"Our Mission is to Provide Customers Clean Water Treatment Solutions to Positively Impact the Environment, Improve Health and Increase Productivity."

Water Quality is a Key Driver of Your Livestock Business

Water is an essential component to the diet of livestock and its quality is directly related to several key production metrics, particularly in today's hyper-competitive and high-producing livestock industries. Several key water constituents are commonly evaluated to determine the potability of new water sources and to monitor for potential changes in existing systems. There are many constituents and contaminants in source waters and their potential interactions with livestock production are complex. Some constituents are directly toxic to livestock at certain levels. Other constituents may impact livestock health by altering the bio-availability of separate key nutrients or by acting synergistically with other potentially toxic metals. Some constituents pose a limited direct health risk due to relatively low toxicity but may contribute to water system fouling and/or palatability issues that can indirectly impact livestock production.

Silver Bullet: Providing You Water Quality Profiles to Help Make the Best Treatment Decision

Using our own expertise and supported by independent, third-party research, Silver Bullet Water Treatment has prepared this reference guide to help you understand the constituents and contaminants in your water quality profile. Our goal is to help you better understand the Silver Bullet evaluation of your water quality, why the constituents and contaminants are important to a livestock producer and the options that are typically employed to effectively treat similar water profiles.

This guide is one of the many tools your Silver Bullet solutions provider will use with you to determine the best water treatment method for your specific water profile and farm. Silver Bullet's promise to you is to make the water treatment solution decision-making process completely transparent. We value the trust you put in Silver Bullet to treat your water. Better.

The Potential Risks, By-Products and Impacts on Livestock of Hazardous Chemical Water Treatment Methods

Silver Bullet does not recommend extensive traditional liquid chemical-based treatments because they often increase logistical, environmental and compatibility risks. Liquid chemicals pose environmental hazard and safety concerns associated with additional handling. Environmental release and exposure issues in storage that could result in violent reactions and toxic releases are a further problem associated with the use of traditional chemicals. Most importantly, your livestock's health and production may be negatively impacted by chemicals such as bleach, acids, and iodine, which form potentially harmful by-products. Relatively low doses of liquid disinfectants can produce a poor water taste and odor, reducing livestock consumption of water and feed, less efficient feed conversion and potentially decreased production.

Silver Bullet: Environmentally-Friendly Livestock Drinking Water Solutions

- ✓ **The Silver Bullet:** Non-corrosive, contributes to water de-contamination, inhibits scale, and improves water taste and odor to positively impact livestock production.
- ✓ **Ultraviolet Disinfection:** Direct ultraviolet radiation system that is lethal to bacteria, viruses and other microorganisms in water. Ultraviolet disinfection is completely safe for both your animals and the consumer.
- ✓ **Media Filtration:** Media filtration is used to reduce the level of suspended solids (turbidity) and precipitated metals from source waters, with the primary goal of improving water taste & odor and to increase overall water system efficiency.

ALKALINITY AND pH

Guideline[1]	Interactions	Health Impacts	System Impacts
>5.5 , < 8.5	• Metabolic acidosis • Metabolic alkalosis	• Reduced water uptake • Reduced feed uptake • Watery stools • Reduced feed conversion	• Corrosion (low pH) • Increased scaling tendency (high pH)

Description: Alkalinity is a measure of water's ability to resist changes in pH, related to buffering capacity, and is typically reported in mg/L as calcium carbonate. The pH of water represents the concentration of hydrogen ions present and is reported as a unit-less number between 0 and 14. Levels lower than 7 are considered acidic and levels above 7 are considered basic or alkaline. The pH of a water source is related to the form in which alkalinity will occur (e.g. carbonic acid, bicarbonate, or carbonate).

Typical Sources: The pH and alkalinity of a water are influenced by a number of factors. Alkalinity is typically higher in ground water sources that come in contact with carbonate formations vs surface waters. The pH of most natural waters is typically near 7.0 which is considered to be neutral. Large discrepancies from the neutral pH range may indicate contamination by an acid or base.

Treatment Options: The most common treatment option for pH and alkalinity is with the addition of acidic or basic (alkaline) chemicals to swing the range back to a desired range.

