

A black silhouette of a trilobite is centered within a black Erlenmeyer flask. The trilobite's head is at the top, with its antennae and eyes visible. Its thorax is in the middle, and its segmented abdomen extends down to the base of the flask. The flask is set against a white background, which is framed by a teal border. A small grey vertical bar is on the left side of the white area.

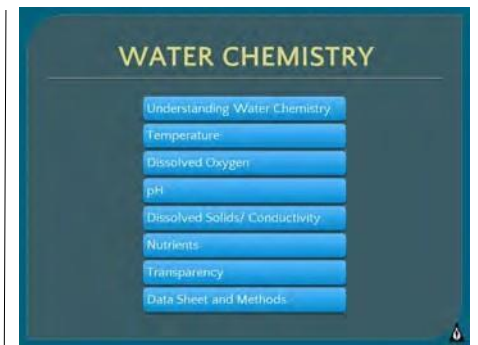
CHEMISTRY



# Chemistry

We will discuss:

- Understanding Water Chemistry
- Temperature
- Dissolved Oxygen
- pH
- Dissolved Solids
- Nutrients
- Transparency



## WATER

- All life on Earth requires water
- Medium that allows necessary biological reactions to occur
- Carries needed nutrients and minerals to aquatic life and carries waste away

## WHY MONITOR CHEMICAL PARAMETERS?

- Water chemistry important to:
  - Health (aquatic and human)
  - Abundance/diversity of aquatic life
- Changes in one parameter can affect other parameters

## TOXICITY

- **Toxicity** is the measurement of how poisonous or harmful a substance is to plants and animals

Acute Toxicity	Chronic Toxicity
Short term (2-4 days)	Longer-term (1/10 of life span or more)
Lethal/Serious harm	Harmful but usually not lethal (affects growth, reproduction)

## WATER QUALITY STANDARDS

- Water quality must meet standards for the uses of that water body (i.e. protection of aquatic life, human health-fish consumption)
- If standards are not met, human health and aquatic life may suffer



## MONITORING WATER CHEMISTRY

- Monitor water chemistry 4 times a year, if possible – once per season
- Flow impacts chemistry – try to also measure stream discharge when monitoring water chemistry



## Why monitor chemical parameters?

Water carries needed nutrients and minerals to aquatic life and carries waste. Chemical parameters play an important role in:

- **Health:** of the stream
- **Abundance:** of aquatic insects
- **Diversity:** of aquatic organisms
- **The life within the stream**

Remember that changes in many of the following parameters can affect other chemical parameters.

## Toxicity Definitions

**Toxicity:** A measurement of how poisonous or harmful a substance is to plants and animals

Acute Toxicity	Chronic Toxicity
Short term (2-4 days)	Longer-term (1/10 of life span or more)
Lethal/Serious harm	Harmful but usually not lethal (affects growth, reproduction)

Water Quality Standards (WQS) are set to protect human health and animal life. These standards can be found on the Missouri Department of Natural Resources website.

## Monitoring Water Chemistry

Water chemistry should be monitored at least four times per year, once every season. Some monitors may have specific project goals which require monitoring more frequently. Since stream flow affects water chemistry, also measure stream discharge while collecting water chemistry data.

## Effects of Temperature

The **amount of dissolved oxygen in the water**, the **rate of photosynthesis** by algae and other aquatic plants, and the **rate of plant growth** are all affected by temperature. Plant growth increases with warmer temperatures. When plants die, they are decomposed by bacteria, which use up oxygen. Increased plant growth means more oxygen being removed from the water during the decomposition process.

The **metabolic rates of organisms** increase with higher temperatures. As respiration and digestion rates increase, fish, aquatic insects, and aerobic bacteria require more oxygen to survive.

The **sensitivity rates of organisms** is also affected by temperature. Many organisms require a specific temperature range, and changing that range may eliminate some organisms from the ecosystem. Under temperature extremes, organisms may become stressed, which makes them more vulnerable to toxic wastes, parasites, and disease.

