C 274

Interpretation of Water Analysis for Livestock Suitability

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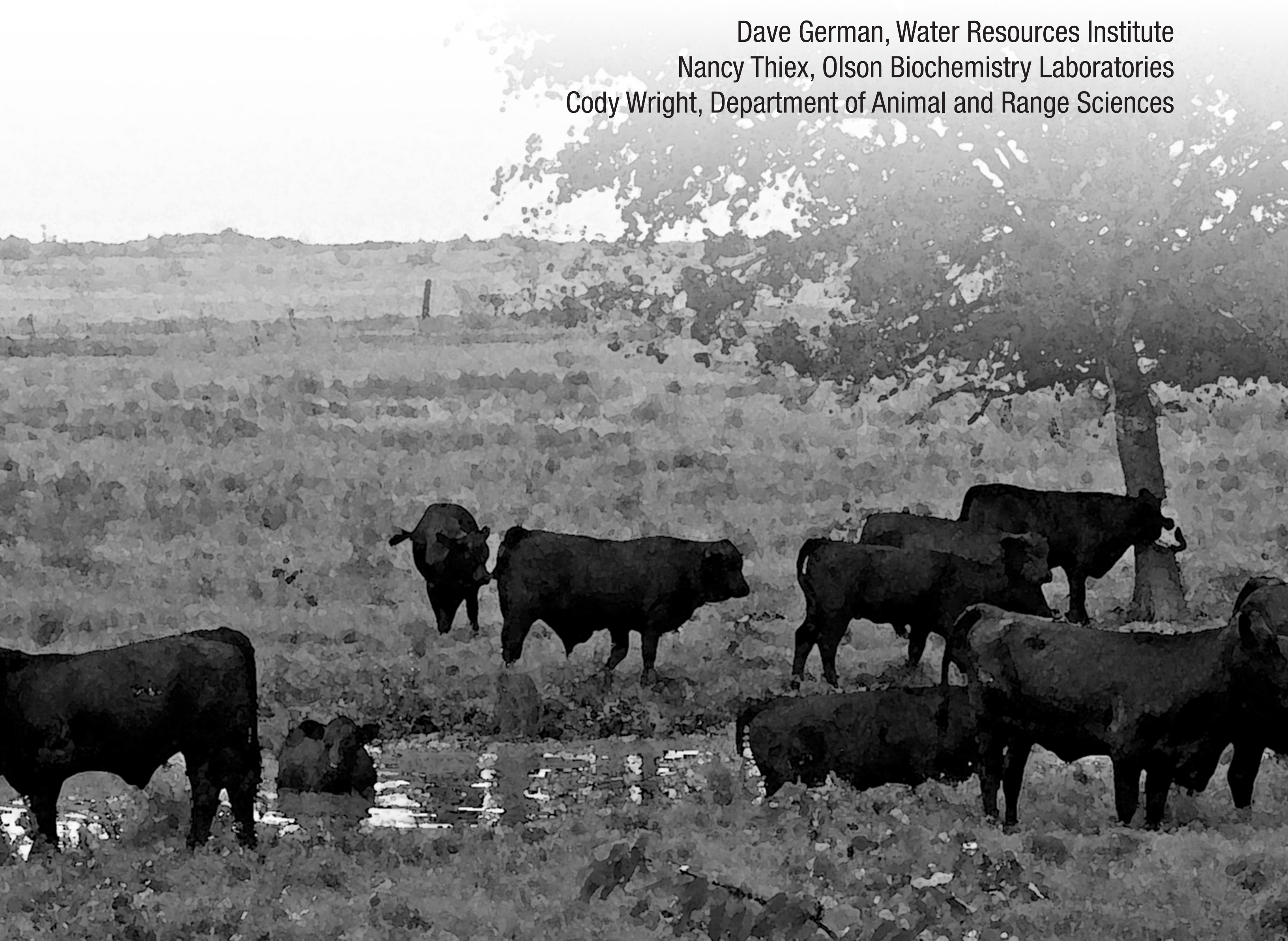

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Introduction

Good quality water is essential for the production of livestock and poultry. In South Dakota, many water supplies have naturally occurring salts that may limit their use. Livestock producers that test their water supply can make informed decisions about the suitability of their water for different classes of livestock. The purpose of this guide is to assist livestock producers in the interpretation of their water analysis.

The interpretation of a water analysis is complicated; when making a recommendation for the use of water for a particular purpose, there are many factors to consider. Often, the person asked to make an interpretation will not have all of the pertinent information about both the water supply and the class of livestock using the water. If you require a more detailed interpretation, please contact the Water Resources Institute (605-688-4910) or email Dave German at david.german@sdstate.edu.

