Northern New York Agricultural Development Program
2015 Project Report

Do High Mineral Concentrations in Water Affect Feed Digestibility, Cow Health and Performance on Northern New York Dairy Farms?

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- Jefferson County: Roger Eastman, Lewis Horst, Greg Mason, Troy Mason, Louis Peachy, Brian Robbins, Doug Shelmidine
- Lewis County: John Williams
- St. Lawrence County: Andrews View Farm, Chambers Farm, Lisbon Centre Farm
- Onondaga County (outside NNY region): New York State Fair

Background:

Water is the most important nutrient for dairy cows. An essential part of bodily processes, it is necessary for nutrient transport, digestion, thermo-regulation, and numerous other vital functions (NRC, 2001). Because of the high body water losses to milk, lactating dairy cows have the highest water intake requirement of any land mammal (Murphy, 1992).

Research has established a relationship between drinking water quality and overall health and milk production in dairy cows (Brew et al., 2008). The goal of most of this research has been to maximize water intake and eliminate potentially toxic mineral concentrations or other compounds from the water supply. However, little research has been conducted on the effect of water quality on ruminal digestion and microbial populations.

Improving Water Quality and Intake

Poor water quality, for the purpose of this report, is defined as having one or more components above the acceptable concentration as defined by DairyOne Forage Laboratories (Ithaca, NY, Table 1).

Maintaining optimal intake of safe, clean water is essential for dairy cows. Water and dry matter intake (DMI) decrease simultaneously, and reductions in water intake will cause decreased DMI and milk production (Brew et al., 2008).

Location and cleanliness of water troughs or other sources should also be considered. Urine and fecal contamination as well as excessive coliform counts can cause significant health problems and should be monitored (Brew et al., 2008; Linn and Raeth-Knight, 2010). Health problems may include increased calf losses, intermittent or chronic diarrhea, and frequent infections (Adams and Sharpe, 1995). Cyanobacteria (blue green algae) and bacterial, viral, or protozoal microorganisms can also cause physiological problems when present in drinking water (Morgan, 2011).

Minerals or compounds most commonly found to decrease water intake due to palatability issues include sulfur (S), Fe, Mn, and total dissolved solids (TDS) (Beede, 2006; Morgan, 2011). Total dissolved solids defines the quantity of all organic and inorganic matter dissolved in water, and also may indicate salinity (Morgan, 2011); however, high TDS does not always denote poor water quality. High TDS levels are generally considered undesirable, but adverse effects may not occur depending on the substance causing the high concentration (Beede, 2006).

Minerals in water can significantly contribute to total mineral intake, and, in some cases, excess minerals in drinking water can cause toxicity or other physiological problems, such as chronic poor performance or interference with absorption of other minerals (Ivancic and Weiss, 2001; Socha et al., 2001; NRC, 2005).

Much research has been devoted to maximizing water intake as well as assuring water is safe for animal consumption by removing toxic mineral concentrations or other compounds (Andersson et al., 1984). Minerals or compounds in water that most commonly cause physiological problems include Fe, nitrate, nitrite, fluorine (F), calcium (Ca), magnesium (Mg), sulfate, copper (Cu), Mn, and lead (Pb) (Adams and Sharpe, 1995; Beede, 2006; Morgan, 2011).

Water hardness, defined as the sum of Ca and Mg reported in equivalent amounts of Ca carbonate, is another concentration often tested in livestock water. Water hardness has been shown to have no effect on water palatability or cow performance, however, mineral buildup as a result of hard water can effect flow rate, heaters, or other vital equipment, which may require more frequent cleaning (Morgan, 2011; Beede, 2006).

A study conducted in Pennsylvania found that water sources on 26% of dairy farms surveyed contained excessive concentrations of one or more solutes that can potentially decrease milk production (Swistock and Clemens, 2013). Morrill et al. (2014) found excessive concentrations of iron (Fe), magnesium (Mg), manganese (Mn), potassium (K), and nitrate in 15% of the water sampled from Northern NY dairy farms in 2014.

