



ENVIRONMENT TECH NOTE

Assessing Water Quality for Human Consumption, Agriculture, and Aquatic Life Uses

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This technical note is a guide for determining the suitability of water supplies for their intended use. This includes groundwater developed by wells or obtained from springs as well as surface water. Beneficial uses addressed include domestic, livestock, irrigation, industrial, aquatic life, and recreation.

The significance of chemical and physical water quality parameters is explained; recommended and permissible limits for the intended beneficial uses are given; and sources for water analysis are provided.

INDEX

<u>Subject</u>	<u>Page</u>
Water Quality Parameters and Their Significance	2
Water for Human Consumption and Use	11
Water for Livestock and Poultry	13
Suitability of Water for Irrigation	16
Water for Aquatic Life and Recreation	22
Water Quality Analysis Recommendations	27
Labs for Analysis	28

WATER QUALITY PARAMETERS AND THEIR SIGNIFICANCE

CONSITUENT OR PHYSICAL PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Alkalinity (expressed as an equivalent of CaCO ₃)	Formed by the presence of certain anions in solution. Some organic materials may also produce alkalinity.	Alkalinity is an indicator of the relative amounts of carbonate, bicarbonate, phosphate, and hydroxide ions. Alkalinity is a measure of waters' capacity to neutralize an acid. Concentrations above 500 mg/l are rarely exceeded. Alkalinity varies with discharge; higher values occur during lower flows. Related to waters potential to corrode or cause scaling on pipes.
Bicarbonate (HCO ₃) and Carbonate (CO ₃) as Alkalinity	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite, oxidation of organic carbon through the carbon cycle.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium in steam boilers and hot water facilities form scale and release carbon dioxide gas. Low-salt water that is high in bicarbonates may present a soil permeability hazard even at low sodium adsorption ratios.
Boron (B)	Dissolved from igneous and sedimentary rocks and soils. May be present in municipal sludge. Sodium-rich water and water in areas of recent volcanic activity may also exhibit somewhat elevated levels of boron.	Boron is essential to plant growth, but is exceedingly toxic at concentrations only slightly above optimum. The optimum concentration varies with each plant type. What is optimum for one plant type may be toxic to another. Many plants exhibit sensitivity at levels as low as 1.8 mg/L. Boron is also essential to optimum animal health; however the exact physiological role is not well understood. Boron is toxic to livestock when found in water in excessive concentrations.
Calcium (Ca) and Magnesium (Mg)	Dissolved from almost all soils and rocks, but especially from limestone, dolomite, and gypsum. Ca and Mg are found in large quantities in some brines. Magnesium is present in large quantities in sea water. Sewage and industrial wastes may account for contributions to surface water. Road salt may also wash calcium into surface water.	Calcium and magnesium causes most of the hardness and scale-forming properties of water thereby restricting a specific water source's use as drinking water, (see hardness). Calcium reduces the toxicity of many chemical compounds to fish and other aquatic fauna. Calcium usually has no effect on the suitability of water for irrigation or stock water. Elevated magnesium may limit the use of water as a source of drinking water or irrigation water. Calcium carbonate precipitates often are responsible for carbonate-induced incrustations on well screens which reduce well yield and performance.
Chloride (Cl)	Weathered from sedimentary rock and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines. Household cleaners and road salt are also potential sources of chloride.	Free chlorine does not occur naturally in water because it rapidly hydrolyzes to chloride. Chloride is often the major ion constituent in water. Chloride salts in excess of 100 mg/L begin to give a salty taste to water; for this reason is recommended that chloride content not exceed 250 mg/L. When combined with calcium and magnesium, chloride may increase the corrosive activity of water. Most tree crops and other woody perennial plants are sensitive to low concentrations of chloride. Most annual crops are not so sensitive; however, they may be affected by higher concentrations. Residual chlorine is extremely toxic to aquatic life and fish at relatively low levels.

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Dissolved Solids (filterable residue) usually expressed as Total Dissolved Solids (TDS)	Primarily mineral constituents derived from rocks and soils. Includes all material that is in solution in water. Alters the physical and chemical properties of water. The base flow acquires minerals from natural sources in the form of dissolved salts in solution, such as sodium, chloride, magnesium, sulphate, etc. Discharges and overland flow from municipal, industrial and agricultural sources may contribute to the TDS load.	High concentrations of TDS limit the suitability of a water source as a drinking water supply. Water with dissolved solids below 500 mg/L is optimum. Concentration exceeding 1000 mg/L is generally unacceptable for most uses. However, water with concentrations exceeding 1000 mg/L has been used for drinking water when no other supply was available. If the concentration exceeds 2000 mg/L, definite laxative effects have been observed in humans. For animals, concentrations less than 2500 mg/L have proven to be satisfactory in most circumstances. Primary guidelines for drinking water are related to taste and palatability associated with TDS. Industries are sensitive to boiler scaling or to accelerated corrosion. High TDS may interfere with the clarity, color, and taste of manufactured products.
Fecal Coliform Bacteria	All warm-blooded (and some cold blooded) animals (including human) excrement. Often associated with high sediment levels in streams.	Fecal coliform bacteria serve as an indicator organism to show that pathogenic organisms may also be present. Qualitative limits are recommended to minimize the potential for transmission of communicable diseases. The current Montana water quality standard is based on <i>Escherichia coli</i> , a type of fecal coliform bacterium, one form (O157:H7 serotype) of which, is linked to food poisoning in humans. The uses of DNA and other genetic fingerprinting techniques to determine the source organism of a bacterium are also in development as risk assessment tools.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Most hot and warm springs contain more than the recommended concentration of fluoride. Some artesian aquifers in Montana are known to contain elevated levels of fluoride.	Fluorine is the 17 th most abundant mineral in the earth's crust and usually occurs as fluoride. Fluoride in drinking water reduces the incidence of tooth decay in children when the water is consumed during the period of enamel calcification, but it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, the amount of drinking water consumed, and the susceptibility of the individual. 0.8 to 1.7 mg/L is optimum, depending upon the air temperature. Fluoride on plant surfaces can be harmful to plants and grazing animals. Fluoride in the soil is generally not harmful. Some groundwater in Montana contains levels of fluoride that is harmful to livestock health and reproductive vigor.
Hardness as CaCO ₃	Hardness varies according to local conditions. Waters in areas of carbonate bedrock (limestone) and most cretaceous shales are characteristically hard. Waters draining igneous rocks are very soft usually due to calcium and magnesium. All the metallic cations besides the alkali metals also cause hardness.	Hard water (greater than 150 mg/L) can result in the formation of scale on boilers and pipes and it adversely affects textiles, plating and canning industries. Hard water results in increased soap consumption because soap is consumed before suds will form. Hardness is usually expressed as an equivalent of CaCO ₃ (see Table 3 for description). When hardness exceeds 180 mg/L, it generally causes problems and a water softener is recommended. Very soft water (less than 50 mg/L) can be corrosive to metal.

CONSTITUENT OR PHYSICAL PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Hydrogen-ion activity (pH)	Acids, acid-generating salts, and free carbon dioxide lower pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise pH. Acid mine drainage that has not been neutralized may significantly lower the pH of receiving water.	pH indicates the balance between the acids and bases in water and is a measure of the hydrogen ion concentration in solution. A pH of 7 indicates a neutral condition; values less than 7 indicate acid conditions, and values greater than 7 indicate increasing alkaline conditions. Natural fresh waters in Montana range from 6 to 8.5. A pH above 9 may lower the solubility of calcium carbonate, causing a precipitate and thus a milky appearance of the water. Surface water tends to be more alkaline, whereas groundwater is usually more acid. The pH influences the availability of nutrients and the relative toxicity of many trace elements. Lower pH levels cause the release of toxic metals trapped in sediment. pH is also important in determining the treatment of water supplies. For example, a pH above 8.3 interferes with the disinfection process of drinking water.
Iron (Fe)	Derived naturally from crustal weathering especially from minerals of igneous rocks and sulfide ores (pyrite), but also from sedimentary and metamorphic rocks. Industrial wastes, acid mine drainage and the corrosion of iron and steel equipment are potential sources. Atmospheric deposition from the burning of coke and coal, also contribute iron to the environment.	Iron is found in both the ferrous (Fe ²⁺) and ferric (Fe ³⁺) state. It is the fourth most abundant element in the earth's crust. Under reducing conditions in water, the mobile ferrous ion is present, but upon exposure to air, it is oxidized to the less mobile form and precipitated as the ferric ion. In water, such iron precipitates produce brown stains on porcelain, enamel, plumbing, and clothing. The solubility of iron increases with decreasing pH. Toxicity has been reported at concentrations in excess of 20 mg/L. Higher concentrations cause unpleasant taste and favor growth of iron bacteria, but do not endanger health. May also interfere with operation of exchange-silicate water softeners. High iron concentrations may cause the fixation of essential elements required by plants and thus be detrimental. Toxic to freshwater aquatic life above 1 mg/L. Will cause problems with oxygen uptake through fish gills at concentration of more than 0.3 mg/L. High concentrations of iron can lead to plugging of pipelines and well screens due to precipitate of Fe ⁺³ oxides (incrustation) and growth of iron oxidizing bacteria when present.
Manganese (Mn)	Soils and sediment are important sources along with metamorphic and sedimentary rocks. Plant decomposition is also an important source. Industrial wastes and acid-mine drainage may contribute manganese to water. In areas where soils are deficient, agricultural uses may require the addition of manganese.	Manganese is not usually present in appreciable concentrations in surface water. Higher levels may occur in groundwater or deep, stratified lakes under reducing conditions. Manganese is an essential element for the nutrition of humans, animals and for plant metabolism. Levels are set based on aesthetic and economic considerations. Concentrations above 0.2 mg/L may make water distasteful to drink. The presence of concentrations above 0.05 mg/L may cause dark brown or black stains and deposits on textiles, cooking utensils and plumbing pipes. Iron and manganese together should not exceed 0.3 mg/L for taste and aesthetic reasons. Higher concentrations do not endanger health and can be used if the objectionable features are tolerated. Together with iron and calcium precipitates, manganese can also form incrustations on well screens with a hard, cement-like deposit.