Table 1. Water Consumption For Various Classes Of Livestock

Species	Water consumption (gallons per day)
Beef Cattle	7-12 per head
Dairy Cattle	10-16 per head
Horses	8-12 per head
Swine	3-5 per head
Sheep and Goats	1-4 per head
Chickens	8-10 per 100 birds
Turkeys	10-15 per 100 birds

Water Consumption

The average daily water consumption for various classes of livestock is presented in table 1 (Olson and Fox 1981).

Water quality can affect both the total water consumption by livestock and the health of that livestock. Objectionable taste and odor will discourage livestock water consumption, reduce livestock feed intake, and decrease livestock weight gain.

The water consumption of livestock varies. Consumption is dependent on the animal's age, physiological condition, and diet, as well as on environmental and other factors. Lactating animals require more water and will be more productive if provided with an adequate supply of good quality water.

Water Quality

What are the characteristics of good quality water for livestock? To determine suitability for livestock, the following parameters are analyzed: sodium (Na), alkalinity, sulfate (SO_4), nitrate (NO_3-N), electrical conductivity (E.C.), and hardness. This list represents the parameters most likely to limit the use of livestock waters. While the interpretation for each factor is included in the sections that follow, other factors not tested can also cause the water to be unfit.

In South Dakota, excessive amounts of minerals dissolved in the water can cause it to be unfit. The cations (positively charged ions) calcium, magnesium, and sodium combine with the anions (negatively charged ions) chlorides, sulfates, nitrates, and bicarbonates to form the inorganic salts most commonly found in livestock waters.

The effects of the various salts are cumulative, so measuring total salts is important. Also, because these salts have different physiological effects, determining the type of salts present is important. Sulfate salts are more likely to cause health problems than chloride salts or carbonate salts.

Conductivity/Total Dissolved Solids

Measuring electrical conductivity (EC) provides an indication of the total salts in the water. Based on data from South Dakota water, EC is roughly equivalent to Total Dissolved Solids (TDS), depending on the type of salts present. If the conductivity or TDS is less than 1000 µmhos/cm, it is unlikely that individual salts would cause health problems and no further analysis for salts is necessary. However, as the concentration of salts increases, the risk of health problems and/or reduced productivity may occur.

Saline water toxicity upsets the electrolyte balance in animals and will result in symptoms similar to dehydration. At EC over 10,000 µmhos/cm, water will not be palatable and diarrhea and weight loss can be expected; use is not recommended.

Livestock producers have reported adult cattle surviving on water over 10,000 µmhos/cm conductivity; however, that is not a desirable situation. It may take a long time for animals to acclimate to saline water, and sudden changes from good quality water to saline water may prove fatal to the animals. See table 2 for a general guide to the use of saline water for livestock and poultry.

Sulfates

Sulfates are common in South Dakota waters. Sodium sulfate (Glauber salt) is the most common sulfate salt, but magnesium sulfate (Epsom salt) and calcium sulfate (gypsum) are also present in many waters. All have a laxative effect and impart an objectionable, bitter taste.

Research dating back to the 1950s has clearly demonstrated the impact of high-sulfate water on animal health and performance, and several excellent reviews have been written on the topic (NRC 2005; Kandylis 1984; Veenhuizen and Shurson 1992).

Recently, Patterson et al. (2003) showed a quadratic decline in average daily gain (ADG), dry matter intake (DMI), and gain/feed in confined steers as water sulfate increased from approximately 400 to 4700 mg/L (ppm). These reports also showed that cattle in confinement consuming water with 3000 ppm sulfates or greater during the summer were at a higher risk of polioencephalomalacia (PEM) (Patterson et al. 2002; 2003). Ruminants consuming high dietary sulfur concentrations in combination with high-grain diets are at a particular risk for sulfur-associated PEM (NRC 2005).

The duration of the negative effects of high-sulfate water on livestock has received little attention in the lit-

Table 2. A General Guide to the Use of Saline Water for Livestock and Poultry

Water Salinity (EC)[a] µmho/cm	Comments
_______Less than 1000	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
_______1000-2999	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to the water. May cause watery droppings in poultry.
_______3000-4999	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to the water. Poor water for poultry, often causing watery feces, increased mortality, and decreased growth, especially in turkeys.
_______5000-6999	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.
_______7000-10,000	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows in confinement, horses, sheep, or for the young of any these three species. In general, use should be avoided, although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
_______Over 10,000	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

[a]Electrical conductivity (EC) expressed in umhos/cm at 25°C. TDS (Total Dissolved Solids) is approximately equal to and can be substituted for EC without introducing error in interpretation.

erature. However, one study conducted at SDSU demonstrated that steers receiving water containing 3000 ppm sulfate or less were able to compensate for lost growth performance during the finishing period (Tjardes et al. 2004). Water containing greater than 3000 ppm sulfate may cause reductions in the final weight of the cattle (Tjardes et al. 2004).

