Drinking Water Operator Certification Training
Instructor Guide

Module 5:
Disinfection

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 Environment Training Center

A Note to the Instructor

Dear Instructor:

The primary purpose of this course, *Disinfection* is to introduce the treatment plant operator to the basics of disinfection such as its purposes, factors influencing it, types of disinfection, regulatory requirements, disinfection processes and equipment, contact time computations and maintenance issues. This module has been designed to be completed in approximately 3.5 hours but the actual course length will depend on content and/or the delivery modifications and results of dry test runs performed by the Pa. DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the Pa. DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topical outline. You may need to adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by Pa. DEP.

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

Delivery methods to be used for this course include:

- Lecture
- Exercises

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

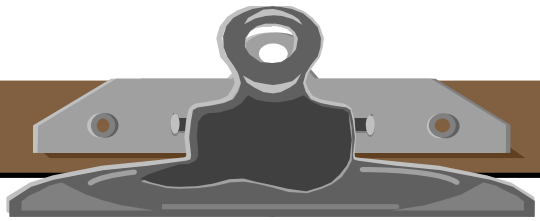
Icons to become familiar with include:

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 are designated by being written in italicized 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 on 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 5: Disinfection.]

[*Welcome participants to "Module 5 – Disinfection." Indicate the primary purpose of this course is to introduce the treatment plant operator to the basics of disinfection such as its purposes, factors influencing it, types of disinfection, regulatory requirements, disinfection processes and equipment, contact time computations and maintenance issues.]*

[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 – Overview of Disinfection.**

[Briefly review outline.]

On page ii is the outline for **Unit 2 – The Disinfection Process** and **Unit 3 -– Contact Time Computations**

[Briefly review outline.]

On page iii, you will see the topical outline for **Unit 4 – Maintenance Issues.**

[Continue to briefly review outline.]

UNIT 1: 75 minutes

[Display Slide 2—Unit 1: Overview of Disinfection.]

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

- Explain the general purpose and regulatory requirements of the disinfection process.
- List bacteria, viruses and intestinal parasites that contaminate drinking water.
- List factors that influence disinfection and explain how they influence it.

[Display Slide 3—Unit 1: Overview of Disinfection.]

The remaining three learning objectives for this unit are:

- List five types of chemical disinfectants and explain the advantages and disadvantages of each.
- Explain how irradiation is used as a disinfection process.
- List eight pertinent drinking water regulations and explain the reason for each regulation and the impact of each.

PURPOSES OF DISINFECTION: 15 minutes

We will begin this module and this unit by covering the purpose of disinfection. The primary purpose of the disinfection process is to protect the public health.

General

Protect Public Health

[Review the definition of disinfection in the workbook.]

[Review the definition of residual disinfection in the workbook.]

Regulatory Requirements

Because of its importance in maintaining public health, the disinfection process is the focus of a number of regulations. Let's learn about some regulatory requirements as they relate to groundwater and surface water.

Groundwater

[Review the information in the workbook.]

[Display Slide 4— A Typical Presentation for a Sanitary Survey.]

This slide shows you what a presentation for a sanitary survey might look like.

[Review the information in the workbook.]

[Display Slide 5— Wellhead Protection Area.]

[Review the information in the workbook.]

This slide shows a wellhead protection area. The small circle on the left side is the proposed well and the wellhead protection area surrounding it is identified on the graphic.

[Review remaining information in the workbook on ground water.]

[Display Slide 6— A Baffled Tank.]

This slide illustrates a typical baffled tank. On the left, the influent water enters the tank. The baffles are represented by the dark vertical lines in the tank. The effluent exits the tank on the right.

Surface Water

Now let's turn our attention to surface water.

[Review the information in the workbook.]

MICROBIOLOGICAL CONTAMINANTS: 10 minutes

As we have just discussed, disinfection is essential because it protects the public health. In this section, we will talk about some of the microbiological contaminants that can impact the public health. Specifically, we will talk about bacteria, viruses and intestinal parasites commonly found in raw water supplies.

