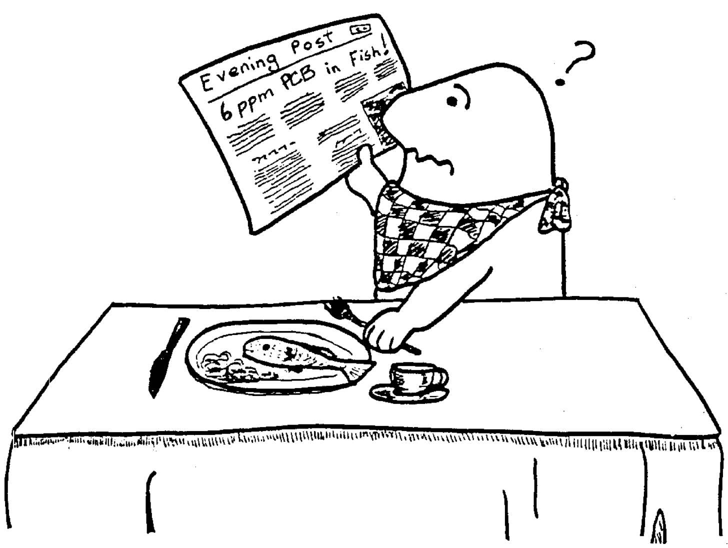
How much is one part per million?

Many potentially dangerous chemicals can be harmful in small concentrations. The level of polychlorinated biphenyls (PCBs) in a solution, for instance, is considered dangerous when there are only two parts of PCB for every million parts of solution. In this investigation students determine the extent of dilution necessary for a substance to have a concentration of a few parts per million.

PCBs are virtually indestructible pollutants produced by people for use as coolants in electrical equipment. They have escaped into the environment and are now found in food and water sources. They are thought to enter bodies of water such as Lake Erie through the air as a result of burning plastic objects containing the chemical, from direct dumping of liquid waste from industries using PCBs in their industrial processes, and from water running through solid waste disposal sites where transformers or other PCB-containing materials have been dumped. Although the United States production of PCBs has ceased, it is estimated that 450 million pounds of PCBs exist in the environment, and 750 million pounds of PCBs are still in industrial and domestic use in the 1990s.

Bioaccumulation of a toxin (such as PCBs) occurs when a toxin collects in the body of the organism that ingests the chemical. The toxin PCB is soluble in fat, which means that it collects in fatty tissue. PCBs are present in small concentrations in some of the waters of the Great Lakes. As fish and other organisms live in these waters, the PCBs collect in their fatty tissue so that the concentration of PCB in their bodies is much higher than in the water around them. The longer they live, the more toxins accumulate. If a bird eats several fish that are contaminated by PCBs, then that bird "collects" the toxins from each of those fish. In this manner, the PCBs are passed up the food chain at higher and higher levels of concentration.



OBJECTIVES

When you have completed this investigation you should be able to explain to someone about the concentration of PCBs that is considered to be dangerous.

Suggested Approach

The first part of this activity is written as a teacher demonstration. It (through Step II) could be conducted as a student lab if sufficient equipment were available.

Materials

Demonstration:
- India ink.
- Two eyedroppers.
- Graduated cylinders: 10 ml, 100 ml, and 1000 ml (or a liter vessel).
- Two 10- gallon aquaria or one 15 to 20-gallon aquarium.

Source

Modified from OEAGLS EP-23. *PCBs in Fish: A Problem?* Activity A, by Victor J. Mayer, Amy J. White-Predieri, Vanessa J. Steigerwald, and Stephanie Martin.

Earth Systems Understandings

This activity focuses on ESU 3 (science process and technology).

PROCEDURE: STEP I

To begin this investigation, your teacher will place one drop of a colored material, probably ink, in a 10 ml graduated cylinder. Then your teacher will add nine drops (parts) of water. Answer the following questions on a sheet of paper.

1. How many parts (drops) of ink are in the cylinder?
2. How many parts (drops) of water are in the cylinder?
3. How many total parts (drops) of solution are in the cylinder?

Since your teacher has 10 drops of solution that has 1 drop of ink in it, the concentration of solution is described as 1 part ink per 10 solution. This ratio can be written 1 part ink: 10 parts solution or 1 part ink / 10 parts solution.

4. Look carefully at the graduated cylinder. What is the volume of the solution?

Keep a record of all the data from Step I in the data chart.

STEP II

In Step I we had 1 part ink in 10 parts solution. Now we want to dilute the ink in solution by adding more water. The concentration of ink will be reduced because more water will be added.

In Step II we want to dilute the solution 10 times.

5. What volume of solution is 10 times greater than the original volume of solution?

6. How many parts (drops) were in the original solution?

7. How many parts (drops) of water must be added to dilute this solution 10 times?

8. Now, what is the total number of parts (drops) in the solution?

Add the data from Step II to the data chart. Be sure to note on your paper what the concentration was when you were unable to see the ink because it was diluted too much.

Teacher's Note

Concentrations of substances in solution are expressed as parts of the substance to the total parts of the solution. Therefore, if there were a solution of 1 part of ink and 9 parts of water, the concentration would be expressed as 1 part in 10. Discuss this with your students as you begin the activity.

