Clark Fork Watershed Education Program
Education Portal Lesson: What is a Part Per Million?

Prep time: 20 -25 minutes **Time:** 55 minutes **Grade:** 8 (Adapt for other grade levels) **Teacher Lesson Plan Outline:** Page 2: Key Vocabulary Page 3: Lesson Procedure Page 6 : Standards Alignment	**Objectives: Students will be able to:** • Describe the concentration measurements "parts per million" and "parts per billion" and make analogies to other measurements • Define "concentration" and make connections to everyday concentrated products • Discuss the parameters of healthy drinking water standards
Materials: • eye droppers • graduated cylinders • plastic cups • food coloring • masking tape • crayons • lab notebooks	**Correlations to Montana Curriculum Standards** (*coming soon!*)

Additional Resource Documents and Websites

Clark Fork Watershed Education Portal. View at: www.cfwep.org

Morrison, Phillip and Phylis Morrison (1982) Powers of Ten. Redding, Conn.: Scientific American Library, 150 pp.

Schwartz, David M. (1985) How Much is a Million? New York: Lothrop Lee and Shepard, 40 pp. View at: http://interactive2.usgs.gov/learningweb/teachers/globalchange_change_lesson.htm

Vocabulary

Parts per million (ppm): The concentration of a particular substance within water. One ppm is equivalent to the absolute fractional amount multiplied by one million. This measurement is used by the EPA to determine exposure standards to protect the public from harmful substances that can cause serious health effects.

Parts per million can be expressed in mg/L concentration. For example:

- 1 ppm = 1mg/L
- 1/1 million = 0.0000001

An analogy: 4 drops of ink in 55 gallons of water would produce an ink concentration of 1 ppm.

Parts per billion (ppb): The concentration of a particular substance within water. One ppb is equivalent to the absolute fractional amount multiplied by one billion. This measurement is used by the EPA to determine exposure standards to protect the public from harmful substances that can cause serious health effects. This measurement is 1000x ***lower in concentration*** than ppm.

- 1 ppb = 1 microgram/L in solutions; also commonly expressed as 1 µg/L
- 1 microgram/kilogram; or µg/kg in solids (e.g., soil samples)
- 1/1 billion = 0.0000000001

Some analogies: one sheet in a roll of toilet paper stretching from New York to London is a ppb; one pinch of salt in 10 tons of potato chips is a ppb.

NOTE: It is important to note whether a concentration level is expressed in parts per million (ppm) or parts per billion (ppb). Values are presented by the EPA in mg/L (*a part per million*). In order to convert mg/L to **parts per billion**, multiply the mg/L measurement by 1,000. For example, the maximum contaminant level for copper is 1.3 mg/L or 1300 ppb.

Lesson Procedure

1. Engage (Pre-assessment)

- **What does it mean when something is "concentrated"?**
- **List some everyday items that are packaged in concentrated form that you later dilute.**
- **What does it mean to measure something in a part per billion or part per million?**
- **How do we know if our water is healthy to drink?**
- **Who sets water quality standards?**

Making Connections:
The quality of water we drink, and the quality of water in our rivers, streams, and lakes is important to all life. Water pollution can sometimes be detected visually or through an unusual odor. Often, the contaminants or pollutants cannot be detected by sight or smell, but they are there nonetheless. Even in very small quantities, some of these substances can cause harm to humans, or be toxic to the living organisms that rely on or live in the water. The effects of historic mining on water can be tested in rivers and streams many years after mining operations have ceased. What is in the water? Is the water safe or unsafe?

2. Explore

Have students make a list of everyday "concentrated" household items. For example, students might list juices, Kool-aid packets, laundry detergent, etc. Have students explain what "concentrated" means and discuss what they do to prepare their products; e.g., to make juice, I have to dilute the juice concentrate with three cans of water. (It may be helpful to have a can of juice concentrate to describe this section of the lesson).

Prepare four containers with beads, marbles or other materials of varied colors, using the ratios of 1:100, 2:100, 5:100, and 10:100. Have students estimate the "parts per 100" in each container and the percent concentration of each container. For example, in the first container, there may be 99 clear beads and one blue bead. The blue bead is 1 part per 100 and the percent concentration of blue beads is 1%. In contrast, 1 part per million is equal to .0001%, or ten thousandths of one percent. (It takes 10,000 parts per million to equal 1%).

3. Explain

Depending on age, ability level and available resources, teachers may want to skip the following procedure.

