Country Club Ichthycide

LESSON 3
Parts per Million

Adapted from, Investigating Groundwater: The Fruitvale Story

TEACHER NOTE: Omit this lesson if students have a working knowledge of ppm.

Overview
Students mix food coloring with water, producing a serial dilution of food coloring in water. Students observe a gradual decrease in color of the solution as more water is added, until color is no longer visible. Students learn the meaning of concentration and dilution and how these terms are expressed.

TEKS (8th Grade Science)
1A, 2A, 2B, 2C, 2D, 11A

Time
One class period

Purpose
The students will:
1. Explain the meaning of concentration and dilution
2. Understand concentrations expressed as parts per million and parts per billion
3. Carry out a serial dilution procedure
4. Understand how ppm and ppb relate to water quality

Materials
For each student:
- Student Sheet 3.1-Parts per Million

Lab materials for each group of 4-5 students:
- Chemplate
- Medicine dropper
- Paper towel
- 15-20 ml tap water for filling large cup in each Chemplate
- Small cup for rinse water

For the teacher:
- Transparencies of newspaper articles with a ppm or ppb reference (at end of this lesson)
- Transparencies of relationship between cups, ppm examples, and math examples (at end of this lesson)
- Dropper bottle of food coloring
- Overhead of Student Sheet 3.1

Getting ready
Prepare the Chemplates and medicine droppers for easy distribution. Duplicate copies of student sheet 3.1. If desired, ask students to bring newspaper articles that discuss ppm or ppb to use with the activity.

BACKGROUND

1. Concentration units
Some toxic substances are dangerous even in very small amounts.
"Parts per million" (ppm) and "part per billion" (ppb) are the units of measure scientists use to describe the concentration of a hazardous substance or contaminant found within a large volume of another substance. For instance, you could find 500 ppm of a pesticide in a lake.

Measuring the Concentration: Expressing the amount of contamination in ppm or ppb is ***measuring the concentration*** of the substance. This way, a scientist can take a relatively small sample of water, from a lake for example, and measure the concentration of one or more contaminants in that sample, then assume that the concentration is the same in the whole lake without testing the entire lake.

☛ Examples from Current Events: Read aloud selected excerpts (or use the one in this lesson) of any newspaper articles that refer to concentration levels, such as parts per million, parts per billion, or parts per trillion. Ask students what these concentration levels mean in everyday terms. For example, if fluoride is added to the city's drinking water supply at levels of 1 ppm or 1 ppb, what is the difference?

Concentration Levels and Toxicity: Some of these substances measured in ppm or ppb are colorless, odorless, and tasteless, yet even in small amounts they can be toxic. Many chemicals become toxic at high levels of a particular concentration (ppm or ppb). For example, the acute toxic dose of fluoride is 8 ppm of body weight. The average amount of naturally occurring fluoride in Austin's drinking water is 0.78 ppm. Austin allows up to 4.0 ppm to be added to our drinking water as a benefit rather than a hazard.

2. The Meaning of Solution and Dilution
Solution is the result of dissolving a solute in a solvent. Solution may be expressed as a percentage, and represents the percent of solute per unit volume. For example, seawater is a 3% solution of salt in water. This solution concentration could also be expressed as five parts per hundred of salt since "percent" means parts per hundred parts.

Dilution is the process of reducing the concentration of a substance (or contaminant) per unit volume. Dilution may be expressed as a fraction. For example, seawater is 3/100 parts salt.

☛ Display Transparency- **The Meaning of Percent.**

Percent means "parts per hundred," so 10% means 10 parts per 100 parts, which in mathematical terms = 1/10.

10% solution= 10 parts per 100 = 1/10 dilution

Example:
Three percent of seawater is salt. Ask students what this means.

☛ Sea water is slightly over 3% salt. Therefore, according to the meaning of percent, 3 parts out of 100 parts of sea water are salt, or a 3/100 dilution. Thus, if 100 grams of sea water were evaporated completely, 97 grams of water would evaporate and 3 grams of salt residue would remain.

Sea Water = 3% salt solution = 3 grams salt + 97 grams water = 100 grams of total solution
A 3% salt solution =3 parts per 100 = 3/100 dilution

Practice Examples:

☛ Suppose you have a 5% solution of sugar in water. How many grams of sugar for every 100 grams of solution? (5 grams). How many parts are water? (95 grams) What is the dilution? (1/20)

5% sugar solution = 5 grams of sugar + 95 grams of water = 100 grams total solution
A 5% sugar solution = 5 parts per100 = 1/20 dilution

☛ Hold up a bottle of food coloring and tell the students that it is made from colored pigments and water. It is a 10% solution. How many parts are pigment? (10 parts) How many parts are water? (90 parts)

10% food coloring solution = 10 grams of pigment + 90 grams of water= 100 grams total solution
A 10% food coloring solution = 10 parts per100 = 1/10 dilution

Independent Practice:

☛ Hand out student sheet 3.1 and have the students answer questions 1-4. Review them if necessary.