Since concentration alone does not fully account for mineral absorption, mineral solubility (availability) should also be measured. Water concentration and availability can be standardized on a milliequivalent (mEq) basis, and is described as strong ion difference (SID). The SID and dietary cation-anion difference (DCAD) should be calculated to accurately predict total intake of cation-anion difference (TICAD). Unfortunately, most dairy nutritionists only focus on DCAD without accounting for mineral contributions from water intake. Ideally, TICAD should be between 25 to 40 mEq/100 g of dry matter for lactating dairy cows and –10 to –15 mEq/100 g of dry matter for close-up dry cows. High intake of anions (negative DCAD) during the lactation period can result in negative effects on ruminal fermentation and lactation performance. Furthermore, high intake of cations (positive DCAD) during the period prior to calving increases the risk for hypocalcemia (milk fever), resulting in greater risk of other metabolic diseases such as ketosis, fatty liver, and displaced abomasum.

Effect of Water Quality on Rumen Digestion

A new consideration when assessing water quality is the effect of water with high mineral concentrations on ruminal digestion. Research in this area is limited, however, a recent study by Casper and Acharya (2014) indicated that further exploration of the effect of water quality on ruminal digestion is warranted. The authors examined the rate and extent of in vitro ruminal fermentation of DM by recording gas production every 5 minutes for 30 hours. Waters tested were used to mix the buffers required for the in vitro system. Distilled water acted as the control, and other water sources included water from a University dairy, and both untreated and treated water from a local South Dakota (SD) dairy operation.

The authors found that the fractional rate of gas production was greater for the in vitro system with distilled water as compared to the other treatments, with the distilled water at 16.4 %/h as compared to the university dairy, treated local SD dairy water, and untreated local SD dairy water at 9.71, 9.66, and 9.50 %/h respectively (Casper and Acharya, 2014).

The authors concluded that the quality of water may influence the rate of ruminal digestion, and further research into this possibility is warranted (Casper and Acharya, 2014). A potential limitation in the design of this study is the limited range of waters tested. A wider range of water qualities sampled from multiple or poorer sources would provide better support for their results as well as more insight to the possible explanation(s) for the reduced rate of digestion.

The objective of this Northern New York Agricultural Development Program-funded study was to 1) determine the variability in SID of water on Northern NY dairy farms identified as having poor water quality, 2) measure water SID and DCAD using wet chemistry and calculate TICAD for lactating and close-up dry cow diets, and 3) examine the effect of water quality on ruminal in vitro DM and neutral detergent fiber (NDF) digestibility of forages on dairy farms in Northern New York.

Methods:

This project focused on testing the effects of water from various sources in Northern New York on in vitro fiber digestibility. Water samples were collected from 18 sources where drinking water was provided to lactating dairy cows. Reverse osmosis (RO) water from the Miner Institute laboratory water supply was used as the water source for all control tests.

All water was sampled from the cold water faucet in the parlor or milk house closest to the cows' drinking area. The aerator was removed, and non-rubber faucets were sterilized with a flame for several seconds. Cold water was run for 3 to 5 minutes, and 250 mL was collected into a sterile collection tube after it was rinsed with a small amount of sample water.

After collection, water was shipped within 24 hours to Dairy One Laboratories (Ithaca, NY) and analyzed for coliform, TDS, pH, hardness, Ca, P, Mg, K, Na, Fe, Zn, Cu, Mn, Mo, chlorine (Cl), sulfates, and nitrates. Strong Ion Difference (SID) of the water was calculated using the Water For Cows model (http://www.waterforcows.com/index.php) based on research published by Goff et al., 1997. Approximately 2 gallons of water were also collected for in vitro evaluation of forage digestibility at Miner Institute.

In Vitro Analyses

Impact of water quality on DM and NDF digestibility of forages commonly fed on Northern NY dairy farms were evaluated. Six forage samples were selected:

- Brown midrib (BMR) corn silage,
- BMR without corn grain,
- conventional corn silage (CS),
- CS without corn grain,
- alfalfa hay,
- grass silage, and
- wheat straw.

Forage samples were ground to 1-mm particle size and in vitro NDF digestibility (24 h) was determined using the Ankom Daisy II in vitro fermentation system. A buffered medium containing 20% ruminal fluid, 15% buffer concentrate and either 65% control RO water or 65% farm water was used with this system to evaluate the effect of farm water on forage digestibility.