[Display Slide – 7 Bacteria Contaminants]

Bacteria

[Review the information in the workbook.]

Viruses

There are three types of viruses we will discuss: enteroviruses, andenoviruses and reoviruses.

Enteroviruses

[Review the definition of enteroviruses in the workbook.]

[Review the information in the workbook.]

Andenoviruses

 *[Review the definition of adenoviruses in the workbook.]*

[Review the information in the workbook.]

Reoviruses

 *[Review the definition of reoviruses in the workbook.]*

[Review the information in the workbook.]

Intestinal Parasites

[Review the information in the workbook.]

FACTORS INFLUENCING DISINFECTION: 7 minutes

Now that we have discussed the purpose of disinfection, as well as some of the common contaminants found in drinking water, let's look at some of the factors that influence the disinfection process. As a treatment plant operator, it is important that you understand various factors that can influence the disinfection process. We will discuss several of these factors in this section.

Organisms

[Review the information in the workbook.]

Temperature and pH

[Review the information in the workbook. on temperature and pH.]

Disinfection Byproducts (DBPs)

Why more is not always better……

[Review the information in the workbook.]

It is preferable to apply chlorine after the clarification process because the reduced organic content creates less DBPs. Prior to implementing the desired disinfection process, it is valuable to test for the presence of disinfection byproduct precursors and determine the impact of the reaction with the disinfectant. Precursors include naturally occurring organics such as humic and fulvic acids that are present in surface water runoff. Naturally occurring organic matter (NOM) is difficult to quantify by specific compound. Instead, bulk indicators are usually used to quantify the total organics. This analysis is referred to as Total Organic Carbon (TOC), which includes particulate and dissolved organic species. Often, dissolved organic carbon (DOC) is measured to determine the organics in solution that will be most difficult to remove. Another indicator of organics that measures the potential to form disinfection byproducts is the Total Trihalomethane Formation Potential (TTHMFP). In this test, the water is spiked with high dose of chlorine and incubated for an extended period prior to analyzing for THM's. This test indicates the probable maximum THM that will form under worst case conditions.

Disinfection Demand

As we discussed with disinfection byproducts, many contaminants, organic and inorganic, in the source water may react with the disinfectant. Not only can this produce potentially hazardous materials, but it will also “consume” your disinfectant.

[Review the information in the workbook.]

Process Control

[Review the information in the workbook.]

Time

[Review the information in the workbook.]

DISINFECTION PROCESSES AND DESCRIPTIONS: 25 minutes

Now that we have reviewed the various factors that can influence disinfection, we will discuss the disinfection process itself in this next section.

Chemical Disinfection

There are a number of chemicals that can be used for disinfection, including gas chlorine, hypochlorite, chlorine dioxide, chloramines and ozone.

Gas Chlorine

[Review the information in the workbook.]

Advantages

[Review the information in the workbook.]

Disadvantages

[Review the information in the workbook.]

Hypochlorite

[Review the information in the workbook.]

Typically, for water treatment plant operations, it is provided in the liquid form called sodium hypochlorite. This chemical is similar to bleach. The calcium form is generally provided as a dry chemical; dissolved in water to form a solution, and typically used only in small treatment applications. This form of the chemical is typically used in small swimming pool applications. Hypochlorite in either form has similar disinfectant capabilities as liquid chlorine.

Advantages

[Review the first two bullet items in the workbook, and then share the following:]

Hypochlorite essentially is equivalent to a bottle of beach, but more concentrated. If the surface of the liquid is exposed in a room, it can off gas, and allow chlorine gas to be present in a room just as you can smell bleach when you place it into a washing machine but stronger. If concentrated enough it is harmful to life forms, and it is corrosive. Generally, it is not deadly. Liquid chlorine on the other hand, is contained in pressurized vessels, and when exposed to the atmosphere evaporates very rapidly and becomes a gas much like the references to gas warfare during world war one. This will react with mucous membranes and can be deadly.

