# IV-3. Introduction to Chemical Monitoring

Most substances in nature are "soluble" in water – water dissolves them. Consequently, streams with "pure" water (free of impurities) do not occur in nature. The amounts and types of impurities in the stream, whether they are natural or human-introduced, determine its chemical composition.

By monitoring the chemical composition we can show, quantitatively, changes in water quality. These changes may indicate disturbances in the watershed affecting the stream community.

This unit explains:

- the meaning of different types of chemical tests;
- how to perform the chemical tests; and
- how to interpret the results of those tests.

**In this section, you will find information and sampling instructions for the following:**

a. pH
b. Dissolved oxygen
c. Nutrients
   Nitrogen (nitrate and ammonia)
   Phosphorus
d. Turbidity
**e.** Temperature

### A note on "detection limits"

Tests for chemicals in water have limitations. Below a certain concentration, a test cannot give you an accurate measurement of a chemical. We call this threshold the **detection limit**. A detection limit is listed for each chemical test method in the *Utah Stream Team* manual. For example, the detection limit for phosphate is .02 mg/L.

The values of most water quality tests (excluding temperature and turbidity) are determined by color change. If you cannot detect a color change in a test, report your result as "less than the detection limit," not "0." For example, if you get no color change when you do a phosphate test, report the results as "<0.02 mg/L."

NOTE: Your actual detection limit may vary from the one listed in the directions depending upon how careful you were in performing the test and how well you can distinguish different colors.

**PPM's and PPB's ?**
In the Chemical Properties Unit you will sometimes see chemical concentrations described as ppm (parts per million) and ppb (parts per billion). These terms indicate the amount of chemical relative to the amount of material in which the chemical is contained (usually, water). A part per million equals one milligram per liter (mg/L). A part per billion equals one milligram per 1000 liters. Visit "A Drop in the Bucket," in the Water Pollution section, for more information on these units.

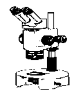
# IV-3a. pH

**Key terms**
acidic basic neutral
alkaline buffer

## What is pH?

The pH of water is a measurement of how **acidic** or how **basic** the water is. We measure pH on a scale of 0 to 14. Distilled water, which has no impurities, is **neutral.** It has a pH of 7.

Many substances dissolve in water. Sometimes when substances dissolve, they produce charged molecules called ions. Acidic water contains extra hydrogen ions (H+). Acidic water has pH values between 0 and 7, zero being the most acidic. Basic, or alkaline, water contains extra hydroxyl ions (OH-). Basic water has pH values between 7 and 14, 14 being the most basic. You might expect rainwater to be neutral. In fact, it is somewhat acidic with a pH of 5 to 6. This is due to the formation of carbonic acid as rain interacts with $CO_2$.



The pH scale is logarithmic – each unit change (e.g., from 7 to 6) in pH represents a 10-fold change in the acidity of the water. Water with a pH value of 6 is ten times more acidic than water with a pH value of 7. Water with a pH value of 9 is a 100-times more basic than water with a pH value of 7. The Richter Scale, which measures earth quakes, is another well-known logarithmic scale.

Look at the pH table below. Notice that substances that are highly acidic or basic, such as battery acid and lye, are toxic to most organisms. Refer back to this chart when you interpret your pH sample values.

**Table IV-3. The pH Scale**

| | Common substances | pH | Biological effects |
|---|---|---|---|
| | Stomach acid | 1 | |
| | Lemon juice | | |
| | | 2 | |
| | Vinegar | 3 | |
| *ACIDIC* | | | All fish die |
| | Soft drinks | 4 | |
| | Tomatoes | | Caddis and may flies die |
| | Carrots | 5 | |
| | Normal rain | | Salmon eggs and **alevin** die |
| | | 6 | Bass and trout begin to die |
| | Milk | | Snails and tadpoles begin to die |
| | | 7 | |
| | Human blood | | Optimum for most fish |
| | Egg whites | 8 | |
| | Baking soda | 9 | |
| | | | All fish die |
| *BASIC* | | 10 | |
| | Ammonia | | |
| | | 11 | |
| | Bleach | 12 | |
| | Lye | 13 | |
| | | 14 | |

# What natural influences cause the pH of our streams to change?

### Watershed effects

- Certain dissolved minerals, such as calcium carbonate, can combine with the extra hydrogen or hydroxyl ions that alter water's pH. When these minerals are present, the pH of the water doesn't change as much when acids or bases are added to the water. We call this buffered water. Many soils in our part of the west contain these minerals. When precipitation percolates these soils the minerals dissolve and the buffering quality is passed along to the water. Some watersheds contain primarily rocks with few of these buffering minerals. These watersheds, therefore, will produce poorly buffered water and any additional acid will change the pH of these waters.

> Limestone rock contains minerals which buffer streams. This type of rock is found throughout central and northern Utah. How do you think this might affect the pH values of our streams? If you found low pH values (high acidity) would you want to investigate further?

- If you have pine or fir forests in your watershed, you may see a lower pH value for your stream. The decomposing needles of these trees add to the acidity of soils and also influence the acidity of nearby streams.

- Water that enters your stream from the water table has had a chance to percolate through soil. If the soil is buffered, and if ground water is your stream's main source, then pH may be somewhat higher (7-8).

### Seasonal effects

- When precipitation falls through the air, it dissolves gases such as carbon dioxide, and forms a weak acid. Natural, unpolluted rain and snow is slightly acidic – it has a pH between five and six. When snow melts rapidly it may not **percolate** through the soil before reaching the stream: soil minerals can't buffer it. At these times, the stream water may also be slightly acidic.

- During autumn, decomposing leaves and needles in the stream may increase the acidity of the water.

### Daily effects

- When aquatic plants convert sunlight to energy during photosynthesis, they remove carbon dioxide from the water. This can raise the pH of your stream. Since photosynthetic activity occurs in sunlight expect the highest pH in your stream to occur in the early afternoon. Lowest pH levels will occur just before sunrise.

# What human influences cause the pH of our streams to change?

- Polluted precipitation, also known as "acid rain," increases the acidity of waters near many industrial or large urban areas. The main contributors to acid rain are sulfuric acid (produced by coal burning industries) and nitric acid (produced by automobile engines). In Utah our buffering soils help to decrease the effects of acid rain.

- Dumping industrial pollutants directly into waters – also known as **point source pollution** – can have intense and immediate effects.

- Mining may expose rocks to rain water and produce acidic runoff. Mining drainage can therefore introduce acids into streams, and if the stream is poorly buffered the pH may quickly reach toxic levels.

# Why do we care about the pH of our streams?

## Animals and plants

Most aquatic animals and plants have adapted to life in water with a specific pH and may suffer from even a slight change.

- Even moderately acidic waters (low pH) may reduce the hatching success of fish eggs, irritate fish and aquatic insect gills and damage membranes.
- Water with extremely high or low pH is deadly. A pH below 4 will kill most fish and very few animals can tolerate waters with a pH below 3.
- Amphibians are particularly vulnerable, probably because their skin is so sensitive to pollutants. Some scientists believe the recent drop in amphibian numbers around the world is due to low pH levels caused by acid rain.

## Other chemicals in the water

- A change in the pH of water can alter the behavior of other chemicals in the water. The altered water chemistry may affect aquatic plants and animals. For example, ammonia is harmless to fish in water that is not acidic. But, as pH increases ammonia becomes toxic.

- A lower pH will cause heavy metals such as cadmium, lead and chromium to dissolve more easily. Many heavy metals become toxic when dissolved in water.

# How do we sample pH?

We measure pH using colored indicator strips which are dipped in the water. The colors on the strips react with the water and change. The color change is compared to a chart to determine the water's pH. The test requires one student and takes 5 to 10 minutes. If the strip cannot be dipped into the water safely, collect water with a bucket hung from a bridge or deck and then sample. The pH of the collected water may change, so sample immediately.

# How do we interpret our results?

Natural pH levels vary between 6.5 and 8.5, depending on the surrounding soil and vegetation.
If your pH value falls out of this range ask your group these questions.

- Did we perform the test correctly? Re-read the pH directions to ensure you sampled properly.
- Is it summer time? Water containing many aquatic plants may have raised pH values on summer afternoons because of the plant photosynthesis.
- Does our watershed contain a lot of granite-like rock, dense conifer forests or acidic soil? If so, you are likely to have relatively acidic waters.
- Does our stream have a lot of snow melt in it? Remember, snow melt will lower pH values.

If you answered "no" to these questions then take a look at your watershed. Are there land use practices that might be affecting the pH of your stream? Refer to the "Human Influences" section for possible sources of abnormal pH.

> The allowable range of pH is 6.5 to 9.0 in the State of Utah.

# Resources for further investigation

**ChemTeam** – This web site provides information in all standard topics for students in high school chemistry. You'll find a special section on acids, bases and pH. Contact: www.dbhs.wvusd.k12.ca.us/ChemTeamIndex.html

**Miami Museum of Science – The pH Factor** – This web site introduces pH at the grade- and middle-school level, with fun lesson plans for teachers. Contact: www.miamisci.org/ph/

**Project Aquatic Wild Education Activity Guide** - Project Aquatic Wild is an interdisciplinary conservation and environmental education program emphasizing aquatic wildlife and the natural and human forces that affect them. You will find several hands-on classroom and field activities that focus on pH. Contact: Project Wild, 707 Conservation Lane, Suite 305, Gaithersburg, MD 20878, (301) 527-8900 (p), (301) 527-8912 (f), email: info@projectwild.org, web: www.projectwild.org

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United States Geological Survey. Water Science for Schools. http://ga.water.usgs.gov/edu/earthriversed.html. no date.

# pH

**Time – 2 minutes**
**Persons** – 1
Materials
- pH strips

**Step 1**
Dip one strip of indicator paper in to the stream and pull out.

**Step 2**
Wait 1 minute.

**Step 3**
Compare the color of the litmus paper to the pH color key on the pH box.

**Step 4**
Record the number associated with the correct color match on the Chemical Properties Field Data Sheet.

Remember: Take pH readings directly in the stream. If this cannot be done safely, collect water in a bucket and take the pH reading of this water immediately.

The allowable range of pH is 6.5 to 9.0 in the State of Utah.

# IV-3b. Dissolved oxygen

**Key Terms**
dissolved oxygen    percent saturation    respiration
eutrophication    photosynthesis

## What is dissolved oxygen?

Did you ever wonder how the bugs and fish in the water breath? We may look at the bubbles of oxygen in the water and think we have our answer. But the oxygen that makes aquatic life possible does not form bubbles, nor is it the oxygen that is part of the $H_2O$ water molecule. It is a separate $O_2$ molecule that is **dissolved** in the water and invisible to our eyes.

