Weld Laboratories

Understanding Limits for Livestock Water

2020 v1.1

by Adam Crooks

About us

Weld Laboratories has served the analytical needs of the agricultural and environmental industries for over 40 years. We have found that they key to good chemistry is having great chemists.

From alfalfa and corn silage analyses to soil, manure, water, and gas/oil spill testing, Weld Labs offers a comprehensive list of analytical services to meet your needs.

Weld Labs has continuously been certified by the National Forage Testing Association (NFTA) since 1986 and holds certification in both NIRS and Wet Chemistry analyses.

Weld Laboratories

Table of Contents

Sample Water Report -Livestock Basic

This is an example of our basic livestock package. Each line is explained in a separate section below.

January 1, 2020

Livestock Water Customer
1527 First Ave.
Greeley, CO 80631

Laboratory No. E19499-12
Sample ID: Well #17

	Results	Livestock Quality Threshold
Calcium (ppm)	27.30	< 500 ppm
Magnesium (ppm)	11.5	> 20 ppm
Sodium (ppm)	155.5	< 400 ppm
Hardness (ppm)	115	--
(in grains/gallon)	6.7	--
Sodium Adsoption Ratio	6.3	--
Sulfate-S (ppm)	**107**	**< 250 ppm**
Total Dissolved Solids (ppm)	663	< 1000 ppm
Nitrate-N (ppm)	**9.7**	**< 20 ppm**
pH	8.38	6 - 8
EC	1.036	< 1.56 mS/cm
Potassium (ppm)		--
Iron (ppm)		< 0.3 ppm
Copper (ppm)		< 0.5 ppm
Zinc (pm)		< 25 ppm
Manganese (ppm)		< 0.3 ppm
Fecal Coliform (cfu/100ml)		< 10 cfu/100ml
Alkalinity, mg $CaCO_3$/L		< 750 ppm
Total Solids (ppm)		< 1500 ppm

Project Manager

Date

Notes: NA = Not Applicable or Not Analyzed
Results in bold are the most important indices for livestock water quality

Introduction

Table 1. Approximate Water Intake (L/day)[1]

Cows	
Beef	26-66
Feeder calves	18-27
Steers	36-45
Dairy	28-110
Dairy (maintenance)	55-68
Dairy (lactating)	68-114
Calves (4-8 weeks)	4.5-6.8
Calves (12-20 weeks)	9.1-20
Calves (26 weeks)	17-27
Heifers (pregnant)	32-45
Sheep	
Lambs (weaned)	3.5-4.0
Ewes (dry)	4.0-5.0
Ewes (lactating)	4.0-12.0
Goats	
Goats	3.0-15
Horses	
Foals	3.9-5.5
Start drinking at ~1 month old	
Adult Horse	15-42.5
300-850 kg (5L/100kg body weight)	
Lactating Horse	25-70.5
~65% more water than adult horse	
Poultry (L water per week)	
Broiler Chickens	0.225-2
White Leghorn	0.2-1.6
Brown Egg-Laying	0.2-1.5
White Turkeys	0.385-7.04
Swine (L water per day)	
Suckling pigs	0.27-2
Weanling pigs	1-5
Growing pigs	5-10
Finishing pigs	5-12
Gestating sows	5-20
Lactating sows	15-35
Boars	8-17

Water is involved in nearly every biological process of animals. Water is consumed in much larger quantities than feed so quality issues become extremely important. Due to these high quantities there is also a higher risk that low-level contaminants could accumulate to dangerous levels in the body. Water intake (Table 1) of animals depends on a number of factors including genetics (e.g. species and breed), environment (e.g. temperature, humidity) and status (e.g. healthy, two year old, lactating).[1] Many animals can double their intake in the summer when they are using the water to cool their body. A lactating, high production dairy cow drinks about 90L per day at 70°F and can drink 180L (40% of their body weight) during the peak heat of the summer.[2] Cattle with access to plenty of high quality water will consume more dry matter. If the animals are eating lush pasture, spent brewers grain, or liquid feeds much of their water requirement may be met by the feed.

Water is lost through respiration, feces, and urine. Animal metabolic rate is correlated to water loss.[1] Water turnover varies depending on species as well. Sheep and goats are more economical than cattle by a factor of about two. Lactation increases body energy and water requirements by 40-65% (Table 1).

