WATER CHEMISTRY CHECKUP

9-12

OBJECTIVES

The student will do the following:

1 Conduct a number of water quality tests.

2. Determine the quality of a sample of water.

SUBJECTS:
Science (Chemistry, Physical)

TIME:
one 50-minute class period
field trip (optional)

MATERIALS:
a fresh sample of water for testing
water analysis kit
student sheet
thermometers

BACKGROUND INFORMATION

Water quality standards are often based on seven criteria - pH, temperature, dissolved oxygen, toxic pollutants, bacteria, radioactivity, and turbidity.

To profile a healthy stream, pH must be within an acceptable range (6.0-8.5). Temperature must not exceed 90° F (86° F in certain rivers) nor have rapid increases or decreases in temperature. Dissolved oxygen must not go below 5.0 mg/l except due to natural conditions. Toxic pollutants and radionuclides must not be present at harmful levels or levels which may cause bioaccumulation or biomagnification throughout the food chain. Bacteria must not be present at levels harmful to human health when stream water is ingested or absorbed. Turbidity (cloudiness) must not be at such levels that sunlight penetration is significantly diminished and sedimentation damages benthic habitat.

Terms

acidic: having a pH value of less than 7; acidic liquids are corrosive and sour **(DO NOT TASTE!)**

alkalinity: (1) a characteristic of substances with a pH greater than 7; (2) the capacity of water to neutralize acids, imparted primarily by the water's content of carbonates, bicarbonates, and hydroxides (expressed in mg/l of $CaCO_3$).

benthic: living on the bottom of a lake or sea; pertaining to the ocean bottom

bioaccumulate: to accumulate larger and larger amounts of a toxin within the tissues of organisms at each successive trophic level

biological magnification (biomagnification): bioaccumulation occurring through several levels of a food chain; process by which certain substances (such as pesticides or heavy metals) are deposited into waterway, eaten by aquatic organisms which are in turn eaten by large birds, animals, or humans, and become concentrated in tissues or internal organs as they move up the food chain.

dissolved oxygen (DO): oxygen gas (O_2) dissolved in water

hardness: a measure of all the multivalent (primarily calcium and magnesium) ions expressed in mg/l of calcium carbonate ($CaCO_3$)

hydrogen sulfide: gas emitted during organic decomposition by anaerobic bacteria which smells like rotten eggs and can cause illness in heavy concentrations (chemical formula, H_2S)

ingestion: the process of taking into the body, as by swallowing

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

plankton: microscopic plants and animals in water which are influenced in mobility by the movement of water (i.e., as opposed to nekton (fish) which can swim)

radionuclides: types of atoms which spontaneously undergo radioactive decay; usually naturally occurring and can contaminate water or indoor air (e.g., radon)

toxic: harmful to living organisms

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

ADVANCE PREPARATION

A. Obtain water testing kits from one of the companies listed on page F-69, Water Testing Fact Sheet.

B. Copy and distribute Student Sheets.

C. Have students collect water samples. Explain that bottles should be filled to the top and sealed.

PROCEDURE

I. Setting the stage

A. Have students carefully read and go over each of the water tests that they will be doing.

B. Answer any questions about these tests before beginning the experiment.

C. Explain to students that they will only be testing for the presence of a few of the many contaminants that may occur in water.

II. Activity

A. Students will use an assortment of test kits to determine the quality of water from a local stream. If a field trip is possible, take students to a local stream to collect water samples.

B. If a field trip is possible, take students to a local stream to collect water samples. If a field trip is not possible, samples can be brought to the classroom and tested for some parameters. The samples must be fresh and sealed tightly, or the DO will be incorrect. Temperature needs to be taken at time of collection, and no air bubbles should be present in the top of the jars. Jars should be capped while they are completely submerged.

Parameter		Limitations on Sample Storage
1. Temperature	→	Must be recorded in the field at the time of sample collection.
2. Dissolved Oxygen	→	First two steps of reaction must be done in field to yield iodide solution that will be titrated. Treated solution must be kept cool in sealed sample container. This can be kept up to six hours before titration.

3. pH → Fill containers to top and keep sample cool. Measure within two hours.

