Missouri Streams Fact Sheet

CHEMICAL MONITORING

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Chemical parameters play an important role in the health, abundance, and diversity of aquatic life. They also determine how suitable water is for drinking water supplies or for industrial uses. Excessive amounts of some constituents, such as *nutrients*, or the lack of others, such as dissolved oxygen, can result in imbalances in water chemistry. These imbalances can degrade aquatic conditions and harm or kill aquatic life. An imbalance in chemical constituents can also make water unsuitable for human consumption, or greatly increase the cost of water treatment before it can be used.

The quality of a stream's health can be determined in several ways. One of the most commonly used methods is to chemically analyze the water. Some of these chemical tests include *nitrates*, *ammonia*, *dissolved oxygen*, *pH*, *temperature* and *conductivity.* Chemical analysis provides information about the condition of the water and stream at the time the sample was collected.

Temperature

Water temperature is very important, affecting many of the physical, biological and chemical characteristics of a stream. Temperature influences the amount of oxygen that can be dissolved in the water, the rate of photosynthesis by algae and larger aquatic plants and the metabolic rates of aquatic organisms and the sensitivity of organisms to toxic wastes, parasites and diseases. Cool water can hold more oxygen than warm water, because gases, like oxygen, are more easily dissolved in cool water.

One of the most serious ways that humans increase the temperature of rivers is through *thermal pollution*. Thermal pollution is water discharged into a stream that is warmer than the water present in the river. Industries such as power plants may cause thermal pollution by discharging water that has cooled equipment and processes that generate a lot of heat. Thermal pollution may also occur when *stormwater* drains from streets, sidewalks and parking lots heated by the sun. Runoff from these hot surfaces can be warmer than water in the river or stream and has been measured as high as 120 degrees Fahrenheit.

People can also impact stream temperatures by cutting down trees that shade the water from the sun. Direct sunlight is a major factor in the warming of rivers. Humans also contribute to warmer water by causing soil erosion. Removing trees and other vegetation from streambanks, plowing near the streambank and construction can cause soil erosion. Soil erosion is an important factor in river temperature because erosion increases the amount of suspended solids in the river. A large amount of suspended solids decrease visibility in the water, or turn the water *turbid*. This turbid water absorbs the sun's rays, warming the water.

As water temperature increases, the rate of photosynthesis and plant growth increases. More plants grow and die. As these plants die, they are decomposed by bacteria that use oxygen. Therefore, when the rate of photosynthesis is increased, the need for oxygen in the water is also increased.

Aquatic organisms have adapted to survive within a range of water temperatures. Very high or low water temperatures may exceed the tolerance limit for some aquatic life. Some aquatic organisms like trout and stonefly nymphs require cooler water temperatures than channel catfish and dragonfly nymphs. Fish can become stressed by higher water temperature and become more vulnerable to parasites, disease and pollutants.

Dissolved Oxygen

Dissolved oxygen is essential for the maintenance of healthy lakes and rivers. The presence of oxygen in water is a positive sign, the absence of oxygen a signal of severe pollution. Most aquatic plants and animals need a certain level of dissolved oxygen for survival. Some aquatic organisms, like trout and smallmouth bass, require medium to high levels of dissolved oxygen to live. Other aquatic organisms, like carp and catfish, can survive in waters with low dissolved oxygen. Waters with consistently high dissolved oxygen are usually considered healthy and have stable aquatic ecosystems capable of supporting many different kinds of aquatic organisms.

Much of the dissolved oxygen in water comes from the atmosphere. Waves and riffles mix atmospheric oxygen with water. Most surface waters contain between 5 and 15 parts per million dissolved oxygen.

Algae and rooted aquatic plants also deliver oxygen to water through photosynthesis. From morning through the afternoon hours, dissolved oxygen levels rise through photosynthesis. Late in the afternoon, dissolved oxygen levels are highest. As the sun sets, photosynthesis stops, but plant and animal respiration continues to consume oxygen. Just before dawn, dissolved oxygen levels fall to their lowest level. Large fluctuations in dissolved oxygen from late afternoon to early morning are characteristic of bodies of water with extensive plant growth (Figure 1).

