

Stray Voltage and Water for Dairy Cattle

A Veterinarian's Perspective

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Introduction:

Concern about the influence of stray voltage on Wisconsin dairy farms has commonly focused on water. Data from 285 stray voltage investigations in Wisconsin found that 50% of the farmers indicated reduced water intake as one of the symptoms that led to their concerns about stray voltage.¹ Experience gained from over 800 farm visits as the veterinarian with the State of Wisconsin's Rural Electric Power Services Program (REPS, previously the Stray Voltage Analysis Team or SVAT) has proved that water is one of the more contentious issues on dairy farms where there is a concern about stray voltage.^a

Working with water issues during farm investigations has revealed that among rural professionals serving dairy farmers there is widespread deficiency in the understanding of how to determine water intake and how stray voltage affects water intake. In addition, there is a significant lack of scientific knowledge about how most aspects of how water quality may affect intake, health, or performance in dairy cattle. This combination increases the vulnerability of dairy farmers to be given misinformation about water. The most disturbing manifestation of this is when the lack of rural expertise on water issues allows enterprising individuals to profit from farmers who are already economically stressed.

In this article consideration will be given to the understanding of water consumption, the relationship of stray voltage to water intake, the interpretation of atypical behaviors associated with water sources, and water quality as these issues relate to dairy cattle.

Water Consumption:

The science of water consumption in dairy cattle is well documented. The National Research Council's Nutrient Guidelines for Dairy Cattle (NRC) contains multiple formulas usable for the prediction of free water intake in lactating and dry cows, as well as a summary of

^a Stray voltage is defined by the Public Service Commission of Wisconsin (PSCW) as a natural phenomenon that can be found at low levels between two contact points in any animal confinement area where electricity is grounded. Electrical systems - including farm systems and utility distribution systems- must be grounded to the earth by code to ensure continuous safety and reliability. Inevitably, some current flows through the earth at each point where the electrical system is grounded and a small voltage develops. This voltage is called neutral-to-earth voltage (NEV). When a portion of this NEV is measured between two objects that may be simultaneously contacted by an animal, it is frequently called stray voltage. It is the "level of concern" defined as follows that dictates the significance of the voltage at cow contact. In Wisconsin, the "level of concern" is derived from the 1996 PSCW docket 05-EI-115. In that docket, the "level of concern" is defined as 2 milliamps, AC, rms (root mean square), steady-state or 1 volt, AC, rms, steady-state across a 500-ohm resistor in the cow contact area. The Institute of Electrical and Electronics Engineers (IEEE) defines "steady-state" as "the value of a current or voltage after all transients have decayed to a negligible value." The State of Wisconsin deems that this level of voltage/current is an amount of electricity where some form of mitigative action is taken on the farmer's behalf, although only some small percentage of cows may actually perceive its presence. The "level of concern" is not a damage level. Instead, it is a very conservative, pre-injury level, below the point where moderate avoidance behavior is likely to occur and well below where a cow's behavior or milk production would be harmed. The "level of concern" is further broken down into two parts. The first part is a 1-milliamp contribution from the utility, at which level mitigative action must be taken by that utility to reduce its contribution to below the 1-milliamp level. The second part is a 1-milliamp contribution from the farm system, at which level mitigative action should be taken by the farmer.

the factors that affect the amount of water that cows, heifers, and calves can be expected to drink.² Another excellent reference on water and the use of a water intake prediction formula is the chapter on water in “Large Dairy Herd Management.”³ Personal experience has shown that these equations are rarely used to assist farmers concerned about water intake. Without exception, on REPS farm investigations between 1994 and 2002 where water consumption was a concern, none of the local farm service professionals (i.e. veterinarians, nutritionists, milk plant field persons, or university extension professionals), who were actively advising the farmers, exhibited familiarity with the available formulas that predict water intake.

In these herds, if any guidelines on water intake were provided, they were based on a loose application of simplistic rules of thumb. Typical of these are: a cow should, “drink more than 30 gallons of water a day,”⁴ or “about 29 gallons of water a day.”⁵ Compare the rule of thumb printed in a popular dairy magazine article and the estimates based on the NRC recommended formula. The rule of thumb is “a cow should drink a half-gallon of water, including water from feed, for each pound of milk produced”.⁴ For a cow producing 80 pounds of milk this should predict her total water needs at 40 gallons. If, however, the ration is 50% water, and dry matter intake is 50 pounds then the ration should provide around 6 gallons of water. Even if this source of water were factored in the predicted intake would only be reduced to 34 gallons. The Murphy-1983 formula recommended in NRC predicts, for an average winter barn temperature of 40°F, that the cow should be expected to need only 25 gallons of water. Not until the average minimum temperature of the week rose to 90°F, or the dry matter of the ration was over 90% should water consumption predicted by the NRC formula begin to approximate the amount predicted by the rule of thumb.

Articles written in popular dairy magazines commonly discuss the importance of improving water intake, especially in relation to reducing the negative impact of heat stress.⁶ The importance of water as a vital nutrient and assuring adequate access to water are well understood.^{7,8} What is not well understood is whether or not increasing water intake in itself is a worthwhile goal. If a cow consumes the amount of water that standard intake formulas predict, will additional water intake improve milk production, or will the surplus merely be lost in increased urine output and fecal moisture? It is common for dairy farmers to profitably use a variety of methods to coax their cows to eat more feed. Is it beneficial or even possible to coax a cow to regularly drink more water than she needs?

Veterinary and dairy scientists generally believe that if cows could be enticed to consume surplus water, the surplus water would be excreted as urine and manure without a beneficial effect on milk production. Two studies in goats found that “after hyperhydration (10% of body weight) 46% of the load was excreted by the kidneys within 6 hours,” and that there was no storage of excess water.^{9,10} Water intoxication, a type of timing-related hyperhydration that occurs with sudden rehydration after extreme dehydration, can cause serious leakage of hemoglobin into their urine and neurological problems.¹¹ Although one author suggests, “adequate intake from a quality water source will improve dry matter intake and overall milk production,”¹² no studies have actually documented whether or not increasing water intake slightly above a dairy cow’s required needs is of any health or production benefit.