The negative response to high-sulfate water does not appear to be as pronounced in grazing cattle. Johnson et al. (2004) demonstrated that water containing 3947 ppm sulfate and greater reduced the ADG of grazing steers and the response was influenced by vegetation (Johnson et al. 2004). In studies with cow-calf pairs, reduced milk production, calf gains, and the percentage of cows bred early in the breeding season occurred when cow-calf pairs consumed water that averaged 3045 ppm sulfate. However, in another year of study, water averaging 2600 ppm sulfate for cow-calf pairs had little impact on calf growth or milk production but caused small reductions in cow body weight and body condition score (Patterson et al. 2005).

Recent evidence suggests that two distinct types of PEM may exist. The first is the PEM traditionally associated with a thiamin deficiency. This form of PEM can be caused by a mild excess of dietary sulfur and can be prevented by supplementing thiamin. If affected animals are identified quickly, they can generally be treated effectively with injectable thiamin and an anti-inflammatory medication.

The second type of PEM has been called sulfur-associated or sulfur-induced PEM. It is more accurately described as a hydrogen sulfide toxicity (Gould 1998; McAllister et al. 1997; Loneragan et al. 1998). Ingestion of high-sulfate water causes increased ruminal H_2S generation (Loneragan et al. 1997). Because of the lower ruminal pH, ruminants consuming high-grain diets are at higher risk for sulfur-associated PEM than those consuming forage-based diets.

In response to the effect of diet on the risk of sulfur-associated PEM in ruminants, the 2005 Mineral Tolerances of Animals (NRC 2005) modified the maximum tolerable sulfur concentration for ruminants. While the 1996 NRC gives a maximum tolerable dietary sulfur level of 0.40% and a requirement of 0.15% of the diet dry matter, the 2005 NRC suggests two different maximum levels, depending on diet. The 2005 NRC suggests a maximum tolerable sulfur level of 0.3% of the diet dry matter for ruminants with diets containing greater than 85% concentrate or more, and 0.5% of the diet dry matter for those consuming at least 40% roughage (NRC 2005). As a rough estimate, each 1000 ppm of sulfate in the water will provide approximately 0.1% sulfur in the total diet.

It is essential to recognize that these maximum tolerable concentrations are expressed as a % of the diet dry matter. As such, it is the combination of sulfur from the diet and water that is critical. Calculating total sulfur intake is wise under any circumstances. However, it is essential for ruminants fed in confinement, particularly if those animals are fed high-sulfur feeds (e.g., molasses, distillers grains, corn gluten feed). The worksheet on page 10 was developed to help calculate total dietary sulfur intake. For assistance with this worksheet, contact Cody Wright by email at cody.wright@sdstate.edu or by phone at (605) 688-5448.

In addition to increasing the potential for sulfur-associated PEM, high concentrations of sulfates can also contribute to copper deficiencies in ruminants. Researchers have clearly demonstrated that the consumption of high-sulfate water can result in a precipitous decline in liver copper stores in growing cattle (Wright et al. 2000; Wright and Patterson 2005). A reduction in copper status can have a negative impact on the health, growth performance, and reproductive function of livestock. Challenges associated with high-sulfate water can often be overcome with alterations to grazing management, water development, and appropriate supplementation strategies (Wright and Patterson 2005). For a guide to the use of water containing sulfates livestock and poultry, refer to table 3.

Sodium

Subsistence on water with a very high sodium content can lead to sodium ion toxicosis, which is diagnosed by high sodium concentration in plasma, cerebrospinal fluid, or brain tissue (Gould 1998).

Excessive levels of sodium (Na) have a diuretic effect. Studies indicate that a sodium level of 50 mg/L (ppm) is detrimental to poultry performance if the sulfate level is also 50 mg/L or higher and the chloride level is 14 mg/L or higher (Carter 1996).

