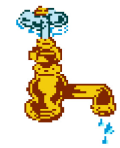
Kingston Water Treatment Plant

The Drinking Water Program, Water Quality and Treatment Services The City of Kingston conducts sampling of waters that are the sources of drinking water for the City of Kingston. These samples are collected to characterize the quality of water used by the City of Kingston. This characterization includes assessing seasonal trends, detecting any possible contaminants that may have entered the water, and identifying the source of any contaminants. The Drinking Water Program collects Yearly, Quarterly, Monthly and Daily water quality samples from locations such as the Tennessee River, Swan Pond Spring Source and throughout the entire Distribution System.

Drinking Water Quality Sampling Procedures



Field Parameters:

Water Temperature is analyzed with NIST Traceable Thermometers and / or Digital NIST Traceable Thermometer and also *Hanna HI 221* Probe. All temperature devices are checked semi-annually.

pH is analyzed with a *Hanna HI 221 dual probe microprocessor pH Meter*. The probe is calibrated with pH 7 and 10 buffers in the drinking water laboratory the day of sampling. Buffers are dated and replaced per requirements.

Laboratory Analysis:

Colorimetric analyses and spectrophotometer analysis are performed using a ***Hach DR2800***.

Alkalinity is measured using Standard Method 2320B (American Public Health Association, 1998) / Method 8221 Buret Titration. Phenolphthalein Alcohol and Bromcresol Green-Methyl Red Indicator Solution is added. The sample is stirred, and temperature and pH are monitored, as 0.02N sulfuric acid (H_2SO_4) is slowly added to the sample. The amount of acid necessary to bring the sample pH down to 4.5 is proportional to the total alkalinity in the sample. This method assumes that the entire alkalinity consists of bicarbonate, carbonate, and/or hydroxide.

Chlorine, Free is measured using DPD Method 1Standard Method 10069. HR (0.1 to 10.0 mg/L as Cl_2) . In this method Chlorine in the sample as hypochlorous acid or hypochlorite ion (free chlorine for available chlorine) reacts with DPD (N, N-diethyl-p-phenylenediamine) indicator to form a pink color is proportional to the chlorine concentration. Test results are measured at 530 nm.

Hardness, Total *USEPA[1] ManVer[2] Buret Titration Method [2] (0 to 25,000 mg/L as $CaCO_3$)* is measured using Standard Method 2340C. A small amount of dye is added to the sample, and buffer solution is added until the pH of the sample reaches 10. If calcium and magnesium are present in the sample, the sample turns red. Ethylenediaminetetraacetic acid (EDTA) is then added until the sample turns blue. The amount of EDTA required to turn the sample blue represents the hardness of the sample.

Fluoride is measured using the SPADNS Method 1 (0.02 – 2.00 mg/L F-) adapted from *Standard and Methods 4500-F B & D. Procedure is equivalent to USEPA Method 340.1*. The SPADNS method for fluoride determination involves the reaction of fluoride with a red zirconium-dye solution. The fluoride combines with part of the zirconium to form a colorless complex, thus bleaching the red color in an amount proportional to the fluoride concentration. This Method is accepted by the EPA for NPDES and NPDWR for reporting purposes.

Iron, Total *FerroVer® Method[1] Adapted from Standard and Methods[1], Federal Register, June 27, 1980; 45 (126:43459)* FerroVer Iron Reagent converts all soluble and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1, 10 phenanthroline indicator in the reagent to form an orange color in proportion to the iron concentration. Test results are measured at 510 nm.

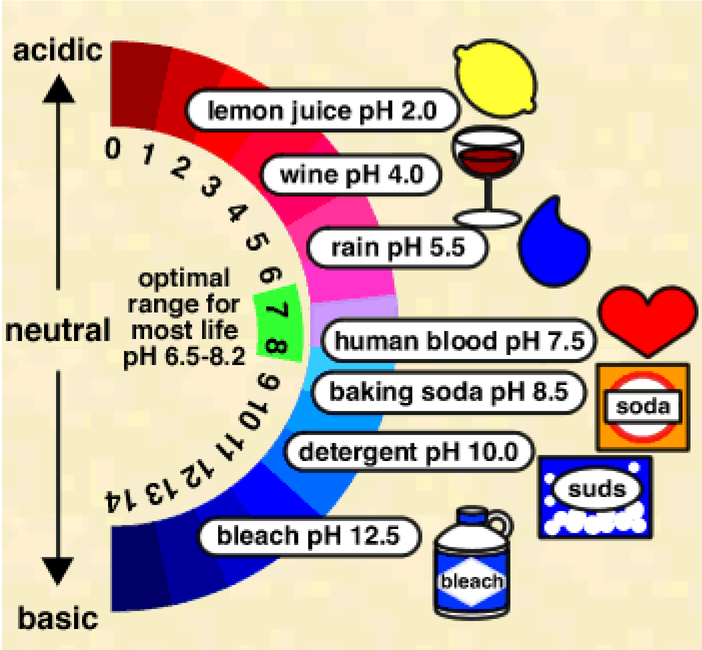
Manganese *1-(2-Pyridylazo)-2-Napthol PAN Method[1], LR(0.006 to 0.700 mg/L), adapted from Goto, K., et al., Talanta,* 24, 652-3 (1977) The PAN method is highly sensitive and a rapid procedure for detecting low levels of manganese. An ascorbic acid reagent is used initially to reduce all oxidized forms of manganese to Mn^{2+} . An alkaline-cyanide reagent is added to mask any potential interferences. PAN indicator is then added to combine with the Mn^{2+} to form an orange colored complex. Test results are measured at 560 nm.