The importance of the above discussion is that reduced water intake is interpreted as a sign of stray voltage on 50% of farms visited by the REPS program.¹ However, experience on farm visits where these concerns exist have shown that:

- 1) Farmers have not been advised of the existence or use of industry standard formulas to predict actual water intake.
- 2) Advice given to farmers about depressed water intake is based on overly simplistic rules of thumb.
- 3) There has not been adequate effort to determine whether or not water consumption is meeting water needs.

- 4) There is the dubious expectation that if water consumption can be increased it will be beneficial to herd health or production.

Local farm professionals, who rarely need to work with water issues, are not the only source of poor information about water. Field experience has provided plenty of examples where representatives of large dairy feed companies suggested to farmers that herd water intake was reduced due to stray voltage without verifying any reduction. When farm service professionals make the unverified suggestion that stray voltage is causing a herd's water intake to be depressed, and stray voltage mitigation efforts (coincidentally) fail to produce an increase in water consumption, the real problem is that the farmer is put into a highly vulnerable position. For some, the improvement of a fictitious water intake problem can be a very expensive business mistake.

Reduced water intake

The effects of reduced water intake on dairy cows has been studied. Well documented in veterinary literature is the acute event of water intoxication, where water ingestion after a short period of water deprivation may produce seizure, coma, or death related to cerebral edema.¹¹ Complete deprivation of water with a dry hay and dry grain ration has been studied in dairy cattle. Among the results was a decrease in mean milk yield to 93% of normal after 24 hours, 52% of normal after 48 hours, and by the end of the 72-hours trial, milk yield was 28% of normal. On the first day of return to free access to water the mean milk yield rebounded to 48% of normal. On subsequent days the mean yield was not significantly different from controls.¹³ In another study, a 48-hour deprivation of water in dairy cattle on a grass and corn pellet ration resulted in a 30% reduction in milk production, with a return to baseline levels after rehydration.¹⁴

Another study allowed either 50% or 90% of voluntary water intake in dairy cows on a dry grain and pasture or silage ration for 14 days. In the 50% restricted water group, milk production reached the minimum of 74% of the controls after 4 days. Milk yield, after a return to free access to water, never regained that of the controls and remained significantly lower during the ten-day recovery period. In the group with 90% of voluntary water intake the milk yield decrease was statistically insignificant during the 14 day trial.¹⁵

A number of other studies consider the difference in effects depending on whether or not water restriction is avoidable or not. Submissive cows can consume significantly less water (7%) than dominant cows.¹⁶ A herd with tethered cows and shared water bowls may have half the herd sharing water. Dominant cows sharing a common water bowl may tend to be heavier, drink more water, and produce more milk.¹⁷ Delays in access to water for up to 2 hours after feeding may not reduce milk production.¹⁷ Lower flow rates at the water bowl resulted in lower production (19.3 kg/day at 2L/min flow, and 19.8 at 12L/min flow).¹⁸ The replacement of a 1" galvanized water supply pipe with a 2" PVC looped line and 5/8" ID supply hoses resulted in an average 3 pound per cow increase in milk yield.¹² However, dairy cows in properly stocked loose housing, by changing their drinking behavior, may avoid the adverse production effects of issues like dominance, low flow, water location, or delayed access.¹⁹

The potential for stray voltage to limit water intake:

The misleading belief that stray voltage causes reduced water intake has been highly popularized. "Stray voltage may be the most common problem limiting water intake"⁸ is an example of the detrimental professional liberties which perpetuate this situation. The above studies suggest that for stray voltage to have a lasting impact on milk production it would need to be present at levels that: 1) cause a complete cessation of drinking for over 72 hours, or 2) cause a 50% (or perhaps more than 10%) reduction in intake for at least four (or perhaps 14) days, and in either case, 3) cause an aversion to water that cows are unable to avoid.

Numerous stray voltage studies have looked at the relationship between stray voltage and water consumption:

- Zero, three and six volts were applied to three equally available water bowls. Heifers drank 20% less at the 3-volt bowl, and 68% less at the 6-volt bowl.²⁰
- At 8-volts 30 heifers refused to drink for 8 hours and drank sparingly over the next 16 hours. After day 3 water consumption was equal to that of the control group.²⁰
- One heifer and one cow refused to drink for 36 hours from the water bowl electrified with 4-volts. All other cows exposed to 0.5, 1, 2, or 4 volts on their water bowls for 3 weeks had a delay in drinking during the first 24 hours. The length of delay was proportional to the voltage. Within 48 hours all these cows were consuming the same amount of water as before the voltage exposure. Over 3 weeks there was no significant difference between water consumption in the control cows those drinking from an electrified water bowl.²¹
- Twenty cows in each of four groups were exposed to 3, 4, 5, or 6 volts on their water bowl for three days. Two cows exposed to 5 volts and two cows exposed to 6 volts did not drink.²¹
- Four groups of 10 cows were monitored over an entire lactation with exposures of 0, 1, 2, or 4 volts. The voltage at any level did not affect water consumption.²²
- On a 120-cow New York dairy farm cows were exposed to current ranging from 3.6 to 4.9 mA for 2 weeks followed by 2 weeks of no exposure. The alternating exposure lasted for 12 weeks. The exposure was alternated for 2 weeks on and 2 weeks of no exposure. No significant effect on water consumption was measured.²³
- Four groups of 4 cows were exposed to 0, 1, 2, or 4 volts for one week. There was no significant difference in water intake among groups.²⁴
- The primary distribution grounding was alternatively disconnected and reconnected for 4 periods over one month. The maximum cow contact voltage measured during the study was .045 volts. No significant effect on water consumption was reported.²⁵
- An aversion response was measured in different cows at a range of currents applied to water bowls from 3.4 mA to 5.9 mA. An increase in electrical frequency required an increase in the current to produce aversion at the water bowl. DC voltage simultaneously applied to the water bowl did not have a significant effect on aversion, indicating that any effect of DC voltages are not additive to the response produced by AC voltages.²⁶
- The most sensitive cows responded to a current of 1.4 mA for 1 cycle. The least sensitive cow did not respond until 9.9 mA. Sixty-four percent of the responses occurred between 4 and 7 mA. Shorter duration transient required higher currents to elicit a response. No response to any electric or magnetic field exposures were observed.²⁷
- Variation in the sensitivity of cows improved the predictability of response. Cows were exposed to 21 days at specific individual levels of each cow's reaction level (R), R plus 1.5 mA, R plus 3 mA, and R plus 1.5 times R. "The average additive increment above R was 4.7 mA peak current with a range of 3.5 to 6.5 mA peak current." Reductions in water intake were measured on the first three days of exposure to 150% of R. After 3 days no effect was seen at any exposure level. A delay to drinking was observed during the first day of exposure at lower levels than those required to cause a measurable change in water consumption. Behavioral changes were observed with no measurable decline in water consumption. No adverse effect was found in water consumption over the 21 day period. Adaptation to exposure was observed.²⁸
- Calculations based on observation of water bowl contact times can estimate the expected exposure for herds of different sizes with different rate of transients during a day. With 10 transient electrical events on a water bowl, the most exposed cows could be expected to experience the event 1.4 times a day in a 50 cow herd, 1.6 times a day in a 100 cow herd, and 1.9 times a day in a 200 cow herd.²⁹