Sodium sulfate is a well-known laxative. By themselves, magnesium and sodium normally pose little risk to livestock, but their association with sulfate is a major

Table 3. A Guide to the Use of Water Containing Sulfates for Livestock and Poultry	
Sulfate (SO4) content mg/L or ppm	Comments
______Less than 250	Recommendations for poultry are variable. The more conservative guidelines indicate that sulfate content above 50 mg/L may affect performance if magnesium and chloride levels are high. Higher sulfate levels have a laxative effect.
______Less than 1500	For livestock, no harmful effects—except some temporary, mild diarrhea near upper limit, and animals may discriminate against the water due to taste at the upper limit (Weeth 1972). The calculation of total sulfur intake is recommended when using sulfur-containing feeds (e.g., molasses, distiller's grains, corn gluten feed).
______1500-2500	For livestock, no harmful effects—except some temporary diarrhea. In cattle this water may contribute significantly to the total dietary sulfur intake. May cause a reduction in copper availability in ruminants. Calculating total sulfur intake is recommended.
______2500-3500	Poor water for poultry, especially turkeys. Very laxative, causing diarrhea in livestock that usually disappears after a few weeks. Sporadic cases of sulfur-associated polioencephalomalacia (PEM) are possible. May cause substantial reduction in copper availability in ruminants. The calculation of total sulfur intake is recommended.
______3500-4500	Very laxative. Unacceptable for poultry. Not recommended for use for pregnant or lactating ruminants or horses, or for ruminants fed in confinement. Sporadic cases of sulfur-associated polioencephalomalacia (PEM) are likely. May cause substantial reduction in copper availability in ruminants. The calculation of total sulfur intake is recommended.
______Over 4500	Not recommended for use under any conditions. The calculation of total sulfur intake is recommended. Increased risk of mortality and morbidity.

concern. Water over 800 mg sodium/L can cause diarrhea and a drop in milk production in dairy cows. High levels of sodium, a major component of salt, may necessitate adjustments to rations. Because chlorine deficiency may result when removing or reducing salt from swine and dairy rations, care should be taken when adjusting rations. Salt may be reduced in swine diets if the sodium in the water exceeds 400 mg/L (Patience 1989; Smart 1989). A guide to the use of water containing sodium for livestock and poultry can be found in table 4.

Alkalinity

Most waters in South Dakota are alkaline. Alkalinity in water is a combined measure of bicarbonates, carbonates, and hydroxide ions. Borates, silicates, and phosphates are also included, but are usually minor. Alkalinity acts as a pH buffer and can also be defined as the ability of water to neutralize acid. Alkalinity alone seldom limits the use of water for livestock. Alkalinity does give us information about salt types.

Alkalinity is expressed either as pH or as titratable alkalinity in the form of bicarbonates and carbonates. A

Table 4. Guide to the Use of Water Containing Sodium for Livestock and Poultry	
Sodium (Na) content mg/L or ppm	Comments
_______Less than 50 (Poultry)	Sodium levels pose little risk to poultry.
_______ 50-1000 (Poultry)	Recommendations are extremely variable and sodium itself poses little risk; however, water with sodium over 50 mg/L (ppm) may affect the performance of poultry if the sulfate or chloride is high. Sodium levels greater than 50 mg/L are detrimental to broiler performance if the sulfate level is also 50 mg/L or higher and the chloride level is 14 mg/L or higher. Excessive sodium has a diuretic effect for poultry.
_______Less than 800 (Livestock)	By itself, sodium poses little risk to livestock, but its association with sulfate is a concern. Water with over 800 mg sodium/L can cause diarrhea and a drop in milk production in dairy cows. High levels of sodium, a major component of salt, may necessitate adjustments to rations. Care should be taken when removing or reducing salt from swine and dairy rations to ensure a chlorine deficiency does not result. Salt may be reduced in swine diets if the sodium in the water exceeds 400 mg/L.

pH of 7.0 is neutral. A pH below 7.0 is acid. A pH above 7.0 is alkaline. Most South Dakota waters have pH values between 7.0 and 8.0, which means that they are mildly alkaline, and this further means that they contain only bicarbonates (they contain no carbonates).

As the pH increases, the waters become more alkaline. At pH values of around 10, waters are highly alkaline and contain carbonates. Most waters have alkalinities of less than 500 ppm, and these are not harmful. Excessive alkalinity in water can cause physiological and digestive upset in livestock.

Regarding alkalinity: both the level at which it begins to be troublesome and its precise effects have not been thoroughly studied; therefore, the establishment of guidelines as to the suitability of alkaline waters for livestock is difficult (Olson and Fox 1981).