Phosphorus, Reactive (Orthophosphate) PhosVer 3 (Ascorbic Acid) Method 1 (0.02 to 2.50 mg/L PO_4^{3-}) is measured using Standard Method 4500-P E. Sulfuric acid (H_2SO_4), potassium antimonyl titrate, ammonium molybdate, and ascorbic acid are added to the sample. The potassium antimonyl titrate and ammonium molybdate react in the acid with the orthophosphate to form phosphomolybdic acid. The phosphomolybdic acid is then reduced to a blue color by the ascorbic acid. The blue color is then analyzed with a spectrophotometer; the darker the blue, the more orthophosphate in the sample.

References

American Public Health Association.1998. "Standard Methods for the Examination of Water and Wastewater." 20th edition.

pH



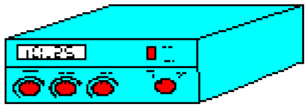
pH represents the effective concentration (activity) of hydrogen ions (H^+) in water. This concentration could be expressed in the same kind of units as other dissolved species, but H^+ concentrations are much smaller than other species in most waters. The activity of hydrogen ions can be expressed most conveniently in logarithmic units. pH is defined as the negative logarithm of the activity of H^+ ions:

$$pH = -\log [H^+]$$

where $[H^+]$ is the concentration of H^+ ions in moles per liter (a mole is a unit of measurement, equal to 6.022×10^{23} atoms). Because H^+ ions associate with water molecules to form hydronium (H_3O^+) ions, pH is often expressed in terms of the concentration of hydronium ions. In pure water at 22° C (72° F), H_3O^+ and hydroxyl (OH^-) ions exist in equal quantities; the concentration of each is 1.0×10^{-7} moles per liter (mol/L). Therefore, pH of pure water = $-\log (1.0 \times 10^{-7}) = -(-7.00) = 7.00$. Because pH is defined as $-\log [H^+]$, pH decreases as $[H^+]$ increases (which will happen if acid is added to the water). Since pH is a log scale based on 10, the pH changes by 1 for every power of 10 change in $[H^+]$. A solution of pH 3 has an H^+ concentration 10 times that of a solution of pH 4. The pH scale ranges from 0 to 14. However, pH values less than 0 and greater than 14 have been observed in very rare concentrated solutions.

Measurement of pH

The pH of water can be measured with a pH meter, which is an electronic device with a probe. The probe contains an acidic aqueous solution enclosed by a glass membrane that allows migration of H^+ ions. The electrical potential of the glass electrode depends on the difference in $[H^+]$ between the reference solution and the solution into which the electrode is dipped. pH can also be measured with pH paper or by adding a reagent (indicator solution) to the water sample and recording the color change.



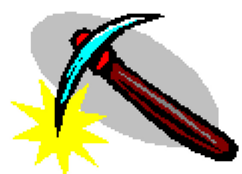
Factors Affecting pH:

The concentration of *carbon dioxide* in the water

Carbon dioxide (CO_2) enters a water body from a variety of sources, including the atmosphere, runoff from land, release from bacteria in the water, and respiration by aquatic organisms. This dissolved CO_2 forms a weak acid. Natural, unpolluted rainwater can be as acidic as pH 5.6, because it absorbs CO_2 as it falls through the air. Because plants take in CO_2 during the day and release it during the night, pH levels in water can change from daytime to night

Geology and *Soils* of the watershed

Acidic and alkaline compounds can be released into water from different types of rock and soil. When calcite ($CaCO_3$) is present, carbonates (HCO_3, CO_3^{-2}) can be released, increasing the alkalinity of the water, which raises the pH. When sulfide minerals, such as pyrite, or "fool's gold," (FeS_2) are present, water and oxygen interact with the minerals to form sulfuric acid (H_2SO_4). This can significantly drop the pH of the water. Drainage water from forests and marshes is often slightly acidic, due to the presence of organic acids produced by decaying vegetation.



Drainage from Mine Sites

Mining for gold, silver, and other metals often involves the removal of sulfide minerals buried in the ground. When water flows over or through sulfidic waste rock or tailings exposed at a mine site, this water can become acidic from the formation of sulfuric acid. In the absence of buffering material, such as calcareous rocks, streams that receive drainage from mine sites can have low pH levels.

Air Pollution

Air pollution from car exhaust and power plant emissions increases the concentrations of nitrogen oxides (NO_2, NO_3) and sulfur dioxide (SO_2) in the air. These pollutants can travel far from their place of origin, and react in the atmosphere to form nitric acid (HNO_3) and sulfuric acid (H_2SO_4). These acids can affect the pH of streams by combining with moisture in the air and falling to the earth as acid rain or snow.

Water Quality Standards and Other Criteria Regarding pH

The U.S. Environmental Protection Agency (U.S. EPA) sets a secondary standard for pH levels in drinking water: the water should be between pH 6.5 and 8.5 Secondary standards are unenforceable, but recommended, guidelines.

