Water quality: COLOR

Is pure water really clear? First, you will rarely see pure water as it is not found in a natural setting. The everyday water you see contains dissolved minerals and often suspended materials. But, for practical purposes, if you fill a glass from your faucet the water will look colorless to you. The water is in fact not colorless; even pure water is not colorless, but has a slight blue tint to it, best seen when looking through a long column of water.

Have you ever gotten a glass of water from your faucet and the water is milky white water or hazy? This is almost always caused by air in the water. To see if the white color in the water is due to air, fill a clear glass with water and set it on the counter. Observe the glass of water for 2 or 3 minutes. If the white color is due to air, the water will begin to clear at the bottom of the glass first and then gradually will clear all the way to the top. This is a natural phenomenon and is caused by dissolved air in the water that is released when the faucet is opened. When you relieve the pressure by opening the faucet and filling your glass with water, the air is now free to escape from the water, giving it a milky appearance for a few minutes.

Color in water you see around you can be imparted in two ways: dissolved and suspended components. An example of dissolved substances is tannin, which is caused by organic matter coming from leaves, roots, and plant remains (left-side picture). Another example would be the cup of hot tea your grandmother has in the afternoon. In the picture below the color is probably attributable to naturally dissolved organic acids formed when plant material is slowly broken down by into tiny particles that are essentially dissolved in the water. If you filtered that tannin-water in the picture the color would probably remain.

Color caused by dissolved matter: tannins

Color caused by suspended material: sediment

Most of the color in water you see around you comes from suspended material, as you can see in the right-side picture of a tributary contributing highly-turbid water containing suspended sediment (fine particles of clay, since this picture is in Georgia) to clearer, but still colored, water in the main stem of the river. Algae and suspended sediment particles are very common particulate matter that cause natural waters to become colored. Even though the muddy water below would not be appealing to swim in, in a way that water has less color than the water containing dissolved tannins. That is because suspended matter can be filtered out of even very dirty-looking water. If the water is put into a glass and left to settle for a number of days, most of the material will settle to the bottom (this method is used in sewage-treatment facilities) and the water will become clearer and have less color. So, if an industry wanted needed some color-free water for an industrial process, they would probably rather start with the sediment-laden water, rather than the tannin colored water.

Suspended material in water bodies may be a result of natural causes and/or human activity. Transparent water with a low accumulation of dissolved materials appears blue. Dissolved organic matter, such as humus, peat or decaying plant matter, can produce a yellow or brown color. Some algae or dinoflagellates produce reddish or deep yellow waters. Water rich in phytoplankton and other algae usually appears green. Soil runoff produces a variety of yellow, red, brown and gray colors.

Highly colored water has significant effects on aquatic plants and algal growth. Light is very critical for the growth of aquatic plants and colored water can limit the penetration of light. Thus a highly colored body of water could not sustain aquatic life which could lead to the long term impairment of the ecosystem. Very high algal growth that stays suspended in a water body can almost totally block light penetration as well as use up the dissolved oxygen in the water body, causing a eutrophic condition that can drastically reduce all life in the water body.

Water quality: DISSOLVED OXYGEN

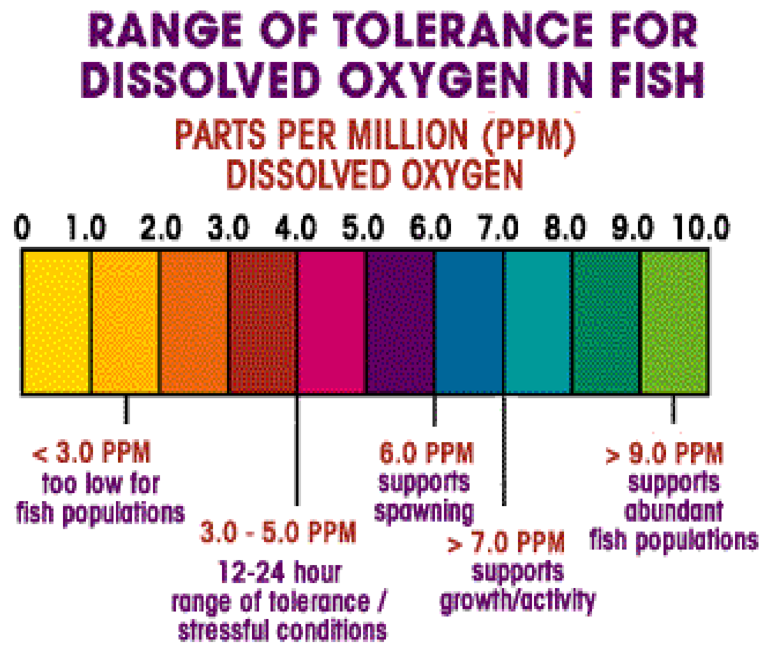
The U.S. Geological Survey (USGS) has been measuring water for decades. Millions of measurements and analyses have been made. Some measurements, such as temperature, pH, and specific conductance are taken almost every time water is sampled and investigated, no matter where in the U.S. the water is being studied. Another common measurement often taken is dissolved oxygen (DO), which is a measure of how much oxygen is dissolved in the water – DO can tell us a lot about water quality.