- A continually pulsed electrical event on the water bowl was shown to produce similar response as exposure to a continually steady electrical application to the water bowl. Significantly aversive electrical pulses were applied to the water bowl once per day, once every 10 seconds and once every second. A significant delay in drinking and decrease in amount of water consumed in 4 and 8 hours was observed in the 1/second exposure group. No differences were observed in drinking behavior between control and the 1 pulse per day, or control and 1 pulse per 10 seconds group. “When cows were given the opportunity to drink between current pulses which could cause aversion, they consumed water at the same rate as cows receiving no current stimulus.”³⁰
- Graph 4 graphically demonstrates the variation in animal perception in relationship to electrical pathway, level of exposure and animal sensitivity.³¹

There is no dispute that at certain levels stray voltage has a significant ability to affect cow intakes. “On the day shocking was initiated, the first three cows to be shocked were subjected to currents of 12.0 mA. [6 volts through a 500 ohm resistance]. These cows could not be approached. We immediately decided to abandon the 12.0 mA treatment and reassign the cows”.³² However, data from over 6,000 first-time stray voltage investigations in Wisconsin indicates that the potential is rare. In these investigations 91.8% found 1 volt or less at cow contact. Only 2.7% were over 2 volts. The research-based understanding of stray voltage indicates that less than 1% of dairy cows can perceive such low levels (Graph 4).

Field data

Experience has shown that requests from farmers to identify and reduce stray voltage are often based on an unsubstantiated perception that water intake is low. If the levels of stray voltage routinely found have the ability to significantly decrease water consumption, then it should be possible to use a water meter to determine if the amount of water being consumed is less than the amount of water required by the animals being monitored. On 31 SVAT farm investigations a meter was installed to measure water intakes. Available data (average minimum air temperature, milk production, dry matter intake, feed moisture, ration salt levels) were collected to assist in calculating the expected water needs for the animals being monitored³³. The data compares the measured water intake and calculated water needs on farms where the cow contact current was monitored (Table 1 and Graphs 1-3). Within its statistical limits this field data agrees with research data and offers several conclusions.

- 1) On average, the amount of water consumed (20.1 gallons per cow per day) closely follows the predicted amount of water needed (20.4 gallons per cow per day). The use of a water intake formula to calculate needs and predict measured intake is supported (Graph 3)
- 2) Water intake for the 13 herds with cow contact currents equal or greater than the 1 milliamp SVAT level of concern (at the time of the investigations) averaged 19.4 gallons per cow per day versus 20.6 gallons per cow per day in the 18 herds with cow contact currents below the 1 milliamp level of concern. No significant difference ($r^2=0.04$) in water intake was found between the two groups (Graph 1).
- 3) For those herds with cow contact currents above the 1 milliamp level of concern, a plot (Graph 2) of cow contact current versus the difference between water intake and calculated needs does not indicate any trend with higher cow contact currents. Depression of water intake related to stray voltage was not noted.
- 4) A water meter does not appear to be a useful field tool to predict the presence or absence of cow contact current levels of 3.7 milliamperes or less.

It may be possible for a water meter to identify a new and unexpected stray voltage exposure if it is sufficient to cause a delay in drinking, but rarely will this scenario present itself

during a field investigation. Water meters installed on a farm may similarly identify a new and unexpected stray voltage exposure if it is sufficient to cause a delay in drinking, but experience has indicated that the data needed to correctly interpret water meter readings (ration moisture, average minimum temperature, dry matter intake, milk production, and salt intake) is not collected.³³ Typically, the readings on the meter are faithfully recorded, but without supporting data these numbers are of little significance. Water meters used without supporting data tend to create false conclusions and confusion. Rather than a water meter, the permanent installation of a standard stray voltage monitoring meter is a more electrically sensitive and time sensitive method for early detection of significant new stray voltage events.

The popularized belief that stray voltage commonly reduces water intake is dangerously simplistic. Over ninety percent of investigations in Wisconsin report less than 1 volt at cow contact.¹ Less than 3% of cows in any herd (5 cows or less in a 200 cow herd) are expected to be sensitive enough to perceive 1 volt of electricity on their water bowl.²⁹ Aversion responses are expected to occur at approximately 1.5 times the electrical exposure level that indicates perception of the current.²⁸ For the cow that is sensitive enough to want to avoid drinking, there are at least two other factors that make water intake an insensitive field parameter to evaluate stray voltage. First, adaptation is known to occur.²⁸ Aversion is most likely to occur only during initial exposure to stray voltage, after which the response may be a short-term delay to drink. Second, if the current on the water bowl is intermittent and a cow learns to avoid exposure, or if there are alternative sources of water for a cow to choose from, then it is expected that water consumption will not be affected³⁰.

The implications here point to one of the primary causes of frustration experienced in working with the stray voltage issue on in Wisconsin dairy farms. Stray voltage is a significant concern for farmers. The State of Wisconsin has recognized that it is significant enough to require all public utilities to perform a PSCW standardize stray voltage investigation on any farm upon request and at no charge to the farmer. Perpetuation of popularized misconceptions about stray voltage and water intake has served to confound well-intended efforts to assist dairy farmers. When increased water intake is relied upon as the evidence of a successful reduction of stray voltage it assumes that water consumption is actually depressed, and that there is a negative cause and effect relationship between stray voltage and water consumption. Neither of these are usually true. The on-farm reality is, first, that depressed water consumption is most commonly unsubstantiated and based on incorrect assumptions, and second, that the level of stray voltage most typically found on farm investigations in Wisconsin has no cause and effect ability to influence herd-based water intake rates. The implication is that a coincidental rise in water intake may be the primary factor used to evaluate the success of a stray voltage investigation. This highly confounded scenario can result in casting a rather insurmountable shadow upon on the validity or intention of the stray voltage investigator. The stray voltage investigator will likely survive, but all too often the farmer, faithfully watching his water meter, may not.