## Water Quality Standard for Temperature

Water temperatures shall not exceed:


Type of Water Body	Water Temperature Standard
Warm water fisheries	32°C (90°F)
Cool water fisheries	29°C (84°F)
Cold water fisheries	20°C (68°F)

## Effects on Temperature

- **Riparian cover removal:** What if the trees in the riparian zone were removed from a cold-water trout stream? It is likely that our cold-water stream would not remain cold as long, because there would no longer be any shade.
- **Soil Erosion:** increased turbidity
- **Thermal Pollution:** Sources of thermal pollution include warm or hot water from a power plant or industrial discharge and runoff from impervious surfaces such as parking lots and streets.
- **Impervious Surfaces:** Impervious surfaces are anything that does not absorb water such as concrete, asphalt, roof tops and compacted soils. Impervious surfaces get very hot in the summer and stormwater runoff from these surfaces can reach as much as 120° Fahrenheit.

### EFFECTS OF TEMPERATURE

- Amount of dissolved gas in water
- Rate of plant growth and photosynthesis
- Toxicity
- Metabolic rate of organisms
- Sensitivity of organisms



### TEMPERATURE (WQ STANDARD)

Water temperatures shall not exceed:

Type of Water Body	Water Temperature Standard
Warm water fisheries	32°C (90°F)
Cool water fisheries	29°C (84°F)
Cold water fisheries	20°C (68°F)

### HUMAN IMPACTS

Riparian cover removal

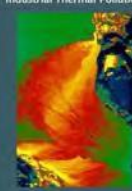


Soil erosion: increased turbidity



### THERMAL POLLUTION

Industrial Thermal Pollution



Impervious Thermal Pollution






### WHY MONITOR DISSOLVED OXYGEN?

- Oxygen is critical for all life in a stream
- Terrestrial vs. Aquatic
  - Air: 210,000 ppm O<sub>2</sub>
    - 21% oxygen
  - Water: 5-15 ppm O<sub>2</sub>
    - 0.0005% - 0.0015% dissolved oxygen

Note: parts per million (ppm) = milligrams per liter (mg/L)



Understanding Water Quality | Temperature | Dissolved Oxygen | pH | Dissolved Solids | Nutrients | Sediment | Toxic Stress & Bioassays

### SOURCES OF DISSOLVED OXYGEN (D.O.)

Oxygen becomes dissolved in water by:

- Waves and tumbling action
- Diffusion from atmosphere
- Photosynthesis



Understanding Water Quality | Temperature | Dissolved Oxygen | pH | Dissolved Solids | Nutrients | Sediment | Toxic Stress & Bioassays

### IMPORTANCE OF D.O.


- Aquatic Organisms need a certain level of D.O. for survival
- Depletion of D.O. can cause a population shift in the organisms present in a stream from sensitive to tolerant organisms

The Water Quality Standard for D.O. is no less than 5 mg/L (5 ppm)

Understanding Water Quality | Temperature | Dissolved Oxygen | pH | Dissolved Solids | Nutrients | Sediment | Toxic Stress & Bioassays

### NATURAL INFLUENCES ON D.O.

- Temperature
- Flow
- Dissolved and suspended solids
- Aquatic Plants: Photosynthesis



Understanding Water Quality | Temperature | Dissolved Oxygen | pH | Dissolved Solids | Nutrients | Sediment | Toxic Stress & Bioassays

### HUMAN IMPACTS ON D.O.

- Removal of riparian corridor vegetation
- Dams
- Organic waste – sources include:
  - Stormwater/Urban Runoff
  - Septic systems
  - Wastewater treatment plants
  - Animal feedlots
  - Discharges from food processing plants

Understanding Water Quality | Temperature | Dissolved Oxygen | pH | Dissolved Solids | Nutrients | Sediment | Toxic Stress & Bioassays

## Dissolved Oxygen

**Dissolved oxygen (DO)** is essential for the maintenance of healthy waterways. Aquatic life needs a certain level of dissolved oxygen for survival and a depletion of DO can cause a major shift in the organisms present in a stream.

Dissolved oxygen comes from 3 major sources:

- **Atmosphere:** The air we breathe contains approximately 21% oxygen, which equates to 210,000 ppm oxygen. Some of this oxygen diffuses into streams. Most surface waters contain between 5 and 15 ppm dissolved oxygen.
  - **Aeration:** Waves and tumbling saturate water with oxygen from the atmosphere like an aquarium aerator.
  - **Photosynthesis:** Algae and other aquatic plants deliver oxygen to water.
- Waters with consistently high D.O. are considered healthy and stable aquatic systems – a positive sign. Absence of D.O. is a sign of severe pollution.

