Chapter 7

Water Chemistry

- Introduction to Volunteer Water Quality Monitoring Training Notebook -

Water chemistry plays an important role in the health, abundance and diversity of the aquatic life that can live in a stream. Excessive amounts of some constituents, such as nutrients, or the lack of others, such as dissolved oxygen, can result in degraded conditions and harm aquatic life.

I. Temperature

Water temperature is important because most of the physical, chemical, and biological characteristics of a river are directly affected by temperature

A. Temperature can affect the following factors:

1. The amount of gas, including oxygen, that can be dissolved in the water; cold water can hold more oxygen than warm water
2. The rate of photosynthesis by algae and other aquatic plants
3. The metabolic rates of aquatic organisms (increased respiration, digestion, etc.)
4. Organisms can become more sensitive. Increased metabolic rates result in the organism being stressed and more vulnerable to disease, parasites, and pollution.

B. What Impacts Stream Temperature?

1. **Air temperature.** The natural seasonal changes in temperature impact stream temperature.

2. **Thermal pollution** occurs when water entering the stream is warmer than the water already present in the stream. One source is from industries like nuclear power plants, which discharge cooling water. Another source is stormwater runoff from heated surfaces such as parking lots, streets, roofs, etc.
3. **Riparian cover removal.** The removal of trees impacts water temperature by eliminating shade along the river and allowing more soil particles to reach the stream.
4. **Soil erosion** increases the amount of suspended solids carried by the water. Particles in cloudy water absorb radiation from the sun, which warms the water.

II. Dissolved Oxygen

A. What is Dissolved Oxygen?

Dissolved oxygen (DO) is essential to the survival of organisms in a stream. The presence of oxygen is a positive sign and the absence of oxygen is a sign of severe pollution. Waters with consistently high dissolved oxygen are considered to be stable aquatic systems capable of supporting diverse aquatic life.

B. Sources of Dissolved Oxygen

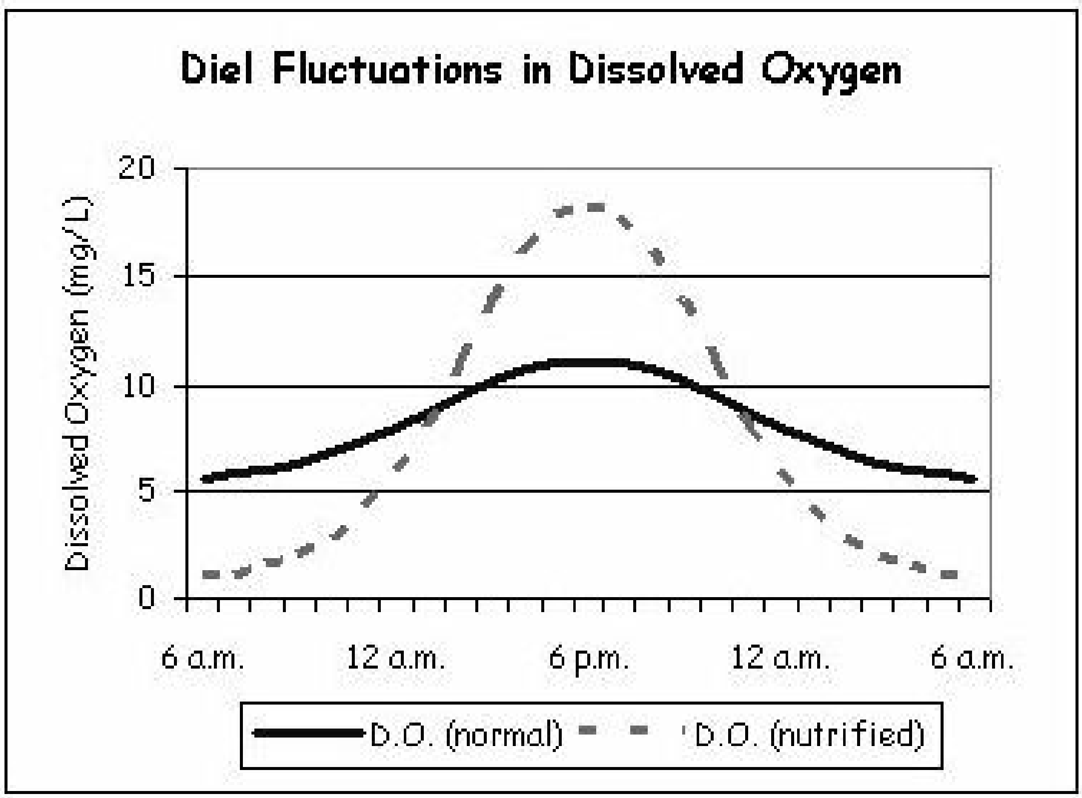
1. **Atmosphere.** The air we breathe contains approximately 21% oxygen which equates to 210,000 ppm oxygen. Most surface waters contain between 5 and 15 ppm DO.
2. **Photosynthesis by algae and rooted aquatic plants.** Plants deliver oxygen to water through photosynthesis.