Students are guided and work through calculations of parts per 100, per 1,000, per 10,000 and per 1,000,000 using the worksheets provided.

Materials needed for each group of three students:

- One eyedropper
- Supply of water
- A cylinder with 10-milliliter graduations
- Three 12-ounce clear plastic cups
- Masking tape
- Marking pen
- One bottle of dark food coloring
- A calculator
- One box of crayons or colored pencils
- Science notebook for recording results

Students will create three samples. **Sample 1** will be 1 part per 100; **Sample 2** is 1 part per 10,000; and **Sample 3** is 1 part per 1,000,000.

Answers to guided inquiry questions:

Sample 1: Because you have added one drop of food coloring to 99 drops of water, the concentration is one part per hundred, which can also be expressed as 1/100 or 1%. The color should be visible.

Student answers to how to clean the water sample will vary, but filtering will probably be a common answer. Although filtering will remove large particles, it will not change the water chemistry or what is dissolved in the water. Depending on age and ability level, the teacher may wish to elaborate on this point.

Sample 2: To 99 drops of new water, you add one drop of the solution from Sample 1, which consists of .99 parts water and .01 parts food coloring. Because you have now diluted the .01 drop of food coloring in a total of 100 drops of solution, divide .01 by 100. Your answer is 0.0001 or 1/10,000. This solution is now 1 part per ten thousand. Depending on the color used, the food coloring in sample 2 should be faintly visible.

Sample 3: To 99 drops of new water, you add 1 drop from the solution in Sample 2. The one drop is 0.9999 parts water and 0.0001 parts food coloring. To calculate the concentration of food coloring in Sample 3, divide 0.0001 by 100 (the total number of drops in the solution). The answer is 0.000001 or one part food coloring in one million or 1/1,000,000. The food coloring will not be visible at this concentration.

Making a parts per billion sample:

Continue the procedures described above. Begin with 99 new drops of water. Use one drop of the parts per million solution. You will get 0.00000001 parts food coloring or one part food coloring in one hundred million (1/100,000,000).

For the final step, take **nine new drops** of water and add it to the previous solution. To calculate the concentration of the sample, divide 0.00000001 by 10 (the total number of drops in the solution). The answer is 0.000000001 or one part per billion.

NOTE: Students may tend to think that adding the number of drops is the appropriate method for calculating the concentration. Remind students that their ONE drop of solution is only a FRACTION of the original solution, therefore that fraction is being diluted 100 times more every cycle. In other words, the amount of food coloring in the solution is getting smaller and smaller by a power of 100 every cycle.

4. Elaborate/Extend

Tailings Storage and Concentration Level:

The issue of concentration levels within the Clark Fork Watershed becomes readily apparent when discussing questions such as where to locate or store the tailings and sediments that are being removed throughout the watershed. The concentration of metals within Silver Bow Creek and sections of the Clark Fork River are too high to sustain healthy plant, macroinvertebrate, and fish populations. The location of the tailings next to stream necessitates removal in order to effectively restore the stream channel.

Communities have struggled to answer the questions related to re-location of the tailings. Where should we locate the tailings we have removed from the rivers? What is the best solution? What is a "safe" storage site for tailings? What are the possible impacts to areas surrounding a tailings storage site? Should we store tailings at a site that is already impacted or should we create a new storage site?

Students could attempt to answer these questions related to where to store tailings as part of their exploration of parts per million and understanding of concentration levels. The activity Not in My Backyard, located in the Clark Fork Education Portal illustrates the point of concentration relevant to storage of tailings and helps students to think through the consequences of locating "toxic substances" at one location or another. View the lesson at www.cfwep.org.

Drinking Water and Concentration Level:

One of the main factors in the decision to remove the Milltown Dam was the impact to groundwater wells that people in the community of Bonner were using for drinking water. Arsenic was found in some of the residents' wells. Scientists suspected that the contamination was coming from tailings deposited behind the Milltown Dam. The concentration of tailings behind the dam was much smaller than concentrations in slickens deposits far upstream in Silver Bow Creek, however, the location of these tailings behind the dam in relationship to the groundwater aquifer were of major concern despite their lower concentration level. The activity Not in My Backyard helps to further illustrate the issue of concentration. When paired with the activity, Mapping Water Quality, students can begin to form a comprehensive picture of what is happening within the Clark Fork Watershed as related to concentration and location of tailings deposits.

5. Evaluate (Assessment)

Evaluation for this lesson consists of the student worksheets and in-class evaluation for understanding of the material.