The main factor reducing dissolved oxygen levels is organic wastes such as sewage, urban and agricultural non-point runoff, manure and industrial discharges. Urban and agricultural run-off contains fertilizers that stimulate excessive growth of algae and other aquatic plants.

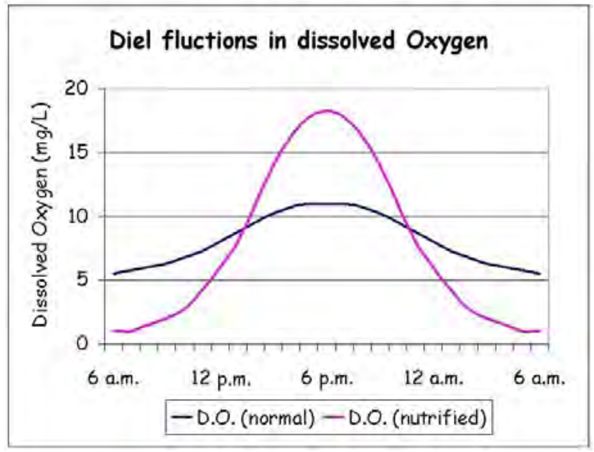

Figure 1

Water temperature and the volume of water moving down a river or stream also affect dissolved oxygen levels. Oxygen is more easily dissolved in cooler water than in warmer water so streams typically have lower levels of dissolved oxygen during the summer. Dry periods often occur during the summer, so the combination of warm temperatures and low flow results in reduced dissolved oxygen levels in water.

Dissolved oxygen saturation is the maximum level of dissolved oxygen that would be present in the water at a specific temperature, in the absence of other influences. Percent saturation is a more meaningful water quality indicator than a DO reading alone. Dissolved oxygen saturation is a good indicator of whether a DO measurement alone is good or bad. For instance, a DO reading of 8.0 mg/L could be an excellent result during the summer when water temperatures are high and the water's ability to hold oxygen is low. That same reading, however, could indicate problems if that result were obtained during the winter months when water temperatures are low and oxygen-holding capacity is high.

A General Rule for Ozark Streams

> 80% DO saturation reflects healthy DO levels

< 80% DO saturation reflects water quality impairment

A General Rule for Prairie Streams and Slow Moving Streams

> 60% DO saturation reflects healthy DO levels

< 60% DO saturation reflects water quality impairment

Depletion of dissolved oxygen can cause major shifts in every category of aquatic organisms from pollution intolerant to tolerant species. If dissolved oxygen levels drop, aquatic insects sensitive to low dissolved oxygen, like mayfly nymphs, stonefly nymphs and caddisfly larvae, are replaced with aquatic worms and fly larvae that are tolerant of these levels.

pH

Water contains both H^+ (hydrogen) ions and OH^- (hydroxyl) ions. “pH” is an abbreviation for the French expression, “pouvoir Hydrogene,” meaning, “the power of Hydrogen.” The pH test measures the H^+ ion concentration. The pH scale ranges from 0 to 14 (Figure 2). Pure *deionized* water contains equal numbers of H^+ and OH^- ions and is considered neutral with a pH of 7.0; it is neither acidic nor basic. If the sample being measured has more H^+ than OH^- ions, it is considered acidic and has a pH less than 7.0. If the sample contains more OH^- ions than H^+ ions, it is considered basic with a pH greater than 7.0.

Concentration of Hydrogen ions compared to distilled water		Examples
10,000,000	pH 0	Battery acid
1,000,000	pH 1	Hydrochloric acid
100,000	pH 2	Lemon juice, vinegar
10,000	pH 3	Grapefruit, soft drink
1,000	pH 4	Tomato juice, acid rain
100	pH 5	Black coffee
10	pH 6	Urine, saliva
1	pH 7	“Pure” water
1/10	pH 8	Sea water
1/100	pH 9	Baking soda,
1/1,000	pH 10	Great Salt Lake
1/10,000	pH 11	Ammonia solution
1/100,000	pH 12	Soapy water
1/1,000,000	pH 13	Bleach
1/10,000,000	pH 14	Liquid drain cleaner

Figure 2

The pH scale is logarithmic. Thus, it is important to remember that every one-unit change on the pH scale is a ten-fold change of the sample. As you go up and down the scale, the values change in factors of ten. A one-point pH change indicates the strength of the acid or base has increased or decreased tenfold; a 2-point change indicates a 100-fold change in acidity or basicity, and a 3-point change in pH indicates a 1000-fold change.

