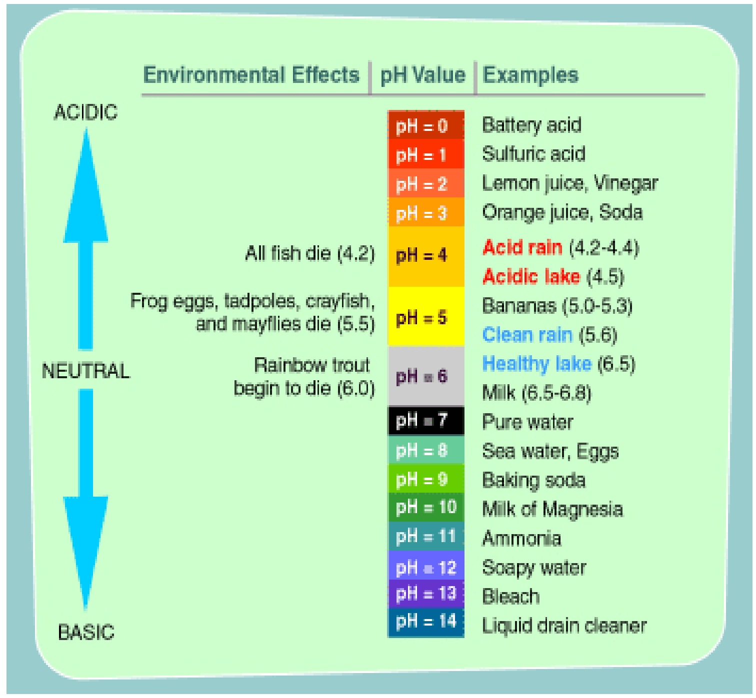
AN OVERVIEW OF BASIC WATER CHEMISTRY

What is pH?

A water molecule is made up of hydrogen ions (H^+) and hydroxide ions (OH^-): $H^+ + OH^- = H_2O$. The hydrogen ion concentration determines the pH of a solution. The term comes from the French "pouvoir hydrogen" literally hydrogen power or hydrogen potential. An acid solution has more hydrogen than hydroxide ions so the net effect when dissolved in water is a lower pH. A base has more hydroxide ions, so the result when dissolved in water is an increase in pH. The pH test allows us to infer how acidic or basic a substance is. The hydroxide and hydrogen ion concentrations are very small absolute numbers, so scientist developed a scale to make reporting and interpretation easier. Since this is a logarithmic scale, for every one change in pH there is a 10-fold change in hydrogen or hydroxide ion concentration. For example, rainwater is slightly acidic with a pH of around 6, while acid rain is ten times more acidic with a pH of about 5.



The carbonate system is one of the most prominent equilibrium systems in natural waters. Aquatic plants also influence pH through photosynthesis and respiration. The landscape of the surrounding watershed can influence pH. Watersheds that contain wetlands or pine forest tend to support waters with a slightly lower pH. Decaying vegetation and other organic matter also produces acids, which leach into nearby waters. Burning fossil fuels and other human activities have a dramatic impact on pH. Coal fired power plants and automobiles emit nitrogen oxides and sulfur dioxides, which react with water vapor in the air to produce nitric and sulfuric acids. Mining, chemical spills, thermal pollution, sewage effluent and agricultural runoff also affect the pH.

What is alkalinity?

Alkalinity is a measure of water's capacity to resist a decrease in pH. In natural waters alkalinity is primarily a function of the carbonate system, which comes from rocks containing calcium carbonate. These rocks dissolve on contact with water and release calcium ions (Ca^{+2}), carbonate ions (CO_3^{-2}), bicarbonate ions (HCO_3^-, or carbonic acid (H_2CO_3), depending on the water's pH. The negative carbonate and bicarbonate ions combine with positive hydrogen ions (H^+) reducing acidity and increasing pH. Different types of carbonate dominate at different pH levels.

The sources of the carbonate minerals are found in some types of sedimentary rocks. Limestone yields calcium carbonate and dolostone yields calcium or magnesium carbonate. In areas where granite or other igneous rocks dominate the geology, waters have little natural alkalinity.

