LaMotte

pH Water & Soil STUDIES

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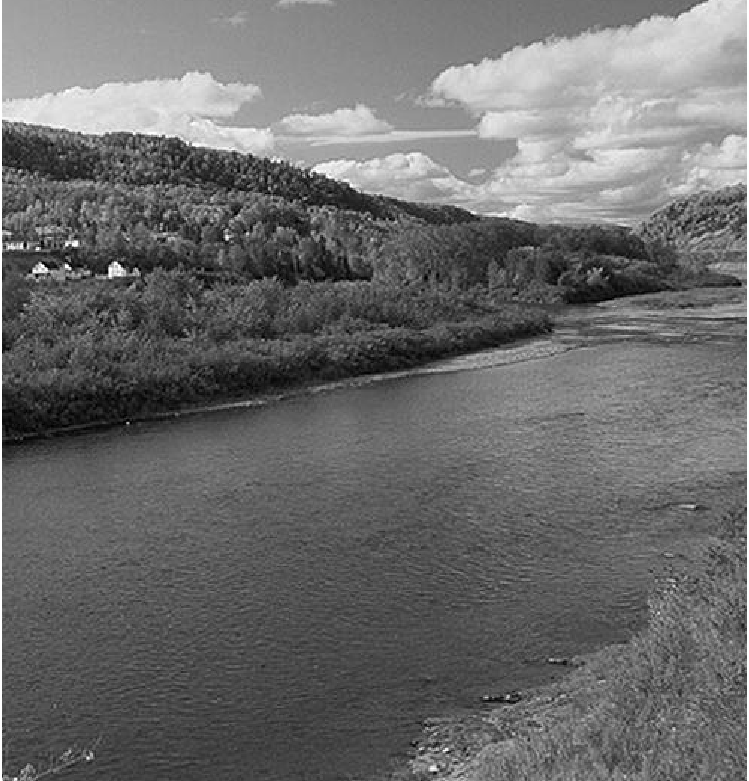

WHAT IS WATER?

Water, a substance which covers approximately 75% of the Earth's surface, exists in three forms: solid, liquid and gas. In the solid form, ice, water is used to cool drinks and other solutions, while the gas form, steam, can be used to power turbines and engines. As a liquid, water is used in many ways, from drinking to agriculture to providing homes for many kinds of aquatic life.

Known as the universal solvent, "pure" water is able to combine with other substances to form solutions. Even "natural" water found in the environment contains dissolved gases, such as oxygen and carbon dioxide, and dissolved minerals, such as iron and calcium. Most of these substances are not harmful at the levels commonly found, but some substances are toxic, or poisonous, to living things. Tests are available to determine levels of many toxic and nontoxic substances in water.

If dangerous or unhealthy substances are discovered, the water can be treated to remove or destroy them. Treatment is not necessary in many industries, such as agriculture, but others require water be purified before use. For instance, many drinking water systems treat the water with chlorine to disinfect and kill bacteria, making it safe for consumption. Other industrial processes add dangerous chemicals or bacteria to the water, which must be removed or rendered harmless before returning it to the environment.

As the human population increases concern over the availability of usable water increases as well. Polluted water will purify itself naturally over time, but as more and more untreated, polluted water is returned to the environment the system is overloaded and unable to cope. Water treatment processes, either chemical, biological or filtration, may be used to supplement the natural purification process.

To determine the efficiency of treatment, and levels of toxic and nontoxic substances, the water must be frequently tested. When establishing a testing program it is important to take samples over a period of time because the character of the water constantly changes. By taking several samples, determining their composition and keeping accurate records, scientists are better able to understand water.

WHAT IS SOIL?

Soil forms the natural covering of the Earth and supports plant life. It is formed by weathering, or the breakdown of rocks into smaller particles by natural forces. Wind, rain, freezing and thawing are all important forms of weathering. Weathering is a continual process, but it is slow, and the formation of new soil takes hundreds of years. Therefore, it is important to conserve existing soil and use it wisely.

Weathered rocks are not the only the components of soil. Soil also contains nutrients necessary for plant growth and survival. These nutrients come from weathered rocks, and from dead decomposed plant and animal material. Plant and animal waste left in soil are decomposed by bacteria and fungi living in the soil, adding nutrients to the soil. The practice of plowing or spading plant leaves into the soil, or adding humus to the soil, will also add nutrients. Humus, composed of decayed organic material, not only adds nutrients to the soil, it helps improve the texture and water-holding capacity of the soil.