Very high (greater than 9.5) or very low (less than 4.5) pH values are unsuitable for most aquatic organisms. Young fish and immature stages of aquatic insects are extremely sensitive to pH levels below 5 and may die at these low pH values. High pH levels (9-14) can harm fish by denaturing cellular membranes.

Changes in pH can also affect aquatic life indirectly by altering other aspects of water chemistry. Low pH levels accelerate the release of metals from rocks or sediments in the stream. These metals can affect a fish's metabolism and the fish's ability to take water in through the gills, and can kill fish fry.

Other Information about pH

The term "pH" was originally derived from the French term "pouvoir hydrogène," in English, this means "hydrogen power." The term pH is always written with a lower case p and an upper case H.

Total Organic Carbon (TOC):

Organic matter plays a major role in aquatic systems. It affects biogeochemical processes, nutrient cycling, biological availability, chemical transport and interactions. It also has direct implications in the planning of wastewater treatment and drinking water treatment. Organic matter content is typically measured as total organic carbon and dissolved organic carbon, which are essential components of the carbon cycle.

Organic matter in water consists of thousands of components, including macroscopic particles, colloids, dissolved macromolecules, and specific compounds.

Measurement of TOC

The TOC samples are analyzed Monthly by an outside Laboratory (Environmental Science Corp.) using Method 5310C. The Raw Water and the Finished water Samples are both analyzed and the difference is the TOC Removal, Depending upon the Source Water Alkalinity a certain amount of Removal is required, from 15% to 50% to remain in compliance.

The TOC of a water body is affected by several factors, including:

Vegetation

Climate

Treated Sewage

Hardness

HARDNESS is measure of polyvalent cations (ions with a charge greater than +1) in water. Hardness generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn^{2+}), may also contribute to the hardness of water, but are generally present in much lower concentrations. Waters with high hardness values are referred to as "hard," while those with low hardness values are "soft".

Hardness affects the amount of soap that is needed to produce foam or lather. Hard water requires more soap, because the calcium and magnesium ions form complexes with soap, preventing the soap from sudsing. Hard water can also leave a film on hair, fabrics, and glassware. Hardness of the water is very important in industrial uses, because it forms scale in heat exchange equipment, boilers, and pipe lines. Some hardness is needed in plumbing systems to prevent corrosion of pipes.

Hardness mitigates metals toxicity, because Ca^{2+} and Mg^{2+} help keep fish from absorbing metals such as lead, arsenic, and cadmium into their bloodstream through their gills. The greater the hardness, the harder it is for toxic metals to be absorbed through the gills.

Measurement of Hardness

Hardness is generally measured by titration. A buffer and a color indicator are added to a volume of water. An acid (the titrant) is then added to the water, and it reacts with the Ca^{2+} and Mg^{2+} in the water. The volume of acid required to change the color of the sample reflects the Ca^{2+} and Mg^{2+} concentration of the sample. The more acid needed, the more Ca^{2+} and Mg^{2+} in the sample. Hardness is generally expressed in units of milligrams per liter (mg/l) or parts per million (ppm) of $CaCO_3$ (calcium carbonate). It can also be expressed in "grains per gallon" (gpg); one gpg equals approximately 17 mg/L.

Hardness can also be calculated from measurements of calcium and magnesium using the following formula:

Hardness, mg equivalent/L $CaCO_3$ = ([Ca, mg/l]*2.497) + ([Mg, mg/l]*4.116)

Factors Affecting Hardness

Geology

Soft waters are mainly derived from the drainage of igneous rocks, because these rocks don't weather very easily and so don't release many cations. Hard water is often derived from the drainage of calcareous (calcite-rich) sediments, because calcite ($CaCO_3$) dissolves, releasing the calcium. Calcium, magnesium, and other polyvalent cations such as iron and manganese may be added to a natural water system as it passes through soil and rock containing large amounts of these elements in mineral deposits.

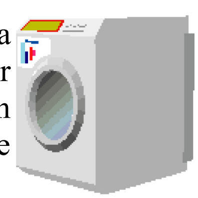
Mining

Drainage from operating and abandoned mine sites can contribute calcium, magnesium, iron, manganese, and other ions if minerals containing these constituents are present and are exposed to air and water. This can increase the hardness of a stream.

Industrial Discharge

Some industrial processes may also produce significant amounts of calcium and manganese that are later discharged into streams.

Sewage Outflow



The effluent from Wastewater Treatment Plants (WWTPs) can add hardness to a stream. The wastewater from our houses contains calcium, magnesium, and other cations from the cleaning agents, food residue, and human waste that we put down our drains. Most of these cations are removed from the water at the WWTP before being discharged to the stream, but treatment can't eliminate everything.

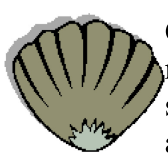
Water Quality Standards and Other Criteria Regarding Hardness

Because hardness varies greatly due to differences in geology, there aren't general standards for hardness. The hardness of water can naturally range from zero to hundreds of milligrams per liter (or parts per million). Waters with a total hardness in the range of 0 to 60 mg/L are termed soft; from 60 to 120 mg/L moderately hard; from 120 to 180 mg/L hard; and above 180 mg/L very hard.