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Mercury (Hg)	<p>Mercury is widely distributed in the environment. The most common source of mercury is cinnabar (HgS) and a number of sulfide minerals. Cinnabar and elemental mercury are not very water soluble, however, weathering of a large variety of rocks and soils can leach small amounts into water. In Montana, these minerals are often associated with coal seams. Mercury is also released from a number of industrial, mining and commercial processes and products. Recently, fossil fuel burning has been linked to downwind atmospheric deposition. The use of mercury-based pesticides has been restricted for some time but since organisms' bio-accumulate mercury, detectable levels may still be present in some locations.</p>	<p>Mercury is a trace element in the earth's crust and occurs in only minor quantities in natural waters. Biologically it is a non-essential or non-beneficial element. It is highly toxic to humans and animals causing organ failure and brain damage. Typically, mercury is sorbed to particulate matter and settles out where it tends to combine with sulfur in anaerobic bottom sediments and becomes more bio-available. The concentration of total mercury in drinking water should not exceed 0.002 mg/L. Mercury compounds are also toxic to fish and other aquatic life. Since mercury concentrations accumulate in the food web, top carnivores such as large pike, walleye and lake trout may exhibit high levels. According to the EPA, mercury has a bio-concentration factor of 5,500. The Montana Department of Health and Human Services along with Montana Fish, Wildlife and Parks maintains a list of waters with fish consumption advisories due to the mercury content in certain fish. The United State Food and Drug Administration, (USFDA) established guideline for mercury in edible fish is 0.5 mg/kg.</p>
Nitrogen (N). There are a number of important chemical forms in which N may occur. The most important aqueous forms of N are described below.	<p>Seventy-eight percent of the atmosphere by volume is nitrogen. Igneous and sedimentary rocks also contain some nitrogen. Nitrogen compounds are present in most plant and animal materials and thus in decaying organic matter. Total nitrogen is the sum of inorganic (nitrate, nitrite, ammonia, ammonium) and organic forms of nitrogen.</p>	<p>The atmosphere provides a reservoir of inorganic nitrogen in the inert gaseous form (N₂), but the combined forms of nitrogen are of most interest in the chemical composition of water. In the aquatic environment, chiefly bacteria and blue-green algae reduce elemental nitrogen (N₂) to free ammonia (NH₃) or ionized ammonium ions (NH₄⁺). Other groups of nitrifying bacteria convert ammonia to nitrite (NO₂⁻); a second group of bacteria converts nitrite to nitrate (NO₃⁻). Nitrification (conversion of ammonia or nitrite to nitrate) is the principal process in the nitrogen cycle. In the process of denitrification, bacteria convert nitrate to nitrite and then to elemental nitrogen (N₂) gas. The concentration of the various nitrogen compounds ranges up to 100 mg/L in surface waters, but groundwaters can contain up to 1000 mg/L. Nitrogen gas causes several cases of asphyxiation each year in the U.S. as it causes a buildup of CO₂ in the bloodstream. While rare, it is not unknown to occur in water supplies.</p>

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Ammonium (NH ₄ ⁺) and dissolved ammonia (NH ₃)	Decomposition of organic matter or microbial reduction of nitrates or nitrites under anaerobic conditions. Common constituent of treated sewage sludge, commercial fertilizers and industrial discharges. Atmospheric precipitation and dry fallout may contain significant amounts of ammonia. Also excreted by fish, wildlife and livestock.	Ammonia is a non-persistent, highly soluble, non-cumulative, toxic compound. Concentrations greater than 0.1 mg/L may indicate human inputs. Typically presents no physiological detriment to humans or livestock. Total ammonia is the sum of free ammonia (NH ₃) and ionized ammonium (NH ₄ ⁺). Free ammonia is highly toxic to fish since it reduces the oxygen-carrying capacity of the blood and thus fish may suffocate depending on both pH and dissolved oxygen. High water temperature and high pH promote elevated levels of free ammonia and thus high toxicity to fish versus low water temperature and low pH promote higher levels of ionized ammonium with relatively low toxicity to fish. Ammonia may also affect treatment of drinking water and promotes the growth of nuisance aquatic vegetation.
Nitrate (NO ₃ ⁻), reported as N, may also be written NO ₃ ⁻ - N. Often includes nitrite (NO ₂ ⁻), then reported as NO ₃ ⁻ + NO ₂ ⁻ as N.	Igneous rocks provide localized sources of nitrates. When present in quantity and upon complete oxidation, vegetable and animal debris and excrement can be significant sources of nitrates. Industrial discharges, municipal sewage, and inorganic nitrate fertilizers may contribute substantial nitrate loads. In the Northern Great Plains, crop-fallow rotations over glacial till or alluvium deposits may lead to increased nitrate loads in groundwater. Rain water may contain a nitrate concentration of up to 0.2 mg/L.	Nitrate is the principal form of combined nitrogen found in natural waters. Concentrations much greater than the local average may suggest pollution. High concentrations in groundwater are generally a characteristic of individual wells and not of whole aquifers. Nitrate concentrations in unpolluted water seldom exceed 10 mg/L as N. Nitrate encourages growth of algae and other organisms, which produce undesirable tastes and odors. There is evidence that consumption of high levels of nitrate decreases the oxygen-carrying capacity of blood. This is particularly important in the health of young infants who may develop methaemoglobinaemia (a.k.a. blue baby syndrome) that may be fatal. To protect young infants, a level of 10 mg/L of nitrate plus nitrite nitrogen has been established for drinking water. Nitrate has also been linked to some forms of cancer, including stomach cancer and non-Hodgkin's lymphoma. Livestock may also be adversely affected by nitrate in drinking water depending on the type of animal (see Table 6).
Nitrite (NO ₂ ⁻)	Discharges from industrial or municipal sewage plants. May also be present in ruminant animal wastes.	Nitrite is unstable in the presence of oxygen since it is an intermediate product between nitrification and denitrification. Nitrite usually only occurs in water in minute quantities in the order of 0.001 mg/L. Nitrite can be used as a nitrogen source by plants. The presence of appreciable nitrites in water indicates active biological process influenced by organic loading. Nitrite is more toxic to humans and livestock than nitrate. Generally, concentrations for humans should not exceed 0.1 mg/L and 10 mg/l for livestock.

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Organic nitrogen also called amino or albuminoid nitrogen.	Results from both the inflow of nitrogenous debris from a watershed and the normal biological activities in a stream. Derived from proteins and urea. Sewage effluent, farm runoff and nitrogenous aerosols are also potential sources. De-icers, commercial fertilizers and manufacturing chemicals contain synthesized or derived urea.	Organic nitrogen is an organically bound form of nitrogen in the most reduced form. Includes a wide variety of compounds such as proteins, amino acids and urea. Organic nitrogen per se is not of concern to human or animal health. However, organic nitrogen provides a source of nitrogen that may provide indirect effects (see ammonia and nitrite for details).
Total Kjeldahl Nitrogen (TKN)	TKN is the sum of ammonia, ammonium, and organic nitrogen. All forms are present in nitrogenous organic detrius from natural biological activities as well as present in human-induced sources.	TKN is important for assessing available nitrogen for biological activity. TKN may contribute to the overall abundance of nutrients in water and thus eutrophication. Named after Johan Kjeldahl who developed the method to determine the nitrogen content of an organic sample.
Phosphorus (P) is measured in several forms and is usually reported as Total Phosphate (PO_4^- - P). The most important aqueous forms are described below.	Phosphorus may be leached or weathered from igneous rocks. The decomposition of organic matter is another natural source of phosphorus. Industrial and domestic wastes (laundry products) and sediment from fertilized and eroded land may also contribute phosphorus. Phosphorus is also subject to atmospheric transport and deposition.	Phosphorus is an essential nutrient and is not commonly toxic to humans, animals or fish. Only the extremely rare form of elemental phosphorus is toxic. Phosphorus is rarely found in significant concentrations since it is readily taken up by plants. Phosphorus is usually present in natural water as phosphate (PO_4^- -P). Phosphate can be present in water in dissolved or particulate form. The combined forms are continually changing in water between organically bound and oxidized inorganic forms. Phosphorus is generally the limiting nutrient for plant growth in freshwater aquatic systems. The primary objectionable effect of elevated phosphorus is accelerated aquatic growth which can impact aquatic life, recreational use and drinking water treatment and aesthetics. Recommend thresholds to limit nuisance aquatic growth are 0.03 mg/L total phosphorus in western Montana streams and lakes. Total Phosphorus is a measure of the organic and inorganic phosphorus present in a sample. Turbidity and suspended sediment content is often related to phosphorus concentration.
Orthophosphate sometimes reported as Soluble Reactive Phosphorus (SRP)	same as above	The inorganic, dissolved form of P is orthophosphate. Orthophosphate is readily available for plant use. Ortho-phosphorus can be measured directly, but since it is so easily taken up by plants it is not very indicative of the phosphorus load in water.

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Organic phosphate	Bound in living plants, animals, by-products and their remains. Also includes phosphate ions bound to soil particles, and in laundry detergents.	Organic phosphate occurs in two particulate forms in water: low solubility particles form and adsorbed or exchangeable form. Low solubility forms may release bio-available P under low D.O. or high pH conditions. Exchangeable forms are held on the surface of solid particles (especially clays) and are alternately released or bound depending on the concentration of P in the water. Organic phosphate cannot be measured independently. It must be digested and processed before an orthophosphate test is run to measure Total Phosphate. Organic phosphate must be broken down before it is available to plants. Lake and streambed sediments act as sinks for organic phosphorus. Wetlands serve as efficient filters for phosphorus by trapping sediment.
Sodium (Na)	Almost all rock and soil provide natural sources of sodium. Some aquifers in Montana are known to have high sodium concentrations. Also widely used in industry. Sewage and oil field drainage may contribute to surface water sodium loads. Road de-icers may also contain sodium.	Often found in association with Potassium (K). Sodium compounds are readily soluble in water and are important in the balance of total cations. Sodium may restrict the use of water for drinking, but impact on agricultural uses is much greater. Sodium is used in normal functioning of biologic processes, but should be limited to 20 mg/L for people on sodium-restricted diets. Waters with concentrations that do not exceed 270 mg/L are generally considered acceptable for consumption. Fruit crops and woody perennial plants are sensitive to relatively low concentrations. Higher concentrations may adversely affect forage crops and soil structure (see SAR section). Adverse effects are enhanced by potassium. Relatively low levels (> 2 mg/L) may cause foaming in boiler water.
Sodium Adsorption Ratio (SAR)	<p>SAR is defined by the equation:</p> $SAR = \frac{NA}{\sqrt{\frac{(Ca + Mg)}{2}}}$ <p>Where the concentrations are expressed in milliequivalents per liter (meq/l)</p>	SAR is important in evaluating the suitability of irrigation water. The ratio provides an estimate of the degree to which sodium will be adsorbed by soil from water. Sodium in irrigation waters adversely affects soil structure and permeability by replacing calcium and magnesium. Waters have been classified according to their sodium or alkali hazard (see Figure 1 for suitability classifications). Sensitive crops such as fruits and woody plants should not be subjected to water with SAR values above 4. Waters with SAR values greater than 7 generally should be avoided.
Specific Conductance (Sp. Cond.) Sometimes reported as Electrical Conductivity (E.C.) Sp. Cond. = E.C. @ 25° Celsius	See Total Dissolved Solids (TDS)	Specific conductance is a numerical expression of water's capacity to conduct an electric current. It provides an approximation of the mineral concentration or TDS. As more dissolved solids are added, the Sp. Cond. increases. Generally about 1.0 to 1.5 times the TDS content but will vary by site. Units were previously reported as micro or milliohms per centimeter. Sp. Cond. is E.C. corrected to 25° C. It is now often reported in micro-Siemens per centimeter (uS/cm). One mmhos/cm is equal to one uS/cm. Sp. Cond. varies with temperature and the degree of ionization of constituents. Can be measured easily with meter-type devices. See Dissolved Solids for other important considerations for use.