The oxygen concentration of most healthy streams is between 6 and 12 oxygen molecules per one million water molecules. By comparison, the atmosphere maintains a ratio of about one oxygen molecule out of five!

## How does it get in the water?

Oxygen dissolves in water in two ways.

1) Atmospheric oxygen mixes into the stream in areas of turbulence, such as **riffles**.
2) Aquatic plants release oxygen into the water during **photosynthesis**.

## What natural influences cause dissolved oxygen concentrations to change?

### Elevation

The amount of oxygen in the atmosphere drops as elevation increases. Since streams get much of their oxygen from the atmosphere, they too, will have less oxygen at higher elevations.

### Temperature

The maximum amount of oxygen that can be dissolved in water is called its saturation concentration. The saturation concentration decreases as water temperature increases. The following chart (Figure IV-7) shows the relationship between water temperature and dissolved oxygen concentrations at sea level. At higher elevations, the entire line would be shifted down (less oxygen can dissolve at higher elevations).

The dissolved oxygen concentration for your stream will vary throughout the year as temperatures rise and fall. As ponds and standing water heat up and cool down on a daily basis, dissolved oxygen concentrations may also change throughout the day.

Open a can of *warm* soda - what happens? You probably end up with a face full of foam, and the soda tastes flat. What happens when you open a *cold* soda? Your face stays dry and the soda tastes carbonated. The carbonation, or bubbles, in the soda comes from gas dissolved in the liquid. Cold soda holds more gas than warm soda – just like your stream.

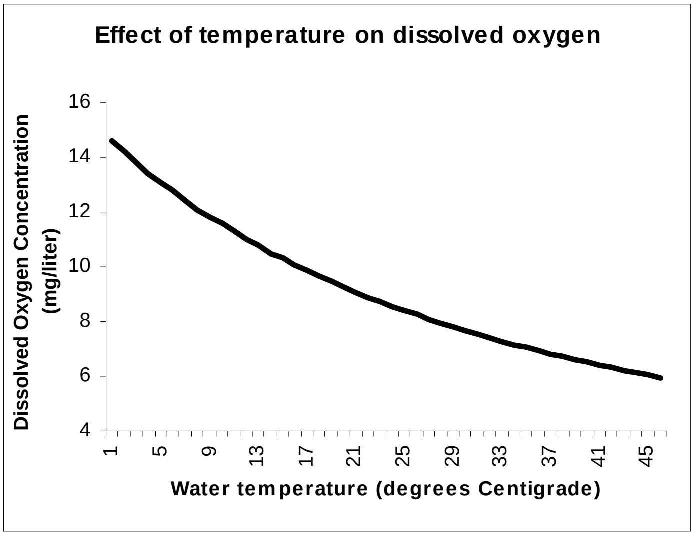


Figure IV-7. The effect of temperature on dissolved oxygen – note that warmer water can hold less oxygen

### Saltiness

Salty water holds less oxygen than fresh water. However, the water must be very salty – as salty as ocean water – for the oxygen level to be affected. Do you think the Great Salt Lake can hold as much dissolved oxygen as a clear mountain stream?

### Turbulence

We already know that one way for oxygen to enter a stream is through the mixing of air and water in turbulent areas. If your stream has rapids or riffles, how do you think the dissolved oxygen concentration will be affected? If you said that it increases it, you're right.

More mixing creates more opportunity for oxygen to enter the stream. In fact, if your stream is very turbulent, it may become *supersaturated* – the dissolved oxygen concentration rises above the saturation level.

In contrast, the deep portion of lakes or reservoirs may be so isolated from the atmosphere that the oxygen concentration drops to zero. Lakes that freeze over in the winter are also isolated from the atmosphere and may lose all their oxygen. Do you think aquatic life must adapt differently to a turbulent stream than a deep lake bottom?

### Aquatic Life

Animals living in water use oxygen just as you and I do. Bacteria also use oxygen when they decompose material. This is why we see dissolved oxygen levels drop in a water body that contains a lot of dead, decomposing material.

### Vegetation

Aquatic plants release oxygen as part of the photosynthetic process. As photosynthesis speeds up and slows down with daily changes in sunlight, the amount of oxygen in the water changes, too. Plants also use oxygen during **respiration**. Streams with a lot of aquatic vegetation see wide daily fluctuations in dissolved oxygen levels.

Riparian vegetation along the banks of a stream affects dissolved oxygen concentrations indirectly. By shading the stream, vegetation maintains lower temperatures, allowing the water to hold more oxygen.

What time of day would you expect to find low DO levels in your stream? Photosynthesis cannot occur without sunlight. When the sun goes down, and photosynthesis stops, plants quit producing oxygen. The plants and animals in the water, however, continue to use oxygen all night long. Because of this, oxygen levels in your stream drop through the night and reach their lowest point just before the sun rises.

# What human influences cause dissolved oxygen concentrations to change?

### Introduction of organic waste

Microorganisms, such as bacteria, decompose organic waste. Organic waste is anything that was once part of a plant or animal, such as leaves and manure. Microorganisms use up oxygen in the decomposition process. If there is a lot of organic waste in the stream, then the microorganisms multiply and use more oxygen than can be replaced in the stream.

Organic wastes may come from a variety of sources:

- untreated sewage
- runoff from dairies, feedlots and other agricultural operations
- lawn clippings, top soil and other materials from around our homes

### Land uses

Land uses throughout the watershed can increase the temperature of streams and introduce excess organic material. Both impacts result in lower-than-normal DO concentrations.

Land use impacts include:

- Destruction of riparian areas from development or overgrazing. Loss of riparian vegetation decreases shading and increases water temperature.
- Land clearing activities such as construction or logging may send excess amounts of organic material into streams.

# Why do we care about dissolved oxygen?

### Animals

All aquatic (and terrestrial) animals need oxygen.

- A change in oxygen concentration may affect the composition of aquatic communities. Many macroinvertebrate species depend on oxygen-rich water. Without sufficient oxygen they may disappear, disrupting the food chain.
- Many fish require a specific range of oxygen concentrations. "Warmwater" fish, such as carp and bass, can usually live with lower oxygen concentrations than "coldwater" fish, such as trout. See Table IV-4.

How do some aquatic animals survive without much oxygen?
Some of them use *hemoglobin*.
The job of hemoglobin, besides turning your blood red, is to carry oxygen. Animals with a lot of hemoglobin can use more of the oxygen that is in the water around them – a handy trick if you're living at the bottom of a lake. You might find some of these critters in your sample. Look for red-colored **macroinvertebrates**, such as fly larvae and Daphnia (water fleas).

| Minimum Oxygen Concentrations Required for Common Fish | | |
|---|---|---|
| | Minimum Summer Concentration (mg/liter) | Minimum Winter Concentration (mg/liter) |
| Pike | 6.0 | 3.1 |
| Black Bass | 5.5 | 4.7 |
| Black Crappie | 5.5 | 1.5 |
| Yellow Perch | 4.2 | 4.7 |
| Sunfish | 4.2 | 1.4 |
| Black Bullhead | 3.3 | 1.1 |

Table IV-4. Minimum oxygen requirements for common fish

### Chemicals

Oxygen concentration affects the behavior of other chemicals in the water.

- In the presence of oxygen some metals such such as cadmium solidify and sink out of the water. Without oxygen, these solids may dissolve again into the water. The dissolved forms of many of these metals are poisonous to animals.
- Nutrients change with oxygen as well. Nitrogen forms shift, and phosphorus will solidify and sink in oxygen-rich waters. Without oxygen, the phosphorus dissolves back into the water, and may overfertilize the lake.

## How do we sample DO?

During this test stream water is mixed with chemicals in a small ampoule, which then change color depending on the amount of oxygen present in the water. The darker blue, the more oxygen in the sample. The entire test takes about 5 minutes.

The concentrations may change after the water sample is collected, so measure the dissolved oxygen immediately after the water sample is taken.

> The dissolved oxygen concentration may not be the same in all parts of your stream. Deep, still waters often have more dissolved oxygen near their surface than at the bottom. Note the location of your sample (e.g. riffle, top of pooled-up area) to help you interpret your results.

## How do we interpret our results?

### Do you meet the Utah State criteria?

The State of Utah has set minimum dissolved oxygen concentrations to protect fish and other aquatic animals. These minimum concentrations vary according to the natural temperature of the stream. Check with the Utah Division of Water Quality (contact information in the "Resources" Appendix) to determine if your stream is a "coldwater fishery" or "warmwater fishery."

> The minimum concentration for:
> Streams which Utah protects for coldwater fish: 6.5 mg/liter
> Streams which Utah protects for warmwater fish: 5.5 mg/liter
> NOTE: Values are for a 30-day average, to account for daily and weekly fluctuations.

# Resources for further investigation

**Streamkeepers Field Guide: Watershed Inventory and Stream Monitoring Methods** by Tom Murdoch, Martha Cheo, and Kate O'Laughlin (2nd Edition). Section on understanding watersheds, conducting field inventories, water quality monitoring programs, keys to plant and animal life, methods of analyzing and presenting your data and how to effect changes in attitude and policy. The manual is adaptable for use by students ages 12-adult. The companion video also available. Contact: The Adopt-A-Stream Foundation at the Northwest Stream Center, 600-128th Street SE Everett, WA 98208-6353 (425)316-8592; Fax: 425-3381423; Email: aasf@streamkeeper.org; www.streamkeepers.org

**"The Volunteer Monitor: The National Newsletter of Volunteer Water Quality Monitoring**." This bi-annual EPA publication addresses all aspects of water quality monitoring, including those specific to school and youth groups. The Spring 1997 edition (vol. 9, no. 1) addresses DO and DO sampling. Back issues are available on the internet. Contact: www.epa.gov/volunteer/spring97

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Williams, Robert. Rivers Curriculum Guide: Biology. Dale Seymour Publications. White Plains, NY. 1998.

# Dissolved Oxygen

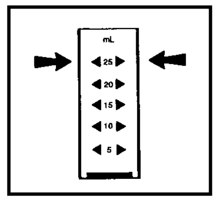


- **This test detects dissolved oxygen concentrations of 0 to 12 mg/L (ppm)**
- Collecting and handling of the water should be done with as little shaking as possible. Shaking may cause oxygen from the air to dissolve into the water sample and produce a inaccurate measurement.

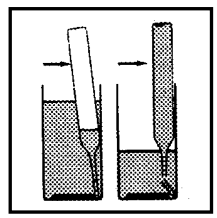
**Time** - 3 minutes
**Persons** - 1
**Materials** -
- CHEMets DO Sampling Kits

STOP Sunlight can damage the ampoules in your DO kit. Keep them shaded at all times.