Examples:

- **An increase in pH from 7.0 to 8.0 means the water is 10 times more basic.**
- **An increase in pH from 7.0 to 9.0 means the water is 100 times more basic.**
- **An increase in pH from 7.0 to 10.0 means the water is 1,000 times more basic.**

The pH of natural water is usually between 6.5 and 8.5, although wide variations can occur. The acceptable range for most aquatic organisms is 6.5 to 9.0. Increased amounts of nitrogen oxides ($N0_X$) 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. These acids combine with moisture in the atmosphere and fall to earth as acid rain, sleet, snow or particulate form. Another source of pH change is acid mine runoff from coal mines. High sulfur concentrations in the *overburden* combine with water to form sulfuric acid. The type of rocks and minerals present in a watershed determine the acidity of the water. In Missouri, limestone neutralizes the effect acids might have on lakes and streams. The exception is in the St. Francois Mountains, in Southeast Missouri, where there are granite outcroppings. Here the waters are not buffered and naturally have a lower pH.

Changes in the pH value of water are important to many organisms. At extremely high pH values, the water becomes unsuitable for most organisms. Immature stages of aquatic insects and immature fish are extremely sensitive to pH values below 4.5 because low pH can result in reproductive failure from egg mortality, larval mortality and/or birth defects. Very acidic waters cause heavy metals to be released into the water and can accumulate on the gills of fish or cause deformities in young fish, reducing their chance of survival.

Nutrients

Nitrogen is an essential plant nutrient required by all living plants and animals for building protein. All organic (living) matter contains nitrogen. 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, some algal blooms are a result of excess nitrogen entering the stream. As aquatic plants and animals die, bacteria break down the organic matter. Ammonia (NH_3) is oxidized (combined with oxygen) by bacteria to form nitrites (NO_2) and nitrates (NO_3).

Ammonia $\rightarrow$ Nitrite $\rightarrow$ Nitrate

$NH_3 \rightarrow NO_2 \rightarrow NO_3$

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

Natural impacts on nitrogen levels include leaf fall and decomposition of organic matter other than leaves. However, an excessive amount of nitrogen causes *eutrophication*. Figure 3 illustrates the process of eutrophication. Sources of nitrates and ammonia include inadequately treated wastewater from sewage treatment plants, poorly functioning septic systems, as well as storm drains may carry wastes from pets, fertilizers, broken sewer lines and septic systems.