CONSITUENT OR PHYSICAL PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Sulfur (S)	Weathered from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in some industrial wastes and fertilizers. Atmospheric contributions from combustion products dominate all other sources.	Sulfur is commonly present in both organic and inorganic forms in nature. Chemical and bacterial processes transform sulfur through a cycle of reduction and oxidation. Sulfate is the most predominant form of inorganic sulfur in aerobic environments. Also see sulfide - hydrogen sulfide.
Sulfate (SO ₄)	Leached from most sedimentary rocks including shale and gypsum particularly in arid regions. Upon oxidation, organic material may contribute sulfates to water. Acid mine drainage is a common potential source. Discharges from some industries may contain sulfate. Wet and dry atmospheric deposition may be appreciable due to burning of fossil fuels.	Sulfate is the stable, highly oxidized form of sulfur produced by bacterial oxidation of reduced sulfur compounds. The sulfate ion (SO ₄ ²⁻) is readily soluble in water. Objectionable effects of sulfate in drinking water are related to taste and cathartic effects. Domestic waters in Montana containing as much as 1,000 mg/L are used for drinking in the absence of a less mineralized water supply. Can limit irrigation use on some soils. Sulfate concentrations are seldom high enough to affect aquatic life adversely. 250 mg/L is generally the maximum recommended level for human consumption while up to 1,000 mg/L is acceptable for livestock. Common metal sulfate compounds are gypsum and alabaster (CaSO ₄ ·2H ₂ O) and Epsom salt (MgSO ₄ ·7H ₂ O).
Sulfide - Hydrogen Sulfide (H ₂ S)	Occurs naturally in some artesian aquifers. Decomposition of natural organic material, algae, and waste sludge under anaerobic (in the absence of oxygen) conditions and from the reduction of sulfates. Also a byproduct of some industrial manufacturing processes.	Hydrogen sulfide is a soluble, highly poisonous and flammable gaseous compound with the characteristic odor of rotten eggs. The toxicity increases as the pH decreases because of the greater proportion of un-dissociated H ₂ S. Causes objectionable odor when in concentration above 1 mg/L and taste when in excess of 0.05 mg/L. Water containing H ₂ S may be unsuitable for both domestic and livestock consumption. Can be a long-term hazard to most fish and other aquatic life. H ₂ S is a common cause of winterkill in ponds and lakes. When present in well water, H ₂ S accumulates in low spots like frost pits where it can reach concentrations presenting a danger to life and health. H ₂ S is highly corrosive to iron and copper plumbing.
Methane (CH ₄)	A gas that is sometimes found dissolved in water, usually in association with coal-bearing formations and in some artesian aquifers. Produced by the decay of organic matter by anaerobic bacteria.	CH ₄ is also known as natural gas. Methane is not directly toxic, but is very explosive. CH ₄ can cause asphyxiation when significant concentrations displace oxygen. The process to release dissolved methane from water in coal-bearing formations is that known as the coal-bed methane (or natural gas) process. Extreme care should be taken to ventilate possible gas buildup in well houses and other confined spaces where methane may be expected to accumulate.

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Carbon Dioxide (CO ₂)	Found naturally in some Montana water wells usually associated with exposed, coal-bearing geologic formations.	CO ₂ gas may be dissolved naturally in water at concentrations between 300 and 600 mg/L. Occasionally, CO ₂ gas will come out of solution in water and present an asphyxiation hazard to life and/or health where it can accumulate to unhealthy levels. CO ₂ (and CH ₄) gas can also interfere with the operation of standard well pumps. Waters with high concentrations of dissolved gases require specialized pumps for proper operation. The Occupational Health and Safety Administration limit CO ₂ concentrations in the workplace to 5,000 mg/L for prolonged periods of exposure.
Trace Metals Arsenic (As), Barium (Ba), Cadmium (Cd), Chromium (Cr), Copper (Cu), Cyanide (Cn), Lead (Pb), Silver (Ag), Zinc (Zn)	Occurs naturally in some springs and wells as metals are weathered from rocks and soils. Some metals may be released from plumbing and industrial pipes. Commercial, manufacturing, resource extraction (abandoned hard rock mines), and fossil fuel burning activities are also potential sources.	Limits are usually recommended based on potential health limits. Detrimental effects are usually related to the form and combination of compounds. pH, temperature, and hardness of a water may affect the availability and toxicity of trace metals. Limits for drinking water are generally conservative, and higher concentrations may be permitted if the water is the best available supply (e.g., copper). Elevated levels of trace metals may be detrimental to livestock, wildlife and aquatic life. Tables 1, 4 and 10 show the recommended concentrations for various uses. In Montana, livestock have been shown to exhibit copper deficiency due to low copper intake and/or an antagonistic effect of excessive consumption of sulfur, sulfates or iron. Adequate trace minerals are essential for good reproduction, vaccination viability, weight gain and other health issues in livestock.

Source:

Modified from Montana bureau of Mines and Geology Water Quality Sourcebook.
A Guide to Water Quality Parameters, Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, 1979.
Quality Criteria for Water, US EPA
Report of the Committee on Water Quality Criteria, Federal Water Pollution Control Administration.

Water for Human Consumption and Use

Table 1. Recommended Limits and Maximum Levels of Constituents in Drinking and Domestic Water (all units in mg/L unless otherwise noted)

Pollutant/Element/Compound	Category	Human Health Standards Surface Water 1/	Human Health Standards Groundwater 1/	Notes
Arsenic (As)	Carcinogen	0.010 MCL	0.010 MCL	
Asbestos	Carcinogen	7,000,000 fibers/L	7,000,000 fibers/L	Fibers longer than 10 microns counted
Barium (Ba)	Toxic	1.0 MCL	1.0 MCL	
Cadmium (Cd)	Toxic	0.005 MCL	0.005 MCL	
Chlorine (Cl)	Toxic	4.0 MCL	4.0 MCL	Total residual
Chromium (Cr) all forms	Toxic	0.1 MCL	0.1 MCL	Total recoverable
Copper (Cu)	Toxic	1.3 PP	1.3 PP	
Cyanide (CN) total	Toxic	0.14 MCL	0.2 MCL	
<i>Escherichia coli</i> (Bacteria)	Harmful	Dependent on water use classification	Less than 1 per 100 ml	See ARM Title 17, Chapter 30, Sub-Chapter 6, Surface Water Quality Standards. Dependent on water body classification and season.
Fluoride (F)	Toxic	4.0 MCL	4.0 MCL	
Iron (Fe)	Harmful (aquatic life) Narrative	na Primary MCL 0.3 Secondary MCL	na Primary MCL 0.3 Secondary MCL	Concentration must not interfere with uses. Secondary MCL based on aesthetic properties (taste, odor, staining). Total recoverable.
Lead (Pb)	Toxic	0.015 PP	0.015 PP	Metal criteria are a function of hardness. Total recoverable.
Manganese (Mn)	Harmful	na Primary MCL 0.05 Secondary MCL	na Primary MCL 0.05 Secondary MCL	Concentration must not interfere with uses. Secondary MCL based on aesthetic properties (taste, odor, staining). Total recoverable.
Mercury (Hg)	Toxic with BCF>300	0.05 ug/L PP	2.0 ug/L PP	
Nitrate (NO ₃ as Nitrogen (N))	Toxic	10.0 MCL	10.0 MCL	
Nitrate plus nitrite (as Nitrogen (N))	Toxic	10.0 MCL	10.0 MCL	
Nitrite (NO ₂ as Nitrogen(N))	Toxic	1.0 MCL	1.0 MCL	
pH	Harmful	Dependent on water use classification	Dependent on water use classification	See ARM Title 17, Chapter 30, SubChapter 6, Surface Water Quality Standards
Selenium (Se)	Toxic	0.05 MCL	0.05 MCL	
Silver (Ag)	Toxic	0.10 HA	0.10 HA	
Strontium	Toxic	4.0 HA	4.0 HA	filtered
Sulfate (SO ₄)	na	na	na	^{2/} 250 mg/L recommended limit for human consumption
Total Dissolved Solids (TDS)	na	na	na	^{2/} 500 mg/L recommended limit for human consumption
Zinc (Zn)	Toxic	2.0 HA	2.0 HA	
Pesticides				
Alachlor (Lasso)	Carcinogen	0.002 MCL	0.002 MCL	
Atrazine (various)	Carcinogen	0.003 MCL	0.003 MCL	
Chlorsulfuron (Glean)	Toxic	1.750 HA	1.759 HA	
Clopyralid (Stinger)	Toxic	3.5 I	3.5 I	I = derived from federal data sources
Dicamba (Banvel)	Toxic	0.20 HA	0.20 HA	
Dichlorophenoxyacetic Acid (2,4-D)	Toxic	0.07 MCL	0.07 MCL	
Glyphosate (Roundup, etc)	Toxic	0.7 MCL	0.7 MCL	
Imazamethabenz-methyl (Assert)	Carcinogen	0.40 I	0.40 I	I = derived from federal data sources
Malathion	Toxic	0.10 HA	0.10 HA	
MCPA	Toxic	0.004 HA	0.004 HA	
Phenolic Compounds (as phenol)	Harmful	0.30 PP	0.30 PP	
Paraquat dichloride	Toxic	0.030 HA	0.030 HA	
Pentachlorophenol (PCP)	Carcinogen	0.001 MCL	0.001 MCL	
Picloram (Tordon, etc.)	Toxic	0.5 MCL	0.5 MCL	
Prometon (Pramitol)	Toxic	0.10 HA	0.10 HA	
Simazine (various)	Carcinogen	0.004 MCL	0.004 MCL	
Tebuthiuron (Spike)	Toxic	0.50 HA	0.50 HA	
Trifluralin (Treflan)	Carcinogen	0.005 HA	0.005 HA	
Radioactivity				
Combined Radium 226 and Radium 228	Carcinogen/ Radioactive	5 picocuries/liter MCL	5 picocuries/liter MCL	Sum of Radium 226 and Radium 228; Filtered
Gross alpha particle activity (including radium-226 but excluding radon and uranium)	Carcinogen/ Radioactive	1.5 picocuries/liter HA	1.5 picocuries/liter	Filtered
Gross beta particle activity	Carcinogen/ Radioactive	0.4 mrem/year	0.4 mrem/year	Filtered
Radon 222	Carcinogen/ Radioactive	300 picocuries/liter HA	300 picocuries/liter HA	Filtered

MCL - Maximum Contaminant Level in drinking water

HA - EPA's Drinking Water Standards and Health Advisories (Oct. 1996)

PP - Priority Pollutant Criteria

1 mg/L = 1 part per million (ppm)

1 ug/L = 1 part per billion (ppb)

1000 ug/L = 1 mg/L

1/ Standards for metals in surface water (except aluminum) are based on the analysis of samples following a "total recoverable" digestion procedure. Standards for metals in groundwater are based on analysis of the dissolved portion of the sample following filtration through a 0.45 mm membrane filter. Standards for organic parameters in surface and groundwater are based on unfiltered samples.