ARSENIC

Guideline[1]	Interactions	Health Impacts	System Impacts
25 µg/L	• Iodine, selenium & copper deficiencies via secretion.	• White muscle disease[2] • Reduced growth • Reduced reproductive efficiency. • Cancer	• None anticipated.

Description: Arsenic is member of metalloids and is commonly found in nature in a number of different forms. Some of these forms are more toxic than others to livestock health but may show similar symptoms once the toxic levels are reached.

Typical Sources: Arsenic can come from a variety of sources including mineral and ore depositions, coal burning, waste incineration, industrial run-off, smelting and subsequent atmospheric deposition.

Treatment Options: The treatment options for arsenic include oxidation with filtration, coagulation, greensand, nano-filtration, activated alumina adsorption or reverse osmosis.[3]

BACTERIA (Total Heterotrophic Plate Count - HPC)

Guideline[4]	Interactions	Health Impacts	System Impacts[5]
1,000 cfu/cc	• Potential for disease illness and infection	• Reduced water uptake • Illness	• Possible plugging / fouling. • System may go septic in extreme cases.

Description: Bacteria and other microbes are extremely prevalent in the environment and occupy virtually all known ecological niches. A common measurement of general bacterial activity in a water source is the heterotrophic plate count (HPC). Bacteria are commonly measured in colony forming units per milliliter (cfu/mL) which is roughly equivalent to "cells per milliliter". HPC measurements includes both harmful bacteria (pathogenic) and harmless varieties which are not directly associated with disease.

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[1] Olkowski, A. A. *Livestock Water Quality.* Department of Agriculture. Saskatchewan. 2009.

[2] Hall, John B. *Selenium Supplementation Strategies for Cow/Calf Herds.* "The Cow-Calf Manager" Virginia Cooperative Extension. Virginia Tech. April 2006.

[3] *Treatment Technologies for Arsenic Removal.* "NSCEP". National Risk Management Research Laboratory. EPA. November, 2005.

[4] Watkins, Susan. *Water: Identifying and Correcting Challenges.* Division of Agriculture. University of Arkansas. November, 2008.

Therefore, HPC can be used only as an indirect level of system "cleanliness" and not as a direct indicator of disease potential. Large numbers of bacteria can be indicative of potential biofilm or slime formation that can cause secondary system issues including plugging and fouling. The use of oxygen by excess levels of HPC can create anaerobic microenvironments that can contribute to corrosion and proliferation of anaerobic bacteria.

Typical Sources: Due to its prevalence in nature, small levels of bacteria in livestock drinking system are not unusual. Elevated levels of HPC may be due to contamination from septic sources, animal waste or may be initiated by changes in the water itself such as increased levels of available nutrients or temperature.

Treatment Options: There are a number of treatment options available for microbial management including; UV disinfection, oxidant chemistries, organic or inorganic biocides, nano-filtration or reverse osmosis (typically with a combination of other disinfection processes).

CALCIUM (Hardness)

Guideline[5]	Interactions	Health Impacts	System Impacts[5]
80 mg/L	• Phosphorous and zinc metabolic interferences. • Secondary sulfur and molybdenum deficiencies.	• Skeletal / muscular issues • Decreased feed uptake • Digestion issues	• Scaling and staining potential at elevated levels.

Description: Calcium is considered an essential nutrient for livestock and most levels of dissolved calcium fall within a range that is considered safe for consumption with a low potential for acute toxicity. Calcium is associated with water hardness (Table 1: Hardness levels) and in most systems acts as a nuisance constituent associated with scale formation at levels between 80 mg/L and above. Livestock health issues may begin to manifest at levels above 1,000 mg/L[6].

Hardness (mg/l as CaCO3)	Classification
0-75	Soft
75-150	Moderately Hard
150-300	Hard
>300	Very Hard

Table 1: Hardness levels

Typical Sources: Calcium is commonly found in a number of natural waters but is most commonly associated with ground water sources that are influenced by geologic formations such as limestone. Contamination from certain industrial processes or chemical additions may also contribute to calcium levels.

Treatment Options: Treatment options include softening technology, ion-exchange, nano-filtration or reverse osmosis.