## Step 1
1. Pre-rinse collection bottle with stream water.
2. Fill the sample cup to the 25 mL mark with your sample.



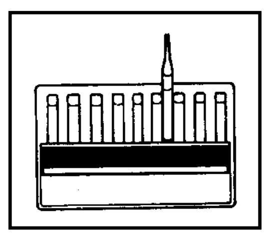

## Step 2
1. Place the CHEMet ampoule in the sample cup.
2. Snap the tip by pressing the ampoule against the side of the cup.
3. The ampoule will fill, leaving a small bubble that will help you mix the contents of the ampoule.



## Step 3
1. Mix the contents of the ampoule by turning it up and down several times, allowing the bubble to travel from end to end each time.
2. Wipe all liquid from the outside of the ampoule.

## Step 4
1. Wait **2 minutes** for color development.

## Step 5
1. With the sun (or another light source) shining on the comporator – rack of colored tubes – from directly above, place the dissolved oxygen ampoule between the color standards for viewing. It is important that the ampoule be compared by placing it on both sides of the color standard tube before deciding that it is darker, lighter or equal to the color standard.
2. Record the concentration of the best color match.



In Utah:
The minimum concentration for coldwater fish is 6.5 mg/L
The minimum concentration for warmwater fish is 5.5 mg/L.

# IV-3c. Nutrients

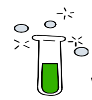
This section describes how to measure the concentrations of several **nutrients** in your stream – nitrogen (nitrate and ammonia) and phosphorus (phosphate). Nutrients are chemicals that are essential for plant growth. We add nutrients when we fertilize our gardens and fields. In the same way, adding nutrients to water fertilizes water-dwelling plants.

Unlike some of the common chemicals in water, such as calcium or sodium, nutrients usually occur at very low concentrations relative to plant demands. Nutrient concentrations may change dramatically throughout the year as growing plants remove them from the water and dying plants release them back into the water.

### Nutrient Limitation

Typically, plants in water will continue to grow until something they need (sunlight, carbon dioxide or oxygen, nutrients) runs out. Adding more of this limiting factor to the water test tube will often stimulate more plant growth.

In most streams and lakes, phosphorus or nitrogen limits plant growth. Adding more of the limiting nutrient, in fact, can stimulate too much plant growth, which starts a chain of events that may eventually deplete oxygen from the water and kill fish and other aquatic animals. For this reason, nutrients are considered a leading cause of water quality impairment in Utah.



What limits plantgrowth?

Collect some water from a local pond or lake. Pour the water into two clear jars and place in a lighted area (such as a window sill). Add a few grains of house plant fertilizer to one jar. After a week, compare the color of the two jars. Is the "fertilized" jar greener? Was your water body nutrient limited?

### What is a plant?

Not all plants in water are visible. Tiny microscopic plants, called algae, may float freely in lakes, reservoirs or big rivers. Although you cannot see these individual plants with you eyes, they can become so abundant that the water turns green. Other types of microscopic algae form slimy coverings on rocks in streams.

Larger plants also grow in water. These attach to the stream or lake bottom and look similar to plants on land, with a stem and leaves.

# Nitrogen (nitrate, ammonia)

**Key terms**

| | | |
|---|---|---|
| ammonia | nitrite | toxicity |
| detritus | nitrogen | |
| nitrate | nitrogen fixation | |

## What is nitrogen?

Nitrogen is used in building proteins and is an essential nutrient for plant and animal growth. In fact, 5 percent of the dry weight of living cells is composed of nitrogen! Nitrogen is found in a variety of forms throughout our environment and changes forms readily. The nitrogen cycle on the next page demonstrates how many different paths nitrogen may follow around our earth.

To simplify things, we can combine all of these forms of nitrogen into two groups: organic and inorganic.

### Organic nitrogen

Organic forms of nitrogen include all the nitrogen that is part of living plants or animals, animal waste, and the remains of living things, such as dead leaves. Nitrogen that is bound up in organic forms cannot be used by plants but must first be broken down to simpler, inorganic forms.

### Inorganic nitrogen

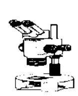
Inorganic forms of nitrogen can be taken up directly by plants and bacteria, or are easily changed to a form that is usable. We measure several forms of inorganic nitrogen when we test for water quality, because of the impacts resulting from the fertilization of water plants.

**Nitrogen gas ($N_2$)** Most of the inorganic nitrogen on earth exists in the form of **nitrogen gas ($N_2$)**, which comprises 79 percent of our atmosphere. Some simple forms of one-celled plants can also use nitrogen gas for their needs in a process called **nitrogen fixation**.

**Nitrate ($NO_3$)** Nitrate is the most common form of inorganic nitrogen in unpolluted waters. It can be used directly by aquatic plants, so nitrate concentrations in natural surface waters may change considerably throughout a year. Because nitrate is so soluble, it moves readily into groundwater, where concentrations can be much higher than in surface waters.

**Ammonia ($NH_3$)** Ammonia is formed when organic nitrogen is broken down by bacteria. Plants prefer to use ammonia over nitrate, but it is typically less abundant in natural waters. It is found at high concentrations only when dissolved oxygen concentrations are very low or when the water is polluted.

**Nitrite ($NO_2$)** Bacteria turn ammonia into nitrite but usually transform it again to nitrate very rapidly. Because of this, nitrite is not usually found at measurable concentrations. If nitrite is present at concentrations above 0.02 mg/liter, it usually indicates polluted waters.

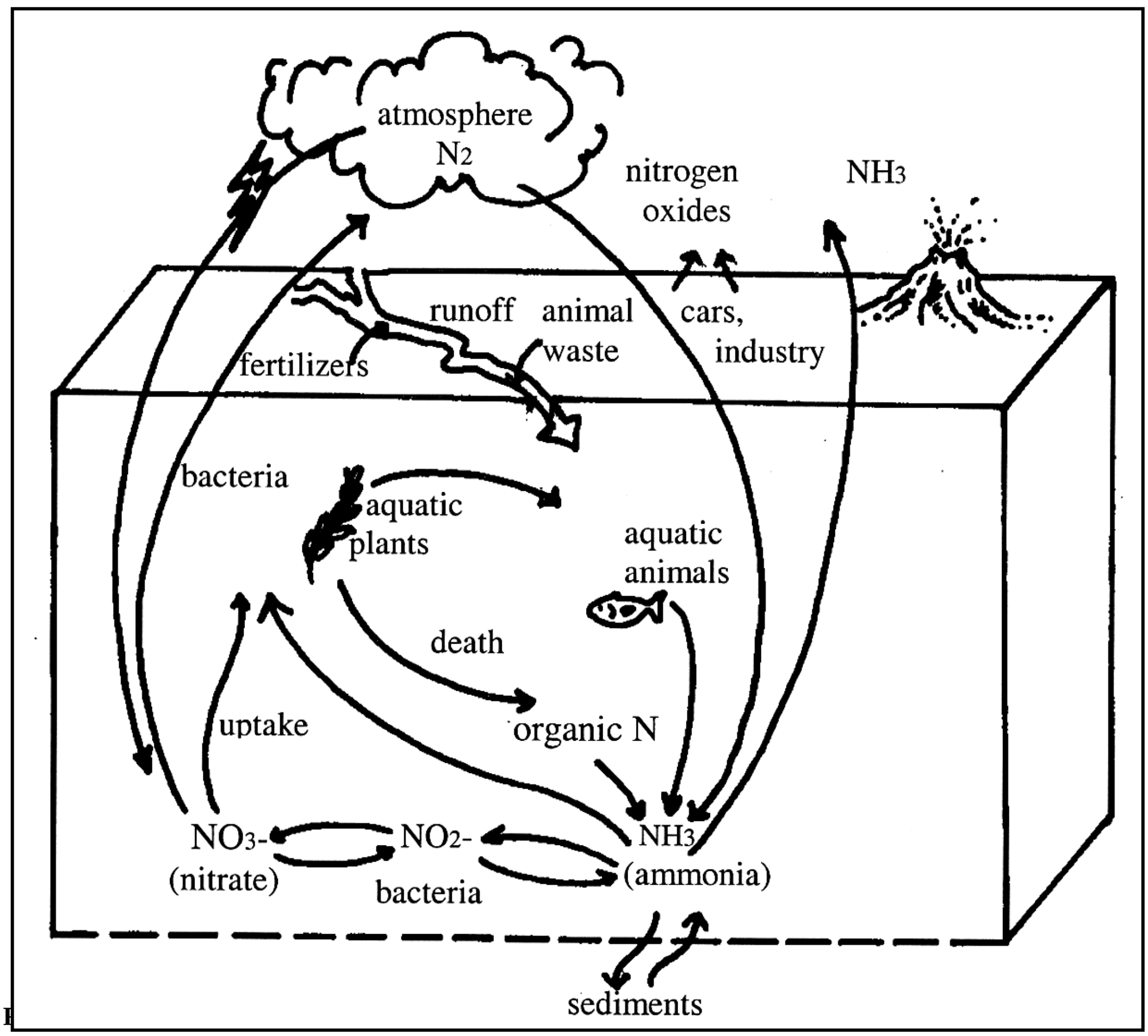


Blue-green algae can use nitrogen gas directly for their nitrogen needs. We say they "fix" nitrogen and convert it to an organic form. While this is a handy trick if there's no other nitrogen in the water, it requires a lot of energy that the algae could use in other ways.

# What is the Nitrogen Cycle?

The **nitrogen cycle** (Figure IV-8) shows the many ways nitrogen moves around our earth. Bacteria play a big role in breaking down organic nitrogen into inorganic forms, and in transforming one type of inorganic nitrogen into another. Plants use the inorganic nitrogen in soil and water and transform it into organic forms. It is then passed on to animals when the plants are eaten. **Detritus** (dead and decaying plant and animal material) becomes part of soils or lake and ocean sediments. Nitrogen from the land returns to streams and lakes in surface runoff.

Nitrogen gas is the most abundant gas in our atmosphere. It can be used by some simple plants, but also may be changed to nitrate by lightening! Although ammonia is usually dissolved in water, it may also enter the atmosphere as a gas. Other types of nitrogen gases are created by automobile engines. These may dissolve in rainwater and produce acid rain.




**F**

**water to living organisms.**

# What natural influences cause nitrogen concentrations in your stream to change?

### Seasonal changes

Concentrations of nitrogen change naturally in streams throughout the season. In Utah, concentrations are often highest during the spring when snow melts, because runoff from the land brings nutrients from lawns, farms, and other areas.

In fall and winter, the main source of water in many streams in Utah is groundwater, which often has naturally high concentrations of nitrate.

