Module 5:
Disinfection and Chlorination
Answer Key

What processes in wastewater treatment serve to remove pathogens?

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

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

9. Match the description with the correct form of chlorine.

Description

_A_ 1. This form of chlorine is provided in liquid form and delivered in 150 lb cylinders and one ton containers. Very large plants may have it delivered in tank cars.

_C_ 2. Also known as high test hypochlorite or HTH.

_C_ 3. Generally not used at wastewater treatment plants due to its higher cost, sludge forming characteristics and explosive nature.

_B_ 4. Available in concentrations of 12.5% and 15% and is the general form of hypochlorite used in most wastewater treatment plants.

_C_ 5. Available in granules, pellets and powder and contains a chlorine concentration of 65 to 70 percent and commonly used in swimming pools.

_D_ 6. Relatively unstable and is manufactured at its point of use and introduced into the flow stream shortly thereafter.

_D_ 7. It is most beneficial to use when pH levels are above 8.5.

_B_ 8. Provided in liquid form and better known as bleach.

Chlorine form

A. Elemental Chlorine (Cl_2)

B. Sodium Hypochlorite (NaOCl)

C. Calcium Hypochlorite $Ca(OCl)_2$

D. Chlorine Dioxide (ClO_2)

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.

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

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. Chlorine concentrations of 0.1% (1000 ppm) in the air may be fatal after only a few breaths. The Immediately Dangerous to Life and Health concentration (IDLH) is 10 ppm.

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

5. 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.

6. 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.

7. If you detect a leak in a gas cylinder, position the cylinder so the leak is on the _____ to release gaseous chlorine rather than liquid chlorine.

    a. top
    b. bottom

8. Ton containers should be secured with chocks to prevent movement after being set in place. An alternative would be to place them on trunnions, which would also allow them to be rotated more readily and set in their proper position.

9. 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

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

11. Chlorine leaks may be detected by several means. One method for testing joints or potential points of leakage is with a(n) ammonia solution. Reaction with chlorine will produce white smoke as a visible indicator of the presence of chlorine.

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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.

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Exercise for Unit 5 - 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

Why have an alternative to chlorination?

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.

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.

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.

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 nm

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