# Wastewater Treatment Plant Operator Certification Training
# Instructor Guide

# Module 5:
# Disinfection and Chlorination

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 this course, *Disinfection and Chlorination*, is to provide an overview of the disinfection process in wastewater treatment. This module has been designed to be completed in approximately 3 hours but the actual course length will depend upon content and delivery modifications and results of course dry runs performed by the approved DEP 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 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
- Quizzes

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

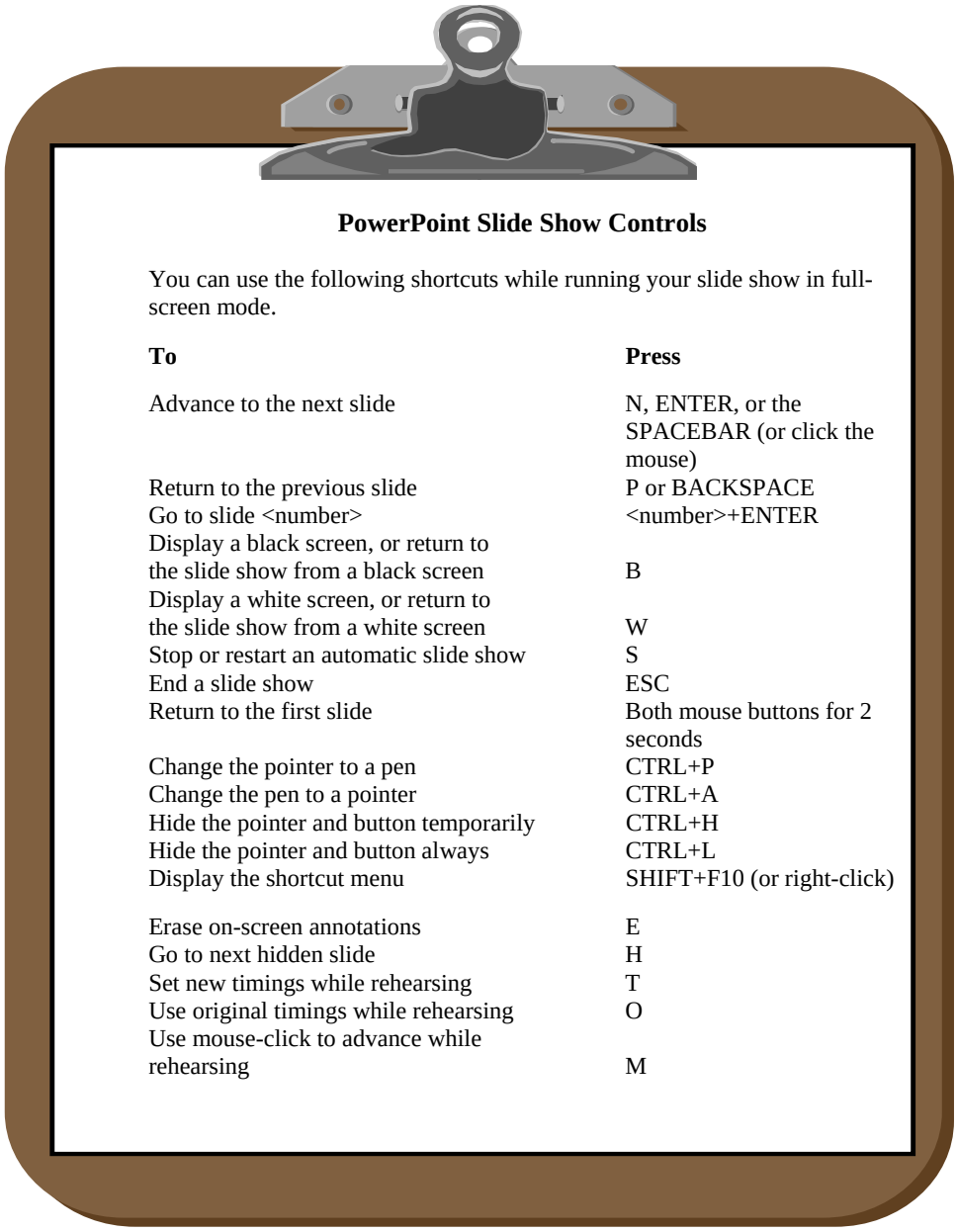
Icons to become familiar with include:

| 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 |
|  | Unit 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 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.

*[Welcome participants to "Module 5: Disinfection and Chlorination."*
*Indicate the primary purpose of this course is to provide participants with an introduction to basic concepts of disinfection of wastewater through chlorination and ultraviolet (UV) processes.]*

*[Introduce yourself.]*

*[Ask the participants to introduce themselves.]*

As treatment plant operators, it is necessary for you to be familiar with the entire disinfection process:

- What chemicals are used for disinfection purposes.
- How the chemical feed is controlled.
- How the chemicals are handled safely.
- What type of equipment is used and how it is maintained.
- How the effluent is dechlorinated before being released into a stream.
- How we keep ourselves and others safe while handling chlorine and its by-products.

The following outline will show you the topics we will cover in the next 3 hours.

*[Review the Topical Outline for Units 1 and 2.]*

*[Finishing reviewing the Topical Outline for Unit 2 and review the Topical Outline for Units 3 and 4.]*

*[Review the Topical Outline for Units 5 and 6.]*

UNIT 1: 55 minutes

Display Slide 2

Let's first talk about the basic principles of disinfection and chlorination. At the end of this unit, you should be able to:

*[Review the Learning Objectives for Unit 1.]*

PURPOSES OF DISINFECTION: 5 minutes

Why do we need to disinfect wastewater? Homes, hospitals and industrial facilities all discharge liquid and solid waste materials into a community's wastewater collection system. In addition to waste, the discharge may also contain disease-causing microorganisms including bacteria, viruses and parasites. Ultimately, these flow to the wastewater treatment system where they are removed or disinfected prior to the final discharge of the wastewater into the environment.