If water is very hard, water softeners may be required to avoid deposits forming on fixtures.

Other Information about Hardness

When hardness equals alkalinity, the only cations present in significant concentrations in the water are calcium and magnesium. When hardness is greater than alkalinity, the waters may contain considerable amounts of other cations.



Calcium is an important component of plant cell walls and the shells and bones of many aquatic organisms. Low calcium levels can cause osmotic problems and affect shell or cuticle secretion in invertebrates (such as crayfish and snails). Magnesium is an essential nutrient for plants and a component of chlorophyll.

Alkalinity

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. The presence of buffering materials helps neutralize acids as they are added to the water. These buffering materials are primarily the bases bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}), and occasionally hydroxide (OH^-), borates, silicates, phosphates, ammonium, sulfides, and organic ligands.

Waters with low alkalinity are very susceptible to changes in pH. Waters with high alkalinity are able to resist major shifts in pH. As increasing amounts of acid are added to a water body, the pH of the water decreases, and the buffering capacity of the water is consumed. If natural buffering materials are present, pH will drop slowly to around 6; then a rapid pH drop occurs as the bicarbonate buffering capacity (CO_3^{2-} and HCO_3^-) is used up. At pH 5.5, only very weak buffering ability remains, and the pH drops further with additional acid. A solution having a pH below 4.5 contains no alkalinity, because there are no CO_3^{2-} or HCO_3^- ions left.

Alkalinity not only helps regulate the pH of a water body, but also the metal content. Bicarbonate and carbonate ions in water can remove toxic metals (such as lead, arsenic, and cadmium) by precipitating the metals out of solution.

Measurement of Alkalinity

Alkalinity is measured by titration. An acid of known strength (the titrant) is added to a volume of a treated sample of water. The volume of acid required to bring the sample to a specific pH level reflects the alkalinity of the sample. The pH end point is indicated by a color change. Alkalinity is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate).

Factors Affecting Alkalinity

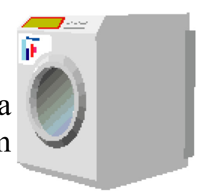
Geology and Soils

Carbonates are added to a water system if the water passes through soil and rock that contain carbonate minerals, such as calcite ($CaCO_3$). Where limestone and sedimentary rocks and carbonate-rich soils are predominant, (such as the eastern part of the Boulder Creek watershed) waters will often have high alkalinity. Where igneous rocks (such as granite) and carbonate-poor soils are predominant (such as the western part of the Boulder Creek watershed) waters will have low alkalinity.

Changes in pH

Because alkalinity and pH are so closely related, changes in pH can also affect alkalinity, especially in a poorly buffered stream. See the section on pH for more information on factors affecting pH.

Sewage Outflow



The effluent from Wastewater Treatment Plants (WWTPs) can add alkalinity to a stream. The wastewater from our houses contains carbonate and bicarbonate from the cleaning agents and food residue that we put down our drains.

Water Quality Standards and Other Criteria Regarding Alkalinity

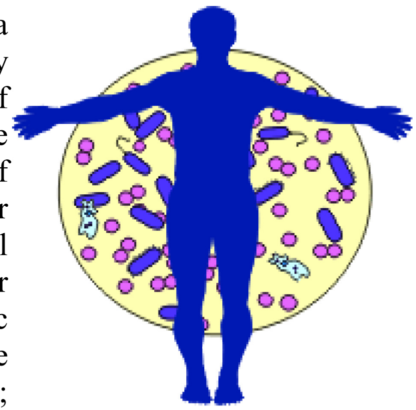
Because alkalinity varies greatly due to differences in geology, there aren't general standards for alkalinity.

Levels of 20-200 mg/L are typical of fresh water. A total alkalinity level of 100-200 mg/L will stabilize the pH level in a stream. Levels below 10 mg/L indicate that the system is poorly buffered, and is very susceptible to changes in pH from natural and human-caused sources.

Other Information about Alkalinity

Above pH 8.3, alkalinity is mostly in the form of carbonate (CO_3^{2-}); below 8.3, alkalinity is present mostly as bicarbonate (HCO_3^-).

TOTAL AND FECAL COLIFORM BACTERIA



The coliform bacteria group consists of several genera of bacteria belonging to the family *enterobacteriaceae*. These mostly harmless bacteria live in soil, water, and the digestive system of animals. Fecal coliform bacteria, which belong to this group, are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals, and can enter water bodies from human and animal waste. If a large number of fecal coliform bacteria (over 200 colonies/100 milliliters (ml) of water sample) are found in water, it is possible that pathogenic (disease- or illness-causing) organisms are also present in the water. Fecal coliforms by themselves are usually not pathogenic; they are indicator organisms, which means they may indicate the presence of other pathogenic bacteria. Pathogens are typically present in such small amounts it is impractical monitor them directly.

Swimming in waters with high levels of fecal coliform bacteria increases the chance of developing illness (fever, nausea or stomach cramps) from pathogens entering the body through the mouth, nose, ears, or cuts in the skin. Diseases and illnesses that can be contracted in water with high fecal coliform counts include typhoid fever, hepatitis, gastroenteritis, dysentery and ear infections. Fecal coliform, like other bacteria, can usually be killed by boiling water or by treating it with chlorine. Washing thoroughly with soap after contact with contaminated water can also help prevent infections.