[Review the remaining two bullet items in the workbook.]

Disadvantages

[Review only those disadvantages not covered in the script on the previous page.]

Chlorine Dioxide

[Review the information in the workbook.]

Advantages

[Review the information in the workbook.]

Disadvantages

[Review the information in the workbook.]

Chlorite and chlorate are generated both in the production of chlorine dioxide and by subsequent downstream reactions in the treated water. During production of chlorine dioxide, the ratio of chlorine and sodium chlorite is critical. Too much sodium chlorite will result in chlorite in the final product. Excess levels of chlorate in the sodium chlorite will result in the presence of chlorates in the final product. High or low pH can result in the generation of chlorate during the production of chlorine dioxide.

During downstream reactions, exposure of chlorine dioxide to sunlight may result in the production of chlorate and chlorite. Subsequent reactions with chlorine applied to water containing chlorine dioxide may result in the production of chlorate and chlorite also. The reaction of chlorine dioxide with both inorganic and organic materials may result in degradation to chlorate and chlorite.

Chloramines

Chloramines are formed by the reaction of chlorine with ammonia. The compound is quite stable and will remain in distribution systems for long periods of time. This assures that a disinfectant is available to maintain the sanitary quality of the water even in remote portions of the distribution system.

[Review the information in the workbook.]

Advantages

[Review the information in the workbook.]

Disadvantages

[Review the information in the workbook.]

Ozone

[Review the information in the workbook.]

Ozone is formed by passing an electrical current through a stream of gas containing oxygen. The oxygen is ionized to form ozone.

Advantages

[Review the information in the workbook.]

Disadvantages

[Review the information in the workbook.]

Irradiation

The final type of disinfection we will talk about is irradiation.

Ultra-violet Light

[Review information in the workbook.]

Advantages

[Review the first bullet item in the workbook and then share the following:]

An oocyst is a microorganism that has formed a shell around itself and gone into a dormant state. If ingested, and allowed to become active, they can infect a body.

[Review the remaining bullet items in the workbook.]

Disadvantages

[Review the information in the workbook.]

HISTORY OF DISINFECTION PROCEDURE: 3 minutes

Now that we have reviewed the various disinfection processes, we will briefly review the historical practices of chlorination in Europe and the United States.

Chlorination

Europe – Historical Practices

[Review the information in the workbook.]

United States – Historical Practices

[Review the information in the workbook.]

REGULATIONS: 15 minutes

Earlier, we discussed that one of the purposes of disinfection is to fulfill regulatory requirements. In this section, we will review some of the common regulations that are related to disinfection. We will start with the Surface Water Treatment Rule.

Surface Water Treatment Rule

[Review the information in the workbook.]

Information Collection Rule

Next is the Information Collection Rule.

[Review the information in the workbook.]

Interim Enhanced Surface Water Treatment Rule

The next regulation is the Interim Enhanced Surface Water Treatment Rule.

[Review the information in the workbook.]

Stage 1 (US EPA) Disinfectants and Disinfection Byproducts (D-DBP) rule

The fourth regulation is the Stage 1 Disinfectants and Disinfection Byproduct Rule.

[Review the information in the workbook.]

Long Term 1-Enhanced Surface Water Treatment Rule

The Long Term 1-Enhanced Surface Water Treatment Rule is next.

[Review the information in the workbook.]

Long Term 2-Enhanced Surface Water Treatment Rule

The next regulation is the Long Term 2-Enhanced Surface Water Treatment Rule.

[Review the information in the workbook.]

Stage 2-Disinfectants and Disinfection Byproduct Rule

Now let's learn about the Stage 2 Disinfectants and Disinfection Byproduct Rule.

[Review the information in the workbook.]

Ground Water

The Ground Water regulation is next.

[Review the information in the workbook.]

