The field test kit requires a visual observation of color intensity of the prepared sample to a standard color range.
- The colorimeter or spectrophotometer provides more accurate analytical results and direct readout in mg/L.

Note that the analytical equipment above can be used for measuring concentrations of a disinfectant, but cannot be used for detecting microorganism concentrations. (Microorganism concentrations, such as total coliform, require approved laboratory techniques for compliance.)

[Continue to review the material in the workbook.]

- The abbreviations MUG and M-ColiBlue may be familiar to some participants. Analysis for total coliform is one of the most routine and basic sampling and analyses performed by or for the public water supplier (samples analyzed on-site for compliance if the public water supplier laboratory is certified to conduct these analyses; otherwise sent out to commercial lab for analysis). It is “the indicator” for assuring the bacteriological safety of treated water.

The next section presents sampling techniques and monitoring requirements for another classification of water quality parameters, inorganic constituents.

INORGANICS: <u>5 minutes</u>

Inorganics monitoring is the primary technique used for determining the effectiveness of the physical/chemical treatment processes used for inorganics removal.

Monitoring Oxidant Residuals

Oxidation Processes

[Review the material in the workbook.]

Free Chlorine Residual

[Review the material in the workbook.]

Potassium Permanganate Residual

[Review the material in the workbook.]

Analytical Tools for Monitoring Oxidant Residuals

[Review the material in the workbook.]

Another chemical process that is essential for the physical treatment processes to work is coagulation, presented on the next page.

Monitoring the Effectiveness of Surface Water Treatment

[Review the material in the workbook.]

Water Quality and Indicators

[Review the material in the workbook.]

[Continue to review the material in the workbook.]

Analytical Tools

[Review the material in the workbook.]

[Continue to review the material in the workbook at the top of the page.]

Sampling techniques and monitoring requirements for another classification of water quality parameters, natural organic matter, is presented in the next section.

ORGANICS: <u>4 minutes</u>

Parameters and Equipment Commonly Used for Monitoring Natural Organic Matter

Monitoring natural organic matter (NOM) in raw and processed water is important because it serves as the main ingredients, in conjunction with the disinfectant, for the generation of disinfectant byproducts.

[Review the material in the workbook.]

[Continue to review the material in the workbook.]

UNIT 4 EXERCISE

1. A grab sample is collected at a specific site and is representative of the conditions at the time of sampling.

2. A sample from a continuously flowing source which is taken automatically is called a on-line sample.

3. A sample collected at a specific site, but portions of the sample are collected at different time intervals is called a composite sample.

4. When there is considerable variation in water quality, the sampling frequency should be (pick the best answer):

   a. Higher _X__
   b. Lower ____

5. Good insight into the effectiveness of filter operations can be provided by using a:
   a. pH meter
   b. particle counter
   c. flow meter
   d. thermometer

6. On-line monitoring for disinfectant residual can be used to automatically control the chlorine feed rate to maintain a set chlorine residual.

7. To assure that water delivered to the consumer is bacteriological safe, total coliform is used as a:

   a. Microbiological indicator
   b. Color comparator
   c. Turbidity measurement
   d. Taste and odor test

8. A DPD Colorimetric test using a color comparator field test kit is a common method for measuring chlorine residual in water.
   a. True X   b. False _____

9. An on-line ____________ is an analytical instrument used to measure the effectiveness of the surface water treatment process. Readings from the instrument are in NTUs.
   a. Atomic absorption spectrometer
   b. Turbidimeter
   c. Spectrophotometer
   d. Gas Chromatograph

Key points for Unit 4 – Water Quality Parameter Sampling and Monitoring

- The three types of samples are: grab, on-line, and composite samples.
- The sampling frequency (how often samples are taken) should be higher when there are large variations in water quality.
- The DEP requires public water suppliers to provide customers with an annual Consumer Confidence Report (CCR).
- On-line monitoring for disinfectant residual can be used to automatically control the chlorine feed rate to maintain desired chlorine residual.
- DPD is a commonly used method for measuring chlorine residual in water in both lab and field situations.
- The pH has an influence on how effective the coagulation process will be.
- Temperature has an impact on floc formation. Water at less than 40^{o}F may have a very slow coagulation rate.
- Low alkalinity may require the addition of an alkali such as lime before proper coagulation can take place.

This is the end of *Unit 4 – Water Quality Parameter Sampling and Monitoring for Treatment Process Optimization and Control* and the end of *Module 4: Water Quality and Characteristics*.

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