

University Curriculum Development for Decentralized Wastewater Management

Disinfection

Suggested Course Materials

**Mark Gross, PhD
University of Arkansas**

**Kitt Farrell-Poe, PhD
University of Arizona**

September 2004

NDWRCDP Disclaimer

This work was supported by the National Decentralized Water Resources Capacity Development Project (NDWRCDP) with funding provided by the U.S. Environmental Protection Agency through a Cooperative Agreement (EPA No. CR827881-01-0) with Washington University in St. Louis. These materials have not been reviewed by the U.S. Environmental Protection Agency. These materials have been reviewed by representatives of the NDWRCDP. The contents of these materials do not necessarily reflect the views and policies of the NDWRCDP, Washington University, or the U.S. Environmental Protection Agency, nor does the mention of trade names or commercial products constitute their endorsement or recommendation for use.

CIDWT/University Disclaimer

These materials are the collective effort of individuals from academic, regulatory, and private sectors of the onsite/decentralized wastewater industry. These materials have been peer-reviewed and represent the current state of knowledge/science in this field. They were developed through a series of writing and review meetings with the goal of formulating a consensus on the materials presented. These materials do not necessarily reflect the views and policies of University of Arkansas, and/or the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT). The mention of trade names or commercial products does not constitute an endorsement or recommendation for use from these individuals or entities, nor does it constitute criticism for similar ones not mentioned.

Citation of Materials

The educational materials included in this module should be cited as follows:

Gross, M.A. and K. Farrell-Poe. 2005. Disinfection Text. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Gross, M.A. and K. Farrell-Poe. 2005. Disinfection - PowerPoint Presentation. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Disinfection

Suggested Course Materials

Table of Contents

Item	Page
Overview	1
Agenda	2
Outline.....	3
Goals	4
Learning Objectives	5
Prerequisites	6
Evaluation Form	7
Problem Sets.....	8
Problem Set with Solutions	9

Disinfection Overview

This section presents the concepts of wastewater disinfection as it applies to onsite and decentralized systems. Although the processes are the same for small wastewater flows as they are for large wastewater flows, some of the applications are different. In particular, tablet chlorination and liquid chlorination are typical solutions for disinfecting small flows, whereas gas chlorination using one-ton cylinders of chlorine gas is the typical method chosen for gas chlorination in large wastewater treatment plants. Also, when disinfecting wastewater prior to using a soil dispersal system as the final treatment and method for returning the treated water to the hydrologic cycle, considerations must include the effect of the residual disinfectant upon the beneficial soil organisms. The material in this section includes chlorine disinfection methods, ultraviolet disinfection methods, and ozone disinfection methods.

Disinfection Agenda

- I. Introduction (1/2 Class Period – 30 Minutes)
 - A. The purpose of disinfection
 - B. The concept of C T values
 - i. inactivation/kill levels
 - ii. variability of flow & implications on CT
 - C. Why would you disinfect
 - D. Why would you not disinfect
 - E. When to choose which option
 - F. Discharging systems
 - G. Soil-based dispersal
 - H. Requires management, and homeowner management has not worked in the past
- II. Chlorine (1-1/2 Class Periods - 90 Minutes)
 - A. Chlorine Chemistry
 - B. Tablet chlorination
 - C. Liquid Chlorination
 - D. Advantages
 - E. Disadvantages
- III. Ultraviolet Radiation (1 Class Period - 60 Minutes)
 - A. Process Description
 - B. Types of Ultraviolet Radiation Equipment
 - C. Advantages
 - D. Disadvantages
- IV. Ozonation (1/2 Class Period - 30 Minutes)
 - A. Process Description
 - B. Equipment Description
 - C. Advantages
 - D. Disadvantages

Disinfection

Outline

I. Introduction

- A. The purpose of disinfection
- B. The concept of CT values
 - 1. Inactivation/kill levels
 - 2. Variability of flow and implications on CT
- C. Why would you disinfect
- D. Why would you not disinfect
- E. When to choose which option
- F. Discharging systems
- G. Soil-based dispersal
- H. Requires management

II. Chlorine

- A. Chlorine chemistry
- B. Tablet chlorination
- C. Liquid chlorination
- D. Advantages
- E. Disadvantages

III. Ultraviolet radiation

- A. Process description
- B. Types of UV equipment
- C. Advantages
- D. Disadvantages

IV. Ozonation

- A. Process description
- B. Equipment description
- C. Advantages
- D. Disadvantages

Disinfection

Goals

The goal of this section of the course is to teach students the methods, concepts, and chemistry of wastewater disinfection. After having studied this section of the course, students will be familiar with some of the methods available for wastewater disinfection. The students will be able to select the appropriate disinfection system for a decentralized wastewater treatment system and compute dosage rates for chemical disinfection.

How this section relates to decentralized wastewater and the other material in the curriculum:

Disinfection of wastewater in decentralized wastewater treatment may be used in cases where the final dispersal is to surface water under an NPDES permit, or under a state general permit. Some states allow surface discharging systems, and disinfection is practiced for those cases. Also, where decentralized wastewater treatment is chosen for developments or for satellite collection and treatment systems, in some cases surface discharge is used as the final method for returning the treated wastewater to the hydrologic cycle.

Other cases may include soil-based dispersal where the wastewater is treated to secondary quality or even to advanced secondary or tertiary quality and then dispersed into soil. There is some research suggesting that high-quality effluent may not form the biomat at the soil interface, and therefore pathogens may be transported deeper into the soil profile. In these cases, disinfection may be considered as a method of pathogen control prior to the soil dispersal system.

