Water Testing Lab

Read the lab ***carefully*** and fill out the table below

Water Test	IMPORTANCE (Why its needed in aquatic ecosystems)	FACTORS that affect it or SOURCES of pollutant	EFFECTS on aquatic ecosystems (if not normal)	Normal Levels	Procedure	Our Results

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Test 1

Temperature

INTRODUCTION

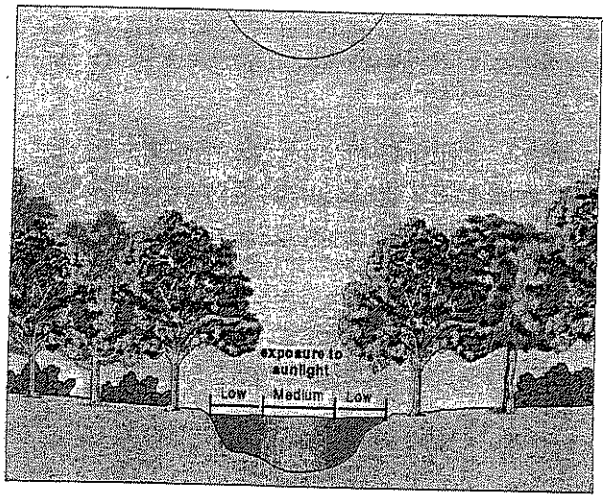
The temperature of a body of water influences its overall quality. Water temperatures outside the "normal" range for a stream or river can cause harm to the aquatic organisms that live there. It is for this reason that the *change* in the temperature of the water over a section of a stream is measured, not just the temperature at one location. If the water temperature changes by even a few degrees over a one-mile stretch of the stream, it could indicate a source of thermal pollution.

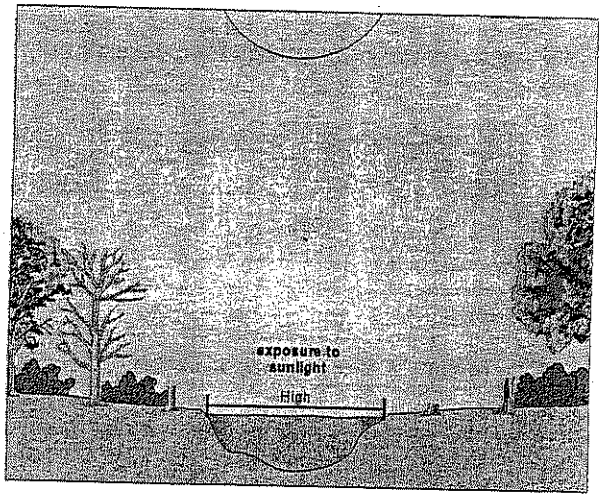
Factors that Affect Water Temperature

- Air temperature
- Amount of shade
- Soil erosion increasing turbidity
- Thermal pollution from human activities
- Confluence of streams

Thermal pollution caused by human activities is one factor that can affect water temperature. Many industries use river water in their processes. The water is treated before it is returned to the river, but is warmer than it was before. Runoff entering a stream from parking lots and rooftops is often warmer than the stream and will increase its overall temperature.

Shade is very important to the health of a stream because of the warming influences of direct sunlight. Some human activities may remove shade trees from the area which will allow more sunlight to reach the water, causing the water temperature to rise.





Another factor that may affect water temperature is the temperature of the air above the water. The extent of its influence has a great deal to do with the depth of the water. A shallow stream is more susceptible to changes in temperature than a deep river would be.

Effects of Water Temperature

- Solubility of dissolved oxygen
- Rate of plant growth
- Metabolic rate of organisms
- Resistance in organisms

While many factors can contribute to the warming of surface water, few cause it to be cooled. One way water can be cooled is by cold air temperatures. A second, natural method of cooling a river or lake comes from the introduction of colder water from a tributary or a spring.

Table 1: Optimal Temperature Ranges	
Organism	Temperature Range (°C)
Trout	5 – 20
Smallmouth bass	5 – 28
Caddisfly larvae	10 – 25
Mayfly larvae	10 – 25
Stonefly larvae	10 – 25
Water boatmen	10 – 25
Carp	10 – 25
Mosquito	10 – 25
Catfish	20 – 25

One important aspect of water temperature is its effect on the solubility of gases, such as oxygen. More gas can be dissolved in cold water than in warm water. Animals, such as salmon, that require a high level of dissolved oxygen will only thrive in cold water.

Increased water temperature can also cause an increase in the photosynthetic rate of aquatic plants and algae. This can lead to increased plant growth and algal blooms, which can be harmful to the local ecosystem.

A change in water temperature can affect the general health of the aquatic organisms, thus changing the quality of the stream. Table 1 lists the optimal temperature ranges of some selected aquatic organisms. When the water temperature becomes too hot or too cold, organisms become stressed, lowering their resistance to pollutants, diseases, and parasites.

Expected Levels

Water temperatures can range from 0°C in the winter to above 30°C in the summer. Cooler water in a stream is generally considered healthier than warmer water, but there are no definitive standards. Problems generally occur when changes in water temperature are noted along one stream on the same day. Some sample data are listed in Table 2.

Table 2: Water Temperatures of Selected Rivers				
Site	Season	Temperature (°C)	Season	Temperature (°C)
Hudson River, Poughkeepsie,	Winter	5	Summer	25
Missouri River, Garrison Dam,	Winter	3	Summer	14
Rio Grande, El Paso, TX	Winter	16	Summer	21
Mississippi River, Memphis, TN	Winter	7	Summer	29
Willamette River, Portland, OR	Winter	9	Summer	22

Summary of Method

You will use a Vernier Temperature Probe to measure the temperature of the water at one site and at a second site upstream (one mile upstream is the standard, but a shorter distance may be used). Because water temperatures can fluctuate so greatly from region to region and season to season (see Table 2), it is the *difference* in temperatures along one stretch of a particular stream or river on a single day that is measured.

Test 2

pH

INTRODUCTION

Water contains both hydrogen ions, H^+, and hydroxide ions, OH^-. The relative concentrations of these two ions determine the pH value.[1] Water with a pH of 7 has equal concentrations of these two ions and is considered to be a *neutral* solution. If a solution is *acidic*, the concentration of H^+ ions exceeds that of the OH^- ions. In a *basic* solution, the concentration of OH^- ions exceeds that of the H^+ ions. On a pH scale of 0 to 14, a value of 0 is the most acidic, and 14 the most basic. A change from pH 7 to pH 8 in a lake or stream represents a ten-fold increase in the OH^- ion concentration.