Total Intake Cation Anion Difference
The influence of individual farm water SID on total intake cation anion difference (TICAD) of diet and water was calculated using Water For Cows model. Calculations of TICAD were made for each farm water sampled in 2014 and 2015 using a standard high producing diet balanced for 120 pounds of production and 68 pounds of dry matter intake. Calculations of TICAD were also made for each farm water using a standard closeup diet balanced for 30.5 pounds of dry matter intake.

Statistical Analyses
The effect of RO water (Control) versus farm waters (Treatment) on in vitro NDF digestibility of various forages was compared using analysis of variance. Relationships between farm water analytes and in vitro NDF digestibility of forages were determined using either Pearson or Spearman Correlation Coefficients depending on whether the variable was normally distributed.

Results:

Water was collected from farms identified with possible water quality issues based on a survey of Northern New York farms in 2014. Water analyses results for the selected farms from both 2014 and 2015 are presented in Table 1 along with expected ranges and problem water quality values provided by Dairy One Forage Laboratory (Ithaca, NY).

Table 1. Expected ranges and problem water quality values and water quality analyses for selected study farms in 2014 and 2015 (DairyOne Forage Laboratory; Dairy Reference Manual, 3rd ed., NRAES-63, June 1995).

Component	Expected range	Possible problems*	Range for study sites -2014	Range for study sites-2015
Total coliform / 100 ml	< 1	15	0-2	0-2
e. Coli			0-1	0-1
Nitrates, ppm	0 – 44	100	0-121	0-97
Nitrate – N, ppm	0 – 10	23	0-28	0-22
Sulfates, ppm	0 – 250	1000	0-280	4-170
Sulfates- S, ppm	0 – 83	333	0-92	1-56
Chlorides, ppm	0 – 250	300	7-116	19-137
Hardness, $CaCO_3$ ppm	0 – 370		5-491	1-472
TDS ppm	0 – 500	3000	386-769	231-794
Ca, ppm	0 – 100	500	2-156	0-168
P, ppm	0 – 0.3	0.7	0-1.29	0-0.29
Mg, ppm	0 – 29	125	0-59	0-51
K, ppm	0 – 20	20	1-52	2-23
Na, ppm	0 – 100	300	10-213	8-240
Fe, ppm	0 – 0.3	0.3**	0-2.2	0
Zn, ppm	0 – 5	25	0-0.05	0
Cu, ppm	0 – 0.6	0.6	0-0.58	0
Mn, ppm	0 – 0.05	0.05**	0-0.9	0
Mo, ppm	0 – 0.07	0.7	0-0.02	0
pH	6.8 – 7.5	< 5.5 or > 8.5	7.0 – 7.6	7.0 – 8.2
SID, mEq/L			-0.78 - 7.91	-1.19 - 8.58

* Values are for mature cattle

** Palatability concern

For the majority of parameters evaluated, values were lower in 2015 than 2014. In particular, none of the farms tested in 2015 had measurable levels of Fe, Zn, Cu, Mn or Mo. The SID values ranged from ~-1.0 to 8.0 mEq/L across both years on farms tested.

Based on the outcome of the water analyses, we did not anticipate farm water would affect the in vitro fiber digestibility of forages evaluated. As shown in Table 2, 24 h-NDF digestibility of most forages, with the exception of CS, were similar when farm water was used in replacement of RO water.

Table 2. In vitro digestibility of neutral detergent fiber (% DM) for a variety of forage types when farm water (Treatment) is used as replacement for RO water (Control) and combined with buffering solutions and ruminal fluid.

Forage Type	**Control RO Water**	**SE**	**Treatment Farm Water**	**SE**	***P*-value**
Brown midrib (BMR) corn silage	48.69	0.96	49.23	0.69	0.657
BMR without corn grain	47.28	1.40	48.35	0.97	0.532
Conventional corn silage (CS)	44.15	0.76	46.97	0.55	**0.008**
CS without corn grain	51.50	0.63	51.85	0.44	0.654
Alfalfa hay	47.85	0.59	46.95	0.42	0.232
Grass silage	61.55	0.40	62.12	0.29	0.271
Wheat straw	26.69	0.35	26.45	0.25	0.584

Farm water improved the 24-h NDF digestibility of conventional CS when compared to the normal lab procedures using RO water (46.97 vs 44.15, respectively; $P \leq 0.05$). These results indicate that farm water could be used to replace RO water in the in vitro digestibility system and further investigation into effects of individual elements could be evaluated.