The most common water problems are high concentrations of minerals, nitrates, nitrites, sulfates, bacterial contamination, and chemical contamination from industrial activities.[1] Issues with these contaminants are more likely during the summer months where intake is highest and animals are fed low moisture feed. River water is generally safer than pond or well water because large bodies of free-flowing water are capable of natural decontamination (Figure 1, below).[1]

Horses may be more sensitive to water quality. When the water sources are unpalatable, intake drops. Without enough water there is increased risk of colic.[1] If the horse is working hard (eg. pulling a plow, racing, or even just a longer than usual ride) it will need extra water during and after the work.[A]

Water should be tested every year. It should also be tested any time animal performance or behavior while drinking changes. If there are new issues with clarity or odor of the water sources it is worth testing again. It is always important to speak with a nutritionist and acknowledge feed inputs as sources of the same contaminants which could have additive effects with water.

Calcium

Calcium is one of the seven minerals required in large amounts (macrominerals) by all animals. The seven macrominerals are Calcium, Phosphorus, Magnesium, Potassium, Sodium, Chloride, and Sulfur. The primary use for calcium is bone formation.

Olkowski provides a dietary calcium example for a 1200-pound pregnant cow. Safe calcium levels were 20-144 grams per day, excessive 145-201, and toxic levels are reached at over 201 grams/day.[1] This 1200-pound cow would drink about 36 liters (9 gallons) of water per day. The Canadian CCME livestock limit for calcium is 1000 mg/L. At the CCME limit water would contribute 36 grams of calcium. Some labs have set the calcium limit as low as 200 mg/L. We set our calcium limit at 500 mg/L to minimize problems that could occur if dietary calcium was already excessive.

Excessive calcium (especially from water) is rare but health consequences exist. Prolonged exposure to excessive levels of calcium can cause osteopetrosis, vertebral ankylosis, and degenerative osteoarthritis.[1] High dietary calcium can also reduce feed intake and reduce the absorption of phosphorus, zinc, and other metals. In high producing dairy cows excess calcium can be a factor in milk fever and at over 100 grams per day calcium can inhibit parathyroid hormone production.[1]

Water softening and reverse osmosis are the most common treatment technologies to remove excess Ca.

[A] Following strenuous exercise offer about 2L of water every 20 minutes while walking the horse.[3] The walking process helps remove the built-up lactic acid and other metabolites from exercise.[4] Once the horses pulse and respiration rates are back to normal there should be adequate intestinal blood flow to offer feed and unrestricted water.

Magnesium

Another member of the seven macrominerals, magnesium is required in large amounts. It is a cofactor in many enzymes and a component of skeletal tissue. In deficiency it causes grass tetany and a number of other problems. In general, excess magnesium is not a problem, in fact there are no CCME or EPA limits for Mg. Toxic effects related to calcium and phosphorus metabolism have been observed at very high levels. Symptoms don't start until 0.3% (3000 mg/L) in poultry and swine and closer to 0.5% (5000 mg/L) in cattle and sheep. Lethargy and laxative effects can be seen with very high magnesium. Above 400 ppm it may become important to include water contributions to the ration. Although the primary source of magnesium is feed; we are setting a lower limit of 20 ppm to help alleviate the problems with grass tetany in Colorado.

Water softening and reverse osmosis are the most common treatment technologies to remove excess Mg.

Sodium

Another member of the seven macrominerals, sodium is required in large amounts. Thousands of tons of NaCl are produced each year for mineral supplements.[2] Sodium plays a pivotal role in regulating osmotic pressure around the cells of the body.[B] Part of the problem with determining toxicity of sodium is that it is always associated with chlorides and sulfates.

Although sodium concentrations above 200 mg/L can decrease palatability, milk production is not affected until 975 mg/L.[2] Most animals can tolerate large excesses of sodium by increasing their water intake and subsequent Na excretion. We set our limit at 400 mg/L to help protect animals that require extra water to flush any excess dietary sodium. If the water already has too much sodium this natural mechanism fails.[C]

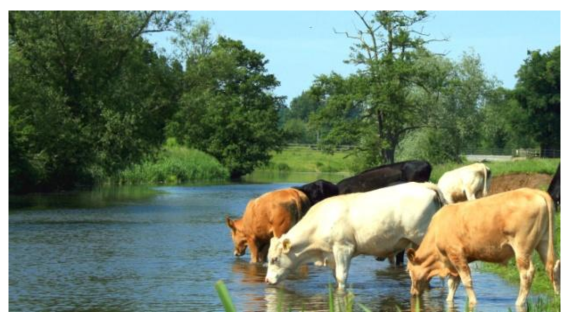

FIGURE 1. CATTLE DRINKING FLOWING WATER BY KEVEN LAW. CC-BY-SA 2.0.