Rainfall generally has a pH value between 5 and 6.5. It is acidic because of dissolved carbon dioxide and air pollutants, such as sulfur dioxide or nitrogen oxides. If the rainwater flows over soil containing hard-water minerals, its pH usually increases. Bicarbonate ions, HCO_3^-, resulting from limestone deposits react with the water to produce OH^- ions, according to the equation:

$$HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$$

As a result, streams and lakes are often basic, with pH values between 7 and 8, sometimes as high as 8.5.

The measure of the pH of a body of water is very important as an indication of water quality, because of the sensitivity of aquatic organisms to the pH of their environment. Small changes in pH can endanger many kinds of plants and animals; for example, trout and various kinds of nymphs can only survive in waters between pH 7 and pH 9. If the pH of the waters in which they live is outside of that range, they may not survive or reproduce.

Table 1: Effects of pH Levels on Aquatic Life

pH	Effect
3.0 – 3.5	Unlikely that fish can survive for more than a few hours in this range, although some plants and invertebrates can be found at pH levels this low.
3.5 – 4.0	Known to be lethal to salmonids.
4.0 – 4.5	All fish, most frogs, insects absent.
4.5 – 5.0	Mayfly and many other insects absent. Most fish eggs will not hatch.
5.0 – 5.5	Bottom-dwelling bacteria (decomposers) begin to die. Leaf litter and detritus begin to accumulate, locking up essential nutrients and interrupting chemical cycling. Plankton begin to disappear. Snails and clams absent. Mats of fungi begin to replace bacteria in the substrate.
	Metals (aluminum, lead) normally trapped in sediments are released into the acidified water in forms toxic to aquatic life.
6.0 – 6.5	Freshwater shrimp absent. Unlikely to be directly harmful to fish unless free carbon dioxide is high (in excess of 100 mg/L)
6.5 – 8.2	Optimal for most organisms.
8.2 – 9.0	Unlikely to be directly harmful to fish, but indirect effects occur at this level due to chemical changes in the water.
9.0 – 10.5	Likely to be harmful to salmonids and perch if present for long periods.
10.5 – 11.0	Rapidly lethal to salmonids. Prolonged exposure is lethal to carp, perch.
11.0 – 11.5	Rapidly lethal to all species of fish.

[1] The pH value is calculated as the negative log of the hydrogen ion concentration: $pH = -\log [H^+]$.

Factors that Affect pH Levels
• Acidic rainfall
• Algal blooms
• Level of hard-water minerals
• Releases from industrial processes
• Carbonic acid from respiration or decomposition
• Oxidation of sulfides in sediments

Changes in pH can also be caused by algal blooms (more basic), industrial processes resulting in a release of bases or acids (raising or lowering pH), or the oxidation of sulfide-containing sediments (more acidic).

To gain a full understanding of the relationship between pH and water quality, you need to make measurements of the pH of a stream, as described in this test, and also determine the stream's *alkalinity*, as described in Test 11 in this manual. Alkalinity is a measurement of the capacity or ability of the body of water to neutralize acids in the water. Acidic rainfall may have very little effect on the pH of a stream or lake if the region is rich in minerals that result in high alkalinity values. Higher concentrations of carbonate, bicarbonate, and hydroxide ions from limestone can provide a natural buffering capacity, capable of neutralizing many of the H^+ ions from the acid. Other regions may have low concentrations of alkalinity ions to reduce the effects of acids in the rainfall. In the Northeastern United States and Eastern Canada, fish populations in some lakes have been significantly lowered due to the acidity of the water caused by acidic rainfall. If the water is very acidic, heavy metals may be released into the water and can accumulate on the gills of fish or cause deformities that reduce the likelihood of survival. In some cases, older fish will continue to live, but will be unable to reproduce because of the sensitivity of the reproductive portion of the growth cycle.

Expected Levels

The pH value of streams and lakes is usually between pH 7 and 8. Levels between 6.5 and 8.5 pH are acceptable for most drinking water standards. Areas with higher levels of water hardness (high concentrations of Mg^{2+}, Ca^{2+}, and HCO_3^-) often have water with higher pH values (between 7.5 and 8.5).

Summary of Methods

The preferred method is to use a pH Sensor to make on-site measurements of the pH level in a stream or lake.

As an alternative, the water sample is taken from the stream or lake and stored in an ice chest or refrigerator. After returning to the lab, samples are allowed to return to room temperature, and the pH is measured using a pH Sensor.

Test 3

Turbidity

INTRODUCTION

Turbidity is a measure of water's lack of clarity. Water with high turbidity is cloudy, while water with low turbidity is clear. The cloudiness is produced by light reflecting off of particles in the water; therefore, the more particles in the water, the higher the turbidity.

Many factors can contribute to the turbidity of water. An increase in stream flow due to heavy rains or a decrease in stream-bank vegetation can speed up the process of soil erosion. This will add suspended particles, such as clay and silt, to the water.

Runoff of various types contains suspended solids that may add to the turbidity of a stream. Agricultural runoff often contains suspended soil particles. Other types of runoff include industrial wastes, water treatment plant effluent, and urban runoff from parking lots, roads, and rooftops.

Bottom-dwelling aquatic organisms, such as catfish, can contribute to the turbidity of the water by stirring up the sediment that has built up on the bottom of the stream. Organic matter such as plankton or decaying plant and animal matter that is suspended in the water can also increase the turbidity in a stream.

Sources of Turbidity

- Soil erosion
  - silt
  - clay
- Urban runoff
  - road grime
  - rooftops
  - parking lots
- Industrial waste
  - sewage treatment effluent
  - particulates
- Abundant bottom-dwellers
  - stirring up sediments
- Organics
  - microorganisms
  - decaying plants and animals
  - gasoline or oil from roads

Effects of Turbidity

- Reduces water clarity
- Aesthetically displeasing
- Decreases photosynthetic rate
- Increases water temperature

High turbidity will decrease the amount of sunlight able to penetrate the water, thereby decreasing the photosynthetic rate. Reduced clarity also makes the water less aesthetically pleasing. While this may not be harmful directly, it is certainly undesirable for many water uses.

When the water is cloudy, sunlight will warm it more efficiently. This occurs because the suspended particles in the water absorb the sunlight, warming the surrounding water. This can lead to other problems associated with increased temperature levels.

While highly turbid water can be detrimental to an aquatic ecosystem, it is not correct to assume that clear water is always healthy. Slightly turbid water can be perfectly healthy, while clear water could contain unseen toxins or unhealthy levels of nutrients.

Expected Levels

Turbidity is measured in *Nephelometric Turbidity Units,* NTU. According to the USGS, the turbidity of surface water is usually between 1 NTU and 50 NTU. Turbidity is often higher than this, however, especially after heavy rain when water levels are high. Turbidity can be lower than expected in still water because of the settling of suspended particles that might occur. The turbidity of some selected rivers are shown in Table 1. Water is visibly turbid at levels above 5 NTU. The standard for drinking water is 0.5 NTU to 1.0 NTU.