### Plant uptake

Concentrations of nitrate and ammonia may be very low during periods of rapid aquatic plant growth, because the plants are taking as much as is available. During fall and winter, when plants quit growing and die, much of this nitrogen is released back into the water and concentrations generally increase.

# What human influences cause nitrogen concentrations in your stream to change?

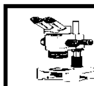
### Land uses in your watershed

Inorganic nitrogen is extremely soluble. This means that it is easily carried in surface water and also travels easily through soils and groundwater. This allows human introductions of nitrogen to have wide-ranging effects.

Common human-influenced sources of inorganic nitrogen include:

- fertilizers, animal manure
- malfunctioning septic systems
- discharge from sewage facilities and acid precipitation.

Some of these sources also introduce organic nitrogen to our waters, which are eventually transformed into ammonia and nitrate.



We usually don't think of acid rain as a source of nitrogen to our watersheds. This can happen, however, when nitric acid is formed as a by-product of the combustion in cars and other engines. Nitric acid falls to the ground as rain and snow. In some areas this is becoming a significant source of nitrogen in streams.

# Why do we care about nitrogen?

### Excessive plant growth

When we over-fertilize our waters with nitrogen, we can cause heavy plant growth. Sometimes these plants grow on stream and river bottoms. More often, the problem occurs in the lakes and reservoirs that the streams enter. Too much nitrogen can cause floating scum or "blooms" of microscopic algae in lakes and reservoirs.

Over fertilization of water can cause various problems:

- Excessive plant growth can decrease the aesthetic value of water bodies by making the water cloudy or causing unsightly and smelly mats of decaying plants on the shore.
- When plants die in the water, bacteria go to work decomposing the dead material. This uses oxygen. If there is too much plant material in the water, the bacteria multiply and use up all the oxygen.

- In extremely high concentrations, some simple bacteria called blue green algae form neurotoxins that can kill actually kill animals drinking from the water.

### Health concerns

Some forms of inorganic nitrogen are poisonous to humans or to aquatic organisms.

- Concentrations of nitrate in drinking water greater than 10 mg/liter can be harmful to young babies.
- Nitrite can be toxic to fish, such as rainbow trout, at concentrations of about 4 mg/liter.
- Ammonia may be toxic to fish and aquatic invertebrates at very low concentrations. Ammonia can affect fish at very low concentrations, especially when the water is somewhat basic (high pH) and at temperatures above 20 degrees C.

**What does toxic mean?**
Scientists need to identify the concentration of pollutants that will harm animals that live in our streams and lakes. Laboratory experiments called "toxicity tests" are often the way we determine these concentrations. These experiments expose fish to different concentrations of a pollutant and determine what effect the pollutants have.

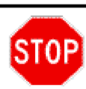
Pollutant concentrations that cause fish to die within a few hours are called "short term toxicity concentrations." Sometimes, the fish survive but just don't grow or reproduce. The concentrations that produce these results are called "long term toxicity concentrations."

## How do we sample nitrate and ammonia?

**Both nitrate and ammonia tests are color tests, where the amount of color change is proportional to the amount of pollutant being measured.**

If you wish, you can collect water samples and save them for up to two days before actually conducting the tests. If you do this, keep the water in sealed plastic jars in a dark cool place (a cooler with ice or a refrigerator).

Step-by-step directions are found at the end of this section.




Both these tests use very small quantities of poisonous chemicals. Be careful that students never use their mouths to open reagent packets, and that they use plastic gloves or wash their hands well after running the test.

# How do we interpret our results?

## Nitrate

- Usually nitrate concentrations in natural streams and rivers are less than 2 to 3 mg/liter.
- If the stream or river is used as a source of drinking water, Utah has set a standard of 10 mg/liter.
- For waters used for other purposes, such as fisheries, recreation, or irrigation, the state lists a "pollution indicator" concentration. This is not an enforceable standard, but is a benchmark the state uses to indicate possible water quality problems. When these concentrations are found, the state conducts additional studies to find the source.

In Utah:

The maximum concentration of nitrate allowed in drinking water is 10 mg/liter.

The State of Utah considers nitrate concentrations of 4 mg/liter to be an indicator of pollution problems.

## Ammonia

The toxicity of ammonia to fish and other aquatic life is affected by the pH of the water, by the temperature of the water, and by how long the fish are exposed to the ammonia in the water.

## pH effects

The common form of the ammonia molecule has one nitrogen and three hydrogen atoms (NH3). This form is toxic to fish at very low concentrations. In somewhat acidic water, however, a fourth hydrogen atom attaches to ammonia, creating the ammonium ion (NH4+). Ammonium is much less toxic to fish. Therefore, we need to know the pH of water to know how toxic the ammonia concentration really is.

## Temperature effects

At temperatures above room temperature (about 20 degrees C), both forms of ammonia become more toxic to fish.

## Exposure times

Most fish can handle higher concentrations of ammonia for short periods of time (hours or less) than over longer periods of days and weeks.

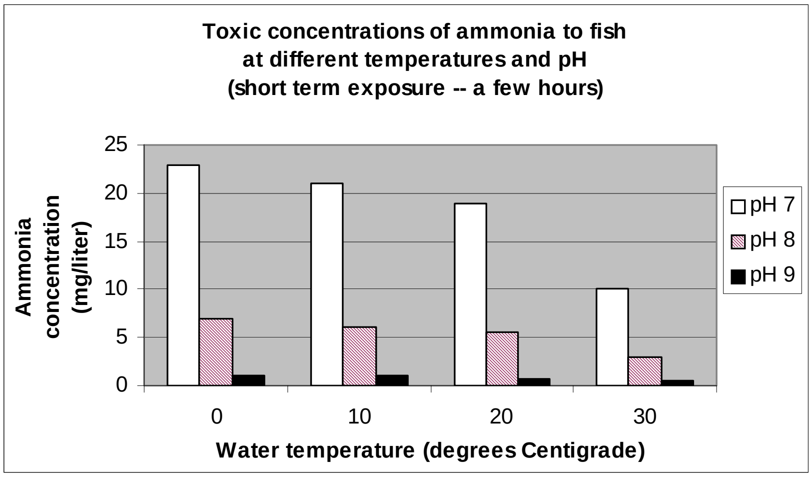



Figure IV-9

Figure IV-9 The effect of temperature and pH on ammonia toxicity to fish (short term exposure, just a few hours).

- Notice how ammonia becomes much more toxic as the water's pH increases from 7 to 9. For example, at water temperatures of 10 degrees C, the toxic concentration at pH 7 is 21 mg/liter, but at pH 9, the toxic concentration is 1 mg/liter.

- A change from pH 7 to pH 9 could occur within a single day in some streams.

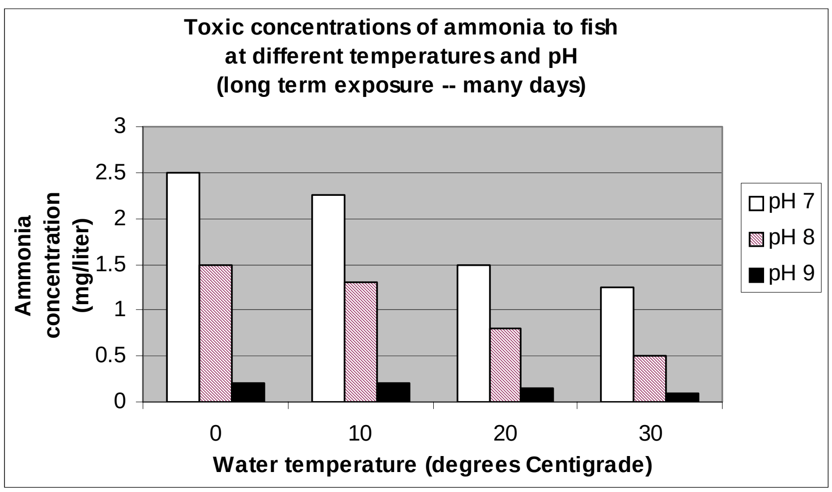



Figure IV-10

Figure IV-10 The effect of temperature and pH on ammonia toxicity fish (long term exposure, many days).

- Compare this graph with the one above. Notice that at the same pH and temperature, much lower concentrations affect fish exposed for long periods of time.

- Notice how the toxic concentration of ammonia degrees as the temperature increases. For example, at a pH of 7, the toxic concentration is 2.5 mg/liter at 0 degrees C, but at 30 degrees C the toxic concentration is 1.2 mg/liter. Luckily, temperatures this high are not often found in natural streams.

## Resources for further investigation

**"The Volunteer Monitor: The National Newsletter of Volunteer Water Quality Monitoring**." This bi-annual EPA publication addresses all aspects of water quality monitoring, including those specific to school and youth groups. You'll find plenty of useful information on nitrogen and nitrogen sampling. Back issues are available on the internet. www.epa.gov/volunteer/spring97

**Water Pollution** - This web site covers most major water pollution concepts in detail. You'll find an entire section on nitrogen and how to measure it. Information is presented at a middle- to high school level. http://www.geocities.com/RainForest/5161/lab3.htm

## Bibliography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Mitchell, Mark and William Stapp. Field Manual for Water Quality Monitoring. Thompson-Shore Printers. Dexter, MI. 1994.

Morton, Stephen D. Water Pollution: Causes and Cures. Mimir Publishers, Inc. Madison, WI. 1976.

United States Geological Survey. Water Science for Schools. http://ga.water.usgs.gov/edu/earthriversed.html. no date.

# Nitrate

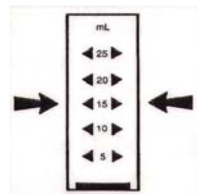
- **This test detects Nitrate at concentrations of 0.1 to 5 mg/L (ppm)**
- **The range for this test is 0 to 5 mg/L (ppm)**

**Time** – 15 minutes
**Persons** - 1
**Materials** -
- CHEMets Nitrate Sampling Kits

Sunlight can damage the ampoules in your Nitrogen kit. Keep them shaded at all times.

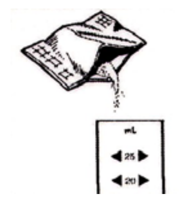


### Step 1



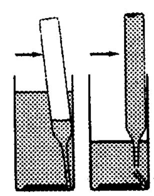

1. Pre-rinse collection bottle with stream water.
2. Fill the sample cup to the 15 mL mark with your sample.

### Step 2



1. Empty the contents of one Cadmium Foil Packet into the sample cup. Use caution when handling the Cadmium Packet. Tear it carefully or open with scissors. Do NOT use teeth.
2. Cap the sample cup and shake it vigorously for exactly **3 minutes**.
3. Allow the sample to sit undisturbed for **30 seconds**.

### Step 3



1. Place the ampoule in the sample cup.
2. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill leaving a small bubble to help mixing.

