Solving Bad Water Problems for Thirsty Cows

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Take Home Messages

- Abundant, high quality drinking water is the most important essential nutrient for your dairy cows. If water nutrition (quality and/or quantity) is an issue, you and your cows have a big problem!
- Based on analyses of over 200 'suspect' drinking water samples from across the U.S. in the last 10 years the most common water quality problems are high iron and high anion contents that can affect cow health and performance.
- The only way to know for sure if drinking water in your dairy has excess concentrations of iron (greater than 0.3 ppm) or anions (sulfate + chloride; greater than 1,000 ppm) is to have water samples analyzed periodically at a reputable laboratory.
- Procedures for sampling and a few certified laboratories are listed at: http://www.msu.edu/~beede/; click on Extension and then "Taking a Water Sample".
- Water treatment methods are available to remove iron, sulfate and chloride: chlorination with filtration; ion exchange; ozonation; reverse osmosis; and/or, an oxidizing filter.
- If water quality is not an issue, the most common water nutrition problem in most dairies is not providing enough watering stations, enough space at watering stations, and thus, enough uninhibited drinking opportunities for each cow during her normal daily routine where she lives and is milked. In recent years, lack of adequate water supply is often related to over-stocking in group housing areas, whether free stalls barns or loose housing.

Introduction

This paper focuses specifically on the most common bad water problems and potential solutions encountered in the last several years. For a more comprehension review of published information on water nutrition for dairy cattle readers are referred to McFarland (1998), NRC (2001), and Brouk et al. (2001), and Beede (2006).

Bad Water – Primary Quality Problems

Based on analyses of over 200 'suspect' drinking water samples from dairies across the U.S. in the last 10 years the most common potential water quality problems are high iron and high anion (sulfate + chloride) contents that can affect cow health and performance. The only way to know for sure if drinking water in your dairy has excess concentrations of iron or anions (sulfate + chloride) is to have water samples analyzed periodically by a reputable laboratory.

Iron. Excess iron in drinking water can cause iron toxicity and is a major problem in some dairies across the country. In this time of high input costs, excess iron in drinking water and subsequent poor cow performance can be the business-breaker. Fortunately, excess iron in drinking water is relatively easy to measure with a standard laboratory analysis and then corrective action can then be taken.

The recommended maximum tolerable concentration of iron in drinking water is 0.3 ppm (parts per million; or, milligrams/liter). Concentrations in excess of this can be detrimental to normal health and lactational performance of dairy cows, and a significant health risk for humans consuming the water. A cow producing 100 pounds of milk requires about 35 milligrams of absorbed iron daily, commonly supplied in her ration (NRC, 2001). However, if she consumes drinking water with 0.3 ppm iron (versus no iron in water) her total absorbable iron intake doubles. If the drinking water contains 0.6 ppm iron, then total absorbable iron intake is about three-times the daily requirement.

Typically, there is plenty of total iron in rations to meet the cow's daily absorbed iron requirement, even though dietary iron is poorly absorbed from the digestive tract; only about 10 percent of iron from rations is absorbable. The common chemical form in feed ingredients is ferric iron, Fe^{+3}, which is quite insoluble. In contrast, the iron in drinking water is highly soluble and very absorbable (ferrous iron, Fe^{+2}), so major problems can result from excess iron in drinking water which is readily absorbed into the body.

Excess absorbed iron from drinking water can lead to cellular oxidative stress and inhibit copper and zinc absorption. Oxidative stress results in damage to cell membranes and disrupts normal physiological functions and biochemical reactions. It is suspected that consequences of excess absorbed iron and heightened oxidative stress are magnified in transition and fresh cows. These consequences include compromised immune function, increased fresh cow mastitis and metritis (excess ferrous iron in the body enhances the potential for bacterial infections), greater incidence of retained fetal membranes, diarrhea, depressed feed intake, and reduced growth and milk production.

Experience in commercial dairies the last several years indicates rather remarkable improvements in lactational performance and cow health when excess iron is removed from drinking water (treatment options to remove excess iron are addressed in a later section of this paper).