We will begin this unit by covering the definitions of disinfection and pathogenic organisms.

## Basic Principles

Review the definitions for Disinfection and Pathogenic Organisms in the workbook.

## Common Pathogenic Illnesses

Pathogenic (disease-causing) organisms in wastewater can cause the following types of illnesses.

*[Review the Common Pathogenic Illnesses section in the workbook.]*

## Pathogen Removal

*[Review the Pathogen Removal section in the participant workbook.]*

What processes in wastewater treatment serve to remove pathogens?

Ans: See Table at top of page 1-3.

*[Complete the review of pathogen removal begun on page 1-2. Go over the various treatment processes table, on the top of page 1-3.]*

As you can see, chlorination as a disinfection process is the best one for pathogen removal. The next unit will get into the details of chlorination. However, there are other disinfection treatment processes:

*[Review Other Disinfection Treatment Processes, as stated on page 1-3. Include the following information in your discussion:*

- *All wastewater treatment plants use at least some of the physical and biological treatment processes described in addition to chlorination or UV radiation. The physical removal processes (screening, grit removal, etc.) are used first to remove large and fine materials from the wastewater. Others are used for biological and other contaminant removal. Chlorination or UV radiation is used as the final step for pathogen disinfection.*
- *Of these, we will cover ultraviolet light in unit 6.]*

We are now going to move onto a more detailed description of chlorination. Please turn to the next page in the workbook.

DISINFECTANTS AND CHEMISTRY: 10 minutes

## Chlorination

*[Review the Chlorination section in the participant workbook.]*

Let's go over each one of the forms of chlorine in more detail.

### Elemental Chlorine ($Cl_2$)

*[Review Elemental Chlorine. Point out that this is the most common form of chlorine used in disinfection because it is:*

- *The most concentrated form of chlorine (100% chlorine)*
- *Easy to use*
- *Relatively safe*
- *Economical]*

Display Slide 3

*[Review the Chemistry section of Elemental Chlorine ($Cl_2$).]*

*[Continue with the rest of the Elemental Chlorine information on this page.]*

Hypochlorite (OCl-)

Chlorine in some plants is provided by the use of hypochlorite compounds.

*[Review Sodium Hypochlorite in the participant workbook. This form of chlorine is also a concentrated form of what is commonly known as bleach.]*

Display Slide 4

*[Review the Chemistry section of Sodium Hypochlorite.]*

*[Review Calcium Hypochlorite in the participant workbook. Point out that Calcium Hypochlorite comes in powder form.]*

Display Slide 5

*[Review the Chemistry section of Calcium Hypochlorite.]*

Hypochlorites are less efficient than chlorine gas/liquid. They are a less concentrated form of chlorine and per pound of available chlorine are more expensive. Hypochlorites also cost more to ship because of the additional quantities that are needed. The primary benefit to the system comes from the increased safety of this form of chemical. However, it is safer because elemental chlorine (in its gas form) runs the risk of a chlorine leak which is hard to contain and deadly.

## Chlorine Dioxide ($ClO_2$)

*[Review the Chlorine Dioxide ($ClO_2$) section in the participant workbook.]*

Display Slide 6

*[Review the Chemistry section of Chlorine Dioxide ($ClO_2$).]*

Chlorine dioxide is not as reactive as chlorine and chlorine is a better oxidant. In waters with a pH above 8.5, chlorine dioxide is more effective than other forms of chlorine as a disinfectant. It is also used to preclude the generation of trihalomethanes that could be generated when the wastewater is treated with chlorine. Trihalomethanes are a form of chemical that has been found to be carcinogenic, therefore dangerous to release into a drinking water supply system.

Ask participants what forms of chlorine they have used in their treatment plants.

The next section discusses chlorine demand and residual.

*[Ask participants to turn the page.]*

CHLORINE REQUIREMENTS: 35 minutes

## Chlorine Demand

Review the definition of Chlorine Demand in the participant workbook.

*[Review the Chlorine Demand section in the workbook. Point out:*

- *Hydrogen sulfide is among the most common inorganic materials which will react with chlorine. The hydrogen sulfide is made odorless and oxidized to form either sulfuric acid or elemental sulfur depending upon the concentration in the wastewater and its pH.*
- *Of these combined forms of chlorine, the mono and di form of chloramine are useful in disinfection.]*

## Chlorine Residual

Review the definition of Chlorine Residual in the participant workbook.

*[Review the Chlorine Residual section in the participant workbook.]*

Once you know chlorine demand and residual, you can figure out the dosage
Chlorine Demand = Chlorine Dose – Chlorine Residual

## Establishing Dosages

*[Review the Establishing Dosages section in the workbook.]*

Lead the participants through Example 1.1 to determine the chlorine dosage and chlorine demand, as outlined in the participant workbook. Use a flip chart if necessary.

## Breakpoint Chlorination

This section describes the chlorination process that produces free chlorine.

Review the definition of Breakpoint Chlorination in the participant workbook.