3. Dilution Math

☛ Tell students that during the lab, they will dilute a 10% food coloring solution. How would you express mathematically a 10% solution as a dilution?

A 10% food coloring solution = 10 parts per100 = 1/10 dilution

☛ Display second half of Transparency- The Meaning of Percent and **Serial Dilution.**

If you start with one drop of the 1/10 food coloring dilution and add 9 drops of water.

1 drop red food coloring dilution + 9 drops water = 1 part of 10 = 1/10 dilution
or a 1/10 dilution of the 1/10 food coloring dilution
= 1/10 x 1/10
= 1/100
1/100=x/1,000,000
x=10,000 ppm

If you take one drop of the 1/100 food coloring dilution and add 9 drops of water, you have

A 1/10 dilution of the 1/100 food coloring dilution
=1/10 x 1/100
=1/1,000
1/1,000 = x/1,000,000
x=100 ppm

If you continue to add 9 drops of water to 1 drop of the previous food coloring dilution, you will continue to multiply the previous dilution by 1/10 to determine the dilution and ppm. This is called a serial dilution.

LAB ACTIVITY

During the lab, you will be making a serial dilution to help you comprehend very small numbers.

☛ Distribute Chemplates, medicine droppers, and food coloring. The large reservoir of the Chemplate holds sufficient water for the activity. Students may obtain water from the tap, or you may prefer to distribute water to students in a small beaker or similar container.

☛ Demonstrate how to add drops of food coloring. It is important that they hold the bottle of food coloring vertically so that the drops produced are consistently the same size. A piece of white paper placed under the Chemplate makes it easier to detect and describe colors.

☛ Model the correct technique for using the medicine dropper. In order to fill the dropper, students should first squeeze the bulb gently and place the tip into the solution. If the bulb is then released, the solution may be drawn up evenly without spattering or introducing solution into the bulb. The dropper should never be turned over so that solution runs into the bulb. Holding the dropper vertically makes it possible to obtain drops of water between uses. Monitor student progress and assist them as needed. Encourage them to proceed as independently as possible. Have students fill out the results table on student sheet 3.1

4. Follow-up discussion

☛ Ask the students, "In which cup are you first unable to observe any color?" This will generally occur in cup 6, but be prepared for a range of answers. Discuss their answers, pointing out that **any time a task requiring a measurement is performed by individuals, variation is expected**. For example, drop sized vary somewhat when using droppers. The physical quantity or relationship does not change; the ratio of color to water that is detectable by the average human eye are not expected to vary. The variation arises as we carry out the procedures that depend on our perception, technique, and judgement.

☛ Ask the students whether food coloring is present in cups 6, 7, 8, and 9. (Yes, they removed some liquid from cup 5 to add to cup 6; this liquid contained food coloring; therefore, food coloring is present in cup 6, but at a dilution too small to be visually detected.)

☛ Ask them whether they can think of a way to prove the presence of food coloring in each cup. Allowing the water to evaporate is one possibility. If this is done, a colored residue will generally form in cups 1-6. They can also run a chemical test to detect the presence of food coloring in very small concentrations.

5. Meaning of part per million and part per billion

☛ Display the transparency "Relationship between cups". The chart can help students understand the relationships between the cups. As students understand the relationships between cups 1 and 2, the rest should follow by induction. Cup 3 represents a concentration of one part per thousand, cup 6 represents a concentration of one part per million, cup 9 represents a concentration 1 part per billion.

☛ Highlight the cups showing the difference between ppm and pbb. Discuss the relation between part per million and part per billion shown in the table. Most contaminant screening levels in water are measured in parts per billion. This is one thousand times smaller than ppm.

☛ Discuss question #10 and display the drinking water standards. The allowable limit for Toxaphene (a type of pesticide) in drinking water is 3.0 ppb (or 0.003 ppm). In 1976 it was 5.0 ppb. Some students may disagree with these levels, suggesting that they would not drink water containing any pesticide. For them 0 ppb is the only safe level. You may wish to respond that it is impossible to remove all the pesticide. Even to reduce it to extremely small levels, say 1 ppb or less, is extremely time consuming and costly. The important decision health officials have to make concerns the level at which the pesticide is harmful to our health.

6. Answers to questions on student sheet 2.1

1. 3 grams of salt would remain.