## Water Quality Standard for Dissolved Oxygen

The Water Quality Standard for D.O. is no less than 5 mg/L (5 ppm)

Dissolved oxygen fluctuates throughout the day. It is natural to be lowest just before sunrise and peak during the middle of the day. This is because algae and other aquatic plants switch from photosynthesis to respiration at night and are therefore using oxygen, not producing it.

Some of the factors that can cause extreme fluctuations in DO include:

- Removal of trees
- Excess nutrients

It's best to sample water quality first thing in the morning to measure the lowest dissolved oxygen for your stream.

## Dissolved Oxygen Percent Saturation

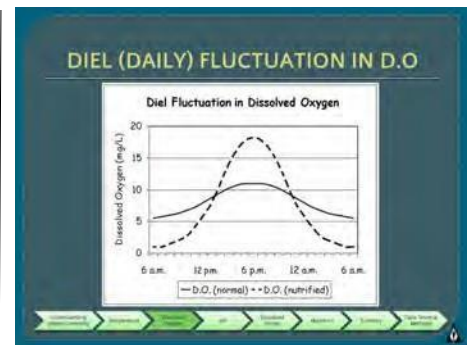
**Dissolved Oxygen Saturation** is the maximum level of dissolved oxygen that would be present in the water at a specific temperature, in the absence of other influences.

**Percent Saturation** is the percentage of dissolved oxygen concentration relative to that when completely saturated. This tells us whether a DO measurement is good or bad.

As water temperature increases, DO saturation decreases, and as water temperature decreases, DO saturation increases. Therefore, cold water will hold more DO than warm water.

### Acceptable D.O. Percent Saturation Levels

Ozark Stream (high gradient, rocky bottom)	>80% D.O. Saturation
Prairie Streams (Low-gradient or slow moving)	>60% D. O. Saturation



### D.O. PERCENT SATURATION

- D.O. concentration tells us how much oxygen is in the water
- How do we know whether there is *enough* oxygen in the water?
- **DO Percent Saturation:** Ratio of amount of oxygen present in water to the maximum the water *could hold* at that **temperature** in the absence of other influences
- More meaningful indicator than a D.O. reading alone

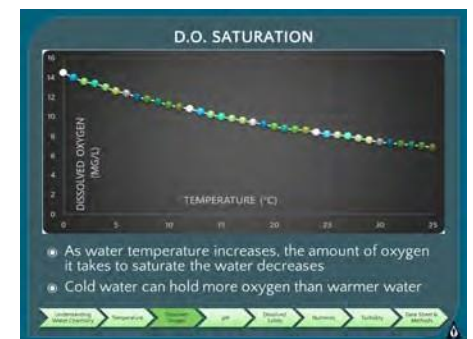
### HOW DOES TEMPERATURE INFLUENCE D.O. SATURATION?

**Warm Water**

\*Due to more energy in warm water, water molecules move faster resulting in a lower ability to hold on to oxygen molecules

**Cold Water**

\*Cold water has lower energy and slower moving water molecules, allowing it to retain oxygen molecules




### D.O. PERCENT SATURATION

- Example: a D.O. of 8 mg/L
- In the summer, when water temperatures are high, could be an excellent result
- In winter, when water temperatures are low, could indicate problems
- D.O. Saturation takes the guesswork out of interpreting D.O. measurements

**pH = PARTS HYDROGEN IONS (H<sup>+</sup>)**


- Water contains both Hydrogen (H<sup>+</sup>) and Hydroxide (OH<sup>-</sup>) ions
- pH measures the H<sup>+</sup> concentration on a scale from 0 to 14
- Water that contains equal numbers of H<sup>+</sup> and OH<sup>-</sup> is considered neutral (pH 7)



0 7 14  
Acid Neutral Basic

**pH = PARTS H<sup>+</sup> IONS**

- Water that contains more H<sup>+</sup> ions than OH<sup>-</sup> ions is acidic and has a pH less than 7
- Water that contains more OH<sup>-</sup> ions than H<sup>+</sup> ions is basic and has a pH greater than 7