Display Slide 7 – Breakpoint chlorination curve (Figure 1.1 of participant workbook)

*[Review Figure 1.1, Breakpoint Chlorination Curve.]*

The initial demand reflects the reaction of inorganics with chlorine. Since totally combined, this form is not available for disinfection. The second portion of the graph reflects the reaction with ammonia and formation of chloramines. The third portion of the graph is the reaction with other organic compounds and the formation of chloroganic compounds. The last portion of the graph represents the combined residual, plus the surplus chlorine, free chlorine applied over and above that required for the previous reactions.

Any questions?

The chlorine residual is used to disinfect the wastewater from pathogens. If this isn't done properly, there won't be optimal pathogen kill. The following section describes factors influencing disinfection.

Factors Influencing Disinfection

Review the first bullet in the participant workbook.

The operator must provide the addition of chlorine upstream ahead of the contact basin at a point where adequate mixing takes place in order to have effective disinfection of pathogens. This is generally at a point of high velocity in the flow stream. Sometimes mechanical mixers are also provided.

Display Slide 8 – Typical layout, contact basin (Figure 1.2 of participant workbook). Review the chlorine contact basin section in the workbook. Include the following information:

- A contact basin is like a holding tank which allows the chlorine to react with the water. It provides an adequate detention time for the chlorine to react with pathogens.

Display Slide 9 – Relative effectiveness vs. pH (Figure 1.3 of participant workbook)

Lower pH will result in more efficient use of chlorine as a disinfectant. To optimize the process, the operator would want to apply a disinfectant when the pH is low, then raise the pH to meet discharge standards (between 6 - 9), if necessary.

Deleted: 8

Display Slide 10 – Relative effectiveness vs. temperature (Figure 1.4 of participant workbook)

Higher temperature will result in more efficient disinfection. Although you can't control the temperature of the water, you can control the chlorine dosage—in winter a higher application of chlorine is required than in summer to get the same amount of disinfection.

Display Slide 11 – Relative effectiveness vs. dosage (Figure 1.5 of participant workbook)

Higher dosages of disinfectant will result in more rapid disinfection. However, by maintaining a residual at the end of your process, you have met the disinfection requirements. If there is no residual, you have to increase your dosage. If your residual is too high, you pay for the excessive chlorine, and you will have to dechlorinate more (there is no danger in having a high residual chlorine unless you discharge water that has not been dechlorinated into the receiving stream).

Display Slide 12 – Relative effectiveness vs. contact time (Figure 1.6 of participant workbook)

Longer detention time will result in a higher degree of disinfection and chlorine dosages may be reduced, as long as a residual is maintained at the end of the process. Contact basins are designed to provide 30 minute detention times at average monthly flow and 15 minutes at peak hourly flow. If these conditions cannot be met, additional basins should be activated to increase the detention time to meet the minimum requirements for disinfection purposes.

*[Review the types of organisms to be treated in the participant workbook. Point out that cysts and spores may be resistant and difficult to treat. If treatment is required, additional detention time may be effective, or alternative processes may be required such as ultraviolet radiation.]*

APPLICATION POINT: 5 minutes

*[Review the various application points as described in the participant workbook.]*

Alternative chlorination points are established based upon treatment goals established during design, or subsequently added to a system. These may be added to reduce septicity, control odor, reduce BOD, protect structures, aid in settling, foam control, oil removal, sludge bulking, algae and biological growths, etc. However, the most common usage is for plant effluent disinfection.

Any questions?

*[Review the Key Points for Unit 1 – Disinfection and Chlorination Principles.]*

Exercise for Unit 1 – Disinfection and Chlorination Principles

1. Disinfection is the process designed to __kill___ or ___inactivate_____ most microorganisms in wastewater including essentially all pathogenic organisms.

2. Pathogenic organisms consist of ___bacteria__, ___viruses___, or __cysts__ that can cause disease in a host.

3. List three physical processes used in wastewater treatment that are useful in removing some of the microorganisms.
   a. screening
   b. Grit removal
   c. Primary sedimentation

4. The most commonly used disinfection process for wastewater treatment is:
   a. Ultraviolet light
   b. Ozonation
   c. Chlorination
   d. Sterilization

5. Chlorine and its various forms are powerful oxidants that will kill or inactivate most pathogenic organisms that are harmful to human and animal life. Typical forms of chlorine used in wastewater treatment are:
   a. Elemental chlorine
   b. Hypochlorite
   c. Chlorine dioxide
   d. All of the above

6. Calculate the chlorine dosage required if it is desired to have a chlorine residual of 0.5 mg/l and the chlorine demand is 6.0 mg/l.

Chlorine dosage = Chlorine demand + Chlorine Residual

Chlorine dosage = 6.0 mg/l + 0.5 mg/l = 6.5 mg/l

7. Baffling is used in chlorine contact chambers to aid in mixing and to prevent Short-circuiting.

8. Chlorine is widely used as a disinfectant in wastewater treatment, but it can also be used to:
   a. Control odor
   b. Reduce BOD
   c. Control foaming
   d. Aid in sludge thickening
   e. All of the above

Let's move on to how we go about controlling the chlorine feed to be sure we're applying the proper dosage.

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

UNIT 2 – CHLORINATION PROCESS CONTROL: 25 minutes

Display Slide 13

This unit covers the importance of controlling the chlorination process. It is important to feed enough chlorine to kill the appropriate pathogens, but not an excessive amount that the chlorine is wasted.

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

*[Review the Learning Objectives for Unit 2.]*

CHLORINATOR CONTROL MODES: 10 minutes

Application of chlorine should be accomplished under controlled conditions to assure proper dosing of the wastewater. In the following section, we will be discussing common chlorine application control modes.

Manual

*[Review the information provided at the top of page 2-2 in the participant workbook.]*

Display Slide 14 – Manual Control (Figure 2.1 of participant workbook).

