Wisconsin Department of Natural Resources
Wastewater Operator Certification

Introduction to Disinfection Study Guide

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Photos from Appleton Wastewater Treatment Plant

Subclass E

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Preface

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and wastewater businesses, jointly prepared the objectives and exam questions for this subclass.

How to use this study guide with references

In preparation for the exams you should:

1. Read all of the key knowledges for each objective.

2. Use the resources listed at the end of the study guide for additional information.

3. Review all key knowledges until you fully understand them and know them by memory.

It is advisable that the operator take classroom or online training in this process before attempting the certification exam.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates is available on the internet at http://dnr.wi.gov, keyword search "operator certification". It can also be found in the annual DNR "Certified Operator" or by contacting your DNR regional operator certification coordinator.

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Table of Contents

Part 1 - Disinfection Introduction - Chlorination

Chapter 1 - Theory and Principles

Section 1.1 - Definitions	pg. 1
Section 1.2 - Pathogen Knowledge	pg. 1
Section 1.3 - Chlorine/Dechlorination Chemistry	pg. 2
Section 1.4 - Process Understanding/Performance Limiting Factors	pg. 2

Chapter 2 - Operation and Maintenance

Section 2.1 - Definitions	pg. 3
Section 2.2 - Methods	pg. 3
Section 2.3 - Equipment	pg. 4
Section 2.4 - Handling & Storage	pg. 7
Section 2.5 - Preventive Maintenance	pg. 8

Chapter 3 - Monitoring, Process Control, and Troubleshooting

Section 3.1 - Definitions	pg. 9
Section 3.2 - Sampling & Testing	pg. 10
Section 3.3 - Data Understanding & Interpretation	pg. 10

Chapter 4 - Safety

Section 4.1 - Definitions	pg. 12
Section 4.2 - Regulations & Procedures	pg. 12
Section 4.3 - Equipment	pg. 13
Section 4.4 - Chemical Considerations	pg. 14

Chapter 5 - Calculations

Section 5.1 - Calculating chlorination chemical feed rates and amount of chlorine used	pg. 16

Part 2 - Disinfection Introduction - Ultraviolet

Chapter 6 - Theory and Principles

Section 6.1 - Definitions	pg. 18
Section 6.2 - Pathogen Knowledge	pg. 18
Section 6.3 - Process Understanding/Performance Limiting Factors	pg. 18

Chapter 7 - Operation and Maintenance

Section 7.1 - Definitions	pg. 19
Section 7.2 - Methods	pg. 19
Section 7.3 - Equipment	pg. 19
Section 7.4 - Preventive Maintenance	pg. 20

Table of Contents

Chapter 8 - Monitoring, Process Control, and Troubleshooting

Section 8.1 - Definitions pg. 20

Section 8.2 - Sampling & Testing pg. 20

Section 8.3 - Data Understanding & Interpretation pg. 20

Chapter 9 - Safety

Section 9.1 - Definitions pg. 21

Section 9.2 - Regulations & Procedures pg. 21

Section 9.3 - Equipment pg. 21

Chapter 10 - Calculations

Section 10.1 - Calculations pg. 21

Part 1 - Disinfection Introduction - Chlorination

Chapter 1 - Theory and Principles

Section 1.1 - Definitions

1.1.1 Define pathogenic organisms and their source in wastewater.

Pathogenic organisms are disease-causing microorganisms. They include various bacteria, viruses, and parasites. The discharge of waterborne human wastes will contain these organisms from ailing individuals, and would be expected to be present in wastewater entering a wastewater treatment plant.

1.1.2 Define dechlorination and why it is required at wastewater treatment plants using chlorine.

Dechlorination is the process of removing chlorine from treatment plant effluent prior to discharge to surface water. Dechlorination is used to remove potentially toxic chlorine compounds that could injure fish and other aquatic life in the receiving water.

1.1.3 Define hypochlorination.

Hypochlorination is the use of liquid chlorine compounds to achieve disinfection.

1.1.4 Define geometric mean and why it is used to average fecal coliform counts.

Geometric mean is a statistical measure of central tendency which minimizes the effect of outliers. It is different from an arithmetic average and is used because of geometric growth rates of bacteria (1, 2, 4, 8, 16, 32, etc). When calculating a geometric mean, a zero value cannot be used in the calculation and therefore all zeros should use one (1) as the value.

1.1.5 Define chlorination.

Chlorination is the addition of chlorine and/or chlorine compounds to a treated wastewater in order to achieve disinfection.

Section 1.2 - Pathogen Knowledge

1.2.1 Identify prevalent diseases that can be contracted through wastewater exposure.

- Gastroenteritis
- Dysentery
- Hepatitis
- Giardiasis
- Upper respiratory illnesses

1.2.2 State the reasons/seasons for disinfecting water.

Disinfection of treated wastewater is practiced to reduce the discharge of waterborne pathogenic organisms. This is done to protect public health as related to surface drinking water supplies and recreational use of downstream areas. Seasonal disinfection is to provide effluent disinfection during the period when recreational activities are using downstream areas, and are discontinued when use of the water is limited due to climatic conditions.

1.2.3 Explain the significance of the use of an indicator organism.

In the disinfection process, the destruction of the indicator organism would mean the likely destruction of pathogenic organisms. The indicator bacteria, fecal coliform, are not pathogenic, but are much easier and less costly to detect than individual pathogens. If fecal coliform bacteria are adequately controlled, it can be expected that other pathogenic bacteria are proportionally inactivated. The inactivation of viruses cannot be expected at the same rate as the indicator organism because viruses are more difficult to destroy.

Section 1.3 - Chlorine/Dechlorination Chemistry

1.3.1 Explain the relationship between chlorine dosage, chlorine demand and chlorine residual.

Dosage: The amount of chlorine fed to achieve disinfection. This is normally reported as a concentration in milligrams per liter (mg/L) or pounds per day (lbs/day).