Table 1: Turbidity Levels in Selected Rivers

Site	Turbidity (NTU)
Sacramento River, Keswick, CA	4
Hudson River, Poughkeepsie, NY	15
Mississippi River, Memphis, TN	39
Rio Grande, El Paso, TX	80
Colorado River, CO-UT state line	180

Summary of Method

Turbidity is measured using a Vernier Turbidity Sensor. A cuvette of sample water is placed in the Turbidity Sensor and the value in NTU is read directly from the computer. Measurements can be made on site or in the lab at a later time.

Turbidity Water Test

Why Test Turbidity?

Turbidity is the measure of water clarity. The more suspended solids in the water, the murkier it becomes. The increased turbidity of water can reduce the diversity of life in three ways:

- Suspended particles absorb heat from sunlight and warm the water. Warmer water holds less oxygen and organisms begin to suffer. Also, some organisms can not live in the warmer water.
- Particles also block sunlight. Plants and algae grow less and release less oxygen from photosynthesis.
- Particles also settle on the bottom and can cover and suffocate fish eggs and insect larvae

Turbidity is often tested by dropping a Secchi disk into the water and measuring at what depth it disappears. This test is not practical in the Los Angeles River, however. Instead purchase a kit, such as the La Motte turbidity test, which involves observing a dot at the bottom of a column of water.

Refer to the Field Manual for Water Quality Monitoring for details on performing this test.

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Test 4

Total Solids

INTRODUCTION

Total solids, TS, is a measure of all the suspended, colloidal, and dissolved solids in a sample of water. This includes dissolved salts such as sodium chloride, NaCl, and solid particles such as silt and plankton. An excess of total solids in rivers and streams is a very common problem. The Environmental Protection Agency's National Water Quality Inventory[1] has concluded that siltation, one of the primary contributors to total solids, is the most common pollutant of streams and rivers they sampled.

Sources of Total Solids

- Soil erosion
  - silt
  - clay
  - dissolved minerals
- Agricultural runoff
  - fertilizers
  - pesticides
  - soil erosion
- Urban runoff
  - road grime
  - rooftops
  - parking lots
- Industrial waste
  - dissolved salts
  - sewage treatment effluent
  - particulates
- Organics
  - microorganisms
  - decaying plants and animals
  - gasoline or oil from roads
- Abundant bottom-dwellers

Many factors can contribute to the total solids in water. Soil erosion is a large contributor. An increase in water flow or a decrease in stream-bank vegetation can speed up the process of soil erosion and contribute to the levels of suspended particles such as clay and silt. Naturally occurring rocks or minerals in the soil such as halite, NaCl, or limestone, $CaCO_3$, may also dissolve into the water, adding to the total solids.

Total solids can also come from various types of runoff. Agricultural runoff often contains fertilizers and suspended soil particles. Other sources include industrial wastes, effluent from water treatment plants, and urban runoff from parking lots, roads, and rooftops.

Bottom-dwelling aquatic organisms, such as catfish, can contribute to the total solids in the water by stirring up the sediment that has built up on the bottom of the stream. Organic matter such as plankton or decaying plant and animal matter that are suspended in the water will also add to the total solids in a stream.

Dissolved solids often make a significant contribution to the amount of total solids in water. In fact, the mass of the dissolved solids is sometimes higher than the mass of the suspended particles. Dissolved solids in freshwater samples include soluble salts that yield ions such as calcium, chloride, bicarbonate, nitrates, phosphates, and iron.

If the levels of total solids are too high or too low, it can impact the health of the stream and the organisms that live there. High levels of total solids will reduce the clarity of the water. This decreases the amount of sunlight able to penetrate the water, thereby decreasing the photosynthetic rate. Reduced clarity also makes the water less aesthetically pleasing. While this may not be harmful directly, it is certainly undesirable for many water uses. When the water is cloudy, sunlight will warm it more efficiently. This occurs because the suspended particles in the water absorb the sunlight which, in turn, warm the surrounding water. This leads to other problems associated with increased temperature levels.

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[1] From the EPA's Office of Water web site at www.epa.gov/OW/resources.

As previously mentioned, dissolved solids often make a large contribution to total solids. The correct balance of dissolved solids in the water is essential to the health of aquatic organisms for several reasons. One reason is that many of these dissolved materials are essential nutrients for the general health of aquatic organisms. Another reason is that the transport of ions through cellular membranes is dependent on the total ionic strength of the water. Too many dissolved salts in the water can dehydrate aquatic organisms. Too few dissolved salts, however, can limit the growth of aquatic organisms that depend on them as nutrients.

Effects of High Total Solids

- Can be harmful to aquatic organisms
- Reduce water clarity
- Aesthetically unpleasing
- Decrease photosynthetic rate
- Increase water temperature

Expected Levels

Total solids in surface water usually fall within the range of 20 mg/L to 500 mg/L. Values can go much higher especially after heavy rain when the water levels are high. Some sample data from selected rivers are listed in Table 1.

Table 1: Total Solids in Selected Rivers

Site	Season	Total Solids (mg/L)	Season	Total Solids (mg/L)
Hudson River, Poughkeepsie, NY	Spring	134	Fall	259
Colorado River, CO-UT state line	Spring	1226	Fall	873
Sacramento River, Keswick, CA	Spring	112	Fall	68
Mississippi River, Memphis, TN	Spring	222	Fall	371
Columbia River, Northport, WA	Spring	81	Fall	88

Summary of Method

You will determine the total solids in a sample of water by adding a precise amount of water to a carefully cleaned, dried, and weighed beaker. The water is then evaporated away using a drying oven and the beaker is reweighed. The difference in mass before and after is the mass of the total solids. Calculations are made to convert the change in mass to mg/L total solids.

Total Solids Water Test

Why Test for Total Solids?

Total solids (somtimes called total residue) is related to turbidity, except that it includes not just suspended solids, but also dissolved solids such as the mineral ions calcium, phosphorus, iron, sulfur and bicarnonate. A certain level of these ions is essential for life. Cells also depend on the density of total solids to determine the amount of water that flows in and out of the cell.

However, too much dissolved solids in water can affect humans by inducing a laxative effect and giving the water a mineral taste. Increased total solids has a similar effect to turbidity in that water clarity is reduced, water temperature can rise, oxygen levels can fall as a result of less photosynthesis, and solids can bind to toixc compounds and heavy metals.

