Using Serial Dilution to Understand ppm/ppb

Adapted from *Investigating Groundwater: The Fruitvale Story,* Science Education for Public Understanding Program (SEPUP), Lawrence Hall of Science (1996) by Dana Haine, UNC Superfund Research Program.

Overview:

Students will perform a serial dilution of food coloring to create highly diluted solutions to learn about the units, parts per million (ppm) and parts per billion (ppb), that scientists often use to describe chemical contamination of water or soil.

Objectives:

At the end of this activity, students will be able to:

- Define serial dilution;
- Define ppm and ppb;
- Observe that a contaminant can be present in water even if it isn't visible.

Alignment to North Carolina Essential Standards for Science

This lesson addresses components of the specific learning objectives:

8th Grade Science

8.E.1.3 Predict the safety and potability of water supplies in North Carolina based on physical and biological factors, including temperature, dissolved oxygen, pH, nitrates and phosphates, turbidity, bio-indicators

8.E.1.4 Conclude that the good health of humans requires: monitoring of the hydrosphere, water quality standards, methods of water treatment, maintaining safe water quality, stewardship

Earth and Environmental Science

EEn.2.4.1 Evaluate human influences on freshwater availability.

EEn.2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.

Physical Science

PSc.2.1.2 Explain the phases of matter and the physical changes that matter undergoes.

Materials:

- ☐ *Student Data Collection Sheet*, one per student
- ☐ Plastic tray with at least 9 wells or 9 test tubes, one tray/set of tubes per group
- ☐ White scrap paper to place under trays/tubes to observe results, one per group
- ☐ Red Food Coloring
- ☐ Two small cups of water, one labeled "rinse"
- ☐ Medicine dropper, one per group
- ☐ Paper towels
- ☐ Red colored pencils (*optional*)

Duration

20-30 minutes

Procedure:

1. Ask students to consider these questions:
   - "How do we know when soil or water is contaminated with hazardous waste?
   - "How much chemical does it take for the environment to be labeled as contaminated?"
   - "Why is water often referred to as a "universal solvent?"
   - "If water is contaminated with a chemical, can we always see, smell or taste the chemical?"
   - "Name several chemicals (natural or man-made) that can be detected in water."

2. Hold up a dropper bottle of food coloring and ask students:
   - "How could we dilute this solution?"
   - "How would the appearance change as a result?"

3. Tell the students that this food coloring solution represents a 10% concentration of food coloring. Percent means "parts per hundred" so 10% means that there are 10 parts food color to 90 parts water (10/100 = 10% or 1/10). When scientists measure contaminants, scientists often use the terms "parts" per million (ppm) or billion (ppb). The million and billion are the whole or 100% of the water being sampled or tested. The "parts per" represents the number of parts of the whole that is contaminant.

4. Next, provide students with some examples:
   - Sea water is slightly over 3% salt. Therefore, according to our meaning of percent, 3 parts out of 100 parts of sea water are salt. We could evaporate 100 grams of sea water to find 3 grams of salt.
   - If we mix 5 parts of sugar with 999,995 parts of water—how could we represent this as a fraction?
     5/100,000,000! How about a percent? .0005%! Or we could just say "Five parts per million." Which is easier to understand and write? We use ppm or ppb to denote very small concentrations of chemicals.

5. Circulate around and give each tray one drop of 10% food coloring solution in wells 1 and 2. Well 1 is the control. Instruct the students to add 9 drops of water to well #2 (this is step 3 on their *Data Collection Sheet*) and to follow the remaining directions on their *Data Collection Sheet*. Students are diluting each subsequent solution by a factor of ten; thus, well 2 will represent a 1/100 concentration and well 3 will have a 1/1,000 concentration etc.

Conclusion:

1. Ask students to review their results and consider the following questions:
   a. In which well does the solution first appear colorless?
   b. Do you think there is any food coloring present in this well?
   c. How could we test to see if any is present?
   d. Which represents a higher concentration, parts per million or parts per billion?
   e. Do you think chemicals present in ppm or ppb concentrations are significant to human health? Why or why not?

2. Go to http://www.epa.gov/safewater/contaminants/index.html#mcls to observe the federal drinking water standards and obtain a list of drinking water contaminants that are regulated by the EPA. What contaminants are regulated by the EPA? Notice the allowable

concentration of each contaminant listed (*MCL or Maximum Contaminant Level*) in the nation's drinking water supply. To help students think of terms of ppm and ppb, it may be helpful to tell students that:

mg/L (milligrams per liter) is the same as **parts per million**;
µg/L (micrograms per liter) is the same as **parts per billion**.

Follow-Up Activities:

- Ask students to find their municipality's local water quality report to observe the contaminant profile for their drinking water (if applicable).
- Ask students to select a contaminant listed in the federal drinking water standards and research the source of this contaminant in drinking water.
- Ask students to investigate a case where contaminated drinking water was connected to adverse human health effects – what was the concentration of the contaminant in the water supply? (Also see lesson titled *A Civil Action Case Study* available for download at *http://www.learnnc.org/lp/pages/756*).
- Tour a water treatment plant to see how drinking water is treated prior to distribution to residences and businesses.
- Invite a local water quality expert to your class to discuss local water quality issues with students.
- An emerging concern is that of pharmaceuticals and personal care products (PPCPs) in our drinking water. Ask students to investigate the prevalence of pharmaceuticals in drinking water – at what concentrations are pharmaceuticals present?

Serial Dilution Activity: Student Data Collection Sheet

1. Place your plate with wells on top of a white sheet of paper.
2. Your teacher will place one drop of 10% food coloring solution in wells 1 and 2. Well 1 represents the control well; do not do anything to this well.
3. Using a dropper, add 9 drops of clean water to well #2 and mix; next, place one drop of the colored solution from well 2 into well 3. Rinse dropper.
4. Using the dropper, add 9 drops of clean water to well #3 and mix; next, place one drop of the solution from well 3 into well 4. Rinse dropper.
5. Repeat procedure for wells 4 through 9.
6. Well 1 contained a 10% or 1/10 solution of red food coloring; determine the concentration of food coloring in the remaining wells and record in the data table below.
7. Record the color of the solution in each well in the data table below; you may choose to use a red colored pencil or a ranking system (a ranking of ++++ would indicate a solution was more concentrated than one receiving a + ranking) to record color change.

Well	Concentration	Color of Solution
1 (control)	10% or 1/10	
2		
3		
4		
5		
6		
7		
8		
9		

1. In which well does the solution *first* appear colorless?

   a. Do you think there is any food coloring present in this well?

   b. How could we test to see if any food coloring is present in this well?

2. Which represents a higher concentration, parts per million or parts per billion?

3. Do you think chemicals present in ppm or ppb concentrations are significant to human health? Why or why not?