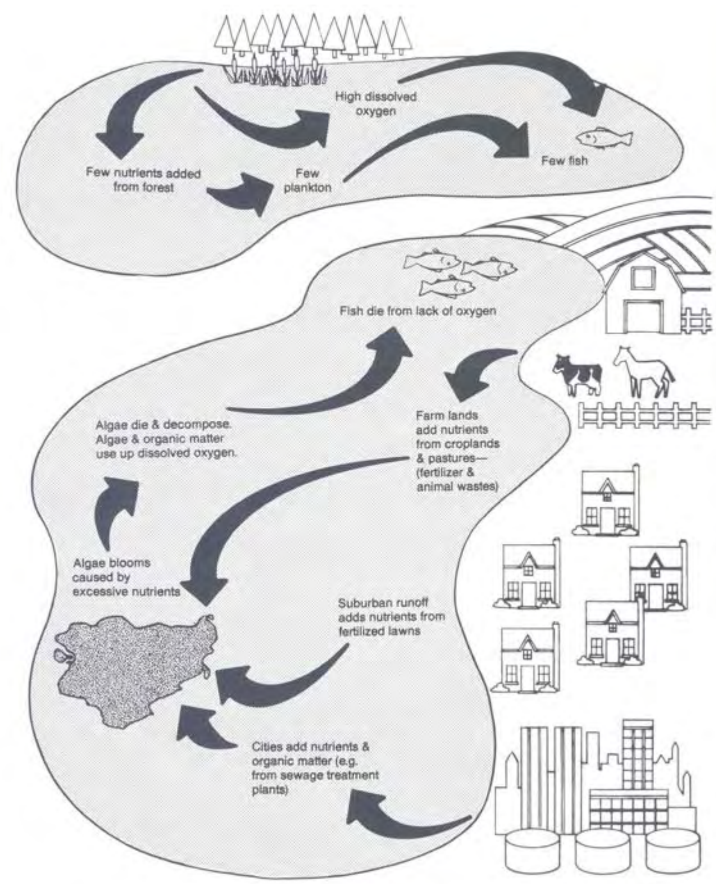

Figure 3 From the Terrene Institute, 1996

River	Avg. Value	# of Samples	Range
Mississippi	2.77	n = 15	1.1 – 4.7
Chariton	0.46	n = 12	0.02 – 1.3
Pomme de Terre	0.46	n = 12	0.02 – 0.43
Jacks Fork	0.32	n = 6	0.24 – 0.43

Nitrate as Nitrogen Values in Missouri (in mg/L)

Source: USGS, 1997

Ammonia as Nitrogen Values in Missouri (in mg/L)

Source: USGS, 1997

River	Avg. Value	# of Samples	Range
Mississippi	0.56	n = 14	0.4 – 1.2
Chariton	1.55	n = 12	0.38 – 7.5
Pomme de Terre	0.45	n = 12	0.2 – 1.4
Jacks Fork	0.02	n = 6	0.01 – 0.02

Phosphorus is also a plant nutrient. Phosphorus is most readily available to plants as orthophosphate, a reactive form of phosphorus commonly referred to as PO_4 (phosphate). In nature it is generally present in very low levels measured in tenths or hundredths of a mg/L.

Phosphorus occurs naturally in rocks and enters the water column through the natural weathering of rock. Phosphorus binds readily with soil particles. Soil must be highly saturated with phosphorus before excess amounts are detectable in shallow groundwater, which will eventually enter streams where it can have negative impacts.

In many instances phosphate can be the nutrient that limits plant growth. This occurs when phosphorus is less abundant in surface water than nitrogen; small increases in the amount of phosphorus entering a stream can have a large impact. If point source or nonpoint sources of pollution are high in phosphate, they can over-stimulate the growth of all types of aquatic plants.

Phosphate (PO_4) Values in Missouri (in mg/L)

Source: USGS, 1997

River	Avg. Value	# of Samples	Range
Mississippi	0.56	n = 14	0.4 – 1.2
Chariton	1.55	n = 12	0.38 – 7.5
Pomme de Terre	0.45	n = 12	0.2 – 1.4
Jacks Fork	0.02	n = 6	0.01 – 0.02

Conductivity

All liquid solutions conduct electricity to some degree. The measurement of water's ability to conduct electricity is called *conductivity*, or *specific conductance*, and is measured in a unit of current, or flow of electricity, called microsiemens (ì S) per centimeter (cm). Conductivity is determined by the amount of solids that are dissolved in the water. Rainfall, interacting with the atmosphere, vegetation, rocks and soil, is the major source of dissolved solids in streams. Groundwater entering streams is another source. Water is uncommonly good at dissolving a wide variety of materials and is the medium that allows the necessary biochemical reactions in organisms to proceed. Water carries needed minerals and nutrients to living organisms and transports wastes away.

Seven common substances make up about 99% of the dissolved solids in streams. In their approximate order of abundance in Missouri waters, these include the following:

1. Bicarbonate
2. Calcium
3. Magnesium
4. Sulfate
5. Chloride
6. Sodium
7. Potassium

It is not surprising that the three most abundant dissolved substances come from the dissolution of limestone and dolomite, Missouri's most abundant rocks. The remaining one percent of dissolved substances can vary considerably, but can include nitrates, different metals, ammonia, phosphorus and man-made compounds such as pesticides and fuels. Conductivity is a general indicator of water quality, because it can tell us the amount of solids dissolved in the water, but does not tell us what kind of dissolved solids are present. Unexplained changes in conductivity can indicate problems in the watershed.

Conductivity may vary primarily due to the influence of rainfall or snowmelt. Precipitation is low in dissolved solids, and an unimpacted stream that has recently received rainfall will have a lower conductivity value. The conductivity values on the next page are typical readings for various waters and geographic regions.