In summary, testing for dissolved solids involves weighing a clean 300ml beaker to the nearest mg. Fill the beaker with test water and evaporate off the water. Weigh the beaker again with the resulting residue. Then subtract the two results to determine the amount of milligrams of residue per liter of water.

Refer to the Field Manual for Water Quality Monitoring for details on performing this test.

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Test 5

Dissolved Oxygen

INTRODUCTION

Oxygen gas dissolved in water is vital to the existence of most aquatic organisms. Oxygen is a key component in cellular respiration for both aquatic and terrestrial life. The concentration of dissolved oxygen, *DO*, in an aquatic environment is an important indicator of the environment's water quality.

Some organisms, such as salmon, mayflies, and trout, require high concentrations of dissolved oxygen. Other organisms, such as catfish, mosquito larvae, and carp, can survive in environments with lower concentrations of dissolved oxygen. The diversity of organisms is greatest at higher DO concentrations. Table 1 lists the minimum dissolved oxygen concentrations necessary to sustain selected animals.

Table 1: Minimum DO Requirements

Organism	Minimum dissolved oxygen (mg/L)
Trout	6.5
Smallmouth bass	6.5
Caddisfly larvae	4.0
Mayfly larvae	4.0
Catfish	2.5
Carp	2.0
Mosquito larvae	1.0

Oxygen gas is dissolved in water by a variety of processes—diffusion between the atmosphere and water at its surface, aeration as water flows over rocks and other debris, churning of water by waves and wind, and photosynthesis of aquatic plants. There are many factors that affect the concentration of dissolved oxygen in an aquatic environment. These factors include: temperature, stream flow, air pressure, aquatic plants, decaying organic matter, and human activities.

Sources of DO

- Diffusion from atmosphere
- Aeration as water moves over rocks and debris
- Aeration from wind and waves
- Photosynthesis of aquatic plants

As a result of plant activity, DO levels may fluctuate during the day, rising throughout the morning and reaching a peak in the afternoon. At night photosynthesis ceases, but plants and animals continue to respire, causing a decrease in DO levels. Because large daily fluctuations are possible, DO tests should be performed at the same time each day. Large fluctuations in dissolved oxygen levels over a short period of time may be the result of an algal bloom. While the algae population is growing at a fast rate, dissolved oxygen levels increase. Soon the algae begin to die and are decomposed by aerobic bacteria, which use up the oxygen. As a greater number of algae die, the oxygen requirement of the aerobic decomposers increases, resulting in a sharp drop in dissolved oxygen levels. Following an algal bloom, oxygen levels can be so low that fish and other aquatic organisms suffocate and die.

Factors that affect DO levels

- Temperature
- Aquatic plant populations
- Decaying organic material in water
- Stream flow
- Altitude/atmospheric pressure
- Human activities

Temperature is important to the ability of oxygen to dissolve, because oxygen, like all gases, has different solubilities at different temperatures. Cooler waters have a greater capacity for dissolved oxygen than warmer waters. Human activities, such as the removal of foliage along a stream or the release of warm water used in industrial processes, can cause an increase in water temperature along a given stretch of the stream. This results in a lower dissolved oxygen capacity for the stream.

Expected Levels

The unit mg/L[2] is the quantity of oxygen gas dissolved in one liter of water. When relating DO measurements to minimum levels required by aquatic organisms, mg/L is used. The procedure described in this chapter covers the use of a Dissolved Oxygen Probe to measure the concentration of DO in mg/L. Dissolved oxygen concentrations can range from 0 to 15 mg/L. Cold mountain streams will likely have DO readings from 7 to 15 mg/L, depending on the water temperature and air pressure. In their lower reaches, rivers and streams can have DO readings between 2 and 11 mg/L.

Table 2

DO Level	Percent Saturation of DO
Supersaturation[1]	≥ 101%
Excellent	90 – 100%
Adequate	80 – 89%
Acceptable	60 – 79%
Poor	< 60%

When discussing water quality of a stream or river, it can be helpful to use a different unit than mg/L. The term percent saturation is often used for water quality comparisons. Percent saturation is the dissolved oxygen reading in mg/L divided by the 100% dissolved oxygen value for water (at the same temperature and air pressure). The manner in which percent saturation relates to water quality is displayed in Table 2. In some cases, water can exceed 100% saturation and become supersaturated for short periods of time.

Summary of Methods

Dissolved oxygen can be measured directly at the site or from water samples transported from the site. Measurements can be made at the site by either placing the Dissolved Oxygen Probe directly into the stream away from the shore or by collecting a water sample with a container or cup and then taking measurements with the Dissolved Oxygen Probe back on the shore. Water samples collected from the site in capped bottles and transported back to the lab must be stored in an ice chest or refrigerator until measurements are to be made. Transporting samples is not recommended, because it reduces the accuracy of test results.

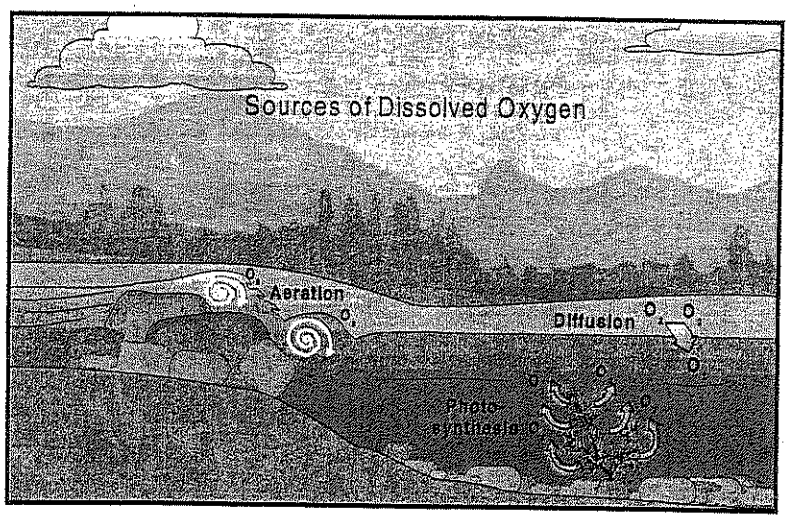
[1] Supersaturation can be harmful to aquatic organisms. It can result in a disease known as Gas Bubble Disease.
[2] The unit of mg/L is numerically equal to parts per million, or ppm.