Demand: The amount of chlorine used to disinfect wastewater after a given contact time.

Residual: The amount of chlorine remaining after a given contact time.

A general expression of this relationship is:
Chlorine Residual = Chlorine Dosage - Chlorine Demand

1.3.2 Describe conditions that affect chlorine demand.

Treated wastewater can have a large number of complex substances and chemicals that can affect chlorine demand. Since chlorine is a strong oxidizing agent, it will react with these various substances and chemicals using up chlorine.

Some of the conditions affecting chlorine demand include:
- Mixing
- Contact time
- Total suspended solids
- BOD
- pH
- Various compounds such as sulfides, ammonia (chloramines), ferrous iron, manganese, nitrite and numerous other substances creating chlororganic compounds

1.3.3 Describe the relationship between total chlorine residual and the dosage of sodium bisulfite for dechlorination.

The dosage rate of sodium bisulfite (NaSO2) to chlorine residual is 1 mg/L active sulfite ion to 1 mg/L of chlorine residual. The lower the chlorine residual, the less sodium bisulfite is needed for dechlorination.

1.3.4 Describe the relationship between total chlorine residual and the dosage of sulfur dioxide for dechlorination.

The dosage rate of sulfur dioxide (SO2) to chlorine residual is 1 mg/L sulfur dioxide to 1 mg/L of residual chlorine. The lower the chlorine residual, the less sulfur dioxide is needed for dechlorination.

Section 1.4 - Process Understanding/Performance Limiting Factors

1.4.1 Discuss the significance of discoloration to metal surfaces in chlorination application rooms.

Any discoloration or corrosion of gas piping would indicate a gas leak. The gas system should be shut down and repaired or replaced as quickly as possible.

Chapter 2 - Operation and Maintenance

Section 2.1 - Definitions

2.1.1 List the most common methods for disinfecting treated wastewater.

- Hypochlorination
- Gaseous Chlorination
- UltraViolet Radiation
- Ozonation

Section 2.2 - Methods

2.2.1 Identify chemicals used for dechlorination.

Chemicals used for dechlorination include the following: sulfur dioxide and sulfite salts (sodium bisulfite, sodium metabisulfite, and potassium sulfite). All the sulfite salts come as an acidic liquid solution except sodium metabisulfite which comes as a powder. Sulfite salts are oxygen scavengers which can decrease oxygen levels in water. Being acidic solutions, they can also lower pH.

2.2.2 Identify chemicals used for hypochlorination.

The two compounds used are sodium hypochlorite (NaOCL) or calcium hypochlorite [Ca(OCL)2]. Sodium hypochlorite is supplied as a liquid with different percentages (usually 12.5% by weight, 15% by volume) of chlorine. Calcium hypochlorite is supplied in a solid form (powder, granules or tablets) and must be mixed with water for solution feeding. Tablets are usually 65% active chlorine. Of the two, sodium hypochlorite is favored because calcium hypochlorite causes a precipitate.

2.2.3 Describe the procedure for opening the valve on chlorine cylinders and tanks.

Use only wrenches specially designed for the valve by the manufacturer (do NOT use an extension). An oversized wrench could cause too much torque and damage the valve. If the valve does not open easily, strike the end of the wrench to unseat the valve. Rotate the valve stem in a counter-clockwise direction. One full turn provides maximum discharge.

2.2.4 List the steps to start-up a gas chlorination system.

1. Place the cylinder securely on a scale.
2. Remove the protective hood and the cap covering the outlet valve. Use only the proper tools.
3. Attach the vacuum regulator yoke assembly to the outlet valve.
4. Open the chlorine outlet valve one half turn and then close the chlorine outlet valve.
5. Using your ammonia hydroxide leak detector, check for chlorine leaks.
6. Open the water supply inlet and outlet valves to the chlorine injector.

7. Inspect the water supply and discharge piping for leaks.
8. Connect the vacuum line and vent line to the vacuum regulator.
9. Open the chlorine rate valve on the vacuum regulator.
10. Check all chlorine connections with the ammonia hydroxide solution bottle for leaks.
11. Inspect the chlorine system for proper operation.
12. Monitor the system operation.

2.2.5 List the steps for removing an empty 150 pound chlorine cylinder.

1. Close the chlorine cylinder outlet valve completely (with the chlorine injector operating and making vacuum).
2. Allow the chlorine system to withdraw all chlorine gas out of the vacuum regulator. The chlorine gas flow indicator ball will drop to the bottom of the flow tube and the loss of chlorine pressure indicator button will be sucked in flush or indicator dial will be allowed to spin.
3. Remove the vacuum regulator from the chlorine outlet valve.
   a. Replace the outlet valve cap.
   b. Replace the chlorine cylinder protective hood.
   c. Move the empty chlorine cylinder to the empty cylinder storage area. Secure the empty chlorine cylinder with safety chain.

2.2.6 Describe how the daily usage of chlorine is determined.

The total daily usage of chlorine is determined by using a scale to measure the weight of the chlorine applied per day from the difference in weight readings of the scale.

2.2.7 Describe how to get a good mixing of the chlorine solution with the plant effluent and why it is important.

The chlorine solution is generally fed through diffusers designed to provide good dispersion. Good mixing can be obtained in open channels where there is sufficient turbulence to mix the chlorine solution with the plant effluent. Good mixing is important because it optimizes contact between the chlorine and the organisms thus allowing for the optimum use of chlorine and reliable reduction in pathogenic organisms. The chlorine contact basin provides the necessary time, once the chlorine is mixed into the effluent, to allow the chlorine time to affect the organisms and reliable reduction in pathogenic organisms.