Typical Conductivity Readings in Missouri

Missouri River at St. Joseph **550-850 µS/cm**

Conductivity is high in the Missouri River since it drains all of the water for 420,300 square miles.

Grand River near Sumner **350-550 µS/cm**

Pomme de Terre near Polk **300-400 µS/cm**

Big Piney at Devil's Elbow **200-350 µS/cm**

Little Ditches near Rives **100-500 µS/cm**

Jacks Fork at Alley Spring **100-350 µS/cm**

Pickle Creek at Hawn State Park **40-60 µS/cm**

Pickle Creek is located in Hawn State Park near Ste. Genevieve, which is in a geologic region that consists of granite. Granite does not dissolve as easily as limestone, so the amount of natural dissolved minerals and nutrients is very low in the waters of this ecoregion.

Municipal wastewater treatment plant effluent **1000-2000 µS/cm**

The conductivity of wastewater tends to be very high since most plants do not treat wastewater for dissolved solids. The most common and abundant dissolved solid that may pass through the plant is sodium chloride, the salt that we ingest. Salt is a good electrical conductor.

North and west Missouri shallow groundwater **800-2000 µS/cm**

Groundwater in North Missouri is high in salt (dissolved minerals) since the aquifer rests on an ancient seabed.

Please continue on to the next page to view a Water Chemistry Reference Table to learn what certain water quality parameters really mean.

WATER CHEMISTRY REFERENCE TABLE

Use this table as a guide as you interpret your water quality field data. Remember that each aquatic system is different, so this table is only a guide, <u>not a hard fast rule</u>!

WATER PARAMETER TESTED	WHAT IT MEASURES	NATURAL READINGS	CAUTIONARY READINGS (could be a problem)	POSSIBLE SOURCES/ INFLUENCES	REMEDIES
Water Temperature	average amount of heat in the water	0° - 34°C (32° - 93°F)	above 32ºC (90ºF) above 24ºC for smallmouth bass/goggle eye streams (84°C) above 20°C for trout streams (68°C)	- thermal discharges (e.g., industrial, waste water treatment plants) - increased turbidity - solar heat (e.g., loss of shade in riparian areas) - heated runoff from impervious surfaces (e.g., asphalt, concrete)	- discharges adhering to limits set in permits/regulations - increased riparian (stream side) shade - decrease impervious surfaces (i.e., revegetate watershed)
Dissolved Oxygen	amount of oxygen dissolved in the water	**natural readings:** 5 – 15 mg/L (milligrams per liter) or more than 80% dissolved O_2 % saturation in Ozark streams and more than 60% dissolved O_2% saturation in prairie streams or streams with no aeration **cautionary readings:** - below 6 mg/L cold water *Standard*s violation - below 5 mg/L cool and warm water *Standards* violation - 3 - 5 mg/L (40% - 80%) causes stress resulting in abnormal feeding , reduced reproduction - < 3 mg/L (<40%) results in death in most species - 0 mg/L = anoxic		- atmosphere via aeration (e.g., wind, running water) - photosynthesis by algae and other aquatic plants	- can control quantity of algae by limiting nutrients (N, P) entering the water - reduce water temperature
pH	acid/base of the water	generally 6.5 – 9.0	below 6.5 above 9.0	- acid rain - industrial pollution - chemical spills	- pollution controls - pH moderation by addition of acid or basic compounds
Nitrates	organic matter or fertilizer materials in water	0.0 – 2.0 mg/L	consistent readings above 2 mg/L	- human sewage - industry output - domestic use of detergents - fertilizer (urban and agricultural) - animal wastes	vegetated riparian zones limit usage of agricultural and yard fertilizers properly maintained septic systems
Phosphates	organic matter or fertilizer materials in water	0.0 – 0.2 mg/L	consistent readings above 0.2 mg/L	- animal wastes - fertilizer - domestic use of detergents - industry output	vegetated riparian zones agricultural waste management limit use of agriculture and yard fertilizers
Turbidity	clarity of the water	highly variable measured in Nephelometric Turbidity Units (NTUs)	increasing turbidity measurements in a waterbody over a period of time	- sediment, usually from increased surface runoff (e.g., off construction sites, cropland) - excessive algae growth - watercraft traffic	sediment controls riparian zones to reduce nutrients watercraft speed limits