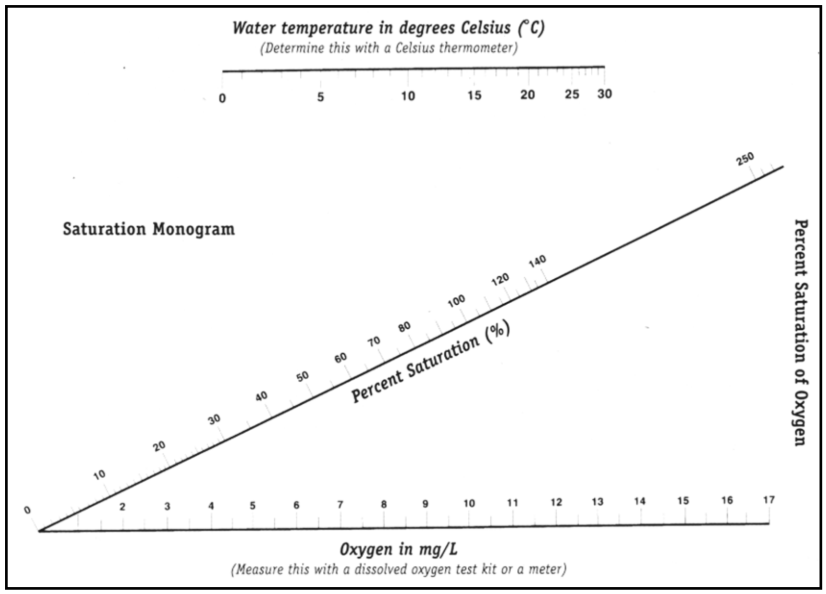
Green plants also influence the carbonate system. During photosynthesis, plants consume CO_2, which would otherwise form carbonic acid when dissolved in water. Thus, plants are the primary buffering system in areas with little geologic potential.

http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/Chemistry.aspx pH > 10: Carbonate (CO_3^{-2})   pH 6–10: Bicarbonate (HCO_3^-)   pH < 6: Carbonic acid (H_2CO_3)

What is dissolved oxygen?

Dissolve oxygen (DO) is simply the oxygen that is dissolved in water. Stream and river systems both produce and consume oxygen. Waters gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen. If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die. Wastewater from sewage treatment plants often contains organic materials that are decomposed by microorganisms, which use oxygen in the process. The amount of oxygen consumed by these organisms in breaking down the waste is known as the biochemical oxygen demand (BOD).

DO levels fluctuate seasonally and daily! The levels also vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes. Thermal discharges, such as water used to cool machinery in a manufacturing plant or a power plant, raise the temperature of water and lower its oxygen content. Aquatic animals are most vulnerable to lower DO levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset.



Instead of using (mg/L) or (ppm) to report your DO results, it is sometimes more useful to determine percent saturation. Percent saturation varies with temperature, altitude, motion of the water and barometric pressure. The actual calculation of these relationships can be complex, so we use a saturation monogram to estimate percent saturation.

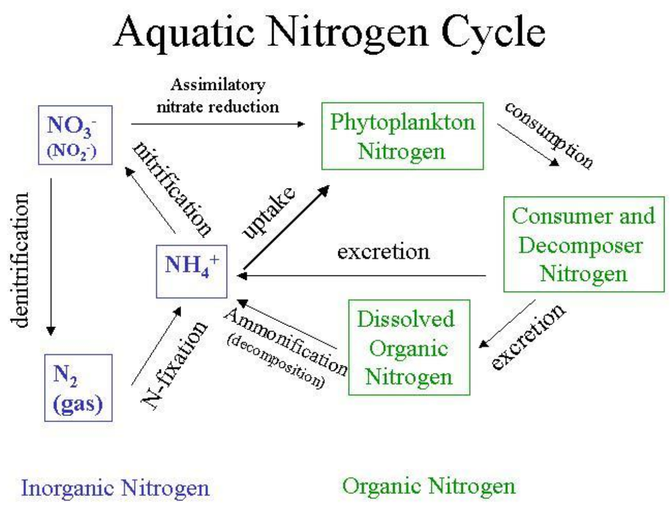
What is iron?

Iron is usually present as a mineral in soils in small amounts but it is most obvious when exposed through sub-surface mining. If exposed to air and water, iron is released through oxidation of metal sulfides (usually pyrite, which is iron-sulfide) and generates acidity. Colonies of bacteria greatly accelerate the decomposition of metal ions, although the reactions also occur in an abiotic environment. These microbes, called extremophiles for their ability to survive in harsh conditions, occur naturally in the rock, but limited water and oxygen supplies usually keep their numbers low. Special extremophiles known as acidophiles especially favor the low pH levels of abandoned mines and are a key contributor to pyrite oxidation.