Section 2.3 - Equipment

2.3.1 Explain the following for chlorine and sulfur dioxide 150 pound cylinders and 1 ton tanks:

A. Weight of a full cylinder or tank
B. Cylinder or Tank Handling
C. Cylinder or Tank Storage
D. Form of the Chemical (gas or liquid)

A. Weight of a full cylinder or tank
- A full 150 pound cylinder contains 150 pounds of product but actually weighs approximately 240-270 pounds.
- A full one ton tank contains 2000 pounds of product but actually weighs approximately

3500 pounds.

B. Cylinder or Tank Handling
- The 150 pound cylinder should be moved with a well balanced hand truck with the cylinder clamped securely. The cylinder can be rolled in a vertical position for short distances. The protective hood should always be in place when moving a cylinder.
- The one ton tank should be moved with a suitable tank lifting beam with hooks that attach to the end of the tank. A hoist or crane with a minimum of two-ton capacity can be used to move the tank. Trunion rollers should be available to properly position the tank. The valve bonnet should always be in place when moving a tank.

C. Cylinder or Tank Storage
- The 150 pound cylinder should be stored vertically and positively secured to a wall or other immovable structure with cylinder protective hood in place.
- The one ton tanks should be stored on their sides in properly designed cradles to support the tank and keep the valves vertically one above the other.

D. Form of the Chemical (gas or liquid)
- Full cylinders and tanks at room temperature contain 75-85% liquid.

2.3.2 Discuss the purpose of a fusible plug

A fusible plug is a safety device used to prevent excessive pressure and possible rupture in case of fire or other causes of high temperatures. A fusible plug melts at temperatures of 158-165ºF (70-74ºC).

2.3.3 Describe the location of fusible plug(s) on 150 pound cylinders and one ton tanks.

The fusible plug for 150 pound cylinders is located on the cylinder valve. The fusible plugs for one ton tanks are located on the tanks ends, with three or four on each end.

2.3.4 Describe a yoke adaptor connection used on chlorine cylinder valves.

The yoke adaptor connection is used to connect the cylinder valve to the piping system. It is a device specially designed to fit the cylinder valve.

2.3.5 Explain the purpose of the following parts of a vacuum operated gas chlorinator/dechlorinator:

A. Vacuum Regulating Valve
B. Gas Flow Rate Valve (V-Notch Variable Orifice)
C. Rotameter
D. Injector

A. Vacuum Regulating Valve
A valve is designed to regulate chlorine/sulfur dioxide gas from varying supply pressures to a constant vacuum which measures about 20 inches of water.

B. Gas Flow Rate Valve (V-Notch Variable Orifice)
This valve and its size regulates the amount of flow of gas to the system.

C. Rotameter
A rotameter is a graduated vertical tube containing a ball or float used to visually measure the flow rate of gas to the system.

D. Injector
An injector is a water jet aspirator creating a vacuum which pulls the gas from the cylinder or tank through the system.

2.3.6 Explain why sulfonator and chlorinator equipment are NOT interchangeable.

The two look identical except the internal components (o-ring plastic material and valve seat material) are different. The valve seat material for the sulfonator is stainless steel; the chlorinator uses titanium silver. The o-ring material for the sulfonator is Hypalon and for the chlorinator it is Viton.

2.3.7 Describe the difference between chlorine and sulfur dioxide cylinders.

The cylinders and tanks are identical except they are color coded. Chlorine is color coded silver or blue and sulfur dioxide is color coded red.

2.3.8 Describe the following parts of a calcium hypochlorination system:

A. Product Contact Tank
B. Solution Storage Tank
C. Application Pump
D. Solution Diffuser

A. Product Contact Tank
- A tank where tabular or granular calcium hypochlorite is submerged and dissolved in water to form a liquid chlorine solution.

B. Solution Storage Tank
- A tank where the chlorine solution is stored before being applied to the wastewater effluent.

C. Application Pump
- Typically a centrifugal pump that conveys the chlorine solution from the storage tank to the diffuser.

D. Solution Diffuser
- A perforated PVC pipe used to disperse the chlorine solution over the contact area.

2.3.9 Given the following problems with a gas chlorination system, state the cause (IF) and the solution (THEN) for each:
A. Low Gas Flow
B. Frosting of the Cylinder
C. Loss of Vacuum

A. Low Gas Flow

- IF cylinder is empty, THEN replace the cylinder.
- IF cylinder valve is closed, THEN open the valve.

B. Frosting of the Cylinder
- IF the gas withdrawal rate from the cylinder is too high, THEN add more cylinders to meet chlorine feed requirements.
- IF chlorine leaks to vent, THEN repair, service or clean the pressure reducing valve to eliminate the leak.

C. Loss of Vacuum
- IF inadequate injector water supply, THEN check injector water pump and service as needed.
- IF injector diaphragm is damaged, THEN repair injector.
- IF the diffuser or diffuser discharge line is plugged, THEN clean the diffuser and discharge piping.

Section 2.4 - Handling & Storage

2.4.1 Explain how chlorine is withdrawn from a cylinder.

From a cylinder, gas is always delivered in an upright position.

2.4.2 Explain how chlorine is withdrawn as a gas or liquid from one ton tanks.

For a one ton tank, the chlorine is delivered as a gas from the upper valve and as a liquid from the bottom valve.

2.4.3 Discuss the following requirements for the storage of chlorine gas:

A. Type of Room and Location
B. Door Opening and Location
C. Storage Room Window
D. Storage Room Temperature
E. Storage Room Ventilation
F. Chlorinator Location (150-pound cylinders and one-ton tanks)

A. Type of Room and Location
- The chlorine storage room should be a gas tight room, separated from all other portions of the building, or in another separate building.

B. Door Opening and Location
- The door to the chlorine storage room should be on the outside wall with the door opening outward. The door should have a warning sign indicating chlorine is present and have quick exit panic or emergency hardware.