Behavior at water source as an indicator of stray voltage

Cow behavior is a more sensitive indicator of exposure to transient current than water intake,²⁸ but unfortunately some behaviors of cows at their water source have also wrongly become popularized as an indication of stray voltage. The wide distribution of the following undocumented misconception in educational publications on stray voltage is unfortunate. “A rather specific symptom indicative of a probable stray voltage problem is the uncharacteristic ‘lapping of water’ during animals’ attempts to meet their demand for water.”^{34, 35} On the contrary, lapping of water is not a reliable indicator of stray voltage.

Videotaping of eating and drinking behavior on SVAT investigations has indicated that lapping behavior is a characteristic behavior in dairy herds regardless of the presence or absence of stray voltage.³⁶ Such behaviors are well-documented in animal behavior literature as stereotypic mouth movements that can beneficially^{37, 38, 39} increase as a coping mechanism⁴⁰ for a

variety of stresses, from low fiber intake and restrictive stalls, to feed restrictions^{41,42} (i.e. crowded bunk, dominance in shared stalls, or empty manger scenarios). The occurrence of repetitive oral coping behaviors does have some negative implications on welfare⁴³, but it is related to inadequate cow comfort and feed-associated frustrations. Lapping at water is not a good indicator of stray voltage.

Urine drinking is a puzzling behavior that is widely misunderstood and occasionally brought into the group of behavioral misconceptions about stray voltage. It makes common sense to farmers and farm service professionals that an animal, well supplemented with salt and minerals, must have an aversion to its water source if she is seen seeking urine to drink. However, animal behaviorists understand urine drinking as another stereotypic behavior that, again, increases particularly when inadequate cow comfort issues exist.⁴⁴ One representative study found that urine drinking was observed in 52.7% of animals that were over-crowded, on slatted floors, and offered a low-fiber ration.⁴⁵ Urine drinking is not a good indicator of stray voltage.

A behavior that can be indicative of an encounter with an annoying level of stray voltage is a flinch response.⁴⁶ At the very first shock from a water source the reaction has been described as similar “being surprised” or “startled”.⁴⁷ If a cow is not shocked on the next drink, the expectation is for her to go back to her normal drinking behavior.²⁹ If, however, she is greeted by an annoying shock on her next approach, a delay to drinking again is the expected behavior²⁸. Waiting in some animals may produce a hovering over the water source. One unsubstantiated hypothesis is that some light touching of the guard hairs around the muzzle may provide a clue as to the continued presence or absence of the offending electricity.⁴⁷ If waiting or the selecting of another water source is not an option, a drinking pattern of less frequent visits to the water with higher intakes at each visit is the initial behavior modification that has been observed.⁴⁷ Variation in sensitivity to stray voltage has been well-documented.^{48,30,28} If the level of shock is annoying but not prohibitive, adaptation and a resumption of normal pre-exposure levels of water consumption has the behavior most commonly reported.^{28,30}

Another example of a behavioral misconception that has become popularized as evidence of stray voltage is that of a cow pressing her nose against a water bowl. In this behavior a cow may lean her head into a water bowl (or another cow, or part of her stall). She may remain, somewhat trance like, in that position for a curiously long time. This behavior has been observed on videotapes recorded during SVAT investigations as a characteristic behavior in dairy herds regardless of the presence or absence of stray voltage.³⁶ Such behaviors are also well documented in the literature of animal behavior as stereotypic behaviors that increase in relationship to increased standing time.⁴⁹ European literature refers to this behavior as leaning. Pressing of the nose into a water bowl is a behavior that is opposite of how animals respond to annoying levels of stray voltage. When it occurs in the herd, it should be seen as potential evidence of inadequate cow comfort. Nose pressing is not a good indicator of stray voltage.

Lapping at the water, biting the water bowl, nose pressing against the water bowl, splashing and throwing water, and blowing blasts of air into the water have all inaccurately become part of the popular animal behavior myths surrounding stray voltage. A temporary delay in drinking after first exposure is the behavioral response most repeatedly identified in stray voltage studies. Avoidance, rather than seeking of contact, is the behavior that studies have repeatedly indicated to be the anticipated response to annoying levels of stray voltage.

Neither avoidance nor the behaviors that have been mistakenly popularized as indicators of stray voltage are what occur when water intake is experimentally limited. “Cows receiving a restricted water allowance tended to spend more time standing up (57.2% standing) than did cows supplied with water ad libitum(42.7% standing). Cows allowed 50% of voluntary water intake visited their water trough 23 times per hour. Cows allowed 90% of their predicted intake visited their water trough 22 times per hour, compared to 10 times per hour for control cows with no restriction of intake. It was noticeable that the restricted cows spent more time around the

troughs, which remained empty except when water was being supplied. After each milking these cows cantered back to troughs to obtain water, and at this time, there was some aggressive behavior. Cows arriving too late tried to push their way through those who had arrived earlier in order to get water.”¹⁵ When water intake is less than adequate the behavior to be expected is a relatively strong attraction to the water source rather than the avoidance that is expected with an annoying shock at the water source.

Avoidance rather than prolonged direct contact is the behavioral response expected when an annoying shock is present at drinking. Lapping at the water, biting the water bowl, head pressing against the water bowl, and other displays in the water should decrease in the presence of aversive levels of stray voltage.

Water quality evaluation on farms concerned about stray voltage

In dairy herds where the stray voltage concern involves the perception that water intake is depressed, the testing of water quality seems like a relevant consideration. Water quality tests were performed routinely on SVAT investigations and as needed on REPS investigations. Water quality has been tested on a total of 49 farms. The first 26 farms tested were at the state of Wisconsin Soil and Plant Analysis Lab.⁵⁰ Water was tested for 25 elements and cost \$35. The results were uniformly uninteresting, in that not a single element on any of the tests were found at levels known to affect intake or health (Table 2).