The material presented here addresses these disinfection issues and attempts to relate them to the other curriculum sections such as treatment using media filters, Aerobic Treatment Units (ATU's), constructed wetlands, and soil-based treatment.

Disinfection

Learning Objectives

After completing this material, the students should be able to:

1. Understand the methods, concepts and chemistry aspects of wastewater disinfection.
2. Be familiar with some of the methods available for wastewater disinfection.
3. Select the appropriate disinfection system for a decentralized wastewater treatment system
4. Compute dosage rates and contact times for chemical disinfection.

Disinfection

Prerequisites

Prerequisites for this section include a college level course in chemistry, a college level course in microbiology, and college algebra.

Disinfection Evaluation Form

Please rate each of the following aspects of the disinfection section of the course using a scale of 1 to 5 with 1 being the poorest and 5 being the best.

The course objectives were clearly explained 1 2 3 4 5

Each of the following aspects was covered adequately:

General principles of disinfection 1 2 3 4 5

Methods of wastewater disinfection 1 2 3 4 5

Concepts of wastewater disinfection 1 2 3 4 5

Calculating disinfectant dose 1 2 3 4 5

Selecting disinfection equipment 1 2 3 4 5

Please provide comments in the space provided, noting that the goal is to evaluate the course material rather than the instructor:

The strongest points of the disinfection section of the course are:

The aspects of the course needing the most improvement are:

Specific suggestions for improvement are as follows:

Disinfection Problem Sets

Q. What is the goal of disinfection?

Q. Name 4 general categories of pathogens

Q. Calculate the volume of the chlorine contact chamber required to provide 30 minutes of contact time for an average daily flow of 15,000 gallons per day.

Q. If liquid bleach has a chlorine concentration of 6.0% by weight, calculate the volume of bleach required to result in a concentration of 2 mg/l in 1000 gallons of water.
Water and chlorine bleach weigh 1000 g/Liter. 1 gallon = 3.78 liters.

Q. What are two advantages and two disadvantages to using chlorine as a method of disinfection?

Q. Under what conditions would you recommend the use of ozone disinfection? Why?

Disinfection

Problem sets with solutions

Q. What is the goal of disinfection?

A. The goal of disinfection is to reduce the number of pathogens in the treated effluent so that the risk of disease is minimized.

Q. Name 4 general categories of pathogens

- A.
1. Bacteria
 2. Viruses
 3. Protozoa
 4. Helminths

R. Calculate the volume of the chlorine contact chamber required to provide 30 minutes of contact time for an average daily flow of 15,000 gallons per day.

A. Flow rate = 15,000 gallons per day ÷ 1440 minutes per day = 10.42 gallons per minute

Volume = 10.42 gallons per minute x 30 minutes = 312.5 gallons

Q. If liquid bleach has a chlorine concentration of 6.00% by weight, calculate the volume of bleach required to result in a concentration of 2 mg/l in 1000 gallons of water. Water and chlorine bleach weigh 1000 g/Liter. 1 gallon = 3.78 liters.

A. 2 mg chlorine/L ÷ 1 liter of bleach/60.0 grams of chlorine x 1000 gallons x 1 gram/1000 mg = 0.033 gallons of liquid bleach

Q. What are two advantages and two disadvantages to using chlorine as a method of disinfection?

A. Advantages of chlorine disinfection:

- Chlorination is a well-established technology
- Presently, chlorine is more cost-effective than either UV radiation or ozone disinfection.
- The chlorine residual that remains in the wastewater can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness.
- Chlorine disinfection is reliable and effective against a wide spectrum of pathogenic organisms.
- Chlorine is effective in oxidizing certain organic and inorganic compounds.
- Chlorination has flexible dosing control.

Disadvantages of using chlorine disinfection:

- The chlorine residual, even at low concentrations, is toxic to aquatic life and treated wastewater discharging to aquatic environments may require dechlorination.

- All forms of chlorine are highly corrosive and toxic. Thus storing, shipping, and handling pose a risk, requiring special safety regulations.
- Chlorine oxidizes certain types of organic matter in wastewater, creating more hazardous compounds (e.g. trihalomethanes – THM's).
- The level of total dissolved solids is increased in the effluent
- The chlorine content of the wastewater is increased
- Chlorine residual is unstable in the presence of high concentrations of chlorine-demanding materials, thus requiring higher doses to effect adequate disinfection.
- Some parasitic species have shown resistance to chlorination, including oocytes of *Cryptosporidium parvum*, *Endamoeba histolytica*, and *Giardia lamblia* and eggs of parasitic worms.
- Long-term effects of discharging dechlorinated compounds into the environment are unknown.

Q. Under what conditions would you recommend using ozone disinfection? Why?

A. Ozone may be the preferred method of disinfection of large commercial systems when

- 1) The incoming wastewater is known to contain *Giardia* and *Cryptosporidium* because ozone is more effective than chlorine in destroying viruses, protozoa, and bacteria
- 2) The receiving water body is sensitive to residuals, particularly chlorine residuals and chlorination by-products because there are no harmful residuals that need to be removed following ozonation since ozone decomposes so rapidly.
- 3) Safety issues are a primary concern because ozone is generated onsite, therefore, there are fewer safety problems associated with shipping and handling

Ancillary benefits to using ozone include:

1. Ozonation elevates the dissolved oxygen (DO) residual in the treated wastewater, therefore the increase in the DO can eliminate the need for reaeration.
2. If discharged to a stream, the elevated DO in the treated wastewater can also raise the DO on the receiving stream.