C. Storage Room Window
- A clear glass air-tight window should be installed in the door or wall to allow viewing the room without entering.

D. Storage Room Temperature
- The storage room should be supplied with adequate heating/cooling to maintain a temperature between 64-110ºF. A temperature that is too cold will not allow liquid chloine to vaporize.

E. Storage Room Ventilation
- Forced mechanical ventilation is required capable of providing one complete air exchange per minute. The intake of the ventilation system must be near the floor, because chlorine is heavier than air. The exhaust of the ventilation system should be located as to not contaminate the air inlet to any buildings or inhabited areas. The ventilator and room lights must turn on automatically whenever the door is opened. Manual operation of the ventilation system must be provided with switches located outside of the room.

F. Chlorinator Location (150-pound cylinders and one-ton tanks)
- When using 150 pound chlorine cylinders, the chlorinator may be located within the storage room. When using one ton tanks, the chlorinators should be in a separate room.

2.4.4 Describe the factors that affect hypochlorination chlorine dosages.

- Strength of solution
- Dilution of product
- Time of storage (age causes deterioration)
- Conditions of storage (heat, light, certain chemicals, etc)
- Accuracy of metering pumps

2.4.5 Describe the following parts of a sodium hypochlorination system.

A. Positive Displacement Metering Pump
B. Solution/Storage Tank
C. Solution Diffuser

A. Positive Displacement Metering Pump
- Used to pump metered amounts of chlorine solution to the chlorine contact tank. The dosage can be regulated by adjusting the step pulley drive belts, stroke length and solution concentrations.

B. Solution/Storage Tank
- Sodium hypochlorite is supplied as a liquid. Liquid storage tanks should be protected against heat, light, and iron compounds; all of which will cause deterioration of the chlorine solution. Storage tanks should be plastic or fiberglass.

C. Solution Diffuser
- The diffuser is a peforated PVC pipe used to disperse the chlorine solution in the contact area.

Section 2.5 - Preventive Maintenance

2.5.1 Define the term “Preventive Maintenance”

Preventive maintenance is a comprehensive planned program of daily, weekly, monthly, annual and seasonal inspection and repair of equipment. This would involve a record system of needed maintenance, frequency of maintenance, documenting performance of the required maintenance, providing historical trends and procedures used for maintenance. Preventive maintenance would involve a spare parts inventory to ensure continuous operations of equipment. A good preventive maintenance program keeps equipment functioning, ensures good efficiency, reduces equipment down-time and saves money in the long term operation of equipment and the plant.

2.5.2 List the maintenance tasks for gas chlorinator and sulfonator systems.

- Weigh the containers on a regular basis.
- Inspect and clean the vacuum regulators.
- Inspect and replace seal O-rings and gaskets if needed. Inspect and replace the temporary flexible connections to the main pipeline on a routine basis. Immediately replace any temporary connection that has any discoloration or kinking.
- Inspect and clean the pressure relief valves (if a pressure system).
- Clean the rotameter when deposits are noticed in the glass tube or the float sticks.
- Clean the gas flow rate valve (v-notch variable orifice) when cleaning the rotameter.
- Inspect, service and test the leak detection system (if the system is so equipped).
- Inspect and clean the injector system and pump.
- Check all equipment and piping for leaks, discoloration, apparent moisture and repair/replace if necessary.

2.5.3 List the maintenance tasks for hypochlorination systems.

- Clean the positive displacement metering pump regularly
- Replace diaphragms as needed
- Alternate the use of the metering pumps and operate them briefly at all speeds
- Check and operate all valves in the piping system
- Use the proper oil and maintain levels in all pumps
- Inspect and clean the tanks using safety precautions such as confined space if applicable

2.5.4 Explain why a chlorine contact tank should be regularly cleaned.

The low velocity of flow through a chlorine contact tank will result in the deposition of solids. Small gas bubbles on the water surface of the chlorine contact tank caused by denitrification (nitrogen gas) are an indication of a buildup of solids in the tank. Solids can float to the surface. Biological growths can also grow on the walls of the tank. These solids and growths can build up in the tanks and increase the chlorine demand. Proper cleaning will reduce the amount of chlorine required.

Chapter 3 - Monitoring, Process Control, and Troubleshooting

Section 3.1 - Definitions

3.1.1 Define fecal coliforms

The organism used to determine the effectiveness of disinfection is bacteria called fecal coliform. They are commonly found in the intestinal tracts of humans and warm-blooded animals.

Section 3.2 - Sampling & Testing

3.2.1 Describe the laboratory test method most commonly used to measure fecal coliforms in wastewater treatment plants.

The most commonly used test method is the membrane filter technique (Standard Method 9222D). The colonies for fecal coliform are various shades of blue.

3.2.2 List reasons why fecal coliforms are used as an indicator organism.

- Always present in domestic wastewater
- Easy, fast and economical laboratory test
- Indicative of pathogen destruction

3.2.3 Discuss the discharge permit limit for fecal coliform.

The discharge permit limit for fecal coliform is 400 cfu per 100 mL of sample, based on a monthly geometric mean (average).

3.2.4 Describe the analyses used to measure the overall effectiveness of a chlorination/dechlorination system.

- Total residual chlorine less than 37 ug/L
- Fecal coliforms less than or equal to 400 cfu/100mL based on a geometric mean

3.2.5 Explain the type of fecal coliform sample to be taken, what the sample holding time would be, and sample preservation requirements.

The type of sample to be collected is a grab sample taken in a sterile bottle after dechlorination. Sodium thiosulfate is added to the sample if any residual chlorine is present. The holding time is 6-24 hours, preferably 6 hours. Preservation of the sample is cooling immediately to 6ºC.

3.2.6 Explain the type of residual chlorine sample to be taken, where to collect the sample, and the recommended holding time.