Total Coliform Rule

The final regulation is the Total Coliform Rule.

[Review the information in the workbook.]

Exercise

1. List the common bacteria, viruses and intestinal parasites that contaminate drinking water.

Ans: Common bacteria include: *Salmonella*, *Shigella*, *Bacillus Typhosus*, *Salmonella Paratyphi* and *Vibrio Cholerae*.

Common viruses include: enteroviruses, andenoviruses and reoviruses.

Common intestinal parasites include: *Entamoeba Histolytica, Giardia Lamblia, Ascaris Lumbricoides* and *Cryptosporidium*.

2. List five types of chemical disinfectants.

Ans: Liquid chlorine, hypochlorite, chlorine dioxide, chloramines and ozone.

3. Match the regulation from the following list with its appropriate description in the column on the right.

Information Collection Rule
Long Term 1-Enhanced Surface Water Treatment Rule
Ground Water
Stage 2 Disinfectant and Disinfection Byproduct Rule (DBP Stage 1)
Long Term 2-Enhanced Surface Water Treatment Rule
Interim Enhanced Surface Water Treatment Rule
Stage 1 Disinfectants and Disinfection Byproduct Rule (DBP Stage 2)
Total Coliform Rule
Surface Water Treatment Rule

Regulation	Purpose of Regulation
Ground Water Rule	This rule provides guidelines for identifying ground water sources at risk for contamination and guidelines for taking corrective action.
Interim Enhanced Surface Water Treatment Rule	This rule primarily addresses the reduction of risk from *Cryptosporidium* by limiting the turbidity levels of filter effluents.
Long Term 1-Enhanced Surface Water Treatment Rule	This rule requires all systems serving fewer than 10,000 people to achieve at least 99% removal or inactivation of *Cryptosporidium*.
Total Coliform Rule	This rule sets the monitoring and compliance requirements for coliform bacteria.
Information Collection Rule	It required large public water suppliers to undertake monitoring of microbial and disinfection byproducts in their water systems.
DBP Stage 1	This rule set maximum contaminant level goals and maximum contaminant levels for trihalomethanes, five haleocetic acids, bromate and chlorite.
Surface Water Treatment Rule	This rule required all surface waters or ground waters under the influence of surface waters to provide filtration and/or disinfection of the source to meet 3 log removal or inactivation of *Giardia Lamblia* cysts and 4 log removal or inactivation of enteric viruses.
Long Term 2-Enhanced Surface Water Treatment Rule	This rule is anticipated to propose treatment techniques to improve control of microbial pathogens, specifically including C*ryptosporidium*. The techniques are to consider the risks of treatment for *Cryptospodrium* versus the potential for generation of disinfection byproducts.
DBP Stage 2	The purpose of this rule is to assess information and research that was not fully considered in the Stage 1 process or that has only been available since 1998, as it relates to microbial standards to protect public health.

[Go over the key points for this unit]

[Point out the references that are listed on this page.]

We have now concluded the first unit of this module. You should be familiar with the purpose of disinfection, typical microbiological contaminants found in drinking water, factors that influence disinfection, various disinfection processes, the history of disinfection and the various regulations that impact disinfection. Are there any questions before we begin the second unit?

UNIT 2: 60 minutes

Display Slide 8—Unit 2: The Disinfection Process.

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

- Explain the importance of organic and inorganic oxidant demand.
- Define residual and explain why it is necessary to measure and monitor it.
- Identify and explain the points of application of the disinfection process.

[Display Slide 9—Unit 2: The Disinfection Process.]

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

- Identify chemical feed equipment used in the disinfection process.
- Identify ultra-violet equipment used in the disinfection process.
- Identify laboratory equipment used in monitoring the disinfection process.

DISINFECTANT APPLICATION: 20 minutes

In this unit, we are going to discuss how disinfectant is applied and about the equipment used for disinfection. We will start by talking about chlorine demand and then move on to chlorine residual.

