Lesson 2. Pollution and Water Quality

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Pollution Sources

Water becomes polluted when foreign substances enter the environment and are transported into the water cycle. These substances, known as **pollutants**, contaminate the water and are sometimes harmful to people and the environment. Therefore, **water pollution** is any change in water that is harmful to living organisms.

Sources of water pollution are divided into two main categories: point source and non-point source. **Point source pollution** occurs when a pollutant is discharged at a specific source. In other words, the source of the pollutant can be easily identified. Examples of point-source pollution include a leaking pipe or a holding tank with a hole in it, polluted water leaving a factory, or garbage being dumped into a river. These sources of pollution are easy to identify because the cause of the pollution can be observed.

Non-point source pollution is more common, and contributes more pollution to surface water than does point source pollution. This type of pollution is difficult to identify and may come from pesticides, fertilizers, or automobile fluids washed off the ground by a storm. Non-point source pollution comes from three main areas: urban-industrial, agricultural, and atmospheric sources.

Urban pollution comes from the cities, where many people live together on a small amount of land. This type of pollution results from the things we do around our homes and places of work. **Agricultural pollution** comes from rural areas where fewer people live. This type of pollution results from runoff from farmland, and consists of pesticides, fertilizer, and eroded soil.

Atmospheric pollution comes from small particles that are carried in the air. A good example of atmospheric pollution is **smog**. These pollutants are carried around the world by winds, and reach the ground through rain. **Acid rain** is rain that has a high concentration of atmospheric pollutants.

Types of Pollution

Nutrients

Plants living in the water require a sufficient supply of nutrients to grow and mature properly. The most common nutrients found in our waters are nitrogen, phosphorous, and carbon.

However, large amounts of nutrients in the water can cause problems such as algae blooms. **Algae** is a general term for small, chlorophyll-containing plants such as seaweed and pond scum. When a body of water has a high level of nutrients, aquatic plants will grow and reproduce quickly. If algae grows in high density on the surface it will block sunlight from reaching plants at greater depths. This will cause the plants to die. When algae die, the decaying process uses oxygen in the water. Decreasing the amount of dissolved oxygen will cause aquatic animals to die.

The process of aquatic overgrowth, followed by death, decay, and oxygen depletion is called **eutrophication**. Eutrophication can result from human influences on the chemicals that enter our waters. This process causes an imbalance between plants and animals in the water.

Phosphates are one of the more common nutrients to move through the ecosystem in large quantities. Phosphates enter the waterways through runoff from natural sources such as phosphate-containing rocks and from human sources such as fertilizers, pesticides, detergents, and industrial wastes.

Organic Pollution

Human sewage, animal waste, and plant residue also contain organic material, which can pollute water. Bacteria in the water decompose the organic material, producing additional nutrients for plant growth. This can cause further decreases in oxygen content in the water. Human and animal wastes can also carry harmful bacteria and viruses that can spread diseases.