Water softening increases sodium content of water. The most common treatments for removing sodium are distillation, reverse osmosis, and deionizers (which typically replace Na^+ with H^+).

[B] Sodium is the main extracellular cation while potassium is the main intracellular cation.[2]

[C] Note that many labs set the sodium limit lower (50-150 mg/L or ppm)[5], and the literary references herein would place the limit closer to 1000 ppm.[1,2]

SAR, Hardness

Hardness can become a problem if limescale (mostly calcium carbonate) builds up inside boilers or pipes to the point that flow or capacity is reduced.[D] Water hardness can be classified according to severity: soft water is 0-60 mg $CaCO_3$/L (ppm), moderately hard water is 61-120 ppm, hard water is 121-180 ppm, and anything over 180 is very hard. There are no known risks associated with drinking[E] hard water; in fact, there may be health benefits because dietary requirements for magnesium and calcium are more easily met.

Water softening and reverse osmosis are the most common treatment technologies to decrease hardness. Water can be softened by exchanging Na (or K) for Mg and Ca in an ion exchange resin.[F]

The Sodium Adsorption Ratio (SAR) is valuable if the water is also used for irrigation. It is included on the livestock report because many times water must be shared with crops.

Sulfate-S

Sulfur is another essential nutrient for all animals. High levels of sulfate (and other sulfur forms) can be detrimental to all livestock but ruminants are particularly sensitive. If cattle drink too much sulfate or consume too much sulfur in their diet (>0.4% dry matter)[6] they may begin to exhibit muscle spasms, depressed state, and blindness. Goats and sheep may begin pressing their head into walls or other objects (Figure 2). These are symptoms of 'Polio' polioencephalomalacia (PEM) a disease generally caused by disrupted thiamine (vitamin B1) production/utilization in the body.[G] Ruminants generally consume sulfur to produce methionine, homocysteine, cystathionine, cysteine, and other S-amino acids[2] but overconsumption can cause the rumen microflora to produce hydrogen sulfide gas which is inhaled[H] as the animal burps.[6]

[D] Limescale formation is also a function of pH, temperature, and other dissolved species. The Langelier Saturation Index (LSI) is a better model for predicting scale formation.

[E] Humans and livestock can both drink hard water. There are no EPA or CCME guidelines for hardness. Olkowsky sets no limit for livestock in general but mentions 200 ppm as the upper limit for horses.[1]

[F] Many times only the hot water line to the water heater is softened. By softening this line your hot water heater is protected from scale and your dishwasher etc. may require less detergent.

[G] To diagnose PEM your vet will intravenously inject thiamine three times per day to determine whether the problem is thiamine deficiency or sulfate toxicity. If symptoms don't improve after the injections, excess sulfur may be the cause.[6]

[H] This H_2S inhibits cytochrome C. oxidase (part of the electron transport system) and the brain softens. Autopsy of animals killed by excess sulfate reveals characteristic necrotic lesions in the cortical gray matter.[1] As a final note, high sulfur in the rumen can interact with molybdenum forming thiomolybdates which can induce a copper deficiency in the diet (due to reduced bioavailability).[1]

Our reports always list Sulfate-S; to convert to Sulfate simply multiply by three. The CCME guideline for Sulfate-S is 333 mg/L,[1] veterinarian Dr. Tony Knight[6] also recommends staying below 1000 ppm SO_4 (333 mg/L Sulfate-S). Our reports set the limit at 250 ppm to create a small margin of safety in the diet.

Treatment technologies to remove sulfate include distillation, nano-filtration, reverse osmosis, and ion exchange.[1,2]

FIGURE 2. HEAD PRESSING IN SHEEP, A SYMPTOM OF PEM. FROM MIRMANS30.

Total Dissolved Solids (TDS), EC

TDS is defined as all solids that pass through a filter with 2 μm pores.[2] It is the best measure of salinity in a water sample. In clear water it is comprised primarily of positive and negative ions including calcium, magnesium, sodium, carbonate, bicarbonate, fluoride, chloride, sulfate, and nitrate. Due to this ionic composition we can estimate the TDS using electrical conductivity (EC on the report).