COLIFORMS

Guideline[13]	Interactions	Health Impacts	System Impacts[5]
50 cfu/cc	• Potential for disease, Illness and infection • Septicemia in extreme cases.	• Reduced water uptake • Illness	• Possible biofilm formation. • System may go septic in extreme cases.

[5] Edzwald, James K., ed. *Water Quality & Treatment: A Handbook on Drinking Water*. Sixth ed. New York: McGraw-Hill, 2011. Print.

[6] Beede, David K. *Evaluation of Water Quality and Nutrition for Dairy Cattle.* Department of Animal Science. Michigan State University. 2006.

Description: Coliforms are a broad classification of gram-negative rod-shaped bacteria often associated with a number of pathogenic species. Coliforms include a number of genus' including *Escherichia, Klebsiella, Enterobacter, Citrobacter* and *Hafnia*. Coliforms are a common indicator of sanitary quality of water and many species are associated with common diseases. Under certain circumstances, coliforms can also contribute to biofilm formation.

Typical Sources: Coliforms can be found in a number of environments including aquatic, soil and vegetation. Coliforms can be found in the feces of all warm-blooded animals. Under appropriate growing conditions, coliforms can proliferate from relatively low levels to hazardous levels.
Treatment Options: There are a variety of treatment options available for coliforms including oxidation, UV, biocides, non-filtration and reverse osmosis (with additional pre-treatment).

CHLORIDE

Guideline[4]	Interactions	Health Impacts	System Impacts
150 mg/L	• Cellular dehydration • Disturbed acid-base homeostasis.	• Decreased water uptake • Decreased feed uptake • Decreased growth rate • Mild diarrhea • Edema	• None anticipated.

Description: Chloride ion is a common dissolved constituent in natural waters and is often the most prevalent anion in a water system. Most livestock can tolerate chloride ingestion at relatively large amounts without significant health issues. Most guidelines, including the one listed above, represent an aesthetic limit where the palatability of the water may be reduced causing a decrease in water uptake. Chlorides above 1,000 mg/L may begin to show some health impacts, keeping in mind that chlorides are associated with other constituents (cations), such as sodium, that also contribute to similar health concerns.

Typical Sources: Chloride can come from a variety of sources both natural and as a result of various anthropogenic processes. Water from deep wells commonly have elevated levels of chlorides. Surface waters that originally have low to moderate levels of chlorides can concentrate those levels by evaporation to the point where they may cause some concern.

Treatment Options: Treatment for chlorides is typically restricted to reverse osmosis technologies.

FLUORIDE

Guideline[1]	Interactions	Health Impacts	System Impacts
2 mg/L	• Metabolic Interferences in Fe, Mn, Mo, Zn, Mg & Cu • Folic acid and vitamin B12 deficiencies.	• Tooth enamel reductions • Cardiac issues • Respiratory issues • Gastroenteritis • Bone lesions • Suppressed immune system	• None anticipated.

Description: Fluoride is a stable anionic form of fluorine and is commonly found in the environment. Fluoride toxicity can occur at elevated levels, known as fluorosis, and can lead to numerous health issues. The toxicity of fluoride varies based on its form as some forms are more soluble and bio-available than others.

Typical Sources: A large portion of dissolved fluoride introduced into the environment comes from industrial processes such as aluminum smelting, phosphate fertilizer manufacturing, and various other chemical processes. Municipalities often dose low levels of fluoride that can be concentrated during evaporation.

Treatment Options: Treatment for fluoride is typically restricted to ion-exchange, nano-filtration or reverse osmosis.

HYDROGEN SULFIDE

Guideline[7]	Interactions	Health Impacts	System Impacts[8]
20 mg/L	• Binds to iron, limits aerobic respiration • High lipid solubility	• CNS & pulmonary system Impacts. • Suffocation • Reduced water uptake • Potential death at high levels.	• Corrosion • Metal sulfides are insoluble and can cause plugging / fouling • Rotten egg smell • "Black water"

Description: Hydrogen sulfide (H_2S) is a colorless gas that has a characteristic "rotten egg" odor. In high levels it is corrosive and flammable. It is denser than air and can settle into low-laying pockets and dissolve into water. It can be detected at levels as low as 0.5 ppb but can overwhelm the olfactory system at higher levels making it unnoticeable. OSHA sets exposure limits to 20 ppm, with 50 ppm being the maximum exposure peak and 100 ppm considered immediately dangerous to life or health.