The type of sample to be collected is a grab sample collected after dechlorination. The analysis should begin immediately upon sample collection (no longer than fifteen minutes from the time of collection) as chlorine dissipates rapidly.

3.2.7 State the reason for total residual chlorine limits.

Chlorine is acutely and chronically toxic to aquatic organisms. The acute toxic chlorine limit is 37 ug/L as a daily maximum limit. Where there is little dilution in the receiving water, a chronic concentration limit may also be needed. Exceeding these limits can harm aquatic life.

3.2.8 List the three recommended testing methods for total chlorine residual.

1. Iodometric back titration (Standard Method 4500* CL C.), using amperometric endpoint detection method (Standard Method 4500* CL D.)
2. DPD spectrophotometric method (Standard Methof 4500 CL G.)
3. Specific ion electrode method (Standard Method 4500 CL I.)

Section 3.3 - Data Understanding & Interpretation

3.3.1 Discuss WPDES permit reporting and effluent compliance for total chlorine residual.

Test methods for total residual chlorine normally achieve a limit of detection of about 20 to 50 micrograms per liter (ug/L) and a limit of quantitation of about 100 micrograms per liter. Reporting of test results and compliance with effluent limits for chlorine residual shall be as follows:
- Sample results which show no detectable levels of chlorine are in compliance with the limit. These test results shall be reported on wastewater Discharge Monitoring Report (DMRs) forms as “<100 ug/L”. (note 0.1 mg/L = 100 ug/L)
- Samples showing detectable traces of chlorine are in compliance if measured at less than 100 ug/L, unless there is a consistent pattern of detectable values in this range. These values shall also be reported on wastewater Discharge Monitoring Report (DMRs) forms as “<100 ug/L”. The facility operating staff shall record actual readings on logs maintained at the plant, will take action to determine the reliability of detected results (such as sampling and/or calculating dosages), and will adjust the chemical feed system if necessary to reduce the chances of detectable levels of chlorine.
- Samples showing detectable levels greater than 100 ug/L shall be considered as exceedances and shall be reported as measured. To calculate average or mass discharge values, a “0” (zero) may be substituted for any test result less than 100 ug/L. Calculated values shall then be compared directly to the average or mass limitations to determine compliance.

3.3.2 Discuss the management and environmental concerns of overdosing chlorine and dechlorination products.

- Dissolved oxygen depletion and lower pH in the effluent and receiving stream (dechlorination chemicals are acidic and oxygen scavengers).
- Chlorine toxicity in the receiving stream that can affect fish and aquatic organisms.
- Biomonitoring (whole effluent toxicity) impacts.
- Increased effluent BOD (due to oxygen uptake of dechlorination chemicals).

3.3.3 Discuss the causes and solutions for wide variations in chlorine residuals in the final effluent caused by:

A. Upstream Treatment Processes
B. Chlorine Contact Tank
C. Chlorine Solution Diffuser

A. Upstream Treatment Processes
The operation of treatment units preceding disinfection can cause wide variations in chlorine demand, based on the quality of effluent entering the chlorine contact tank. Poorly performing secondary treatment with high BOD, suspended solids, or ammonia can cause high chlorine demand.

B. Chlorine Contact Tank
The contact tank can cause variations in chlorine residual due to inadequate detention time, short-circuiting, deposition of solids within the tank, and poor mixing. Solutions to contact

tank problems would include: sufficient detention time, additional baffles to stop short circuiting, routine cleaning to minimize deposition of solids, and adding mechanical mixers to improve dispersion of chlorine within the effluent.

C. Chlorine Solution Diffuser
The chlorine solution diffuser can cause variations in chlorine residuals due to: blockage of diffuser openings, damaged diffuser parts, and a diffuser location which does not provide adequate mixing.
Solutions to diffuser problems would include: adequate routine cleaning and repair of any damaged parts, relocating the diffuser, and changing the type of diffuser to improve the mixing of the chlorine solution with the treated wastewater.

3.3.4 List the possible causes of fecal coliform levels that exceed the discharge permit levels for chlorination systems.

- Poor upstream treatment
- Chlorine feed rate too low
- Inadequate capacity of chlorination equipment
- Solids build up in the contact tank
- Short circuiting in the contact tank
- Detention time in the contact tank too short
- Poor mixing in the contact tank

3.3.5 List the possible causes of high chlorine residuals following dechlorination.

Successful dechlorination results in very low to non-detectable total residual chlorine. If chlorine residuals are too high following dechlorination, the problem may be :

- The chlorine feed rate is too high for the dechlorination dosage
- Inadequate dechlorination feed rate
- Dechlorination equipment malfunction or failure
- Inadequate mixing of the dechlorination chemicals
- Chlorine demand of the treated wastewater has decreased with no change in chlorine

3.3.6 Discuss the ways one might determine if mixing is a problem in the chlorine contact tank.

Inadequate mixing can lead to fluctuating chlorine residuals, and violations of the fecal coliform discharge limit. Samples taken along the length of the contact tank should show a consistant chlorine residual and low numbers of fecal coliform bacteria.

Chapter 4 - Safety

Section 4.1 - Definitions

4.1.1 We currently have no key knowledges in this section.

Section 4.2 - Regulations & Procedures

4.2.1 Discuss the response an operator should take if there is a chlorine leak.

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

4.2.2 List the items that should be included in safety programs for chlorine and sulfur dioxide usage.

- Establish a formal plant safety program
- Provide written specific safety procedures
- Provide Material Safety Data Sheets
- Develop a preventive maintenance program
- Set up a training plan for leak detection equipment, leak repair kits, and respiratory protection
- Establish a written emergency procedure plan that includes emergency phone
- Know and follow pertinent local, state, and federal requirements as appropriate

4.2.3 Explain the importance of having a stand-by person available when working with chlorine or sulfur dioxide systems.

In the event of an accident or an emergency, a second person can assist, be available to obtain emergency help, and provide first aid.