What are nitrates?

Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH_3), nitrates (NO_3), and nitrites (NO_2), all of which are part of the nitrogen cycle. Nitrogen is plentiful in the atmosphere making up 79% of the air we breathe but it is not readily available in a useable form to plants and animals because of the very strong covalent bond between nitrogen atoms. Fortunately there are many ways to "fix" or bound it to hydrogen or oxygen making it useable. Once fixed, plants quickly consume nitrogen, which in turn feeds the animal community.

Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L.



Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

What is turbidity?

Turbidity is a measure of the relative clarity of water. Turbid water is caused by a variety of factors including suspended particles such as clay, silt, organic and inorganic matter, and even organisms. Turbid water may be caused by erosion, run-off from urban areas, algal blooms and disturbances to the bottom sediments.

Disposal of low volume chemical waste

All the waste generated by the LaMotte test procedures, and most others as well, (not including bacteria test) may be poured down the drain with the water running to dilute it. The only time the waste may not be disposed of in this manner is if the waste generated is from 30 or more tests for a single parameter. For example, if 30 students all use the LaMotte test kit to test the dissolved oxygen levels of a sample, the waste cannot be poured down the drain. A waste management facility should be contacted to determine the correct method of disposal. But if 10 students test for pH, 10 students test for nitrates and 10 students test for dissolved oxygen, the waste generated by this group can be disposed of down the drain with the water running to dilute it.
If the tests are done in the field, carry a waste container with a lid along with the kits. Pour all the waste into the container and save it for appropriate disposal at a later time. Before using a kit, be sure to read its instruction manual and all related safety precautions. Also, review the material safety data sheets (MSDS) for the chemicals included with the kits. MSDS for all LaMotte test kits are available from the LaMotte web page at by entering the product code of the kit. You can also download a program that contains the MSDS information.

http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/Chemistry.aspx

Overall chemical integrity

Analysis	Optimal	Suboptimal	Marginal	Poor	Units
Alkalinity	> 40	21 - 40	5 - 20	< 5	mg/l or ppm
pH	7.6 - 9.0	6.6 - 7.5	6.0 - 6.5	< 6.0 > 9.0	
Dissolved oxygen	> 10.0	7.0 – 10.0	5.0 – 7.0	< 5.0	mg/l or ppm
Conductivity	50 - 250	251 - 500	< 50	> 500	µs/cm
Nutrients (nitrogen + phosphorous)	< 1.0	1.0 - 2.0	2.0 - 4.0	> 4.0	mg/l or ppm
Total metals	< 0.5	0.5 – 1.2	1.3 – 2.0	> 2.0	mg/l or ppm
Bacteria (fecal coliform)	< 100	100 - 200	201 - 400	> 400	#/100 ml

Note: The values provided here are those necessary to maintain the best ecological integrity in a stream environment; they are not based on water quality standards and in some cases the standard may not exist. To learn more about our water quality standards visit the website below:

http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/WQS.aspx

Water samples should be collected from the most represented portion of a stream, which is usually the **run** (a fast moving area without surface breaks) and as close to the downstream end of the reach as possible. Analysis can be performed either in the field or lab. Your results should fall within in the optimal or suboptimal ranges; an exception is pH (marginal – optimal).

Note: The Program's SOPs do not provide information on the use of any specific chemical kits or meters. WV Save Our Streams recommends that whatever type of kit you choose to use, always follow the manufactures instructions and recommendations for its maintenance. If you are using a meter; these must be calibrated at regular intervals and always before using them in the field. When submitting chemical data always describe the kit you are using, unless the kit was provided by WV Save Our Streams. This description should include the manufacturer, kit-type, range, model number etc.

Additional Resources

1. A citizen's guide to monitoring lakes and streams (Washington State Dept. of Ecology)
2. An introduction to "the properties of water" (Wikipedia)
3. Bacteria Monitoring (A Methods Manual for Citizen Volunteers)
4. LaMotte's' custom designed **Water Chemistry Kit** for the WV Save Our Streams Program
5. Marcellous shale monitoring resources (from Dickinson College)
6. Periodic Table of Elements
7. Pollutant Load Calculator (A simple spreadsheet that calculates loads based on concentration and discharge)
8. River Networks virtual training: Water quality standards