0 7 14  
Acid Neutral Basic

**pH = PARTS H<sup>+</sup> IONS**

- One unit on the pH scale is a ten-fold H<sup>+</sup> ion change

Examples:


- Increase from 7 to 8 = 10 times more basic
- Increase from 7 to 9 = 100 times more basic



0 7 14  
Acid Neutral Basic

**pH SCALE**

- Normal stream water pH ranges from 7.0 to 8.0
- The Water Quality Standard in Missouri for pH is a range of 6.5-9.0
- pH outside this range is toxic to most aquatic life



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14  
Lethal  
Ammonia converts to Toxic form  
Neutral  
Lethal  
Metals (Aluminum, Zinc, Copper) become insoluble

## pH

Water contains both Hydrogen (H<sup>+</sup>) and Hydroxyl (OH<sup>-</sup>) ions. **pH** measures the H<sup>+</sup> concentration on a scale from 0 to 14.

- neutral (pH 7)** contains equal numbers of H<sup>+</sup> and OH<sup>-</sup> ions
- acidic (pH < 7)** contains more H<sup>+</sup> than OH<sup>-</sup> ions
- basic (pH > 7)** contains more OH<sup>-</sup> ions

The pH scale is logarithmic, meaning that every one-unit change on the pH scale is a ten-fold H<sup>+</sup> ion change. A one-point pH change indicates the strength of the acid or base has increased or decreased tenfold. A two-point change indicates a 100-fold change.

- Increase from 7 to 8 = 10 times more basic
- Increase from 7 to 9 = 100 times more basic

## pH Effects on aquatic life

Normal stream water pH ranges from 6.5 to 8.0. Most organisms have adapted to life in water of a specific pH and may die if that fluctuates even slightly. **At extremely high or low pH values (11.0 or 4.5) the water becomes lethal to most organisms.**

Waters that are acidic can cause metals such as zinc, aluminum, and copper to be released into the water column and accumulate in the food chain. Copper and aluminum can accumulate on fish gills and cause deformities in young fish, reducing their chance of survival. Ammonia compounds convert to a toxic form in basic water. The more basic the water, the more toxic the ammonia that is present.

## Water Quality Standard for Ph

The Water Quality Standard for pH is 6.5 – 9.0



## Conductivity

**Conductivity** is a measure of the electrical current passing through water. It is a general indicator of water quality trends because it tells us the amount of dissolved solids are in the water. **Conductivity measurements do not tell us which dissolved substances are in the water, only how much.** Small amounts of certain dissolved solids, such as some metals, can cause significant changes in conductivity.

Common dissolved solids which influence conductivity:

- Bicarbonate
- Calcium
- Magnesium
- Sulfate
- Chloride
- Sodium
- Potassium

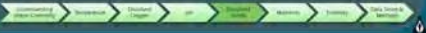
Sources of dissolved solids in streams include: rainfall, vegetation, rocks, soil, and groundwater. The three most abundant dissolved substances come from the dissolution of limestone and dolomite. The remaining one percent of dissolved solids can vary considerably, but can include nitrates, metals, ammonia, phosphorus, and manmade compounds such as pesticides and fuel.

## Water Quality Standards for Conductivity

There is currently no Water Quality Standards for conductivity

### CONDUCTIVITY

- Measure of the potential electrical current passing through water
- General indicator of dissolved solids in a stream (more dissolved solids=higher electrical conductivity)
- Measured in microsiemens per centimeter ( $\mu\text{S}/\text{cm}$ )



### CONDUCTIVITY

- Common dissolved solids:

Bicarbonate	Chloride
Calcium	Sodium
Magnesium	Potassium
Sulfate	



*There is currently no Water Quality Standard for conductivity in Missouri streams*



## CHLORIDES

Chlorides are salts resulting from the combination of gas chlorine and various metals

### Sources:

- Road salt (NaCl)
- Fertilizers
- Underground aquifers
- Water softeners
- Storm sewers
- Animal feed
- Wastewater treatment discharges



Underground aquifers    Storm sewers    Wastewater treatment    Road salt    Fertilizers    Animal feed    Water softeners    Chlorides

## CHLORIDE SPIKES

### Spikes can occur:

- Summer when Evaporation > Precipitation
- Spring/fall with Fertilizer application
- Winter with snow and ice melt, rain



