THE SCIENCE OF
Water

What Is a One Part Per Million Solution?

from *The Science of Water Teacher's Guide* and for *Mystery of the Muddled Marsh*

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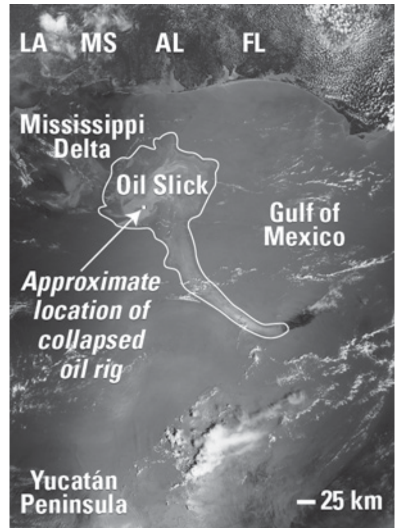
Water Pollution and Health

Environment and Health Basics

All the water on Earth ultimately forms a single, immense system. Oceans, wetlands, streams, lakes and underground water supplies all are linked through drainage patterns in watersheds and through the endless cycling of water on our planet. Because water sources are connected, pollutants travel from part of one ecosystem to another. Eventually, the contaminants can affect very distant ecosystems and populations. Water pollutants can be divided into several major categories, all of which impact human health and well-being.

- **Nutrients.** These can come from chemical sources (fertilizers or detergents) or can be biological in origin (sewage or manure). Nutrients usually are carried into water sources by rainwater. They cause excessive growth of water plants and algae, which can clog navigable waterways and consume oxygen (needed by other organisms such as fish) when they decompose. These changes cause the decline of important lakes and wetlands, and can affect the quality of drinking water. In groundwater, fertilizers can make water from wells unsafe to drink.
- **Soil and sand from plowed fields, construction sites, logging sites, urban lands and areas being strip-mined.** These sediments make lakes, wetlands and streams more shallow, limiting the use of waterways for transportation and decreasing the quality of wildlife habitats. Washed-off soil also can be a source of excess nutrients.
- **Disease-causing organisms.** Bacteria, viruses and single-celled parasites can enter water supplies from inadequately treated sewage, storm water drainage, septic systems, livestock pens, and boats that dump human wastes. These organisms cause diseases such as dysentery and typhoid, and skin and respiratory illnesses.
- **Metals (such as mercury and lead) and toxic chemicals (such as those found in pesticides, herbicides, cleaning solvents, plastics and petroleum derivatives).** These substances can be poisonous to humans and wildlife. Metals and many manufactured chemicals persist in the environment. They build up in the bodies of fish and other animals, and can find their way into groundwater, making it unsafe to drink.
- **Heat.** Warm water discharged from power plants (where water is used for cooling) can drastically alter aquatic ecosystems. Changes in water temperature can affect the quantity of oxygen in the water and can make some organisms more susceptible to disease, parasites and toxic chemicals.

Most sources of water pollution are spread over large areas. Water from rain and irrigation collects pollutants as it washes over the land or sinks into the soil. This type of pollution, which is not attributable to a single location, generally is called non-point source pollution. It is much more difficult to monitor and to control than point source pollution—which is discharged at a single place (such as from a factory or waste treatment plant, or a chemical spill).



A large patch of oil visible near the site of the *Deepwater Horizon* rig collapse and oil spill on May 17, 2010. A long ribbon of oil stretches far to the southeast, entering the loop current, a stream of fast moving water that circulates around the Gulf of Mexico before bending around Florida and up the Atlantic coast.

Source: NASA Earth Observatory.

Satellite image courtesy of NASA Earth Observatory.

WATERSHEDS

An area of land that catches rain and snow and drains into a marsh, river, lake, groundwater or other body of water is called a watershed. Watersheds come in all sizes, and they form based on water drainage patterns. Within watersheds, water always flows downhill—so any activity that changes characteristics of water upstream will affect water quality downstream. Homes, farms, cities, fields and forests all can be part of the same watershed.

What Is a One Part Per Million Solution?

Environment and Health

CONCEPTS

- Substances dissolved in water can be present in very tiny amounts that are not visible to the eye.

OVERVIEW

Students make a solution of food coloring with a concentration of one part per million.