Since there are many types of rocks, and varying amounts of vegetation, many different types of soil are formed. Soil types are classified by the size of the particles; clay particles are the smallest, silt particles are medium-sized, and sand particles are the largest. Each type of soil has a unique feel. Sandy soil feels gritty when rubbed between the fingers, silty soil feels silky or powdery, and clay feels sticky and moist. Many soils are a combination of these three particles, and are called loam. The percentage of each type of particle in loam can be determined by measuring settling rates; sand particles settle fastest, and clay particles settle slowest.

In addition to covering the Earth, soil provides the nutrients necessary for plants to survive. Plants require many different nutrients. Some nutrients, such as nitrogen, phosphorus, and potassium are required in large amounts, while only small amounts of others, such as sulfur, iron, manganese, and calcium, are necessary. It is important that these nutrients are not only present in the soil, but that they are in a form available to the plants. Availability is dependent upon several factors, particularly the pH of the soil. For instance, if the pH is too high iron will not be in a form plants can use; it will not be available to the plants.

What is pH?

One of the simplest, yet most important, analyses of water and soil is the pH test. pH is a measurement of the concentration of hydrogen ions in a substance, or how acidic or basic the substance is. The concentration of hydrogen ions is inversely proportional to the pH; the higher the concentration of hydrogen ions the lower the pH.

pH is measured on a logarithmic scale which ranges from 0 to 14. A pH of 7.0 is considered neutral; substances with a pH below 7.0 are acidic and those with a pH above 7.0 are basic, or alkaline. Since the pH scale is logarithmic, a change of one pH unit reflects a ten fold change in the acidity. Orange juice, pH 4.0, is ten times more acidic than boric acid, pH 5.0, and 100 times more acidic than milk, pH 6.0. The pH of several household substances are shown in Fig. 1.

There are many methods which can be used to measure pH. The simplest, most inexpensive method, is using litmus paper, which, when dipped into the solution, changes color to indicate whether the solution is acidic, alkaline or neutral. Litmus paper will only indicate whether a substance is acidic or alkaline, but not the degree of acidity. pH indicator test papers are also dipped into the solution, but the resulting color is matched to a color standard to indicate the pH of the sample. Liquid pH indicators can also be used to determine pH. When the indicator is added to a solution, the pH of the solution causes the indicator to change color, which is matched to a color standard to determine the pH. The most sophisticated method of pH analysis is a pH meter. When the pH electrode is immersed in a sample, the electrode and meter combine to give a pH reading which can be read directly from the meter.

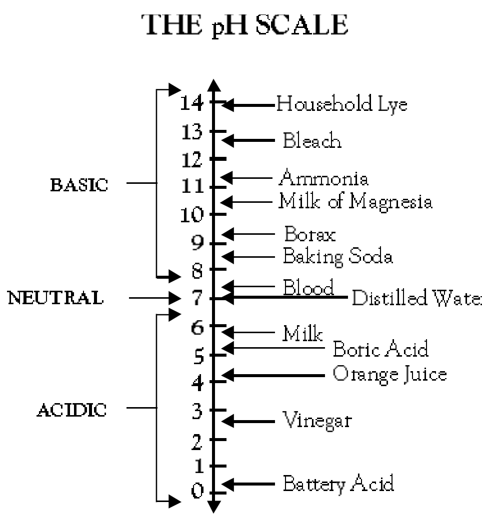

Fig. 1 The approximate pH values of some common substances.

pH & WATER

The pH of water is a concern to many people. Many factors contribute to the pH of water, including the quantity of plant and animal life, the rocks and other minerals the water is exposed to, and the pH of incoming substances.

Plant and animal life in the water are constantly undergoing chemical and biological processes which alter the water's pH. Two of these processes are respiration and photosynthesis. When plants and animals respire, or breathe, carbon dioxide is released. The carbon dioxide reacts with the water to form carbonic acid, which lowers the pH. Simultaneously, plants are undergoing photosynthesis, a process which removes carbon dioxide from the water before it is transformed into carbonic acid, raising the pH of the water. Since plants need light to photosynthesize, photosynthesis only occurs during daylight hours, but respiration occurs throughout the day and night, so the pH of water tends to be higher during the day.

