Parts Per Million

Students gain an understanding of the concepts Parts per Million (ppm) and Parts per Billion (ppb) by carrying out a series of dilutions of food coloring.

Level(s): 6-8

Subject(s): Science, Mathematics

Virginia SOLs: Math 6.2; Math 7.1; Math 8.1 b; 6.9 c; PS1 b,e

Objectives:
Students will be able to:
1. Give the metric equivalent of parts per million (mg/L)
2. Demonstrate how to reach a dilution of Parts per Million.

Materials:
For each pair of students:
- Solid coffee stirrers or equivalent
- Medicine dropper
- Set of 9 small, clear, plastic or glass containers such as watch glasses or plastic spoons
- White paper
- Clean water for rinsing medicine dropper

For each four students:
- Food coloring to represent contaminant
- Clean water for diluting

Estimated Time: 30-50 minutes

Background Information: see www.epa.gov/safewater/mcl.html#mcls for federal drinking water standards for permissible concentrations of pollutants expressed in ppm.

Activity Procedure:
1. Explain to students that concentrations of chemical pollutants and other contaminants are frequently expressed in units of *parts per million* (ppm) or *parts per billion* (ppb). For example, chemical fertilizers contain nitrates, a chemical that can be dangerous to pregnant women even in quantities as small as ten parts per million. Also explain that ppm is the same as milligrams per Liter. (Optional: make up a handout of examples of the use of ppm in federal drinking water standards and discuss these with the class).

2. To better understand how small ppm or ppb is, assign students the task of expressing either unit in terms of the following experiences:

   a. The average distance to the moon is about 239,000 miles, or about 1.2 billion feet. So if you jump 1.2 feet in the air, you have jumped one part per billion of the distance to the moon.
   b. The average distance to the sun is about 93 million miles. When you drive 93 miles you have driven one ppm of the distance to the sun.
   c. If a record sells one million copies, then a single record is one ppm.
   d. Challenge students to find other examples. Encourage creative imagination.

2. Divide the students into pairs. Have each pair line up the clear containers side-by-side and place a piece of white paper under each one. From left to right, number the paper from *one* to *nine*.

3. Place ten drops of food coloring into container #1. Explain that food dye, as it comes from the bottle, is already a dilution of about one part in ten (1:10).

4. Place one drop of food coloring in container #2.

5. Add 9 drops of clean water to container #2 and stir the solution. Rinse the medicine dropper.

6. Use the medicine dropper to transfer one drop of the solution in container #2 to container #3. Add nine drops of clean water and stir the solution. Again rinse the dropper with clean water.

7. Transfer one drop of the solution in container #3 to container #4. Add 9 drops of water and stir. Rinse the dropper with clean water.

8. Continue the above process until all nine containers contain successively more dilute solutions.

9. Complete the PPM and PPB Data Sheet. You may want students to express the numbers using powers of ten (exponents) rather than writing them out.

Assessment Opportunities:
1. The abbreviation "ppm" stands for *parts per million* .
2. List some possible reasons why our senses alone may not be sufficient for detecting pollutants. *In low concentrations chemicals which do have taste, odor or color may be so dilute that our senses cannot detect them.*

Extensions:
1. Allow the water in the containers to evaporate and observe what remains in each container.
2. Perform a test for ppm of Dissolved Oxygen (DO) in water.
3. Do the activity *How Much is Too Much?*
4. Have students perform a similar experiment with salt to discover at what concentration they can no longer detect it by taste.

PPM and PPB Data Sheet

Name: ____________________________________

Class/Section: ____________________________________

Date: ____________________________________

Check off the box for color if you can detect any color in the liquid.

Container #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Color									

Questions

1. The food coloring in container # 1 is a food coloring solution which is one part colorant per ten parts liquid. What is the concentration ins successive dilutions?

Container #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Concentration	1/10	1/	1/	1/	1/	1/	1/	1/	1/

2. What is the concentration of the solution when the diluted solution first appeared colorless?

3. Do you think there is any of the colored solution present in the diluted solution even though it is colorless?

4. What would remain in the containers if all the water were removed?

5. (Optional) Allow the water in the containers to evaporate and record your observation on what remains in the containers.

Adapted from **Water Wisdom, 2nd Edition**, pp. 132-135

Drinking Water Quality

Students learn about regulations governing drinking water quality and how to test drinking water for various parameters. They also graph data on drinking water collected over a month.