Figure 2.1 represents a chlorine feed system operating continuously at a fixed feed rate. The feed rate was set and the system turned on manually by the operator. The system will continue to operate in this manner until it is turned off manually.

*[Review the Manual section in the participant workbook.]*

Start-Stop

Display Slide 15 – Start Stop Control (Figure 2.2 of participant workbook)

Figure 2.2 represents a chlorine feed system that is turned on and off in response to another process within the system which starts and stops intermittently. When the process is on, the chlorination system is on, and conversely, when the process is off the chlorination system is off.

*[Review the Start-Stop section in the participant workbook.]*

## Step-Rate Control

Display Slide 16 – Step Rate Control (Figure 2.3 of participant workbook)

Figure 2.3 represents a chlorine feed system that increases or decreases the feed rate in response to incremental increases or decreases in the process flow. This could be a system that is as simple as turning on and off a process, to one that is more complex and involves incremental increases and decreases in process flow.

*[Review the Step-Rate Control section in the participant workbook.]*

Timed-Program Control

Display Slide 17 – Timed Program Control (Figure 2.4 of participant workbook)

Figure 2.4 represents a chlorine feed system that is set to predict or mimic the daily flow cycle through the system. This may be accomplished through the use of a step timer, or a cam that has been preset to mimic the cycle. In its simplest form, the system would parallel the timed start and stop cycle of a lift station.

*[Review the typical applications in the participant workbook.]*

## Flow-Proportional Control

Display Slide 18 – Flow Proportional Control (Figure 2.5 of participant workbook)

Figure 2.5 represents a chlorine feed system that is controlled directly via a signal that is generated by a flow meter that is proportional to flow. Pump stations that use a variable speed drive to change flow through a lift station could pace a chlorination system that would receive a signal from the metered pumped discharge that is proportional to flow.

*[Review the Flow-Proportional Control section in the participant workbook.]*

## Chlorine Residual Control

*[Review the Chlorine Residual Control section in the participant workbook. Include the following information in your discussion:*

- *In this mode a chlorine feed device is set to apply a chlorine feed rate to the wastewater so that it will maintain a residual at the end of the process within a fixed band. A chlorine analyzer is used to determine the residual at the end of the process. If the residual falls out of the fixed band, a predetermined corrective adjustment is made to the feed rate to bring the residual back into the band. These corrections are made on a timed cycle until the residual is brought back into the band. If the residual is low, the feed rate is incrementally increased, if the residual is high, the feed rate is incrementally decreased.]*

## Compound Loop Control

*[Review the Compound Loop Control section in the participant workbook. Include the following information in your discussion:*

- *In this mode the system monitors both flow and chlorine residual and computes the appropriate feed rate to apply to the wastewater. Residual is again monitored and compared to the desired set point. However, since both parameters (flow and residual) are now being monitored, a controller can be programmed to take into account the system variables and make minor adjustments to the feed rate to bring the residual back to the set point very accurately, and not just within a wide band.]*

At this time we've gone from the most simplistic and economical control mode to one that is the most sophisticated, expensive, and accurate. The compound loop control mode is the least wasteful because it maintains a relatively constant chlorine residual without overfeeding. However, the other systems are more economical.

What kind of control system do you have?

What have been your experiences in optimizing chlorine feed rate?

Do you think you might save chemical costs by optimizing the dosage?

Ans: Depends on size of the plant: the smaller the plant, the less likely it is that you would recoup the cost of the compound loop control system.

MEASUREMENT OF CHLORINE RESIDUAL: 5 minutes

Measurement of Chlorine Residual

Chlorine is monitored by means of a chlorine residual analyzer. If a residual is not measured, it will require an increase in dosage.

*[Review the top portion of the Measurement of Chlorine Residual section in the participant workbook.]*

Review the Iodometric method of measuring the chlorine residual on page 2-8 of participant workbook.

This method is more accurate than colorimetric methods for high chlorine residuals, but is less accurate at lower chlorine concentrations. This method can be used for measuring samples containing wastewater, such as plant effluent. However, interferences from nitrites, ferric iron, and oxidized manganese can be considerable and the titration end point is not distinct.

Review the DPD Titrimetric method of measuring the chlorine residual, at the bottom of page 2-8 of participant workbook.

Display Slide 19 – Chlorine residual analyzer (Figure 2.6 of participant workbook).

Review the Amperometric Titration method of measuring the chlorine residual in the participant workbook.

The method should be used with treated wastewater to minimize interferences. Precautions need to be taken to minimize the loss of chlorine by volatilization. Nevertheless, with the proper titration protocol, this method is considered the best of the three and allows for testing of both free and combined chlorine residual with repeatable results. However, at levels below 0.2 mg/l, it does not distinguish between the free and combined forms.

Amperometric titration provides the most convenient and the most repeatable results; however the equipment costs more than the equipment for the other methods.

Review the Oxidation-Reduction Potential meter (ORP) methods of measuring the chlorine residual in the participant workbook.

Any questions?

USE OF CHLORINATION CONTROL NOMOGRAPH: 10 minutes

Chlorination Control Nomograph

A chlorinator is part of the chlorine feed system, which will be discussed in more detail in Unit 4. This section describes a tool used to determine the setting of the chlorinator in lbs/day.