The pH is also dependent on the minerals in the water. As water passes over and through rocks, minerals from the rocks dissolve into the water. Some minerals, such as calcium, occur in a form which raises the pH, while others lower the pH.

Natural waters normally have a pH between 5.0 and 8.0. When the pH is out of this range, it may be an indication of pollution, and further testing is necessary. Chemicals and other pollutants intentionally or unintentionally added to the water can alter the pH.

One pollutant that can cause water to be acidic is acid rain. Acid rain, defined as rain, snow or other precipitation with a pH of less that 5.6, is formed from air pollutants, particularly sulfur dioxide and nitrogen oxides, which are released as gases into the atmosphere. Power plants, smelters, automobiles, and volcanic activity are all contributors to acid rain. In the atmosphere, the gases combine with moisture to form sulfuric acid and nitric acid solutions, which return to the Earth as acid rain.

pH testing is also important in water used for industrial or domestic purposes. Acidic water can corrode metal pipes, while alkaline water can leave deposits known as scale, potentially clogging pipes and ruining equipment.

pH & SOIL:

The pH of soil is critical to the survival of plants living in the soil. Not only is the pH important in itself, it determines the availability of mineral nutrients for the plants.

Soil can be divided into three pH categories: acid or “sour” soils, alkaline or “sweet” soil, and neutral soil. Most plants prefer soil with a pH between 6.0 and 8.0, but some plants thrive in acid soils. Azaleas and rhododendrons are examples of plants which prefer acid soils.

The pH of soil changes from area to area, but a general rule is that soils in humid regions are acidic, because of rainfall and the “leaching effect,” where minerals are removed from soil as water passes through. In dry areas the soil is normally neutral or slightly alkaline. While acid or alkaline soils can be found anywhere in the United States, areas east of the Great Plains generally have acidic soil, while soils west of the Great Plains are usually neutral or alkaline.

If the pH is outside the desired range, chemicals can be added to adjust the pH. Lime is often used to raise the pH, and sulfur and alum are commonly used to lower the pH.

Neutral and alkaline soils are common.

Acid soils are common.

Fig. 2 General distribution of soils in the continental United States in relation to soil reaction.

TESTING WATER

TAKING WATER SAMPLES

Carefully follow the suggestions below for taking water samples.

1. The water sample should be representative of the source and free of any foreign matter, such as aquatic plants and sediment from the bottom.
2. The container should be clean and free from particles. Use a plastic or glass container with a screw cap that is large enough to hold water for all desired tests.
3. Unless the sample is to be tested immediately, the container should be filled until it overflows, and then capped. This procedure eliminates the possibility of getting air bubbles into the sample. A container which is only half full with water is subject to chemical changes caused by oxidation while being transported. Generally, the best results are achieved by testing the water as soon as possible.
4. If the sample is taken from a tap, it is important to let the water run for several minutes before taking the sample.

TESTING THE pH OF WATER

1. Use a clean pipet (0354) to fill a test tube (0755) to line 2 with sample water. (See Figure 3)
2. Add 10 drops of Tricel Indicator (5945). Cap and mix.

   NOTE: Hold dropper bottle vertically. (See Figure 4)
3. Hold tube flat against white area of Wide Range Color Chart (1353). Match sample color to a color standard. Record as pH. (See Figure 5)

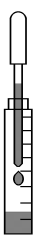

Fig. 3
Transferring portions of

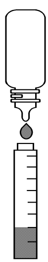

Fig. 4
Adding drops of Tricel Indicator.

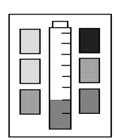

Fig. 5

TESTING SOIL

TAKING SOIL SAMPLES

Carefully follow the suggestions below for taking soil samples. Samples taken from a lawn should be taken from the top 2 or 3 inches of soil. Samples from gardens or farm crops should be taken from the top 6 to 8 inches of soil. When analyzing a large area of soil, samples taken from several locations should be mixed together.

1. Use a clean trowel, spoon, or knife to collect the samples.
2. Collect 4 or 5 heaping teaspoons of soil.
3. Place sample in plastic sampling bags.
4. Do not touch soil any more than is necessary.
5. Place collected sample on a piece of paper or plastic for several hours or overnight to dry.
6. Remove all stones, leaves, roots, and other foreign material.
7. Crush soil so all lumps are smaller than ⅛" in diameter.