## PROBLEMS WITH CHLORIDES

- High levels are toxic to aquatic life
- Invasive species can be more tolerant, and outcompete native aquatic species

*The Water Quality Standard for Missouri*

Designated Use	Chronic	Acute
Aquatic Life	230 mg/L	860 mg/L
Drinking Water	250 mg/L	

Underground aquifers    Storm sewers    Wastewater treatment    Road salt    Fertilizers    Animal feed    Water softeners    Chlorides

## Best Management Practices for ROAD SALT

- Rate adjustments on salt spreaders
- Brine pre-treatment

(St. Louis University research project)

**\*\*Not a problem for all streams; must be Level 2 to monitor**



Underground aquifers    Storm sewers    Wastewater treatment    Road salt    Fertilizers    Animal feed    Water softeners    Chlorides

## Chlorides

**Chlorides** are salts resulting from the combination of chlorine gas and various metals. Most chlorides come from sodium chloride (NaCl) applied to roads and sidewalks to melt ice.

Application of these road salts has drastically increased since the 1970s. These salts can travel up to 130 ft from the roadway and often have heavy metal additives, so other harmful substances may be present.

High levels of chlorides are toxic to aquatic life. They interfere with osmoregulation in freshwater organisms and can lead to fish kills.

Some invasive species (e.g. Eurasian water milfoil) are more tolerant to chloride and can outcompete the native species of the area.

Spikes can occur during the summer during low flows and during the spring and fall after fertilizer applications.

## Water Quality Standards for Chlorides

Designated Use	Chronic	Acute
Aquatic Life	230 mg/L	860 mg/L
Drinking Water	250 mg/L	

## Nitrogen

**Nitrogen** is an essential plant nutrient required by all living plants and animals for building protein. All living, organic matter contains nitrogen. As aquatic plants and animals die, bacteria break down the organic matter. Ammonia ( $\text{NH}_3$ ) is oxidized (combined with oxygen) by bacteria to form nitrites ( $\text{NO}_2$ ) and nitrates ( $\text{NO}_3$ ).

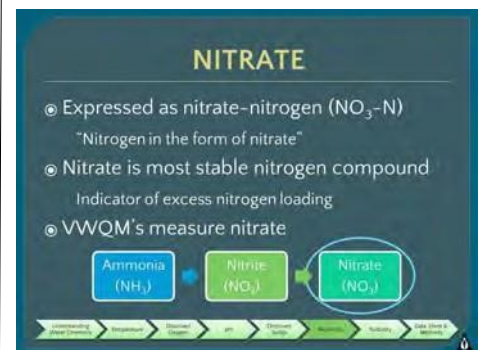
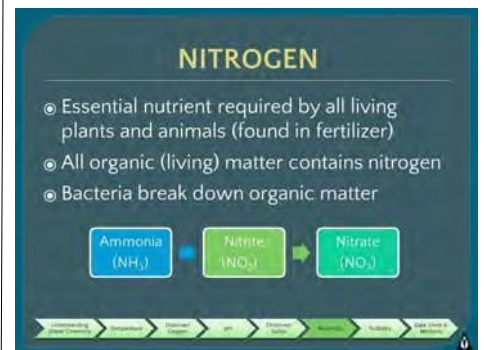
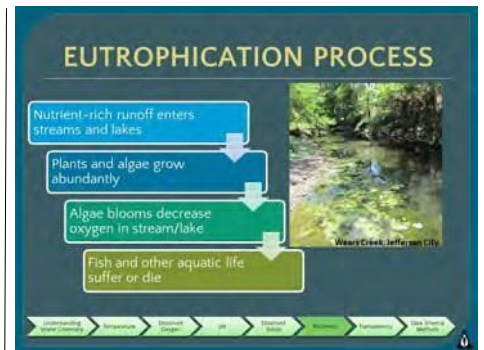


### What affects nitrogen levels?

- Leaf fall
- Organic decay
- Anthropogenic impacts:
  - Poorly functioning septic systems
  - Wastewater from treatment plants
  - Runoff from animal production
  - Runoff from fields and lawns
  - Storm drains
  - Combined sewer overflows (CSO)

## Water Quality Standard for Nitrate

There is a nitrate Water Quality Standard criterion of **10 mg/L**



### AMMONIA (NH<sub>3</sub>)

- The only nutrient directly toxic to aquatic life
- Toxicity dependent on the pH and temperature of the stream water
- \*\*Not a problem at all streams; must be Level 2 to monitor

Water Quality Standard for Ammonia Nitrogen is 0.5 mg/l

## Ammonia

**Ammonia (NH<sub>3</sub>) is the only nutrient that is directly toxic to aquatic life.**

However, the toxicity of ammonia is dependent on the pH and the temperature of the water.