Pesticides and Herbicides

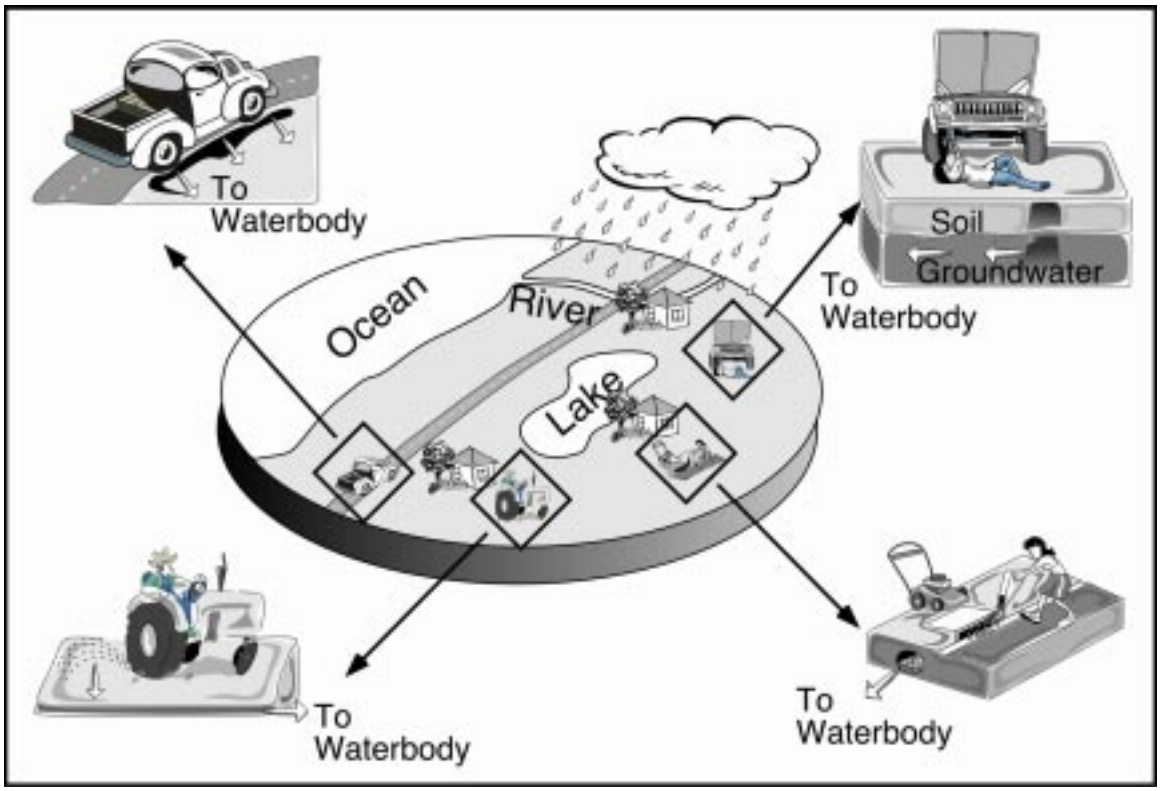
Pesticides and herbicides are used to kill weed and insects on lawns and food crops. They also kill fish, birds, and beneficial insects when they are not used properly. They contribute to water pollution through stormwater runoff. When it rains the water washes these chemicals off the lawns and into water bodies.

Chemical Pollution

Chemical pollution is usually caused by improperly disposing of poisonous materials such as paints, batteries, automobile exhaust, tires, and household cleaners. The pollution from these materials can harm many organisms, including humans.

Sediment Pollution

Sediment pollution occurs when loose soil is carried off streets, parking lots, buildings, and construction sites by rain. When these particles enter the water, they clog the gills of fish, and decrease the amount of sunlight available to aquatic plants. Sediments are also dangerous because they carry other pollutants such as chemicals from lawns and petroleum products from automobiles.



Stormwater Runoff

Stormwater runoff is the leading cause of water pollution. When it rains, the ground is not able to soak up all the water. This excess water flows into stormwater drains which often lead directly into nearby bodies of water such as streams, rivers, and oceans. As the rainwater flows over paved surfaces it picks up pesticides, fertilizers, bacteria, soil, grease, oil, and litter.

Stormwater has become a problem due to increased urbanization. **Urbanization** occurs when streets, parking lots, and buildings begin to cover the soil. These structures do not allow storm water to soak into the ground. When there is not enough open space for water to soak in, stormwater runs over covered surfaces, washing pollutants into lakes, rivers, and bays. Stormwater

can be treated by using stormwater ponds. These man-made ponds collect and filter rainwater before it can reach a larger body of water.