### Step 4

1. Mix the contents of the ampoule by turning it up and down several times, allowing the bubble to travel from end to end each time.
2. Wipe all liquid from the outside of the ampoule.

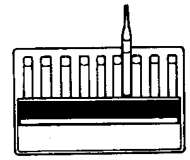
### Step 5

1. Wait **10 minutes** for color development.

### Step 6

1. Use the appropriate comparator to determine the level of nitrate-nitrogen in the sample. For low range, use the tube comparator. For high range use the rack comparator.

    a. Tube Comparator – Place the ampoule, flat end down into the center tube of the low range comparator. Direct the top comparator up to the sun or another bright light source while viewing from the bottom. Rotate the comparator until the color standard below the ampoule shows the closest match.



b. Rack Comparator – Hold the rack horizontal while standing underneath a bright light source. Place the ampoule between the color standards moving it from right to left along the comparator rack until the best color match is found.

**Step 7**

1. Record the number of the best match on the comparator on your Chemical Properties Field Data Sheet. This is your nitrate-nitrogen concentration in mg/liter (ppm).

In Utah:

The maximum concentration of nitrate allowed in drinking water is 10 mg/liter.

The State of Utah considers nitrate concentrations of 4 mg/liter to be an indicator of pollution problems.

# Ammonia

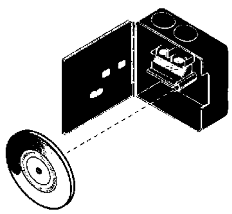


NOTE: These directions are for concentrations less than 3 mg/liter. More detailed instructions can be found in the kit

**Time** – 5 minutes
**Persons** - 1
**Materials**

- Hach ammonia sampling kit

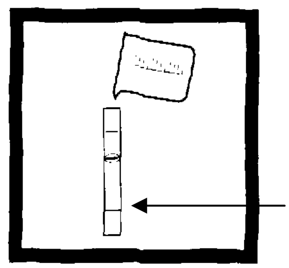
**Detection limit = 0.10 mg/liter**



## Step 1 - assemble color viewer

Add color wheel to color comparator.

## Step 2 – place blank in viewer

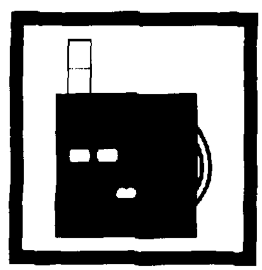


Fill to this mark

1. Pre-rinse two tubes with sample water

2. Fill one tube to the 5 ml mark with sample water

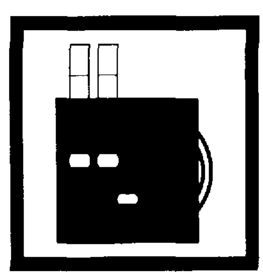
3. Place the tube in the top, left opening of the viewer. This will be your blank to control for natural water color or turbidity.



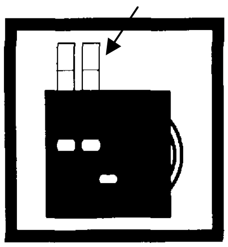
## Step 3 – prepare the sample

1. Add three drops of Nessler Reagent to one tube
2. Swirl to mix.

**NOTE: Wait at least 1 minute but not more than 5 minutes before proceeding to Step 4**

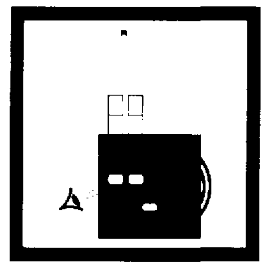


## Step 4 - read concentration

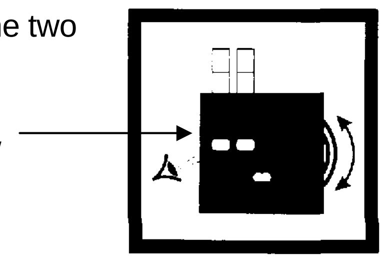


1. Place the tube with the reagent in the top right opening of the viewer.

2. Hold the viewer so that your light source (sun, lamp) is behind the viewing window.



3. Rotate the color disc until the color matches in the two openings. Read the number in the scale window.




## Step 5 – Record your results

The number in the scale window is the ammonia-nitrogen concentration (mg/liter NH3-N) of your sample. Record this on your Chemical Properties Field Data Sheet.

In Utah:
The maximum allowable concentration of a ammonia depends on the pH and temperature of the water.

ease refer to the Utah Stream Team manual for more information.

# Phosphorus

**Key Terms**
decomposition particulate phosphorus total phosphorus
orthophosphate phosphorus

## What is phosphorus?

**Phosphorus** is an important plant nutrient. Phosphorus occurs in many different forms in the environment, much like nitrogen. Unlike nitrogen, however, phosphorus cycles through the environment more slowly. Most of the phosphorus is found in rocks and minerals. We can divide the phosphorus in the environment into two major groups:

- organic and inorganic
- particulate and dissolved

**Organic phosphorus** includes all the phosphorus found in living plants or animals, their dead remains and their waste. **Dissolved** (soluble) forms of organic phosphorus are often organic molecules released when plants and animals decay. These molecules must be broken down by microorganisms before they can be used again by plants.

**Inorganic phosphorus** includes several forms. Most of the phosphorus on Earth is found in minerals, rocks and soil. The soluble form of inorganic phosphorus, called **orthophosphate** ($PO_4^{-3}$), is the form that we will sample. Plants can use this molecule easily, but it is often very scarce in waters. For this reason, phosphorus often limits plant growth in streams and lakes.

One reason orthophosphate is scarce is that it easily attaches to tiny sediment particles and then settles out of the water. This is why orthophosphate does not move quickly through soils and into groundwater (like nitrate).

Phosphorus is common in minerals found throughout Utah and surrounding areas. In fact, deposits of phosphorus are mined in nearby Wyoming and Idaho. This mineral form of phosphorus enters streams mainly through erosion. Phosphorus contained in rocks and sediments cannot be immediately used by aquatic plants. It may take many years for the dissolved orthophosphate molecule (the form plants can use) to develop.

## What natural influences cause phosphorus concentrations in your stream to change?

Phosphorus concentrations can change dramatically throughout the year. When flows are high, such as during spring runoff or after a big summer storm, sediment concentrations can be quite high in the stream. Since phosphorus attaches to sediment it, too, may be quite concentrated in the water.

### How much do plants use?

Concentrations of orthophosphate are usually low throughout the year. During periods of rapid plant growth, plants remove all the orthophosphate they can find. During these times, the concentration might be so low it can't be measured by chemical tests.

During fall and winter, when plants quit growing and die, some of this orthophosphate is released back into the water. However, because orthophosphate tends to attach to little particles of plant and soil materials, the measurable amounts of orthophosphate may be low even during these seasons.

## What human influences cause phosphorus concentrations in your stream to change?

### Land uses in the watershed

Activities that cause erosion in the watershed may result in particulate organic and inorganic phosphorus entering the stream:

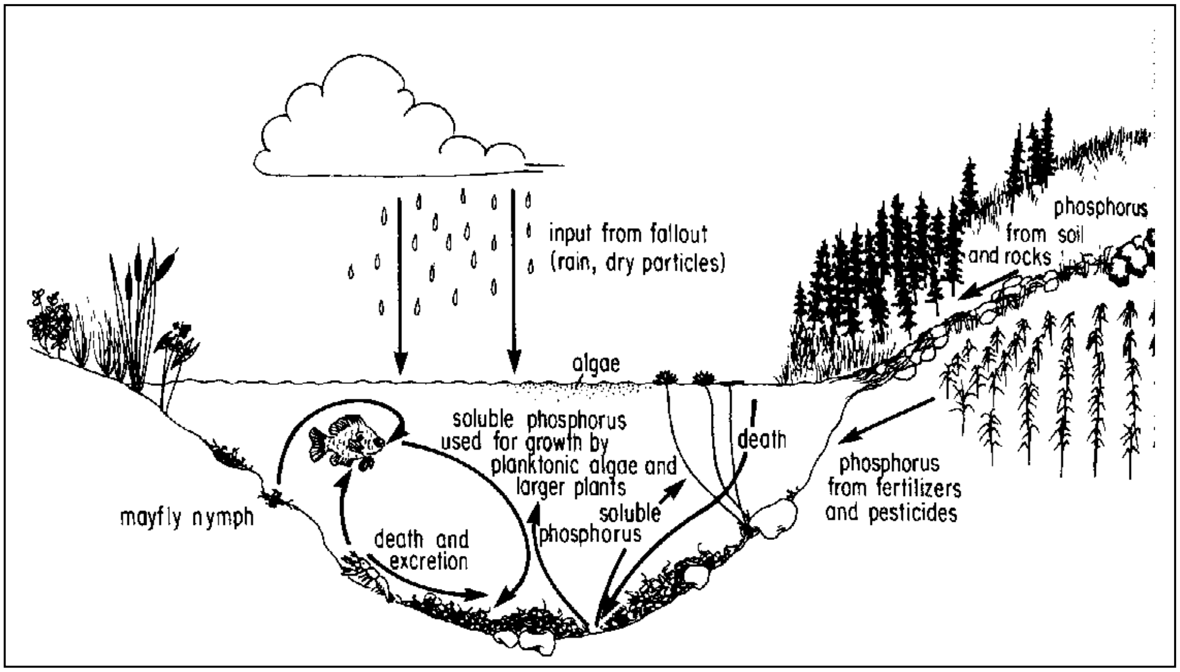
- logging or building activities
- overgrazing in riparian areas
- activities which remove the riparian plants and buffer strips around our streams reduce the ability of these areas to filter out sediments and keep them from entering the streams.

Runoff from the land can also introduce orthophosphate into a stream:

- fertilizers may run off lawns and agricultural fields during snow melt, rainstorms or heavy irrigating;
- poorly functioning septic tanks release phosphorus into groundwater;
- wastewater treatment facilities from our towns often introduce large amounts of dissolved phosphorus into our streams and rivers.

Figure IV-11. The Phosphorus Cycle—note how phosphorus enters the water from land or atmosphere and the cycles between living organisms and decayed material.

**Figure IV-11 The Phosphorus Cycle**



# Why do we care about phosphorus?

### Excessive plant growth

Concentrations of orthophosphorus are often very low in our waterbodies. Phosphorus is often the nutrient that limits how much plant growth occurs in a stream, lake or reservoir. Adding a small amount of phosphorus, therefore, may cause excess plant growth.

