Extension
UNIVERSITY OF WISCONSIN–MADISON

# Impact of copper sulfate footbath use on eastern Wisconsin's manure, soil, and forage copper concentrations

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Healthy soil is the foundation of a productive farm. Monitoring soil health and maintaining soil integrity can improve water filtration, boost crop production and health, and foster biological and physical components of soil.

Fields that receive dairy manure are likely to receive higher copper concentrations than non-dairy manure.

## Copper sulfate usage on dairy farms

Digital dermatitis (DD) is a contagious disease that impacts a cow's hoof health, causing lameness. It is estimated to be in 70% of US dairies and 95% of large herds. Digital dermatitis spread rapidly throughout the US in the 1990s as herds consolidated and grew larger. While DD cannot be cured, outbreaks and the spread of the disease can be managed. Farmers have many options to help control DD, but the most common practice is using a footbath with a copper sulfate solution. Other options for managing DD are zinc sulfate, formalin, and custom premixes.

The University of Wisconsin School of Veterinary Medicine's Dairyland Initiative recommends using a 2-5% concentration of copper sulfate. A survey conducted on 45 Wisconsin dairies in 2016 found that copper sulfate was used on 67% of the farms, 40% of which used it at a 4-6% concentration, and 27% used it at more than three times the recommended level at 12-30% concentration. The Dairyland Initiative also recommends offering a footbath at least three times per week. Forty percent of respondents reported offering a footbath 1-3 times per week, and 33% reported offering a footbath 4-7 times per week, regardless of the type of solution.

The Dairyland Initiative recommends changing the footbath after 150-300 cows pass through it. Commonly, spent footbath solutions are washed into the farm's manure storage.

## Copper in the environment

Elemental copper naturally occurs in soil. When copper is land applied with manure, much of it will bind with soil organic matter and clays, where it is tied up. Copper does not leach or volatilize; plants take up meager amounts, less than one pound per acre per year. Therefore, once the copper is on the farm, it stays there. High available copper levels can negatively impact soil biology, including nitrogen-fixing rhizobium, earthworms, and soil fungi. High copper levels can also lead to copper toxicity, impairing plant growth. Alfalfa tends to be

more tolerant of high copper levels than corn and other grasses. On average, legume silage typically contains slightly more copper than corn silage but still contains low amounts at nine ppm.

## Copper in cattle

Copper is a required nutrient for cattle health and growth. TMRs are recommended to contain 13 to 15 ppm copper, with many farms using mineral supplements. High levels of copper are toxic to cattle, with excess copper often accumulating in the animal's liver. High liver copper concentrations can cause liver, health, and productivity issues. If the animal becomes stressed, the copper can be released into the bloodstream in bulk, causing extreme illness or death. Different breeds have different sensitivities to copper toxicity, with Jerseys more sensitive than Holsteins. Copper accumulation in cattle livers has proven to be a concern. A Michigan State University Veterinary Diagnostic Lab study found a mean liver copper concentration of 432 ppm, ranging from 3 to 1,963 ppm in livers submitted to the lab. Copper levels over 500 ppm have been proven to impact health and productivity, with levels over 850 ppm posing a potential toxicity issue. In the study, almost a third of the animals had liver copper levels over 500 ppm.

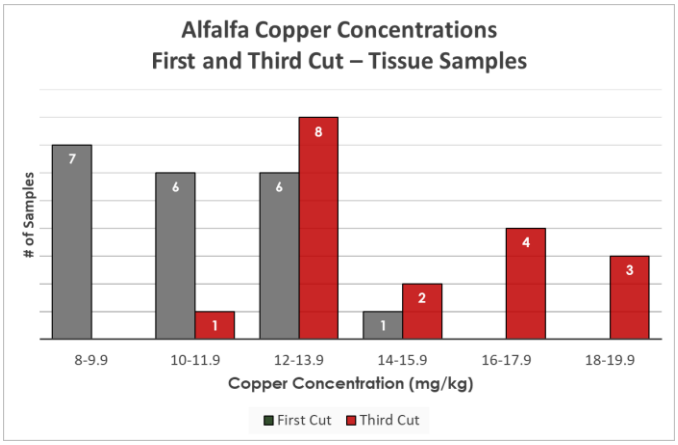
## Wisconsin field study

A 2022 Wisconsin field study was conducted to understand better the impact of copper concentrations in soil, forage, manure, and livestock.