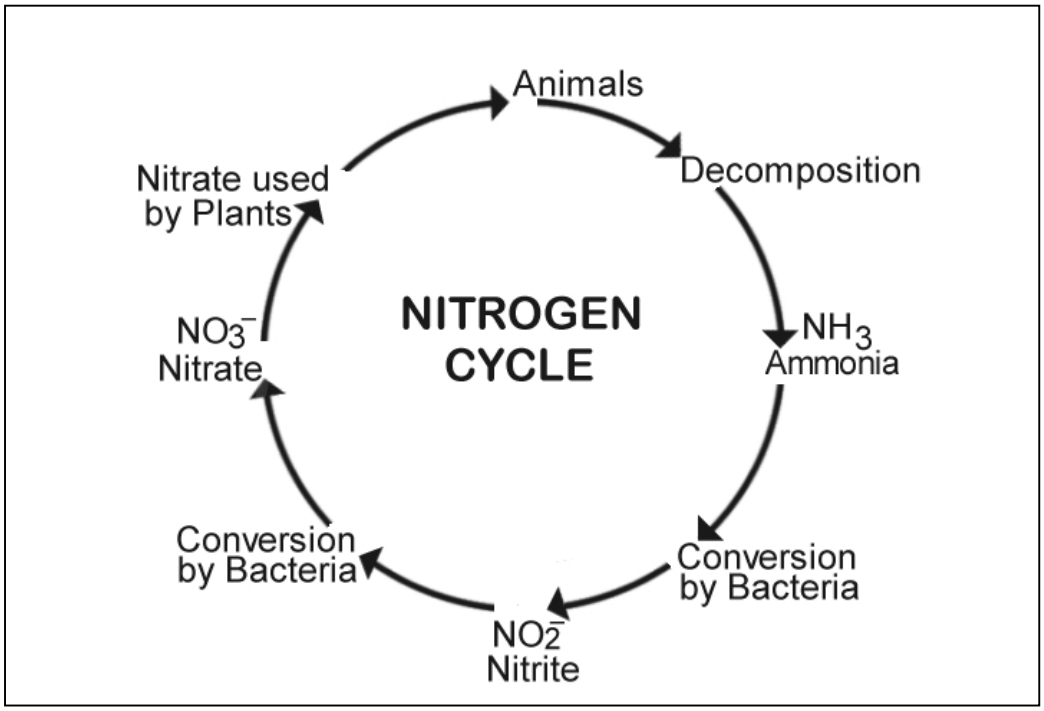
Saltwater Intrusion

In coastal areas, groundwater can become contaminated through **saltwater intrusion**. Some aquifers may contain a layer of saltwater above or below the freshwater aquifer. Freshwater 'floats' on top of the denser, or thicker, saltwater. When large amounts of freshwater are removed from the aquifer the saltwater will move upward because it has less pressure (less freshwater) on top of it. Once the saltwater moves into the freshwater the groundwater is contaminated and becomes very expensive to clean.

The Nitrogen Cycle

Nitrogen, like phosphate, is essential to plants and animals for proper growth and productivity. The air we breathe is composed mainly of nitrogen gas (N_2). However, this form is impossible for aquatic plants to use. Therefore, most plants rely on bacteria, which "fix" or convert the nitrogen gas found in the atmosphere to a form called nitrate. This form of nitrogen can be easily absorbed by plants.

Nirtrate is present as an **ion**, or charged species in water. The **nitrate** ion is composed of a single nitrogen atom and three oxygen atoms (NO^-_3). Nitrate forms the important materials necessary for life, such as proteins and vitamins.



When animals digest these proteins they are converted to ammonia (NH_3). **Ammonia** in high concentrations in the body is toxic. All organisms, including fish, must get rid of ammonia through excretion. Ammonia is also produced when plants and animals decay.

Two kinds of bacteria work in sequence to transform ammonia into nitrate. Ammonium oxidizers convert ammonia to nitrite, and **nitrifying bacteria** convert nitrite to nitrate. Both types of bacteria require oxygen to perform these reactions. Algae also help recycle nitrogen by converting ammonia into plant material. Harmful concentrations of ammonia hardly ever build up in natural waters due to recycling by algae and bacteria.