4.2.4 Describe how to locate small leaks of chlorine gas or sulfur dioxide.

Small leaks of chlorine gas can be located using a squeeze bottle or atomizer filled with ammonia hydroxide solution. When this solution reacts with chlorine gas, a white smoke of ammonium chloride forms indicating a leak. Small leaks of sulfur dioxide can be located using a squeeze bottle or atomizer filled with sodium hypochlorite solution. In both instances a white cloud or smoke indicates a leak.

Section 4.3 - Equipment

4.3.1 Describe the type of respiratory protection that should be provided when working with chlorine or sulfur dioxide leaks.

Respiratory protection should be a Self-Contained Breathing Apparatus (SCBA) or some other form of positive pressure air breathing device. The SCBA must fit properly and be used by trained personnel.

4.3.2 Discuss where chlorine safety equipment should be stored.

Safety equipment such as Self-Contained Breathing Apparatus of chlorine repair kits should not be located in the chlorine storage room, but located outside and nearby the chlorine room where they can be obtained quickly in case of an emergency.

4.3.3 Discuss the significance of discoloration or corrosion in chlorine application rooms.

Any discoloration or corrosion of gas piping systems, including joints, would indicate a gas leak has or is occurring.

4.3.4 Discuss what items should not be in a chlorine storage room for chlorine gas and hypochlorites.

Paints, solvents, gasoline, or other organic material should not be stored in a chlorine storage room. Any of these materials could cause a violent chemical reaction if a chlorine leak occurs because chlorine is such a strong oxidizing agent.

4.3.5 Explain the safety concerns for a chlorine cylinder or tank:
A. Packing Retainer Nut
B. Cylinder Valves
C. Gaskets
D. Protective Hood
E. Fusible Plug

A. Packing Retainer Nut
Always check the packing retainer nut for cracks, breakage, or damage. A broken packing nut can cause gas leakage.

B. Cylinder Valves
Cylinder valves should not be used to regulate flow. Flows are regulated with a gas flow rate valve. Do not open the cylinder/tank valve more than one turn. One full turn provides maximum discharge and forcing the stem beyond the full open position could damage the internal valve stem threads. This could possibly cause a leak and might make it impossible to close the valve.

C. Gaskets
Always change gaskets when changing any connections, because once a gasket is used, it is compressed and not reusable. These gaskets are made of compressed asbestos or lead.

D. Protective Hood
Never transport cylinders or tanks without fastening the cylinder protective hood. Accidental striking on the unprotected valve end could cause breakage and a possible leak.

E. Fusible Plug
Never tamper with a fusible plug. The fusible plug is designed to melt and release pressure under high temperatures.

4.3.6 Describe what should be done if you discover a chlorine leak around a valve stem.

Contact your chlorine supplier because new Teflon packing material has high torque requirements. Operator adjustment is dangerous because the entire valve may loosen from the cylinder or tank.

Section 4.4 - Chemical Considerations

4.4.1 Explain what effect chlorine or sulfur dioxide gas has when released into a moist environment.

If chlorine or sulfur dioxide gases are mixed with moist atmospheres they form hypochloric or sulfuric acid, respectively. These two acids are very corrosive compounds that can attack metals and other equipment causing severe damage. This is why an operator should never use water on a chlorine or sulfur dioxide leak, as the acids formed will only make the leak worse.

4.4.2 Describe the safety concerns of the following:

A. Chlorine Gas
B. Sodium Hypochlorite (liquid bleach)
C. Calcium Hypochlorite (tablets and granules)
D. Sulfur Dioxide
E. Sodium Bisulfite

A. Chlorine Gas
Chlorine gas is 2.5 times heavier than air, is extremely toxic, and very corrosive in moist environments. The characteristic sharp odor of chlorine is noticeable at low concentrations. The gas is detectable at 1 part of gas per million parts of air (ppm). With large leaks, high concentrations may be fatal after only a few breaths. Extreme care must be exercised when working with chlorine.

B. Sodium Hypochlorite (liquid bleach)
Sodium hypochlorite (liquid bleach) is a strongly alkaline (basic) and corrosive solution. The mixing of sodium hypochlorite with any acid solution will cause the immediate release of chlorine gas. Hypochlorites are destructive to wood, corrosive to most metals, and will adversely affect the skin, eyes and other body tissues with which they come into contact (MOP FD-10).

C. Calcium Hypochlorite (tablets and granules)
Calcium hypochlorite comes as a dry form (Tablets, pellets, granules) and is unstable under normal atmospheric conditions. Reactions may occur spontaneously with numerous chemicals including turpentine, oils, water and paper. Calcium hypochlorite, therefore, should be stored in dry locations and used with equipment free of organics. Serious fire and explosion hazards exist when using this material (MOP FD-10).

D. Sulfur Dioxide
Sulfur dioxide is a colorless gas and has about the same density as chlorine, about 2.4 times heavier than air. It has a very strong pungent odor. The gas is detectable at low concentrations and is immediately dangerous at high concentrations. Inhaling sulfur dioxide will cause sulfurous acid to form on mucous membranes (eyes, throat, lungs, skin), causing severe irritation and may be fatal after only a few breaths. Extreme care must be exercised when working with sulfur dioxide.

E. Sodium Bisulfite
Sodium bisulfite is an acidic liquid solution. It is an oxygen scavenger which decreases oxygen levels in an enclosed environment. If sodium bisulfite (an acid) is mixed with sodium hypochlorite (a base), an immediate uncontrolled release of chlorine gas will occur. Cleaning any sodium bisulfite equipment with any base will result in an acid-base reaction producing heat and possible explosion.