2/ Values do not represent numeric standards.

Source: Circular QWB-7 Montana Numeric Water Quality Standards. August 2010
Quality Criteria for Water, USEPA, 1976.

Table 1 gives numeric water quality standards and recommended limits for selected constituents in ground and surface water. The numeric standards listed in Table 1 have been compiled by DEQ as required under the Montana Water Quality Act in Circular WQB-7 Numeric Water Quality Standards (August 2010). The standards are set by the Board of Environmental Review at the level necessary to protect the uses of ground and surface water based on the best available scientific information. The information presented is current as of May 2011. These values are adjusted occasionally as new information (water quality criteria) becomes available. Always check the current version when making specific interpretations. The full and current version of WQB-7 may be accessed over the Internet from the index page at: <http://www.deq.mt.gov/wqinfo/Standards/Index.asp> Please note that concentrations for sulfate and TDS represent recommended levels rather than established standards. Additional considerations concerning fluoride and hardness in domestic water supplies are given below.

Human health standards for common pesticides are presented in Table 1 for information. The Montana Agricultural Chemical Ground Water Protection Act requires the adoption of standards for pesticides when detected through the statewide monitoring program. Appendix 1 lists pesticides and pesticide metabolites detected between 2006 - 2011 in groundwater in Montana counties under the Groundwater Protection Program conducted by the Montana Department of Agriculture. Groundwater consumers on individual wells within these areas should consider inclusion of these parameters in drinking water quality analyses.

Corrosivity

The degree to which water will corrode pipes is known as corrosivity. This index is commonly measured by the Langelier Index (LI). This scale runs from a -4.0 to +4.0 (+/- 0.5 is most desirable) and is calculated based on pH, temperature, total dissolved solids, alkalinity and total hardness. Knowledge of the LI is useful to help plan appropriate mitigation techniques. Corrosion control options include pre-treatment systems, installation of non-conductive unions, reducing hot water temperature, and replacing metal piping with PVC or CPVC. Analytic labs will calculate the LI on request.

Fluoride

Optimum fluoride levels will reduce dental caries by 60 to 65 percent. Excessive fluoride in drinking water will mottle teeth. The optimum fluoride level for a give location depends on climatic conditions because the amount of water (and consequently the amount of fluoride) ingested is primarily influenced by air temperature.

Table 2. Recommended Fluoride Limits by Air Temperature

Annual Average of Maximum Daily Air Temperature, °F	Fluoride Concentrations in mg/L			Maximum ¹ Limit mg/L
	Lower	Optimum	Upper	
50.0 - 53.7	1.1	1.2	1.3	2.4
53.8 - 58.3	1.0	1.1	1.2	2.2
58.4 - 63.8	0.9	1.0	1.1	2.0
63.9 - 70.6	0.8	0.9	1.0	1.8
70.7 - 79.2	0.7	0.8	0.9	1.6
79.3 - 90.5	0.6	0.7	0.8	1.4

¹ Where fluorides are native to the water supply, these concentrations will not mottle teeth.
Source: Public Health Service, DHEW.

Table 3. Classification of Water by Hardness Content

Hardness

mg/L CaCO ₃	Class	Description
0-75	soft	minimum soap required
75-150	moderately hard	moderate soap consumption
150-300	hard	high soap consumption; scum forms; mineral deposits
300 up	very hard	excessive soap consumption; scum and curds form; mineral deposits

Water for Livestock and Poultry

Providing ground or surface water of poor quality to livestock can limit production and growth and may cause health problems or make livestock more susceptible to disease. An adequate supply of clean water promotes normal function, high feed intake and efficient nutrient use. High quality water is extremely important to the dairy industry because high-producing animals will consume 200–300 pounds of water per day. Tables 4, 5, and 6 give recommendations for selected water quality constituents and parameters. Upper limits represent maximum values at which toxicity or severe health problems are thought to occur. In some cases, values below the upper limit have been shown to interfere with dietary requirements or to cause mild health problems. High sulfate and magnesium intake may cause diarrhea and increase dietary requirements for selenium, Vitamin E and copper. Water with high iron levels may also increase the need for dietary copper. In many cases, individual animal tolerance is based on age class, overall health, and length of exposure. Specific questions concerning dietary interference or toxicity should be directed to an animal nutritionist or Extension Service specialist.

Table 4. Recommendations for Livestock Drinking Water

Constituent	Upper Limit (mg/L)
Alkalinity (CO ₃ + HCO ₃)	1,000
Aluminum (Al)	5
Arsenic (As)	0.01
Beryllium (Be)	No data available
Barium (Ba)	10
Boron (B)	5
Cadmium (Cd)	0.05
Calcium (Ca)	500
Chlorides (Cl ⁻) (Calcium and Magnesium)	Over 1,500
Chromium (Cr)	1
Cobalt (Co)	1
Coliform, fecal (colony forming units (cfu) per 100 mL)	0-200 cfu per 100 mL for calves; 200-1000 cfu per 100 mL for mature cows
Copper (Cu)	0.5 (dependant on Mo and Sulfate)
Fluoride (F)	2
Hydrogen Sulfide (H ₂ S)	Over 0.1 may affect taste
Iron (Fe)	Over 0.3 may affect taste
Lead (Pb)	0.1 ^{1/}
Magnesium (Mg)	Over 125
Manganese (Mn)	Over 0.05 may affect taste
Mercury (Hg)	0.01
Molybdenum (Mo)	No data available
Nitrate + Nitrite (NO ₃ – N + NO ₂ – N)	100 ^{2/}
Nitrite (NO ₂ – N)	10
Selenium (Se)	0.05
Sulfate (Magnesium and Sodium)	1,000
pH (units)	Over 8.5 units
Total Dissolved Solids (TDS)	10,000 ^{3/}
Vanadium (V)	0.10
Zinc (Zn)	25

^{1/} Lead is accumulative and problems may begin at threshold value of 0.05 mg/L

^{2/} See Table 6

^{3/} See Table 5

Source: Environmental Studies Board. 1972. National Academy of Science, National Academy of Engineering, Water Quality Criteria and Adams, R.S. 1986. Pennsylvania State University, Water Quality for Dairy Cattle.

Table 5. Guide to the Use of Saline Waters for Livestock and Poultry

Specific Conductance ^{1/} EC in μmhos/cm @ 25° C <i>(TDS in mg/L)</i>	Description of water Use Limitations
Less than 1,500 EC <i>(Less than 1,000 TDS)</i>	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
1,500 to 5,000 EC <i>(1,000 to 3,000 TDS)</i>	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to saline water. Poultry may exhibit watery droppings.
5,000 to 8,000 EC <i>(3,000 to 5,000 TDS)</i>	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing watery feces, increasing mortality, and decreased growth, especially in turkeys.
8,000 to 11,000 EC <i>(5,000 to 7,000 TDS)</i>	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
11,000 to 16,000 EC <i>(7,000 to 10,000 TDS)</i>	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, or swine may subsist on them under certain conditions.
Greater than 16,000 EC <i>(Greater than 10,000 TDS)</i>	Risks with these highly saline waters are so great that they cannot be recommended for use under any condition.

^{1/} 1 millimhos (mmhos) /centimeter (cm) equals 1 deci Siemen (dS) /meter (m)

1,000 micromhos (μ mhos)/cm equals 1 mmhos/cm

1,000 micrograms (μ g) / liter (L) equals 1 milligram (mg) / liter (L)

1 μ g/L equals 1 part per billion (ppb)

1mg/L equals 1 part per million (ppm)

Source: Environmental Studies Board, National Academies of Science, National Academy of Engineering. Water Quality Criteria 1972.

Table 6. Effects of Nitrate on Livestock

Nitrate Concentration (mg/L NO ₃ ⁻ – N)	Effect
Below 10	Not harmful
10 to 30	Slight possibility of harm
30 to 50	Risky, especially over a long period of time
50 to 100	Interference syndrome likely (trembling, weakness, discolored urine)
100 to 145	More serious; possible acute losses
145 to 195	Increased acute losses, secondary diseases
Above 195	Acute losses

Source: "Professional Topics". Bulletin No. 14, University of Illinois. July-August 1964.

Suitability of Water for Irrigation

Suitability of a water source for irrigation depends on the total amount of salts and the specific kinds of ions that make up the salts, especially if some are toxic or have negative impacts on soils. Suitability must also consider the nature of the soil medium, the kinds of crops grown, irrigation water management factors, cultural practices and climatic factors such as the ratio of precipitation to irrigation water. As such, it is difficult to set rigid quality standards for irrigation waters because of these varied and complex factors.

Montana has adopted numeric water quality standards in the Powder River Basin for electrical conductivity (salinity) and sodium adsorption ratio (SAR) (sodicity). The values are dependent on the specific drainage within the Basin. These rules apply only to the Powder River, Little Powder River, Tongue River and Rosebud Creek main stem and tributaries. See Chapter 30, Water Quality, Subsection 6, ARM 17.30.670 available through the index page at: <http://www.deq.mt.gov/wqinfo/Standards/Index.asp>. At the time of this writing, these rules are under review and may be subject to change.

Some general guidelines have been established that indicate the relative usability of a water source for irrigation and indicate the waters for which more detailed study may be appropriate. There are four basic criteria for evaluating irrigation water quality:

- Total soluble salt content (salinity hazard).
- Relative proportion of sodium cations (Na^+) to other cations (sodium hazard).
- Carbonate ($\text{CO}_3^{=}$) and bicarbonate (HCO_3^-) anion concentration as related to calcium (Ca^{++}) plus magnesium (Mg^{++}) concentration (alkalinity).
- Concentration of elements that may be directly toxic to plants (toxicity).