4. Alkalinity → Should be done in field to get valid data.

5. CO_2 → Must be done in field to get valid data.

C. Students will work in teams to complete tests on alkalinity, hardness, DO, ammonia, phosphate, turbidity, silica, pH, carbon dioxide (CO_2), nitrate, and hydrogen sulfide (H_2S).

III. Follow-up

A. Teams should compare results to those found in standards.

B. Alkalinity, hardness, and carbon dioxide are not regulated parameters but are important to water quality.

IV. Extensions

A. Ask students to try to identify the source of their sample, if unknown, by looking at data (groundwater or surface water: lake, river, pond). Discuss how this might be done. (e.g., groundwater would have comparatively low turbidity).

B. Discuss what students think could be done to improve water quality in the body of water from which this sample was taken.

RESOURCES

Water Analysis Kit, page F-69, Water Testing Fact Sheet

Team Member Names ____________________

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WATER TEST KITS
DATA SHEET

We have all heard reports about water being contaminated by many different types of substances. You are aware that water can be crystal clear and still have substances dissolved in it. How does anyone determine if water contains dissolved materials and whether they are harmless or dangerous? In this activity, you will have the opportunity to conduct a number of tests to determine if a sample of water contains certain substances.

Materials:

sample of water to be tested assortment of test kits

Gathering Data:

1. When you have been assigned a series of tests to perform, read the instructions completely before actually going through the procedures.

2. When you have completed a test, record the value in Table 1.

3. When all groups have finished, combine all the data on the master data sheet.

Organizing Data: **Table 1: Water Chemistry Data**

Source: ______________________________
Your Name: ____________________________
Date: ________________________________
Water Temperature: _____________________

Parameter	Results (mg/l)	Typical Discharge Limitations
* Alkalinity		
* Hardness		
Dissolved Oxygen		not below 5.0 mg/l
Ammonia		
Phosphate		
Turbidity		
pH		6.0 - 8.5
* Carbon dioxide		
Nitrate		
Sulfide		

* not regulated parameters but important to note

Testing will be done on five basic water quality parameters.

1. Temperature
2. Turbidity
3. pH
4. Dissolved oxygen
5. Total alkalinity

Most tests are colorimetric; that is, they are based on adding chemical reagent to the water sample until a color change is produced. The amount of reagent used to produce the color change is then directly related to a quantitative measure of the parameter being tested.

Temperature

Temperature affects the physical and chemical properties of water and greatly influences aquatic organisms by affecting feeding, reproduction, and metabolic rate. Most species have optimal temperatures for normal growth with corresponding upper and lower lethal limits. Temperature determines the density of water, the amount of oxygen it can hold, and how quickly nutrients will be recycled through the process of decomposition.

Turbidity

Turbidity, exhibited as cloudiness in water, is caused by suspended matter that scatters light passing through the water. The suspended particles range in size from colloidal (small) to coarse (large) dispersion.

There are many sources of turbidity. Although sediment from disturbed or eroded soil is often thought of as the source of cloudy water, turbidity can also be caused by dissolved organic matter from an abundance of microscopic **plankton**. Apparent water color, microscopic examination, and streamwalk observations can help determine the sources of turbidity.

Measuring Turbidity

Turbidity can be measured by using the clear plastic tubes in a water analysis kit. This method involves a clear plastic tube with a turbidity "target" at the bottom. The sample turbidity causes a "fuzziness" of the target that can be matched in a second tube containing clear water by adding a standard turbidity reagent [calibrated in Nephelometric Turbidity Units (NTUs)] dropwise until the fuzziness of both targets are equal.

Assuring Accuracy

Turbidity is best measured in the field. The turbidity of a bottled sample will change due to biological activity, settling, clumping, and absorption of particles onto surfaces of the sample container. If time elapses between sampling and measurement, be sure to shake the sample well to suspend particles before measuring turbidity.

pH

Water is an effective ionizing solvent. Water ionizes into hydrogen (H^+) and hydroxyl (OH^-) ions as demonstrated by the equation below:

$$H_2O <=> H^+ + OH^-$$

Even perfectly pure water contains some hydrogen and hydroxyl ions. The equilibrium condition for the two ions depends upon temperature.

