Practical Water Evaluation for Dairy Cattle

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Water is an essential component of the ration of all types of livestock. While most dairy farms have an ample supply of good quality water, bacterial contamination, high levels of dissolved minerals, or physical factors which restrict intake can cause health problems and reduce milk production.

Water consumption of cattle varies with body size, level of milk production, ambient temperature and intake of dry matter, protein salt and other minerals. Typical water requirements of ruminant livestock are listed in Table 1.

TABLE 1. Livestock Water Requirements (Litres per day from all sources). Dairy Replacements (5), Dairy Cows (12), Beef Cattle (15).

Dairy Cattle:		**Liters/Day**
Holstein Calf 2 months		6
4 months		13
Heifer 18 months		32
	4°C	27°C
Dry Cow	40	66
23 KG. Milk	77	104
36 KG. Milk	95	122

Murphy 1983:

$$\text{Water (kg/day)} = 15.99 + 1.58\ (\text{kg DM}) + .9\ (\text{kg milk}) + .05\ (\text{g Na}) + 1.2\ (\text{min. temp. } ^{\circ}\text{C})$$

Beef Cattle:	4°C	27°C
Heifers and Steers		
182 kg	15.1	25.4
273 kg	20.1	33.7
364 kg	23.8	40.1
Pregnant Cow		
410 kg	25.4	
Lactating Cow		
410 kg	43.1	67.8

In predicting water intake it should be noted that the presence of high levels of mineral salts in water causes an increase in water intake (4). Beef steers offered water containing 1600 milligram per litre sodium from sodium chloride increased water intake 19% (18) while in another study water with 1360 milligram per litre sodium from sodium sulfate resulted in no change in water intake but an increase in urine output (19).

Dairy cows given water containing 975 milligrams per litre sodium from sodium chloride increased water intake by 9.3 kg. per day in a trial conducted during hot weather in Arizona (7). Much higher levels of salts can cause a severe depression in water consumption combined with dramatically reduced feed consumption, severe weight loss and eventual death (4).

As noted in Table 2, restricting water intake by physically limiting access to water significantly decreases dry matter intake and milk production of dairy cows and results in loss of body weight (9).

TABLE 2. Effect of Restricted Water Intake (6 day trial).

	% of Control Water Intake			
	100	87	73	60
Dry Matter Intake (kg/day)	13.4	13.1	12.6	11.2
Milk (kg/day)	14.4	13.3	13.3	12.1
Body Weight Change (kg)	+7.9	-4.9	-10.9	-21.0

Source: Little, 1979

Factors which can restrict water consumption include handling practices which limit access, poor location of watering devices, inadequate pump and line capacity, and tingle voltage or electrical faults on water bowls. Metal watering devices, particularly heated water bowls, should be checked with an appropriate voltmeter for faults or tingle voltage. In many cases, simple preventable problems such as frozen water tanks or handling practices which force cattle to go without water for periods of the day are reflected in low milk production. Insulated commercial tanks which draw heat from below the frost line are proving to be an effective solution to freezing problems.

Except in very extreme situations, water quality is unlikely to restrict water intake, and while it is a good practice to keep water supplies clean and fresh, there is little evidence that dirty water bowls or tanks impact on production through decreased water consumption.

Similarly, chemical aspects which affect the taste of water, such as dissolved iron or the rotten egg odor caused by hydrogen sulfide, do not appear to reduce water consumption or animal performance. Dissolved solids in excess of 7000 milligrams per litre cause decreased water consumption, but even at lower levels of salts, the impact on productivity and health is associated with the nutritional affects of toxic levels of salts rather than with reduced water consumption.

A number of research studies have demonstrated that under extreme heat stress, providing cold water, especially at the afternoon milking, can reduce body temperature and increase milk production. A moderate increase in water consumption is associated with this practice. Similarly, dairymen report increased water consumption in cold weather when more water captured from heat exchangers is offered to livestock. However, no research has been conducted to quantify potential improved production.