Test 6

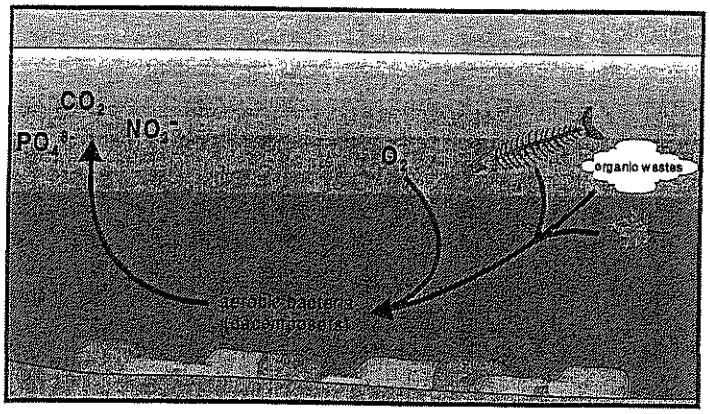
Biochemical Oxygen Demand

INTRODUCTION

Oxygen available to aquatic organisms is found in the form of *dissolved oxygen*. Oxygen gas is dissolved in a stream through aeration, diffusion from the atmosphere, and photosynthesis of aquatic plants and algae. Plants and animals in the stream consume oxygen in order to produce energy through respiration. In a healthy stream, oxygen is replenished faster than it is used by aquatic organisms. In some streams, aerobic bacteria decompose such a large volume of organic material that oxygen is depleted from the stream faster than it can be replaced. The resulting decrease in dissolved oxygen is known as the *Biochemical Oxygen Demand* (BOD).



When it rains, organic material found in the soil is transported in the rainwater to streams and rivers. Additional organic material accumulates in the stream when aquatic organisms die. Bacteria and other microorganisms decompose this organic material. In a healthy body of water, this process has only a slight impact on dissolved oxygen levels. It serves to release vital nutrients, such as nitrates and phosphates, which stimulate algae and aquatic plant growth. If the amount of decomposing organic material is too high, dissolved oxygen levels can be severely reduced. In a body of water with large amounts of decaying organic material the dissolved oxygen levels may drop by 90%—this would represent a high BOD. In a mountain stream with low levels of decaying organic material, the dissolved oxygen levels may drop by only 10% or 20%—a low BOD.



Organic materials, such as leaves, fallen trees, fish carcasses, and animal waste, end up in the water naturally and are important in the recycling of nutrients throughout the ecosystem. Organic materials that enter the water as a result of human impact can be considered sources of pollution.

Expected Levels

BOD levels are dependent on the body of water being tested. Shallow, slow-moving waters, such as ponds and wetlands, will often have large amounts of organic material in the water and high BOD levels. A water sample from a pond could have an initial dissolved oxygen reading of 9.5 mg/L. After the five-day incubation period, the dissolved oxygen could be down to 1 mg/L resulting in a high BOD level of 8.5 mg/L. In contrast, a water sample collected from a cold mountain stream with an initial dissolved oxygen reading of 11 mg/L may have decreased to 9 mg/L after incubation, resulting in a BOD of only 2 mg/L. Use Table 1 as a rough guide for the data you gather[1].

Table 1: Interpretation of BOD Levels

BOD Level (mg/L)	Status
1 – 2 mg/L	Clean water with little organic waster.
3 – 5 mg/L	Moderately clean water with some organic waste.
6 – 9 mg/L	Lots of organic material and many bacteria.
>10 mg/L	Very poor water quality. Large amounts of organic material in the water.

Summary of Methods

Included in this test are the procedures for High and Low BOD levels. Decide beforehand, based on expected BOD levels (see Table 1), which procedure is appropriate for the water you are testing. Only one of the two tests should be performed.

Method 1: Low BOD Levels (0 – 6 mg/L)

BOD is calculated from two separate dissolved oxygen measurements made using the Dissolved Oxygen Probe. The initial dissolved oxygen reading is taken at the sampling site using the procedures outlined in Test 5. Using a light-free sample bottle, a water sample is collected at the same site. The sample is transported back to the lab and incubated at 20°C for a total of five days. After five days, the incubated sample is tested for dissolved oxygen. The oxygen reading at the end of the five days is subtracted from the initial reading. The resulting value is the BOD level.

Method 2: High BOD Levels (> 6 mg/L)

This method is recommended when testing stagnant or polluted waters, in which all of the dissolved oxygen may be consumed before the end of the 5-day period. The initial dissolved oxygen test, sampling, storage and incubation, are performed in the same manner as found in Method 1. Differences for Method 2 are:

- Five water samples are collected.
- A sample is tested for dissolved oxygen every 24 hours for five days.
- If, before the fifth day, the dissolved oxygen concentration falls below 2 mg/L, oxygen is added to the remaining samples by aeration.
- Add each bottle's change in dissolved oxygen concentration to obtain the BOD value.

[1] Table 1 is from the Student Watershed Research Project manual, 3rd Edition 1996.

Biological Oxygen Demand Water Test

Why Test for Oxygen Demand?

The biological oxygen demand (BOD) water test is used to determine how much oxygen is being used by aerobic microorganisms in the water to decompose organic matter. If these aerobic bacteria are using too much of the dissolved oxygen in the water, then there will not be enough left over for the fish, insects, and other organisms that rely on oxygen. The rich diversity of life on a healthy river is then reduced to a low diversity (but sometimes high volume) of pollution tolerant organisms.

There are two ways that humans inadvertently drive up biological oxygen demand. First, too much organic material is dumped into a river or lake from paper mills, food processing plants, wastewater treatment plants, urban runoff, etc. Second, fertilizers in the form of nitrates and phosphates flow into a river from agricultural and urban runoff and then stimulate the overgrowth of plants and algae. However, once this organic matter (plants, algae, human, food, and animal waste, yard clippings and saw dust) begin to decompose, it begins to suck the oxygen out of the water.

The BOD test is done by taking a water sample and keeping it cool and dark for five days so as not to stimulate algal growth. Then take a water sample from the same site after five days. Perform a dissolved oxygen test on both samples and subtract the two results so see how much oxygen was used during the time period.

Refer to the Field Manual for Water Quality Monitoring for details on performing this test.

[Back to Water Testing]

Test 7

Phosphates
(ortho- and total)

INTRODUCTION

Phosphorus is an essential nutrient for all aquatic plants and algae. Only a very small amount is needed, however, so an excess of phosphorus can easily occur. Excess phosphorus is usually considered to be a pollutant because it can lead to *eutrophication*—a condition where an overabundance of nutrients, such as phosphorus, causes increased plant and algal growth. Eutrophication can lower the levels of dissolved oxygen in the water and can render the water uninhabitable by many aquatic organisms. Phosphorus is often the limiting factor that determines the level of eutrophication that occurs.