4.4.3 Explain why a release of liquid chlorine is much worse than a gas leak.

When liquid chlorine is released, one volume of liquid will evaporate to produce almost 460 volumes of gas because of liquid chlorine's high rate of evaporation.

Chapter 5 - Calculations

Section 5.1 - Calculating chlorination chemical feed rates and amount of chlorine used

5.1.1 Given data, calculate the amount of chlorine used per day in pounds.

GIVEN:
Flow = 0.60 MGD and Chlorine Dosage = 8 mg/L

FORMULA & SOLUTION:
Chlorine Feed Rate (lbs/day) = Flow (MGD) × Chlorine Concentration (mg/L) × 8.34 lbs/MG/mg/L

= 0.60 MGD × 8 mg/L × 8.34 lbs/MG/mg/L
= 40 lbs/day

5.1.2 Given chlorine scale readings, calculate the amount of chlorine used per day in pounds.

GIVEN:
Chlorine scale readings: Day 1 = 204 pounds; Day 2 = 167 pounds

FORMULA & SOLUTION:
Pounds Per Day (lbs/day) = Difference in Scale Readings

Day 1 Reading = 204 lbs
Day 2 Reading = 167 lbs
Daily Use = 204lbs - 167 lbs = 37 lbs

5.1.3 Given data, calculate the chlorine demand of an effluent.

GIVEN:
Chlorine Dosage = 10 mg/L and Chlorine Residual = 3 mg/L

FORUMULA & SOLUTION:
Chlorine Demand = Chlorine Dosage - Chlorine Residual

= 10 mg/L - 3 mg/L
= 7 mg/L

5.1.4 Given data, calculate the applied chlorine dosage in mg/l.

GIVEN:
Flow = 0.500 MGD
Chlorine Feed Rate = 30 pounds per day (lbs/day)

FORMULA & SOLUTION:
Chlorine Dosage (mg/L) = Chlorine Feed Rate (lbs/day) ÷ (Flow (MGD) × 8.34lbs/MG/mg/L)

= 30 lbs/day ÷ (0.500 MGD × 8.34lbs/MG/mg/L)
= 7.2 mg/L

5.1.5 Given data, calculate the amount of available chlorine by weight (pounds) in a gallon of sodium hypochlorite (bleach).

GIVEN: Percent (%) of active chlorine = 12.5% and Weight (lbs) of gallon of solution = 10 lbs/gallon

FORMULA & SOLUTION:
Pounds (lbs) of Chlorine Per Gallon of Solution = Weight of Gallon of Solution x (% Active Chlorine ÷ 100)

= 10 lbs × (12.5 % ÷ 100%)
= 10 lbs × 0.125
= 1.25 lbs

5.1.6 Given fecal coliform test results, calculate the fecal coliform geometric mean.

GIVEN:
Weekly Fecal Coliform Sample Results (cfu/100mL) = 10, 20, 18, 50

FORMULA & SOLUTION:
The geometric mean can be calculated using either of the following two formulas:

Formula:
Geometric Mean = nth root of [FC1 × FC2 × FC3 × FC4...]

where n = number of samples
FC# = fecal coliform result of each sample

Geometric Mean = 4th root of [10 × 20 × 18 × 50]
= 4th root of 180,000
= 21

Alternate Formula:
Geometric Mean = AntiLog [Sum of Log Data ÷ Number of Values]

Log of 10 = 1.000
Log of 20 = 1.3010
Log of 18 = 1.2553
Log of 50 = 1.6989

Geometric Mean = AntiLog [(1.000 + 1.3010 + 1.2553 + 1.6989) ÷ 4]
= AntiLog [5.253 ÷ 4]
= AntiLog [1.313]
Geometric Mean = 21

Part 2 - Disinfection Introduction - Ultraviolet

Chapter 6 - Theory and Principles

Section 6.1 - Definitions

6.1.1 Describe ultraviolet (UV) disinfection.

Ultraviolet disinfection uses a light source just below the range of the wavelengths of visible light. Ultraviolet radiation inactivates bacteria and some viruses by destroying cellular material preventing the bacterial cell from reproducing.

6.1.2 Define UV intensity.

UV intensity is a measure of radiative power per unit of exposed area. It is a function of lamp life, lamp fouling and configuration, and placement of the lamps in the channel. Intensity is expressed as milliwatts per square centimeter (mW/cm2).

6.1.3 Define UV transmittance.

It is a measure of water quality. UV transmittance is a measure of the ability of the wastewater to transmit UV light. UV transmittance is expressed as %T.

6.1.4 Define UV dosage.

UV dose delivered by a UV system is a product of UV intensity and detention in seconds. The delivered dose in a flow-through UV system will depend on the intensity of radiation and duration of exposure. Dose is expressed as milliwatts - second per square centimeter (mW-s/cm2)

Section 6.2 - Pathogen Knowledge

6.2.1 We currently have no key knowledges in this section.

Section 6.3 - Process Understanding/Performance Limiting Factors

6.3.1 Discuss how a typical ultraviolet unit functions.

Treated wastewater is exposed to ultraviolet radiation, and disinfection effectiveness is a function of UV intensity and exposure time. Wastewater flows through a chamber or channel containing quartz glass tubes containing mercury vapor lamps. The ultraviolet lamps resemble fluorescent tubes and are spaced close together to ensure good mixing and exposure of the microorganisms. The ultraviolet units are relatively small as compared to a chlorine contact tank for a given flow.

6.3.2 Describe the effluent characteristics that can inhibit the effectiveness of ultraviolet disinfection.

The main effluent characteristics that can inhibit ultraviolet disinfection are dissolved, colloidal, and particulate materials that interfere with the passage of light through water. Suspended solids, in particular, can block the transmission of the ultraviolet rays, thus reducing the effectiveness of disinfection.