You can't tell by looking at water that there is oxygen in it (unless you remember that chemical makeup of a water molecule is hydrogen and oxygen). But, if you look at a closed bottle of a soft drink, you don't see the carbon dioxide dissolved in that – until you shake it up and open the top. The oxygen dissolved in lakes, rivers, and oceans is crucial for the organisms and creatures living in it. As the amount of dissolved oxygen drops below normal levels in water bodies, the water quality is harmed and creatures begin to die off. Indeed, a water body can "die", a process called eutrophication.

Although water molecules contain an oxygen atom, this oxygen is not what is needed by aquatic organisms living in natural waters. A small amount of oxygen, up to about ten molecules of oxygen per million of water, is actually dissolved in water. Oxygen enters a stream mainly from the atmosphere and, in areas where ground-water discharge into streams is a large portion of streamflow, from groundwater discharge. This dissolved oxygen is breathed by fish and zooplankton and is needed by them to survive.

Eutrophic conditions, Hartbees River, South Africa
Credit: National Eutrophication Monitoring Programme

Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, whereas stagnant water contains less. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in lakes and rivers can cause eutrophic conditions, which is an oxygen-deficient situation that can cause a water body "to die." Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer (the concentration of dissolved oxygen is inversely related to water temperature), when dissolved-oxygen levels are at a seasonal low. Water near the surface of the lake- the epilimnion- is too warm for them, while water near the bottom-the hypolimnion- has too little oxygen. Conditions may become especially serious during a period of hot, calm weather, resulting in the loss of many fish. You may have heard about summertime fish kills in local lakes that likely result from this problem. ((Source: A Citizen's Guide to Understanding and Monitoring Lakes and Streams)



Dissolved oxygen in surface water is used by all forms of aquatic life; therefore, this constituent typically is measured to assess the "health" of lakes and streams. Oxygen enters a stream from the atmosphere and from ground-water discharge. The contribution of oxygen from ground-water discharge is significant, however, only in areas where ground water is a large component of streamflow, such as in areas of glacial deposits. Photosynthesis is the primary process affecting the dissolved-oxygen/temperature relation; water clarity and strength and duration of sunlight, in turn, affect the rate of photosynthesis. Dissolved-oxygen concentrations fluctuate with water temperature seasonally as well as diurnally (daily).

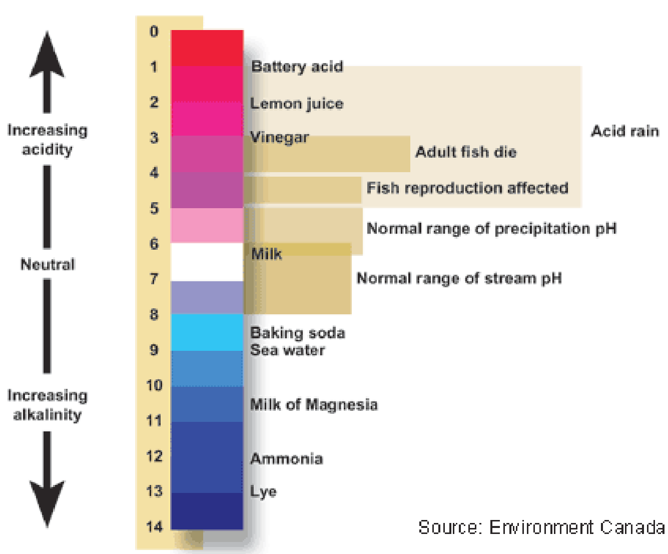
Field and lab meters to measure dissolved oxygen have been around for a long time. As this picture shows, modern meters are small and highly electronic. They still use a probe, which is located at the end of the cable. Dissolved oxygen is dependent on temperature (an inverse relation), so the meter must be calibrated properly before each use.