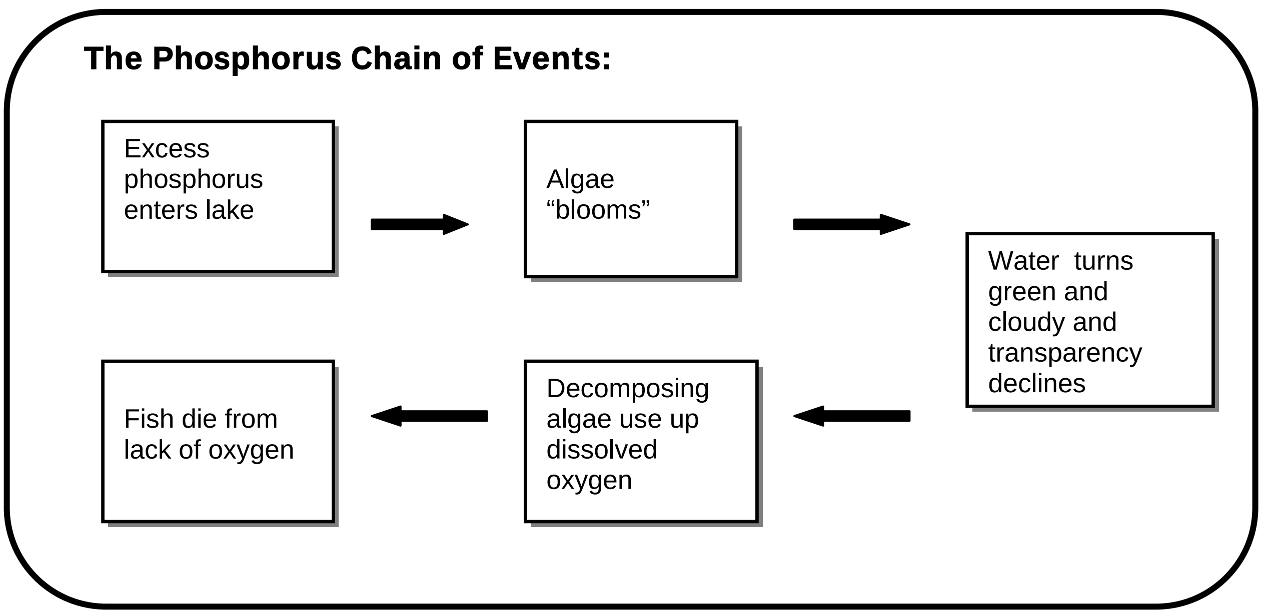
Sometimes these plants are large and grow from the lake bottoms in shallow areas. Sometimes, the plants that grow are microscopic algae.

Heavy plant growth caused by over fertilization of water can cause various problems (Figure IV-12):

- Large attached plants in shallow areas of lakes entangle boaters and swimmers. When the plants die, huge mats of decaying plants create odor and aesthetic problems.
- "Blooms" of algae make the water cloudy and unsightly.
- When the plants in lakes and reservoirs die, more oxygen may be used in the **decomposition** process than can be replaced. During winter, an entire lake may freeze and lose all its dissolved oxygen. If this happens, all the fish and other aquatic life will die.
- Certain types of microscopic algae can be toxic if they reach very high concentrations. Animals, such as dogs or livestock, that drink from these toxic water bodies can become sick or even die.

> We may not realize we have a phosphorus problem until we look at the lakes and reservoirs fed by our streams and rivers. Too much phosphorus can cause huge amounts of plant growth in lakes and reservoirs, while, at the same time, the contributing streams are relatively free of plants.

Figure IV-12. The Indirect Effect of Phosphorus on Fish. This chain of events leads from too much phosphorus in a lab to fish kills from lack of oxygen.



## How do we sample phosphorus?

[Step-by-step sampling directions can be found at the end of this section.]

*Utah Stream Team* field tests measure the orthophosphate in water (the dissolved, inorganic form of phosphorus). This is a color test, where the amount of color change is proportional to the amount of pollutant being measured. The chemicals added to our sample cause the water to change blue if orthophosphate is present. The darker the blue, the more orthophosphate present. A color wheel is used to determine the concentration in the water.

If you wish, you can collect water samples and save them for up to two days before actually conducting the tests. If you do this, keep the water in sealed plastic jars in a dark cool place (a cooler with ice or a refrigerator).

## How do we interpret our results?

Phosphorus is considered a pollution indicator. It is not toxic, and its negative impacts come from the series of events that result from over-fertilizing a water body.

> The State of Utah considers a total phosphorus concentration of 0.05 mg/liter in a stream or river to be an indicator of pollution problems. A concentration of 0.025 mg/liter in lakes is considered a potential problem.

How much is 0.050 mg/liter? It is equivalent to 50 phosphorus atoms for every *billion* water molecules! Because orthophosphate is usually a very small percentage of the total phosphorus, the concentrations of actual plant fertilizer in water are even lower.

# Resources for further investigation

**Environmental Protection Agency's Volunteer Stream Monitoring: A Methods Manual** - This 210-page manual takes the reader through an introduction to streams and watersheds then proceeds to offer in-depth, step-by-step approaches to monitoring a variety of water quality components. You will find helpful background information on stream temperature. For a free copy of the manual, contact Alice Mayio at USEPA (4503F), 401 M St. SW, Washington, DC 20460; 202/260-7018; mayio.alice@epamail.epa.gov. Also available on the web: www.epa.gov/owow/monitoring/vol.html.

**Kentucky Water Watch** – This Kentucky Water Watch web site, administered by the State of Kentucky Natural Resource and Environmental Protection Cabinet, offers background information on all major water quality parameters, including phosphorus. You'll also find lots of other useful information to support classroom and field monitoring. www.state.ky.us/nrepc/water/wwhomepg.htm

**Water Conservation and Nonpoint Source Pollution** – This activity book features hands-on, minds-on activities for younger ages. Several activities specifically address temperature concepts (in both indoor and outdoor settings). Contact: Your local County Cooperative Extension Service – or – Utah State University Extension, 1500 N 800 E, ASTE Dept, Utah State University, Logan, UT 84322-2300, (435) 797-3389. extension.usu.edu/natres/wq/

# Phosphorus (phosphate)



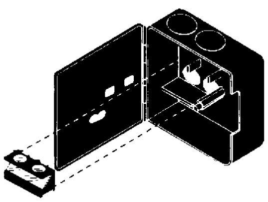
NOTE: These directions are for concentrations less than 0.3 mg/liter $PO_4$ - P. More detailed instructions can be found in the kit.

**Detection limit = 0.01 mg / liter**

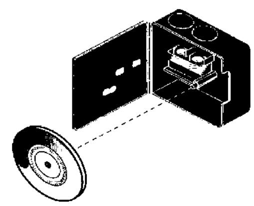
**Time** – 5 minutes
**Persons** – 1
**Materials**
- Hach phosphorus sampling kit

## Step 1 - assemble color viewer

1. Add Long Path Viewing Adaptor.



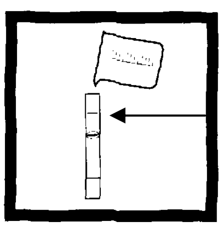
2. Add color wheel.



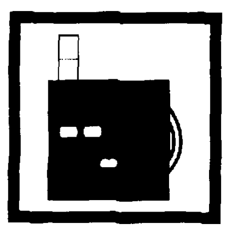
## Step 2 - pour the blank

1. Pre-rinse 1 test tube with stream water and fill to top mark with sample water.

2. Place this tube in the left top opening of the viewer. This is your blank.



Fill to this mark

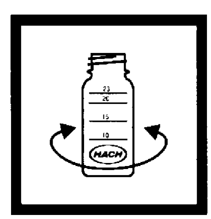


## Step 3 – develop color

1. Fill square bottle to the 20 ml mark with stream water.

2. Add contents of Phosphorus Reagent packet into bottle.

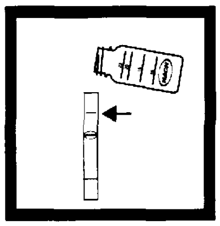
3. Swirl until the powder is dissolved.



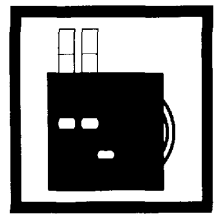
**NOTE: Wait at least 8 minutes but not more than 10 minutes before proceeding to Step 4.**

## Step 4 - read the color (concentration)

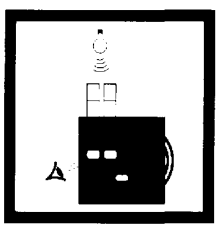
1. Fill 2nd tube to the top mark with prepared sample from Step 3.



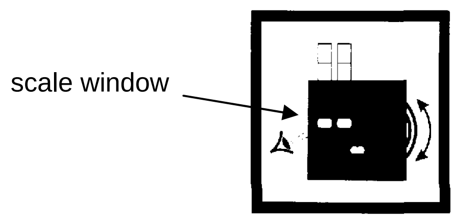
2. Place in top right opening of viewer.



3. Hold the viewer so that the top of the tube points toward a light source.



4. Rotate the color disc until the color matches in the two openings. Read the # in the scale window.




## Step 5 – Calculate and record your results

Divide the number in the scale window by 150.

This is the phosphate-phosphorus concentration (mg / liter of ($PO_4^{3-}$ -P) .

> The State of Utah considers a total phosphorus concentration of 0.05 mg/liter in a stream or river to be an indicator of pollution problems. A concentration of 0.025 mg/liter in lakes is considered a potential problem.

# IV-3d. Turbidity

**Key terms**

| | |
|---|---|
| nephelometric turbity units (NTUs) | turbidity |
| Secchi disk | turbidity tube |
| suspended solids | |

## What is turbidity?

If you've ever visited the Colorado River you were probably able to see only about 30 centimeters (~1 ft) beneath the water's surface. On the other hand, if you visit some lakes in Alaska, you will see 30 meters (100 ft) below the surface! The amount of material suspended in the water – soil (sediment), microorganisms, pollution – affects how deeply light can penetrate. We call this material **suspended solids**. The Colorado River has more suspended solids in it than the Alaskan lakes and so light cannot penetrate as deeply. The degree to which light penetration is blocked by suspended solids is called **turbidity.**

Turbidity tells us how much material is suspended in the water. Common types of suspended solids include small pieces of soil, plant material, industrial waste, and microorganisms. Any natural or artificial process that places suspended matter in water causes turbidity.

## What natural influences cause the turbidity of our stream to change?

- The types of material that form the stream channel affect the turbidity of the water. For example, if a stream channel runs through hard basalt bedrock, less erosion will occur than if the channel is composed mainly of loose soil.

- Smaller streams carry sediments eroded from the surrounding area, and from their banks and streambeds. Larger rivers, which generally are wider, slower and more exposed to the sun, may contain many microscopic plants, which also increase turbidity.