A further effort was made to use the National Testing Laboratories⁵¹ to test water on 23 subsequent farms. This more comprehensive test looks at 95 different elements, including bacteria, 15 heavy metals, 10 inorganic chemicals and properties, 49 organic chemicals, and 20 pesticides or herbicides (including PCB), and costs \$125 plus \$25 for express shipping. The presence of bacteria in 3 water samples may potentially be of some health significance, although, at least one study has found that coliform bacteria counts of 29,900 per ml in drinking water for calves had no effect on growth rate.⁵² None of the other elements were found at levels known to affect intake or health.(Table 3)

It is common in popular dairy magazines to urge farmers to check water quality.^{4, 7, 8} The experience gained from 49 water quality tests across Wisconsin suggests that it is not a cost-effective routine consideration. In herds where there is a concern about reduced water consumption related to stray voltage, the evaluation of water quality may be of personal interest to the farm owner, or as a rule-out to a stray voltage investigator; but at least in Wisconsin, the probability of identifying any water quality issues that have a known negative effect on water intake or animal health is very slim.

One of the major difficulties encountered when testing water is how to interpret the results. A laboratory may report some element of water as elevated relative to their level of concern but this is no guarantee that the elevation is a risk to cattle. The NRC summarizes the situation well: “Some water contaminants – such as nitrates, sodium, chloride and sulfates – have been reported to affect animal performance and health. However, most water contaminants have an unknown effect on animal performance. That is particularly true for water that has low concentrations of contaminants and is consumed over a long period. On the basis of scientific literature, no widespread specific beef cattle or dairy cattle production problems have been caused by consumption of water of low quality”²

Consider the following examples concerning hardness, pH, and manganese. Hardness on water quality reports is given a level-of-concern, yet the NRC summarizes the literature by saying “the hardness of water had no effect on animal performance or water intake.”² Acidity (pH) is an easy test to perform and has normals of 6.6-8.5 or 6-9 in print from several sources.^{3, 50, 51, 53} However, these limits are based on EPA human standards. For animals, “no information was found in the scientific literature as to what affect the pH of water has on water intake, animal health, animal production, or the microbial environment in the rumen.”²

Sixteen percent of farms tested over the laboratory level of concern for manganese. The highest level found was four times the recommended level of .05ppm. However, there has been no research done on manganese levels in water for cattle. The recommended levels for cattle is based on 1) human taste preference, and 2) the potential to stain bathroom fixtures black. “Manganese toxicity in ruminants is unlikely to occur, and there are few documented incidents with adverse effects limited to reduced feed intake and growth. These negative effects began to appear when dietary manganese exceeded 1,000 ppm. The maximum tolerable amount of manganese, as given by the NRC is 1,000 ppm.”² However, the only research cited is on preruminant calves, and 1,000 ppm is the amount set for feed intake not water.

Taking an example from one concerned farm service professional, on the farm in question, the level of manganese in the water was reported as 0.2ppm (four times the 0.5ppm limit). Water intake was measured at 21 gallons/cow/day, so an average cow was getting around 15.5 mg of manganese in the water. NRC guidelines are that 30-40 ppm is a reasonable level for manganese in a ration. Dry matter intake in this herd was estimated at 50 pounds. Forty ppm in this ration would give a total intake of around 908 mg of manganese per day from the feed. The 15 mg of manganese from water is insignificant compared to the desired level that cows consume from feed, and not anywhere near the 23,000 mg that would be considered as this ration’s beginning daily level of concern for toxicity.

Unless the suspicion of a specific contaminant exists, the value of testing water quality is limited by the availability of information. Information exists on nitrates, sodium, chloride and sulfates to help determine if a given level in the water has the potential to affect water intake, animal health or animal performance. Excellent reviews of the literature on these four contaminants of water are available^{2,3}. As a general diagnostic tool the testing of water quality, at least in Wisconsin, appears not to be a cost-effective or informative routine procedure.