Correlation coefficients were used to evaluate linear relationships between farm water elements and 24-h in vitro NDF digestibility of forages (Table 3). Sodium level of farm water exhibited a moderate positive correlation to fiber digestibility for BMR, BMR and conventional CS without grain, and grass silage (Table 3).

Table 3. Correlation between water quality parameters and in vitro digestibility of neutral detergent fiber (24-h) for a variety of forage types when farm water is used as 80% replacement of RO water in buffering solutions combined with ruminal fluid.

Forage Type	n	Hardness[1]	Ca[1]	P[2]	Mg[1]	K[2]	Na[2]	Cl[2]	Nitrate-N[2]	Sulfate-S[1]
Brown midrib (BMR) corn silage	18	-0.08	0.002	-0.26	-0.23	-0.18	0.46**	0.47*	0.42**	-0.05
BMR without corn grain	18	-0.24	-0.22	0.23	-0.19	-0.02	0.44**	0.36	0.10	-0.02
Conventional corn silage (CS)	18	-0.18	-0.14	-0.28	-0.19	-0.20	0.34	0.45**	0.15	-0.10
CS without corn grain	14	-0.27	-0.19	-0.31	-0.32	-0.04	0.60*	0.29	0.22	-0.13
Alfalfa hay	18	-0.23	-0.08	-0.11	-0.46**	-0.21	0.40	0.24	0.57*	-0.20
Grass silage	18	-0.21	-0.05	-0.12	-0.47*	-0.45**	0.41**	0.37	0.39	-0.16
Wheat straw	18	-0.17	-0.01	-0.22	-0.41**	-0.26	0.37	0.30	0.54*	-0.11

[1]Pearson Correlation Coefficient
[2]Spearman Correlation Coefficient
*$P \leq 0.05$
**$P \leq 0.10$

As sodium levels in water increased, the 24-h in vitro NDF digestibility also increased (Figure 1). Nitrate-N also had a moderate positive correlation with fiber digestibility for BMR, alfalfa hay and wheat straw (Figure 2). There was a moderate positive relationship between SID and forage digestibility of grass silage and CS without corn grain (R=0.410 and R=0.539, respectively).

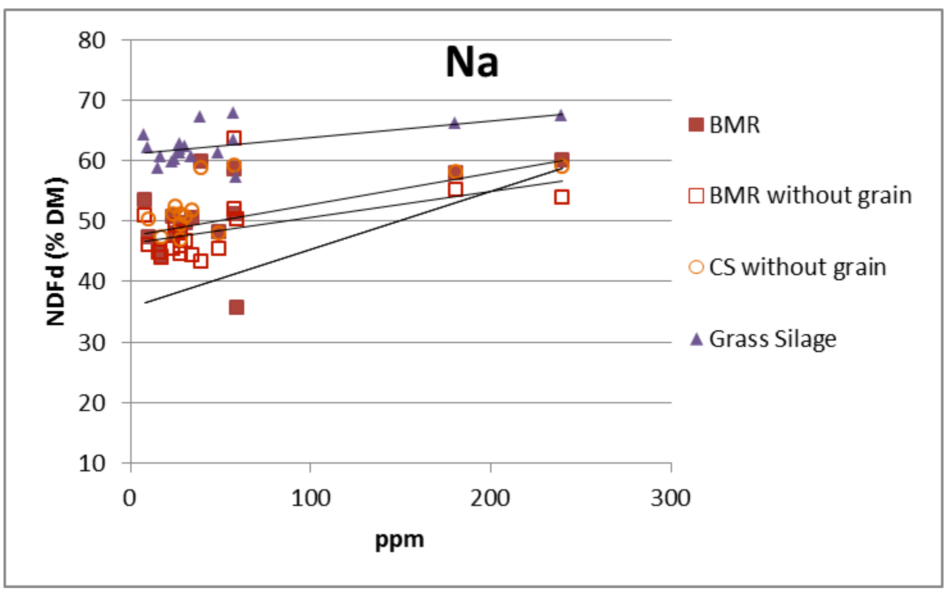

Figure 1. Effect of sodium (Na) level in farm water on 24-h in vitro NDF digestibility of various forages (P≤0.10).