Display Slide 20 – Chlorination control nomograph (Figure 2.7 of participant workbook)

*[Review the Chlorination Control Nomograph section in the participant workbook. Include the following information in your discussion:*

- *With this knowledge and a known flow through the wastewater plant, an operator can determine the setting of the chlorinator in lbs/day using the Chlorination Control Nomograph. After monitoring the residual, a manual adjustment may have to be made in order to increase or decrease the feed rate. If the residual is too low it will not be effective in the disinfection of pathogens. If it is too high, it will be wasteful both in the cost of extra chlorine and the usage of the dechlorination agent. Note that when performing bench scale testing of the chlorine demand, it does not take into account the loss of chlorine that takes place in a basin due to normal dissipation into the atmosphere or reaction with sunlight. Adjustments may have to be made to account for this.]*

*[Review the top of page 2-11 in the participant workbook.]*

Example Problems

Work through problem 2.1 together as a class. If lighting permits, use the flipchart as needed to demonstrate the calculations. Use a laser pointer if necessary when pointing to the graph in Slide 15.

*[Review the Key Points for Unit 2 – Chlorination Process Control]*

Exercise for Unit 2 – Chlorination Process Control

1. The most commonly used mode of control in a chlorine feed system is the:
    a. Flow proportional
    b. Step-rate
    c. Time-program
    d. Manual control
    e. Chlorine residual control

2. By using a Chlorination Control Nomograph like the one in this workbook, an operator can determine the setting of a chlorinator in units of
    a. Kg/gallon
    b. Mg/ft
    c. Lbs/day
    d. Lbs/metric tonne

3. Measurement of chlorine residual at a wastewater plant can be determined by the use of which of the following methods:
    a. ORP
    b. Amperometric Titration
    c. DPD Titrimetric
    d. Iodometric
    e. All of the above

4. If the flow thru the wastewater plant is 4.5 mgd and the chlorine dosage is 2.5 mg/l, determine the chlorinator setting in lbs/d. Review of the nomograph scale indicates that it only spans from a flow of 0 to 1.0 mgd. To allow for a flow greater than this multiply both the flow and chlorine feed rate scales by a factor of 10. These two scales now represent a flow of 0 to 10 mgd, and a chlorine feed rate of 0 to 100 lbs/d. Following the same procedures as outlined earlier in this unit, find the chlorine feed rate in lbs/day.

93.8 lbs/day

5. If the chlorine feed rate is 3.5 lbs/d, and the flow through the wastewater plant is 700,000 gallons per day, determine the dosage by using the nomograph.

0.6 mg/l

*[There is no need to talk about the references on this page.]*

So far we've talked about disinfection chemicals and how to measure them. Now let's talk about safety.

UNIT 3 – CHLORINE SAFETY AND HANDLING: 15 minutes

Display Slide 21

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

*[Review the Learning Objectives for Unit 3.]*

SAFETY PROGRAM: 5 minutes

Chlorine Hazards

*[Review the information provided at the top of page 3-2 in the participant workbook. Point out that operators are more susceptible to chlorine hazards when changing cylinders. They should follow standard operating procedures when changing out containers to minimize the risk of exposure.]*

Display Slide 22 - Physiological response to concentrations of chlorine gas (Figure 3.1 of participant workbook)

Figure 3.1 presents the physiological effects on human life after being exposed to various chlorine concentrations for set time periods.

## Personnel Safety and Protection

Every good safety program begins with the cooperation between employer and operator. Everyone needs to take the safe handling of disinfection products seriously. The operator must be responsible and take all necessary steps to prevent accidents. The employer must take an active part by supporting safety programs.

*[Review the Personnel Safety and Protection section in the participant workbook.]*

Have participants describe their own emergency scenarios.

First Aid

Remember, chlorine exposure does happen from time to time around chlorination equipment, so the following first aid procedures should be kept handy for the eventuality of such a case.

*[Review the First Aid section in the participant workbook.]*

Have participants describe any real life scenarios where they had to provide or receive first aid.

CHLORINE HANDLING: 5 minutes

Let's move on to how chlorine is handled.

## Chlorine Containers

Display Slide 23 – Cylinder (Figure 3.2 of participant workbook)

*[Review the cylinders information in the participant workbook. Use Figure 3.2 to illustrate.]*

*[Continue reviewing the cylinder information.]*

Display Slide 24 – Ton container (Figure 3.3 of participant workbook)

*[Review the ton containers information in the participant workbook. Use Figure 3.3 to illustrate. Include the following information in your discussion:*

*Cylinders are delivered on flat bed trucks and the operator uses a hoist and lifting device to move the cylinder into the storage room and set it into place. Prior to using it, the valve protection hood is removed (this is provided in case anyone bangs into the container and knocks the valve off), and the cylinder is rotated so that the two withdraw valves are at the 12:00 o'clock and 6:00 o'clock positions. An operator would then decide whether he wants to remove the chlorine in the gas or liquid phase prior to hooking up the valve. There are six fusible plugs that serve as safety relief devices to relieve the pressure inside the container.]*

*[Continue reviewing the ton container information.]*

*[Review the tank cars information in the participant workbook.]*

Display Slide 25 – Excess flow valve (Figure 3.4 of participant workbook). Include the following information in your discussion:

- If there is a high velocity of chlorine (gas or liquid) caused by a leak, the excess flow valve will cause a weighted float to rise, which will stop the release of chlorine to the tank car.

CHLORINE LEAKS AND RESPONSE: 5 minutes

## Chlorine Leaks

Let's turn to page 3-8 of the workbook. This section describes how to respond to chlorine leaks.

Chlorine leaks must be taken care of immediately or they will become worse. Corrective measures should be undertaken only by trained operators wearing proper safety equipment. All other personnel should leave the danger area until conditions are safe again.