Summary

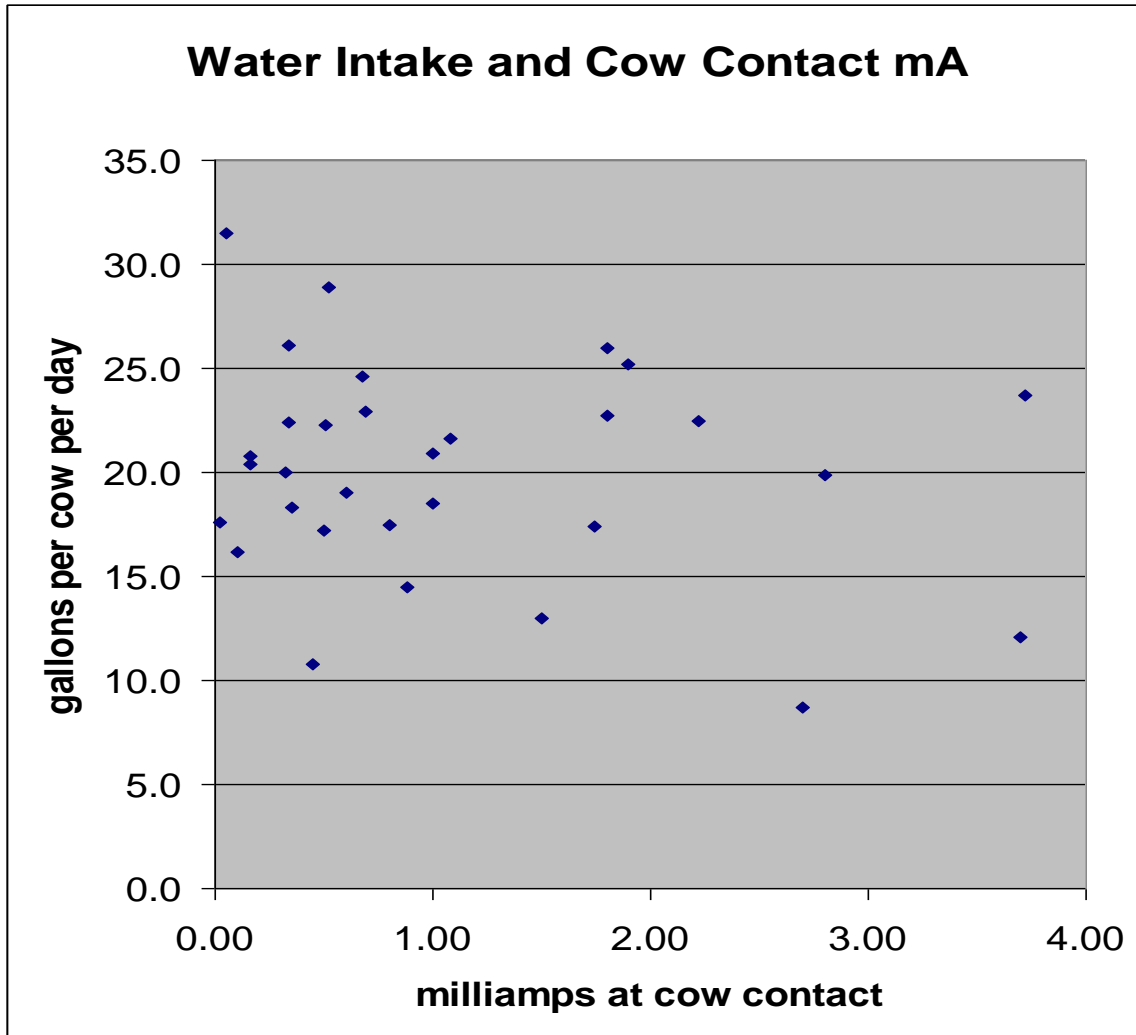
Milk is 87% water⁵⁴. Cows are 55-70% water.³ “A loss of 20% of the body water is fatal.”⁵⁵ Of nutrients indispensable for life, water ranks second only to oxygen in importance.”³ Water is the most important nutrient for dairy cattle.² The importance of water is not in question, but the experience of trying to assist farmers with concerns about stray voltage has revealed that a lack of understanding about water issues amongst rural farm service professionals can be detrimental to dairy farmers. Years of witnessing the tragedy of farmers struggling to find answers to the loss of premiums, the loss of production, the loss of animals, the loss of profits or the loss of their farms is heart-wrenching. It is hard, in this context, to see such situations made worse when local trusted professionals fail to provide basic services or information. Harder still to see the profitable perpetuation of misinformation further draining strapped farmers of what resources they may have. The experience of working with farmers concerned about stray voltage is fully burdened with all such tragedy.

Water is basic. Basic to the understanding of water issues in dairy cattle is how to determine the amount of water a cow needs. The information is readily available from the primary references^{2,3,55}. It is difficult to comprehend how the understanding of this is so universally lacking. It was not 50% or 75%, but 100% of the farms visited where water consumption had been perceived as evidence of stray voltage that a basic understanding of how to evaluate water consumption was missing. These farmers had unmistakably legitimate concerns. Perhaps it is the responsibility of the owner of a dairy business to understand how much water cows should be drinking. It surely seems that it is the responsibility of a person professing to be a nutritionist, or a veterinarian, or dairy extension agent to either know, or know where to find such basic information. Basic references on water intake are indispensable to the proper understanding of the issue.

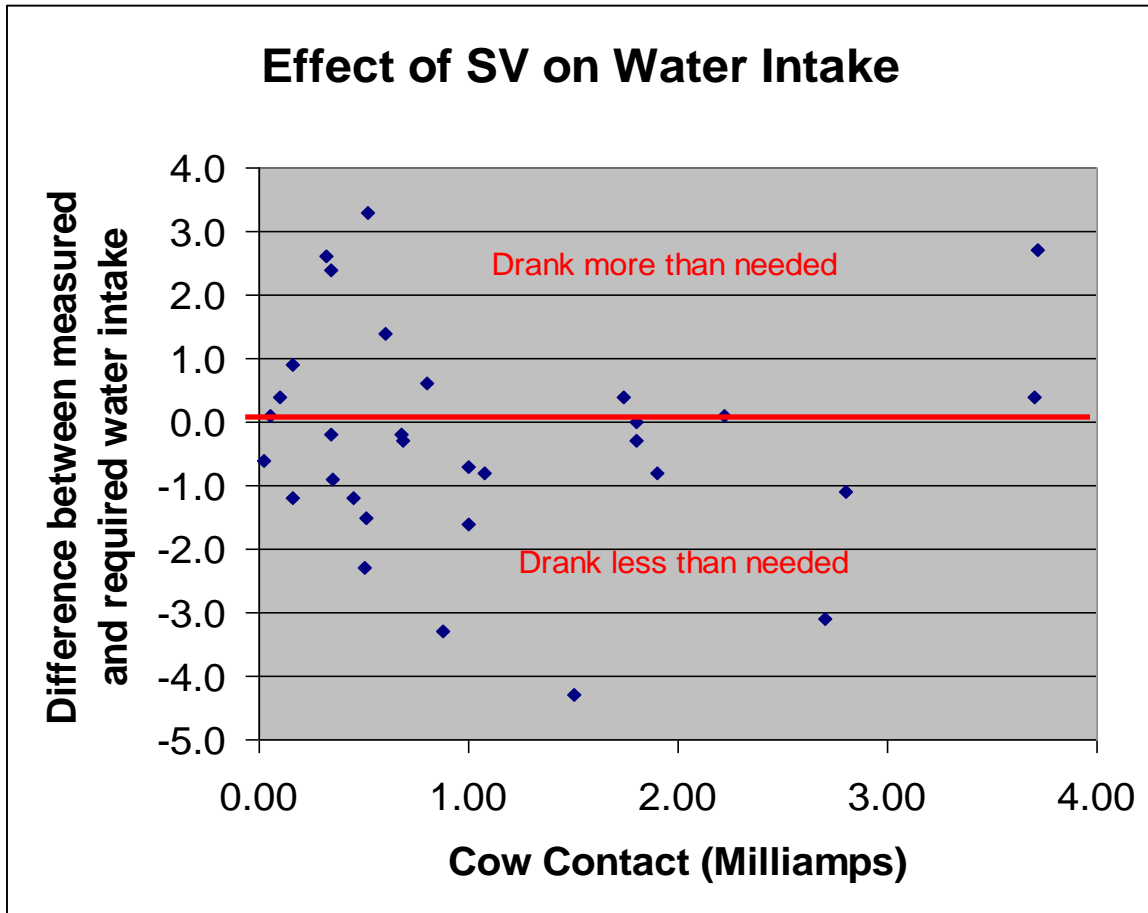
The current understanding of the relationship between stray voltage and water intake is well-documented, but poorly disseminated. Scientific publications on this issues have mostly

remained within academic journals. An informal personal survey of dairy veterinarians at a recent national seminar found that veterinarians are basically unaware of any of the research publications on stray voltage over the last decade. Similarly, the basics of how stray voltage interacts with dairy animals has been found not to be taught in most veterinary curriculums. The situation has been made worse by the wide distribution of undocumented misconceptions, especially concerning the interpretation of atypical behaviors of dairy cattle around their water source. Unless the available information is made more readily available to rural farm service professionals (and farmers), the tragedy of farmers trying to make good business decisions on inadequate or bad information will persist.