Bacterial Quality

Bacterial quality of livestock water has received no research attention, and established standards are based on speculation and circumstantial evidence only. Nevertheless, a recent effort by Ontario Ministry of Agriculture staff to assess water quality on Ontario farms points to a number of potential problems. Table 3 is a summary of 75 water samples from three regions of the province, showing the presence of coliform bacteria in the water supply provided to cattle. The presence of these organisms indicates contamination with fecal material either from livestock manure or human sources. This contamination increases the likelihood of spreading an infectious disease organism, particularly if it originates outside of the farm boundaries. The presence of any coliform bacteria in water is considered a cause of scours in young calves. Older cattle can probably tolerate levels of 20 to 50 organisms per 100 ml. with no serious effects. Higher levels may cause chronic or intermittent diarrhea and off-feed problems. Our survey showed that 83% of the farms in Hastings County, half of the farms in the Niagara Region, and 24% in Oxford and area had some fecal contamination of water while 50%, 19% and 10% respectively were over 50 organisms per 100 milliliters. Out of three farms in the Niagara Region using pond or river water, two had levels over 160 organisms/100 ml.

Bacteriological analysis of water is readily available through public health authorities in most areas. If a problem is identified in a well or cistern, it may be possible to locate and eliminate the source of contamination, and correct the problem by disinfecting the well. If the source of contamination cannot be identified, or a pond or stream is used for water, continuous treatment with chlorine or ultra violet light is required. An analysis of production records of one farm in the Niagara area showed no change in production attributable to the installation of a chlorination system. Records did indicate that treatment eliminated a problem with high bacteria counts in milk by eliminating the direct contamination of milling equipment during cleaning. Other reports occasionally appear in the farm press which document a dramatic improvement in production and health as a result of water treatment; however, there is no clear research evidence to support this observation.

TABLE 3. Bacterial Quality of Livestock Water

Total Coliform (No./100 ml)	Percent of Samples		
	Hastings County* (30 farms)	Niagara Region** (16 farms)	Oxford, Middlesex, Perth (29 farms)
< 2	16.7	50.0	75.8
2 - 49	33.3	31.3	13.8
50 - 160	23.3	6.2	5.2
> 160	26.7	12.5	5.2

* Data collected by Dairy Specialist Tom Dropo, in a calf health study.
**Includes three farms using a creek or pond as a water source. Of the three, one sample was < 2, and 2 were > 160. There were no drilled wells in the > 160 group.

On many farms surveyed, the farm family also consumed the same water without any form of treatment.

Dissolved Minerals

Farm water supplies normally contain dissolved minerals at low levels of little nutritional significance. Specific situations such as soil and bedrock formations high in certain elements, concentration of salts through evaporation and contamination with pollutants can result in levels of minerals which reduce the growth, production and health of livestock. That such toxicity problems occur is documented in research (4,18,9,3,7) and is also a logical reflection of mineral toxicity in the diet as illustrated in Table 4. Highly saline water can contribute a major portion of mineral nutrients to the diet. Nutrient requirements of dairy cattle (16) suggest a minimum requirement for sulfur of 0.20% of dry matter intake and a maximum safe level of 0.40%. By these standards, the ration in Table 4 is deficient in sulfur when only the dry feed stuffs are considered, and contains a near toxic level of sulfur when the cows' predicted consumption of saline water is included.

TABLE 4. Typical Ontario ration for a 625 kg Cow, 36 kg of Milk and 3.75% Butterfat.

		Sulphur	
		percent	grams
12.8	kg. Mixed Hay	.05	14.1
9.1	kg. Grained Corn	.12	11.0
3.2	kg. Soymeal	.39	12.5
0.2	kg Mineral Premix	.46	0.9
22.1	kg. Dry Matter	.17	38.5
130	kg Water (1000 ppm SO_4)	.034	44.2
Total Diet Dry Matter		.37	82.7

Toxic effects of minerals from water are comparable to mineral toxicities associated with other feedstuffs and are most appropriately addressed by analyzing water for major minerals, including a predicted intake of water in ration formulation and evaluating the potential for mineral toxicities in the total diet. Evaluation of the diet may be *confounded by wide variation in water intake*, the unknown effects of a combination of several elements at toxic or near toxic levels and a general lack of knowledge concerning the extent of interactions between minerals in all parts of the diet. It should also be noted that minerals dissolved in water have a high nutritional availability.

Routine water analysis should include total dissolved solids, sodium, magnesium, calcium, sulfate, nitrate, iron and pH. Where evidence of pollution and associated symptoms in livestock exist it may also be necessary to test for specific heavy metals, trace elements or pesticides.

As noted earlier, the presence of high levels of dissolved minerals usually increases water consumption. Clearly, if water intake is being monitored, high intake is more likely to reflect a problem with water quality than low intake. This phenomenon further confounds assessing potential toxicity of minerals entering the diet through water since mineral intake will spiral upward as water consumption increases.

