Chapter 3. Mixing and Moving in the Environment

Lesson 2. Diffusion and Convection

Overview: Water quality varies with several factors, including:

1. contaminants and other things that might show up in the water,
2. the standards or limits of water quality we will accept or tolerate, and
3. the history and processes the water goes through before it is used.

In essence, almost anything can be considered a "potential" contaminant. Correspondingly, do not view anything physical, chemical or biological as a contaminant until it is in the water supply. How water behaves affects how contaminants behave.

Purpose:

The purpose of this lesson is to show that the physical environment in which the contaminant is placed strongly influences the contaminant. Water plays a very significant role in contaminant behavior; consequently, contaminant behavior is much different in ground water systems than in surface water systems like lakes, streams, ponds and reservoirs.

Ideas Taught:

- Contaminants generally move much more quickly in surface water systems than in soil/ground water systems; consequently, dilution and soil mixing occur much more quickly in surface water systems than in soil and ground water systems.
- The processes responsible for contaminant movement are diffusion (movement due to concentration gradients) and convection (movement due to physical transport and dynamic mixing).

Materials Needed:

- Two small plastic or styrofoam soup bowls
- Red and blue food coloring
- Supply of cold water
- Supply of hot water (warm/hot tap water will work)
- Four 1/2 pint wide-mouth jelly jars
- 3" x 3" sheet of very thin metal sheeting (index card may work)

- Plastic wash tub or metal cake pan (to catch the spills)
- Plastic spoon

Procedure:

This demonstration works because of differences in water temperature, which cause differences in water density, molecular motion and a gradient or driving force to illustrate diffusion and convection. For the warm/hot water part of this activity, use the warmest tap water you can work without any risk of injury.

1. ___ About five minutes in advance of this activity, fill one bowl to within 1/2 inch of the top with warm water. Fill two of the jelly jars completely to the top with warm water (they must be filled right to the very top).

2. ___ Fill the other bowl to within 1/2 inch of the top with cold water and fill the two remaining jelly jars completely to the top with cold water.

3. ___ Place the jelly jars inside the plastic tub and place the bowls on the desk. The purpose of filling the bowls and jars in advance is to give the after time to stop moving in the bowls and jars before starting the demonstration.

4. ___ For the first part of this demonstration, add one drop of red food coloring to each bowl of water. When you add the food coloring, add the same amount to each bowl, one drop at a time, from a distance of about an inch above the water surface.

5. ___ Observe what happens to the food coloring in each bowl. You should see a different pattern of movement in the cold water than in the warm water.

6. ___ Discuss with the class what has happened. Explain that cold water has a different density than warm water. Consequently, the water molecules are closer together in cold water than in warm water. (If you really want to exaggerate this phenomenon, you could also use a block of ice. contaminants do not move very well through solid objects.) In addition, the molecules in the warm water have more motion than the molecules in the cold water. The primary process of movement of the color is due to "diffusion" - a slow migration away from the concentrated source to the less concentrated water.

7. ___ To see the effect of diffusion, and to contrast it with convection, use the plastic spoon to mix the cold water vigorously. NOte that the food

coloring mixes quickly throughout the bowl. Compare this with the unmixed water.

8. ___ Leave the bowls undisturbed for several hours or overnight. You can see that by convection, (rapid physical movement and mixing) the cold water bowl was completely contaminated in a short time. The unmixed warm water bowl was contaminated by diffusion, which took much longer, but eventually got to the same point.

9. ___ Discuss these mixing processes concerning contamination in surface water in the soil, where very little rapid mixing occurs except from irrigation, flooding or drainage.

10. ___ For the second part of this demonstration, you will need to use the water-filled jelly jars. All the jars should be in the plastic tub (to catch any spills).

11. ___ Add one drop of red food coloring to each of the cold water jars. Add one drop of blue food coloring to each of the warm water jars.

12. ___ Place the index card or metal sheeting over the mouth of a jar filled with warm water (blue food coloring). Hold firmly the card or sheeting which you have pressed tightly against the mouth of the jar.

13. ___ Invert the jar of warm water, and place it directly over the opening of a cold water (red food coloring) jar. Hold both the jars in place.

14. ___ Slowly slide the card until the edge of the card is immediately above the point where the jar mouths meet.

15. ___ Now quickly pull the card out, causing the mouths of the two jars to line up exactly on top of each other. All (or almost all) of the water in the top jar should stay in the top jar.

16. ___ Observe what happens to the red and blue colors. If you do everything right, the colors should stay in place, with a small amount of mixing right at the point where the mouths of the jars meet each other. If you observe the jars for an extended period, you will begin to see some mixing. It is very gradual, and occurs only where the two fluids mix. The mixing process is mostly due to diffusion, with some thermal mixing also occurring. Remember

that the warm, blue water on the top is less dense than the cold, red water on the bottom.

17. ___ To observe mixing due to convection, or physical movement such as in a stream or river, follow the same procedure as above, except place the cold, red jar on top and the warm blue jar on the bottom. Watch closely, because the mixing occurs almost instantaneously when the card is removed.

Lesson Learned: Keep in mind that lakes do mix regularly due to thermal gradients. However, at the bottom of a lake or pond, most of the mixing will be due to diffusion, movement due to concentration gradients. At the surface or in a stream or river, much of this mixing occurs due to convection, or physical mixing. In groundwater systems, especially under saturated conditions, little mixing or movement occurs except due to diffusion or very slow, gradual convection.

The lesson above was adapted from "*What is Water Quality? A Resource Guide for 4-H Leaders and Teachers*," 80 pages of activities and experiments related to water quality. ($5.00) Order from the Montana 4-H Program at Montana State University-Bozeman. Phone 406-994-3501.