Level(s): 6-8

Subject(s): Life Science, Chemistry

Virginia SOLs: 6.5 a,b,f,g; 6.7 f,g; 6.9 a,d; LS7 a; LS12 e; PS1 a,j

Objectives:
Students will be able to:
1. Explain the difference between **Maximum Containment Levels** (MCLs) and **Maximum Containment Level Goals** (MCLGs).
2. Explain the difference between primary standards and secondary parameters.
3. Perform chemical tests on drinking water and explain their significance.
4. Graph data for several parameters collected over a month.

Materials:
- thermometer
- commercial water test kits to measure chlorine, iron, hardness/alkalinity, color, pH
- (optional) commercial water test kits to measure nitrates and/or heavy metals such as copper or lead
- Drinking Water Monitoring Data Sheet

Estimated Time: 45-50 minutes for the initial and final class
15 minutes two or three times a week for a month

Background Information: *Water and Drinking Water Quality*, p.72.

Preparation:
1. Familiarize yourself with the concepts outlined in the article *Drinking Water*.
2. Make a copy of the Drinking Water Monitoring Data Sheet for each student group, and one for each test, to be posted in the classroom.
3. Identify a source of water to monitor, such as a classroom or laboratory sink, or a hallway water fountain.
4. Decide how many times a week you will be having students monitor their drinking water and prepare a rotating schedule of water monitoring to be done two or three times a week for a month. Rotate the test kits through the groups so that every group has an opportunity to perform each test at least once or twice.

Activity Procedure:

1. Discuss the importance of standards for drinking water quality. Ask the students to list contaminants that might be dangerous in drinking water. Discuss the significance of MCLs and MCLGs. Discuss some of the origin and effects contaminants such as lead, dioxin, arsenic, mercury and benzene, and what their MCLs are (you may want to discuss the concept of parts per million and milligrams per Liter).

2. Demonstrate the use of each test kit, calling on volunteers to perform each test under your direction.

3. Divide the students into groups and assign each group a thermometer, a test kit, and a copy of the Drinking Water Monitoring Data Sheet. Each group will follow the rotation chart you have prepared and perform a test two or three times a week (a different test each time). As temperature is a simple test, you could combine temperature with pH.

4. Have each group record their test results on their own data sheet and on the classroom data sheet. Continue the process for a month.

5. At the end of a month have each group graph the data for one test and report any trends they perceive. Discuss possible reasons for any fluctuations (including inconsistencies in performing tests). Do any of the fluctuations among parameters seem to coincide either negatively or positively? Graphs of different parameters can be combined for comparison.

Assessment Opportunities:

Have students:

1. Explain the difference between MCLs and MCLGs.

2. Give examples of 2 contaminants that are regulated in drinking water, their possible sources and potential effects on human health.

3. Explain the difference between primary and secondary parameters and give examples of each.

4. Have students graph a set of data.

Extensions:

1. Arrange a tour at the local water treatment plant.

2. Have students research drinking water quality issues such as contamination by lead, arsenic and bacteria such as *cryptosporidium*.

Adapted from **Action for a Cleaner Tomorrow**, pp. 502-504.

Drinking Water Monitoring Data Sheet

TEST: ____________________________

Date	Group	Results ppm

Date	Group	Results ppm

Water and Drinking Water Quality

In a water molecule, the two hydrogen atoms and one oxygen atom share the molecule's electrons in a covalent bond. The atoms are positioned so that the two hydrogen atoms are together at one end of the water molecule and the oxygen atom is at the other end, forming a "V" shape. While the electrons are shared between all three atoms, the oxygen atom holds the electrons for most of the time and the two hydrogen atoms hold the shared electrons only briefly. This causes the water molecule to act like a tiny magnet with a mild negative charge at the oxygen end of the molecule and a mild positive charge at the hydrogen end. Because the water molecule exhibits definite positive and negative charged ends it is classified as a polar molecule.

Water is also known as the universal solvent because it has the ability to dissolve most of the substances with which it comes in contact. These substances tend to dissolve because they interact with the weak electrical charges on each end of the water molecules.

As water travels through the hydrologic cycle, it binds to various substances from its surroundings and becomes contaminated. Contaminated water travels down rivers and streams carrying the dissolved materials to the ocean. Some dissolved substances contribute to the ocean's salinity.

If water is to be used for drinking, it must be cleaned of contaminants to make it suitable for consumption. The federal government and the VA Department of Health, have established regulatory limits for more than 80 known contaminants, and acceptable levels for other parameters such as pH, temperature and color.