Traditionally, total dissolved solids or salinity which includes all dissolved mineral elements has been used as a primary criteria for evaluating mineral quality of water. Standards adopted by the United States (14) are also generally excepted in Canada (6). These guidelines are outlined in Table 5.

TABLE 5. Guide to the Use of Saline Waters for Livestock Watering

Total soluble salts content of waters (mg L-1)	EC[1]	Suitability for Livestock
< 1000	< 1.5	Relatively low level of salinity; excellent for all classes of livestock
1000-3000	1.5-5	Satisfactory for all classes of livestock and poultry but some loss in productivity should be anticipated; may cause temporary and mild diarrhea in livestock not accustomed to them or watery droppings in poultry.
3000-5000	5-8	Satisfactory for livestock, may cause temporary diarrhea or be refused at first by animals not accustomed to them; poor waters for poultry, often causing watery feces, increased mortality and decreased growth, especially in turkeys.
5000-7000	8-11	Can be used with reasonable safety for beef cattle, sheep, swine and horses; avoid use for pregnant or lactating animals and dairy cattle; not acceptable for poultry.
7000-10000	11-16	Unfit for poultry and probably for swine; considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species; in general, use should be avoided, although older ruminants, horses, poultry and swine may subsist on them under certain conditions.
> 10000	> 16	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

[1]EC = electrical conductivity

Livestock will normally avoid water of high salinity if given a choice, but when forced to drink water of poor quality a loss in overall condition and reduction in weight gain and milk production can occur. A sudden change from water of low salinity to water of high salinity can initiate toxicity symptoms and in some cases may cause death (6). Guidelines for total dissolved solids are useful in that they recognize the need to deal with combination of salts in natural waters that collectively exceed the animal's capacity for digestion and excretion while no individual element is at a toxic level. However, studies demonstrate that magnesium, sodium and sulfate are toxic at lower levels than calcium, chloride or bicarbonate, and that there will be highly variable response to water of 1000 to 5000 milligrams per litre total dissolved solids, depending on which ions dominate.

In determining toxic levels of individual minerals, the maximum safe concentration of a mineral element in water for each class of livestock is a function of the relative dry matter and water intake of the animal. Lactating dairy cows who require proportionally more water versus dry matter than the other classes are more likely to show toxicity symptoms when exposed to high mineral waters. As indicted in Table 6, the maximum safe concentration for any element in water for a diary cow would be 17% of the maximum safe concentration of that element expressed as a percent of dry matter intake. This level would be adjusted downward if significant amounts of the mineral in question are also present in the diet. Based on the table, it would appear that dairy replacements, growing beef steers and pregnant beef cows can tolerate higher levels of toxic minerals than high producing dairy cows.

TABLE 6. Calculation of Maximum Safe Concentration of Minerals in Water.

Livestock Class	Predicted Intake: Dry Matter (kg/day)	Predicted Intake: Water (1/day)	Maximum Concentration in Water (% Dry Matter Max. Conc.)
High producing dairy cow	22.0	130.0	17*
Dry dairy cow	11.0	66.0	17
400 k. dairy heifer	8.6	32.0	27
364 kg. beef steer gaining 0.9 kg/day	10.2	40.1	25
Pregnant beef cow in winter	13.4	25.4	35

*Adjust if toxic material is also present in diet.

Among the individual elements, sulfate is probably most worthy of attention. At concentrations of 1000 milligrams per litre, sulfate causes diarrhea in young animals (2). Studies with beef heifers demonstrated a decreased rate of gain at 1500 milligrams per litre sulfate (19). For high producing dairy cattle consuming a typical diet of hay, corn, grain and soybean meal, the maximum recommended dietary intake of sulfur (16) is reached at 1200 milligrams per litre when ambient temperature is 27°C. Toxicity symptoms occur at relatively lower levels when sulfate is associated with magnesium than with sodium or with calcium. Dairymen in the Niagara region who have switched from deep well water containing 1500 to 2500 milligrams per litre sulfate to surface ponds with negligible sulfate content report increased dry matter intake, milk production and butterfat test, particularly in early lactation. It is suggested that the level of sulfate in water for livestock should not exceed 1000 milligrams per litre. Water containing 500 to 1000 milligrams per litre sulfate will be satisfactory. However, because sulfur is known to tie up dietary copper, zinc and manganese, it is advisable to ensure adequate levels of these elements in the diet.