SCIENCE, HEALTH & MATH SKILLS

- Using pipets (droppers) as a measuring tool
- Observing
- Drawing conclusions

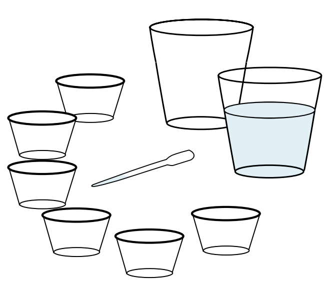
TIME

Preparation: 10 minutes
Class: 30 minutes

MATERIALS

Each group will need:

- 6 cups, 2-oz clear plastic (see SETUP)
- 2 cups, 9-oz clear plastic
- 2 pipets (or droppers)
- Small bottle (or container) of blue or red food coloring
- Water
- Copy of "What Does One in a Million Look Like?" page



Students will create a series of dilutions by successively adding one drop of solution to nine drops of water.

Water that looks clean and clear still may contain many different types of chemical and biological materials. In fact, even water from crystal clear wilderness sources, or "natural spring water" sold in stores contains dissolved minerals and other substances. Most of these are harmless—especially in tiny quantities.

However, some types of water contaminants are harmful to human health, even in very small amounts. The concentration of many of these substances usually is measured in parts per million, or even in parts per billion. The Environmental Protection Agency (EPA) sets limits for the amounts of potentially harmful chemicals in drinking water sources.

In the following exercise, students create a solution that contains a concentration of one part per million of commercial food coloring.

Unit Links

Mystery of the Muddled Marsh
Story, pp. 26–31

Explorations
Let's Talk About Water and Health, pp. 2–3

SETUP

Prepare 6 small cups for each group of students, numbering each set "1" through "6" with a permanent marker.

As an alternative, use commercially available chemistry trays or cut the bottoms of plastic egg cartons in half to create trays with 6 wells.

Students should carry out this activity in groups of four. Set up a station in a central area with materials that each group will need.

PROCEDURE

1. Make sure that each group has six numbered 2-oz cups (or a tray), one 9-oz cup of clean tap water, one empty cup (for cleaning the pipet) and two pipets (one for use with food coloring and one for use only with water).
2. Following the instructions on the "What Does One in a Million Look Like?" student sheet, have students place 1 drop of food coloring into "Cup 1." (OR put one drop of food coloring into the cup for each group.) Have students use a clean pipet to add 9 drops of water to the cup. Ask, *How many colored drops did you add to the cup? How many drops are in the cup all together?*
3. Instruct students to collect 1 drop of the mixture in Cup 1 and place it into Cup 2. Next, have them use a clean pipet to add 9 drops of water to Cup 2. Students may need to rinse their pipets with tap water and squirt the excess into the empty cup.

Each group should repeat the procedure, using 1 drop from the previous cup until all 6 cups are filled.

4. When students have made all their solutions, have them observe the color of the solution in each cup. Ask, *What happened to the color of the water in the different samples? In which sample does the color seem to disappear? Does this mean that there is no food coloring in the water?*
5. Look at the table on the "What Does One in a Million Look Like?" sheet. Be sure students notice that the concentration in Cup 6 is one part in one million. Each cup has a food coloring solution that is 10 times more diluted than the solution in the preceding cup. Ask, *Is there another way to make a mixture that has one part in 1 million?* (One way is to add 1 drop of food coloring to 999,999 drops of water! Another would be to add one drop of food coloring to a bathtub full of water—this would be an approximation.)
6. Hold up a glass of tap water. Ask, *Could this water also contain tiny amounts of other things that we can't see? What might those tiny things be?* Possible answers could include minerals, microorganisms (germs), or chemicals. Ask, *Are all of these things necessarily harmful?* Help students understand that almost no water, except in a laboratory, is completely pure. On the other hand, point out that some pollutants can be harmful to human beings even in very tiny amounts, often measurable only in parts per million or parts per billion (for example, heavy metals like lead and mercury, pesticides and some industrial chemicals). Mention that certain city, county, state and federal agencies test drinking water for potentially harmful chemicals. Ask, *Why might this be important?*