The *pH*, a term coined in 1909 meaning the power of hydrogen, is a quantitative indicator of concentration of hydrogen ions. The pH is defined as the negative logarithm of the hydrogen ion activity [$pH = -\log (H^+)$].

If the hydrogen ion concentration is greater than that of the hydroxyl ions, the solution is said to be **acidic**. When the reverse situation exists and there are more hydroxyl ions, the solution is said to **basic**. When the concentrations of the two ions are equal, the solution is **neutral**.

Values for pH are usually between 0 and 14.0 with the neutral point at (25°C) at 7.0. Solutions with pH values less than 7.0 are considered acidic; those between 7.0 and 14.0 are designated as basic. Most natural waters have pH values between 5.0 and 10.0 with the greatest frequency of values found between 6.5 and 9.0. Since the pH scale is logarithmic, every one-unit change represents a tenfold change in acidity (a pH value of 6.0 indicates 10 times more acidity than a value of 7.0; a value of 5.0 represents 100 times more acidity than the neutral condition). pH is affected by carbon dioxide concentrations (CO_2) because CO_2 in water forms a weak organic acid (carbonic acid). Both plants and animals continuously release carbon dioxide through the *process of respiration*. During daylight, aquatic plants use carbon dioxide during photosynthesis. Since CO_2 is acidic, and if plants remove more than is being produced through respiration, the pH will increase during periods of high photosynthetic activity, decreasing at night when photosynthesis stops. Daily fluctuations in pH are less when water is *buffered* (has higher alkalinity).

Measuring pH

The pH is measured using liquid indicator kits or electronic pH meters.

Significant Levels

The following figure and table represent pH values for common substances and natural water supplies, and the effect on the aquatic community of varying pH values, respectively.

What measured levels may indicate

Routine monitoring of a waterbody should provide baseline information about normal pH values. Unanticipated decreases in pH could be indications of acid rain, runoff from acidic soils, or contamination by agricultural or livestock chemicals or by-products. pH values outside the expected range of 5.0 to 10.0 could be considered as an indication of industrial pollution.

Assuring accuracy

When using test kits, accuracy is a function of the sensitivity of the kit. Many groups use kits with a test range of pH 3.0 to 10.0 with a sensitivity of 1.0 units. This can be complemented with a test range of 6.8 to 8.2 with a sensitivity of 0.2 pH units.

When using pH meters, these should be calibrated frequently. Temperature affects the function of the electrode, and the meter must calibrate for temperature to provide correct pH values.

pH should be measured in the field since the pH of bottled samples will rapidly change due to biological and chemical activity in the sample container.

Effects of pH on aquatic life

AT pH	EFFECT ON AQUATIC LIFE
3.0 - 3.5	Unlikely fish can survive for more than a few hours in this range although some plants and invertebrates can be found at pH levels this low.
3.4 - 4.0	Known to be lethal to salmonids.
4.0 -4.5	All fish, most frogs, and insects absent.
5.0 -5.5	Bottom-dwelling bacteria (decomposers) begin to die. Leaf litter and detritus begin to accumulate, locking up essential nutrients and interrupting chemical cycling. Plankton begin to disappear. Snails and clams absent. Mats of fungi begin to replace bacteria in the substrate.
5.5 - 6.0	Metals (aluminum, lead) normally trapped in sediments are released into the acidified water in forms toxic to aquatic life.
6.0 -6.5	Freshwater shrimp absent. Unlikely to be directly harmful to fish unless free carbon dioxide is high (in excess of 100 ppm).
6.5 - 8.2	Optimal for most organisms.
8.2 - 9.0	Unlikely to be directly harmful to fish, but indirect effects occur at this level due to chemical changes in the water.
9.0 - 10.5	Likely to be harmful to salmonids and perch if present for long periods.
10.5 - 11.0	Rapidly lethal to salmonids. Prolonged exposure may be lethal to carp and perch.
11.0 - 11.5	Rapidly lethal to all species of fish.

In addition to direct effects on aquatic systems, pH affects many chemical processes. The toxicity of ammonia increases as the pH increases. Low pH can reduce the amount of dissolved inorganic phosphorus and carbon dioxide available to plankton. Low pH can also increase the risk of hydrogen sulfide toxicity.