Water and Impurities

Water is the universal solvent and in nature, it is never totally pure. No matter how isolated it is from sources of contamination, it will always have some chemicals. Gases or minerals in the air, soil, or rock are dissolved by the water. Some dissolved materials give water its characteristic taste, and "pure water" is generally considered to be flat and tasteless.

Minerals can cause hardness (calcium or magnesium), color (iron), contamination (arsenic), and radioactivity (radium, radon) in the water. Humans can cause contamination through the improper use of pesticides or fertilizers and through the disposal of waste. These impurities can dissolve in the water, causing it to be contaminated.

Minerals and impurities are normally present in very small concentrations, and are measured in parts per million (ppm) (how many parts of impurities in a million parts of water) or milligrams per liter (mg/l). The terms are equivalent and are used interchangeably in water and wastewater. Some contaminants can also be measured in parts per billion (ppb) or micrograms per liter (µg/l), which are also essentially equivalent.

Groundwater dissolves much of the material that it percolates through. It is generally harder than surface water, and it usually contains more iron and manganese. As stated earlier, water in nature is not pure. The table below shows typical concentration ranges for chemicals dissolved in ground or surface water.

	CONCENTRATIONS FOUND IN GROUND WATER	**CONCENTRATIONS FOUND IN SURFACE WATER**
Total Hardness	300 - 400 ppm	75 - 200 ppm
Alkalinity	250 - 350 ppm	45 - 250 ppm
Dissolved Oxygen	near 0	2 - 14 ppm
Carbon Dioxide	1 - 10 ppm	low
Calcium Hardness	high	sometimes high, usually low
Magnesium Hardness	tends to be high	sometimes high, usually low

Water that exists in nature, like any other material, undergoes changes. These changes are driven by both physical and chemical means. The quality of groundwater is generally slower to change, especially when it comes from deeper aquifers. Groundwater is not directly exposed to air pollution, contamination from run-off (if the well is properly constructed), or wastewater discharge. The quality of groundwater is also protected by natural filtration, which can remove some contaminants, as water percolates through the soils and rock.

Chemicals (either organic or inorganic) that dissolve in water can change its characteristics and may cause it to become contaminated. Among other things, these chemicals could change its pH, cause hardness, or add dissolved oxygen.

When contamination is found in groundwater, the use of a specific aquifer may have to be discontinued. Some organic chemicals that have contaminated some aquifers are very difficult and expensive to remove. It may be cheaper to drill a new well into a different aquifer. However, in many circumstances other aquifers do not exist, and contaminant cleanup or treatment is necessary.

WATER CHARACTERISTICS

Temperature

The most basic physical change is caused by temperature changes of the water. The warmer the temperature of the water, the more rapid the settling characteristics of the water. This occurs because the molecules of water become more active with a rise in temperature. Any chemicals added will dissolve and react more readily with the solids in the water.

Temperature will affect the time required for mixing and sedimentation when a chemical is added for coagulation. The reaction is accelerated considerably when the water is warmer. The colder the water, the longer it will take for the floc to form. Fortunately, in winter when the temperature generally is colder, less water is needed in the community and the water treatment plant flow is lower. This lower flow lengthens the detention time and allows the floc to form. Warmer temperatures also make disinfection of the water much easier.

Turbidity

Turbidity refers to the cloudiness of the water. It can be a problem in surface water sources. The materials causing the cloudiness can be inorganic (such as clays, silts, or sand) or organic, such as algae and leaf particles.

Turbidity of drinking water is important for a number of reasons. The turbidity in the water may shield bacteria, preventing disinfection chemicals from attacking and destroying the cells. Another health concern relates to organic materials that cause turbidity in the water. These materials, in conjunction with chlorine, can form trihalomethanes and other potentially harmful chemicals.

From an aesthetic standpoint, turbidity in the water makes it less appealing to many people. Most operators have had to field complaints about bubbles and cloudiness in the water, which may be caused, not by turbidity, but by the aerator on faucets in the home.