C. Natural Influences on Dissolved Oxygen

1. **Seasonal Temperature Changes.** Gases, like oxygen, are more easily dissolved in cooler water than in warmer water. DO levels may be higher in winter than in summer.
2. **Stream Discharge.** Dry periods often result in severely reduced stream discharge and increased water temperatures. This combination acts to reduce DO levels. Wet weather or melting snows increase stream discharge and the possibility for mixing of atmospheric oxygen.
3. **Dissolved or suspended solids.** Oxygen dissolves more readily in water that does not contain a high concentration of salts, minerals, or other solids.
4. **Aquatic Plants.**
    a. **Density.** The density of aquatic plants will affect DO. Fewer plants grow in winter because of cold temperature and shorter day length. More green plants mean more photosynthesis, which produces more oxygen during the day when the sun is shining

    b. **Respiration.** Conversely, plants and animals respire 24 hours per day, using oxygen and producing carbon dioxide. So there is a net gain in DO as long as photosynthesis is occurring. In addition, when plants die, DO is used in the decomposition process. This occurs when organic matter decomposes. If there is an overabundance of algae or other aquatic plants and a large die-off occurs at one time, DO can be dramatically impacted.

D. Diel Oxygen Fluctuation. The term, "diel" refers to a 24-hour period that usually includes a day and adjoining night. During the daylight hours, DO levels rise due to plant photosynthesis. When the sun sets, photosynthesis stops and respiration continues. As a result, DO levels naturally drop overnight, reaching their lowest level just before dawn, at which time the sun rises and photosynthesis again pumps more DO into the water. Extensive algal growth can result in large fluctuations in oxygen from late afternoon to early morning. If the DO levels fall too low, aquatic animals can die. This is more problematic in ponds and in backwaters of streams where flow is nonexistent or very slow.



E. Human-Caused Changes in Dissolved Oxygen

1. **Organic waste.** This includes waste from once-living plants and animals and from animal feces. Excessive organic waste often comes from sewage treatment

plants, malfunctioning septic systems, or manure runoff from animal operations. Organic waste can act as a fertilizer to stimulate aquatic plant growth. In time, these plants die, and they too become organic waste.

2. **Urban runoff.** Rain carries heat, salt, sediment, and other pollutants from impervious surfaces (streets, roofs, parking lots, etc.) into streams. This raises the water temperatures and total solids in the water reducing its capacity to hold DO.
3. **Dams.** Some dams are constructed so water is released from the bottom of a lake or reservoir. Seasonally this water can be almost devoid of oxygen. The opposite problem can occur when water is released from the top of a dam or spillway. This can cause excessive uptake of air from the atmosphere and result in water that has too much atmospheric gas.
4. **Removal of vegetation, especially trees, in the riparian corridor.** A lack of shade causes increased water temperature and a lack of protection from erosion. This causes increased suspended solids that can work together to reduce oxygen levels.

Depletion of DO can cause a major shift in the types of aquatic organisms present in a stream from pollution-sensitive species to pollution-tolerant species.

III. Nitrates and Ammonia

A. What is Nitrogen?

Nitrogen is required by all living plants and animals for building protein. In aquatic ecosystems, nitrogen is present in different forms. The usable forms of nitrogen for aquatic plant growth are ammonia (NH_3) and nitrate (NO_3). Excess amounts of nitrogen compounds can result in unusually large populations of aquatic plants and/or organisms that feed on plants. For instance, algal blooms can be a result of excess nitrogen. As aquatic plants and animals die, bacteria break down the organic matter.

B. Ammonia (NH_3 or NH_4) is oxidized, or combined with oxygen (O_2), to form nitrites (NO_2) and nitrates (NO_3)

$$\mathbf{NH_3 + O_2 \rightarrow NO_2 + O_2 \rightarrow NO_3}$$

The cycle for breaking down organic matter (both the biological process and the chemical process) uses up dissolved oxygen.

Sources of Excess Nitrates and Ammonia in Streams:

1. Poorly functioning septic systems
2. Inadequately treated wastewater from sewage treatment plants
3. Storm drains
4. Runoff from feed lots
5. Runoff from crop fields, parks, and lawns

IV. Phosphorus

A. What is Phosphorus?

Phosphorus usually takes the form of phosphate (PO_4) in water. Phosphorus is also a plant nutrient and is often the limiting nutrient for plant growth, as it is less prevalent in surface water than nitrogen. Small increases in phosphorus, however, can result in a large impact on the growth of aquatic plants. Phosphorus binds readily with soil particles. Soil must be highly saturated with phosphorus before excess amounts are detectable in shallow groundwater that can enter streams and cause negative impacts.

B. Sources of Excess Phosphorus in Streams:

1. Septic systems and wastewater from sewage treatment plants
2. Runoff from feed lots and from the application of animal wastes on fields
3. Runoff of commercial fertilizer from crop fields, lawns, golf courses, or parks

V. Turbidity

A. What is Turbidity?

Turbidity testing measures the clarity of water. Low turbidity water is clear while high turbidity water is cloudy or murky. Cloudy water is most often caused by suspended matter (such as soil particles) and plankton (such as diatoms). By evaluating how turbid the water is, you can evaluate whether excess soil erosion or algal growth is occurring.