Hardness

Hardness is caused by divalent metallic cations that react both with soap to form precipitates and with certain anions to form scale. The principle hardness-causing cations are calcium, magnesium, strontium, ferrous iron, and manganous ions. During the softening process these cations are replaced with sodium, increasing the sodium concentration of the water, thus softened water will lather easily.

The hardness in water is derived largely from contact with the soil and rock formations. In general, hard waters originate in areas where the topsoil is thick and limestone formations are present. Soft water originates in areas where the topsoil is thin and limestone formations are spare or absent (Sawyer 1967).

Water hardness is not necessarily correlated with salinity. Saline waters can be very soft if they contain low levels of calcium and magnesium (the principle cations that cause hardness). Calcium and magnesium are usually present at less than 1000 mg/L in water. Waters are commonly classified in terms of the degree of hardness; this is shown in table 5 (Sawyer and Perry 1967).

Table 5. Water Hardness

Hardness	Calcium plus Magnesium, mg/L	Grains per Gallon (gpg)
Soft	0-75	0-4.4
Moderately Hard	75-150	4.4-8.8
Hard	150-300	8.8-17.5
Very Hard	300 and ⬆	17.5 or ⬆

If the water is already high in salinity, softening the water through the exchange of divalent cations with sodium may cause problems.

Hardness does not usually affect the palatability or safety of water for livestock; the hardness of livestock waters is measured in order to determine the amount of calcium and magnesium relative to other salts in the water. Hardness does have an impact on fish cultures; hardness can reduce the toxicity of various metals to fish and other aquatic life.

Hard water has not been demonstrated to have either a positive or negative impact on poultry performance. If poultry drinking water is treated (softened), care should be taken to balance the diet for the increased sodium content of the water (Carter 1996).

Although hardness has no effect on water safety, it can result in the accumulation of scale (mostly magnesium, manganese, iron, and calcium carbonates) in water delivery equipment. The clogging of pipes and drinkers can lead to reduced water consumption and its associated problems (Manitoba 2004).

Fresh water contains dissolved minerals that are associated with hardness and alkalinity. Potassium bicarbonate ($KHCO_3$), potassium carbonate (K_2CO_3), sodium bicarbonate ($NaHCO_3$), and sodium carbonate (Na_2CO_3) are alkaline and cause sodium and potassium alkalinity. Calcium bicarbonate ($Ca[HCO_3]_2$) and magnesium carbonate ($MgCO_3$) cause carbonate hardness.

Comparing Hardness and Alkalinity

Determining both hardness and alkalinity helps to complete an interpretation of suitability of water for use by livestock. The information helps determine what types of salts are in the water, which is important because some salts are more harmful than others.

When alkalinity equals hardness, salts of calcium and magnesium combined with carbonates and bicarbonates are indicated. When alkalinity is less than hardness, salts of calcium and magnesium are more likely to be sulfates (instead of carbonates). Because of an interaction between sulfates and alkalinity, the laxative effects of high-sulfate water will be more pronounced as alkalinity levels increase. Refer to Table 6 for a guide to the use of water alkalinity and hardness for livestock and poultry.

Nitrates

High concentrations of nitrate in water can poi-

Table 6. Guide to the Use of Water Alkalinity and Hardness for Livestock and Poultry	
_____Alkalinity less than hardness	Indicates the presence of salts of calcium and magnesium are more likely to be sulfates (instead of carbonates).
_____Alkalinity equal to hardness	Indicates the presence of mostly salts of magnesium and calcium.
_____Alkalinity greater than hardness	Indicates the presence of sodium and potassium salts in addition to calcium and magnesium.

son livestock. Nitrate is almost always found in higher concentration in water supplies than the more toxic nitrite. In ruminant animals and horses (which have a cecum), bacteria reduce nitrate to nitrite, which enters the bloodstream and interferes with the ability of hemoglobin to carry oxygen. Animals may die due to lack of oxygen.

In poultry and hogs, which have a more simple stomach than ruminants, bacterial conversion of nitrate to nitrite occurs but is less of a problem.

If nitrate concentrations are high in a livestock water supply and in the animal's feed, nitrite poisoning is more likely to occur. Feeds can contain high amounts of nitrate and should be tested. Silage or hay cut during drought can have high nitrate concentrations.

Symptoms of nitrate poisoning include labored breathing, a blue muzzle, trembling, lack of coordination, and an inability to stand. If the animals do not die, they can often recover completely after the nitrate source is removed. A guide to the use of water containing nitrates for livestock and poultry can be found in Table 7.