Ammonia levels are not usually a problem in most Pennsylvania Rivers and streams. Ammonia is only monitored when a need is determined.

## Water Quality Standard for Ammonia

The Water Quality Standard for Ammonia Nitrogen is 0.5 mg/l

### PHOSPHORUS

- Occurs through natural weathering of rock and breakdown of organic matter
- "Limiting nutrient" for plant growth in a body of water
- Very small additions (0.01 mg/L) can cause large algal blooms
- \*\*Not a problem for all streams; must be Level 2 to monitor

In 1998 and 1999 two large algal blooms occurred on Table Rock Lake.

Water Quality Standard for Phosphorus is 0.10 mg/l

## Phosphorus

**Phosphorus** is also a plant nutrient. It is most readily available to plants as **orthophosphate**, a reactive form of phosphorus commonly referred to as "phosphate" (PO<sub>4</sub>). Phosphorus occurs naturally in rocks and enters the water column through the weathering of rock. When additional phosphorus enters an aquatic system, even very small amounts (0.01 mg/L) can cause large algal blooms.

### Natural:

- **Rocks and soil**
- **Breakdown of organic matter**

### Anthropogenic:

- **Runoff from animal production:** especially from poultry litter
- **Wastewater from treatment plants**
- **Poorly functioning septic systems**
- **Runoff from fields and lawns:** Many people fertilize their lawns in urban areas. Runoff from rainfall events following application can cause high phosphorus levels after storm events.
- **Storm drains** - Storm drains may carry waste from pets, lawn fertilizer, broken wastewater lines and septic systems.
- **Combined sewer overflows (CSO)** - These systems caused excessive algae blooms in Lake Erie in the 1960's. Starting in 2011, projects began to reduce the volume of discharges by CSOs around Lake Erie.
- 

## Water Quality Standard for Ammonia

- The EPA established a goal for total phosphorus concentration of 0.10 mg/L to limit cultural eutrophication of flowing water.



# Transparency

**Transparency** is a measure of water clarity. It measures the depth in centimeters that light can penetrate the water. Suspended matter and plankton can cause cloudy, murky, or green water. A larger reading means the transparency is higher, thus the water is clearer.

Having a low transparency is detrimental to aquatic life. Sediment can block out light needed for vegetation, and it can bury fish eggs and benthic invertebrates. Suspended particles can also absorb heat and increase the water temperature.

**Monitoring transparency can be particularly valuable:**

- In areas being developed
- Agricultural areas not adopting best management practices to prevent soil erosion
- Downstream from quarries and gravel mining operations



## TRANSPARENCY

- Measures the clarity of the water
- Suspended matter and plankton cause cloudy, murky or very green water
- Measured in centimeters
  - Measures the depth that light can penetrate water
  - The larger the depth reading, the higher the transparency




Transparency is a measure of water clarity. It measures the depth in centimeters that light can penetrate the water. Suspended matter and plankton can cause cloudy, murky, or green water. A larger reading means the transparency is higher, thus the water is clearer.

## TRANSPARENCY

Impacts from low levels:

- Sediment blocks light needed for vegetation
- Suspended particles absorb heat and increase water temperature
- Sediment buries fish eggs and benthic invertebrates



Transparency is a measure of water clarity. It measures the depth in centimeters that light can penetrate the water. Suspended matter and plankton can cause cloudy, murky, or green water. A larger reading means the transparency is higher, thus the water is clearer.

## Suspended Sediment from SOIL EROSION = DECREASED TRANSPARENCY



## TRANSPARENCY

Areas where monitoring transparency can be particularly valuable:

- Areas being developed
- Areas not adopting best management practices to prevent soil erosion
- Downstream from quarries and gravel mining operations