Salinity

Salinity refers to the total amounts of soluble ions in a water supply. The cations Ca^{++} , Mg^{++} , Na^+ , and K^+ , and anions Cl^- , SO_4^- , CO_3^- , and HCO_3^- usually dominate in freshwater. Because ions carry electrical charges, water with a high salt concentration will carry a greater electrical current than water with a lower concentration of salts. The measure of electrical conductivity (EC -- a simple field measured parameter) is used as an indicator of salinity and has the units of mhos/cm at 25°C or an equivalent term. Total dissolved solids (TDS -- a laboratory determined parameter) is usually expressed in milligrams per liter (mg/L) or ppm. Depending on the specific types of salts present, multiplying the EC (mmhos/cm) by 640 can provide an approximation of TDS in mg/L or ppm. Table 7 gives basic guidelines for water use relative to its salt content.

Salinity or salts are a concern for irrigators because as water is evaporated and used by plants, the salts carried in the water are left behind (along with salts inherent to the soil). Irrigation water with a conductivity of 1 mmhos/cm can produce a conductivity of 2 mmhos/cm or more in the soil solution with time or as the soil dries. Over time, accumulated salts in the soil-water solution decrease the amount of water available for plant uptake (Available Water Capacity) in addition to making it difficult for plants to take up nutrients. Impacts can appear as drought damage even under high moisture levels.

Leaching, or the application of more water than the plants can use, is generally required to move accumulated salts below the root zone to maintain soil health and plant productivity over time. Fine-textured or inadequately-drained soils may be difficult to leach effectively. For these reasons, management of salts in irrigation water and soil is very important in Montana's arid climate. Plants vary in their tolerance to salinity depending on species and growth stage. Tables 13-3 and 13-4 in Chapter 13 of the National Engineering Handbook (NEH), Part 652, Irrigation Guide, depict the relative salt tolerance for a number of plants. Montana Plant Materials Technical Notes 60, 61, and 62 provides more specific guidance for determining and interpreting the suitability of salt-affected water and soil on tree and shrub plantings. These and other Technical Notes may be accessed online by subject from the index at <http://www.mt.nrcs.usda.gov/technical/technotes.html>.

Table 7. Salinity Hazard of Irrigation Water

Salinity Hazard	Dissolved Salt Content EC water (mmhos/cm at 25 °C)
Water for which no detrimental effects will usually be noticed. Little chance for increases in salinity to develop.	Less than 0.75
Water which may have detrimental effects on sensitive crops. ^{1/} Moderate leaching required to reduce salt accumulations.	0.75 to 1.50
Water that may have adverse effects on many crops and require careful management practices. Salinity increases will result unless adequately leached.	1.50 to 3.0
Water that can be used only for salt tolerant plants ^{2/} on permeable soils with careful management practices and only occasionally for more sensitive crops. A high leaching requirement is necessary. Soil should be tested for salinity increases yearly.	Greater than 3.0

^{1/} Field beans, lettuce, bell pepper, onion, carrots, and string beans

^{2/} Sugarbeets, wheat, and barley

Source: Adapted from Ayers and Westcott (1985) FAO 29, Revision 1

Sodicity

Sodicity refers to excess exchangeable sodium, which is sodium held onto the soil clay particles. Sodium is not directly harmful to most plants; however, sodium can make fine-textured soil extremely impermeable to water and difficult for roots to penetrate. Permeability and infiltration may be negatively affected when the soil or water is relatively high in sodium and low in calcium.

When irrigation water containing a high proportion of sodium relative to calcium plus magnesium is applied to porous, aggregated soil, the sodium replaces the adsorbed calcium and causes the soil particles to rearrange (disperse) and form smaller pores. The smaller pores slow the movement of irrigation water and in severe cases water movement is nearly halted. The Sodium Adsorption Ratio (SAR) is most often used to indicate the potential for infiltration and permeability problems. The combination of SAR and EC of the irrigation water is generally more indicative of potential permeability and infiltration hazard. Permeability hazard is related to either high sodium levels or to extremely low salt content. Fine-textured soils and sprinkler irrigated areas have the greatest sensitivity to permeability hazard from irrigation water. Figure 1 shows threshold hazard values for various combinations of SAR and EC in irrigation water relative to soil texture.

Deciduous tree crops and woody plants as well as several field crops (including beans) are directly sensitive to sodium. Most crops are moderately tolerant to sodium. Effects on sensitive species are stunted growth, leaf and tip burn, and leaf drop. When these conditions persist, death can occur.

Alkalinity

Excess carbonate and bicarbonate may cause problems. Excess bicarbonate can result in damage to leaves where water is applied via sprinkler irrigation. Iron deficiencies in some plants are related to high bicarbonate water. High bicarbonate and carbonate concentrations also increases the sodium hazard of water to a level higher than indicated by the SAR due to precipitation of calcium and magnesium when the soil solution concentrates during soil drying. Knowledge of soil properties and calculation of adjusted SAR values for the soil help determine management practices needed when using high bicarbonate water. A qualified lab is best suited to perform these calculations.

Toxicity

Some elements in irrigation water may be directly toxic to crops. Crop toxicity occurs when certain elements are available for uptake by plants and/or alter the uptake or metabolism of essential nutrients. Toxic elements delivered via irrigation water can accumulate in amounts that reduce yield or quality. Establishing toxicity limits is complicated by the fact that in some cases toxic elements are inactivated by chemical reactions or have beneficial effects for certain crops. Toxicity is usually related to ions such as boron, chloride, magnesium, sulfate, and sodium (see above). Certain other highly toxic elements commonly occur in Montana's irrigation water at low levels. Most of these elements (i.e., selenium, arsenic, and mercury), are not necessarily toxic to plants, but may concentrate and become harmful to soil biota and animal life over time. Table 8 lists recommended maximum concentrations of trace elements in irrigation waters.

Boron

Excess boron is frequently present in saline soils. Boron is essential to the normal growth of all plants, but the concentration required is very small and if exceeded, may cause injury. Groundwater in particular and some surface water sources in Montana may contain elevated levels of boron. Irrigation waters containing more than 1 mg/L of boron may cause accumulation of toxic levels for sensitive crops. Symptoms of boron injury may include leaf burn, chlorosis, and necrosis. Table 9 lists the relative boron tolerance of common crops and ornamentals.

Chloride

High levels of chloride may interfere with nutrient availability. With overhead sprinkler irrigation and low humidity, chloride may be absorbed through the leaves of sensitive crops. Most tree crops and woody ornamentals are sensitive. Most annual crops are not sensitive. The primary symptom of chloride toxicity is leaf burn. For specific sensitivity of various crops to chloride absorption, see NEH, Part 623, Irrigation Water Requirements, Chapter 2, Table 2-36.

Sulfate

Specific sensitivity to sulfate concentrations has been noted for a number of crops. Such sensitivity is related to the tendency of high sulfate concentrations to limit the uptake of calcium by the plant. Associated with a decrease in calcium are increases in the absorption of sodium and potassium so that the harmful effects are likely related to a disturbance in the ionic balance within the plant rather than a direct injury.

Additional Considerations

Nutrients

In some circumstances, irrigation water may be an appreciable source of nutrients for crop growth. For example, each 1.0 mg/L or 1.0 ppm of nitrate-nitrogen in an irrigation water source adds 2.7 pounds of nitrate-N per acre-foot of water applied to a field. Analysis of nutrient concentration should be completed for any proposed new source of irrigation water as well as for existing sources where nutrient management plans are required. Please see NRCS, Montana Nutrient Management (Code 590) Standard for details on calculating nutrient loads in irrigation water.

Figure 1. Classification of Irrigation Waters

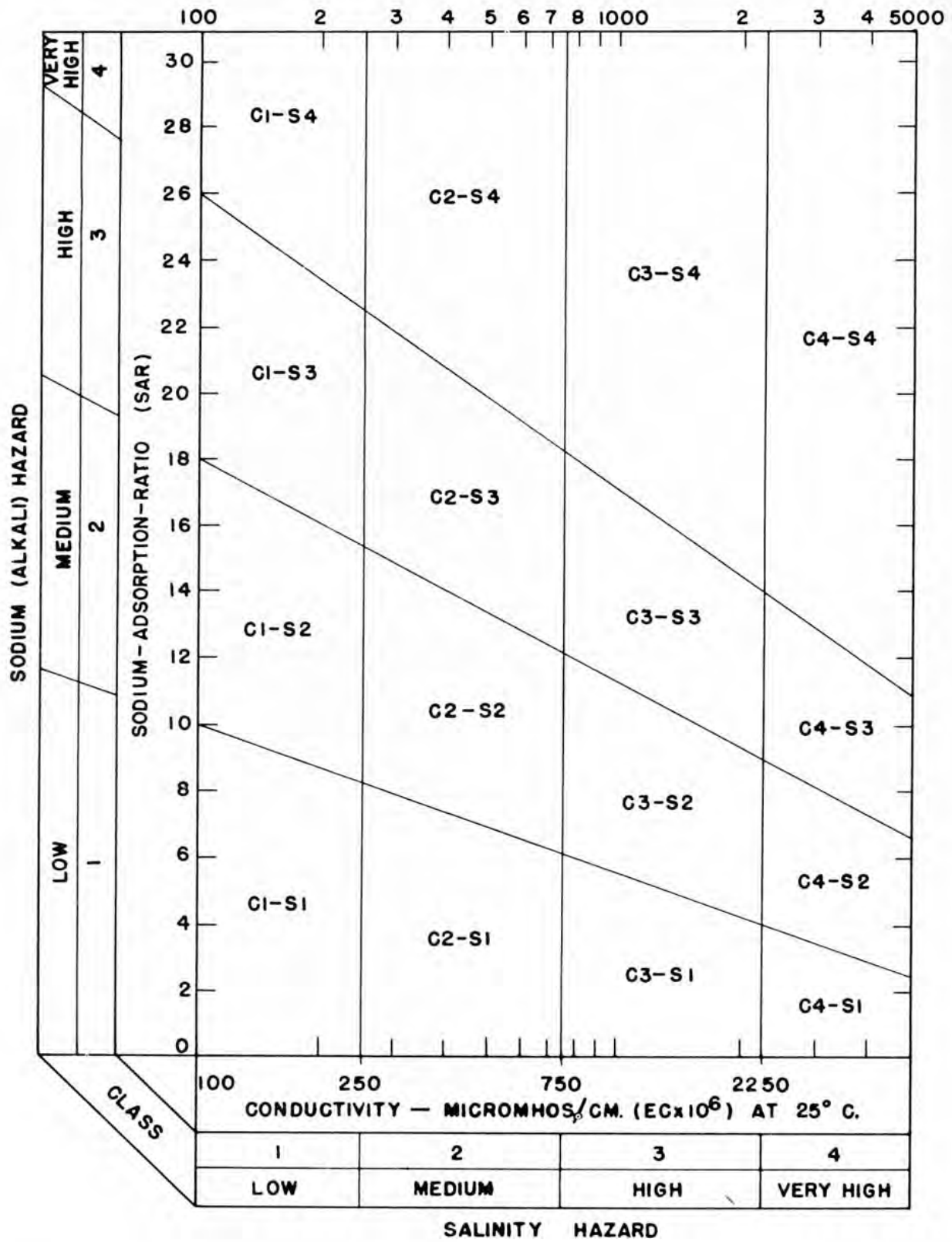


Figure 1. Classification of Irrigation Waters--continued

Low Salinity Water (C1) can be used for irrigation on most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium Salinity Water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High Salinity Water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected.