Demand

[Review the definition of chlorine demand in the workbook.]

[Review the definition of free chlorine residual in the workbook.]

[Review the information in the workbook.]

Inorganic Demand

[Review the information in the workbook.]

Organic Demand

[Review the information in the workbook.]

Residual

For the next few minutes, we will learn about how chlorine residual is measured. Remember, for reporting purposes the method must be an approved Standard Method.

Measurement

[Review the information in the workbook.]

Iodometric

The first measurement method is the iodometric method.

[Review the information in the workbook.]

DPD Colorimetric

The second method of measurement is called DPD Colorimetric.

[Review the information in the workbook.]

Amperometric Titration

The third type of measurement is called amperometric titration.

[Review the information in the workbook.]

[Display Slide 10—Chlorine Residual Analyzer.]

This slide shows how a sample flows through a chlorine residual analyzer. If you take a look at the bottom left of the illustration, you will see the sample pump. From this point, you can follow the flow of the sample through the analyzer by following the arrows.

Oxidation-Reduction Potential Meter (ORP)

The last measurement method is the ORP, or Oxidation-Reduction Potential, meter.

[Review the information in the workbook.]

Monitoring

Now that we have completed our review of the various measurement methods, let's talk about monitoring the disinfection process.

[Review the information in the workbook.]

Table 2.1 in your workbook summarizes the microbial standards that must be met for three types of contaminants: total coliform, *giardia lamblia* and viruses. The table includes information regarding maximum contaminant levels, monitoring requirements and check sampling, reporting and public notice requirements.

The second column lists the maximum contaminant levels. For total coliform, the maximum contaminant level is based on the number of samples per month. If less than 40 samples per month are taken, then there can be no more than one positive. If 40 or more samples are taken, then no more than 5% can be positive. A 99.9% removal is required for *Giardia lamblia* and a 99.99% removal is required for viruses.

The third column explains the monitoring requirements for the various contaminants and the fourth column explains the check sampling, reporting and public notice requirements for each contaminant.

POINTS OF APPLICATION: 15 minutes

In this next section, we will cover the points of disinfection application for ground water and for surface water.

Ground Water

There are two points of application for ground water: spring house intakes and well pump discharges.

Spring House Intakes

[Review the information in the workbook.]

You will recall that we discussed baffled tanks previously in Unit 1. The baffles ensure that the time of flow through the vessel is lengthened and in contact with the disinfectant longer to maximize treatment.

Well Pump Discharge

[Review the information in the workbook.]

Surface Water

For surface waters, disinfectant can be applied pretreatment and post treatment. In terms of pretreatment, disinfectant is applied to raw water, mixed water and filter influent.

Pretreatment

Raw Water

[Review the information in the workbook.]

Mixed Water

[Review the information in the workbook.]

Filter Influent

[Review the information in the workbook.]

Post Treatment

During post treatment, disinfectant is applied at the filter effluent, clearwell influent, clearwell effluent and plant effluent.

Filter Effluent

[Review the information in the workbook.]

Clearwell Influent

[Review the information in the workbook.]

Clearwell Effluent

[Review the information in the workbook.]

Plant Effluent

[Review the information in the workbook.]

EQUIPMENT USED IN DISINFECTION PROCESS: 25 minutes

Now that we know where disinfectant is applied, let's talk about the equipment used during the disinfection process. First, we will discuss chemical feed equipment. Next, we will talk about ultra-violet light equipment and then we will discuss laboratory equipment.

Chemical Feed Equipment

In terms of chemical feed equipment, we will review gas regulators, chlorinators, eductors, feed pumps, on-site generators and ammoniators.

Gas Regulators

[Review the information in the workbook.]

[Display Slide 11—A Typical Gas Regulator.]

This slide shows a typical gas regulator. On the left, you will see the gas supply I just mentioned. The vacuum regulator is on the top, right of the graphic and at the bottom, you will see the supply vacuum.