Turbidity is normally tested using instruments that pass a light through the water and measure the light refraction at a 90-degree angle from the light source. This may be done by process meters that continuously measure the water in line, or by using meters in the lab for grab samples. Most meters used today are of the nephelometric type. They are calibrated by using formazin standards supplied with the meters. The turbidity is expressed in NTU units. For turbidity limits, see Chapter 3 on Regulations and Sanitary Surveys.

Surface water sources usually have higher turbidity than groundwater sources. Groundwater is filtered naturally as it passes through an aquifer. The turbidity of a surface water source can vary greatly from a low of less than one to a high of over 200 NTU.

Color

Color, a physical characteristic of water that is not noticed unless it is very high, is measured by comparing a water sample to a color standard. One color unit has no effect on the water and is usually not detectable while 100 color units could be compared to the color of light tea. There could be many reasons for excessive color in water. For example, in surface water, tannin (which makes the water look brown) is caused by a chemical formed from organic material.

pH

pH is a measure of the hydrogen ion concentration in water. pH is measured on a scale ranging from 0 to 14 with seven considered neutral. At a pH below 7, the water is acidic; at a pH above 7, the water is alkaline. The lower the pH, the greater the acidity; the higher the pH, the greater the alkalinity. A change of one (1) pH means a ten-fold increase or decrease in the hydrogen ion concentration.

When mixed with water, an acid releases excess hydrogen ions (H+), and an alkaline material produces excess hydroxyl ions (OH-). Carbon dioxide (CO_2), which creates a "weak" acid (H_2C0_3), lowers the pH of the water, while lime, calcium hydroxide ($CA[OH]_2$), raise the pH.

The normal range of pH for drinking water is 6.5 to 8.5. Water with a lower pH tends to be more corrosive; at a higher pH it tends to produce scale. However, it is not always true that water with a pH below 7 will cause corrosion or that water above pH 7 will scale. The corrosion index must be calculated separately for each condition. The stability point of water is the point at which it is neither corrosive nor scale forming. Softened water, for example, usually has a stability point at slightly over 8 on the pH scale. For more information on corrosion, see Chapter 25 on Corrosion in this manual.

Hardness

Hardness in water is caused by significant amounts of calcium or magnesium components. The hardness is classified into carbonate or non-carbonate hardness depending on what molecules are combined with the calcium or magnesium. If they are combined with carbonate ions (CO_3), the hardness is carbonate hardness; if combined with other ions, it is non-carbonate hardness.

The operator needs some basic information about the water to be able to determine if the hardness is carbonate or non-carbonate. Either type can be calculated if the total hardness and total alkalinity is known. If the total hardness equals the total alkalinity, the hardness is of the carbonate type. Non-carbonate hardness is equal to the total hardness minus the total alkalinity.

Example:

Total Hardness ....265 ppm as $CaCO_3$,
Total Alkalinity.................................200 ppm as $CaCO_3$,
Carbonate Hardness ....200 ppm $CaCO_3$
Non-carbonate Hardness....................265 ppm - 200 ppm = 65 ppm $CaCO_3$

This information is useful for an operator of a softening plant when selecting the type of chemical to use in removing hardness from the water. If the carbonate hardness is high, the chemical of choice for removal of the hardness would most likely be lime; if the non-carbonate hardness is high, some soda ash or caustic soda may need to be added to attack that hardness. See Chapter 15 on Hardness in this manual for a further, more detailed discussion of hardness.

Dissolved Solids

The total dissolved solids can have a significant impact on the quality of water. The amount of dissolved solids affects the water for almost all of its uses, whether for drinking, agricultural, or industrial use. The recommended maximum limit of dissolved solids in drinking water is 500 ppm. The problems caused by dissolved material relate to taste and odor, hardness, and corrosion and scaling in the distribution system, among others.

