POLLUTANTS: HOW MUCH TOTAL OR HOW MUCH PER UNIT OF WATER?

9-12

OBJECTIVES

The student will do the following:

1. Define the concept of concentration as different from an expression of total amount.

2. Explain that chemicals may be present in water or wastewater in concentrations so low that they are undetected.

3. Demonstrate changing concentrations through a serial dilution.

4. Distinguish between loading and concentration as these terms apply to wastewater effluents discharged into a receiving stream.

5. Calculate concentration and loading.

SUBJECTS:
Math, Science (Chemistry)

TIME:
1 class period

MATERIALS:
red food coloring
toothpicks
2 medicine droppers, 1 for color, 1 for water
beaker or jar of water
1 bottle that will hold 10 ml
one 2-liter soda bottle
10 ml pipette
1 liter graduated cylinder
white foam egg cartons
spectrophotometer if available (to measure dilution)

BACKGROUND INFORMATION

Often, consumers must think not only in terms of the total amounts, but also in terms of "unit per unit" measurements. An example of this is unit pricing, where product costs for groceries are expressed in terms of total cost and cost per unit weight (e.g., cost per ounce or cost per gram). This same "unit per unit" i.e., units of pollutant per unit of water, concept is applied to water and wastewater quality measurements.

Water is called the "universal solvent," since many common substances are easily dissolved in water. Other substances, such as suspended solids do not dissolve in water, but are often present in water or wastewater discharges (effluent). Pollutants which are either dissolved or suspended in water are often measured or expressed in terms of "concentration," typically milligrams per liter (mg/l) or micrograms per liter (µg/l). However, pollutants in wastewater effluents are often required, through permit conditions, to be measured in terms of "loadings" as well as concentration. Loadings are simply the total amounts (mass) of a pollutant as measured on a daily (or some other time interval) basis, such as pounds per day (lb/day) or kilograms per day (kg/day). Wastewater pollutant concentrations are also typically expressed in mg/l (parts per million, ppm) or µg/l (parts per billion, ppb).

The flow of rivers or streams can play a major role in determining the effects of a pollutant on them. This is because stream flow (also called stream velocity) is defined as the volume of water flowing over a point per time interval, which can be expressed as m^3/s or cubic feet per second (cfs). Therefore, if the average flow of a river is 14 m^3/s, the volume of water flowing at any one "point" of the river in one second is 14 m^3. And if a different river had twice the average flow, 28 m^3/s, the volume of water flowing at any one "point" of this river in one second is 28 m^3. Now, if two pollutant samples of an equal amount (mass) are discharged in the two rivers described above, what would happen to the concentration of the pollutant in the two rivers? In simple terms, the river with the higher flow would have a lower concentration of pollutant, but by how much? Since concentration is a unit of mass per unit of volume, if the amount of pollutant stays the same and the flow doubles, then the concentration will be reduced by one-half. The following equations demonstrate this numerically:

River I	*or*	*River II*
$\frac{500mg}{14m^3}$		$\frac{500mg}{28m^3}$
$35.71\ \frac{mg}{m^3}$		$17.86\ \frac{mg}{m^3}$
$0.03571\ \frac{mg}{l}$		$0.01786\ \frac{mg}{l}$

ADVANCE PREPARATION

Set up lab stations with the listed materials for students to work in groups.

PROCEDURE

I. Setting the stage

A. Explain to students that they will be modeling a very common lab procedure called a serial dilution in Activity 1 that is widely used in medical and bacteria- logical labs as well as water quality labs. In water quality labs, it is most commonly used to dilute water samples for coliform bacteria determinations. If students are familiar with growing bacteria in petri dishes, ask them what happens when there are too many bacteria added to the dish. (They grow all over the place, and it becomes difficult to count each colony.) The ideal is to have separate colonies such that each represents a single original cell.

B. Explain to students the material in the background and be sure that they understand about discharges into a receiving stream in high and low flow conditions.

C. Warn students about keeping droppers separate for food coloring and water.

II. Activity

A. Serial dilution:

1. Place 10 drops of red food coloring into the first egg carton well. Food coloring as it comes from the bottle is already a 1:10 dilution.

2. Use a clean dropper to add 9 drops of clean water to well #2, then take 1 drop of well #1 and add to well #2. Mix with toothpick before taking from Well #1 and adding to Well #2. Caution: Be sure that the medicine dropper that is used for the color is cleaned between each use. If not, the dilutions will be incorrect.

3. Again add 9 drops of water to well #3, then 1 drop of well #2 to well #3. Mix.

4. Repeat until there are 10 wells with liquid.

5. The food coloring in well #1 is 1 part color per 10 parts liquid. What is the concentration in well #2? Make a chart that shows each dilution all the way to well #10.

Example

Well #	Calculation	Expression of dilution
1	1/10	1 part per 10
2	1/10 x 1/10	1 part per 100
3	1/100 x 1/10	1 part per 1000
4	1/1000 x 1/10	1 part per 10,000
5	1/10,000 x 1/10	1 part per 100,000
6	1/100,000 x 1/10	1 part per 1,000,000
7	1/1,000,000 x 1/10	1 part per 10,000,000
8		
9		
10		

6. At which concentration did the color disappear? Do you think there were any parts of the red coloring in well #10? Explain.

7. What would remain in the wells if all the water were removed? Allow the water to evaporate and observe.

B. Difference between loading and concentration:

1. Fill the small bottle with 10 ml of water and add 1 drop of red food coloring. If one drop were to equal 0.01 mg of pollutant, express the resulting concentration in mg/liter. How much total pollutant in mg do you have?

2. Now add the whole 10 ml bottle to the 2-liter bottle. How many total mg of pollutant do you have? Express the concentration in mg/liter.

III. Follow-up

A. To explain further how small 1 ppm or 1 ppb is, give students the following examples.

1. Distance to the sun = 93 million miles. If you drive 93 miles, that is 1 ppm.

2. Distance to the moon = 239,000 miles = 1.26 billion ft. If you move 1.26 ft., that is 1 ppb.

B. Ask students to write other examples.

C. Give students the pollutant concentration amounts in Extension A. Ask students if they feel these regulations are strict enough and if they think that keeping pollutants at such a low level is cost effective. Discuss. (The instructor may want to have students complete Extension A before the discussion.)

IV. Extensions

A. The maximum contaminant levels of some pollutants in drinking water (as of 1996) are given below. Ask students to do reports on these substances and explain why they are considered to be so toxic. Students should research health effects of each substance.

arsenic	50 ppb
cadmium	5 ppb
mercury	2 ppb
endrin	2 ppb
lindane	0.2 ppb
2,4-D herbicide	70 ppb

B. Ask students to discuss the differences between release of the toxic pollutants listed above and discharge of wastewater from treatment plants that containammonia, nitrates, phosphate, or BOD. (The former are either not able to be broken down or have a long life in nature; the latter, except BOD, are very biodegradable in a short period of time and typically break down into simple non-toxic compounds.)

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.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works,4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Seuss, Dr., The Lorax, Random House, New York, 1971. (Also available on video)