Chlorinator

The next type of equipment is the chlorinator.

[Review the information in the workbook.]

[Display Slide 12—A Typical Gas Chlorinator.]

This slide shows an example of a typical gas chlorinator. The chlorinator itself is shown in the middle of this illustration. If you look on the left side, you will see the controller, which is wall mounted in this example. On the far right of this graphic, you will see a side view of the chlorinator.

Eductor

The eductor is the next type of feed equipment we will review.

[Review the information in the workbook.]

[Display Slide 13—A Typical Eductor.]

In this slide, you will see a typical eductor. At the bottom of this illustration, you can see the injector water and gas supply. As we just learned, these till mix and form a chlorine/gas solution. This solution is discharged at the area indicated on the top of the illustration.,

Feed Pumps

Feed pumps are another type of equipment used in disinfection.

[Review the information in the workbook.]

On-Site Generators

The next type of equipment we will cover is on-site generators.

[Review the information in the workbook.]

Let's take a look at some examples of on-site generators.

[Display Slide 14—A Chlorine Dioxide Generator.]

This slide is an example of a chlorine dioxide generator. The generator mixes a chlorine gas/water solution with a feed from a sodium chlorite supply in a reaction tank. The result of this reaction is the production of chlorine dioxide.

[Display Slide 15—An Ozone Generation System.]

This slide shows a schematic of an ozone generation system. In this system, ozone is produced by routing an oxygen supply through a generator where high voltages and current running through the gas supply produce ozone.

[Display Slide 16—A Sodium Hypochlorite Generator.]

This is a schematic of a sodium hypochlorite generator. In this system salt is run through an electrolyzer to produce sodium hypochlorite.

Ammoniators

The final piece of equipment we will cover is the ammoniator.

[Review the information in the workbook.]

Ultra-violet Light

Now that we have discussed various types of equipment used for chemical feeding, let's talk about some of the equipment used when ultra-violet light is used for disinfection.

[Review the information in the workbook.]

Low Pressure/Low Intensity

[Review the information in the workbook.]

Low Pressure/High Intensity

[Review the information in the workbook.]

Medium Pressure/High Intensity

[Review the information in the workbook.]

Laboratory

 In this final section, we will briefly review some of the laboratory equipment used in disinfection.

[Review the information in the workbook.]

Colorimeters

[Review the information in the workbook.]

Amperometric Titrators

[Review the information in the workbook.]

[*Go over the key points for Unit 2]*

[Point out that references are listed on this page.]

We have now completed the second unit of this module. You should have an understanding of disinfectant application, the points of application and the equipment used for disinfection. In our next unit, we will discuss contact time and how to perform contact time calculations.

UNIT 3: 30 minutes

[Display Slide 17—Unit 3: Contact Time Computations.]

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

- Define contact time.
- List five factors that impact contact time and explain how they impact it.
- Perform disinfection contact time computations.

CONTACT TIME COMPUTATIONS: 30 minutes

In this unit, we will discuss contact time – what it is, what influences contact time and how to compute contact time. Let's begin with a review of the definition of contact time.

Definition

[Review the defintion of contact time in the workbook.]

Factors Influencing Contact Time

Now let's turn our attention to some factors that influence contact time.

[Review the information in the workbook.]

Factors Influencing Contact Time

[Display Slide 18— The Relationship Between pH and Disinfection When Using Chlorine.]

This graphic demonstrates the relationship between the effectiveness of chlorine and pH. Chlorine is more effective (the % of HOCl is greater) at a lower pH.

[Review the information in the workbook.]

[Display Slide 19— The Relationship Between Temperature and Disinfection When Using Chlorine.]

[Review the information in the workbook.]

This graph is a representation of the relationship between temperature and disinfection with chlorine. Like the previous graph, the relative effectiveness of chlorine as a disinfectant is plotted on the y-axis, and it increases as we move from bottom to top. The temperature is plotted along the x-axis and it increases as we move from left to right. Based on this, you can see that as the temperature increases, the chlorine becomes more efficient as a disinfectant.