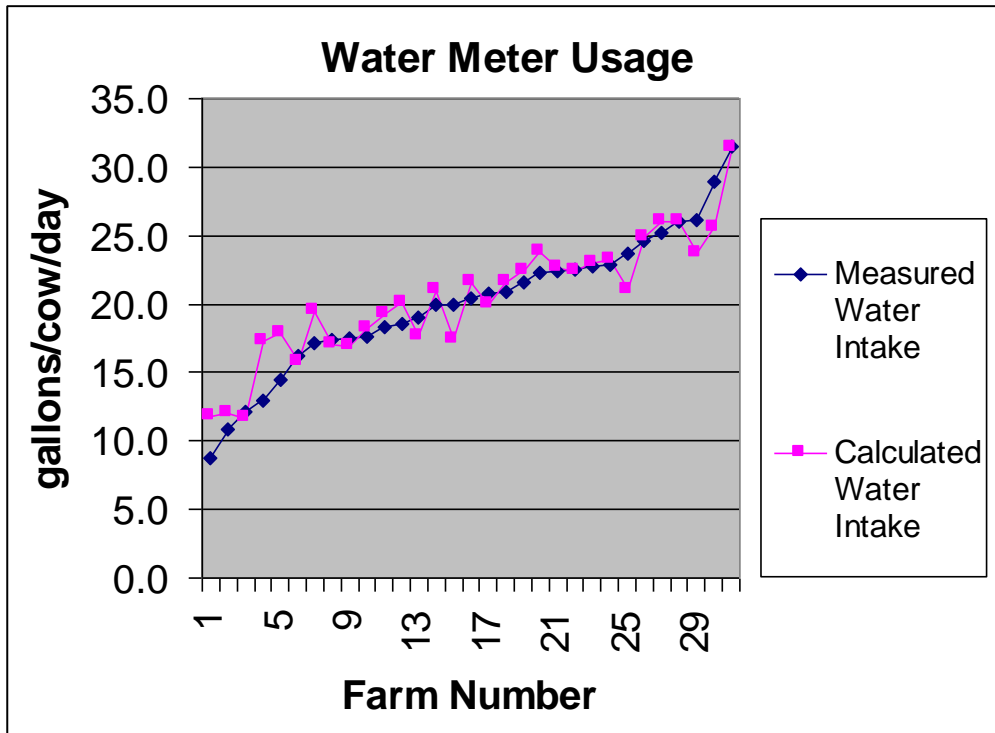
Graph 1: Field Data from SVAT investigations between 1994 an 1995:
Distribution of measured water intake versus cow contact current



Graph 2: Field Data from SVAT investigations between 1994 and 1995:
Distribution of the water intakes above and below the calculated water need



Graph 3: Field Data from SVAT investigations between 1994 and 1995:
Distribution of measurements water intakes and calculated water intakes



Graph 4: (With permission from Dr. Doug Reinneman)