Water Quality Testing

Water quality is a term used to describe the chemical, biological, and physical characteristics of water. Water quality is not simply "good" or "bad", but usually is applied to its purpose. For example, water that is suitable for washing a car may not be suitable for drinking. For most purposes water quality refers to water for drinking, swimming, and fishing.

Often these days we hear about illnesses from water contaminated by microorganisms and chemical pollutants, which are endangering plants and animals. Water quality has become an important issue because of the increasing population size. As the population increases so does development, which creates greater potential for harmful substances to enter our water supplies.

Chemical tests have been developed to determine water quality. The factors that affect water quality are pH, dissolved oxygen, temperature, and salinity.

pH

pH is a measure of a sample's acidity and is the most commonly used water quality test.

pH is a measure of the hydrogen ion concentration, which is high in **acids** and low in **bases**.

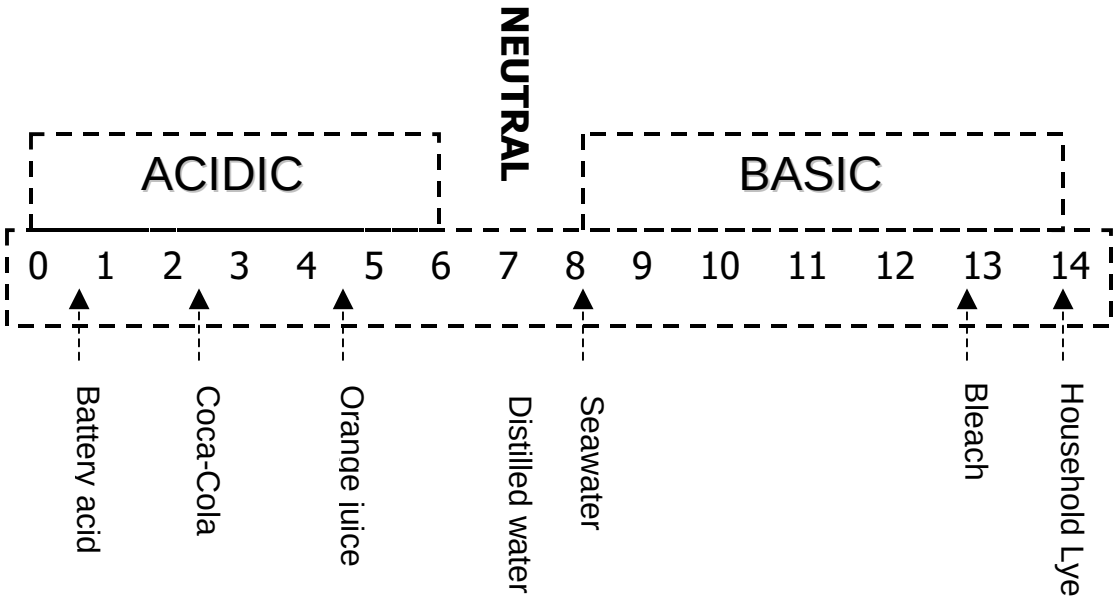
$$pH = -\log[H^+]$$

pH is measured on a logarithmic scale from 1 to 14, with 1 being the highest concentration of H^+ (most acidic) and 14 the lowest (most basic).
Some examples of acids include vinegar and lemon juice. Basic substances include baking soda and drain cleaner (lye). A substance that has a pH of seven is called **neutral**.

Distilled water has a pH of 7. The groundwater that we drink will have a slightly higher or lower pH depending on the type of rocks through which it

flows. Water that flows through granite rocks will have a slightly lower pH, and water that flows through limestone rocks will have a slightly higher pH. Rain naturally has a low pH, around 5.5, because it contains dissolved carbon dioxide from the atmosphere. The toxins that enter the atmosphere from automobile exhaust and power plant emissions will combine with the water in the air and fall to earth as **acid rain** or snow.

pH is a common measurement made when assessing the quality of water. pH values that are very high or very low can be harmful to living organisms. Organisms can tolerate pH values of about 5.0 to 9.0, but fish prefer waters between 6.5 and 8.2. Most rivers, lakes, and streams in the United States fall within this range, but acid rain and pollutants are compromising many of them.