One of the most important biological functions of water is as a solvent for animal nutrients and waste products.[2] So-called toxicity of highly saline water may be due to the reduction of its ability to transport nutrients and waste when excess salts are already dissolved in it.[2]

FIGURE 3. HORSES, LIKE THIS AMERICAN QUARTERHORSE ARE TYPICALLY LESS SUSCEPTIBLE TO ELEVATED TDS THAN DAIRY CATTLE. PHOTO BY EVELYNBELGIUM.

There are reports of decreased summer production in dairy cattle at 2040 ppm TDS,[2] swine don't suffer until about 5000 ppm. While horses (Figure 3) are reluctant to drink saline water there is a report suggesting that they can technically survive on 9500 ppm TDS water. Sheep are the least sensitive, one reports suggests they can survive on 13000 ppm TDS water (see Raisbeck et al.[2] and references therein). Poultry are even more sensitive than dairy cattle. The major problem with this TDS test is that it is considered non-specific: animals have different tolerances to different ions. The best way to reduce risk to livestock is to set the TDS limit artificially low (you will see some labs set the limit at 500 ppm TDS). We set our limit at 1000 ppm because that is where palatability problems arise (the NRC sets their limit[5] at 1000 ppm as well).[I] All of our water reports include the most common ions so that there is a good metric for how the TDS is distributed. If your TDS is high and your ions don't approximately sum to your TDS you should consider upgrading to our complete package or ordering an alkalinity test with an additional panel of metals.

Treatment technologies to remove dissolved solids include nano-filtration and reverse osmosis.[1]

pH

The pH of water is a measurement of how acidic or basic the water is.[J] pH 7 is neutral, anything less than seven is acidic, and anything more than 7 basic. pH is a logarithmic scale, so water with a pH of 6 contains ten times as many protons (H^+) as water of pH 7.

The preferred pH of water for cows is 6-8. The EPA lists 6.5 to 8.5 as the preferred pH for humans. Water in swine and rodent facilities is frequently acidified below this to help control bacteria (sometimes down to pH 3).[2] Despite these exceptions, pH 6-8 water seems to be safe for all animals.

Nitrate-N

Nitrate (NO_3^-) is a common oxidized form of nitrogen in the environment. It is one of the forms of nitrogen readily absorbed by plants and is intentionally added for many crops (eg. corn). We always encourage testing of sorghum/sudan, oat hay, millet, and other nitrate-accumulating feeds. Many plants will absorb extra nitrogen to facilitate repair following cell damage (eg. early frost, drought) so it is especially important to test these feeds (for both nitrate and prussic acid) following a large storm. When feeding it is important to stay below 0.5% NO_3 set by the NRC.[1] The numbers we report on manure, water, and fertilizer reports are Nitrate-N (NO_3-N); to convert to nitrate (NO_3) simply multiply by 4.43. To convert from %NO_3 to ppm NO_3 multiply by 10000.

[I] The CCME limit for TDS is 3000 ppm. Olkowski claims[1] that water with less than 1000 ppm TDS is "safe" and adds that 1000-3000 ppm may cause mild temporary diarrhea. At 3000-5000 ppm Olkowski adds[1] that "animal performance may be adversely affected."

[J] pH = -log[H^+]. A distinction should be made between "how basic the water is" and "how alkaline the water is". Alkalinity is the capacity for water to resist changing pH (specifically becoming more acidic). Natural waters are buffered systems of weak acids and their conjugate bases. When measuring alkalinity we titrate water samples with acid to determine the buffer capacity or "alkalinity."

How does nitrate get into the water? Ground and surface water can have nitrate from natural processes but frequently it is due to excessive fertilizers or manure. This excess is consumed by the animal and in the GI tract microbial reduction of nitrate converts it to nitrite (NO_2^-). This nitrite is absorbed into the bloodstream where it oxidizes the ferrous iron in hemoglobin forming methemoglobin which can no longer carry oxygen.[2] Monogastric animals like horses are less susceptible to nitrate, some authors suggest they are ten times less susceptible (see Raisbeck et al. and references therein).[2] This is primarily because they are capable of passing more of the excess nitrate in urine.[K]