2. To produce 50 grams of a 10% salt solution, mix 5 grams of salt with 45 grams of water.

3. To produce a 10% solution, mix powdered dye and water in a 1:9 ratio.

4. parts per million is larger than parts per billion (do not count this wrong if they answer incorrectly)

5. Student answers may vary. Most report cup 6 as the first cup in which color is no longer visible.

6. The concentration of cup 6 is 1 part per million.

7. Answers vary. Most will infer the presence of food coloring, even though it cannot be seen.

8. Students might answer that filtering the water through a substance like sand or through paper might "clean" it, but filtering will not remove a chemical solution. No such simple process as filtering the water will remove all the food coloring. Reducing the amount of pollution by human activity reduces the need to remove it later.

9. Some students may suggest evaporating the water and examining the cups for residue.

10. No wrong answer. The allowable limit for Toxaphene (a type of pesticide) in drinking water is 3.0 ppb (or 0.003 ppm).

7. Clean up

Unless students wish to set out their Chemplates to evaporate the water, have them rinse, dry, and store them according to your directions. If you are using the module with more than one class, you may wish to save one Chemplate to show color residues.

8. Homework (optional)

Have students research the world wide web to find articles that discuss ppm or ppb, particularly as they relate to Austin or Texas. They might try searching www.cnn.com, www.statesman.com, or www.enn.com using "ppb" as a search term.

"Powers of Ten" is another great website to explore.
http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

Elevated toxic levels found in parking lots

High levels of chemical detected at Statesman, churches, apartments

By Ralph K.M. Haurwitz

The City of Austin sent notices Tuesday to several property owners — including the Austin American-Statesman, two churches, a home improvement store and an apartment complex — informing them that elevated concentrations of a toxic chemical have been found in soil and sediment on or next to their parking lots.

The chemical, known as benzo(a)pyrene, causes harmful developmental and reproductive effects and is also considered a likely human carcinogen. It is a member of a class of compounds known as polycyclic aromatic hydrocarbons, which are primarily byproducts of incomplete combustion.

The concentrations of benzo(a)pyrene found in the city's testing at the parking lots range from 43,000 to 290,000 parts per billion. Those concentrations far exceed the maximum levels that state environmental authorities consider safe in soil: 500 ppb in residential settings and 2,400 ppb in commercial or industrial areas...

In samples taken Jan. 15 from the newspaper's west parking lot, benzo(a)pyrene levels were 219,000 ppb in sediment that collected against a curb and 43,000 ppb in sediment taken from several landscaped beds. Sediment from a fenced stormwater retention pond between the west parking lot and Town Lake registered 104,000 ppb of benzo(a)pyrene...

Mike Laosa, publisher of the American-Statesman, said the newspaper would contact authorities to learn whether testing, cleanup or other measures are warranted.

"We will make sure we will do whatever is required to continue to have a safe place for our employees and to be a responsible corporate citizen," Laosa said. Polycyclic aromatic hydrocarbons, or PAHs, occur naturally in crude oil and coal and are produced by industrial and power plant emissions, vehicle exhaust, tires and asphalt roads and roofs. They are also generated by grilling or smoking meat and by smoking tobacco.

Articles published by the American-Statesman have documented elevated levels of PAHs in sediment in Barton Springs Pool and Barton Creek and in soil upstream of the pool...Elevated levels of these chemicals also have been detected in other Austin waterways, including Waller and East Bouldin creeks. City officials say they believe that the contaminants in the Barton Creek area, as well as in the parking lots, come from coal-tar-based sealants that are widely used to cover asphalt parking lots.