TESTING THE pH OF SOIL

1. Use the 1.0 g spoon (0697) to fill test tube (0755) to line 2 with sample soil.
2. Fill to line 7 with Tricon Flocculating Reagent (5941). Cap and shake vigorously for 1 minute.
3. Let tube stand undisturbed for 2 minutes to allow soil particles to settle.
4. Use the pipet (0364) to transfer the clear solution above the soil to a second test tube. Fill to line 2 with the clear solution. (See Figure 6)

   NOTE: The remaining soil in the first test tube can be discarded.
5. Add 10 drops of Tricel Indicator (5945) to second test tube. Cap and mix.

   NOTE: Hold dropper bottle vertically. (See Figure 7)
6. Hold tube flat against white area of Wide Range Color Chart (1353). Match sample color to a color standard. Record as pH.

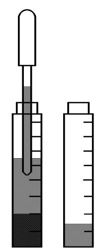

Fig. 6 Transferring clear solution to clean tube.

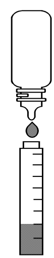

Fig. 7 Adding drops of Tricel Indicator.

TESTING OTHER PRODUCTS

TESTING THE pH OF HOUSEHOLD PRODUCTS

Many substances commonly found around the home or school can be tested for pH using the previously described procedures. Colorless or slightly colored liquids, such as ammonia, bleach, or vinegar, can be tested using the **Testing the pH of Water** procedure. Colored liquids may require filtration or a dilution with distilled water before the pH can be tested.

Solid substances, such as bread, fruit and vegetables should be ground up, and the **Testing the pH of Soil** procedure followed.

NOTES TO THE TEACHER

The materials in this kit are provided as tools to conduct several experiments. In addition to the procedures described in this manual, a number of open-ended experiments are suggested to spur the student's imagination to investigate related problems. Students can use the materials in this and other test kits to develop additional experiments.

ADDITIONAL EXPERIMENTS FOR pH

1. Ask students to bring different water and soil samples from home. Test for pH and compare the results. What is the general pH range for soil and water samples? Are these ranges in general agreement with the ranges stated in the text?
2. Add a pinch of lime (calcium carbonate, $CaCO_3$) to the soil in a soil sample bag. Mix thoroughly. Test the pH. What does lime do to the soil? Why do farmers add lime to their fields?
3. Add a small amount of lime (calcium carbonate, $CaCO_3$) to a water sample. Test the pH. What does lime do to the water?
4. Obtain a water sample which is green with algae. Test the pH. Let sample sit in the dark overnight. Measure the pH. Let the sample sit in the sunlight for several hours. Measure the pH. How can algae change the pH of water? What other organisms are present in the water sample? How can they change the pH?
5. Fill a test tube almost full with sample water. Add several drops of Tricel Indicator (5945) until a color of suitable intensity develops. With a straw or tube blow air into the sample for a few minutes. How does this change the pH of the sample?

   HINT: For best results select water that is alkaline and use a control tube to make the comparison.
6. Measure the pH of several household products, using the procedure outlined on page 10.
7. Add a small amount of boric acid to a water sample. Add pH indicator. Note color. Add a piece of an Alka-Seltzer tablet. What happens as the tablet dissolves?

GLOSSARY OF TERMS

ABSORB: To take a substance into the physical structure of a liquid or solid without a chemical reaction.

ACIDIC: A substance with a pH below 7.0.

ALGAE: Plants, usually aquatic, with simple cellular structure which do not have leaves, roots, flowers or seeds. All algae contain chlorophyll to convert solar energy (sunlight) to chemical energy, which is needed for survival.

AQUATIC: Living or growing in a water environment.

AVAILABILITY: Generally refers to plants; nutrients which are in a form which can be used by the plants.

BACTERIA: Microscopic, single-celled organisms which live in soil and water. In soil, bacteria increase soil fertility by breaking down complex substances, fertilizer and vegetable matter in the soil by decay, and convert these substances to simpler forms which can be used by the plants. In water, bacteria are responsible for the breakdown of organic matter and may produce disease.

BASIC: A substance with a pH above 7.0.