High iron in drinking water also may reduce water intake, apparently because ferrous iron is unpalatable (not acceptable). Reduced water intake directly reduces feed intake and milk production (Beede, 2006). Also, the dark reddish-brown slime formed by iron-loving bacteria in water troughs may affect water intake and even the rate flow and volume through pipes. To my knowledge, it is not known if these iron-loving microorganisms directly affect the digestion, metabolism, or physiology of cows. However, field experience suggests that treating drinking water with high iron content (such as treating with a solution of 35% hydrogen peroxide at a rate of about 8 ounces per 1000 gallons of water) will eliminate these microbes and improve milk yield and health of cows. In the time immediately after treatment with hydrogen peroxide it may be necessary to remove filters, open valves, and even open (e.g., cut) the water pipes at the terminal end of flow to purge the slime that has been loosened from the plumbing. Hydrogen peroxide treatment at this low dosing level can be continued if felt necessary.

If high-iron (greater than or equal to 0.3 ppm) drinking water is present, an alternative water source with lower iron concentration should be found. Or, a method to remove the iron from water before consumption by cattle or humans should be used. Water treatment methods to remove iron are addressed below under the section on 'Water-treatment Options'.

Sulfate + Chlorine. Typically, if the total dissolved solids (TDS) concentration of a water sample is high (greater than 500 ppm) the first constituents to focus on are sulfate and chloride. Sulfate and chloride are biologically active anions (negatively charged ions) that if in excess potentially can negatively influence a cow's digestion, electrolyte balance, acid-base status and lactational performance. If the sum of the concentrations of sulfate plus chloride is greater than 1,000 ppm a thorough evaluation should be done to determine whether or not the anions are affecting cow health and performance.

Based on field experience, excessively high concentrations of sulfate plus chloride (greater than 1,000 ppm) in drinking water can reduce water consumption. However, much of the early research addressing effects of sulfate and chloride concentrations in drinking water evaluated much higher concentrations than are typically found, even from the deep wells in the western U.S. states (Beede, 2006). In summary, the maximum tolerable concentrations of sulfate found in experimentation ranged from about 3,500 ppm, causing significant reduction in water intake, weight gain, and feed intake of beef heifers, to as low as about 1,450 ppm sulfate when beef heifers still gained some weight, but less than heifers drinking low-sulfate water. In that study, heifers discriminated against the water containing 1,450 ppm sulfate, and outright rejected water with 2,800 ppm sulfate. These results suggest that the tolerance threshold for sulfate may be around 1,450 ppm, at least for growing heifers. More recent research from the University of British Columbia showed that drinking water was unpalatable to beef heifers and steers if it contained 3,200 or 4,700 ppm sulfate from sodium or magnesium sulfate salts. Animals offered high-sulfate water also changed their pattern of consumption, drinking more frequently at night compared with animals offered low-sulfate water that drank more during the day. Also, when the poorer quality, high-sulfate water was offered, animals showed more aggressive behavior towards each other when trying to drink. However, 1,500 ppm sulfate did not reduce water consumption (Zimmerman et al., 2002).

Similar controlled experimentation is not available for lactating dairy cows assessing the maximum tolerable concentrations of sulfate and chloride that affect water intake and lactational performance. However, field experience suggests that the tolerable concentration is likely well below 1,450 ppm. Based on available research reports and personal field experience, when sulfate plus chloride concentrations in water exceed 1,000 ppm careful evaluation of animal performance, including measurement of water intake, should be done. A proposed approach for evaluation is listed subsequently. High-sulfate (e.g., 1,200 ppm) drinking water reduced performance of transition-fresh dairy cows by causing reduced feed intake and milk yield, and increased incidences of retained fetal membranes and abomasal displacement (Beede, personal observation). When reverse osmosis treatment was instituted and low-sulfate water (less than 15 ppm) was provided, fresh cow problems declined dramatically. Because, chloride also is a biologically active anion, a useful rule of thumb in assessing water quality is to check whether or not the sulfate plus chloride concentrations exceed 1,000 ppm. If they do, careful evaluation and testing are highly recommended. Water treatment methods to remove excess sulfate and chloride are addressed under the section on 'Water-treatment Options' below.

