The Lone Drop

One aspirin tablet in 86 gallons of water makes 1 part per million!

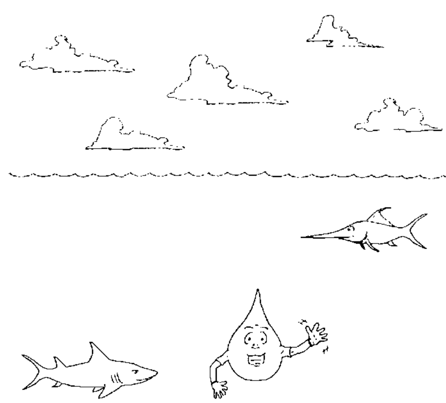
Municipal water supplies are commonly tested for many chemicals and bacteria. Modern equipment like flame spectrometers can detect some pollutants in amounts as small as a part per billion (ppb) or a part per trillion. Many pollutants reach “actionable” levels at one or more parts per million (ppm).

This activity creates graphic examples of how diluted one part per million, one part per billion and one part per trillion are. Note that some contaminants (like dioxin) have actionable levels as low as one part per trillion. *Instructors please note: two dilution demonstrations are provided for your use. The first one requires a substantial amount of equipment and large volumes of water. The second requires very little equipment and provides a graphic comparison of dilution against a neutral background. For most classes, the second demonstration is both easier and more graphic. To grasp the concept of comparative volume, however, the comparison of a BB or some other item you have measured to the size of a room is vital.*

Time Required: 15 minutes to an hour, depending on the activities selected

Equipment/Materials

eye droppers (at least two)
20-gallon aquarium
gallon jug, marked to volume
measuring cup (glass, 16-ounce)
tablespoon
teaspoon
1/4 teaspoon
1/8 teaspoon
yardstick
tape measure (50 to 100 feet)
white foam egg carton
water
dark food coloring
BB or BB-sized bead



Dilution Demonstration 1

1. Fill the aquarium with 13 gallons, 3 1/2 cups, 1 Tbsp, 1 3/8 tsp, and six drops of water.*
2. Add one drop of dark food coloring and allow to mix thoroughly with the solution. This is one part per million (1 ppm) of dye.
3. Assuming that the container and the water put into it were clean, do you think the water would be safe to drink with this 1 ppm of pollutant in it?

* All of these activities and calculations are easier if metric measures are used. A single drop from an eye dropper is assumed to be approximately 1/20 cubic centimeter (cc) or milliliter (ml). A dilution rate of 1 ppm requires 50 liters of water. One can get from liters to cubic meters (m^3) by multiplying by 0.001. More advanced students can figure out the conversion by multiplying 0.01 m x 0.01 m x 0.01m x 1000 (the number of ml in one liter) to get the same conversion factor.

Dilution Demonstration 2

1. Add 10 drops of dye to one cell in a white foam egg carton.
2. Draw 1 drop of dye from that cell and place it in the second cell of the carton. With a clean eye dropper add 9 drops of water to that cell and mix thoroughly. Clean and dry the “dye” eyedropper completely. Mark the top edge of the cell showing that the dye is in a 1:10 or 10 percent solution.

3. With a clean eye dropper, remove 1 drop of the solution from the 1:10 cell and add it to the next cell. Use the other eye dropper to add 9 drops of water to that cell and mix completely. Label this cell as a 1:100 or 1 percent solution.

4. Clean and dry the eye dropper and transfer one drop of the 1:100 solution to the fourth cell in the container. Using the other eye dropper, add 9 drops of water to the solution and mix completely. Label this cell as a 1:1,000 or 0.1 percent solution.

5. Continue in this fashion, transferring one drop of the previous solution with a clean, dry eye dropper and adding 9 drops of water to the current cell. At each transfer add one zero to the end of the large number or one decimal place to the percentage to indicate the strength of the solution. A summary of the concentration in each cell is listed here.