Fecal coliform, like other bacteria, can usually be killed by boiling water or by treating it with chlorine. Washing thoroughly with soap after contact with contaminated water can also help prevent infections.

Measurement of Fecal Coliform

Bacteria are single-celled organisms that can only be seen with the aid of a very powerful microscope. However, coliform bacteria form colonies as they multiply, which may grow large enough to be seen. By growing and counting colonies of coliform bacteria from a sample of water, it is possible to determine approximately how many bacteria were originally present.

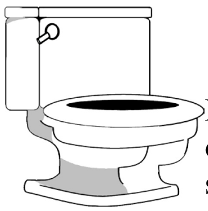
There are several ways coliform bacteria are grown and measured. Methods commonly used include the most probable number (MPN) method and the membrane filter (MF) method.

In the MPN method, a "presumptive test" is performed first. A series of fermentation tubes that contain lauryl tryptose broth are inoculated with the water sample and incubated for 24 hours at 35 °C. Fermentation tubes are arranged in 3 or more rows, with 5 or 10 tubes per row, with varying dilutions of the samples in the tubes. The fermentation tube contains an inverted tube to trap gases that are produced by the coliform bacteria. After 24 hours, the fermentation tube is examined for gas production. If there is no gas production, the samples are incubated for another 24 hours and reexamined. If gas production is observed by the end of 48 hours, the presumptive test is positive; coliform bacteria are present in the sample. A "confirmed test" is then performed to determine if fecal coliform bacteria are present. For the confirmed test, some of the content of the fermentation tube is transferred with a sterile loop to a fermentation tube containing another broth. The sample is incubated in a water bath at 44.5 ° C for 24 hours. Gas production in the fermentation tube after 24 hours is considered a positive reaction, indicating fecal coliform. Based on which dilutions showed positive for coliform and/or fecal coliform, a table of most probable numbers is used to estimate the coliform content of the sample. The results are reported as most probable number (MPN) of coliform per 100 ml (American Public Health Association, 1998).

The MF method is more rapid than the MPN method, but the results are not as reliable for samples that contain many non-coliform bacteria, high turbidity, and/or toxic substances such as metals or phenols. The water sample is filtered through a sterile membrane filter. The filter is transferred to a sterile petri dish and placed on a nutrient pad saturated with broth. The plates are inverted, placed in watertight plastic bags, and incubated in a water bath at 44.5 degrees C for 24 hours. Colonies produced by fecal coliform bacteria are blue, and are counted using a microscope or magnifying lens. The fecal coliform density is recorded as the number of organisms per 100 ml.

Sometimes the unit of colony producing units per 100 milliliters of water (CPU/100 ml) is used; this is equal to the number of organisms per 100 ml.

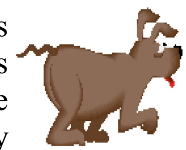
Factors Affecting Fecal Coliform



Wastewater and Septic System Effluent

Fecal coliform is present in human waste, so the bacteria goes down the drains in our houses and businesses, and can enter streams from illegal or leaky sanitary sewer connections, poorly functioning septic systems, and poorly functioning wastewater treatment plant (WWTPs) effluent.

Animal Waste



A significant amount of fecal coliform is released in the wastes produced by animals. This can be a serious problem in waters near cattle feedlots, hog farms, dairies, and barnyards that have poor animal keeping practices and waste is not properly contained. In urban areas, fecal coliform can be contributed to surface water by dog, cat, raccoon, and human waste when it is carried into storm drains, creeks, and lakes during storms.

Sediment Load

High amounts of sediment are often related to high concentrations of pathogenic bacteria. The bacteria can attach to sediment particles, escaping invertebrate predators (Murdoch and Cheo, 1996). Fast-running water can carry more sediment, so higher levels of bacteria can occur during high runoff events. Bacteria are much more abundant on soils than in water.

Temperature

Bacteria grow faster at higher temperatures. The growth rate slows drastically at very low temperatures.

Nutrients

High levels of nutrients can increase the growth rate of bacteria.

Water Quality Standards Regarding Fecal Coliform

The U.S. Environmental Protection Agency (EPA) requires all drinking water systems to monitor for total coliforms in distribution systems. The EPA states that no more than 5.0% of samples can test positive for total coliform in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive). Every sample that has total coliforms must be analyzed for fecal coliforms. There cannot be any fecal coliforms in drinking water (U.S. EPA Office of Water current drinking water standards).

Other Information About Fecal Coliform

The fecal coliform group includes all of the rod-shaped bacteria that are non-sporeforming, *Gram-Negative* , lactose-fermenting in 24 hours at 44.5 ° C, and which can grow with or without oxygen.

Fecal coliform is a type of fecal bacteria. Another type of fecal bacteria is *Fecal Streptococcus* . Fecal Streptococcus is a group of bacteria normally present in large numbers in the intestinal tracts of warm-blooded animals other than humans.

*Some strains of *Escherichia coli* , which are a type of fecal coliform, can cause intestinal illness. One such strain is E. coli O157:H7, which is found in the digestive tract of cattle. For more information on E.coli O157:H7 and other pathogenic bacteria, see the U.S. FDA Center for Food Safety & Applied Nutrition's "Bad Bug Book" .