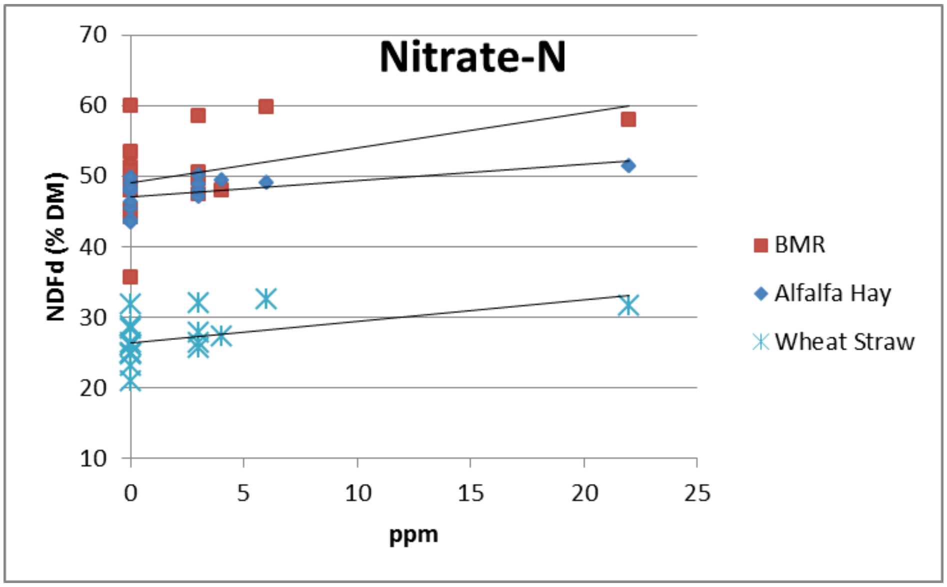

Figure 2. Effect of nitrate-nitrogen (N) level in farm water on 24-h in vitro NDF digestibility of various forages ($P \leq 0.10$).

Chlorine levels in the water also showed a positive relationship with fiber digestibility for BMR and CS (Figure 3).

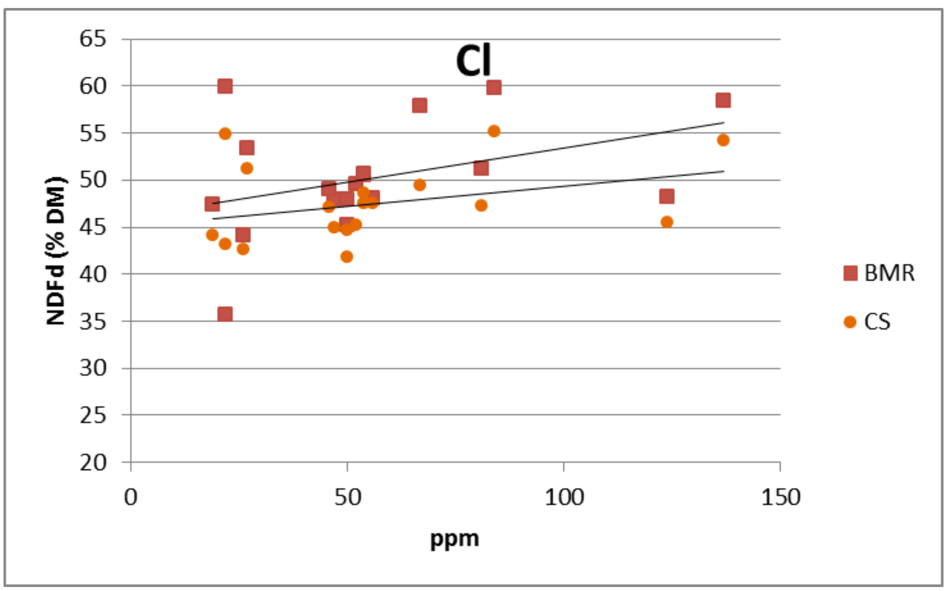

Figure 3. Effect of chlorine (Cl) level in farm water on 24-h in vitro NDF digestibility of BMR and conventional CS ($P \leq 0.10$).

Interestingly, there were moderate negative relationships between both Mg and K and forage digestibility for some of the forages evaluated (Figures 4 and 5). These findings indicate that farms with high levels of Mg and K may experience reduced digestibility of legumes and grasses.