Water quality: pH

No, you don't often hear your local news broadcaster say "Folks, today's pH value of Dryville Creek is 6.3!" But pH is quite an important measurement of water. Not only does the pH of a stream affect organisms living in the water, a changing pH in a stream can be an indicator of increasing pollution or some other environmental factor.

pH is a measure of how acidic/basic water is. The range goes from 0 – 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. pH is reported in "logarithmic units," like the Richter scale, which measures earthquakes. Each number represents a 10-fold change in the acidity/basicness of the water. Water with a pH of five is ten times more acidic than water having a pH of six.

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH also determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.



As this diagram shows, pH ranges from 0 to 14, with 7 being neutral. pHs less than 7 are acidic while pHs greater than 7 are alkaline (basic). Normal rainfall has a pH of about 5.6—slightly acidic due to carbon dioxide gas from the atmosphere.

Water quality: TURBIDITY

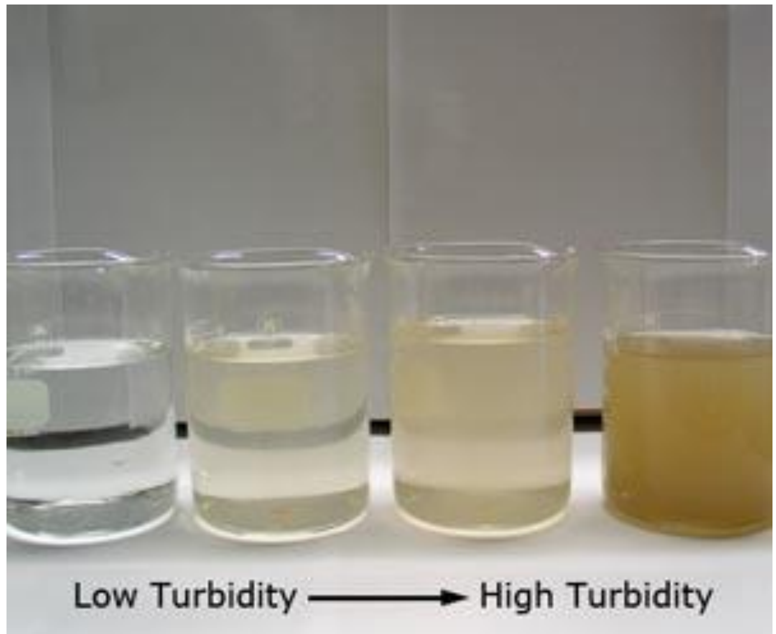
Sediment-data collection in the Little Colorado River a kilometer upstream from the Colorado River, Grand Canyon, Arizona Credit: USGS View full size

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms.

Turbidity makes water cloudy or opaque. The picture to the left shows a USGS hydrologist sampling highly turbid water in the Colorado River in Arizona. The water collected in the bottle will be used to find out the turbidity, which is measured by shining a light through the water and is reported in nephelometric turbidity units (NTU). During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the stream bed, causing higher turbidities.

High concentrations of particulate matter affect light penetration and productivity, recreational values, and habitat quality, and cause lakes to fill in faster. In streams, increased sedimentation and siltation can occur, which can result in harm to habitat areas for fish and other aquatic life. Particles also provide attachment places for other pollutants, notably metals and bacteria. For this reason, turbidity readings can be used as an indicator of potential pollution in a water body.

Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis throughout the United States and the world. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. The particles of turbidity provide "shelter" for microbes by reducing their exposure to attack by disinfectants. Microbial attachment to particulate material has been considered to aid in microbe survival. Fortunately, traditional water treatment processes have the ability to effectively remove turbidity when operated properly. (Source: EPA)



Water quality: SEDIMENT & SUSPENDED SEDIMENT

Storms, of course, deliver large amounts of water to a river, but did you know they also bring along lots of eroded soil and debris from the surrounding landscape? Rocks as small as tiny clay particles and as large as boulders moved by the water are called sediment. Fast-moving water can pick up, suspend, and move larger particles more easily than slow-moving waters. This is why rivers are more muddy-looking during storms—they are carrying a **LOT** more sediment than they carry during a low-flow period. In fact, so much sediment is carried during storms that over one-half of all the sediment moved during a year might be transported during a single storm period.