Very High Salinity Water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Low Sodium Water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium Sodium Water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured soils or organic soils with good permeability.

High Sodium Water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very High Sodium Water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably, and this should be taken into account in the use of C1-S3 and C1-S4 waters. For calcareous soils with high pH values or for non-calcareous soils, the sodium status of waters in classes C1-S3, C1-S4, and C2-S4 may be improved by addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when C2-S3 and C3-S2 waters are used.

Source: Agriculture Handbook 60, U.S. Department of Agriculture

For additional information concerning the suitability of irrigation waters please consult the National Engineering Handbook, Part 623, Chapter 2, Irrigation Water Requirements, and Part 652, National Irrigation Guide, Chapter 13, Quality of Water Supply. Another good source of information is American Society of Civil Engineers (ASCE) Report 71, Agricultural Salinity Assessment and Management.

Table 8. Recommended Maximum Concentrations of Trace Elements in Irrigation Waters*

Element (Symbol)	For waters used continuously on all soils (mg/L)	For use up to 20 years on fine-textured soils of pH 6.0 to 8.5 (mg/L)
Aluminum (Al)	5	20
Arsenic (As)	0.1	2.0
Beryllium (Be)	0.1	0.5
Boron (B)	^{1/}	2
Cadmium (Cd)	0.01	0.05
Chromium (Cr)	0.1	1
Cobalt (Co)	0.05	5
Copper (Cu)	0.2	5
Fluoride (F)	1	15
Iron (Fe)	5	20
Lead (Pb)	5	10
Lithium (Li)	2.5	2.5
Manganese (Mn)	0.2	10
Molybdenum (Mo)	0.01	0.05 ^{2/}
Nickel (Ni)	0.2	2
Selenium (Se)	0.02	0.02
Vanadium (V)	0.1	1
Zinc (Zn)	2.0	10

* These levels will normally not adversely affect plants or soils. No data available for Mercury (Mg), Silver (Ag), Tin (Sn), Titanium (Ti), or Tungsten (W).

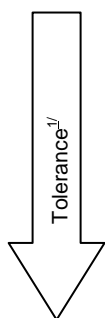
^{1/} See Table 10.

^{2/} Concentration only for acid fine-textured soils or acid soils with relatively high iron oxide contents.

Source: Environmental Studies Board. National Academy of Science, National Academy of Engineering. Water Quality Criteria 1972.

Table 9. Relative Tolerance of Crops and Ornamentals to Boron ^{1/} (in order of descending tolerance in each column)

	Tolerant <i>4.0 mg/L of boron</i>	Semi-tolerant <i>2.0 mg/L of boron</i>	Sensitive <i>1.0 mg/L of boron</i>
	Asparagus	Sunflower, native	Walnut, Black, Persian or English
	Sugarbeet	Potato	Jerusalem artichoke
	Garden beet	Tomato	Navy bean
	Alafalfa	Sweetpea	American Elm
	Gladiolus	Radish	Plum
	Broadbean	Field Pea	Pear
	Onion	Barley	Apple
	Turnip	Wheat	Persimmon
	Cabbage	Corn	Cherry
	Lettuce	Milo	Peach
	Carrot	Oat	Apricot
		Zinnia	Thornless blackberry
		Pumpkin	
		Bell Pepper	
		Lima bean	
	<i>2.0 mg/L of boron</i>	<i>1.0 mg/L of boron</i>	<i>0.3 mg/L of boron</i>



^{1/} Relative tolerance is based on boron in irrigation water at which boron toxicity symptoms were observed when plants were grown in sand culture. Does not necessarily indicate a reduction in yield.

Source: Wilcox, 1960.

Water for Aquatic Life and Recreation

Maintaining water quality is critical for protecting aquatic life (including aquaculture operations) and recreational uses of water in Montana. Organisms that now make up the aquatic flora and fauna successfully adapted over long periods of time to a unique range of conditions. This range in conditions now represents their long-term adaptive requirements. Any relatively rapid persistent change in conditions that affect water quality and aquatic habitat can be detrimental to their continued well being and survival. Because the present aquatic flora and fauna is the result of a long interactive process, marked change in the biota can have far reaching effects beyond any one species of plant or animal.

In determining water quality requirements for aquatic life and recreation, it is essential to recognize that there are not only lethal levels but also tolerable, favorable, and optimal levels of dissolved materials that may affect health, growth and reproductive success at each of several life stages. Montana Fish, Wildlife and Parks has prepared a table for the purpose of identifying periods when “early life stages” of fish may be present. EPA has defined the early life stage for salmonids to be 30 days after emergence/swim-up; for all other species it is 34 days after spawning. This information is necessary when applying dissolved oxygen and ammonia water quality standards to individual water bodies. Access the Spawning Time of Montana Fishes Table at: <http://www.deq.mt.gov/wqinfo/Standards/Index.asp>

Interpretations of water quality parameters may also be useful to evaluate the feasibility of aquaculture operations and recreational fisheries. Following are common water quality parameters and considerations for aquatic life and recreation. These recommendations are based on protection of optimum levels. Table 10 describes acute (short-lasting or less than one hour exposure) and chronic (long-lasting or four days or longer average) maximum levels for selected water quality parameters set forth in Circular WQB-7 Numeric Water Quality Standards (August 2010) – Aquatic Life Standards. These values are adjusted occasionally as new information becomes available. Always check the current version when making specific interpretations for aquatic life. The full and current version of WQB-7 may be accessed over the internet at: <http://www.deq.mt.gov/wqinfo/Standards/Index.asp>

Some important water quality considerations for aquatic life and recreation:

Alkalinity

Alkalinity is important for fish and wildlife because it buffers pH changes that occur naturally. A minimum recommended alkalinity is 20 mg/L for aquatic life and fishery uses. Excessive alkalinity can cause eye irritation in swimmers.

Ammonia

Fish cannot tolerate large quantities of ammonia since it reduces the oxygen-carrying capacity of the blood and causes them to suffocate. Early life stages of fish are more sensitive to ammonia. The toxicity of ammonia is dependent on pH and on temperature and indirectly on dissolved oxygen. Circular WQB-7 Numeric Water Quality Standards (August 2010), provides formulas and tables to determine specific acute and chronic values for total ammonia nitrogen (NH₃-N plus NH₄-N) dependant on the presence or absence of early life stages of fish.

Coliform, fecal

Waters used for swimming (primary contact) should have fecal coliform counts below 200 colony forming units (cfu) per 100 milliliters. Waters used for fishing and boating (secondary contact) should be below 1000 cfu/100 milliliters. *Escherichia coli* (*E. coli*) is a specific type of fecal coliform bacteria. At least one serotype of the *E. coli* bacterium (O157:H7) is known to cause serious food poisoning in humans, particularly the very young, old, and others with impaired immune systems. Standards for *E. coli* bacteria are based on a minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period analyzed by the most probable number or equivalent membrane filter methods.

Flow

Sustainable minimum flow levels in streams are generally determined through individual analysis of a given water body. Such analysis takes into consideration a number of parameters: maintenance of tolerable physical parameters such as temperature and dissolved oxygen (D.O.) in addition to required mechanics such as velocity,

depth, and sediment transport. A commonly accepted procedure used in Montana to determine thresholds for critical flow levels in streams relies on the relationship of discharge to wetted perimeter for riffle sections. The inflection point or point where the slope of the graphed line changes significantly is used to determine at what point (or points) a change in flow results in a significant change in available habitat (riffle depth and area covered).

Recommended flow levels in impoundments are generally based on the minimum required flow needed to provide a relatively frequent turnover in the volume impounded. Five days is usually the minimum recommended turnover time. The following formula is used to calculate turnover time.

$$\text{Turnover time (in days)} = \frac{\text{impoundment volume in acre-feet}}{(2) \text{ (flow in cubic feet/second (cfs))}}$$

Dissolved Oxygen (D.O.)

Dissolved oxygen (D.O.) concentrations are an important measure of existing water quality and the ability of water to support a well-balanced aquatic biota. D.O. varies with many factors including pH, salinity, atmospheric pressure (altitude), season, time of day, turbulence and temperature. The D.O. concentration in stream water ranges from about 14 mg/L (at freezing) to about 7 mg/L at 86° F. In ecologically healthy situations, D.O. concentration depends primarily on temperature. For flowing water, generally it is desirable that oxygen concentrations be at or near saturation (above 90% saturation for a given water temperature).

Established D.O. standards for aquatic life are based on levels required by the least tolerant organism or life form to thrive. As with standards for temperature, those for D.O. are dependent on stream classification and life stage (Table 13). Early life stages generally have higher requirements because their ability to take oxygen from water is not fully developed and they cannot move away from adverse conditions. Low D.O. levels may also contribute to the onset of anaerobic decomposition and the formation of toxic gases such as hydrogen sulfide. Excessive organic or chemical loading can increase the demand for oxygen to the point where toxic conditions occur. Measures of these values are known as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Neither value is a direct measure of D.O., but rather indicates the potential for reducing the D.O. content in water.

Oxygen stress increases the metabolic rate of aquatic organisms. Stress beyond threshold levels increases their susceptibility to disease and pathogens. In evaluating the suitability of a water source for cold water ponds, a D.O. concentration of 7 mg/L or greater is optimum. Minimum is 5 mg/L. For warm water species, 5 mg/L or greater is optimum and 3 mg/L is minimum.

Direct measurements of D.O. with meters or test kits should be adjusted for altitude using the following formula:

$$\text{Adjusted D.O.} = (\text{D.O. reading}) \times (\text{correction factor from Table 10})$$

Table 10. D.O. Correction for Atmospheric Pressure (elevation-based)

<u>Altitude (ft.)</u>	<u>Correction Factor</u>	<u>Altitude (ft.)</u>	<u>Correction Factor</u>
0	1.00	5,403	.82
542	.98	6,065	.80
1,094	.96	6,744	.78
1,688	.94	7,440	.76
2,274	.92	8,204	.74
2,864	.90	8,939	.72
3,466	.88	9,694	.70
4,082	.86	10,472	.68
4,756	.84		

As with interpretation of the ammonia standard, consult the Spawning Time of Montana Fishes Table at: <http://www.deq.mt.gov/wqinfo/Standards/Index.asp> for assistance in determining whether early life stages of fishes may be present.