Effects of Phosphate Levels

- High levels
  - eutrophication
  - increased algal blooms
  - increased BOD
  - decreased DO
- Low levels
  - limiting factor in plant and algal growth

Most phosphorus in surface water is present in the form of phosphates. There are four classifications of phosphates often referred to in environmental literature:

- *orthophosphates* are the inorganic forms of phosphate, such as PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^-$. These are the forms of phosphates used heavily in fertilizers and are often introduced to surface waters through runoff.
- *organically bound phosphates* are found in human and animal wastes or in decaying organic matter.
- *condensed phosphates (also called polyphosphates)*, such as $P_3O_{10}^{5-}$, are sometimes added to water supplies and industrial processes to prevent the formation of scaling and to inhibit corrosion. This is the form of phosphate that was commonly found in detergents in the past.
- *total phosphates* are the sum of all three of the forms described above. This is the most commonly reported form of phosphate concentration.

Sources of Phosphates

- Human and animal wastes
- Industrial wastes
- Agricultural runoff
- Human disturbance of land

Phosphates are added to surface waters by a variety of means. Humans add phosphates to water through industrial and agricultural wastes. Fertilizers contain high levels of phosphates and will enter the water by means of runoff and soil erosion. In areas where land and vegetation have been disturbed, soil erosion will increase. This will lead to even more phosphates being washed out of the soil and into the water. Phosphates can also come from the excrement of animals living in or near the water.

Expected Levels

The concentration of phosphates will be expressed throughout this test in units of mg/L PO_4-P, meaning phosphorus in the form of phosphates.[1] Levels above 0.1 mg/L PO_4-P can stimulate plant growth above its natural rate. Water that receives runoff from heavily fertilized areas may have higher levels of phosphates.

[1]Note that no charge is given to the PO_4 when it is used in reporting phosphate units. Here it is being used as a generic symbol for many forms of phosphates with varying charges, such as PO_4^{3-} and HPO_4^{2-}.

A study by the U.S. Geological Survey, based on 410 sites throughout the United States, reports that in 1982, approximately 55% of the sites reported phosphate levels of greater than 0.1 mg/L PO_4-P. By 1989, this percentage had dropped to close to 40%. This decline is due in part to the reduction of phosphorus content in detergents and fertilizers.[2]

Table 1: Phosphate Levels of Selected Rivers

Site	Total Phosphates (mg/L PO_4-P)	Ortho-phosphates (mg/L PO_4-P)
Missouri River, St. Joseph, MO	0.64	0.11
Hudson River, Poughkeepsie, NY	1.60	0.02
Missouri River, Garrison Dam,	0.02	0.01
Rio Grande, El Paso, TX	0.41	0.07
Willamette River, Portland, OR	0.09	0.06

Summary of Methods

Both of the methods referred to below include procedures for determining levels of orthophosphates and total phosphates. The only difference between methods is the number of standards used to create the standard curve.

Orthophosphates are relatively easy to measure and will usually give a rough indication of the total level of phosphates in the water. Orthophosphate concentration is determined by means of a chemical reaction resulting in a color change dependent on the concentration of orthophosphates present. The intensity of the color is then measured with a Vernier Colorimeter.

The test for total phosphates involves *digesting*, or treating the sample with an acid and an oxidizer, and boiling for 30 minutes to convert all the phosphates into orthophosphates. The orthophosphate test is then conducted on the sample. The results are reported as total phosphates. This test is more involved than the orthophosphate test, but it is the form of phosphates most commonly reported.

Method 1: Phosphates—Colorimeter with Single Standard

A Vernier Colorimeter is used to create a 2-point standard curve of phosphate absorbance *vs.* concentration using a blank and one phosphate standard. This method is faster and easier than the multiple-standard method, but because your measurement depends upon one standard, the chances for error are somewhat higher.

Method 2: Phosphates—Colorimeter with Multiple Standards

A Vernier Colorimeter is used to create a 4-point standard curve of phosphate absorbance *vs.* concentration using a set of four phosphate standards. This method takes more time and effort than the single-standard method, but the standard curve will be based on four points, reducing the chance of error.

[2] U.S. Geological Survey, *National Water Summary 1990–91, Hydrologic Events and Stream Water Quality*, Water-Supply Paper 2400, United States Government Printing Office, 1993, 124–125.

Measured to determine

Test 8

Nitrate

INTRODUCTION

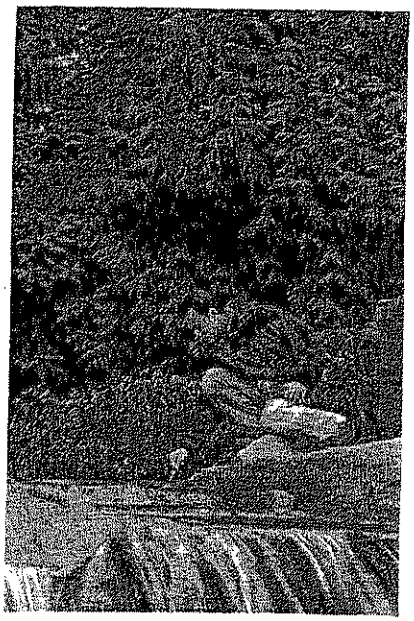
The tests described here are used to measure the concentration of nitrate ions, NO_3^-, in a water sample. The concentration of nitrate will be expressed throughout this section in units of mg/L NO_3^--N. The unit, NO_3^--N, means simply "nitrogen that is in the form of nitrate."

Nitrate ions found in freshwater samples result from a variety of natural and manmade sources. Nitrates are an important source of nitrogen necessary for plants and animals to synthesize amino acids and proteins. Most nitrogen on earth is found in the atmosphere in the form of nitrogen gas, N_2. Through a process called the *nitrogen cycle*,[1] nitrogen gas is changed into forms that are useable by plants and animals. These conversions include industrial production of fertilizers, as well as natural processes, such as legume-plant nitrogen fixation, plant and animal decomposition, and animal waste.

Sources of Nitrate Ions

- Agriculture runoff
- Urban runoff
- Animal feedlots and barnyards
- Municipal and industrial wastewater
- Automobile and industrial emissions
- Decomposition of plants and animals

Although nitrate levels in freshwater are usually less than 1 mg/L, manmade sources of nitrate may elevate levels above 3 mg/L. These sources include animal feedlots, runoff from fertilized fields, or treated municipal wastewater being returned to streams. Levels above 10 mg/L in drinking water can cause a potentially fatal disease in infants called *methemoglobinemia*, or Blue-Baby Syndrome. In this disease, nitrate converts hemoglobin into a form that can no longer transport oxygen.



High nitrate concentrations also contribute to a condition in lakes and ponds called *eutrophication*, the excessive growth of aquatic plants and algae. Unpleasant odor and taste of water, as well as reduced clarity, often accompany this process. Eventually, dead biomass accumulates in the bottom of the lake, where it decays and compounds the problem by recycling nutrients. If other necessary nutrients are present, algal blooms can occur in a lake with as little as 0.50 mg/L NO_3^--N.