Typical Sources: Hydrogen sulfide is typically generated by the anaerobic decay of organic matter (often mediated by sulfate reducing bacteria). H_2S can also be generated as a result of industrial processes.

Treatment Options: There are a number of treatment options for hydrogen sulfide including oxidation, media filtration, ion-exchange, greensand, aeration, chemical scavengers (e.g. triazine), and/or microbial intervention to limit the source of H_2S.

IRON

Guideline[9]	Interactions	Health Impacts	System Impacts[5]
0.3 mg/L	• Deficiencies in Cu, Se, Co, Mn & Zn • Proliferation of *Clostridium spp.*[1]	• Reduced feed uptake • Decreased growth rate • Reduced water uptake • Gastroenteritis	• Precipitated form may lead to plugging or clogging of piping systems. • Staining • Metallic taste

Description: Iron is a common element found in the earth's crust and in the biosphere. The amount of iron present in a water system is highly dependent on the source of water. Iron found in water can exist in two primary forms, dissolved and suspended (ferrous and ferric, respectively). Iron is considered to have relatively low toxicity in the levels commonly encountered in water systems. Therefore, iron is considered more of a nuisance constituent associated with staining, solids accumulation, plugging/fouling and metallic taste which can reduce the amount of water consumed by livestock.

Typical Sources: Dissolved iron typically exists in ground water sources or environments low in oxygen as ambient air tends to oxidize it into an insoluble form. Waters high in dissolved oxygen (DO) tend to be lower in iron[10].

Treatment Options: Treatment options include oxidation followed by filtration, greensand filters, coagulation, nano-filtration or reverse osmosis[8].

[7] *Toxic Substances Portal – Hydrogen Sulfide Carbonyl Sulfide.* Agency for Toxic Substances & Disease Registry. Center for Disease Control. <https://www.atsdr.cdc.gov/mmg/mmg.asp?id=385&tid=67> October, 2014.

[8] Tchobanoglous, George. Wastewater Engineering Treatment and Resource Recovery. Fifth ed. New York: McGraw-Hill Education, 2014. Print.

[9] Swistock, Bryan. *Interpreting Drinking Water Tests for Dairy Cows.* Penn State college of Agricultural Sciences Extension. "Water Facts 12." Pennsylvania State University. 2017.

[10] Civardi, John. Tompeck, Mark. *Iron and Manganese Removal Handbook.* American Water Works Association. 2015.

LEAD

Guideline[7]	Interactions	Health Impacts	System Impacts
0.1 mg/L	• Increase Zn but reduce Cu & Mn in the Liver. • Limits vitamin D metabolism.	• Skeletal, renal, endocrine, immune and reproductive systems can be negatively impacted.	• None anticipated

Description: Lead is a naturally occurring metal in the earth's crust. However, lead typically does not exceed levels above 13 mg/kg outside of particular lead ore deposits. Most lead in water systems is carried in suspended particulate matter with an estimated 10% of the total lead concentration considered to be dissolved.

Typical Sources: Outside of naturally occurring lead ore deposits, much of lead (that exceeds the average 13 mg/kg average) is due to anthropogenic sources including industrial activities, battery waste, unleaded gasoline emissions, lead shot/bullets, lead fishing sinkers and leaded paints, among others.

Treatment Options: Treatment of lead typically consists of nano-filtration or reverse osmosis.

MAGNESIUM

Guideline[4]	Interactions	Health Impacts	System Impacts[5]
125 mg/L	• Deficiencies in Cu, Fe Mn, Zn, & Ca • Bone mineralization Adversely effected.	• Scouring • Altered locomotion • Lethargy • Frequent, watery stools (particularly when associated with high sulfates.)	• Scale formation may lead to plugging or clogging of piping systems. • Staining

Description: Magnesium is an essential nutrient and is commonly found in natural waters and is associated with calcium in water hardness. Like calcium, the amount of magnesium present depends heavily on the water's source with ground water typically containing higher amounts of magnesium than fresh surface water. The bioavailability of magnesium depends heavily on its source (e.g. drinking water, feed stock, supplements, etc.) Livestock health effects associated with excess magnesium are uncommon. However, if high levels of sulfates are also present, the combination can produce Epsom salts leading to a laxative effect. Typically, elevated levels of magnesium are associated with system fouling due to scale formation from hard water.