B. Sources of Excess Turbidity in Streams:

1. Development, construction, and land disturbance can result in soil erosion.

2. Quarries and gravel mining operations can result in fine sediment entering a stream and smothering habitat.
3. Agricultural areas that have not adopted "best management practices" to prevent soil erosion leak sediment to local waterways.

VI. pH (parts Hydrogen)

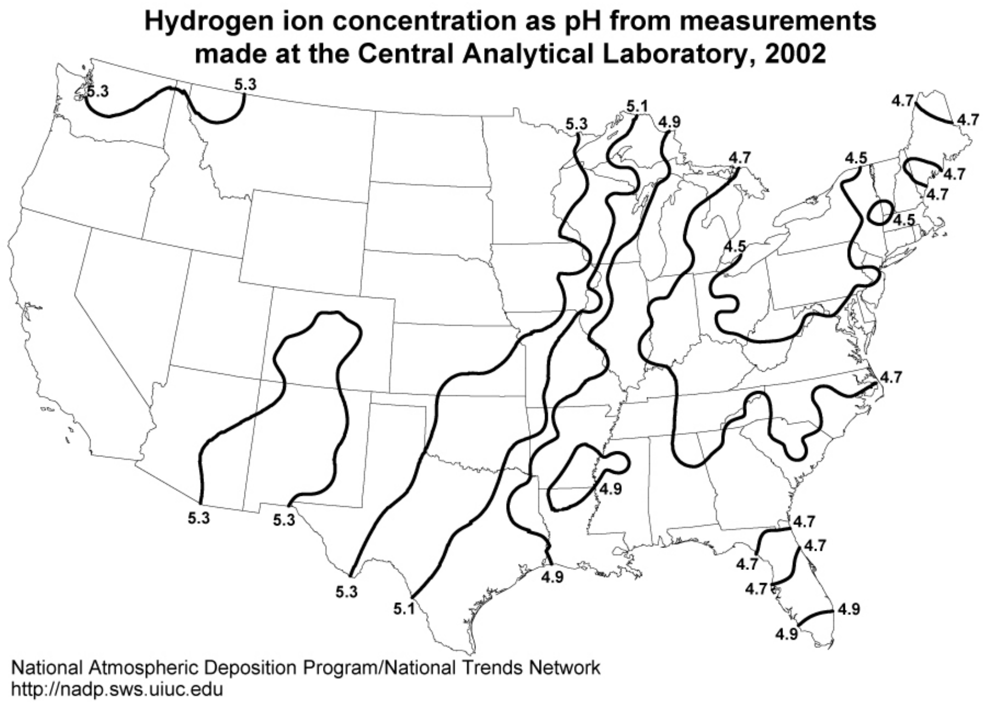
A. What is pH?

Water (H_2O) contains both H^+ (hydrogen) ions and OH^- (hydroxide) ions. "pH" is an abbreviation for the French expression, "Pouvoir Hydrogene," meaning "the power of Hydrogen." It measures the H^+ ion concentration of substances and gives the results on a scale from 0 to 14. Water that contains equal numbers of H^+ and OH^- ions is considered neutral (pH 7). If a solution has more H^+ than OH^- ions, it is considered acidic and has a pH less than 7. If the solution contains more OH^- ions than H^+ ions, it is considered basic and has a pH greater than 7.

The pH scale is logarithmic. This means that as you go up and down the scale, the values change by a factor of 10. A pH change of one point indicates the strength of the acid or base has increased or decreased tenfold; a two-point pH change indicates a 100-fold change in acidity or basicity; a three point change indicates a 1000-fold change in acidity or basicity. For example, when the pH changes from 7 to 8, there are now 10 times more OH^- ions present than H^+ ions. If it changes from 10 to 8, there are 100 times more H^+ ions than OH^- ions. Small changes in pH result in large changes in water chemistry.

B. Human-Caused Changes in pH:

In the United States, the pH of rivers is usually between 6.5 and 8.5. Rain water is more acidic and normally has a pH between 5.0 and 5.6. Increased amounts of nitrogen oxides (NO_3) and sulfur dioxide (SO_2), primarily from automobile and coal-fired power plant emissions, are converted to nitric acid and sulfuric acid in the atmosphere, resulting in acid rain or snow. The geology of an area determines the pH of the local water. If limestone is present, like much of Missouri, the alkaline limestone neutralizes the effect acid rain might have on lakes and streams.



C. Changes in Aquatic Life

Most organisms have adapted to life in water of a specific pH and may die if the pH changes. At extremely low or high pH values (4.5 or 11.0 respectively) the water becomes lethal to most organisms. pH is also important because of how it affects other pollutants in the water. Very acidic waters can cause heavy metals to be released into the water column. The metals can then be taken up and accumulated in the food chain. Metals in the water, such as copper and aluminum, can accumulate on the gills of fish or cause deformities in adolescent fish, reducing their chances of survival. In basic water, ammonia compounds convert to a toxic form; the more basic the water, the more toxic the ammonia that is present.