Other Factors

This interpretation sheet contains interpretations for the most common parameters that limit use of water for livestock. Other factors that sometimes limit the use of water include other salts, bacteria, blue-green algae, pesticides, temperature, or even stray voltage. If you suspect you may have any of these problems, please contact your local veterinarian or the Water Resources Institute (605-688-4910) to discuss additional analysis that may be required to detect these problems.

The following references and information on other water analysis packages are available online at http://wri.sdstate.edu.

Table 7. Guide to the Use of Water Containing Nitrates for Livestock and Poultry	
Nitrate-nitrogen (NO_3N)[a] content, mg/L or ppm	Comments
___Less than 100[b]	Experimental evidence indicates that this water should not harm livestock or poultry.
___100[b] to 300[c]	This water should not by itself harm livestock or poultry. If hays, forages, or silages contain high levels of nitrate, this water may contribute significantly to a nitrate problem in cattle, sheep, or horses.
___Over 300[c]	This water could cause typical nitrate poisoning in cattle, sheep, or horses, and its use for these animals is not recommended. Because this level of nitrate contributes to the salts content in a significant amount, the use of this water for swine or poultry should be avoided.

[a]1 mg/L of nitrate-nitrogen (NO_3–N) is equivalent to 4.4 mg/L of nitrate (NO_3)
[b]Less than 440 mg/L (NO_3)
[c]Over 1300 mg/L nitrate (NO_3)

References

Carter, Thomas A., Ronald E. Sneed. 1996. Drinking water quality for poultry. North Carolina Cooperative Extension Service. PS&T #42. http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/pst42.html.

Embry, L.B., M.A. Hoelscher, R.C. Whalstrom, C. W. Carlson, L.M. Krista, W.R. Brosz, G.F. Gastler, O.E. Olson. 1959. Salinity and livestock water quality. South Dakota State University. Brookings, SD.

Evaluating water quality for livestock. Manitoba Agriculture, Food and Rural Initiatives. 2004. http://www.gov.mb.ca/agriculture/livestock/nutrition/bza01s06.html.

Gould, D.H. 1998. Polioencephalomalacia. J. Anim. Sci. 76:309-314.

Johnson, P.S., H.H. Patterson, and R. Haigh. 2004. Effects of sulfates in water on performance of steers grazing rangeland. South Dakota Ag Experiment Station. Beef 2004-08.

Kandylis K. 1984. Toxicology of sulfur in ruminants: review. J. Dairy Sci. 67:2179–87.

Loneragan, G.H., D.H. Gould, J.J. Wagner, F.B. Garry, and M.A. Thoren. 1997. The effect of varying water sulfate content on H_2S generation and health of feedlot cattle. J. Anim. Sci. 75 (Suppl. 1):272 (Abstr.).

Loneragan, G.H., D.H. Gould, R.J. Callan, C.J. Sigurdson, and D.W. Hamar. 1998. Association of excess sulfur intake and an increase in hydrogen sulfide concentrations in the ruminal cap of recently weaned beef calves with polioenephalomalacia. J. Am. Vet. Med. Assoc. 213:1599-1604.

McAllister, M.M., D.H. Gould, M.F. Raisbeck, B.A. Cummings, and G.H. Loneragan. 1997. Evaluation of ruminal sulfide concentration and seasonal outbreaks of polioencephalomalacia in beef cattle in a feedlot. J. Am. Vet. Med. Assoc. 211:1275-1279.

National Academy of Sciences. 1974. Nutrients and toxic substances in water for livestock and poultry.

National Research Council. 1996. Nutrient requirements of beef cattle. 7th ed. National Academy Press: Washington, D.C.

—. 2005. Mineral tolerance of animals. 2nd ed. National Academy Press: Washington, DC.

Olson, O.E. and D.G. Fox. 1981. Great plains beef cattle feeding handbook. GPE-1401. South Dakota State University. Brookings, SD.

Olson, O.E., R.J. Emerick, and L. Lubinus. 1973. Nitrates in Livestock Waters. FS 603. South Dakota State University. Brookings, SD

Patience, J.F., J. McLeese and M.L. Tremblay. 1989. Water quality—implications for pork production. Proceedings Of The 10th Western Nutrition Conference. Saskatoon, Saskatchewan.

Patterson, H.H., P.S. Johnson, E.H. Ward, and R.N. Gates. 2004. Effects of sulfates in water on performance of cow-calf pairs. Proc. of West. Section of Amer. Soc. of Anim. Sci. 55:265-268.

Patterson, H.H., P.S. Johnson, T.R. Patterson, D.B. Young, and R. Haigh. 2002. Effects of quality on animal health and performance. Proc. of West. Section of Amer. Soc. of Anim. Sci.: 53:217-220.