[Review the information in the workbook.]

[Display Slide 20—The Relationship Between Disinfection and Dosage.]

This graph represents the relationship between the dosage of disinfectant and the effectiveness of the disinfectant. Again, chlorine is used as the disinfectant in this graph and its effectiveness is plotted along the y-axis, with the effectiveness increasing as we move from the bottom of the axis towards the top of it. Along the x-axis is the dosage, which increases as you move from left to right. Based on this information, we can see that the effectiveness of chlorine as a disinfectant increases as the dosage of chlorine increases.

[Review the information in the workbook.]

[Display Slide 21—Chlorine Contact Basin.]

This slide shows an example of a chlorine contact basin. As we just mentioned, if the length to width ratio is greater than 25:1, the baffling efficiency should be 70% or more. In this example, the length is 75 feet, as indicated along the left side of the illustration. The width of each baffle is 15 feet. The flow path in the contact basin is serpentine, so the flow changes direction a total of six times; therefore, we need to multiply 6 times the length of 75 feet, which gives us a total length of 450. If we divide this by the width of 15 feet, we get a ratio of 30, which is greater than 25.

Disinfection Contact Time Computation

Now that we have learned about the various factors that influence disinfection, we will spend some time talking about contact time computations.

[Review the information in the workbook.]

On this page, you will find Table 3.1, which we just mentioned. This table shows the CT value required for inactivation of *Giardia* cysts by free chlorine for various conditions of pH, chlorine residual and desired Log inactivation at a water temperature of 10 degrees Centigrade. This is one of a series of Tables that can be used to establish the required CT for water at various temperatures. Additional tables for other temperatures and disinfectants can be found in the *EPA Guidance Manual for Disinfection Profiling and Benchmarking.*

Disinfection CT Computation

Let's review the contact time computation in your workbook.

[Review the information in the workbook.]

Now it's time for you to do a computation on your own. Read the information in your workbook and perform the computation, then we will review the answer.

What size clearwell is required to provide 3.0 log removal of Giardia if the flow rate through the water treatment plant is 3 million gallons per day, the pH is 7.0, the temperature of the water is 10° C and the chlorine residual is 2.0 mg/L? Assume that the clearwell baffling efficiency is 70%.

Ans: Consulting Table 3.1 indicates that the CT required under these conditions is 124 mg/L-minutes. Use the above equation to determine the storage required.

$$\text{CT (mg/L-minutes)} = \frac{\text{Capacity (Gallons)} \times \text{Baffling Efficiency (\%)} \times \text{Chlorine Residual (mg/L)}}{\text{Flow (gpm)}}$$

$$\text{Capacity (Gallons)} = \frac{\text{CT (mg/L-minutes)} \times \text{Flow (gpm)}}{\text{Baffling Efficiency (\%)} \times \text{Chlorine Residual (mg/L)}}$$

$$\text{Capacity (Gallons)} = \frac{124 \text{ (mg/L-minutes)} \times 2{,}082 \text{ (gpm)}}{0.70 \text{ (\%)} \times 2.0 \text{ (mg/L)}}$$

Capacity (Gallons) = 184,400 (Gallons)

We have now completed the third unit of this module. You should be able to define contact time and identify factors that impact it as well as perform contact time computations. Are there any questions before we move on to the final unit?

UNIT 4: 45 minutes

[Display Slide 22—Unit 4: Maintenance Issues.]

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

- Identify the residual maintenance issues that must be considered when protecting treated water.
- List and explain distribution system issues that must be considered when protecting treated water.
- Describe the disinfection procedure for each of the following:
  - Pipelines
  - Storage tanks
  - Water treatment plants
  - Wells
  - Distribution systems
- Explain the dechlorination process.