Clinical signs of nitrate poisoning in monogastric animals begin with gastritis while in ruminants symptoms look like methemoglobinemia.[1] According to Olkowski[1], key symptoms of acute poisoning include "gasping for air, labored breathing, rapid pulse, frothing at the mouth, convulsions, blue muzzle and bluish tint around the eyes, and chocolate-brown blood." Raisbeck et al. note that all of these symptoms, including eventual collapse (Figure 4) and death, can be explained by a lack of oxygen transport to critical organs like the brain and heart. Nitrate poisoning has also been implicated in abortion[L] and infertility.[1]

FIGURE 4. FOUND ON THE GROUND. PHOTO CROPPED. ORIGINAL BY BEN RUDIAK-GOULD. PUBLIC DOMAIN.

How much Nitrate-N is too much? The CCME guideline is 23 ppm NO_3-N (100 ppm for horses). The NRC claims that < 10 ppm NO_3-N is safe for all ruminants while < 20 ppm is safe for balanced diets with low nitrate feeds.[1] Raisbeck et al. recommend staying below 113 ppm in water (noting that permissible levels may change with feed composition).[2] We have seen a lot of problems with nitrates in Colorado and recommend staying below 20 ppm NO_3-N in livestock water.[M]

Treatment technologies to remove nitrate include nano-filtration, reverse osmosis, specific ion-exchange resins, and biological processes.[1]

[K] Raisbeck et al. note that rumen metabolism allows the animal to convert some of the nitrate to ammonia and amino acids.[2] Unfortunately this digestive process is slow and can permit nitrite to accumulate to dangerous levels. It is possible for ruminants to acclimate to a higher nitrate diet but the process takes time.[1,2]

[L] Pregnant animals that survive episodes of acute nitrate poisoning in late stages of pregnancy may abort within one to two weeks.[2] Animals in early stages are less likely to abort.

[M] It is important to note that nitrite is ten times as toxic as nitrate in monogastric animals and about 2.5 times as toxic in ruminants.[2] The NO_3-N number you receive is analyzed via cadmium reduction which will sum both the nitrate and nitrite species. There have been reports (albeit controversial)[2] that nitrates are more bioavailable in water than feed.

Other

These categories are only seen on our livestock complete test.

Potassium: Potassium is one of the seven macrominerals required in large amounts. While a few other labs have set the upper limit for livestock-water potassium at 20 ppm[5] we can't find any research to support this. There are no CCME limits for potassium. There are no EPA limits for potassium in human drinking water. Olkowski reports that one author set a limit for horses at 1400 mg/L.[1] We don't set potassium limits for livestock water.

Very high dietary potassium can depress magnesium absorption in ruminants.[1] When blood levels of magnesium drop grass tetany can become a problem. Water is not likely to contribute to this problem.[N]

Iron: Iron is the most common element on earth by mass. It is an essential micronutrient, and in deficiency causes anemia in both humans and livestock. Iron is not a toxin in general but can change the taste of the water enough that intake can drop. Iron in extreme excess can interfere with bioavailability of Cu, Zn, Mg, Mn, and Ca.[1] We set our limit at 0.3 ppm because horses are more sensitive than cattle[1] and that is the secondary standard set by the EPA for rusty color and metallic taste in humans.[8]

Treatment technologies to remove iron include: coagulation/flocculation, slow sand filters, specialized activated carbon filters, nano-filtration, reverse osmosis, and oxidation/aeration with settling ponds.[1,9]

Copper: Copper is an essential micronutrient required by all species but toxic in excess. Monogastric animals seem to tolerate excess better than ruminants. Sheep are by far the most sensitive animals to copper poisoning while pigs are the least.[10] The CCME guideline for copper recommends staying below 0.5 to 5 ppm. Olkowski reports a limit for horses at 0.5 ppm.[1] Oetzel recommends staying below 0.5 ppm.[5] The EPA limit for copper in human drinking water is 1.3 ppm.[11] We set our limit at 0.5 ppm to protect the most sensitive species.

Treatment technologies to remove copper include: distillation, reverse osmosis, ion exchange, and activated carbon filters.[12]

Zinc: Zinc is an essential cofactor in many biological enzymes of all animals. Toxic thresholds for zinc are much higher than other micronutrients. The EPA sets a secondary drinking water standard at 5.0 ppm for humans above which a metallic taste is present.[8] The CCME recommends staying below 50 ppm.[1] Oetzel recommends staying below 25 ppm for livestock.[5] Olkowski reported a limit for horses at 25 ppm.[1] We recommend staying below 25 ppm.