Patterson, H.H., P.S. Johnson, and W.B. Epperson. 2003. Effect of total dissolved solids and sulfates in drinking water for growing steers. Proc. of West. Section of Amer. Soc. of Anim. Sci.: 54:378-380.

Patterson, H., P. Johnson, G. Perry, R. Gates, and R. Haigh. 2005. Response of cow-calf pairs to water high in sulfates. South Dakota Ag Experiment Station. 2005 Beef Report. Paper # 05.

Sawyer, Clair N. and Perry L. McCarty. 1967. Chemistry for sanitary engineers. 2nd Ed. McGraw-Hill Series in Sanitary Science and Water Resources Engineering. McGraw-Hill. 349-53.

Smart, M.E., D. McLean and D.A. Christensen. 1989. The dietary impact of water quality. Proceedings of the Tenth Western Nutrition Conference. Saskatoon, Saskatchewan.

Tjardes, K.E., H.H. Patterson, and B.D. Rops. 2004. Effects of supplying water with varying levels of total dissolved solids and sulfates to steers during the growing period on subsequent finishing performance. J. of Anim. Sci. 82 (Suppl 2): 113 (abstr).

Veenhuizen M.F. and G.C.Shurson. 1992. Effects of sulfate in drinking water for livestock. J. Am. Vet. Med. Assoc. 201:487-92.

Ward, Earl H. and Hubert H. Patterson. 2004. Effects of thiamin supplementation on performance and health of growing steers consuming high sulfate water. South Dakota Ag Experiment Station. Beef 2004-07.

Water quality criteria 1972. EPA. Washington D.C. Water for Agriculture Food and Agriculture Organization of the United Nations. Rome, 1976.

Weeth, H.J. and D.L. Capps. 1972. Tolerance of growing cattle for sulfate-water. J. of Anim. Sci. 34:256-60.

Wright, C.L. and H.H. Patterson. 2005. Effect of high-sulfate water on trace mineral status of beef steers. South Dakota Ag Experiment Station. 2005 Beef Report. Paper # 17.

Wright C.L., J.W. Spears, T.E. Engle, and T.A. Armstrong. 2000. Effect of dietary copper level and high sulfate water on copper metabolism and growth in cattle. In: Roussel AM, Anderson RA, Favier AE, editors. Trace elements in man and animals 10. New York: Kluwer Academic/Plenum Publishers. 759–62.

Total Sulfur Intake Worksheet

For assistance with this worksheet,
email Cody.Wright@sdstate.edu or phone (605) 688-5448

	Feed	lb/head/day as-fed basis	% dry matter	lb/head/day dry matter basis (A)	% sulfur in feed	Sulfur intake lb/head/day (B)
1						
2						
3						
4						
5						
			Total dry matter intake (lb) (C)		Total sulfur intake (lb) (D)	
					% dietary sulfur from feeds (E)	

A. Calculate the lb. of dry matter intake of each feed by multiplying the lb. fed per head per day on an as-fed basis by the % dry matter (as a decimal). For example, to determine the lb. of dry matter from 20 lb. of corn silage at 30% dry matter: 20 x 0.30 = 6 lb. of dry matter from corn silage.

B. Calculate the lb. of sulfur intake from each feed by multiplying the lb. of dry matter fed per head per day of that feed (calculated in A) by the % sulfur in the feed (as a decimal). For example, to determine how much sulfur comes from the 6 lb. of corn silage calculated above (assuming the corn silage contains 0.3% sulfur on a dry matter basis): 6 x 0.003 = 0.018 lb. of sulfur from corn silage.

C. Total the lb. of dry matter calculated in column A.

D. Total the lb. of sulfur calculated in column B.

E. Divide the total lb. of sulfur by the total lb. of dry matter. Then multiply by 100 to get the % sulfur from the feeds. For example, if the total dry matter intake is 25 lb. and the total sulfur intake is 0.05 lb, then the % sulfur from the feeds would be 0.2% (0.05 ÷ 25 x 100 = 0.2).

F. Determine the % dietary sulfur from water.

Sulfate concentration of water sample		ppm or mg/L
Move decimal four places left to approximate the % dietary sulfur from water. For example, 1000 ppm is approximately 0.1% dietary sulfur.		% (F)

G. Calculate total dietary sulfur intake by adding the % dietary sulfur from feeds and water.

% sulfur from feeds	% sulfur from water	% total dietary sulfur (G)

Livestock Interpretation Summary Sheet

For Laboratory Sample No.__________

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________7000-10,000	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows in confinement, horses, sheep, or for the young of any these three species. In general, use should be avoided, although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
________Over 10,000	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

[a]Electrical conductivity (EC) expressed in umhos/cm at 25°C. TDS (Total Dissolved Solids) is approximately equal to and can be substituted for EC without introducing error in interpretation.