The Meaning of Percent

10% = 10 parts per 100 parts = 1/10

Sea Water = 3% salt solution

3 g salt + 97 g water = 100 grams of total solution

A 3% salt solution = 3 parts per 100 = 3/100 dilution

5% sugar solution

5 g of sugar + 95 g of water = 100 grams total solution

A 5% sugar solution = 5 parts per 100 = 1/20 dilution

10% food coloring solution

10g of pigment + 9 g of water= 100 grams total solution

A 10% food coloring solution = 10 parts per 100 = 1/10 dilution

Serial Dilution

*A **10%** food coloring solution*

10 parts of 100 = **1/10 dilution**

1 drop red food coloring dilution + 9 drops water =

1 part of 10 = 1/10 dilution

A 1/10 dilution of the 1/10 food coloring dilution

= 1/10 * 1/10

= 1/100

1/100= x /1,000,000

x=10,000 ppm

A 1/10 dilution of the 1/100 food coloring dilution

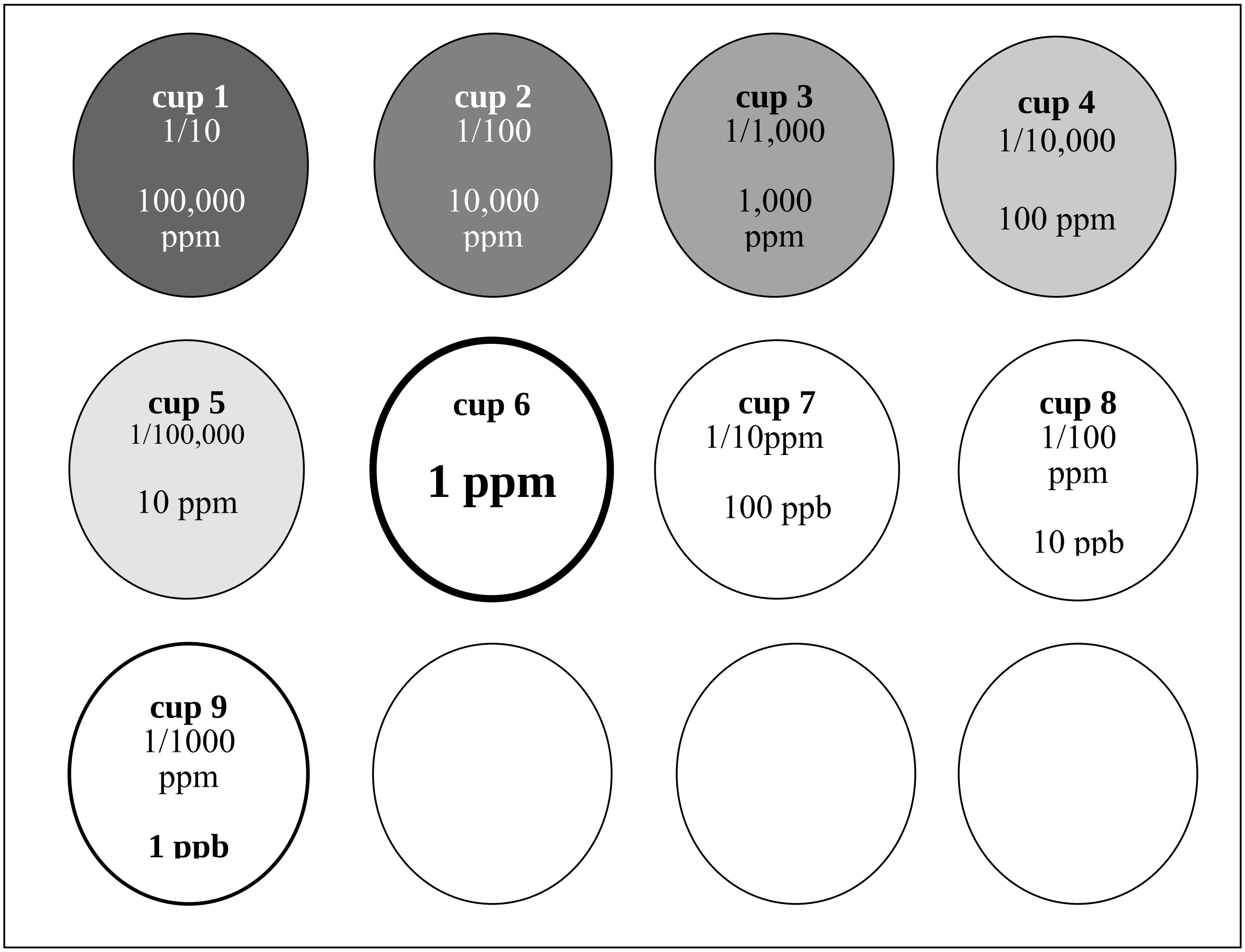
=1/10 * 1/100

=1/1,000

1/1,000 = x /1,000,000

x=100 ppm

Relationship between cups



Parts Per Million and Parts Per Billion Comparison

One part per million	One part per billion
1.0×10^{-06} or 0.000001	1.0×10^{-09} or 0.000 000 001
1 second in 12 days	1 second in 32 years
1 cent in $10,000	1 cent in $10 million
1 inch in 16 miles	1 inch in 16,000 miles
1 drop in 10 gallons (about the size of a fish tank)	1 drop in 10,000 gallons (about the size of a small swimming pool
1 mg/l	1 µg/l

- One part per trillion would be equal to one drop in 10,000,000 gallons (about the size of a small stock pond)

- Some forms of the organic compound, *Dioxin*, are considered so harmful, that maximum levels are set in terms of parts per quadrillion (0.000 000 000 001)