If you scoop up some muddy river water in a glass you are viewing the suspended sediment in the water. If you leave your glass in a quiet spot for a while the sediment will start to settle to the bottom of the glass. The same thing happens in rivers in spots where the water is not moving so quickly—much of the suspended sediment falls to the stream bed to become bottom sediment (yes, mud). The sediment may build up on the bottom or it may get picked up and suspended again by swift-moving water to move further downstream.

So what does this have to do with people? On the positive side, sediment deposited on the banks and flood plains of a river is often mineral-rich and makes excellent farmland. The fertile floodplains of the Nile in Egypt and of the Mississippi River in the United States have flooding rivers to thank fo rtheir excellent soils. On the negative side, when rivers flood, they leave behind many tons of wet, sticky, heavy, and smelly mud—not something you would want in your basement.

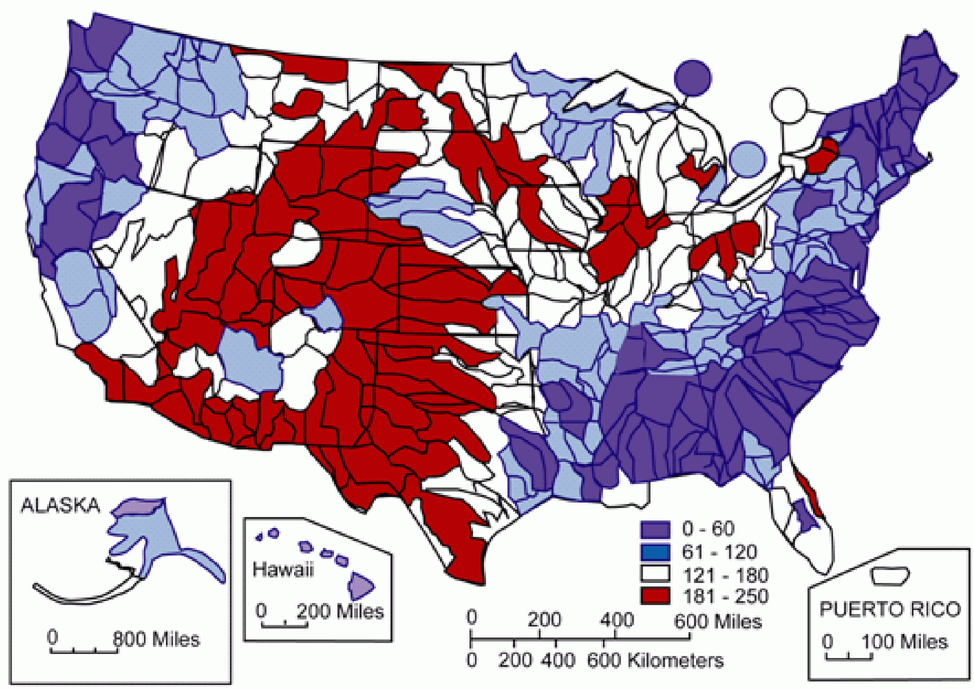
Sediment in rivers can also shorten the lifespan of dams and reservoirs. When a river is dammed and a reservoir is created, the sediments that used to flow along with the relatively fast-moving river water are, instead, deposited in the reservoir. This happens because the river water flowing through the reservoir moves too slowly to keep sediment suspended -- the sediment settles to the bottom of the reservoir. Reservoirs slowly fill up with sediment and mud, eventually making them unusable for their intended purposes.

The U.S. Geological Survey (USGS) does quite a lot of work across the country measuring how much sediment is transported by streams. To do this, both the amount of water flowing past a site (streamflow or flow) and the amount of sediment in that water (sediment concentration) must be measured. Both streamflow and sediment concentration are continually changing.

Streamflow is measured by making a discharge measurement. Suspended sediment, the kind of sediment that is moved in the water itself, is measured by collecting bottles of water and sending them to a lab to determine the concentration. Because the amount of sediment a river can transport changes over time, hydrologists take measurements and samples as streamflow goes up and down during a storm. Once we know how much water is flowing and the amount of sediment in the water at different flow conditions, we can compute the tonnage of sediment that moves past the measurement site during a day, during the storm, and even during the whole year.