Approximate 60 Hz Steady State Behavioral Response Distribution

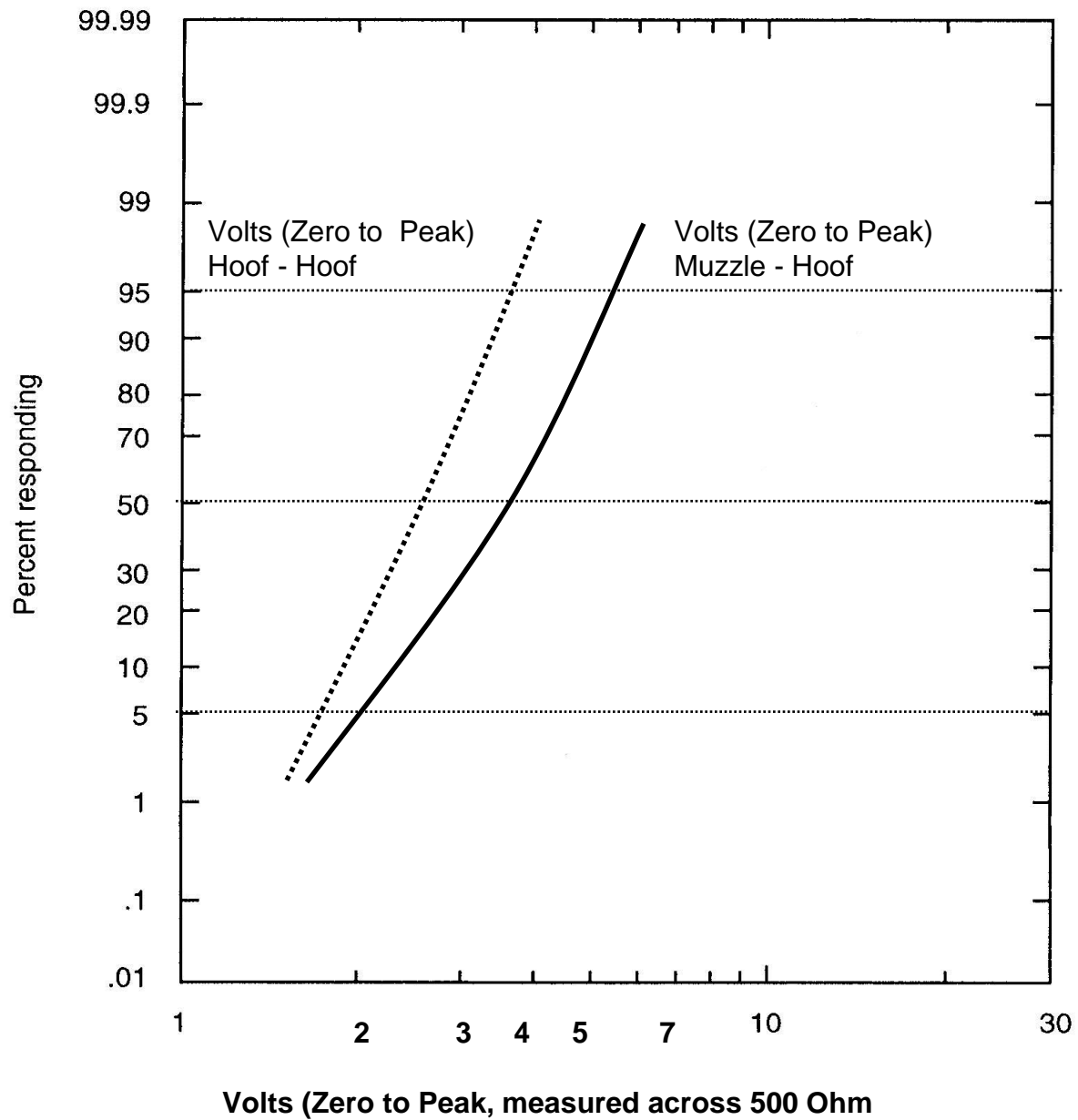


Table 1: Field Data from SVAT investigations between 1994 an 1995

WATER INTAKE FIELD DATA					
		MEASURED INTAKE	CALCULATED INTAKE	DIFFERENCE	COW CONTACT CURRENT (mA)
	1	17.6	18.2	-0.6	0.02
	2	31.5	31.4	0.1	0.05
	3	16.2	15.8	0.4	0.10
	4	20.8	19.9	0.9	0.16
	5	20.4	21.6	-1.2	0.16
	6	20.0	17.4	2.6	0.32
	7	22.4	22.6	-0.2	0.34
	8	26.1	23.7	2.4	0.34
	9	18.3	19.2	-0.9	0.35
	10	10.8	12.0	-1.2	0.45
	11	17.2	19.5	-2.3	0.50
	12	22.3	23.8	-1.5	0.51
	13	28.9	25.6	3.3	0.52
	14	19.0	17.6	1.4	0.60
	15	24.6	24.8	-0.2	0.68
	16	22.9	23.2	-0.3	0.69
	17	17.5	16.9	0.6	0.80
	18	14.5	17.8	-3.3	0.88
	19	18.5	20.1	-1.6	1.00
	20	20.9	21.6	-0.7	1.00
	21	21.6	22.4	-0.8	1.08
	22	13.0	17.3	-4.3	1.50
	23	17.4	17.0	0.4	1.74
	24	26.0	26.0	0.0	1.80
	25	22.7	23.0	-0.3	1.80
	26	25.2	26.0	-0.8	1.90
	27	22.5	22.4	0.1	2.22
	28	8.7	11.8	-3.1	2.70
	29	19.9	21.0	-1.1	2.80
	30	12.1	11.7	0.4	3.70
	31	23.7	21.0	2.7	3.72
HERD COUNT		WATER INTAKE			
	31	MEAS. INTAKE	CAL. INTAKE	DIFF.	
SV AVERAGE		19.4	20.1	-0.7	
NON SV AVERAGE		20.6	20.6	0.0	
	DIFF	1.2	0.5		
	MIN	8.7	11.7	-4.3	
	MAX	31.5	31.4	3.3	
	AVG	20.1	20.4	-0.3	

Table 2: Water Quality Test Results from 26 Wisconsin Farms Tested at UW Lab

Totals From 26 Farm Water Tests from UW Lab					
ELEMENTS	TEST RESULTS				
	NORMALS	"N" UNITS	MAXIMUM	# OVER "N"	% OVER "N"
PHOSPHORUS	<0.03	PPM	0.70	6	23%
POTASSIUM	<5.0	PPM	22.32	1	4%
CALCIUM	<200	PPM	117.70	0	0%
MAGNESIUM	<100	PPM	55.00	0	0%
SULFUR	<25	PPM	21.32	0	0%
ZINC	<1.3	PPM	0.09	0	0%
BORON	<1	PPM	0.12	0	0%
MANGANESE	<0.05	PPM	0.20	3	12%
IRON	<0.3	PPM	0.19	0	0%
COPPER	<1	PPM	0.17	0	0%
ALUMINUM	<0.2	PPM	0.61	3	12%
SODIUM	<175	PPM	110.20	0	0%
CHLORIDE	<250	PPM	58.50	0	0%
CADMIUM	<.01	PPM	0.01	0	0%
CHROMIUM	<.05	PPM	0.03	0	0%
COBALT	<1	PPM	0.02	0	0%
MOLYBDENUM	?	PPM	0.02	0	0%
NICKEL	<1	PPM	0.15	0	0%
LITHIUM	?	PPM	0.00	0	0%
ARSENIC	<.2	PPM	0.00	0	0%
LEAD	<.1	PPM	0.00	0	0%
SELENIUM	<0.01	PPM	0.00	0	0%
AMMONIUM	<0.5	PPM	2.00	3	12%
NITRATES	<10	PPM	26.00	7	27%
HARDNESS	100		255.00	1	4%

Table 3: Water Quality Test Results from 23 Wisconsin Farms Tested at National Testing Lab

Totals From 23 Farm Water Tests from National Testing Lab					
ELEMENTS	TEST RESULTS				
	NORMALS	"N" UNITS	MAXIMUM	# OVER "N"	% OVER "N"
ABOVE "N"					
HARDNESS	100		655.00	19	83%
NITRATE	10PPM		23.40	7	30%
SULFATE	250PPM		485.00	1	4%
TDS*	500PPM		881.00	3	13%
TURBIDITY	1PPM		1.00	0	0%
IRON	0.3PPM		0.87	1	4%
COLIFORM	0PPM		6.00	3	13%
PH(6.5-8.5)	6.5-8.5		5.40	3	13%
MANGANESE	0.05PPM		0.17	5	22%

* TDS = total dissolved solids

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