Typical Sources: Like calcium, magnesium is commonly found in a number of natural waters but is most commonly associated with ground water sources that are influenced by geologic formations such as limestone. Contamination from certain industrial processes or chemical additions may also contribute to magnesium levels including certain road de-icing processes.

Treatment Options: Treatment for magnesium may include water softening technologies, ion-exchange, nano-filtration or reverse osmosis.

MANGANESE

Guideline[11]	Interactions	Health Impacts	System Impacts[5]
0.05 mg/L	• Effect metabolism in Ca, Co, Cd, P, Zn & Fe • Reduction in hemoglobin.	• Reduced water uptake • Reproductive and neurological issues. • Lethargy	• Precipitation may lead to plugging or clogging of piping systems. • Staining • Metallic taste

[11] Higgins, Stephen F. Agouridis, Carmen T. *Drinking Water Quality Guidelines for Cattle.* UK Cooperative Extension Service. University of Kentucky. College of Agriculture. 2008.

Description: Manganese is a metal found in naturally occurring water either dissolved or precipitated depending on its oxidation state. Manganese is considered to be relatively low in toxicity and there is no generally accepted limit in water for health risks. Additionally, the majority of manganese exposure is likely to come from feed stocks vs water sources. The listed health impacts only occur in extreme cases where total dietary exposure occurs in the 1,000 to 2,000 mg/L range. An aesthetic limit of 0.05 mg/L has been generally accepted to limit staining, palatability issues and water system impacts due to precipitation that may lead to plugging/fouling.

Typical Sources: Dissolved manganese is typically associated with ground water or sources of water low in oxygen as exposure to air over time tends to oxidize manganese causing it to precipitate into a suspended solid.

Treatment Options: Treatment for manganese may include oxidation followed filtration, greensand filtration, nano-filtration or reverse osmosis.

MOLYBDENUM

Guideline[1]	Interactions	Health Impacts	System Impacts
0.5 mg/L	• Deficiencies in Cu, & sulfate • Bone dystrophies	• Growth reduction • Appetite suppression • Watery stool • Anemia	• None anticipated.

Description: Molybdenum is a metal that is present in varying levels in livestock drinking water. Generally the majority of dietary molybdenum exposure is from feedstock as opposed to water consumption. Poultry and swine are most tolerant to excess levels of molybdenum whereas horses and cattle are more sensitive, particularly young or sick individuals.

Typical Sources: Molybdenum levels are closely related to the concentration present in the local soils which can be impacted by local geologies or industrial processes.

Treatment Options: Treatment for molybdenum is typically restricted to nano-filtration or reverse osmosis.

MERCURY

Guideline[12]	Interactions	Health Impacts	System Impacts
0.01 mg/L	• Impacts metabolism Of Se and Zn. • Neurologic, gastrointestinal and/or renal issues.	• Vomiting • Bio-accumulation • Uremia (nitrogen waste in blood) • Ataxia (loss of coordination)	• None anticipated.

Description: Mercury is a toxic metal that occurs in three forms; elemental, organic and inorganic mercury. All forms are toxic but the organic form, particularly methylmercury due to its ability to be readily absorbed into the body. Elemental mercury can volatize and be absorbed by the lungs. In addition to its acute toxicity, mercury bio-accumulates making it a concern for human consumption of livestock that have been exposed to mercury.

Typical Sources: Mercury is typically found in very low concentrations in nature (< 0.05µg/L) unless a contamination event occurred. Mercury contamination can come from a variety of consumer waste products and industrial processes.

Treatment Options: Treatment for mercury is typically restricted to nano-filtration or reverse osmosis.

[12] Heugten, Eric van. *Guidelines for Water Quality in Pigs.* Animal Science Facts. Extension Swine Husbandry. North Carolina State University. ANS00-8118.