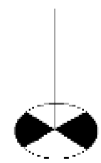
TURBIDITY

Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water (American Public Health Association, 1998). Turbidity is closely related to total suspended solids (TSS), but also includes plankton and other organisms.

Turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth. It also may indicate the presence of microbes (U.S. EPA Office of Water, Current Drinking Water Standards).

Measurement of Turbidity

Turbidity is a measure of how much of the light traveling through water is scattered by suspended particles. The scattering of light increases with increasing suspended solid and plankton content. Turbidity in slow moving, deep waters can be measured using a device called a Secchi disk. A Secchi disk is a black and white, 20-cm diameter disk. The disk is lowered into the water until it just disappears from sight. The depth at which the disk disappears is called the Secchi depth, and is recorded in meters.



A Secchi disk does not work in shallow, fast-moving streams. In these waters, a turbidimeter (sometimes called a nephelometer) is used. A turbidimeter measures the scattering of light, and provides a relative measure of turbidity in Nephelometric Turbidity Units (NTUs). A less expensive method of measuring turbidity is to evaluate the fuzziness of a mark at the bottom of a clear tube when a water sample is poured in the tube. Units are reported in Jackson Turbidity Units (JTUs). This method can only be used in highly turbid waters. (Mitchell and Stapp, 1992; Murdoch and Cheo, 1996)

Factors Affecting Turbidity

Because one of the primary factors affecting turbidity is total suspended solids, the factors affecting TSS will also affect turbidity. In addition, organic matter contributes to turbidity.

High Flow Rates

The flow rate of a water body is a primary factor influencing turbidity concentrations. Fast running water can carry more particles and larger-sized

sediment. Heavy rains can pick up sand, silt, clay, and organic particles from the land and carry it to surface water. A change in flow rate also can affect turbidity; if the speed or direction of the water current increases, particulate matter from bottom sediments may be resuspended

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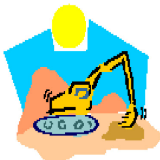


Soil Erosion

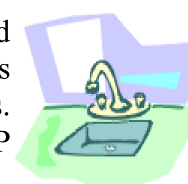
Soil erosion is caused by disturbance of a land surface. Soil erosion can be caused by ***Building and Road Construction, Forest Fires, Logging,*** and ***Mining***. The eroded soil particles can be carried by stormwater to surface water. This will increase the turbidity of the water body.

Urban Runoff

During storm events, soil particles and debris from streets and industrial, commercial, and residential areas can be washed into streams. Because of the large amount of pavement in urban areas, natural settling areas have been removed, and sediment is carried through storm drains to creeks and rivers.

Wastewater and Septic System Effluent

The effluent from Wastewater Treatment Plants (WWTPs) can add suspended solids and organic material to a stream. The wastewater from our houses contains food residue, human waste, and other solid material that we put down our drains. Most of the solids and organic material are removed from the water at the WWTP before being discharged to the stream, but treatment can't eliminate everything.



Decaying Plants and Animals

As plants and animals present in a water body die and decay, suspended organic particles are released and can contribute to turbidity.

Bottom-Feeding Fish

Bottom-feeding fish (such as carp) can stir up sediments as they remove vegetation. These sediments can contribute to turbidity.

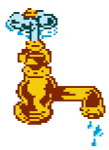
Algal Blooms

Algal blooms can contribute to turbidity. Algal production is enhanced when nutrients are released from bottom sediments during seasonal turnovers and changes in water current.

Flooding

As flood waters recede, they will bring along inorganic and organic particles from the land surface, and contribute this to the stream.

Water Quality Standards Regarding Turbidity

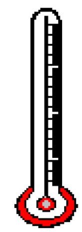


The U.S. Environmental Protection Agency's (EPA) Surface Water Treatment Rule requires systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that at no time can turbidity go above 5 nephelometric turbidity units (NTUs). Systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. (U.S. EPA Office of Water, Current Drinking Water Standards; http://www.epa.gov/safewater/mcl.html)

TEMPERATURE

Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities, and determines which fish species can survive. Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water.

Measurement of Temperature



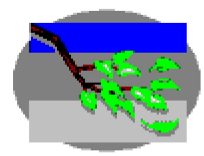
Temperature is measured using a thermometer, and is recorded in either degrees Celsius (° C) or degrees Fahrenheit (° F). While air temperatures reported on television and the newspaper in the U.S. are given in degrees Fahrenheit, scientists usually record temperatures in Celsius, because this is the unit designated by the International System of Units. To convert from ° F to ° C, use this equation:

$$T°_{C} = [T°_{F} - 32° F] * 5° C / 9° F$$

For example, the freezing temperature of water is 32° F; this translates to 0° C. The boiling temperature of water is 212° F, or 100° C.

Factors Affecting Temperature

Riparian Vegetation



Riparian vegetation, or trees and plants growing along the banks of a river or creek, provide shade, preventing the sun from heating up the water. If the sun shines directly on water, the water can warm up very quickly, and to very high temperatures.

Flow Rate

During dry seasons, there is less water in a river or creek, and it flows more slowly. This allows the water to warm up more quickly, and to warmer temperatures.