- Seasonal weather patterns will alter turbidity. Both spring snow melt and rain increase runoff, which generally increases turbidity.

- Plant root systems, both in the riparian zone and throughout the watershed, help keep soil out of the stream which reduces turbidity. Dramatic natural events, such as forest fires, floods or wind storms, may destroy plants, resulting in erosion.

Many large rivers in Southern and Western Utah are naturally very turbid. The loose, sandy soils add a lot of sediment to the stream. What other factors cause our large rivers, such as the Green and San Juan, to be so turbid? Look at the "Natural Influences" section for help with your answer.

## What human influences cause the turbidity of our stream to change?

- Bank stabilization helps reduce erosion and turbidity. We can improve bank stability by maintaining healthy riparian vegetation or installing reinforcements such as wire wrap or boulders.

- In pools and slower moving, larger rivers, activities that introduce nutrients (plant food) to a stream will increase microscopic algae production and increase turbidity.

- Any activity that increases erosion in a stream will increase turbidity (e.g. road building, development and overgrazing in riparian zones and dredging or deepening channels).

## Why do we care about turbidity?

If a stream's turbidity increases beyond natural levels, it loses its ability to support life that has adapted to those levels.

- Suspended solids prevent sunlight from reaching aquatic plants that grow on the stream bottom. Without light, photosynthesis cannot take place, which may reduce the concentration of dissolved oxygen in the water. Dissolved oxygen is necessary for the survival of fish and other aquatic life.
- Turbidity can raise the surface water temperatures of ponds and lakes because suspended sediment absorbs heat.
- Turbidity makes it difficult for fish to see their prey. Heavy loads of suspended solids can also clog fish gills and filter-feeding devices of aquatic **macroinvertebrates**.
- As solid matter settles, it may cover and harm bottom-dwelling plants and animals and spawning beds. Fish, such as trout, which lay eggs in **redds** are particularly vulnerable to sediments in the stream.
- All streams have a natural level of turbidity. While some forms of aquatic life need clear water to survive, other aquatic species are adapted to and thrive in high turbidity. The Colorado River is very turbid, yet its waters hold abundant life.

## How do we sample turbidity?

We measure turbidity of streams with a **turbidity tube**. Fill the tube with stream water, then release the water until you can see the black and white disk at the bottom. The depth in the tube to this point is recorded. The test takes about 5 minutes.

For ponds, wetlands or lakes, a **Secchi disk** is usually used. This black and white disk is lowered into the water until it is no longer visible and that depth is recorded.

## How do we interpret our results?

To compare our results with state standards, we need to convert the distance measured with the turbidity tube to standard turbidity units. Because turbidity is usually measured with an instrument called a nephelometer, the turbidity unit is a **NTUs** (Nephelometric Turbidity Units). The higher the turbidity (NTUs) the greater the amount of scattered light, or the cloudier the appearance. Use the conversion chart on the back of the field directions.

**Standards for NTUs in Utah** (Utah's Standard is for an *increase* in turbidity over natural levels. This increase may apply to one site over time or from one site to another at the same time).

In Utah:

- An *increase* of more than 10 NTUs over natural levels is considered unacceptable for:

  Aesthetics — Warmwater fisheries — Coldwater fisheries
  Drinking water — Non-game aquatic life

- An *increase* of more than 15 NTUs over natural levels is considered unacceptable for:

  Water-oriented wildlife

Check with the Utah Division of Water Quality for an established natural level of turbidity for your water body. If no level has been established, you can create a benchmark and then monitor for increases or decreases over time. Be sure to note natural conditions or events that may affect your measurements at the time of sampling, such as spring melt or recent heavy precipitation.

## Resources for further investigation

**"The Volunteer Monitor: The National Newsletter of Volunteer Water Quality Monitoring**." This bi-annual EPA publication addresses all aspects of water quality monitoring, including those specific to school and youth groups. You'll find plenty of useful information on turbidity and turbidity sampling. Back issues are available on the internet. www.epa.gov/volunteer/spring97

**Water Conservation and Nonpoint Source Pollution** – This activity book features hands-on, minds-on activities for younger ages. Several activities specifically address temperature concepts (in both indoor and outdoor settings). Contact: Your local County Cooperative Extension Office – or – Utah State University Extension, 1500 N 800 E, ASTE Dept, Utah State University, Logan, UT 84322-2300, (435) 797-3389. extension.usu.edu/natres/wq/index/htm.

**Water Pollution** - This web site covers most major water pollution concepts in detail. You'll find an entire section on nitrogen and how to measure it. Information is presented at a middle- to high school level. http://www.geocities.com/RainForest/5161/lab3.htm

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Camp, Thomas R. Water and its Impurities. Reinhold Publishing Corporation. New York, 1963.

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# Turbidity

**Detection limit = 6 NTU**

**Time** – 2 minutes
**Persons** - 1
**Materials** –
- Turbidity tube

## Step 1 – collect your sample

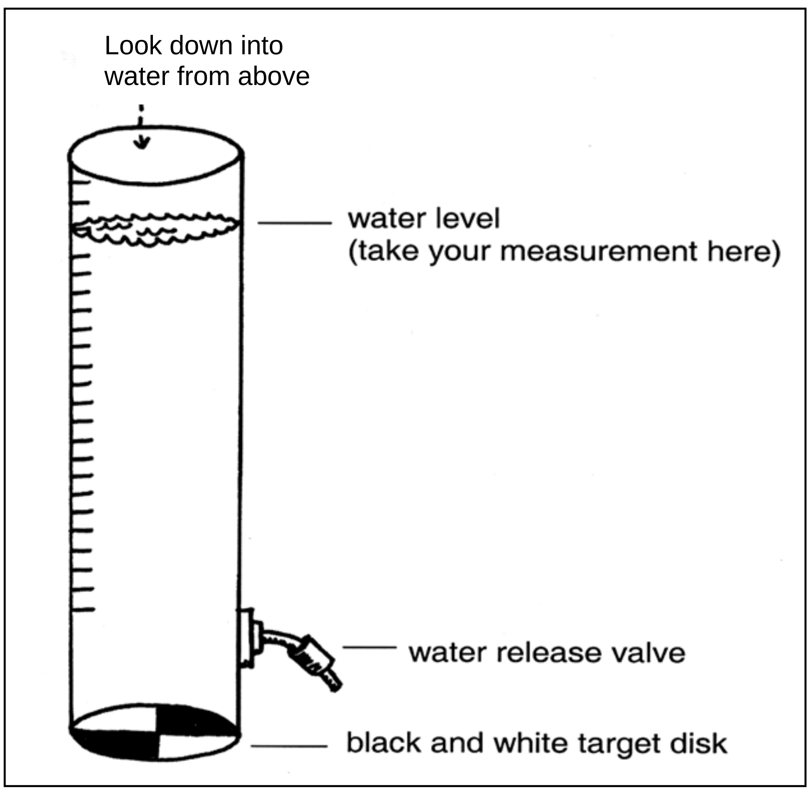
1. Dip the tube into the water at your sampling site and fill to the top. Be careful to sample flowing water and not the stream bottom.

## Step 2 – Take your measurement (see figure below for help)

1. Take your filled turbidity tube to a shaded spot. If there is no shade around, use your body to block the sun from shining on the tube.
2. With your hand over the opening, shake the tube vigorously. This will help to re-suspend any sediment that has settled to the bottom.
3. Look down through the tube toward the target disk on the bottom of the tube.
   - If the disk is visible, record the water level in centimeters (cm).
   - If the disk is not visible, slowly release water from the release valve, until the disk becomes visible. Record the water level in centimeters (cm) on the Chemical Data Collection Sheet.

## Step 3 – Convert from centimeters (cm) to turbidty units (NTU's)

1. Match your turbidity measurement in centimeters to the corresponding NTUs using the conversion chart on the back of this page. Record on the Data Collection Sheet.



## Turbidity Conversion Chart

| Distance from bottom of tube (cm) | NTU's |
|---|---|
| < 6.25 | > 240 |
| 6.25 to 7 | 240 |
| 7 to 8 | 185 |
| 8 to 9.5 | 150 |
| 9.5 to 10.5 | 120 |
| 10.5 to 12 | 100 |
| 12 to 13.75 | 90 |
| 13.75 to 16.25 | 65 |
| 16.25 to 18.75 | 50 |
| 18.75 to 21.25 | 40 |
| 21.25 to 23.75 | 35 |
| 23.75 to 26.25 | 30 |
| 26.25 to 28.75 | 27 |
| 28.75 to 31.25 | 24 |
| 31.25 to 33.75 | 21 |
| 33.75 to 36.25 | 19 |
| 36.25 to 38.75 | 17 |
| 38.75 to 41.25 | 15 |
| 41.25 to 43.75 | 14 |
| 43.75 to 46.25 | 13 |
| 46.25 to 48.75 | 12 |
| 48.75 to 51.25 | 11 |
| 51.25 to 53.75 | 10 |
| 53.75 to 57.5 | 9 |
| 57.5 to 60 | 8 |
| Over the top | 6 |

- Utah standards state that an **increase** of more than 10 NTUs is unacceptable for most waters.
- This increase can be over natural levels or from one location to another nearby downstream location.

# IV-3e. Temperature

| **Key terms** | |
|---|---|
| temperature | Centigrade |
| Fahrenheit | Celsius |
| warmwater fish | coldwater fish |

## What is temperature?

Have you ever put your hand in mountain stream in the spring? How about a big lake or reservoir in late summer? Why were the **temperatures** so different? Why does it matter to water quality? Read below and find out.

The temperature of water is a measure of how much heat energy the water contains. Temperature can be measured on many different scales. In the U.S. we usually use the Fahrenheit scale. On the Fahrenheit scale, water freezes at 32 degrees and boils at 212 degrees. Scientists usually use the Centigrade (or Celsius) scale. Water freezes at 0 degrees C and boils at 100 degrees C.