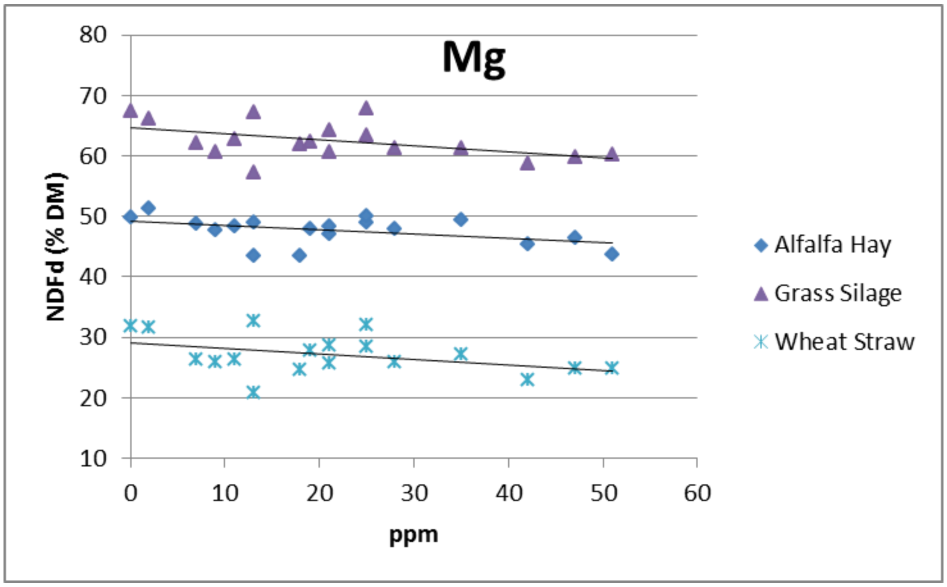

Figure 4. Effect of magnesium (Mg) level in farm water on 24-h in vitro NDF digestibility of various forages (P≤0.10).

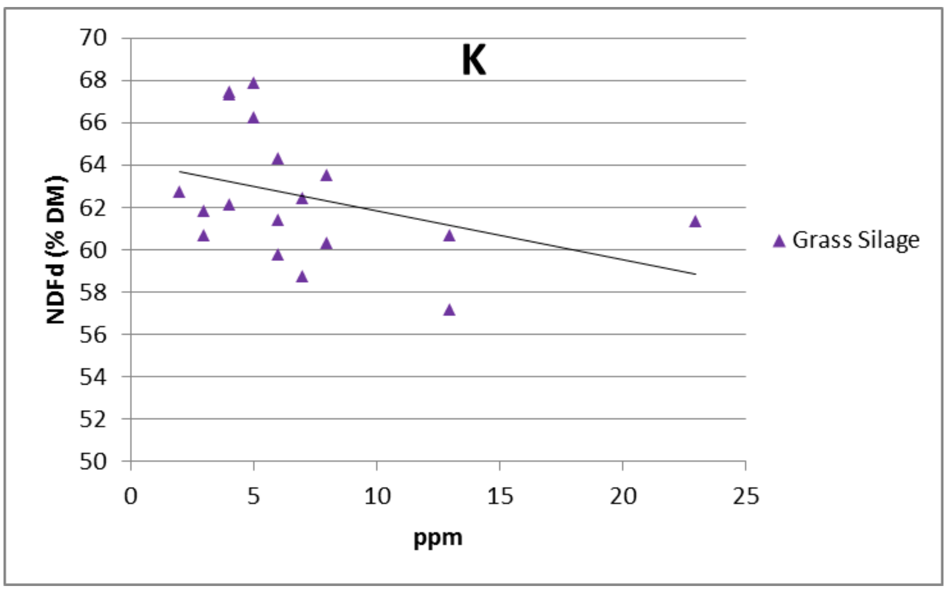

Figure 5. Effect of potassium (K) level in farm water on 24-h in vitro NDF digestibility of grass silage (P≤0.10).

Based on these results, additional testing of the impact of Mg level on fiber digestibility was investigated using the more sensitive Tilley Terry digestion system. System solutions were titrated to represent 11, 22, 34 and 44 ppm of Mg and its effect on alfalfa hay, grass silage, BMRcorn silage and conventional corn silage is presented in Figure 6. Titrating Mg levels using the Tilley Terry system found that the NDF digestibility of conventional corn silage was the only forage which was significantly reduced as Mg levels increased (P=0.024). Unlike previously indicated, the NDF digestibility of other forages were not significantly impacted by Mg levels.