[N] If water contains 500 ppm K (a very high number for natural waters)… and a dairy cow at maintenance is drinking about 60L of water… she is obtaining 30 grams of K from the water alone. This is only 12.4% of the K requirement for a mid-lactation dairy cow at 1300 lbs. (Total Mixed Ration containing ~1.2% K with the cow eating 3.4% of its body weight in dry matter).[7]

Treatment technologies to remove zinc include: distillation, reverse osmosis, coagulation/flocculation, ion exchange, activated carbon filters, and slow sand filters.[13]

Manganese: Manganese (Mn) alone has very low toxic potential but it may interfere with metabolism of calcium, cobalt, iron, copper, phosphorus, and zinc. At elevated levels of 45 mg/L anemia was seen in lambs.[1] At concentrations greater than 0.5 ppm palatability becomes an issue.[1] Olkowsky recommends staying below 5 ppm.[1] Oetzel recommends staying below 0.5 ppm. The CCME does not set a limit. We set our limit at 0.3 ppm to protect both animals and water distribution systems. Manganese can still cause gray to black staining down to 0.05 ppm.

Treatment technologies to remove manganese (Mn) include pH modification and filtration, activated carbon filters, nano-filtration, reverse osmosis, oxidation/aeration with settling, and ion exchange.[1,9]

Total Solids: Total solids are typically measured by standard method 2540 B. We dry down 100-200 ml of water at 105°C and weigh the residue. In most clean water supplies the total solids will match the total dissolved solids (TDS).[O] When the water is not clean (eg. particles floating in the water, insect larvae etc.) the Total Solids number will exceed the TDS number. We recommend clear water[P] with total solids below 1500 ppm.

Treatment technologies depend on the nature and size of the particles.

Alkalinity: Alkalinity is the capacity for water to resist changing pH (specifically becoming more acidic). Natural waters are a buffered system in which alkalinity can be approximated by carbonate and bicarbonate alone.[Q] Alkalinity is measured in equivalent ppm $CaCO_3$. Much of the water in Colorado is 200-500 mg/L (ppm) $CaCO_3$ alkalinity. While not a health risk, intake can drop if alkalinity gets too high. Pfost and Fulhage recommend staying below 2000 ppm total alkalinity.[15] Oetzel recommends staying below 500 ppm.[5] We set our limit at 750 ppm for palatability reasons. This 750 mg/L (ppm) equates to water with 1 tablet of common antacid per liter.

Much of the total solids found in natural waters are from alkalinity. When your TDS is more than 500 ppm away from the sum of the other measured species (Ca, Na, Mg, NO_3, SO_4, etc.) in the water it is worth checking.

Treatment technologies to remove alkalinity include: chloride cycle anion exchange, nano-filtration, reverse osmosis, and acidification.

[O] Total Solids can also be measured by filtering water for total suspended solids (TSS) and then drying down the filtrate to determine total dissolved solids (TDS). When this is performed Total Solids = TDS + TSS. It must be understood that TSS is determined from the middle portion of water while stirring. Material with high density (eg gravel) won't be measured because it is stuck at the bottom. Material with low density (eg Styrofoam) also won't be measured because it is floating on the surface.
[P] Water with < 30 Jackson Turbidity is recommended.[14] Staying below about 20 ppm TSS will also accomplish this clarity goal.
[Q] This is carbonate alkalinity and it is the molarity of HCO_3^- + twice the molarity of CO_3^{2-}.

Fecal Coliforms: There are a number of pathogens that livestock may come in contact with. These include *escherichia coli* (E. coli), Salmonella, *campylobacter jejuni* (C. jejuni), leptospira, *burkholderia pseudomallei*, and *clostridium botulinum*. All of these bacteria (and many other parasites) are capable of spreading through the fecal-oral pathway. Since 1976 government has used fecal coliforms as the indicating organism for contamination on this pathway.[16] When fecal coliforms are present other pathogens probably are too.