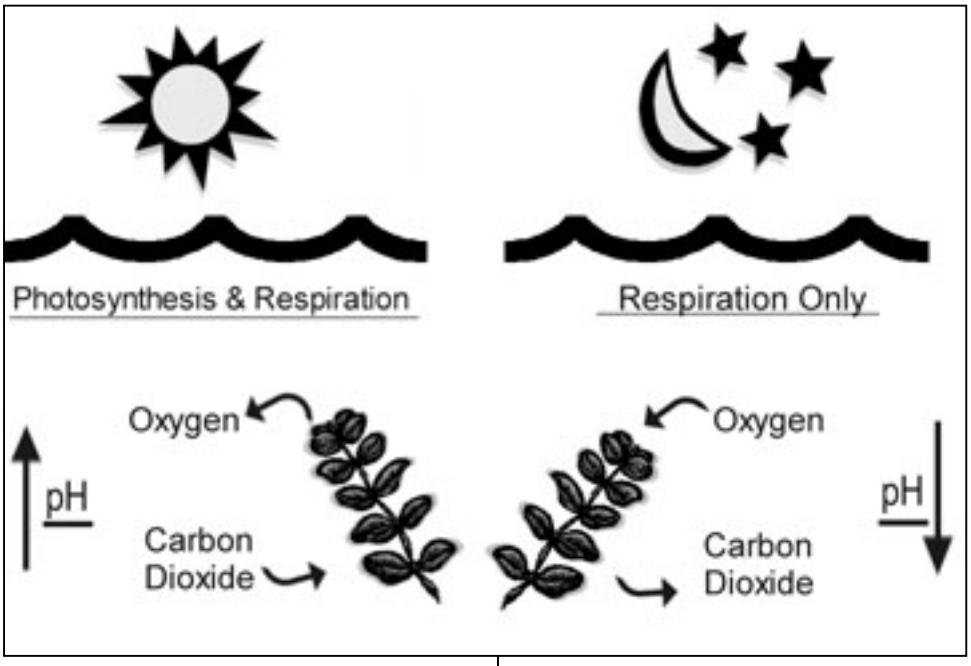
At pH:	Effects on Aquatic Life:
11.0-11.5	Lethal to all fish species
10.5-11.0	Prolonged exposure is lethal to some species
9.0-10.5	Prolonged exposure is harmful to some species
8.2-9.0	Unlikely to be directly harmful to fish
6.5-8.2	Optimal for most organisms
6.0-6.5	Unlikely to be directly harmful to fish
5.5-6.0	Metals trapped in sediments are released in forms toxic to aquatic life
5.0-5.5	Bottom dwelling bacteria die, detritus accumulates, plankton begin to disappear, snails and clams absent
4.5-5.0	Many insects absent, most fish eggs will not hatch
4.0-4.5	All fish, most frogs, and insects absent
3.5-4.0	Lethal to some fish species
3.0-3. 5	Unlikely that fish can survive for more than a few. hours in this range.

The pH scale is logarithmic. This means for every one unit change in pH, there is actually a ten-fold change in acidity. For example, pH 5 is ten times more acidic than pH 6 and pH 4 is one hundred times more acidic than pH 6.

Dissolved Oxygen

Have you ever wondered where the bubbles come from when water boils? Oxygen molecules are dissolved in water and measured as **dissolved oxygen**. The presence of dissolved oxygen in lakes and rivers is good because most aquatic plants and animals need dissolved oxygen to survive. Therefore, dissolved oxygen is a good indicator of healthy water quality.