Hydrogen Sulfide. In reporting of water analysis, sulfur typically is differentiated from sulfate. Sulfur present as hydrogen sulfide (H_2S), imparting the rotten egg smell, is believed to affect water intake. Water intake increased at least in the short-term when water without the smell was offered (Beede, personal observation). However, it is not known what concentration of hydrogen sulfide or what intensity of smell reduces normal water intake of cattle; or, if they adapt to the smell and have normal water intake rates if no other water is available.

Water-treatment Options

If based on water analysis, excess iron, sulfate, or chloride is a concern for cow health and performance, the next question is --- "What can and should be done about it?" A different water source may be the best long-term solution (such as a new well or perhaps a municipal water source). To treat water to remove constituents in excess is the other option. This has been accomplished successfully and economically in some dairy farms (Beede, personal observations). However, it may not be cost-effective in every case. Careful evaluation of the magnitude of the problem, how much potential benefit can be expected from removing unwanted constituents, and at what cost are key considerations. Most dairy farms use relatively large volumes of water and treatment systems must be sized accordingly. Table 1 provides questions that should be addressed if considering a water treatment system to remove unwanted constituents.

Table 2 provides a general guide for major treatment methods to remove excess iron, sulfate and chloride, and some other unwanted constituents (adapted from www.midwestlabs.com). This table is meant to provide an initial guide for treatment methods; then a user can address specific water quality problems with water treatment companies in the local region. It is highly recommended that dairy producers and consultants compare effectiveness, life expectancy, volume capacity, maintenance time, and initial capital and maintenance costs of each method with several regional commercial companies before making any significant investments (Table 1).

Removal of Iron.

Excess water-soluble iron can be removed by one or a combination of five methods (Table 2): 1) chlorination with filtration; 2) a cation-anion exchange system, especially when iron concentrations are less than 1.0 ppm; 3) ozonation; 4) reverse osmosis; and/or, 5) an oxidizing filter.

Chlorination can remove dissolved iron, manganese, and hydrogen sulfide if followed by mechanical or activated carbon filtration. Chlorine is pumped directly into the water in proportion to water flow and it may have some residual effects in the system. If the chlorination system is not properly operated, it can be expensive and potentially hazardous if chlorine byproducts are allowed to escape. In typical systems the chlorine content of the treated water should not be high enough to cause problems for cattle. However, cases of over-chlorination have been noted where the chlorine concentration was high enough in water to reduce milk fat percentage dramatically (presumably by affecting ruminal fermentation); the situation quickly reversed when chlorination was discontinued (Beede, personal observation). In another case, high concentrations of chlorine (1,000 to 1,500 ppm) resulted in a dairy's watering system when the city cleaned its system; in this case water intake and lactational performance were reduced. In other situations, addition of chlorine tablets in the water tanks, causing spikes in chlorine content mainly to control algae growth, apparently affected water consumption, even with the slow-release tablets. Alternative methods (cleansers, brush and thorough rinsing) are recommended for routine water trough cleaning.

Filtration. Use of mechanical filters is recommended with chlorination to remove soluble and insoluble iron and manganese, sand, silt and clay (turbidity) and to reduce plugging or wear on equipment. Activated carbon filters use carbon granules to adsorb free chlorine, and some compounds associated with coloration, odor and off-taste of water; mercury; some pesticides; radon gas; and volatile organic compounds. Depending upon the amount of water treated, the filters may have to be replaced frequently and regularly. Infrequent filter maintenance may result in bacterial growth on the filter and reduced effectiveness.

Cation - Anion Exchange. An ion exchange system can be used to remove iron and manganese at relatively low concentrations (such as less than 1 ppm or less); a common system is known as the 'iron curtain' although other ion exchange systems are available commercially for various applications. Consultation with local vendors will help determine the most cost-effective and reliable systems to treat large volumes of water used in most dairies.

Ozonation can be used to remove solubilized iron and manganese, if the water is subsequently passed through mechanical or activated carbon filtration. Ozonation also destroys microorganisms and there are no residual effects of the ozone (a potent oxidizer of organic compounds) on the environment or treated water. This method also can be used to remove color, off-taste, odors, and hydrogen sulfide.