CLAY: The smallest soil particle. When wet clay soil is sticky or greasy to the touch, but is extremely hard and brick-like when dry.

COMPOUND: A mixture of several chemicals. Two or more elements combined by chemical bonds.

CORROSION: The process of deterioration where metal parts are slowly eaten away, usually by acidic solutions. Corrosion usually occurs when oxygen comes into contact with metal surfaces.

FERTILIZER: Any natural or manufactured product added to soil to supply one or more nutrients.

FLOCCULATION: The process by which particles in solution are bound together to promote the formation of an aggregate; flocculation speeds the rate of settling of particles in solution.

FUNGUS: A primitive group of plants characterized by the absence of chlorophyll; includes mushrooms, molds, mildews, rusts and smuts which live primarily on dead or living organic matter.

HUMUS: Well decomposed vegetable and animal material in the soil which is capable of holding large amounts of plant nutrients and water.

HYDROXYL ION: A negatively charged particle (OH^-) containing oxygen and hydrogen. Hydroxyl ions raise pH.

HYDROGEN ION: A positively charged particle (H^+) containing only hydrogen. Hydrogen ions lower pH.

INDICATOR: A chemical reagent added to a test sample which causes a color change.

INDICATOR SOLUTION: A liquid reagent added to a test sample to cause a color change.

ION: An electrically charged particle.

LEACHING EFFECT: The removal of dissolved chemical compounds from the soil by passing water through it.

LEAF MARGIN: The border or edge of a leaf. A leaf margin may appear smooth, saw-like, or tooth-like.

LITMUS PAPER: Paper used to determine pH. When dipped in a solution litmus paper turns blue if the solution is alkaline, pink if it is acidic.

LOAM: Soil which contains sand, silt, and clay. Soils that are predominantly sand but contain some silt and clay are called sandy loams. Soils that are predominantly clay but contain sand and silt are called clay loams.

MACRONUTRIENT: Those nutrients which the plants require in large quantities. The macronutrients are nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.

MICRONUTRIENT: Also known as trace elements. Those nutrients which are required by the plants in small quantities. The micronutrients are manganese, boron, zinc, copper, cobalt, aluminum, and molybdenum.

MINERAL DEFICIENCY DISEASE: A plant disease caused by the lack of one or more nutrients.

MINERAL SOIL: General term used for a soil composed primarily of inorganic matter.

NEUTRAL: A substance with a pH of 7.0.

NUTRIENT, PLANT: Any element taken in by a plant which is essential to its growth. Nutrients are used by the plant to produce food and tissue.

ORGANIC MATTER: Usually refers to living or dead plant and animal matter.

ORGANIC SOIL: General term used for a soil composed primarily of organic matter.

OXIDATION: Chemical change caused by oxygen reacting with the substance.

pH: A measurement of the acidity or alkalinity of a substance. The pH scale runs from 0 to 14, with 7.0 considered neutral.

PHOTOSYNTHESIS: The process by which plants manufacture carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll, using sunlight as an energy source.

POLLUTION: The presence of matter or energy whose nature, location or quantity produces undesired environmental effects.

PURIFY/PURIFICATION: The process by which polluted substances are cleaned. Purification can occur naturally, or by any of several mechanical means, such as filtration or chemical treatment.

RESIDUE: The particles or sediment which remains after the solution is removed.

RESPIRATION: The process by which living organisms convert food into energy by chemical reactions and liberate carbon dioxide.

ROOT HAIRS: Very small roots of a plant which take in nutrients from the soil solution.

SAND: The largest soil particle. Sandy soil feels gritty when rolled between the fingers and is formed by the erosion of rock material.

SCALE: A hard crusty deposit which may be formed on the inside of pipes and valves; usually a result of calcium and magnesium in the water.

SETTLING RATE: The amount of time required for particles in solution to settle.

SILT: The mid-sized soil particle. Silty soil feels silky to the touch and is usually found in combination with sand and/or clay.

SOIL TEXTURE: The relative amounts of sand, silt, and clay in soil.

SOLUTION: One or more substances dissolved in a liquid.

STUNTING: The lack of normal growth and development of plant parts. May be an indication of mineral deficiency.

WEATHERING: The process of disintegration or wearing down of substances by natural forces, including wind, rain, freezing. Weathering produces smaller rock particles which form the basis of soil.

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