Table 11. Numeric D.O. Standards for Montana Water Use Classifications (units in mg/L)

Period of Evaluation	Standards for Waters Classified A-1, B-1, B-2, C-1 and C-2		Standards for Waters Classified B-3, C-3, and I	
	Early Life Stages ^{1/, 2/}	Other Life Stages	Early Life Stages ^{2/}	Other Life Stages
30 day mean	N/A	6.5	N/A	5.5
7 day mean	9.5 (6.5)	N/A	6.0	N/A
7 day mean minimum	N/A	5.0	N/A	4.0
1 day minimum ^{3/}	8.0 (5.0)	4.0	5.0	3.0

^{1/} These are water column concentrations recommended to achieve the inter-gravel D.O. concentrations shown in parentheses. For species that have early life stages exposed directly to the water column, the figures in parentheses apply.

^{2/} Includes all embryonic and larval stages and all juvenile forms of fish to 30-days following hatching.

^{3/} All minima should be considered as instantaneous concentrations to be achieved at all times.

Source: Circular WQB-7 Montana Numeric Water Quality Standards, August 2010.

Nutrients

While important for life processes and growth rates, nitrogen and phosphorus concentrations outside the normal seasonal variation can adversely affect aquatic life indirectly. Increased aquatic plant growth can inhibit recreational use and aquatic life by creating nuisance algal growth, reducing D.O. levels, increasing temperature, and increasing the toxicity of other compounds. In severe instances, some species of blue-green algae produce toxins that affect animals and aquatic life. Phosphorus is rarely found in concentrations high enough to be directly toxic to aquatic organisms. Levels of unionized ammonia, a form of nitrogen, above 0.02 mg/L can be toxic to aquatic life, especially trout. Because available phosphorus generally occurs in lower concentrations in surface water, phosphorus is usually the limiting nutrient for aquatic growth in streams and lakes. The natural ratio of total N to total P is often near 10:1; however this figure does vary with the setting. Ratios well outside this value may indicate a system out of balance. Streams and lakes in the Great Plains generally have more phosphorus so that nitrogen frequently becomes the limiting nutrient. In mountain and foothill streams, levels of total phosphorus above 0.03 mg/L and of total nitrogen above 0.3 mg/L are often used as thresholds for accelerated aquatic growth. Surface water in the Great Plains environments, due to unique geology, hydrology, and climate, may have higher background ranges of nutrients on the order of 0.2 to 0.6 mg/L total phosphorus and 1.0 to 3.0 mg/L total nitrogen. Natural surface waters generally have nitrate-N concentrations below 1.0 mg/L.

Montana is in the process of developing numeric nutrient criteria and standards for surface waters that applies to the aquatic life use. At this time, however, the nutrient standard relies on a narrative standard for nutrients in ARM 17.30.637 General Prohibitions. This narrative states in part: (1) State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: (d) create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life and (e) create conditions which produce undesirable aquatic life.

Pesticides

Due to the lack of current scientific information concerning the toxicity of pesticides on aquatic life, relatively few water quality criteria for modern-day pesticides are available. The listing in Table 12 for pesticides is not complete. New criteria and standards for many pesticides and pesticide metabolites are adopted regularly. Since new standards are added as information is published and validated, please check WQB-7 for current pesticide standards for aquatic life. Appendix 1 provides a map of pesticides detected in Montana counties. For a detailed listing of the pesticides in each county visit <http://www.mt.nrcs.usda.gov/technical/ecs/water/pesticide/index.html>.

Investigators are also currently looking into the potential risk of pharmaceutical compounds to human and aquatic life health. Pharmaceuticals include growth regulators, cosmetics, insect repellent and stimulants. Due to their common use and resistance to breaking down into less persistent substances, many of these compounds are now being detected in trace amounts in ground and surface water supplies throughout the country. Most of these compounds are not regulated at the present time.

pH

Although used as an indication of alkalinity and/or acidity, pH is not directly a measure of either. pH is a function of many complex factors within a water source including water chemistry, geology, climate, and vegetation. A

range of 6.5 to 8.5 is generally expected, although in some waters, photosynthetic activity will increase short-term levels to above 9.0. pH below 4.5 is generally unsuited for aquatic life. Short-term increases do not produce the same harmful effects of continuous high levels caused by the addition of strong alkalis. The availability of nutrients and the toxicity of metal compounds are directly related to hydrogen ion activity. Ammonia toxicity increases considerably with small increases in pH. As with temperature and oxygen, Montana water quality standards for induced pH variation are based on Water-Use Classifications. See Administrative Rules of Montana (ARM) Title 17, Chapter 30, Sub Chapter 6 - Surface Water Quality Standards and Procedures to determine the classification of a particular water and the pH variation allowed. The ARM is accessible via the internet at: <http://www.deq.mt.gov/wqinfo/standards/default.mcp>

Temperature

While adapted to natural fluctuations in temperature, aquatic life may be adversely affected by sudden and/or prolonged changes in temperature. Temperature regimes of waters in Montana vary greatly from plains to mountains as a function of many variables including latitude, elevation, climatic regime, time of day and flow. To allow for this variation, Montana water quality temperature standards are based on Water-Use Classifications. See Administrative Rules of Montana (ARM) Title 17, Chapter 30, Sub Chapter 6 - Surface Water Quality Standards and Procedures for the classification of a particular water and the temperature variation allowed. The ARM is accessible via the internet at: <http://www.deq.mt.gov/wqinfo/standards/default.mcp>

Cold water fish ponds and commercial fish production facilities should be maintained between 50° and 65° F. For economical production, temperatures should be greater than or equal to 50° F for at least six months of the year. Warm water ponds should reach a temperature of at least 70° F for two weeks during the summer.

TDS

Salinity related to Total Dissolved Solids (TDS) may have both direct and indirect impacts on aquatic life. In general, most forms of aquatic life must tolerate a range of TDS concentrations in order to survive under natural conditions. Concentrations above 15,000 mg/L of dissolved solids are unsuitable for most freshwater fishes. Levels above 5,000 mg/L have been shown to be toxic to fathead minnows. Associated wildlife such as waterfowl may be adversely affected by dissolved solids in the same manner as poultry (see Table 5). Indirect effects of salinity are primarily the elimination of salt sensitive desirable food plants and habitat-forming plants. An undesirable impact to such vegetation occurs at far lower TDS levels than concentrations causing direct impacts to aquatic life.

Turbidity

Turbidity is a measure of light scatter in water and is dependent on the size of suspended particles and their amount. Relationships have been developed between turbidity and total suspended sediment but are site-specific and should not be generally applied. In most cases, the relationship is weaker than one would suspect.

Turbidity can have both positive and negative effects depending on the desired use. The suspended particles that create turbidity may have a positive effect on many agricultural uses such as providing fine-suspended material to seal canals and ponds and to improve the water holding capacity on irrigated fields. On the other hand, excessive turbidity also creates accelerated wear on irrigation equipment and devices increasing maintenance expense.

Turbidity levels above or below normal amounts however, can be very detrimental to recreation and aquatic life due to the combination of factors. For recreation, turbid water is less aesthetically appealing and may have an increased potential for carrying pathogens. For aquatic life, turbid water transmits less light; therefore photosynthesis is reduced resulting in less D.O. production. The higher particle load also absorbs more heat from sunlight resulting in increased water temperatures. Warmer water has less capacity to store dissolved oxygen. This combination is detrimental to species requiring cold water and higher D.O. levels. In addition, higher concentrations of suspended materials can clog gills, smother eggs and cover important microhabitats. The same particles can also carry attached nutrients and pesticides. In the case of some warm water fisheries, excessive reduction of background sediment loads can also have a detrimental effect by removing the source material for required habitats.

The optimum turbidity level then, is maintaining the natural range of variation within a given water body. Because of the variation between mountain and prairie stream systems, the numeric Montana Water Quality Standard for

turbidity increase is based on stream classification rather than absolute numbers. See Administrative Rules of Montana (ARM) Title 17, Chapter 30, Sub Chapter 6 – Surface Water Quality Standards and Procedures to determine the classification of specific surface water bodies and the increase in turbidity allowed.
<http://www.deq.mt.gov/wqinfo/standards/default.mcp>

Table 12. Montana Numeric Water Quality Standards for Aquatic Life^{1/}

Pollutant/Element Compound	Category	Acute	Chronic	Notes
Aluminum, dissolved. pH 6.0 to 9.0 only	Toxic	750 NPP	87 NPP	
Ammonia - total ammonia nitrogen (NH ₃ -N plus NH ₄ -N)	Toxic	See Table 1 in WQB-7	See Table 2 in WQB-7	Concentration dependent on pH and temperature relative to freshwater life forms present.
Arsenic (As)	Carcinogen	340 PP	150 PP	Total recoverable through digestion.
Cadmium (Cd)	Toxic	0.52 @ 25 mg/L hardness PP	0.097 @ 25 mg/L hardness PP	Metal criteria are a function of hardness. Total recoverable through digestion.
Chlorine (Cl) total residueal	Toxic	19 NPP	11 NPP	
Chromium (Cr) hexavalent	Toxic	16 PP	11 PP	
Chromium (Cr) trivalent	Toxic	579 mg/L @25 mg/L hardness PP	27.7 @ 25 mg/L hardness PP	Metal criteria are a function of hardness.
Copper (Cu)	Toxic	3.79 @ 25 mg/L hardness PP	2.85 @ 25 mg/L hardness PP	Metal criteria are a function of hardness. Total recoverable through digestion.
Cyanide (CN) total	Toxic	22 PP	5.2 PP	Total recoverable through digestion.
Iron (Fe)	Harmful (aquatic life) Narrative	na	1000 NPP	Concentration must not interfere with uses. Total recoverable through digestion.
Lead (Pb)	Toxic	13.98 @ 25 mg/L hardness PP	0.545 @ 25 mg/L hardness PP	Metal criteria are a function of hardness. Total recoverable through digestion.
Mercury (Hg)	Toxin with BCF>300	1.7 PP	0.91 PP	Total recoverable through digestion.
Nitrate (NO ₃ as Nitrogen (N))	Toxic	Narrative	Narrative	Concentration must not interfere with uses.
Nitrate plus nitrite (NO ₂ as Nitrogen (N))	Toxic	Narrative	Narrative	Concentration must not interfere with uses.
Nitrite (NO ₂ as Nitrogen (N))	Toxic	Narrative	Narrative	Concentration must not interfere with uses.
Oxygen, dissolved.	Toxic	See WQB-7	See WQB-7	Standard dependent on stream classification and freshwater aquatic life form present.
Selenium (Se)	Toxic	20	5 HA	Total recoverable through digestion.
Silver (Ag)	Toxic	0.374 @ 25 mg/L hardness PP	na	Metal criteria are a function of hardness. Total recoverable through digestion.
Sulfate (SO ₄)	na	na	na	No aquatic criteria established.
Temperature	Harmful	See ARM	See ARM	Allowable change from natural range is dependent on stream classification.
Total Dissolved Solids (TDS)	na	Narrative	Narrative	Concentration must not interfere with uses.
Turbidity	Harmful	See ARM	See ARM	Maximum allowable increase above naturally occurring turbidity is dependent on stream classification.
Zinc (Zn)	Toxic	37 @ 25 mg/L hardness PP	37 @ 25 mg/L hardness PP	Metal criteria are a function of hardness. Total recoverable through digestion.
Pesticide	Category	Acute	Chronic	Notes
Chlordane	Carcinogen	1.2 PP	0.0043 PP	
Chlorpyrifos	Toxic	0.083 NPP	0.041 NPP	
Diazanone	Toxic	0.17 NPP	0.17 NPP	
Nonyphenol	Toxic	28.0 NPP	6.6 NPP	
Parathion	Carcinogen	0.065 NPP	0.013 NPP	
Pentachlorophenol (PCP)	Carcinogen	5.3 @ pH of 6.5 PP	4 @ pH of 6.5 PP	Criteria dependent on pH.
Polychlorinated biphenols (PCBs)	Carcinogen	--	0.014 PP	Sum of all isomers
Toxaphene	Carcinogen	0.73 PP	0.0002 PP	