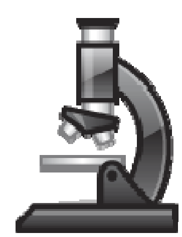
Several different types of dissolved solids could be toxic if the levels become too high. These include barium, arsenic, cadmium, chromium, lead, mercury, selenium, and silver. Each of these is regulated by the EPA and has maximum contaminant levels assigned to them. See Chapter 3 on Regulations and Sanitary Surveys in this manual for further information about the rules.

Organics

Organic material can cause problems in terms of health effects, treatment and taste, odor, and color of water. Some organics are potential carcinogens; that is they may cause cancer. Cancer-causing substances may be formed when naturally occurring organic material formed by plant and animal decomposition combines with chlorine, forming trihalomethanes. Others may already be present in the raw surface or groundwater as a result of contamination of the water source.

Some major sources of organic contamination are pesticides, herbicides, domestic waste, and industrial waste.

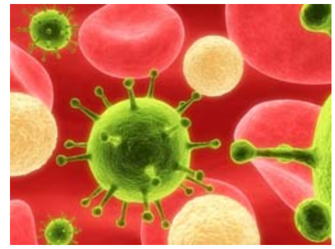
Algae



Algae (one-celled, microscopic, and larger) aquatic plants, some microscopic, can be quite abundant in a surface water source, especially during the summer months and especially if the water contains nutrients that encourage their growth, such as phosphorus from domestic run-off or industrial pollution. Algae may cause taste and odor problems, clog filters, and produce nuisance slime growths on intake pipes and equipment.

Bacteria

Bacteria are microscopic one-celled organisms that multiple by simple division. Bacteria are universally distributed. Many of them are essential. For example, they aid in the decomposition of dead organic material. However, there are numerous disease-producing bacteria that the water industry needs to guard against. These may cause typhoid fever, dysentery, cholera, and gastroenteritis. Some bacteria, although not harmful, may cause taste and odor problems. Examples of such bacteria are sulfur bacteria, which may produce hydrogen sulfide, or crenothrix iron bacteria which can produce disagreeable taste, odors, and stains.



Disease-causing bacteria are called pathogenic bacteria. It is often hard to test for and identify them. Therefore, their presence is determined by testing for the presence of an indicator organism, usually coliform bacteria. This group of bacteria is found in the intestines of warm-blooded animals; it is also common in soil. A more specific group of bacteria are the fecal coliforms, which are directly associated with contamination from human or animal wastes. Presence of coliform bacteria indicates general bacterial contamination. The presence of fecal coliform indicates contamination from a human or animal source.

Protozoans

Protozoans are single celled, usually microscopic, organisms. Some protozoans, such as Giardia and Cryptosporidium, are commonly found in rivers, lakes, and streams contaminated with animal feces or which receive wastewater from sewage treatment plants. When a water system uses surface water as its source, Giardia and Cryptosporidium must be removed in the clarification process because they are very difficult to kill with the usual forms of disinfection. If a person is infected, the symptoms may last seven or more days and include diarrhea, stomach cramps, nausea, fatigue, dehydration, and headaches. Protozoans are very difficult to test for; 100 or more gallons of water must be piped through a filter with openings less than one micron in size at 1 gpm or less. The particles trapped by the filter are then analyzed using very sophisticated methods to determine if any protozoa are present.

Viruses

Viruses are the smallest living organisms capable of producing infection and causing disease. Viruses that may be carried by water include the hepatitis and polio virus. They are very difficult to test for; usually large amounts of water have to be tested by using very sophisticated methods.

Radionuclides

Radiological contaminants emit radioactivity as they decompose. Sources of radioactive material are likely the aquifer minerals the water moves through. Radium 226, radium 228, uranium, and radon are the most common radioactive elements found in Minnesota. Radiological elements tend to be a greater problem in groundwater than in surface water, and radon may be elevated in groundwater that has been in contact with granite.