*[Review the Chlorine Leaks section in the participant workbook.]*

## Response

*[Review the Response section in the participant workbook.]*

Display Slide 26 – Chlorine repair kit (Figure 3.5 of participant workbook)

*[Continue to review the Response section in the participant workbook.]*

Display Slide 27 – Chlorine scrubber (Figure 3.6 of participant workbook)

Figure 3.6 presents a photo of a typical chlorine scrubber that utilizes a dry media as the scrubbing medium. In the event of a chlorine leak, sensors that monitor the chlorine storage room send a signal to the scrubber control. This will start a fan that withdraws chlorine from the storage room and runs it through media (e.g., a dry chemical), which removes the chlorine and discharges clean air.

For systems with a Risk Management Plan it is important to follow the plan and provide all follow-up documentation that may be necessary in the event of a release.

*[Review the Key Points for Unit 3 – Chlorine Safety and Handling.]*

Exercise for Unit 3 – Chlorine Safety and Handling

1. Chlorine is hazardous and when combined with moisture (including body moisture) it becomes extremely acidic and corrosive.
    a. True
    b. False

2. Any facility that uses chlorine should have a written __safety__ program that is well documented and distributed to all operators.

3. Facilities that store more than 2,500 pounds of chlorine must also have a Risk Management Plan on hand.

4. Chlorine cylinders come in sizes to hold 100 and 150 pounds of chlorine. The cylinders have a shut off valve, a protective cap, and a fusible plug that is designed to fail and leak chlorine to the atmosphere if the temperature rises to a range of __158__ to __165__ degrees Fahrenheit.

5. Ton containers of chlorine should be stored on their sides with the two valves in the __6__ and the ___12_ o'clock position to assure that one valve will release chlorine gas and the other valve will release liquid chlorine.

6. Only trained personnel should respond to a chlorine leak. All others should leave the area until conditions are once again safe.
    a. True
    b. False

7. The largest container that is used to transport chlorine is a railroad tank car.

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

The next unit will describe the equipment used to feed chlorine into the wastewater. It will also discuss troubleshooting the equipment if anything goes wrong.

UNIT 4 – CHLORINATION EQUIPMENT AND MAINTENANCE: 50 minutes

Display Slide 28

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

*[Review the Learning Objectives for Unit 4.]*

GAS FEED SYSTEM: 40 minutes

As mentioned in Unit 1, gas is the most common form of chlorine used in the disinfection process. This unit will discuss the chlorine gas feed system and alternative feed systems.

## Equipment

*[Review the top paragraph of the Equipment section in the participant workbook.]*

Display Slide 29 – Gas feed system (Figure 4.1 of participant workbook)

*[Review the major components of the feed system. Use Figure 4.1 to illustrate the system. The components described in the workbook flow approximately from left to right on Figure 4.1.]*

*[When discussing the "Cylinders or containers" section in the workbook, point out that the numbers used are approximations—the exact values vary due to temperature.]*

*[Continue to review the components of the feed system in the participant workbook. Use Figure 4.1 to illustrate the system.]*

*[Continue to review the components of the feed system in the participant workbook. Use Figure 4.1 to illustrate the system.]*

*[Continue to review the components of the feed system in the participant workbook. Use Figure 4.1 to illustrate the system.]*

Display Slide 30 – Evaporator (Figure 4.2 of participant workbook)

[*Review the evaporator section, in the participant workbook. Use Figure 4.2 to illustrate the system. Include the following information in your discussion:]*

- *[The evaporator is much like a double boiler. There are two containers—the outer container contains water and an electric immersion heater to warm the water. The inner container holds the liquid chlorine. The heated water then transfers heat through the internal jacket to the inner container to heat the liquid chlorine. The heated chlorine then boils and is converted into a gas. The gas is fed through chlorinators to the feed point.]*

- *[The use of an evaporator is limited to plants that require high rates of flow from the chlorine supply system and is generally used with multiple chlorine ton containers or tank cars. This equipment is not normally provided at smaller wastewater plants, but is generally found at larger facilities.]*

Any questions?

Normal operation and maintenance of the gas feed system requires regular observation of facilities and a regular preventative maintenance program. Corrective action must be taken immediately when abnormal conditions occur.

## Operation

*[Review the operation section in the participant workbook.]*

## Maintenance

*[Review the maintenance section in the participant workbook.]*

Maintenance of the chlorine system is very important. If you, as an operator, cannot perform the maintenance due to time constraints, an outside company should be hired to perform the maintenance following the manufacturer's requirements.

Have any of you had any component of the feed system fail? What happened? How was it addressed?

HYPOCHLORINATOR: 5 minutes

The next section discusses a sodium hypochlorite chlorination system. The useful chlorine concentration in hypochlorite compounds is lower than the concentration in pure gaseous or liquid chlorine, so therefore more expensive to use. However, the safety, storage, and application equipment costs can be much lower in smaller plants and so hypochlorite use is often cost effective when all costs are considered.

Equipment

Display Slide 31 – Sodium hypochlorite feed system (Figure 4.3 of participant workbook)

*[Review the Equipment section in the participant workbook. Use Figure 4.3 to illustrate the system. The items in the workbook can be found in the diagram.]*

*[Review the remainder of the hypochlorinator section on page 4-9. Use Figure 4.3 to illustrate the system.]*

Hypochlorite Generator

Display Slide 32 – Hypochlorite generator (Figure 4.4 of participant workbook). Review the Hypochlorite Generator section in the participant workbook. Include the following information:

- *[Hypochlorite is manufactured from a salt water solution. A brine solution (salt and water) is run through an electrolytic process, which converts salt into sodium hypochlorite and a by-product, hydrogen gas, which is discharged into the atmosphere. The manufactured hypochlorite is stored in a vented tank for use by metering pumps to be transferred to the point of application.]*

- *[Point out that the hypochlorite generator may require a water softener to avoid the adverse impacts of hardness on the equipment. Hard water can cause scaling in the hypochlorite generator, which will reduce the efficiency, or foul the process. If scaling does occur the best way to remove these calcium deposits from a feed pump is to use an acid solution to dissolve the calcium deposits.]*

Any questions?