Reverse osmosis technology has been used successfully to remove iron, sulfate, chloride and other unwanted constituents (Beede, personal observation). Basically impurities are filtered from water using membranes. The initial costs are relatively high with high membrane replacement costs. High volume through-put capacity is needed in most dairies because the process is relatively slow. The systems take routine and consistent maintenance. They also are somewhat wasteful of water and the high-solutes filtrate must be disposed of. A wide variety of constituents can be removed: most inorganic substances, nitrate, some pesticides, odors, off-taste compounds, radium, salts, and some volatile organic compounds.

Oxidizing filters remove undissolved and dissolved iron, and manganese by filtering and chemical (oxidizing) reactions; hydrogen sulfide also can be removed in this manner.

Removal of sulfate and chloride (anions)

Two approaches to remove excess sulfate and chloride are: 1) reverse osmosis, as described above, is most common; and possibly, 2) distillation. Otherwise, an alternate water source must be found if it is clear that high sulfate and/or chloride are affecting negatively animal performance and profitability. *Distillation* can purify water that contains any assortment of solids such as inorganic compounds, nitrate, odor, off-taste, some pesticides, radium, salt, and volatile organic chemicals that have high boiling points. However, the process is slow, expensive (high energy cost), and for a dairy farm, large volume-capacity may be needed to provide sufficient distilled water, depending upon herd size.

Whatever the most appropriate treatment method to remove iron, sulfate and/or chloride from drinking water, here are some recommendations on how to proceed to a solution if one suspects high anti-quality constituents in drinking water.

1. Take a water sample(s). For guidelines on how to take drinking water samples and standard water analysis refer to: http://www.msu.edu/~beede/, click on Extension and then "Taking a Water Sample".
2. Have a standard laboratory analysis for "livestock water" done by a certified laboratory.
3. If the laboratory reports iron concentrations greater than 0.3 ppm and/or either sulfate or chloride concentrations greater than 500 ppm, take two more samples and send each to a different certified laboratory for analyses. This may seem like over-kill at the time, but water treatment systems are a major investment, so it is important to know for sure that concentrations are in excess.
4. When collecting samples for laboratory testing, take and label two more samples to save as back-ups and a historical record.
5. If one or more of these constituents is in excess, contact at least two or three water treatment companies and ask about their treatment methods, and if and how they remove iron, sulfate, and/or

chloride from water. Local or regional companies typically are best to ensure good customer service and maintenance after installation. Also, refer to Table 1 for guidelines on fact-finding about water treatment options.

6. After a treatment system is installed, take treated water samples at least every month, label, and tightly seal them (to stop possible evaporation), and store in a cool place for historical purposes. At least every third month send a sample to a certified laboratory for a standard "livestock" analysis, including iron, sulfate and chloride. Is the water-treatment system removing the anti-quality constituents as guaranteed?

H_20_{dot} con: Water-related Pseudoscience Fantasy and Quackery

There is a plethora of people and companies willing to sell water treatment systems of every size, shape, and treatment method, whether water treatment is needed or not, and whether their method actually works or not. For those wondering about the effectiveness of one or many of the supposed treatment methods an interesting and helpful Web Site is called "*H_20_{dot} con: Water-related Pseudoscience Fantasy and Quackery*" < http://www.chem1.com/CQ/ >. This site was developed by Dr. Stephen Lower, retired faculty member in the Department of Chemistry at Simon Fraser University, Burnaby, Vancouver, Canada. Dr. Lower developed and writes at the Site to address and help consumers sort out which of the many alleged water treatment methods actually have scientific merit and which ones are most likely quackery. It seems that most water treatment methods offered to solve purported bad water problems in commercial dairy farms were (are) first available and/or sold to homeowners and consumers. To quote from the Web Site about Junk Science in the Market Place, *"Magnets and "catalysts" for softening water, magnetic laundry balls, waters that are "oxygenated", "clustered" , "unclustered" or "vitalized" (purporting to improve cellular hydration, remove toxins, and repair DNA), high zeta potential colloids and vortex-treated waters to raise you energy levels, halt or reverse ageing and remove geopathic stress --- all of these wonders and more are being aggressively marketed via the Internet, radio infomercials, seminars, and by various purveyors of new-age nonsense. The hucksters who promote these largely worthless products weave a web of pseudoscientific hype guaranteed to dazzle and confuse the large segment of the public whose limited understanding of science makes them especially vulnerable to this kind of exploitation.*