There are no research studies specific to magnesium content of water for livestock, and maximum safe levels for magnesium in diets are poorly defined. In dairy rations, magnesium oxide is used as a buffer at up to 0.6% of dry matter intake and no maximum safe feeding level is specified (16). A Canadian publication (1) suggests that levels greater than 1% magnesium reduce feed intake, retard growth and result in diarrhea. Nutritional requirements for beef (15) list a maximum dietary level of 0.4% of dry matter intake. Field experience indicates that high levels of magnesium oxide in diets or magnesium sulfate in water cause diarrhea and possibly depress dry matter intake. The magnesium-safe level for beef cattle is reached at 625 milligrams per litre magnesium in water if the diet contains .15% magnesium, and the 0.6% level for dairy cattle is reached at 680 milligrams per litre if the diet contains .2%. A suggested maximum safe level for magnesium in livestock water is 800 milligrams per litre.

Based on limited research, the effect of water high in sodium is highly variable depending on the class of ruminant livestock involved. In a study with beef heifers, 1600 milligrams per litre increased water intake 19% but did not effect average daily gain (18). Three thousand-nine hundred milligrams per litre had no effect on wethers but 5850 milligrams per litre decreased average daily gain and caused diarrhea (17). Nine hundred-seventy five milligrams per litre decreased milk production 1.9 kg. per day and increased water intake 9.3 kg per day in heat stressed dairy cows (7). Current nutrient requirement standards (15,16) define a maximum of 1.57% and 3.9% sodium in ration dry matter for dairy and beef cattle. These levels are reached at 2600 and 9750 milligrams per litre respectively.

Field experience suggests these levels may be associated with chronic diarrhea and depressed dry matter digestibility in dairy cattle. Based on the Jaster study with lactating dairy cattle, a suggested maximum safe level for sodium in water for lactating dairy cows is 800 milligrams per litre. Other classes of ruminant livestock may be able to tolerate somewhat higher levels.

There are no research studies specific to calcium from water; however, a recent publication suggests a maximum guideline of 1000 milligrams per litre (6). Beef cattle nutrient requirements (15) suggest a maximum safe level of 2% of dry matter intake. No maximum for dairy cattle is defined, although calcium above 100 grams per day during the dry period is linked to increased incidence of milk fever at calving, and levels above 1.2% of dry matter intake may cause osteoarthritis in dairy bulls (8). Based on one study (11), levels above 1% of dry matter intake may reduce intake and performance in dairy cattle. However, there is little evidence of economic loss associated with high calcium diets and no reports of toxicity associated with water. Using the level of water consumption for hot weather, 1700 milligrams per litre would supply 100 grams per day to the dry cow without consideration for other calcium sources. Since the remainder of the diet may contribute large and variable amounts of calcium, it is difficult to set guidelines for water; however, with little evidence of calcium toxicity, these guidelines may be of little practical importance. A maximum safe level of calcium in water of 1000 milligrams per litre for dry cows and growing bulls, and 2000 mg. per litre for other classes of cattle is suggested.

Iron content of most well water varies from 0 to 5 milligrams per litre, and while at the upper end of this range iron imparts a characteristic taste to water, stains metal surfaces and clogs and corrodes metal pipes and taps, it does not affect intake or productivity of livestock. Iron is toxic at 1000 parts per million in diet dry matter for beef and dairy cattle (15,16), and is typically found in dry feed stuffs at levels up to 300 to 400 parts per million. Theoretically, livestock water could have up to 120 milligrams per litre for lactating dairy cows and 175 milligrams per litre for other ruminant livestock before a toxic level is reached. In view of this, no recommended safe limit is suggested. However, levels as low as 0.1 milligram per litre reportedly cause red meat and downgrading of white veal calves.

Nitrates are most common in surface waters and shallow wells and are often associated with organic contamination. Acute nitrate toxicity is characterized by dark brown colored blood resulting from nitrite occupying the oxygen binding site of hemoglobin, resulting in respiratory failure, convulsions and death. Chronic toxicity expressed as infertility has been reported in dairy cattle at 52 milligrams per litre, nitrate-N; however, common guidelines (6,14) suggest a maximum safe concentration of nitrate as nitrogen of 100 milligrams per litre. Field reports from white veal producers suggest that calves in an induced anemic state during the last month before slaughter may experience health problems and reduced growth with nitrate-N concentrations as low as 3 to 10 milligrams per litre in water used to formulate liquid diets. Units for reporting nitrate content of water or feedstuffs vary widely between laboratories. The following equations apply for conversion to nitrate nitrogen: $NO_2 \times .3 = NO_3 \times .23 = KNO_3 \times .14. = N$.