Nitrate pollution of surface and groundwater has become a major ecological problem in some agricultural areas. Although fertilizer in runoff is most often blamed, there is evidence that concentration of livestock in feedlots is now the major source of agricultural nitrate pollution. Runoff from fertilized fields is still a significant source of nitrate, although fertilizer use peaked in 1981 and has remained fairly constant since.

[1] See *Test 10: Ammonium Nitrogen*, p. 10-1, for further information on the nitrogen cycle.

Expected Levels

The nitrate level in freshwater is usually found in the range of 0.1 to 4 mg/L NO_3^--N. Unpolluted waters generally have nitrate levels below 1 mg/L. The effluent of some sewage treatment plants may have levels in excess of 20 mg/L.

In a study based on 344 USGS sites throughout the United States,[2] 80% of the sites reported nitrate levels less than 1 mg/L, 16% were in the range of 1–3 mg/L, and 4% were greater than 3 mg/L. The percentage of various land types reporting greater than 1 mg/L of nitrate were range land <5%, forested land ~10%, urban areas ~30%, and agricultural land ~40%.

Table 1: Nitrate Concentration in Selected Sites

Site	Nitrate spring level (mg/L NO_3^--N)	Nitrate fall level (mg/L NO_3^--N)
Mississippi River, Clinton, IA	0.55	1.20
Mississippi River, Memphis, TN	1.60	2.90
Rio Grande River, El Paso, TX	0.38	0.59
Ohio River, Benwood, WV	0.87	1.30
Willamette River, Portland, OR	0.28	0.98
Missouri River, Garrison Dam, ND	0.40	0.14
Hudson River, Poughkeepsie, NY	0.49	0.64
Platte River, Sharpes Station, MO	1.90	1.30

Summary of Methods

Method 1: Nitrate Ion-Selective Electrode

A Vernier Nitrate Ion-Selective Electrode (ISE) is used to measure the nitrate-ion concentration in the water, in mg/L NO_3^--N, either on site or after returning to the lab.

Method 2: Nitrate—Colorimeter with a Single Standard

A Vernier Colorimeter is used to create a 2-point standard curve of absorbance *vs.* nitrate concentration using a blank and one nitrate standard solution. This method is faster and easier than the multiple-standard method, but because your measurement depends upon one standard, the chances for error are somewhat higher.

Method 3: Nitrate—Colorimeter with Multiple Standards

A Vernier Colorimeter is used to create a 4-point standard curve of absorbance *vs.* nitrate concentration using a set of four nitrate standards. This method takes more time and effort than the single-standard method, but the standard curve will be based on four points, reducing the chance of error.

[2] U.S. Geological Survey, *National Water Summary 1990–91, Hydrologic Events and Stream Water Quality*, Water-Supply Paper 2400, United States Government Printing Office, 1993, 122–123.

Test 9

Fecal Coliform

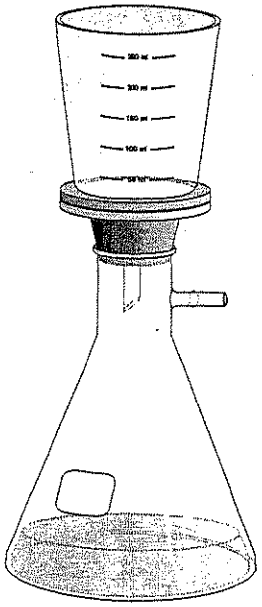
INTRODUCTION

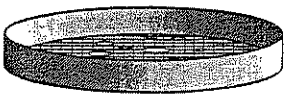
The concentration of fecal coliform bacteria in water is measured to determine the likelihood of contamination by microbiological organisms. While fecal coliform are not pathogenic (disease causing), they are commonly found alongside pathogenic organisms such as those responsible for dysentery, gastroenteritis, and hepatitis A. It is easier to test for fecal coliform than for pathogenic organisms; therefore, the presence of fecal coliform in a water sample is used to indicate potential contamination. A common source of coliforms and pathogenic bacteria is raw sewage. Fecal coliform bacteria occur naturally in the digestive tract of warm-blooded animals, where they aid in the digestion of food.

Sources of Raw Sewage

- Urban stormwater runoff containing domestic animal waste
- Agricultural sources such as dairies and cattle
- Sewage treatment overflow

The results of coliform bacteria tests are generally used to monitor recreational areas, stormwater out-falls, and drinking water supplies. Water is commonly tested for three types of coliform bacteria: fecal coliforms, total coliforms, and *E. coli.* The standards for drinking water are generally based on total coliforms. The accepted standard for drinking water is that there should be no coliforms present after the water is filtered or treated. Natural waters will nearly always contain some form of bacteria. That is why you should never drink untreated water from a river or lake. Currently, the most common measurement for surface waters is fecal coliform. In some areas, standards for surface water contamination are shifting to the measurement of *E. coli.*





Expected Levels

Standards for fecal coliform differ from state to state. For specific requirements, it is best to contact your state or regional health department. Standards for fecal coliform are considerably more strict if the water is used for total body contact such as swimming, rather than used only for boating with minimal direct contact.

When interpreting data from fecal coliform tests, it is important to remember that there can be a high degree of randomness of distribution within a sample. A large number of data points are necessary to obtain statistically significant data. Fecal coliform is measured in *colony forming units* per 100 mL, CFU/100 mL, of water tested.

Table 1[1]

Water use	Desired level (CFU/100mL)	Permissible level (CFU/100mL)
drinking	0	0
swimming	<200	<1,000
boating or fishing	<1,000	<5,000

Summary of Methods

This test uses the membrane filtration technique to measure quantity of fecal coliform bacteria present in a water sample. Samples are obtained from a water source, such as a river or stream, using Whirlpak containers. Water is then filtered through sterile 47-mm filters. The filters are placed in petri dishes containing mFC agar and incubated for a period of 24 hours at 44.5°C. Following incubation, the petri dishes are removed from the incubator and each dish is counted for fecal coliform colonies.