Oxygen gets into the water through the air. Wind and waves on the surface of lakes and rivers help mix the air and water. These and other mixing processes will increase the amount of dissolved oxygen in the water. Aquatic plants also add oxygen to the water through photosynthesis. Because plants need sunlight for photosynthesis, dissolved oxygen tends to be highest during the late afternoon. At night, when no sunlight is available for photosynthesis, plants use oxygen for respiration so dissolved oxygen levels are lowered and carbon dioxide is elevated.



Climate can also affect dissolved oxygen levels. When it rains the water is mixed well with the surrounding air and contains high dissolved oxygen. During the dry season there is less mixing and dissolved oxygen decreases.

The main human factor causing dissolved oxygen levels to change in a negative way is the build up of organic wastes. Organic material is anything living or once living. Examples of organic wastes are grass clippings, leaves, dead plants and animals, and sewage. Organic wastes are broken down by bacteria, which consume oxygen. When organic wastes are dumped into rivers and lakes it causes dissolved oxygen to decrease, which causes plants and animals to die.

Temperature

Temperature is important to the plants and animals that live within the water. Most organisms cannot tolerate extreme cold or heat. Many aquatic plants and animals have adapted to survive in a certain range of temperatures.

Temperature also affects how much oxygen the water can hold. Cold water holds more oxygen. Extreme changes in temperature can place stress on the organisms within an ecosystem. Therefore, temperature is important to aquatic plants and animals and the overall health of the watershed.

Humans can harm the quality of water by changing its temperature.

Thermal pollution is an increase in water temperature caused by adding warm water to lakes and rivers. The source of this warm water is runoff from streets and pavements, or from power plants.

Salinity

Water is sometimes called the universal solvent because of its ability to dissolve other compounds. As water travels through the atmosphere and watershed it dissolves many minerals and carries them away. These dissolved minerals are called salts. Salts can come from organic material such as leaves, silt, plankton, and sewage or from inorganic material such as rocks and air. **Salinity** is the mass of the dissolved salts in a sample of water.

A certain amount of salt necessary for aquatic life. Dissolved salts help water flow in and out of an organism's cells. However, changes in the amount of dissolved salts can be harmful. Organisms are adapted to life within a range of salinity. Salinities higher or lower than this range places stress on the organism and can be harmful, or lead to death.

Changes in salinity are a result of variations in evaporation and freshwater flow rate. These can be natural and occur seasonally or they can be the result of human influence, such as increasing freshwater flow discharging from power plants or diverting freshwater for drinking and irrigation of fields.

Activity 2-1. What's in the Water?

Source: Just Add Water! Classroom curriculum for Ponds and Streams developed by Hach Company, Loveland, Co. For more information call 1-800-227-4224 or visit http://www.hach.com/h2ou

Match the category of a nonpoint source pollution to its definition in sections "Sources" and "Pollutant" by writing the letter in the corresponding blank.

Categories of Nonpoint Source Pollution:

A. Urban Pollution
B. Rural Pollution
C. Atmospheric Pollution
D. Natural Pollution

Definitions – Sources:

_____cultivation soil, production crops, raising livestock, mining, logging, and construction

_____concentrated population areas including homes, industry, business, and schools

_____wind and rain-carried particles

_____rocks, minerals, and soil that erode by wind and runoff that contribute their natural characteristics to water

Definitions – Pollutant:

_____motor oil, grease, herbicides, pesticides, household chemicals, pet waste, dirt and dust from construction

_____nutrients in the form of pesticides, herbicides, dirt and dust from plowing agricultural fields

_____nitrogen from lightning storms, nutrients from wildlife, salts and metals from rocks and minerals

_____acid rain

Activity 2-2. Testing Products For Phosphate and Nitrate

Source: Just Add Water! Classroom curriculum for Ponds and Streams developed by Hach Company, Loveland, Co. For more information call 1-800-227-4224 or visit http://www.hach.com/

Objective

To test products used at homes and schools for phosphate and nitrate content.