NITRATE AND NITRITE

Guideline	Interactions	Health Impacts	System Impacts
100 mg/L and10 mg/L respectively	• Limits ability to absorb and utilize oxygen. • Conversion of hemoglobin to methemoglobin.	• Reduced growth rates. • Symptoms of lack of oxygen. • Vitamin A & E deficiencies.	• Can lead to algae and biofilm growth, causing plugging and fouling. • Can impact the taste and palatability of water.

Description: Nitrate and nitrite can be found in natural waters and are both forms of oxidized nitrogen (NO_3, NO_2, respectively). Typically, nitrate is more prevalent but occurs in concentration of < 1mg/L in most unpolluted waters. Nitrates and nitrites can be reported as their ion (e.g. nitrate ion, NO_3^-) or as total nitrogen content (e.g. nitrate nitrogen, N-NO_3). Nitrogen makes up roughly 22.6% of the mass of nitrate ion so limits reported as N-NO_3 are lower than those reported as nitrate ion. In addition to being a potential toxin, nitrates and nitrites are an essential nutrient in the development of algae and can contribute to algal blooms.

Typical Sources: Elevated levels of nitrates and nitrites may occur in some ground waters but are most commonly associated with contamination from excessive fertilization practices and subsequent run-off.

Treatment Options: Treatment for nitrates and nitrites may include ion exchange resins, controlled biological processes, nano-filtration or reverse osmosis.

TASTE AND ODOR

Guideline[13]	Interactions	Health Impacts	System Impacts
3.0 T.O.N.	• Depends on T&O source but may include interactions similar to Fe, Cu, Mn, SO_4, TDS, Zn, etc.	• Reduced water uptake • Impacts related to Fe, Mn, Cu, SO_4, TDS, Zn, etc. depending on T&O source.	• Depends on T&O source.

Description: Taste and odor (T&O) is considered a secondary contaminate associated with water aesthetics and palatability. Taste and odor in excess can impact an animal's willingness to consume sufficient amounts of water to maintain a healthy lifestyle. Water consumption is linked to several key production metrics including total weight, morbidity and mortality. A lack of quality, palatable water can negatively impact those key production metrics. Taste and odor can by characterized semi-quantitatively using the Threshold Odor Number (T.O.N.) which is determined using various dilutions of the sample water into odor-free water until no odor is perceived. The test is subjective based on the tester's interpretation so panel evaluations are preferred. Similar tests can be conducted to determine the taste threshold.

Typical Sources: Taste and odor metrics represent an index of several possible contributing constituents. Different combinations and levels of each T&O constituent means there are several possible sources that contribute to T&O. Some common constituents include chlorides (and TDS), iron, manganese, copper, zinc, pH, sulfurous compounds, bacteria, foaming agents, etc.[14]

Treatment Options: The treatment process to limit the impacts of T&O should be determined based on the primary contributing T&O constituent and may include oxidation, media filtration, microbial disinfection, nano-filtration or reverse osmosis. It is important to note that certain treatment processes can negatively impact T&O by adding a chemical or otherwise non-palatable taste/odor to a water source (e.g. excess bleach used as a biocide).

[13] Bradshaw, Michael H. Powell, Morgan G. *Water Quality: Understanding your Water Test Report.* Kansas State University. Agricultural Experiment Station and Cooperative Extension Service. 2004.

[14] *Secondary Drinking Water Standards: Guidance for Nuisance Chemicals.* United States Environmental Protection Agency. <https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals>. 2017.

TOTAL DISSOLVED SOLIDS

Guideline[9]	Interactions	Health Impacts	System Impacts
1,000 mg/L	• Depends on TDS source.	• Reduced water uptake • Watery stools • Decreased growth rate • Reduced dairy yield	• None anticipated.

Description: Total dissolved solids (TDS) is a measure of the soluble materials in a water system. It is typically associated with a water's salinity which is made up of soluble inorganics such as sodium, chloride, sulfates, calcium and magnesium. The recommended range of TDS varies species to species due to differences in metabolic activity and water requirements. TDS below recommended levels are considered safe for consumption, maximum levels should be avoided if possible but should not present adverse effects under normal growing conditions and tolerance limits should be avoided for normal growing conditions but may safe under limited exposures. The direct metabolic interacts of TDS are difficult to define as TDS constitutes a number of separate constituents but may correlate with the interactions associated with chlorides, sodium and/or sulfates.