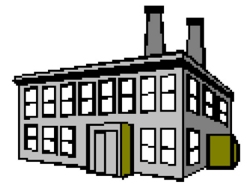
Paved Surfaces

As business and housing developments are built, previously open lands are covered with buildings and pavement. This covered area is called "impermeable surface." Less rain water is soaked into the ground, and more of it runs over land into streams during storms. This runoff also moves faster into the stream than would natural runoff because it travels through straight concrete or plastic storm drain pipes. This increased volume and velocity of runoff scours the stream channel and widens it. During dry weather between storms, the channels have a very shallow flow. These wide, shallow streams heat up much more quickly than do more natural narrow, deep ones.

Additionally, black surfaces, like many streets and parking lots, absorb heat, and rainwater moving over these surfaces during storm events becomes warmer.

Industrial Discharge

Some industries use water as a coolant during processing. This water is sometimes discharged to a stream or lake. When this water is discharged to a creek, it is much warmer than the water in the creek, and the temperature of the creek becomes higher. This phenomenon is called thermal pollution. This can cause the period of ice cover on the water to be shortened, and can increase the metabolic rate of plants and animals, producing an increase in oxygen demand.



Sewage Outflow

Water discharged from treatment plants is warm, because of the wastewater entering the plant (coming from our homes and businesses) is warm. This is another form of thermal pollution.

Temperature preferences among aquatic species vary widely, but all species tolerate slow, seasonal changes better than rapid changes.

Other Information about Temperature

Respiration of organisms is temperature-related; respiration rates can increase by 10% or more per 1° C temperature rise. Therefore, increased temperature not only reduces oxygen availability, but also increases oxygen demand, which can add to physiological stress of organisms (Giller and Malmqvist, 1998).

DISSOLVED OXYGEN (DO)

Dissolved Oxygen (DO) is found in microscopic bubbles of oxygen that are mixed in the water and occur between water molecules. DO is a very important indicator of a water body's ability to support aquatic life. Fish "breathe" by absorbing dissolved oxygen through their gills. Oxygen enters the water by absorption directly from the atmosphere or by aquatic plant and algae photosynthesis. Oxygen is removed from the water by respiration and decomposition of organic matter.

Measurement of DO

Dissolved Oxygen can be measured with an electrode and meter or with field test kits. The electronic meter does not measure oxygen directly; rather, it uses electrodes to measure the partial pressure of oxygen in the water, which is converted to oxygen mass weight concentration. The field test kits (such as a drop bottle, a microburet, or a digital titrator) involve adding a solution of known strength to a treated sample of water from the stream. The amount of solution required to change the color of the sample reflects the concentration of DO in the sample. The amount of oxygen dissolved in water is expressed as a concentration, in milligrams per liter (mg/l) of water.

Dissolved oxygen levels are also often reported in percent saturation. Temperature affects DO concentrations, and calculating the percent saturation will factor out the effect of temperature. The "saturation level" is the maximum concentration of dissolved oxygen that would be present in water at a specific temperature, in the absence of other factors. Scientists have determined the saturation DO level for various temperatures. Saturation levels also vary with elevation. Percent saturation is calculated by dividing the measured dissolved oxygen concentration by the saturation level and multiplying by 100.

This equation is shown as:

% Saturation = (DO / Saturation Level) x 100

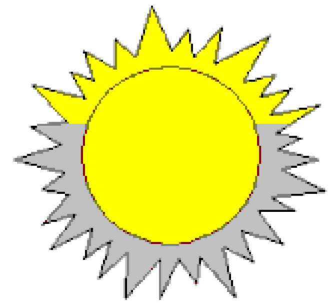
Factors Affecting DO

***Volume* and *velocity* of water flowing in the water body**

In fast-moving streams, rushing water is aerated by bubbles as it churns over rocks and falls down hundreds of tiny waterfalls. These streams, if unpolluted, are usually saturated with oxygen. In slow, stagnant waters, oxygen only enters the top layer of water, and deeper water is often low in DO concentration due to decomposition of organic matter by bacteria that live on or near the bottom of the reservoir.

Dams slow water down, and therefore can affect the DO concentration of water downstream. If water is released from the top of the reservoir, it can be warmer because the dam has slowed the water, giving it more time to warm up and lose oxygen. If dams release water from the bottom of a reservoir, this water will be cooler, but may be low in DO due to decomposition of organic matter by bacteria.

Climate/Season

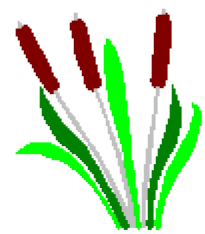


The colder the water, the more oxygen can be dissolved in the water. Therefore, DO concentrations at one location are usually higher in the winter than in the summer.

During dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases. During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls.

More sunlight and warmer temperatures also bring increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration.

The type and number of *organisms* in the water body



During photosynthesis, plants release oxygen into the water. During respiration, plants remove oxygen from the water. Bacteria and fungi use oxygen as they decompose dead organic matter in the stream. The type of organisms present (plant, bacteria, fungi) affect the DO concentration in a water body. If many plants are present, the water can be supersaturated with DO during the day, as photosynthesis occurs. Concentrations of oxygen can decrease significantly during the night, due to respiration. DO concentrations are usually highest in the late afternoon, because photosynthesis has been occurring all day.