Water quality: HARDNESS

The amount of dissolved calcium and magnesium in water determines its "hardness." Water hardness varies throughout the United States. If you live in an area where the water is "soft," then you may never have even heard of water hardness. But, if you live in Florida, New Mexico, Arizona, Utah, Wyoming, Nebraska, South Dakota, Iowa, Wisconsin, or Indiana, where the water is relatively hard, you may notice that it is difficult to get a lather up when washing your hands or clothes. And, industries in your area might have to spend money to soften their water, as hard water can damage equipment. Hard water can even shorten the life of fabrics and clothes! Does this mean that students who live in areas with hard water keep up with the latest fashions since their clothes wear out faster?



Mean hardness as calcium carbonate at NASQAN water-monitoring sites during 1975 water year. Colors represent site data representing streamflow from the hydrologic-unit rea.

(Map edited by USEPA, 2005)

Mean hardness as calcium carbonate at NASQAN water-monitoring sites during the 1975 water year. Colors represent streamflow from the hydrologic-unit area.

Map edited by USEPA, 2005. Modified from Briggs, J.C., and Ficke, J.F., 1977, Quality of Rivers of the United States, 1975 Water Year -- Based on the National Stream Quality Accounting Network (NASQAN): U.S. Geological Survey Open-File Report 78-200.

Water quality: TEMPERATURE

The U.S. Geological Survey (USGS) has been measuring how much water is flowing in rivers, determining the water levels in groundwater, and collecting water samples to describe what the quality of those waters are for over a century. Millions of measurements and analyses have been made. Water temperature is taken almost every time water is sampled and investigated, no matter where water is being studied.

Temperature exerts a major influence on biological activity and growth. Temperature governs the kinds of organisms that can live in rivers and lakes. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature. Water, particularly groundwater, with higher temperatures can dissolve more minerals from the rocks it is in and will therefore have a higher electrical conductivity. It is the opposite when considering a gas, such as oxygen, dissolved in the water. Think about how much bubblier a cold soda is compared to a warm one. The cold soda can keep more of the carbon dioxide bubbles dissolved in the liquid than the warm one can, which makes it seem fizzier when you drink it. How warm stream water is can affect the aquatic life in the stream. Warm water holds less dissolved oxygen than cool water, and may not contain enough dissolved oxygen for the survival of different species of aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures. (Source: A Citizen's Guide to Understanding and Monitoring Lakes and Streams)

You might not think that water temperature is considered an important water-quality measurement. After all, temperature is not a chemical and it doesn't have physical properties. But, if you ask a fish if the temperature of the water it is living in is important, it would yell yes! (if it could talk). In natural environments, temperature is not too much of a concern for aquatic life, since the animals and plants in the water have evolved to best survive in that environment. It is when the temperature of a water body changes, either by a natural event or by a human-induced event that the fish start to worry.

The picture to the left shows a typical parking lot after a strong summer rainstorm. Parking lots and roads, which are examples of impervious surfaces, where water runs off into local streams instead of soaking into the ground, as in natural environments, act as "fast lanes" for rainfall to make its way into streams. Rain that falls on a parking lot that has been baking in the sun all day during summer gets super heated and then runs off into streams. This heated water can be a shock to the aquatic life in the stream and can, thus, harm the water quality of the stream.

Along with the heat, runoff from parking lots can contain pollutants, such as leaking motor oil, hydrocarbons from exhaust, leftover fertilizer, and normal trash. Some communities are experimenting with using permeable pavement in the parking lot and water gardens and absorbent plants alongside the lot to see if this cuts down on harmfull runoff from the lots into streams. In the right side picture the parking surfaces are tilted so that they drain into a natural area that allows runoff to soak into the ground. Water-loving plants are also being grown in the area. A significant amount of the runoff should be captured by these areas, and by the time a portion of the runoff reaches a stream, the water temperatures should be closer to normal stream temperatures.

Temperature is also important in lakes and reservoirs. It is related to the dissolved-oxygen concentration in water, which is very important to all aquatic life. Many lakes experience a "turning" of its water layers when the seasons change. In summer, the top of the lake becomes warmer than the lower layers. You've probably noticed this when swimming in a lake in summer – your shoulders feel like they're in a warm bath while your feet are chilled. Since warm water is less dense that colder water, it stays on top of the lake surface. But, in winter some lake surfaces can get very cold. When this happens, the surface water becomes more dense than the deeper water with a more constant year-round temperature (which is now warmer than the surface), and the lake "turns", when the colder surface water sinks to the lake bottom.

The way that temperatures vary in lakes over seasons depends on where they are located. In warm climates the surface may never get so cold as to cause the lake "to turn." But, in climates that have a cold winter, temperature stratifications and turning do occur.