Typical Sources: TDS is affected by a number of potential sources in natural systems. Ground water, particularly in deep wells, tends to be higher in TDS as it contacts local geologic formations that contain soluble inorganic salts. In certain regions, salt water intrusion can also influence TDS.

Treatment Options: Treatment for TDS is typically limited to nano-filtration or reverse osmosis.

SELENIUM

Guideline[1]	Interactions	Health Impacts	System Impacts
0.05 mg/L	• May be substituted for sulfur in some biological processes. • Interacts with As, Cd, Ag, Ca, Cu, Hg, Zn, Pb	• Weight loss • Fertility issues • Shedding of hoofs or hair • Joint issues	• None anticipated.

Description: Selenium is a non-metal element that is present in low levels in soils and rocks. Elevated levels of selenium may be present in certain plants that act as a point of bio-accumulation. Livestock that consume plants of this type may be at risk of an acute, toxic dose of selenium. A deficiency in vitamin E may exacerbate selenium toxicity.

Typical Sources: Selenium is naturally present in low levels in the environment. Excess levels may occur in areas contaminated by various industrial processes.

Treatment Options: Treatment for selenium typically consists of nano-filtration or reverse osmosis.

SODIUM

Guideline[6]	Interactions	Health Impacts	System Impacts
1,000 mg/L	• Cellular dehydration • Disrupted acid-base homeostasis • Interactions similar to Cl^- or SO_4 toxicity.	• Watery stools • Increased thirst • Muscle spasms • Reduced water uptake	• None anticipated.

Description: Sodium is an alkali metal that is prevalent throughout the environment. In human drinking water the aesthetic limit for sodium is 200 mg/L, above which water begins to lose its palatability. On its own, sodium is not considered a toxic element as livestock have effective biological methods for handling sodium intake. Sodium ions do not occur on their own, they are accompanied with an associated anion. Chloride and sulfate are common examples of anions associated with sodium and may play a major role in sodium toxicity.

Typical Sources: Sodium's concentration in water systems depends on local and geologic conditions as well as anthropogenic activities such as road de-icing or other industrial activities. Certain water treatment activities such as ion-exchange softening systems can contribute a significant amount of sodium as a treatment by-product.

Treatment Options: Treatment for sodium is typically restricted to nano-filtration or reverse osmosis.

SULFATE

Guideline[15]	Interactions	Health Impacts	System Impacts
1,000 mg/L or 333 mg/L as S	• Conversion to toxic sulfide metabolites. • Increase in gut SRBs • Cu deficiencies • Interactions with Ca, P, Se, Zn, Mn, Mg, Mo, Fe, and I • Cytochrome C oxidase inhibition	• PEM (brain tissue necrosis) • Watery stools • Decreased water uptake • Symptoms associated with Cu deficiencies.	• Possible scale formation • Possible SRB proliferation leading to H_2S.

Description: Sulfate is a polyatomic molecule and is the most common form of sulfur in naturally occurring water systems. In reducing environments or anaerobic environments with the aid of certain microbes, sulfates can be converted into sulfides, such as hydrogen sulfide, which have their own unique properties. Sulfur can be detrimental to all classes of livestock but is of particular concern in ruminants. In ruminants sulfate is metabolically converted into sulfides by gut microbiota. The sulfides are oxidized by separate tissues into sulfites and back into sulfate which is secreted through saliva and subsequently recycled in this process. This cyclic metabolic process can lead to an increase in sulfate reducing bacteria (SRB) in the gut which can further contribute to toxic buildup of sulfur metabolites. In addition to direct toxicity, dietary sulfur has several important nutrient interactions that can pose adverse effects.

Typical Sources: Sulfates are commonly found in natural waters. Ground waters in contact with local geologies tend to have higher levels of sulfates than fresh surface waters.

Treatment Options: Treatment options include ion exchange, nano-filtration or reverse osmosis.

[15] Knight, Tony. *Sulfate Toxicity in Cattle.* CSU Veterinary Extension. Colorado State University. <http://webdoc.agsci.colostate.edu/ansc/bb_s11.pdf>.