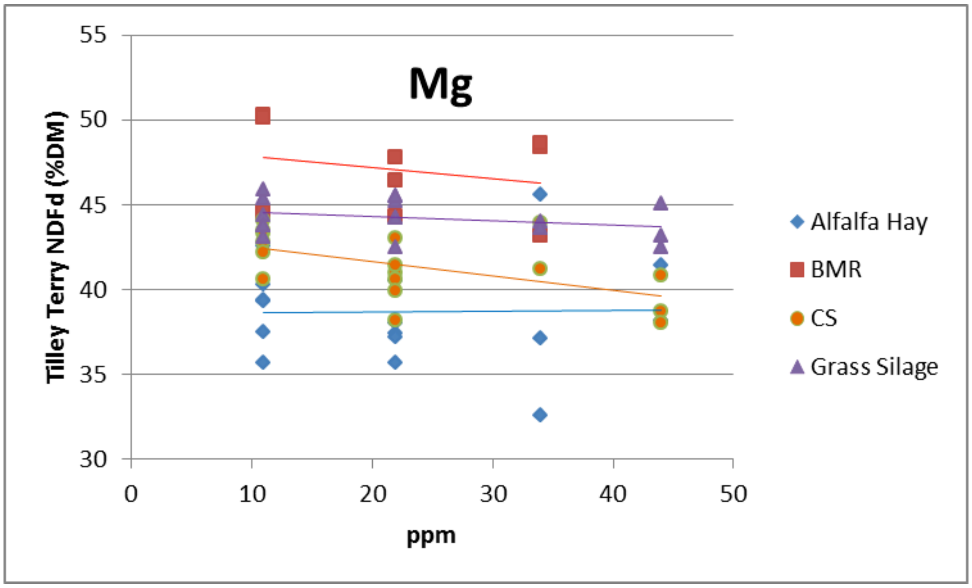

Figure 6. Effect of magnesium (Mg) level on 24-h in vitro NDF digestibility of forages evaluated by titrating into solutions used in the Tilley Terry system.

The calculated TICAD for waters sampled in 2014 and 2015 are presented in Table 4. The cations and anions present in the water samples evaluated did not strongly impact the TICAD as indicated by the narrow range of TICAD values calculated for a constant closeup and high production diet. The biological impact on the production of more or less blood buffers contributed by water intake of cations and anions from the water sampled is limited.

Table 4. Total intake cation anion difference (TICAD) calculated from farm waters sampled on Northern New York dairy farms in 2014 and 2015.

Diet DCAD (Meq/L)	Year	Range (Meq/L)
Closeup - -1.44	2014	-1.8 – 2.17
High Production – 31.48	2014	31.13 – 35.03
Closeup - -1.44	2015	-1.98 – 2.47
High Production – 31.48	2015	30.49 – 35.33

Conclusions/Outcomes/Impacts:

This research indicates that positive and negative relationships between water quality/mineral content and fiber digestibility of various forage types may exist. The Ankom Daisy II system allowed for identifying trends in water quality/mineral content relative to NDF digestibility. Initial use of the more precise Tilley Terry system confirms that as Mg levels increase, the digestibility of some forages, specifically conventional corn silage decreases. To our knowledge, no research has been published to confirm or refute our findings. Further research is warranted to determine critical levels of water minerals and possible interactions between water elements that may influence rumen function.

Our findings that water quality may not have a large impact on TICAD should not diminish the importance of good water quality on animal health and productivity. The improvement of water quality may also increase forage digestibility and subsequent animal productivity on farms.

Outreach:

Two informational articles about water quality and the impact of water quality on animal health have been published in the Miner Institute Farm Report: *Water quality might mean more to milk production than we think* by Danielle Andreen August 2015. This article was also re-published in Dairy Herd Management, and *Cool Clear Water* by Rick Grant, April 2016. The Andreen articles was reprinted by Dairy Herd Management: http://www.dairyherd.com/news/water-quality-might-mean-more-milk-production-we-think.

Next Steps:

The effect of iron should be evaluated since no water tested in 2015 had high levels of iron which may adversely impact ruminal digestion. This research could be conducted using Tilley Terry NDF digestion system.

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