Fecal Coliforms include *escherichia coli*. We test for these with standard method 9222D (membrane filtration and incubation at 44.5°C on m-FC agar with rosolic acid). The EPA requires human water to detect no fecal coliforms.[11] This is reported as "< 1" colony forming unit (cfu) per 100 ml. The CCME recommends no fecal coliforms and no total coliforms be present for intensive livestock operations. Beede recommends no coliforms for calves but allows up to 10 for cows.[17] We set our limit at 10 cfu/100 ml but warn that younger animals may require cleaner sources. Notably concentrated animal feeding or industrial scale agriculture can cause contaminantion. Typically the water submitted is from the source after flowing for two minutes. If one were to pull the sample from a non-flowing trough or a dugout pond counts would be much higher.[R]

Treatment technologies to remove fecal coliforms (and many of the other parasites) include: chlorination, UV exposure, and boiling.[18]

Notes

If you have reached the end of this document and you have additional questions please first read Olkowsky's pivotal work[1] "Livestock Water Quality: A Field Guide for Cattle, Horses, Poultry, and Swine." After reading Olkowsky, read Raisbeck[2] and Jackson's "Water Quality for Wyoming Livestock & Wildlife: A Review of the Literature Pertaining to Health Effects of Inorganic Contaminants." Links are provided in the Bibliography section. After reading everything I could find on livestock water, these two are truly exemplary.

License and Copyright

[R] Olkowski allows up to 100 cfu/100 ml when sampled in front of the cow.[1] Olkowski reports that clean water in a rural dugout is typically 20-100 E. Coli cfu/100ml (from wildlife presumably) but has seen excess of 10000 after cattle were watered on it.[1]

Bibliography

(1) Olkowski, A. Livestock Water Quality A Field Guide for Cattle, Horses, Poultry, and Swine. University of Saskatchewan 2009. https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf

(2) Raisbeck, M. F.; Riker, S. L.; Tate, C. M.; Jackson, R.; Smith, M. A.; Reddy, K. J.; Zygmunt, J. R. Water Quality for Wyoming Livestock and Wildlife: A Review of the Literature Pertaining to Health Effects of Inorganic Contaminants. University of Wyoming. http://www.wyomingextension.org/agpubs/pubs/B1183.pdf

(3) Blikslager, A. Offering a Horse Water After Exercise - The Horse Owner's Resource. Equus Magazine.

(4) Leading a Hot Horse to Water: Debunking the Myth | petMD https://www.petmd.com/blogs/thedailyvet/aobrien/2013/oct/giving-water-to-horses-after-exercise-myth-reality-30986 (accessed Jun 10, 2018).

(5) Oetzel, G. Water-Quality-Recommendations University of Wisconsin-Oetzel-080104.pdf https://www.vetmed.wisc.edu/dms/fapm/fapmtools/2nutr/Water-Quality-Recommendations-Oetzel-080104.pdf (accessed Apr 18, 2017).

(6) Knight, Dr. T. Sulfate Toxicity in Cattle http://webdoc.agsci.colostate.edu/ansc/bb_s11.pdf (accessed Apr 18, 2017).

(7) Dunham, J. R.; Call, E. P. Feeding Dairy Cows. Kansas State University 1989.

(8) US EPA, O. Secondary Drinking Water Standards: Guidance for Nuisance Chemicals https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals (accessed Dec 21, 2019).

(9) Iron and Manganese In Drinking Water https://www.fs.fed.us/eng/pubs/html/99711308/99711308.html#OFS (accessed Jan 21, 2020).

(10) Van Metre, D. Copper Poisoning in Small Ruminants. Colorado State University Extension Fort Collins, CO.

(11) US EPA, O. National Primary Drinking Water Regulations https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations (accessed Dec 21, 2019).

(12) Copper and Drinking Water from Private Wells | Wells | Private Water Systems | Drinking Water | Healthy Water | CDC https://www.cdc.gov/healthywater/drinking/private/wells/disease/copper.html (accessed Jan 21, 2020).

(13) Zinc (Zn) and water https://www.lenntech.com/periodic/water/zinc/zinc-and-water.htm (accessed Jan 21, 2020).

(15) Pfost, D.; Fulhage, C.; Casteel, S. Water Quality for Livestock Drinking. December 2019.

(16) *USGS Scientific Investigations Report*; Scientific Investigations Report; 2007.

(17) Beede, D. Evaluation of Water Quality and Nutrition for Dairy Cattle. Michigan State University 2006.

(18) Boil Water Response-Information for the Public Health Professional https://www.health.ny.gov/environmental/water/drinking/boilwater/response_information_public_health_professional.htm (accessed Jan 21, 2020).