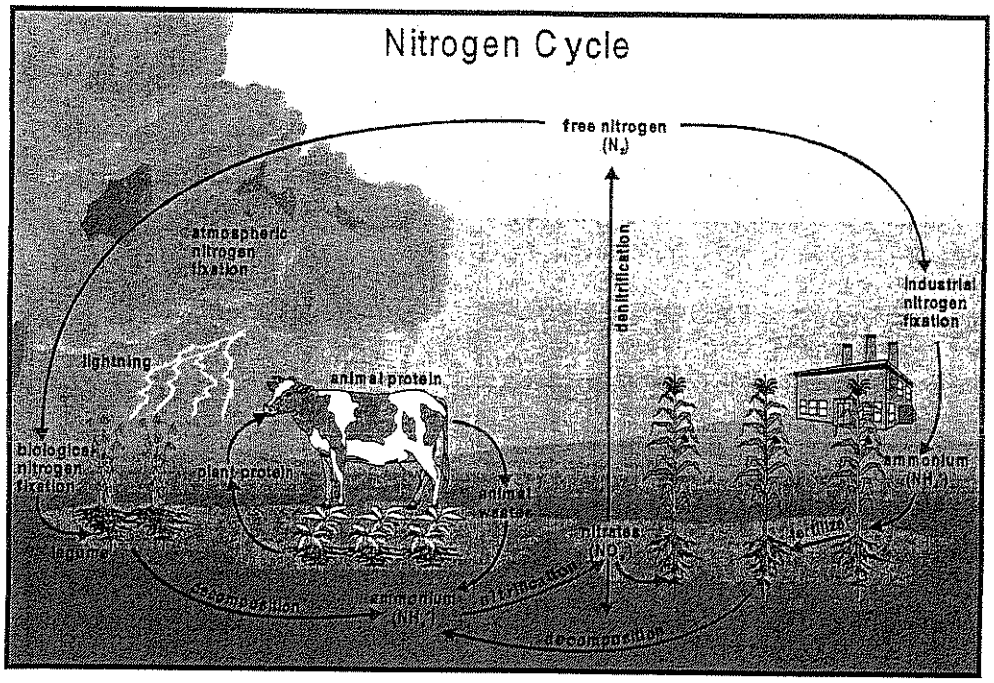
[1] CFU values in this chart were obtained from the LaMotte Company's "*The Monitor Handbook.*" These values are meant to be used as guidelines. Consult your local or state health department or your regional USEPA or USGS office for specific values for your region.

Test
10

Ammonium Nitrogen

INTRODUCTION

The ammonium ion, NH_4^+, is an important member of the group of nitrogen-containing compounds that act as nutrients for aquatic plants and algae. In surface water, most of the ammonia, NH_3, is found in the form of the ammonium ion, NH_4^+. This fact allows us to approximate the concentration of all of the nitrogen in the form of ammonia and ammonium combined, commonly called ammonia nitrogen, by measuring only the concentration of the ammonium ions.



All plants and animals require nitrogen as a nutrient to synthesize amino acids and proteins. Most nitrogen on earth is found in the atmosphere in the form of N_2, but plants and animals cannot utilize it in this form. The nitrogen must first be converted into a useable form, such as nitrate, NO_3^-. These conversions among the various forms of nitrogen form a complex cycle called the *nitrogen cycle*, illustrated above.

In the nitrogen cycle, bacteria convert atmospheric nitrogen into ammonium in a process called *nitrogen fixation*. This process often occurs in the roots of leguminous plants such as alfalfa, beans, and peas.

Bacteria can also convert the nitrogen in decaying plant and animal matter and waste products in the soil or water to ammonium in a process called *ammonification*. Other sources of organic matter for ammonification include industrial waste, agricultural runoff, and sewage treatment effluent.

Sources of Ammonia

- Decaying plants and animals
- Animal waste
- Industrial waste effluent
- Agricultural runoff
- Atmospheric nitrogen

Some trees and grasses are able to absorb ammonium ions directly, but most require their conversion to nitrate. This process, called *nitrification,* is usually accomplished by bacteria in the soil or water. In the first step of nitrification, ammonium ions are oxidized into nitrite. The nitrite is then converted into nitrate, which can subsequently be utilized by plants and algae.

Animals require nitrogen as well. They obtain the nitrogen they need by eating plants or by eating other animals, which in turn have eaten plants.

If ammonium nitrogen levels in surface waters are too high, they can be toxic to some aquatic organisms. If the levels are only moderately high, plant and algal growth will usually increase due to the abundance of nitrogen available as a nutrient. This will have a ripple effect on other attributes of water quality, such as increasing biochemical oxygen demand and lowering dissolved oxygen levels. Dissolved oxygen levels can also be lowered when ammonium nitrogen is high due to the increased amount of nitrification occurring.

Effects of Ammonium Levels

- High levels
  - eutrophication
  - increased algal blooms
  - increased BOD
  - decreased DO
  - toxic to some organisms
- Low levels
  - limiting factor in plant and algal growth

If enough nutrients are present, *eutrophication* may occur. Eutrophication occurs when there is such an abundance of nutrients available that there is a significant increase in plant and algal growth. As these organisms die, they will accumulate on the bottom and decompose, releasing more nutrients and compounding the problem. In some cases, this process of eutrophication can become so advanced that the body of water may become a marsh, and eventually fill in completely.

If too little ammonium nitrogen is present, it may be the limiting factor in the amount of plant and algal growth. Ammonium nitrogen can quickly be converted into nitrites or nitrates; therefore, a low level of ammonium-nitrogen does not necessarily indicate a low level of nitrogen in general.

Expected Levels

Ammonium-nitrogen levels are usually quite low in moving surface waters. This is because there is little decaying organic matter collecting on the bottom. If there is a high level of ammonium nitrogen in a moving stream, it may be an indication of pollution of some kind entering the water. Ponds and swamps usually have a higher ammonium nitrogen level than fast-flowing water. While levels of ammonium nitrogen in drinking water should not exceed 0.5 mg/L, streams or ponds near heavily fertilized fields may have higher concentrations of this ion. Fertilizers containing ammonium sulfate, $(NH_4)_2SO_4$, or ammonium nitrate, NH_4NO_3, may result in runoff from fields containing a high level of ammonium ions.

Table 1: Ammonium Levels of Selected Rivers

Site	Ammonium (mg/L NH_4^+-N)
Mississippi River, Memphis, TN	0.07
Hudson River, Poughkeepsie, NY	0.08
Colorado River, Hoover Dam, AZ-NV	0.03
Willamette River, Portland, OR	0.09
Platte River, Louisville, NE	0.24

Summary of Method

A Vernier Ammonium Ion-Selective Electrode (ISE) is used to measure the concentration of ammonium nitrogen in the water, either on site or after returning to the lab.

Water Testing Investigation:
Lab Conclusion Instructions

Due: _____

For each of the ten tests we performed, you will compose a brief but DETAILED paragraph that:

1. Overviews the testing procedures
2. Discusses "normal" levels
3. Provides our results
4. States if these results are normal or not AND provides a possible explanation if they are not normal

Also include an intro paragraph that provides any necessary background information.

Temperature
pH
Turbidity
DO
BOD
Phosphates
Nitrates
Ammonium
Dissolved Solids
Fecal Coliform