It is not economically feasible to have totally pure water for drinking. Therefore, there are two standards for allowable levels of drinking water contamination. These are called primary standards and secondary standards. Primary standards directly affect human health, while secondary standards are for more aesthetic qualities such as taste and color. Primary standards can be measured in several ways, one of which is the maximum containment level. Maximum containment levels have two categories, maximum containment level goals (MCLG) and maximum containment levels (MCL).

MCLGs are not enforceable, and are not associated with adverse health effects from drinking water with this level of contamination. MCLs, on the other hand, are the enforceable standard and are usually set as close to the MCLG as possible. One factor in establishing MCLs is the cost and technology necessary to attain a specific level of purity. In short, an MCLG would represent a perfect world. The MCL is the contamination level which the public water system may not exceed in order to be in compliance with regulations and still provide, safe, healthy drinking water. For a chart showing federal standards for MCLGs and MCLs, see www.epa.gov/safewater/mcl.html#mcls. Virginia's standards are the same as federal standards.

A water treatment plant is a busy place. Not only is water constantly being cleaned and disinfected, but is also constantly monitored for its quality both entering and leaving the plant. Temperature, pH and chlorine levels are checked around the clock to ensure proper performance of the treatment process. Other parameters are also checked regularly.

Adapted from **Action for a Cleaner Tomorrow**, pp. 502-504.

How Much is Too Much?

Students practice what they've learned about parts per million (ppm) and parts per billion (ppb) by calculating the amount of an environmental contaminant in a body of water. A good follow up for the lesson plan *Parts per Million*.

Level(s): 6-8

Subject(s): Science, Math

Virginia SOLs: Science**:** 6.5 a,f,g; 6.7 a,f,g; 6.9 a,c,d; LS11 b; LS12 d,e Math: 6.10; 8.3; 8.7

Objectives:
Students will be able to calculate ppm and ppb of contaminants in a body of water given the amount of the contaminant and the volume of the body of water.

Materials:
Student worksheet *How Much is Too Much?*

Estimated Time: 30-50 minutes

Background Information: see lesson plan *Parts Per Million*, p.66.

Activity Procedure:

1. Review the concepts parts per million (ppm) and parts per billion (ppb).

2. Hand out the student work sheet *How Much is Too Much?*

3. Have students work on the problems individually or in pairs. If the class has difficulty with the concept or the math involved, you might want to walk them through one or two of the problems.

4. Go over the answers with the class. You might want to have students give instructions to a student at the board, who will perform the calculations step-by-step.

Assessment Opportunities:
Give students a similar word problem to solve for ppm and ppb.

Extensions:

1. Have students make up their own word problems and share them with the class.

2. Find examples of spills of contaminants near large bodies of water in the news and have the class perform calculations of the ppm and ppb of a hazardous or toxic substance that could result.

How Much is Too Much?

Student Worksheet

1. The EPA Criminal Investigations Unit is attempting to track down the parties responsible for dumping five gallons of herbicide 2,4-D in Swimming Pond. If the chemical becomes evenly dispersed, what would be its concentration in ppm? In ppb? Should the U.S. EPA restrict access to Swimming Pond? Why?

2. The State Highway Patrol has notified the VA Department of Environmental Quality that six gallons of benzene were accidentally spilled into Clear Lake. If it is evenly dispersed, what would its concentration be in ppm? In ppb? Should the residents who depend on the lake for drinking water be notified? Why?

3. An old rusted, unmarked 55-gallon drum was discovered on a property of a resort near Clear Lake. Although the manager suspects it may contain a hazardous chemical, he asks his assistant to get rid of it any way he can. Calculate the concentration of contaminant in the ground water if a 55-gallon drum of the chemical were illegally disposed of in an old well and dispersed evenly throughout the Deep Rock Aquifer.

   What if the same quantity of the chemical were disposed of in Clear Lake? In Swimming Pond?

4. Suppose a 5,000 gallon truck loaded with the chemical arsenic ran off the highway and all the chemical spilled into Clear Lake. What would be the concentration of chemical in the lake? Does this violate federal standards?