Altitude

Oxygen is more easily dissolved into water at low altitudes than at high altitudes, because of higher atmospheric pressure.

Dissolved* or *suspended solids

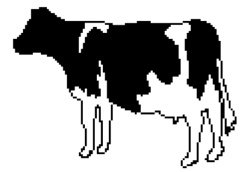
Oxygen is more easily dissolved into water with low levels of dissolved or suspended solids. Waters with high amounts of salt, such as the ocean (which contains about 35 grams of salt for each 1000 grams of water) have low concentrations of DO. Freshwater lakes, streams, and tap water generally contain much less salt, so DO concentrations are higher. As the amount of salt in any body of water increases, the amount of dissolved oxygen decreases. An increase in salt concentration due to evaporation of water from an ecosystem tends to reduce the dissolved oxygen available to the ecosystem's inhabitants.

Runoff from roads and other paved surfaces can bring salts and sediments into stream water, increasing the dissolved and suspended solids in the water.

Amount of *nutrients* in the water

Nutrients are food for algae, and water with high amounts of nutrients can produce algae in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called eutrophication. DO concentrations can drop too low for fish to breathe, leading to fish kills. However, nutrients can also lead to increased plant growth. This can lead to high DO concentrations during the day as photosynthesis occurs, and low DO concentrations during the night when photosynthesis stops and plants and animals use the oxygen during respiration.

Nitrate and phosphate are nutrients. Nitrate is found in sewage discharge, fertilizer runoff, and leakage from septic systems. Phosphate is found in fertilizer and some detergents.

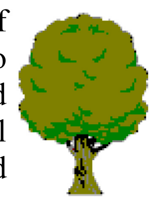


Organic Wastes

Organic wastes are the remains of any living or once-living organism. Organic wastes that can enter a body of water include leaves, grass clippings, dead plants or animals, animal droppings, and sewage. Organic waste is decomposed by bacteria; these bacteria remove dissolved oxygen from the water when they breathe. If more food (organic waste) is available for the bacteria, more bacteria will grow and use oxygen, and the DO concentration will drop.

Directly downstream from where sewage effluent is discharged to a river, DO content often decreases, because of the increase in growth rate of bacteria that consume the organic matter contained in the effluent. The degree and extent of the DO "sag" depends on the Biological Oxygen Demand (BOD) of the effluent (how much oxygen the effluent can consume) (Giller and Malmqvist, 1998).

Riparian Vegetation



Shading tends to lower average summer temperature and reduce the daily duration of higher temperature. Removing trees reduces shade on the creek, allowing the sun to warm the water. This can affect DO concentrations in different ways. As mentioned above, in general, as water temperature increases, DO drops. Also, the bare soil exposed from removing the tree can erode, increasing the amount of dissolved and suspended solids in the water. This also leads to a decrease in DO concentrations. However, direct sunlight, along with increased nutrients can increase the growth rate of aquatic plants. These plants release oxygen to the water during the day, but then remove oxygen from the water at night. This can cause DO concentrations to become very high during the day, then very low during the night. For an example of how DO can vary from day to night,

Groundwater Inflow

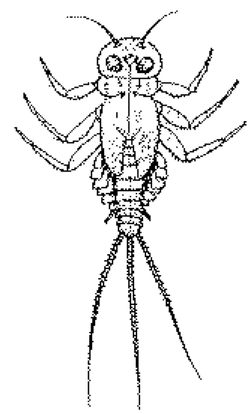
The amount of groundwater entering a river or stream can influence oxygen levels. Groundwater usually has low concentrations of DO, but it is also often colder than stream water. Therefore, groundwater may at first lower the DO concentration, but as groundwater cools the stream or river, the ability of the water to hold oxygen improves.

Very high DO concentrations can also be harmful to aquatic life. Fish in waters containing excessive dissolved gases may suffer a condition in which bubbles of oxygen block the flow of blood through blood vessels, causing death. Abrupt changes in dissolved oxygen induce stress and subsequently make fish more susceptible to disease.

The ideal dissolved oxygen concentration for many fish is between 7 and 9 mg/l; the optimal DO for adult brown trout is 9-12 mg/l. Most fish cannot survive at concentrations below 3 mg/l of dissolved oxygen.

<u>Other Information about DO</u>

When dissolved oxygen concentrations drop, major changes in the types and amounts of aquatic organisms found living in the water can occur. Species that need high concentrations of dissolved oxygen, such as mayfly nymphs, stonefly nymphs, caddisfly larvae, pike, trout, and bass will move out or die. They will be replaced by organisms such as sludge worms, blackfly larvae, and leeches which can tolerate lower dissolved oxygen concentrations. Waters that have low dissolved oxygen sometimes smell bad because of waste products produced by organisms that live in low oxygen environments.



Because of the relationship between temperature, rate of photosynthesis, and DO, fish kills usually occur in late summer just before dawn.

Very low DO concentrations can result in mobilization of trace metals.

A fish that is under stress caused by low oxygen levels in the water is more susceptible to poisoning by insecticides or heavy metals (Caduto, 1990).