Table 3. A Guide to the Use of Water Containing Sulfates for Livestock and Poultry	
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_______Less than 1500	For livestock, no harmful effects—except some temporary, mild diarrhea near upper limit, and animals may discriminate against the water due to taste at the upper limit (Weeth 1972). The calculation of total sulfur intake is recommended when using sulfur-containing feeds (e.g., molasses, distiller's grains, corn gluten feed).
_______1500-2500	For livestock, no harmful effects—except some temporary diarrhea. In cattle this water may contribute significantly to the total dietary sulfur intake. May cause a reduction in copper availability in ruminants. Calculating total sulfur intake is recommended.
_______2500-3500	Poor water for poultry, especially turkeys. Very laxative, causing diarrhea in livestock that usually disappears after a few weeks. Sporadic cases of sulfur-associated polioencephalomalacia (PEM) are possible. May cause substantial reduction in copper availability in ruminants. The calculation of total sulfur intake is recommended.
_______3500-4500	Very laxative. Unacceptable for poultry. Not recommended for use for pregnant or lactating ruminants or horses, or for ruminants fed in confinement. Sporadic cases of sulfur-associated polioencephalomalacia (PEM) are likely. May cause substantial reduction in copper availability in ruminants. The calculation of total sulfur intake is recommended.
_______Over 4500	Not recommended for use under any conditions. The calculation of total sulfur intake is recommended. Increased risk of mortality and morbidity.

Table 4. Guide to the Use of Water Containing Sodium for Livestock and Poultry	
Sodium (Na) content mg/L or ppm	Comments
________Less than 50 (Poultry)	Sodium levels pose little risk to poultry.
________ 50-1000 (Poultry)	Recommendations are extremely variable and sodium itself poses little risk; however, water with sodium over 50 mg/L (ppm) may affect the performance of poultry if the sulfate or chloride is high. Sodium levels greater than 50 mg/L are detrimental to broiler performance if the sulfate level is also 50 mg/L or higher and the chloride level is 14 mg/L or higher. Excessive sodium has a diuretic effect for poultry.
________Less than 800 (Livestock)	By itself, sodium poses little risk to livestock, but its association with sulfate is a concern. Water with over 800 mg sodium/L can cause diarrhea and a drop in milk production in dairy cows. High levels of sodium, a major component of salt, may necessitate adjustments to rations. Care should be taken when removing or reducing salt from swine and dairy rations to ensure a chlorine deficiency does not result. Salt may be reduced in swine diets if the sodium in the water exceeds 400 mg/L.

Table 5. Water Hardness		
Hardness	Calcium plus Magnesium, mg/L	Grains per Gallon (gpg)
Soft	0-75	0-4.4
Moderately Hard	75-150	4.4-8.8
Hard	150-300	8.8-17.5
Very Hard	300 and ⬆	17.5 or ⬆

Table 6. Guide to the Use of Water Alkalinity and Hardness for Livestock and Poultry	
______Alkalinity less than hardness	Indicates the presence of salts of calcium and magnesium are more likely to be sulfates (instead of carbonates).
______Alkalinity equal to hardness	Indicates the presence of mostly salts of magnesium and calcium.
______Alkalinity greater than hardness	Indicates the presence of sodium and potassium salts in addition to calcium and magnesium.

Table 7. Guide to the Use of Water Containing Nitrates for Livestock and Poultry	
Nitrate-nitrogen (NO_3N)[a] content, mg/L or ppm	Comments
___Less than 100[b]	Experimental evidence indicates that this water should not harm livestock or poultry.
___100[b] to 300[c]	This water should not by itself harm livestock or poultry. If hays, forages, or silages contain high levels of nitrate, this water may contribute significantly to a nitrate problem in cattle, sheep, or horses.
___Over 300[c]	This water could cause typical nitrate poisoning in cattle, sheep, or horses, and its use for these animals is not recommended. Because this level of nitrate contributes to the salts content in a significant amount, the use of this water for swine or poultry should be avoided.

[a] 1 mg/L of nitrate-nitrogen (NO_3–N) is equivalent to 4.4 mg/L of nitrate (NO_3)
[b] Less than 440 mg/L (NO_3)
[c] Over 1300 mg/L nitrate (NO_3)