Federal Drinking Water Standards for Selected Chemicals and Compounds

Benzene: 0.005 ppm = 5 ppb

Arsenic, Lead: 0.05 ppm = 50 ppb

2.4-D (a weed killer):
0.10 ppm = 100 ppb

1,1,1,-Trichloroethane (TCE):
0.2 ppm = 200 ppb

Fluoride: 4 ppm = 4,0000ppb

Conversion Table

1 cubic foot = 7.48 gallons
1 gallon = 0.1337 ft^3
1 acre = 43,560 ft^2
1 square mile = 27,878,400 ft^2

Water Body Dimensions

(each depth is an average)

Clear Lake:
100-acre lake, 25 feet deep

Swimming Pond:
1 acre, 10 feet deep

Deep Rock Aquifer:
50 square miles, 6 feet deep

Answers to PPM and PPB Word problems

1. *1.535 ppm* and *1,534 ppb*

   5 gal x .1337 ft^3 = 0.6685 ft^3

   43,560 ft^2 x 1 acre = 43,560 ft^2 x 10 ft = 435,600 ft^3

   0.6685 ft^3 / 435,600 ft^3 = **1.535 ppm**

2. *0.00738 ppm* and *7.38 ppb*

   6 gal x .1337 ft^3 = 0.8022 ft^3

   43,560 ft^2 x 100 acres x 25 ft = 108,900,000 ft^3

   0.08 ft^3 / 108,900,000 ft^3 = **0.0073 ppm**

3. *0.000879 ppm* and *0.879 ppm* (well)

   0.0675 ppm and *67.5 ppb* (Clear Lake)

   16.9 ppm and *16,900 ppb* (Swimming Pond)

   Note: Although concentration is one issue, equally important is knowledge of what chemical spilled. Are any of these concentration within safe limits for any of the maximum acceptable levels provided? For example: in Deep Rock Aquifer all chemicals listed are acceptable at the concentrations in the example. In Clear Lake, some are and some are not. In Swimming Pond, none are acceptable at these concentrations.

4. *6.138 ppm or 6,138 ppb*

Follow-Up Questions for Discussion

1. Does the public have a right to know about all instances of environmental contamination, whether or not concentrations are below federal standards?

2. What is the best way to inform people of a contamination incident? Who should be told? In how wide an area should the information be distributed?

3. Who should be responsible for notifying the public?

4. What are the possible effects of releasing this information (*affects on property values, hysterical reactions, etc*)

from **The No Waste Anthology**, pp. 14-15.

pH

Students determine the pH of various liquids.

Level(s): 6-8

Subject(s): Life Science, Chemistry

Virginia SOLs: 6.7 g; LS4 c; PS1 a; PS2 f

Objectives:
1. Students will be able to test a liquid do determine the pH level.

2. Students will be able to explain acidic, basic (alkaline) and neutral pH levels.

3. Students will be able to give examples of acidic and basic substances.

Materials:
- PH test kits (one for every group of four students)
- ¼ cup of each of the following:
  - Tap Water
  - White Vinegar
  - Lemon Juice
  - Tomato Juice
  - Milk
  - Milk of Magnesia
  - Shampoo
  - Ammonia
  - Bleach
  - Coffee
  - Coca Cola
  - Baking Soda (+ ¼ cup water)
- *pH Ratings of Various Liquids* (one copy for each student group)

Estimated Time: 45-50 minutes

Background Information: *Acid Rain*, p.82.

Preparation:
Prepare and label cups with solutions of the substances listed above.

Activity Procedure:

1. Divide the students into groups of 4. Give each group a pH test kit. Give each group a copy of *pH Ratings of Various Liquids* and have each group record their predictions. Caution the students to handle the solutions with care and not to touch them – the bleach in particular.

2. Divide the solutions in cups among the groups. Have them take turns testing the various solutions, and rotate them through the groups until each group has tested every solution once. Have them record their results on the handout.

3. Chart the results of each group for the class to see and discuss possible reasons for any differences. If only one group has a different result for any of the substances, have them repeat the test to see if they get the same result.

Assessment Opportunities:

1. Give the students various pH readings (e.g. 4.2, 7.0, 9.1) an identify them as acidic, basic or neutral.

2. Have students identify any of the substances they tested in class as acidic, basic or neutral.

3. Have students identify three weak mystery solutions as either water, baking soda, or lemon juice using a pH test. Litmus paper would work fine for this test.