NOTE: All units are expressed in micrograms (ug/L) unless otherwise noted. 1 milligram/Liter equals 1000 micrograms/Liter. 1 ug/L equals 1 part per billion (ppb). PP= Priority Pollutant; NPP = Non Priority Pollutant; HA = Health Advisory

^{1/} Standards for metals in surface water (except aluminum) are based on the analysis of samples following a "total recoverable" digestion procedure. Standards for metals in groundwater are based on analysis of the dissolved portion of the sample following filtration through a 0.45-m membrane filter. Standards for organic parameters in surface and groundwater are based on unfiltered samples.

Source: Circular WQB-7 Montana Numeric Water Quality Standards, August 2011.

Water Quality Analysis Recommendations

Public Water Supplies

Public Water System samples are taken and tested by the system operator. Under the Safe Drinking Water Act (SDWA), all Public Water Systems are required to sample and test their water supplies according to a fixed schedule for all contaminants for which MCLs have been set. Public Water Supplies in general have at least 15 connections and serve at least 25 individuals daily at least 60 days out of a year. Results of these tests are available to the public. If a Public Water System fails to comply with certain aspects of the SDWA, public notification is required. The exact type and frequency of notification depend on the seriousness of any potential adverse health effects, which may be involved. The most common notification is a spring boil order for not meeting the bacteria standard.

New Wells

In Montana, new individual (non-Public Water Supply) wells should be tested for:

- Bacteria (total fecal coliform - Bacteria)
- Nitrate (as Nitrogen) or Nitrate + Nitrite (as Nitrogen)
- Iron
- Manganese
- pH.
- Fluoride (in Cretaceous aquifers).

It may also be advisable to include all the tests for existing sources. A recent nationwide survey by the U.S. Environmental Protection Agency and Cornell University found that contamination of drinking water by septic effluent may be one of the foremost water-quality problems in the Nation.

Existing Source

When buying an existing home with or without a well, it is advisable to insist that the seller provide for water testing before closing on the house. Many lending organizations require water quality testing before mortgages are issued. Recommended minimum water tests for an existing home are:

- Bacteria (total coliform or *Escherichia coli* - Bacteria)
- Nitrate (as Nitrogen) or Nitrate + Nitrite (as Nitrogen)
- Lead.

Consider:

- Volatile Organic Chemical Scan
- Total Hardness
- Total Dissolved Solids
- Common ions (Fe, Cl, K, Na, Ca, Mg)
- Conductivity (specific conductivity)
- Sulfate
- pH
- Corrosivity (Calculated index)
- Radioactivity (Gross Alpha)
- Mercury
- Radon 222
- Fluoride (in Cretaceous aquifers).

The absolute minimum should include the total coliform bacteria test. This test should be done at least once a year during different seasons each year. If taste, odor, or turbidity is a problem, additional testing is recommended. Wells located near heavily industrialized areas, near service stations, dry cleaners, or landfills may warrant additional testing. Consult your local health department or Local Water Quality District official, where available, who can provide advice on what specific tests to have performed. For additional guidance about water well testing and sampling see: <http://www.deq.mt.gov/wqinfo/swp/default.mcp>

For guidance on elimination of bacterial contamination in water wells, see Montana Environment Technical Note MT-6, Disinfecting Wells and Springs at: <http://www.mt.nrcs.usda.gov/technical/ecs/environment/technotes>. Also see: <http://waterquality.montana.edu/docs/WellEducated.shtml>

Livestock Water Source

Existing or new wells supplying livestock water should have nearly the same series of tests performed as for a domestic source (bacteria and nitrate + nitrite (as Nitrogen). Also consider TDS, common ions, alkalinity, sulfate, fluoride (in Cretaceous aquifers) and the LI (since corrosivity may affect pumps, tanks, fittings, and stock water pipelines).

Irrigation Water Source

Irrigation waters should be periodically tested for the following parameters in order to evaluate suitability and to track any change over time:

- Conductivity and/or Total Dissolved Solids (TDS)
- Alkalinity (Carbonate and Bicarbonate)
- Calcium
- Sodium
- Magnesium
- Boron
- Chloride
- Sodium Adsorption Ratio (calculation)
- pH.
- Nitrate – Nitrogen (NO₃-N)
- Fluoride (in Cretaceous aquifers).

Additional specific testing should be done if changes in crop growth or health indicate possible deficiency or toxicity problems.

LABS FOR ANALYSIS – Sources of Water Quality Analysis Services.

Before sampling, contact the lab for collection, preservation, and shipping instructions, and for current prices. The time and expense of sample collection and analysis will be wasted if proper sample collection, handling and storage procedures have not been followed. Nearly all water quality analyses have formal protocols defining these requirements. Some analytic procedures also require the samples to have chemical preservatives added and/or refrigerated. Some have a relatively short shelf life so transportation requirements may dictate the choice of lab. Consult the lab or a water quality specialist for specific protocol requirements. Analytic labs are commonly certified by State Government or the Environmental Protection Agency to perform various classes of tests (microbial, nitrates, inorganic, radon, synthetic organic chemicals and volatile organic chemicals). A list of currently certified Montana analytic laboratories is contained in Table 13.

You should always check with the lab concerning their certification status depending on the desired use of the analysis. Be aware of and follow the chain of custody recordkeeping requirements to preserve the integrity of the sample. In conducting water quality monitoring projects with a formal quality assurance/quality control plan, duplicate samples and lab blanks/spiked samples are usually required to control for possible error in sampling procedure and lab analysis. For a formal discussion of water quality sampling design, refer to the USDA-NRCS National Water Quality Handbook. Laboratory analysis results should be compared to the water quality standards values or recommended threshold levels in the preceding tables to evaluate suitability for the various uses.

Table 13. List of Certified Montana Analytic Laboratories (current as of December 2010)

Laboratory	Bacteria (Total Coliform)	Nitrates	Metals	Inorganics	SOCs ^{1/}	RAD	VOCs ^{2/}	OTHER
Alpine Analytical 1315 Cherry Avenue Helena, MT 59601 Phone: (406) 449-6282	▶							
AMATEC P.O. Box 20873 Phone: (406) 248-2159 Billings, MT 59104 or 1-800-999-0976	▶							
Aqua Tech Laboratory 505 W. Main Str., Ste. 320 P.O. Box 1205 Lewistown, MT 59457 Phone: (406) 538-6988	▶							
Billings Public Utilities Department Laboratory Highway 87 East P.O. Box 30958 Billings, MT 59111 Phone: (406) 657-8353	▶	▶	▶	■				
Bridger Analytic Lab, Inc., 7539 Pioneer Way, Suite C Bozeman, MT 59718 Phone: (406) 582-0822	▶	▶		▶				
Department of Public Health and Human Services Environmental Lab Cogswell Building, Room B105 1400 Broadway P.O. Box 4369 Helena, MT 59620-4369 Phone: (406) 444-2642	▶	▶	▶	▶	▶		▶	
EMSL Analytical Inc. 107 West 4 th Street Libby, MT 59923 Phone: (406) 293-9066								Asbestos
Energy Laboratories, Inc., 1120 South 27 th St. P.O. Box 30916 Billings, MT 59107-0916 Phone: (406) 252-6325	▶	▶	▶	▶	▶	▶	▶	
Energy Laboratories, Inc., 2704 Billings Ave. P.O. Box 5688 Phone: (406) 442-0711 Helena, MT 59604 or 1-800-472-0711	▶	▶	▶	▶	▶		▶	
Little Bear Laboratories, Inc., 22 S. Broadway, Suite B P.O. Box 1434 Red Lodge, MT 59068 Phone: (406) 446-3648		▶		■				
Missoula City-County Health Department 301 West Alder Missoula, MT 59801 Phone: (406) 523-4755	▶							

Table 13. List of Certified Montana Analytic Laboratories (current as of December 2010)--continued

Laboratory	Bacteria (Total Coliform)	Nitrates	Metals	Inorganics	SOCs ^{1/}	RAD	VOCs ^{2/}	OTHER
Montana Bureau of Mines Montana College of Mineral Science and Technology Analytical Division, 11300 West Park Butte, MT 59701 Phone: (406) 496-4747		▶	▶	■				
Montana Environmental Lab 376 West Washington P.O. Box 8900 Kalispell, MT 59901 Phone: (406) 755-2131	▶	▶		▶				
Mountain Zone Laboratory 302 Indian Creek Road 4 Huntley, MT 59037 Phone: (406) 208-4659	▶							
MSE Technical Application, Inc. 200 Technology Way P.O. Box 4078 Butte, MT 59701 Phone: (406) 494-7334	▶	▶		▶			▶	
Pace Analytical 602 South 25 th St. Billings, MT 59107 Phone: (406) 254-7226		▶	▶	▶	▶			
RD Water Lab 3700 S. Russell St. P.O. Box 5064 Missoula, MT 59806 Phone: (406) 721-8179	▶							
Scientia LLC Environmental Measurement USA 2880 Highway 93 N Victor, MT 59875 Phone: (406) 642-3526	▶	▶		▶				
<p>▶ Fully Certified</p> <p>■ Not certified for ALL required tests in this category</p> <p>^{1/} SOCs are synthetic organic chemicals (pesticides, etc.)</p> <p>^{2/} VOCs are volatile organic chemicals (solvents, etc.)</p> <p>List is subject to change at any time. Call before taking and sending samples.</p>								

Appendix 1. Map of Montana Ground Water Pesticide Detections by County 2006-2011 – data provided by the Montana Department of Agriculture

