CHLORINATION FOR DISINFECTION

Objectives:
The student will be able to:

- Explain how chlorine works.
- Describe what it is used for and why.
- Show effects on pond or wastewater.
- Discuss the consequences of its use.

Suggested Grade Level:
9-12

Subjects:
Chemistry, Biology, Environmental Science

Time:
1 Class Period

Materials:
- four 2-L bottles
- pond water
- bleach (NaOCl)
- microscopes
- slides
- stain (crystal violet)
- eye droppers
- stirring rods

BACKGROUND INFORMATION

Chlorine belongs to the class of elements termed the halogens. Each halogen has one less electron than the noble gas that follows it in the periodic table. Since there is only one electron missing from the *3p* shell, chlorine's outer most electron shell, there is a very large tendency for chlorine to form a single covalent bond or a (Cl^-) ion. Under ordinary conditions, chlorine exists as a diatomic molecule that is written as Cl_2. Of the groups in the periodic table, the halogen group is the most reactive nonmetal. Chlorine is used in, both drinking water and wastewater treatment, as a disinfectant. Its germicidal action is due to the hypochlorous acid (HOCl) that forms when chlorine is added to water. Exactly how this acid exerts its killing power is not yet fully known. It possibly releases a reactive form of oxygen that combines with the protoplasm of the microbial cell and, therefore, destroys it. The hypochlorite ion OCl^- also has some killing potential. The following equations describe the chemical action when chlorine is added to water.

$$Cl_2 + H_2O \bullet H^+ + Cl^- + HOCl$$

Chlorine + Water • Hydrogen ion + Chloride ion + Hypochlorous acid

$$HOCl \bullet H^+ + OCl^-$$

Hypochlorous acid • Hydrogen ion + Hypochlorite ion

A liquid form of compressed chlorine gas is widely used in wastewater treatment plants, drinking water treatment facilities, and swimming pools. Other compounds containing chlorine also are widely used for disinfection. Calcium hypochlorite, $Ca(OCl)_2$, is used for disinfection of dairies and barns, slaughter houses, and restaurants' eating utensils. Sodium hypochlorite, NaOCl, known commonly as bleach, is also used in dairies as well as food processors and hemodialysis systems. When the quality of drinking water is in question, household bleach can achieve a rough equivalent of municipal chlorination. For purification of water in emergency situations, add 2 drops of NaOCl (bleach) to a liter of water (4 drops if it is cloudy). Let the water sit for 30 minutes before drinking. THIS IS ONLY FOR EMERGENCY SITUATIONS. Chloramine compounds consisting of chlorine and ammonia are also widely used disinfectants. They also are used as antiseptics and sanitizing agents. Chloramines are very stable compounds that release chlorine over long periods of time. They are used when a long residual time is necessary.

TERMS

covalent bond: bond formed between two atoms when they share pairs of electrons
diatomic molecule: molecule made of two atoms
residual: the quantity left over at the end of a process; remainder

ADVANCE PREPARATION

Acquire some pond water or wastewater in four 2L bottles that have been thoroughly washed.

PROCEDURE

I. Setting the stage
A. Discuss Background Information with students. Ask students these questions.

1. When is chlorine added to drinking water during the treatment process?
2. What are some household products that might contain chlorine? What is the purpose of having chlorine in these products?

B. Write the chemical equation for the breakdown of chlorine in water on the board and have students copy it.

C. Define terms on board and have students record.

II. Activity
A. Use the first gallon bottle of collected water as a control.

B. To the second bottle add 1 drop of NaOCl (bleach).

C. To the third bottle add 2 drops of NaOCl.

D. To the fourth bottle add 4 drops. Let them sit for 30 minutes.

E. Make up some microscope slides with water from each bottle and observe.

F. Record observations. (Optional: prepare some slides for bacterial observation by using a stain such as crystal violet.)

III. Follow-up
A. Based on student observations, what was the most effective concentration of chlorine for "killing" organisms in water?

B. Why is it important to keep a residual concentration of chlorine in drinking water?

C. What effect do students think the chlorine in drinking water has on them? Do the benefits outweigh the problems?

IV. Extensions

A. Have students research diseases caused by microorganisms found in water. What effect has chlorinating water had on the reduction of these diseases?

B. Discover what other types of treatment can be used to disinfect water. Why are these not used as often as chlorine?

C. Have students research human health concerns related to chlorine (the chemical itself and its disinfection by-products). How do the relatively low chlorine levels used in drinking water disinfection (below 2 mg/l) relate to the students' findings?

D. Have students research human health concerns related to alternative drinking water disinfectants such as chloramines, chlorine dioxide, and ozone. Also note the disinfection by-products associated with each of these alternative disinfectants. Compare this information to the concerns related to chlorine in item C above.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.
Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley,
Menlo Park, CA, 1989.
Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: AG lobal
Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.
Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.
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Thank you to the Environmental Protection Agency *Water Sourcebook* for this activity!

http://water.epa.gov/learn/kids/drinkingwater/wsb_index.cfm