VARIATIONS

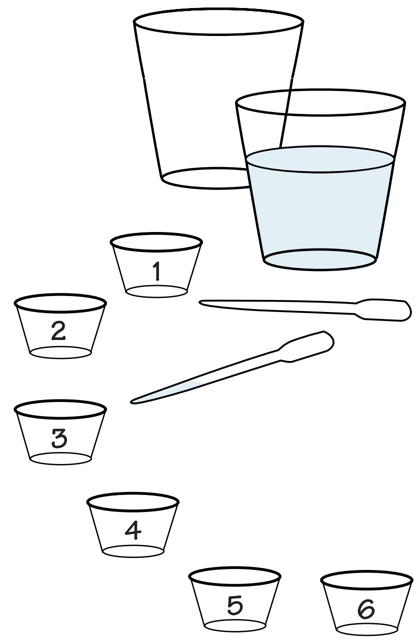
- Refer students to the "Riff and Rosie Talk to . . ." section on page 7 of this unit's *Explorations* magazine. It features a microbiologist who tests water for levels of disease-causing organisms.
- The Safe Water Drinking Act of 1974 requires the EPA to set and enforce standards of safety for drinking water in the United States. Have older students check resources in the library or on the Internet to find out which substances currently are considered hazardous by the EPA, and at what concentrations.
- Water treatment plants typically pass water through a complex filtering process to remove suspended particles and to add chlorine to kill disease-causing organisms. Water also may be sprayed into the air to help evaporate some kinds of chemicals and improve its taste and smell. Organize a class visit to your municipal water treatment plant or have a representative from the local water or health department visit your classroom.

The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996, and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs and ground water wells. However, SDWA does not regulate private wells which serve fewer than 25 individuals.

Source: U.S. Environmental Protection Agency.

Photo by Daniel Schwen, Wikimedia Creative Commons 2.5.

What Does One in a Million Look Like?



1. Add one drop of food coloring and nine drops of water to Cup 1.

   How many drops of food coloring does Cup 1 hold? ____________

   What is the total number of drops in Cup 1? ____________

   The amount of food coloring in Cup 1 is: **1 drop in 10**.

2. Take one drop from Cup 1 and put it into Cup 2. Then add nine drops of water to Cup 2.

   What is the total number of drops in Cup 2? ____________

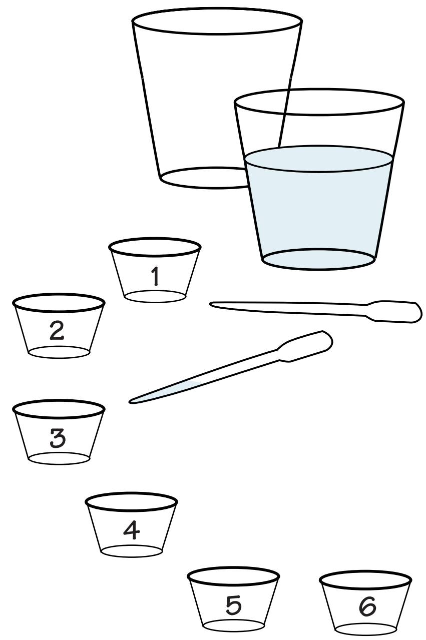
   The amount of food coloring in Cup 2 is: **1 drop in 100**.

3. Continue adding one drop from the previous cup and nine drops of water to each new cup until all six cups hold 10 drops. Then fill out the table.

   Hint: Look for a pattern in the amount of food coloring that ends up in each cup.

Cup Number	Total Drops in Cup	Amount of Food Coloring Present
1	10	1 drop in 10
2	10	1 drop in 100
3	______	1 drop in 1,000
4	______	1 drop in ____________
5	______	1 drop in ____________
6	______	1 drop in ____________

¿Que es uno en un millón?



1. Añade una gota de colorante para alimentos y nueve gotas de agua a la Taza 1.

   ¿Cuanto es el número total de gotas en la Taza 1? ____________

   ¿Cuantas gotas tiene la Taza 1 en total? ____________

   La cantidad de colorante en la Taza 1 es: **1 gota en 10**.

2. Toma una gota de la Taza 1 y ponla en la Taza 2. Añade nueve gotas de agua.

   ¿Cuanto es el número total de gotas en la Taza 2? ____________

   La cantidad de colorante en la Taza 2 es: **1 gota en 100**.

3. Continua añadiendo 1 gota de la taza anterior y 9 gotas de agua a cada taza hasta que las seis tazas tengan 10 gotas en cada una. Ahora, completa la tabla.

   Una sugerencia: Fíjate si hay un patrón en las cantidades de colorante que están en las tazas.

Taza número	Total de gotas en la taza	Cantidad de colorante presente
1	10	1 gota en 10
2	10	1 gota en 100
3	______	1 gota en 1,000
4	______	1 gota en ____________
5	______	1 gota en ____________
6	______	1 gota en ____________