CHLORINE DIOXIDE FACILITY: 5 minutes

The next section discusses another type of chlorination feed system.

## Chlorine Dioxide Generators

*[Review the top of page 4-11.]*

Display Slide 33 – Chlorine dioxide facility (Figure 4.5 of participant workbook)

*[Discuss the first system (instream blending system) used to generate chlorine dioxide. Use Figure 4.5 to demonstrate the system.]*

*[Discuss the remainder of the chlorine dioxide facility information in the participant workbook.]*

*[Discuss the Key Points for Unit 4 – Chlorination Equipment and Maintenance.]*

Exercise for Unit 4 – Chlorination Equipment and Maintenance

1. The chlorine residual is too high in the plant effluent. The probable causes may include:
    a. The organic strength of the wastewater influent has decreased.
    b. The flow through the treatment plant has changed.
    c. The test equipment used to check chlorine residual needs to be calibrated.
    d. All of the above.

2. Low chlorine gas pressure at the chlorinator is suspected to be due to a depleted chlorine container. The best course of action would be to:
    a. Clean the filter.
    b. Switch to a full chlorine container.
    c. Add baffles to the chamber.
    d. Increase the influent flow.

3. A safety concern with the use of sodium chlorite in a wastewater facility is that it is combustible in the presence of organic compounds.
    a. True ____X_____
    b. False _____

4. Day tanks are designed to hold what amount of a chemical compound?
    a. One day.
    b. One week.
    c. One month
    d. Five days.

5. List five major components of a chlorine feed system.

    Answers may vary and may include: cylinders, manual isolation valves, regulating valves, automatic switchover system, drip leg and heater, pressure gauges, chlorinator, expansion tanks, injector, solution tube, piping systems, and evaporators.

6. It is very important to have a detailed maintenance program that is performed on a routine basis. List five items that should be part of a gas feed chlorination maintenance plan.

    Answers may vary. See page 4-7 of the participant workbook for a list of items suggested for a maintenance plan.

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

The next unit describes the dechlorination process, why it is needed, and how it is conducted.

UNIT 5 – DECHLORINATION: 15 minutes

Display Slide 34

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

*[Review the Learning Objectives for Unit 5.]*

BASIC PRINCIPLES: 5 minutes

This unit describes how to remove chlorine (residual) from water.

Dechlorination is the physical or chemical removal of chlorine residual from the plant effluent prior to its discharge to receiving waters. This includes both free and combined residuals. The need for this process is to protect fish and aquatic organisms residing in receiving streams from the toxic effects of chlorine. Some species of fish, such as salmon and trout, can only tolerate trace amounts (O.01mg/l) of chlorine. Regulatory agencies have therefore adopted requirements to limit discharges to values that reflect no measurable values of chlorine to entering a receiving stream.

*[Review Detention Ponds, Aeration, Sunlight, Activated Carbon, and Sulfur Compounds in the participant workbook.]*

The following will expand on the detailed operation of sulfur compounds as a means of dechlorination.

SULFUR COMPOUNDS: 10 minutes

## Sulfur Compounds

*[Review the section on sulfur compounds in the participant workbook. When reviewing, highlight the following point:]*

Approximately one pound of sulfur dioxide will react and neutralize one pound of chlorine

However, point out that: This is a gross approximation; actually, stoichiometrically, 1.23 pounds of SO2 are required for each pound of HOCl.

## Dechlorination Control

*[Review the section on dechlorination control in the participant workbook.]*

Work through Problem 5.1 as a class.

## Safety (Sulfur Dioxide)

*[Review the Safety (Sulfur Dioxide) section in the participant workbook.]*

## Safety Procedures and Response

*[Review the Safety Procedures and Response section in the participant workbook.]*

## Emergency Safety Equipment

*[Review the Emergency Safety Equipment section in the participant workbook.]*

## Equipment

*[Review the Equipment section in the participant workbook.]*

*[Review the Key Points for Unit 5 – Dechlorination]*

Exercise for Unit 6 - Dechlorination

1. The effluent from a wastewater treatment plant may need to be dechlorinated after disinfection because of harmful affects the chlorine residual may have on fish, wildlife, and even human health.
   a. True
   b. False

2. Common methods of dechlorination include:

   Any four of the following five answers are correct: detention ponds, aeration, sunlight, activated carbon, and the addition of sulfur compounds.

3. One pound of sulfur dioxide will neutralize how many pounds of chlorine?
   a. 4 pounds
   b. 2.5 pounds
   c. 1 pound
   d. Neutralization of chlorine is not possible by using sulfur dioxide.

4. Sulfur dioxide is often used to dechlorinate wastewater effluent, however, like chlorine it is very toxic and must be handled with great care.
   a. True
   b. False

5. A wastewater treatment plant operates with a flow of 2.0 MGD. The Chlorine residual is 3.5 mg/l. How much sulfur dioxide should be used to assure that the chlorine residual has fully reacted in the dechlorination process?

   Assume a $SO_2$ residual of 0.5 mg/l to assure all of the chlorine is reacted.