Water quality guidelines are also established in Canada for trace elements, and heavy metals and are listed in Table 6 (6). These guidelines are set using a sufficient margin of safety below reasonably well defined toxic levels. Except in situations involving contamination, natural waters, including saline waters in Ontario, are normally well within these guidelines. Criteria for the five major elements listed in Table 7 are those of the author and represent the dissolved minerals of importance in Ontario.

TABLE 7. Water Quality Criteria for Dairy Cattle

	Maximum Recommended Concentration mg/l
Sulfate	1000
Magnesium	800
Sodium	800
Calcium (dry cows & growing bulls)	1000
Calcium (milking cows & heifers)	2000
Nitrates	100 (300 if feeds are low nitrate)
Aluminum	5.0
Arsenic	5.0
Beryllium	0.1
Boron	5.0
Cadmium	0.02
Chromium	1.0
Cobalt	1.0
Copper	1.0
Fluoride	2.0 (1.0 if feeds contain fluoride)
Lead	0.1
Mercury	0.003
Molybdenum	0.5
Nickel	1.0
Selenium	0.05
Uranium	0.2
Vanadium	0.1
Zinc	50.0

Trace Elements (6)

Table 8. Mineral Levels in Livestock Water Supplies

	Niagara Region deep wells		Niagara Region surface water	Bruce, Grey, Huron, Oxford, Perth, Wellington, Waterloo	
No. of Samples	**23**		**3**	**103**	
	Avg.	Range	Range	Avg.	Range
Mineral:					
Sulfate mg/l	1685	15 - 2500	93 - 140	50	1 - 700
Iron mg/l	0.62	0.02 - 4.90	0.15 - 0.58	0.37	0.01 - 4.7
Magnesium mg/l	182	1.3 - 516	17.8 - 24.0	25.5	8 - 74
Sodium mg/l	314	0.7 - 885	16.5 - 24.0	18.8	1 - 91
Manganese mg/l	0.08	.015 - .42	0 - 0.62	0.25	0 - 0.4
Copper mg/l	0.24	0 - 4.20	.003 - 012	—	—
Zinc mg/l	0.84	0 - 6.90	.007 - 190	—	—
pH	7.3	6.8 - 7.9	7.5 - 7.7	7.8	7.3 - 8.3
Conductivity ohm/cm	3760	91 - 7780	479 - 690	556	277 - 1575

Typical mineral levels in livestock water supplies in two regions of Ontario are listed in Table 8. Samples in the Western region were collected as part of a larger study of factors effecting production and health in dairy cows. In this study, no relationships were found between water quality and health and productivity (10). However, it should be noted that none of the samples exceeded suggested safe limits for any of the minerals tested. Extension programs in the Niagara area have focused on water quality in recent years, resulting in several dairymen switching from deep well water high in sulfates and sodium to surface water. These dairymen report improved productivity in early lactation.

Unfortunately there are few economical options for solving the more common water quality problems, particularly when high levels of sodium or sulfate are involved. Although reverse osmosis can remove these minerals effectively from small quantities of water, large systems which could supply the water requirements of livestock herds are too costly to operate and impractical. When levels border on toxicity it may be possible to compensate for interactions with other minerals by including higher levels of copper, zinc, manganese, etc. in the diet. However, the extent to which requirements for these elements is increased is ill-defined, and attempts to compensate in dairy rations on farms have not corrected the chronic diarrhea and low productivity associated with saline waters. The use of rain water has been investigated; however, calculations of the available roof area on typical livestock farms indicate average annual precipitation would supply less than 10% of the required water under Ontario conditions. The construction of collection ponds for surface water strategically located to accept water from tile drains, preferably restricted to drainage from property within the perimeter of the farm, is proving to be the only practical and economical option when the quality of well water is unacceptable.

The very short list of references following this paper reflects the fact that little research on the effect of minerals quality of livestock water has been conducted during the past 30 years. Nearly all guidelines for water quality are based on one or two trials involving small numbers of animals representing a single class of livestock. In other cases, guidelines are based on nothing more than speculation, and a great deal of further research is required.

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