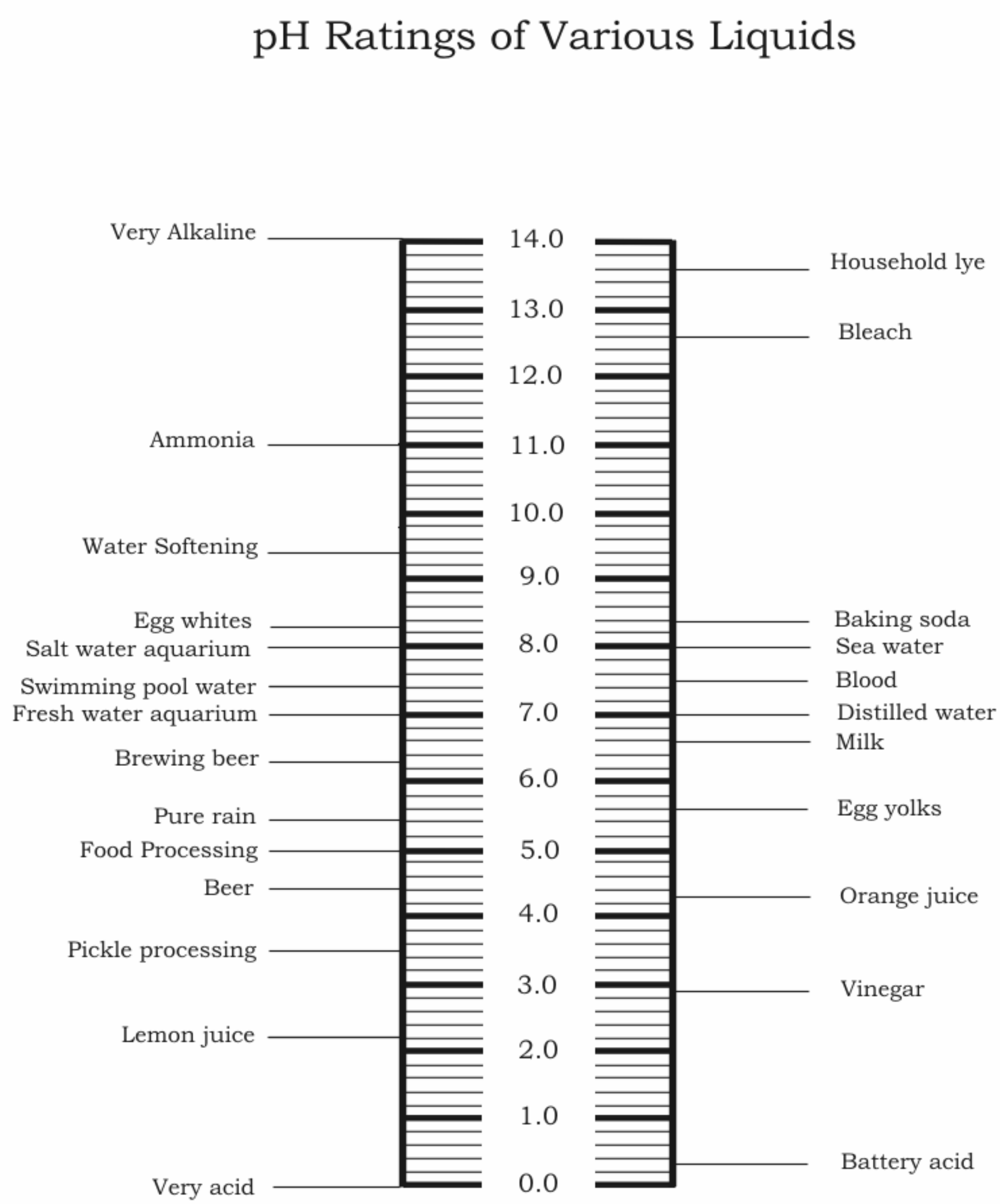
Extensions:

1. Make your own pH indicator by boiling a red cabbage for 30 minutes in a covered pot, and using the water. Test it with vinegar and baking soda.

2. Have students collect rain water and bring it to class to test. Do any samples qualify as acid rain? Correlating samples taken on different days with wind speed and direction might be used to identify a source of acid rain.

PH Ratings of Various Liquids

Liquid	Prediction: Acid, Neutral or Basic	Actual pH	Acidic, Neutral or Basic
Ammonia			
Baking Soda Solution			
Distilled Water			
Lemon Juice			
Milk			
Milk of Magnesia			
Shampoo			
Tap Water			
Vinegar			
Coffee			
Coca Cola			
Bleach			


pH Ratings of Various Liquids
Very Alkaline
Ammonia
Water Softening
Egg whites
Salt water aquarium
Swimming pool water
Fresh water aquarium
Brewing beer
Pure rain
Food Processing
Beer
Pickle processing
Lemon juice
Very acid
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Household lye
Bleach
Baking soda
Sea water
Blood
Distilled water
Milk
Egg yolks
Orange juice
Vinegar
Battery acid

pH and Aquatic Organisms

Students bring in water samples from local bodies of water and test pH levels in class.