PROTECTION OF TREATED WATER: 5 minutes

We will begin this unit by discussing the protection of treated water. Specifically, we will cover residual maintenance and distribution system issues.

Residual Maintenance

[Review the information in the workbook.]

Distribution System Issues

Before we discuss disinfection procedures, we need to first discuss some distribution system issues related to pipes, tanks and rechlorination.

Pipes

[Review the information in the workbook.]

Tanks

[Review the information in the workbook.]

Rechlorination

[Review the information in the workbook.]

Distribution System

[Review the information in the workbook.]

Storage Tank

[Review the information in the workbook.]

FACILITY DISINFECTION PROCEDURES: 15 minutes

Now we will cover facility disinfection procedures as they related to pipelines, storage tanks, water treatment plants, wells and distribution systems

Pipelines

Now we will review the procedure for disinfecting pipelines.

[Review the information in the workbook.]

Storage Tanks

Now let's review the disinfection procedure for storage tanks.

[Review the information in the workbook.]

[Review the remaining bullet items in the workbook.]

Water Treatment Plants

For the next few minutes, we will highlight disinfection procedures for water treatment plants.

[Review the information in the workbook.]

Wells

Now let's discuss disinfection of wells – both new wells and existing wells.

New Well

[Review the information in the workbook.]

Existing Well

[Review the information in the workbook.]

Distribution Systems

The final disinfection procedure we will cover is disinfection of distribution systems.

[Review the information in the workbook.]

DISPOSAL OF CHLORINATED WATER: 25 minutes

In this section, we will cover the disposal of chlorinated water. Let's start with the definition of dechlorination.

Dechlorination

[Review the definition of dechlorination in the workbook.]

[Review the information in the workbook.]

Now that we know what dechlorination is, let's talk about some of the processes used to accomplish dechlorination. Dechlorination of water may be accomplished by various processes, including detention ponds, aeration, sunlight, activated carbon and chemical compounds.

Detention Ponds

[Review the information in the workbook.]

Aeration

[Review the information in the workbook.]

Sunlight

[Review the information in the workbook.]

Activated Carbon

[Review the information in the workbook.]

Chemical Compounds

[Review the information in the workbook.]

Sulfur Dioxide

Let's talk further about sulfur dioxide.

[Review the information in the workbook.]

Sulfur Dioxide Safety

As a result of its chemical nature, sulfur dioxide poses some safety concerns that water treatment plant operators should be aware of. Let's discuss some of those now.

[Review the information in the workbook.]

Dechlorination Control

Now that we have finished reviewing various dechlorination processes, let's talk about dechlorination control.

[Review the information in the workbook.]

Safety

For the remaining portion of this unit, we will review some safety concerns that should be considered when disposing of chlorinated water.

[Review the information in the workbook.]

Emergency Safety Equipment

[Review the information in the workbook.]

Additional Equipment

[Review the information in the workbook.]

Exercise

1. Maintenance of residual levels of 0.2 mg/L at the end of a distribution system is a good indication that the system is disinfected.

Ans: True

2. Water mains taken out of service for inspection or repair do not need to be disinfected prior to being placed back in service.

Ans: False

3. All new water treatment plants, rehabilitated portions of existing plants, facilities that have been taken out of service for maintenance or in general, facilities that are subject to contamination, shall be disinfected prior to placing into service.

Ans: True

4. What is dechlorination?

Ans: It is the physical or chemical removal of chlorine residual from water prior to its discharge to receiving streams. This includes both free and combined residuals

5. List five methods of dechlorination.

Ans: Detention ponds, aeration, sunlight, activated carbon and chemical compounds.

[*Review the key points for Unit 4]*

We have now completed this module. You should be familiar with the purpose of disinfection, the various disinfection processes and the regulatory requirements related to disinfection. You should also understand how and where disinfectant is applied, equipment used in the disinfection process, computations that are performed related to disinfection and maintenance issues related to disinfection. Are there any additional questions about this module that I can answer for you?