The purpose of this site is to examine the credibility of these claims from the standpoint of our present-day knowledge of science. The latter, of course, is always evolving and is never complete, but it makes an excellent "B.S. filter" that is almost always reliable. It is hoped that the information presented here [at the Web Site] *will help consumers make more informed decisions before offering up their credit cards to those in the business of flogging pseudoscience."*

In Conclusion

For dairy producers and their advisers an appropriate closing message on water treatment methods would be, *"Show me the science and the proof of improved cow health and performance before I show you five or six figures in George Washington's finest dollars."*

Suggested References

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Other references about water nutrition of dairy cattle, are available at: < http://www.msu.edu/~beede/ > by clicking on "Extension", and then "Water Ref".

Table 1. Questions to ask sales and service representatives from prospective water-treatment companies.

1. Do you know how much water this particular dairy uses? Obviously, the company representatives will not know this, but you've got to know the answer to this question! Most dairies use a lot of water; often much more than companies are accustomed to treating at a single location. What is the treatment rate (volume/time)? Can their system supply enough water for all functions on the dairy simultaneously during peak usage (e.g., during milking, parlor clean-up and when cows are drinking)? Will a sizable investment in large long-term storage of the treated water be necessary to ensure that you have ample supply during peak usages?

2. Does each company guarantee that their system will remove iron, sulfate or chloride as needed based on the water analyses? Are they willing to provide a written guarantee that their system will remove these unwanted constituents throughout the specified life of the treatment system?

3. How long will the systems last and how much maintenance is required? Who does the maintenance? Do they have "service-after-the-sale" and what does that entail? Do they have or can they provide a maintenance contract?

4. Which other anti-quality factors (besides iron, sulfate, and/or chloride) do their water treatment systems remove? There may be none. But, there also may be additional benefits to one treatment system over another if other constituents are in excess in water samples.

5. What chemicals (e.g., other mineral elements) does their particular treatment method add to the water and what will be their concentrations? There may be nothing added. But, in other cases something may be added, such as significant chlorine during chlorination.
It must be determined if the additions are of any consequence, bad or good.

6. What do the systems cost — installation, and monthly maintenance and operating costs?

Table 2. General guide for treatment methods to remove unwanted constituents from drinking water (adapted from www.midwestlabs.com).

	Treatment Methods[a]									
Constituent	**ACF**	**AS**	**C**	**D**	**C-A**	**MF**	**RO**	**UR**	**O**	**OF**
Chlorine	X[b]									
Coliform bacteria, other microorganisms			X					X	X	
Color	X		X		X				X	
Hydrogen sulfide		X	X[c]						X[c]	X
Inorganics [e.g., some macromine elements and heavy metals (e.g., mercury, arsenic, cadmium, bariu	X[d]			X	X[e]		X			
Iron/ manganese –dissolved			X[c]		X[f]				X[c]	X
Iron/ manganese – insoluble						X				X
Nitrate				X	X[g]		X			
Odor and off-taste	X	X	X	X	X		X		X	
Some pesticides	X[h]						X[h]			
Radium				X	X		X			
Radon gas	X	X								
Salt				X			X			
Sand, silt, clay (turbidity)						X				
Volatile organic chemicals	X	X		X[i]			X			
Water Hardness					X					

[a] ACF = activated carbon filter; AS = air stripping; C = chlorination; D = distillation; C-A E = cation or anion exchange; MF = mechanical filtration; RO = reverse osmosis; UR = ultraviolet radiation; O = ozonation; and, OF = oxidizing filters.
[b] Within the table "X" indicates method that can be used to remove part or all of the constituent present.
[c] When followed by mechanical filtration or an activated carbon filter.
[d] Mercury only.
[e] Barium only.
[f] When present in low concentrations.
[g] Anion exchange units will remove nitrate; but, cation exchange units will not.
[h] For information on ways to treat water for specific pesticides, obtain local pesticide health advisory summaries.
[i] Works for volatile organic chemicals with high boiling points.