At each step of the dilution, hold the vessel containing the solution in front of a white sheet of paper, and ask the class whether they can still see the ink. Alternatively, pour a small amount into a petri dish and display it on the overhead projector.

Answers

1. 1 part/drop of ink
2. 9 parts/drops of water
3. 10 total drops
4. 1/2 ml (There are 20 drops to a milliliter.)
5. 1/2 ml x 10 = 5 ml
6. There were 10 drops in the original solution.
7. 90 parts (drops) must be added.
8. There are 100 total parts (drops) in the solution.

 © The Ohio State University, 1997

STEP III

Our original drop of ink is now diluted to 1 part per 100. Let's keep diluting this solution until the ink is diluted to 1 part per million.

9. What volume in milliliters would be ten times greater than the volume we have obtained in Step II?

9. 50 ml is 10 times greater than 5 ml.

Our 10 ml graduated cylinder is too small to hold this volume, so the teacher must transfer our solution into a larger 100 ml graduated cylinder. Then the teacher will add water to dilute the solution to the volume you have calculated in question 9. Instead of counting drops as in Step II, you can calculate the number of drops (parts) of total solution using the equation:

20 drops (parts) = 1 milliliter

10. How many total parts (drops) of solution are in our newly diluted solution? Record the data in the data chart.

10. There should be 1,000 parts (drops).

STEP IV

11. If we dilute the new solution 10 more times, what volume (in milliliters) of solution would we have?

11. There would be 500 ml of solution.

12. What volume in liters would be equal to the number of milliliters in question 11?

12. 0.5 liters is equal to 500 ml

13. Using the equation 20 drops (parts) = 1 ml, how many total drops (parts) of solution are contained in the volume obtained in question 11?

13. There would be 10,000 parts (drops).

Your teacher will make the dilution to the volume you calculated in question 11. A liter vessel must be used to hold the solution since the 100 ml graduated cylinder is too small. Tabulate your results for Step IV in the data chart.

Data Chart Answers

I	II	III	IV	V final step
1:10	1:100	1:1000	1:10,000	1:1,000,000
1/2 ml	5 ml	50 ml	500 ml	50,000 ml

DATA CHART

STEPS	I	II	III	IV	V final step
PARTS	1:10				
VOLUME	1/2 ml				

© The Ohio State University, 1997

STEP V

14. How many more tenfold dilutions are necessary to dilute the ink to one part per million? Explain how you arrived at this answer.

15. What volume (in liters) of solution is necessary to perform each of these dilutions?

16. How many gallons of solution are needed to dilute the ink to a concentration of 1:1,000,000? HINT: 1 liter = 0.264 gallons.

    As your teacher carries out the dilutions you have determined above, fill in the rest of the data chart.

17. At what concentration were you no longer able to see the ink?

14. Two additional dilutions. One dilution will take it to 100,000 drops and the second to 1,000,000 drops.

15. For the first dilution you will end up with 5,000 ml or 5 liters of solution and for the second, 50,000 ml or 50 liters of solution.

16. 13.2 gallons

17. After a concentration of 1:1000 has been reached, students will find it difficult to see any indication of the presence of the ink.

Teacher's Notes

You might want to bring out some other comparisons of what one part per million means. For example: it is 1 minute in 2 years; one second in 11.6 days, 1 penny in $10,000, and 1 ounce of chocolate in 8,000 gallons of ice cream.

EXTENSION

Contact industries to find out which and what levels of chemicals they add to the water or atmosphere. Conduct research to determine the amount of the pollutants that companies can legally add to the ecosystem. Examine the risks associated with various pollutants and decide whether you think the allowable amounts are appropriate. What points of view could/should be taken into consideration when deciding legal limits of pollution?

In 1990, Congress amended the Great Lakes Critical Programs Act, also known as the Federal Water Pollution Control Act. The amendment mandated that the Environmental Protection Agency (EPA), in consultation with the Agency for Toxic Substances and Disease Registry (ATSDR) and the Great Lakes states, submit to Congress by September 30, 1994, a research report assessing the harmful human health effects of water pollutants in the Great Lakes basin. (Source: Great Lakes Human Health Effects Research Program, November 1994, Executive Summary – http://atsdr1.atsdr.cdc.gov:8080/grtlakes.html)

See http://atsdr1.atsdr.cdc.gov:8080/CHEM/PCB.gif for an image of the molecule. Web addresses sometimes change. Do a word search if necessary.

REFERENCES/ WEB SITES

http://www.epa.gov/glnpo/health/atsdr.htm
The Effects of Great Lakes Contaminants on Human Health, Report to Congress.

http://atsdr1.atsdr.cdc.gov:8080/grtlakes.html
ATSDR (Agency for Toxic Substances and Disease Registry) Great Lakes Human Health Effects Research Program.

http://atsdr1.atsdr.cdc.gov:8080/ToxProfiles/phs8821.html
Agency for Toxic Substances and Disease Registry, Public Health Statement, PCBs, ATSDR Public Health Statement, June 1989. This site answers questions such as: "What are PCBs?" and "How do PCBs affect my health?"

http://atsdr1.atsdr.cdc.gov:8080/tfacts17.html – ATSDR's ToxFAQs, Polychlorinated Biphenyls (PCBs), April 1993.

 © The Ohio State University, 1997