6.3.3 Describe advantages of ultraviolet disinfection.

- Short contact time
- No residual toxicity
- No chemicals to handle
- Minimal space requirements
- Relatively easy inspection of UV system
- Relatively simple maintenance of UV system

Chapter 7 - Operation and Maintenance

Section 7.1 - Definitions

7.1.1 Define fouling.

Fouling occurs when the ability to deliver radiation from the bulbs is impeded by organic or inorganic material which has accumulated on the quartz sleeves.

7.1.2 Describe a lamp, sleeve, module, and bank in a UV system.

1. Lamp: the source of UV radiation that is either low pressure or medium-pressure mercury lamps with low or high intensities.
2. Sleeve: Quartz glass sleeves house the lamps and are in contact with the water.
3. Module: the number of lamps assembled in a metal support frame
4. Bank: the number of modules placed in the channel next to each other spanning the flow stream

Section 7.2 - Methods

7.2.1 We currently have no key knowledges in this section.

Section 7.3 - Equipment

7.3.1 Describe a ballast.

A ballast is an electrical device. Ballasts provide a starting voltage for the lamps and maintain a continuous current to the lamps.

7.3.2 List the types of UV systems:

1. Low pressure mercury lamp
2. Medium pressure mercury lamp
3. Low pressure/high intensity

7.3.3 Discuss the reason for UV lamp replacement, and state the expected life of UV lamps.

As UV lamps age, the intensity of the UV radiation is gradually reduced and the lamps will need to be replaced. The determining factor for lamp replacement would be increasing fecal coliform density. The lamps can have an operating life of greater than 14,000 hours. When using routine fixed time replacement, the time of lamp replacement can vary from 7,500 - 12,500 hours.

7.3.4 Discuss the main components of a UV disinfection system.

A. Mercury vapor lamps are the source of UV radiation. They can be low pressure, medium pressure, or low pressure/high intensity.
B. The reactor is the channel through which the wastewater flows during treatment. The two types of reactors are contact and non-contact. In contact reactors, the lamps are enclosed in quartz sleeves, which must be kept clean. In non-contact reactors, the UV lamps are suspended outside a transparent conduit through which the water flows.
C. Ballasts provide a starting voltage for the lamps and maintain a continuous current to the lamps.

Section 7.4 - Preventive Maintenance

7.4.1 List the maintenance concerns for UV disinfection systems.

1. Organic and inorganic build-up on the surfaces of the sleeves requires periodic cleaning.
2. The limited life of UV lamps require their periodic replacement.
3. A spare parts inventory should include lamps, sleeves, ballasts, and other system components.
4. The channel containing the UV lamps requires periodic cleaning.

7.4.2 Describe steps that can be taken to correct lamp fouling.

Improving upstream treatment processes helps reduce fouling of UV sleeves. When cleaning is needed, a dilute acid or commercial detergent can be used.

7.4.3 List the types of chemicals that can be used to clean quartz sleeves.

Citric acid, phosphoric acid, and commercial bathroom cleaners are the main chemicals used for cleaning the sleeves. Food grade cleaning solutions are recommended so that the spent solution can be returned to the plant headworks. Identifying the fouling material can help determine the best cleaning solution to use for removal.

Chapter 8 - Monitoring, Process Control, and Troubleshooting

Section 8.1 - Definitions

8.1.1 We currently have no key knowledges in this section.

Section 8.2 - Sampling & Testing

8.2.1 Describe the testing used to measure the performance of a UV system.

Changes in process performance can result from factors such as hydraulic loading, lamp aging, lamp fouling, or variations in effluent quality (esp. suspended solids). The main criterion for replacing UV lamps is primarily effluent fecal coliform levels.

Section 8.3 - Data Understanding & Interpretation

8.3.1 List the possible causes of fecal coliform levels that exceed the discharge limits for ultraviolet disinfection units.

1. Poor effluent quality (high suspended solids or low UV transmittance)
2. Dirty lamps
3. Age of the UV lamps (reduced intensity)
4. System not in full operation
5. Hydraulics (high flows, low detention times)

8.3.2 Describe how UV is affected by effluent turbidity, especially dissolved and particulate suspended solids.

The main effluent characteristic that can inhibit ultraviolet disinfection is suspended solids. Suspended solids can block the transmission of the ultraviolet rays, reducing the effectiveness of disinfection. For best ultraviolet disinfection results, the effluent suspended solids should be as low as possible.

Chapter 9 - Safety

Section 9.1 - Definitions

9.1.1 Discuss the harmful effects of direct exposure to UV light.

Direct exposure to eyes and skin can damage eyesight and cause serious burns. Proper protective equipment such as a face shield and clothing should be used. Follow all manufacturer and employer safety procedures.

Section 9.2 - Regulations & Procedures

9.2.1 Discuss the personal protective equipment (PPE) requirements when working with UV disinfection equipment.

Protective clothing should include a full-face shield, gloves, and have all exposed skin covered. Long pants and long-sleeved shirts should always be worn around UV equipment.

9.2.2 Discuss the safety concerns related to UV electrical equipment.

UV equipment utilizes high voltage electricity. Follow all lock-out/tag out procedures before working on UV equipment. Because of the proximity to water, proper grounding is critical. Be sure all electrical connections and switches are water tight.

Section 9.3 - Equipment

9.3.1 Discuss the proper disposal of UV lamps.

UV lamps contain mercury which is a hazardous material and should be disposed of properly.

9.3.2 Discuss the safety concerns with cleaning solutions used to clean equipment.

Many of these cleaning solutions are acidic, so the proper personal protection equipment should be used when working with them. Acid resistant gloves, face shields, rubber aprons, and boots are recommended. The cleaning solutions should be used in a well-ventilated area. If using strong acids, training and the proper spill kits are recommended.

Chapter 10 - Calculations

Section 10.1 - Calculations

10.1.1 We currently have no key knowledges in this section.

References and Resources

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