Cell Number	**Concentration**	**Percentage**
1	1:1	100
2	1:10	10
3	1:100	1
4	1:1,000	0.1
5	1:10,000	0.01
6	1:100,000	0.001
7	1:1,000,000	0.0001
8	1:10,000,000	0.00001
9	1:100,000,000	0.000001
10	1:1,000,000,000	0.0000001
11	1:10,000,000,000	0.00000001
12	1:100,000,000,000	0.000000001
13	1:1,000,000,000,000	0.0000000001

Note that by eliminating the 1:1 or 100 percent dye solution, a series that includes dilutions of 1:10 (10 percent) to 1 part per billion can be contained in a single egg carton.

6. Have the participants compare the dye color in the water through the series.

7. Ask them to determine which cell contains such dilution that the water seems to contain no dye at all. Use their observations to illustrate that some pollutants can be present in water even though we cannot detect them with human senses.

Volume Demonstration

1. Show participants a BB or the plastic head of a dressmaker's pin.

   The approximate volume of a standard 0.177 BB is 0.02903475 inches^3 or 0.000001680251 feet^3, assuming that the BB is a perfect sphere. The volume of a sphere is calculated as $4\pi r^3/3$.)

2. How much water would need to be added to this amount of material to dilute it to one part per million?

   This can be found by multiplying the calculated volume by 1,000,000 (at this level, the difference between 999,999 and 1,000,000 is insignificant and the calculations are much easier). This results in a volume of 29,034.75 inches^3 or 1.68 feet^3. Since each gallon of water occupies a volume of 231 inches^3, a BB in 12.569 gallons of water is approximately 1 part per million.

3. Refer to the dilution experiments and have participants calculate how many cubic inches of water would be required to dilute the single drop of pollutant to one part per million, given that the volume required is approximately 13.2 gallons. ***Note that they can check the volume by measuring the inside width, depth and length of the tank and multiplying those dimensions, although accuracy in measuring these dimensions is critical to their answer. In the other experiment, they could measure a given number of drops (20 to 100) and multiply through the dilutions to get a similar answer.***

   Multiplying 13.2 gallons times 231 cubic inches per gallon yields an answer of 3,049.2 cubic inches or 1.76 cubic feet (cubic inches divided by 1,728). [Note that the calculated amount added was 13.208602 gallons if

each measurement was exactly right and no liquid was spilled or left in the measuring containers. Thus the precisely calculated amount was 3,051.1871 cubic inches. The differences are due to rounding error.]

4. Challenge the group to determine the amount of space required to get to dilutions of one part per billion and one part per trillion.

   One part per billion requires that one drop be diluted with 3,051,187 in^3 or 1,765.7333 ft^3 of water. One part per trillion would require that the drop be diluted by 3,051,187,100 in^3 or 1,765,733.3 ft^3 of water.

5. If desired, have the students compare the volume (length x width x height) of a classroom, assembly hall or cafeteria with the volume of the BB to find a space that comes close to those dimensions. Try to locate rooms or buildings that would approximate these volumes. ***Note that a 30- x 30-foot room with a 12-foot ceiling holds about 1,080 ft^3 of space, a 40- x 30- x 10-foot room would hold about 12,000 ft^3 and a 40- x 30- x 12-foot room would hold about 14,400 ft^3.***

   If the volume of a BB is approximately 0.02903475 in^3 or 0.000001680251 ft^3, a space of about 29,034.8 in^3 or 1.7 ft^3 represents one part per million, while a volume of 13,442.011 ft^3 (23,227,794 in^3) would represent one part per billion and a volume of 13,442,011 ft^3 (23,227,794,000 in^3) would represent one part per trillion. [Note that comparisons with classrooms, auditoriums, or football stadiums might be instructive. One part per billion represents about 1,680.25 ft^3 of classroom with 8-foot ceilings, for example.]

6. Note that some pollutants are considered to be dangerous at dilution rates of one part per trillion or less, and stress that biological amplification or bioaccumulation of pollutants can concentrate pollutants that cannot be detected in water to levels of 50 to 100 parts per million!

7. Ask why these factors could be important to people?

   They are important because we, too, can accumulate these materials and we may eat the organisms that concentrate them, which results in damaging levels being ingested.

Follow Up Activity

Contact local water treatment personnel, district soil and water conservation personnel, Texas Natural Resources Conservation Commission staff, or the county Extension agent for more information on water testing and pollution.