   Then, the Feed Rate of $SO_2$ is (3.5 mg/l) + (0.5 mg/l) = 4.0 mg/l

   Feed Rate in lbs/day = (2,000,000 G/D)x(4.0)/(1,000,000)x(8.34 lbs/G)

   Feed Rate in lbs/day = (2 G/D)x(4.0)x(8.34 lbs/G)

   Feed Rate of $SO_2$ in lbs/day = 67 lbs/D

UNIT 6 – ULTRAVIOLET RADIATION: 25 minutes

Display Slide 35

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

*[Review the Learning Objectives for Unit 6.]*

ALTERNATIVE TO CHLORINATION: 10 minutes

As mentioned in Unit 1, the final unit will discuss an alternative means to disinfect wastewater from pathogens – ultraviolet (UV) radiation.

Why have an alternative to chlorination?

Record the responses onto a flip chart.

Ans: Safety – Eliminates issues related to safe handling of chlorine gas.

Health – Eliminates issues related to generation of bi-products having adverse health effects.

Environmental – Eliminates need to dechlorinate the plant effluent.

What is the downside to UV radiation?

Ans: Unlike chlorine where a residual measurement assumes a level of disinfection, routine bacteriological testing of plant effluent must be performed to assure that the system is operating satisfactorily. Also, UV leaves no residual so there is no protection from recontamination.

Cost of equipment and operation are somewhat more expensive than a chlorination system. However, a total system analysis must be performed that includes the cost of safety issues related to chlorine and the reduced size of the contact basin that UV allows for.

*[Review the information provided in the participant workbook.]*

Display Slide 36 – Typical UV lamp configurations (Figure 6.1 of participant workbook).

*[Figure 6.1 indicates three alternative arrangements for configuration of the lamps. The first is for an installation where the hydraulic conditions do not allow for open channel flow. The other two are for open channel installation and show the UV tubes installed in a vertical and horizontal configuration. Most of the UV installations are the open channel configuration.]*

TYPES OF UV SYSTEMS: 5 minutes

### Low Pressure-Low Intensity

[Review the Low Pressure-Low Intensity section in the participant workbook.]

### Low Pressure-High Intensity

[Review the Low Pressure-High Intensity section in the participant workbook.]

Medium Pressure-High Intensity

*[Review the Medium Pressure-High Intensity UV section in the participant workbook. Point out that this is not commonly used in wastewater. The advantages of this system are that its output may be varied to allow for adjustment of dosage as flow varies and its use of solid mercury also facilitates clean-up in the event of lamp breakage. However, its higher operating cost makes this system less desirable for use in wastewater applications than the low pressure systems.]*

DISINFECTION PROCESS: 10 minutes

### Factors Influencing Effectiveness of UV

What problems could you experience with UV systems?

Ans: UV lamps have a limited life and will experience reduced output as time goes on. This in turn will result in a reduction of pathogen inactivation if the system were not properly sized.

UV sleeves are subject to fouling from materials in the flow stream with accompanying dose (light intensity) reductions.

UV systems are subject to fouling of the quartz sleeve due to crystallization of dissolved solids on the surface of the sleeve and thereby reducing transmission of light into the flow stream and the effectiveness of the system.

UV sleeves are subject to discoloration (known as solarization) resulting in reduced capacity of the lamp to transmit light to the flow stream, reducing its effectiveness. UV sleeves are more prone to solarization when used in medium pressure- high intensity systems.

### UV Control

How can you control UV?

Ans: UV may be controlled by turning on or off selected sections of the UV train and thereby increase or decrease the dosage of UV radiation applied to the flow stream.

UV may be controlled by increasing or decreasing the power to a UV train resulting in increased or decreased levels of radiation emitting from the lamps.

On/Off or variable lamp output can be controlled using signal from plant flow meter – "Flow Pacing."

On/Off or variable lamp output can be controlled using signals from UV intensity sensor and plant flow meter – "Dose Pacing."

Dose pacing accounts for: lamp age, condition of quartz sleeve, and the water quality (transmittance). However, with a greater frequency of on/off cycles, the useful life of the lamps will be shorter.

## Safety

*[Review the Safety section in the participant workbook.]*

## Equipment Maintenance

*[Review the equipment maintenance section in the participant workbook.]*

Monitoring of both lamp dosage and individual power supplies to lamps or lamp modules allows the system to alarm to alert operators of potential problems.

Any questions?

*[Review the Key Points for Unit 6 – Ultraviolet Radiation.]*

Exercise for Unit 6 – Ultraviolet Radiation

1. UV light used to disinfect or inactivate pathogens has a wavelength of:
   a. 580 kHz
   b. 92.7 MHz
   c. 254 nm
   d. 1760 yd

2. Three typical UV lamp configurations are:
   a. Closed vessel lamp arrangement
   b. Vertical and perpendicular to flow lamp arrangement
   c. Horizontal and parallel to flow lamp arrangement

3. UV light is harmful to the eyes and skin.
   a. True
   b. False

4. Low pressure-low intensity UV lamps are often used in wastewater systems with a flow of
   a. >0.5 MGD
   b. <0.5 MGD
   c. >2.0 MGD
   d. Are rarely used because they get too hot during operation.

5. In a typical UV disinfection system, replacement of the UV lamps should occur more often than replacement of the lamp ballasts.
   a. True
   b. False

6. Flow or dose pacing are means of
   a. UV control
   b. Maintenance planning
   c. Dechlorination
   d. Residual monitoring

This concludes the formal instruction for Module 5: Disinfection and Chlorination. Are there any final questions on chlorination, its processes, equipment, dechlorination, or UV radiation?

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

*[Thank attendees for their participation.]*