Table IV-5. Comparison of Celsius and Fahrenheit Temperature Scales.

| **Temperature Scales** | | |
|---|---|---|
| **Celsius** | **Fahrenheit** | |
| **100** | **212** | Boiling point of water at sea level |
| 90 | 194 | |
| 80 | 176 | |
| 70 | 158 | |
| 60 | 140 | |
| 50 | 122 | |
| **40** | **104** | 38°C (98.6 °F) – average human body temperature |
| 30 | 86 | |
| **20** | **68** | Average room temperature |
| 10 | 50 | |
| **0** | **32** | Melting (freezing) point of ice (water) at sea level |
| -10 | 14 | |
| -20 | -4 | |
| -30 | -22 | |
| -40 | -40 | |
| **-50** | **-58** | -50°C (-59°F) – 2nd lowest recorded temperature in continental U.S. (near Logan, UT) |
| -60 | -76 | |
| -70 | -94 | |
| -80 | -112 | |
| **-90** | **-130** | -67°C (-89°F) – lowest recorded temperature - Antarctica, July, 1983 |
| -100 | -148 | |

| Converting Fahrenheit to Celsius | Converting Celsius to Fahrenheit |
|---|---|
| °C = (5/9) x (°F-32) | °F = [(9/5) x °C] + 32 |

## What natural influences cause temperature to change?

Your stream heats up from direct sunlight and from heat in the surrounding land and air. Water is different than almost any other substance on earth. It takes a lot more heat energy to increase the temperature of water than it does to increase the temperature of the surrounding land and air. Thus, water heats up and cools off more slowly than air or land. Water temperatures vary by:

### Geographic area

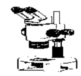
The temperature of streams reflects the surrounding climate. Streams in warm climates generally stay warm throughout the year while streams in colder climates tend to change more throughout the year.

### Seasons

Water temperature changes as the air temperature changes throughout the seasons. Your water body may freeze at the surface in the winter but be very warm during the summer.

### Source of the water

Streams fed by snow melt will be very cold in the early spring and summer. Streams fed by cold water springs may remain cool all year long. Hot water springs may keep sections of a stream warm throughout the year.



The water in a stream is constantly mixing. Therefore, its temperature usually remains the same at all depths. However, if the water is moving very slowly, or pools-up in an area, you may find different temperatures at different depths. Lakes and reservoirs often change dramatically in temperature from the surface to the bottom.

### Channel shape

Because stream water heats up from the sun and from contact with the warmer earth, a narrow, deep stream will be cooler than a wide, shallow stream, if all other factors are equal.

### Riparian shading

A stream that receives a lot of shading from riparian vegetation will stay cooler than a stream that is more exposed to the sun.

## What human influences cause temperature to change?

- When the shade provided by riparian vegetation is removed, streams heat up faster.
- If activities cause a stream channel to become shallower and wider, the stream will heat up faster. Deep, narrow channels remain cooler. Removing riparian vegetation may also lead to a wider and shallower channel which leads to increased temperatures.
- The material on the stream bottom and banks affects water temperature. A stream that travels through a concrete channel absorbs more heat than a stream travelling through a plant-filled meadow.
- Industries (such as power plants) may discharge warm water into a stream.

Because cold water is heavier than warm, it sinks below warm water in lakes. You may feel this when you swim in a lake and dive below the warm surface water into COLD deeper water. A funny thing happens to very cold water, however. At about 4 degrees C (39 degrees F), fresh water becomes as heavy as it will get. As it continues to cool it starts to get lighter again. When water freezes, it is much lighter than liquid water (ice floats, right?). Therefore, in a frozen lake, the water is coldest at the top (0 degrees C), and warmest at the bottom (4 degrees C). In a summer lake, the water is warmest on the top and coldest at the bottom.

## Why do we care about temperature?

- Water temperature greatly affects aquatic organisms. Most aquatic organisms – **macroinvertebrates**, fish, amphibians – are "cold-blooded." Their metabolism speeds up and slows down with the animal's surrounding temperature. Each organism has adapted to survive best at a given range of temperatures. If the temperature changes too drastically, their metabolism will not function as well, decreasing their ability to survive and reproduce.
- The optimal temperature is not the same for all aquatic organisms. For example, trout do best at temperatures below 22°C while carp may do fine in temperatures as high as 28°C. We divide fish into coldwater fish (fish who require fairly cool temperatures) and warmwater fish (fish who can survive warmer water temperatures).
- Warmer water holds less dissolved oxygen than cold water. Aquatic organisms may have trouble getting enough oxygen at very warm temperatures. For example, 11 mg/liter of dissolved oxygen can dissolve in 10°C water, while water at 30°C can dissolve only 7.5 mg/liter.

## How do we sample temperature?

Detailed sampling directions are included at the end of this section.
When measuring temperature with a field thermometer, we usually measure only the surface temperature of the water body. To measure the temperature of deep pools, attach your thermometer to a pole or stick, or attach a string and a weight to it.

If you cannot reach moving water safely from the shore, attach a string to the thermometer and lower it from the bank or a bridge into the water.

Be aware that the temperature below the surface may be different, especially if the water is still (turbulent water mixes and keeps temperature more uniform).

## How do we interpret our results?

### Does it meet Utah State criteria?

You can determine an appropriate stream temperature by looking at temperature criteria for fish. The State of Utah has established maximum water temperatures for both warm and cold water fisheries. Check with the Utah Division of Water Quality to determine the designation for your particular stream (in "Resources" Appendix).

The maximum temperature allowed for warm water fisheries and aquatic wildlife is 27° C (81° F).

The maximum temperature allowed for cold water fisheries and aquatic wildlife is 20° C (68° F).

### Does it protect desirable fish species?

For fish, there are two kinds of limiting temperatures – they can survive exposure to warmer temperatures for short periods (hours) but require cooler temperatures over longer periods of exposure. This may also vary according to the time of year and the life cycle stage of the fish species. Reproductive stages (egg incubation and embryo development) are the most sensitive stages. See Table IV-6 for the maximum temperatures for several common fish species.

Table IV-6

| Maximum temperatures for typical coldwater and warmwater fish | | | |
|---|---|---|---|
| Species | Maximum average temperature for young fish to grow<br>**(long term exposure) 1** | Maximum temperature for fish to survive<br>**(short term exposure) 2** | Maximum average temperature for successful incubation and hatching of eggs<br>**(long term exposure) 1** |
| | | | |
| Brook Trout | 19ºC (66ºF) | 24ºC (75ºF) | 9ºC (48ºF) |
| Rainbow Trout | 19ºC (66ºF) | 24ºC (75ºF) | 9ºC (48ºF) |
| Smallmouth Bass | 29ºC (84ºF) | --- | 17ºC (63ºF) |
| Largemouth Bass | 32ºC (90ºF) | 34ºC (93ºF) | 21ºC (70ºF) |
| Bluegill | 32ºC (90ºF) | 35ºC (95ºF) | 25ºC (77ºF) |
| Channel Catfish | 32ºC (90ºF) | 35ºC (95ºF) | 27ºC (81ºF) |

[1] This is based on maximum temperatures averaged over at least a week.
[2] This is based on maximum temperatures averaged over a few hours.

Source: Volunteer Stream Monitoring: A Methods Manual

## Resources for further investigation

**Environmental Protection Agency's Volunteer Stream Monitoring: A Methods Manual -** This 210-page manual takes the reader through an introduction to streams and watersheds then proceeds to offer in-depth, step-by-step approaches to monitoring a variety of water quality components. You will find helpful background information on stream temperature. For a free copy of the manual, contact Alice Mayio at USEPA (4503F), 401 M St. SW, Washington, DC 20460; 202/260-7018; mayio.alice@epamail.epa.gov. Also available on the web: www.epa.gov/owow/monitoring/vol.html.

**Kentucky Water Watch** – This Kentucky Water Watch web site, administered by the State of Kentucky Natural Resource and Environmental Protection Cabinet, offers background information on all major water quality parameters, including temperature. You'll also find lots of other useful information to support classroom and field monitoring. www.state.ky.us/nrepc/water/wwhomepg.htm

**Water Conservation and Nonpoint Source Pollution** – This activity book features hands-on, minds-on activities for younger ages. Several activities specifically address temperature concepts (in both indoor and outdoor settings). Contact: Your local County Cooperative Extension Office – or – Utah State University Extension, 1500 N 800 E, ASTE Dept, Utah State University, Logan, UT 84322-2300, 435/797-3389. extension.usu.edu/natres/wq/

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Environmental Protection Agency. Volunteer Stream Monitoring: A Methods Manual (EPA 841-B-97-003). Office of Water. Washington, DC, 1997.

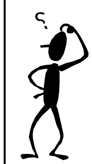
Moore, J.A., and J.R. Miner. “Stream Temperatures: Some Basic Considerations.” Oregon State University Extension Service, 1997.

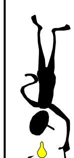
Morton, Stephen D. Water Pollution: Causes and Cures. Mimir Publishers, Inc. Madison, WI, 1976.

# Temperature

**Time** – 2 minutes
**Persons** – 1
**Materials** –
- Thermometer







**Step 1**

1. Dip the thermometer into a moving part of the stream or river.

2. Wait for the temperature to stop changing (at least 1 minute).

**Step 2**

1. Read the temperature and record on the data sheet. Be sure to record your temperature in degrees Celsius.

2. Use the equations below to convert between degrees Celsius to degrees Fahrenheit.

**Converting Fahrenheit to Celsius:** $°C = (5/9) \times (°F - 32)$

**Converting Celsius to Fahrenheit:** $°F = [(9/5) \times °C] + 32$

The maximum temperature allowed for warm water water fisheries and aquatic wildlife is 27° C (81° F).

The maximum temperature allowed for cold water fisheries and aquatic wildlife is 20° C (68° F).

Date:____________________ Recorder:___________________

| Your Results | Compare your results to Utah's requirements |
|---|---|
| **Water Temperature**<br><br>______ ºF (or) ______ ºC | The maximum temperature for:<br>• warmwater fisheries is 27° C (81° F)<br>• coldwater fisheries is 20° C (68° F). |
| **pH**<br>(Value of the color match)<br><br>_________________ | The allowable range for most waters in Utah is 6.5 to 9.0 |
| **Dissolved Oxygen**<br>(Value of the color match)<br><br>_____________ mg / liter | The minimum concentration for:<br>• warmwater fisheries is 5.5 mg/liter<br>• coldwater fisheries is 6.5 mg/liter. |
| **Nitrate**<br>(Value of the color match)<br><br>_____________ mg / liter<br>Nitrate-nitrogen | The maximum concentration for drinking water is 10 mg/liter.<br><br>The concentration which indicates a possible pollution problem for streams and rivers is 4 mg/liter. |
| **Ammonia**<br>(Value of the color match)<br><br>_____________ mg / liter<br>Ammonia-nitrogen | The maximum allowable concentration depends on the water's pH and temperature. Please check the Ammonia section in the manual. |
| **Phosphate**<br>(Divide value of the color match by 150)<br><br>_____________ mg / liter<br>Phosphate-phosphorus | The concentration which indicates a possible pollution problem:<br>• in streams and rivers is .05 mg/liter<br>• in lakes is .025 mg/liter |
| **Turbidity**<br>(Use chart to convert target distance to NTUs)<br><br>________________ NTUs | The maximum *increase* over natural levels in most streams and rivers is 10 NTUs. |

**Chemical Properties Field Data Sheet**