Materials needed:

Test strips for phosphate and nitrate/nitrite
Samples of fertilizer, detergent, and houseplant food with different levels of phosphate and nitrate content
Small cups
Measuring cup
Teaspoon measure
Stir sticks

Acitivity

1. Label each sample with a number.
2. Set out cups to test the samples.
3. Label the cups with corresponding sample numbers.
4. Measure and pour the same amount of water into each cup.
5. Add ½ tablespoon of sample 1 to water cup 1 and stir.
6. Clean the measuring spoon between uses.
7. Repeat steps 4 and 5 for each sample.
8. Use the test strips to test the solutions.
9. Record the results for each sample.

Discussion Questions

1. Did the samples show any phosphate or nitrate content?
2. Did any samples show more or less phosphate than indicated on the package?
3. Did any samples that were labeled "contain no phosphate" reveal any phosphate content?
4. Did any samples that did not mention phosphate content on the label contain phosphate?
5. How does the phosphate and nitrate contained in these products get from homes into surface water?
6. What can people do to reduce the amount of phosphates and nitrates entering surface water?
7. Do you think the water going to the wastewater treatment plant is cleaned of phosphates and nitrates before the water is released back into waterways?

Warning to Teachers: Some fertilizers can be harmful to skin and when ing ested. Closely supervise students when handling these products

Activity 2-3. The pH of Water

Source: Just Add Water! Classroom curriculum for Ponds and Streams developed by Hach Company, Loveland, Co. For more information call 1-800-227-4224 or visit http://www.hach.com/

Objective
To test various water sources for pH

Materials Needed
Test strips for pH, and alkalinity
Measuring cup
Small cups
Water samples from different locations (school drinking fountain, distilled water, well water, water from a lake, water from a puddle)

Activity
1. Pour a small amount of each water type into a small cup.
2. Use a test strip to measure the pH of each water sample.
3. Record the results.
4. Perform the same test for each sample using alkalinity test strips.
5. Record the results.

Discussion Questions
What is the pH of distilled water?
How does this compare with the pH of the other water samples?
Which sample has the highest pH? Which has the lowest.
Discuss why these samples have the highest and lowest pH.
What is the alkalinity of distilled water? How does this compare with the alkalinity of the other water samples?
Which sample has the highest alkalinity? Which has the lowest? Discuss why these samples have the highest and lowest alkalinity.
Write an analysis of your results.

STUDENT INFORMATION SHEET
Pollution and Water Quality

When a substance that does not belong enters a body of water, we call it **water pollution**. Water pollution is harmful and has many sources. Sometimes you can see exactly where the pollution is coming from, this is called **point source pollution.** Examples of point source pollution include water leaving a factory or garbage being dumped into a river. **Non-point source pollution** is harder to identify and is more likely to occur. This type of pollution may come from pesticides, fertilizers, or automobile fluids washed off by a storm, leaky sewers and septic tanks, sediment from soil erosion, and metals found in some paints.

Nutrients are found in fertilizers used on lawns and farms. The misuse of fertilizers can lead to an increase in the growth of unwanted vegetation, decreasing oxygen in the water and killing fish. Other nutrients include phosphates found in laundry detergent. **Eutrophication** is the process of unnatural growth, decay, and oxygen depletion .

Here is a chart summarizing the water quality tests.

Water Test	What it Measures	Natural Reading	Danger Reading	Source
pH	**Acidity of a substance**	**pH 6.5-8.2 is optimal for most aquatic organisms**	**Above pH 8.2 Below pH 6.5**	**Acid rain Chemical Spills**
Dissolved Oxygen	**Amount of oxygen in the water**	**7-14 parts per million (ppm)**	**0-5 ppm**	**Wind and waves**
Temperature	**Amount of heat in the water**	**Varies for different areas and organisms**	**Generally above 27°C**	**Waste heat and Solar heat**
Salinity	**Amount of dissolved salts**	**Varies for the time of year**	**0 in freshwater, 35 in saltwater**	**Rain**