Level(s): 6-8

Subject(s): Life Science, Chemistry

Virginia SOLs: 6.5 g; 6.7 a,f,g; LS4 c; LS12 b,d,e; PS1 a; PS2 f

Objectives:
1. Students will be able to test a liquid do determine the pH level.

2. Students will be able to explain how very low or high pH levels can affect aquatic organisms.

3. Students will be able to give examples of factors that can affect the pH of a body of water

Materials:
- PH test kits (one for every group of four students)
- Sample bottles with caps (one for each student)
- *pH of Common Substances and Lethal pH Limits for Aquatic Organisms* (one copy for each student)
- *Effects of Acid pH on Aquatic Organisms*
- a map or maps of the area from which students will be taking samples

Estimated Time: 45-50 minutes

Background Information: *Acid Rain,* p.82.

Preparation:
Students should have been asked to bring in a sample of water from a local stream, river, pond or lake. If the teacher cannot provide capped test tubes or similar sample bottles, students must by cautioned to make sure that any container they use is clean and dry. Instruct students to provide the following information with each sample: location where the sample was taken and land use in or near the water (forest, pasture/livestock, crops, homes, industry, business, roads, parking lots, etc.).

Activity Procedure:
1. Discuss how changes in pH can affect populations in a lake or stream. Hand out *pH of Common Substances and Lethal pH Limits for Aquatic Organisms* and have students identify lethal limits for various organisms.

2. Post the maps and have students indicate where their samples were taken from.

3. Divide the students into groups of four and have them take turns testing the pH of each sample.

4. Have each group report
   a. where the sample was taken
   b. land use in the vicinity
   c. the pH of the sample
   d. If the pH is below 7.0 or above 8.0, suggest possible explanations based on land use and possible effects on aquatic organisms.

Assessment Opportunities:
1. What is the pH level of a healthy stream, pond or lake?

2. What are the effects of low or high pH levels on aquatic organisms?

3. What are some causes of low or high pH levels in bodies of water?

Extensions:
1. Have students test the pH level of a nearby body of water once a week for two months. Have them chart the results. Do changes coincide with rain events?

2. Have students test the pH of a stream and a pond regularly over a period of time and chart the results. Are there any differences between the two?

Acid Rain

Normal rainfall has a pH of 5.6. It is naturally acidic because the reaction between carbon dioxide and water in the atmosphere produces carbonic acid. Precipitation is referred to as an acid rain when the pH falls below 5.6.

The two main culprits in acid rain formation are:

- Sulfur Dioxide (SO_2) from smelters and coal burning power plants
- Nitrogen Oxide (NO), mainly from vehicle exhaust

In the atmosphere these gases oxidize to form sulfate or nitrate particles. When these particles combine with water vapor they form sulfuric acid or nitric acid. These acids become part of the water cycle and return to earth in precipitation or as dry deposits. In addition to falling directly on bodies of water, acid rain falls on soils surrounding a lake or stream.

Acid-forming compounds come from natural as well as human-made sources. A volcanic eruption can cause acidic conditions covering half the globe. Decay processes involving both plant and animal materials which occur in marshes, swamps and oceans, can also produce chemical that create acid deposits.

A major source of increased acid in rainfall, however, is the burning of fossil fuels like coal, gasoline, fuel oil, and natural gas. Air pollutants in acid rain are responsible for creating acid condition in lakes and streams, particularly in the eastern United States, Canada and Scandinavia.

Some of the impacts of acid rain are:

- The balance of life in an aquatic community is disrupted by acid rain. Fish and other aquatic and terrestrial animals, including microscopic organisms, are harmed. Small amounts of acid can affect the ability of fish to reproduce.
- Lakes and ponds in some areas are becoming lifeless as the water becomes too acidic to support life.
- Heavy metals, including lead, cadmium, and mercury are also found in acid rain. These metals are dissolved by the acid and end up in the bodies of fish. When we consume the fish, we consume these toxic metals.
- Heavy metals and acids in rain cause damage to vegetation and reduce soil fertility. This is having a negative impact on some crops and forested areas.
- Our drinking water supplies can be affected by acid rain. Lead and copper can be leached from watershed soils or from pipes and contaminate our water.
- Acid rain contributes to the deterioration of outdoor art objects, monuments and buildings, causing us to spend an estimated $2 billion each year in the United States for repairs.

Adapted from **The No Waste Anthology**, p. 64.