The study collected soil, alfalfa (1st and 3rd crop), and manure from participating farms. Alfalfa was collected on all farms before first crop harvest; a tissue sample of the top six inches and whole plant samples were collected. Soil samples were collected at depths 6", 12", 24", and 36". A second set of alfalfa tissue plant samples (top six inches) were collected at all participating farms' pre-third crop. For those farms that applied manure to alfalfa fields after the 3rd crop, manure samples were collected from storage, and soil samples were taken at 6" and 12 inches.

Twenty dairies in 12 eastern Wisconsin counties participated in the survey. The farms were located from as far north as the Wisconsin/Upper Peninsula of Michigan to the Wisconsin/Illinois border. The dairies had herds that ranged from 190 to 4,600 cows.

When comparing tissue sample results for first and third cuts, there was a noticeable increase in copper concentration in the third cut, with average forage concentrations at third cut teetering on the boundary for recommended TMR copper levels. Potential explanations for this increase include increased mineralization and Cu availability and increased plant nutrient uptake with increased plant transpiration. The trend for higher nutrient concentrations at third cut was true for all nutrients analyzed (P, K, Mg, S, B, Zn, Mn, Fe), except for Ca.




Not all farms in the survey applied manure after third crop. Manure copper concentrations for the six farms from which samples were taken had an average of 373 ppm, which is lower than copper levels reported in the National Research Council (NRC) literature. A study from Vermont

found increasing copper levels in manures from 1992 to 2005, with average copper concentrations breaching 500 ppm at the end of the study.

Average soil copper levels were not excessive, averaging 4.7 ppm. The NRC literature identifies a critical toxicity level of 20 to 30 ppm for moderately tolerant crops.

Further comparing the survey results to a 2015 industry survey, alfalfa copper concentrations were higher than reported for northeast Wisconsin and lower than their reported southeast Wisconsin values. This is not unexpected due to the variability in manure application rates and frequencies and soil conditions across the region. A dramatic difference was not seen in alfalfa between areas.

Comparing survey results to a 2005 Wisconsin dairy feed study, alfalfa copper concentrations were almost double their reported concentrations of 6.8 ppm. This is likely due to the 2022 survey targeting farms that use copper sulfate footbaths.

In a 2005 study, it is important to note that while indigenous forage levels are low, the copper levels of imported grain and mineral mixes are drastically higher than the recommended 13 to 15 ppm concentration recommended for TMR. This suggests imported feeds are likely adding to manure copper levels, particularly if forages are being heavily supplemented with imported materials.

## Liver copper levels

Samples were collected at one of the survey-participating farms to understand liver copper levels further. Twenty-six fresh liver samples were collected from Holstein cows at harvest and evaluated for copper levels at the Iowa State Veterinary Diagnostic Lab. The cows were 3-9 years old and in lactations 1-6. The liver analyses showed a range low of 230 ppm from a seven-year-old cow, and a high of 740 ppm from a four-year-old cow. The group mean was 433, compared to the mean of 432 from the Michigan State study. Michigan State maintains that adequate liver concentrations range from 75 to 300 ppm. Liver concentration levels over 500 ppm are concerning, and toxicity risk is 850 ppm or higher.

| Age | Number of cows | Cu ppm average |
|---|---|---|
| 3 | 3 | 443 |
| 4 | 10 | 503 |
| 5 | 4 | 388 |
| 6 | 3 | 428 |
| 7 | 3 | 270 |
| 8 | 2 | 453 |
| 9 | 1 | 455 |

Liver analyses show no correlation between the cow's age and liver copper concentration levels.

The same farm offered TMR samples to be evaluated for copper concentration. The six diets evaluated were 6-month-old calves, breeding age/bred heifers, dry cow, steam-up/close-up dry cow, post-fresh, and lactating.

| Diet | Cu ppm | Acceptable Range ppm | Percent of Diet Haylage |
|---|---|---|---|
| 6-12 months | 19 | 15-25 | 45% lactating diet refusals |
| Breeding/Pregnant Heifers | 14 | 15-25 | 45% lactating diet refusals |
| Far Off Dry | 18 | 18-25 | 43 |
| Pre-Fresh | 18 | 18-25 | 43 |
| Post-Fresh | 11 | 11-25 | 43 |
| Lactating | 11 | 11-25 | 43 |

The diet analyses showed that all rations were on the low end or below the acceptable range for each age group.

## Recommendations

Preliminary results from the field survey show forage copper levels are likely increasing in eastern Wisconsin. While within the NRC guidelines for feed rations, it is important to continue to monitor soil, forage, and manure concentrations over time. Even though forage levels are within an acceptable range, the impact of elevated copper on cow health and liver concentration is being noted.

A whole farm team approach is one management strategy to monitor copper levels. Recommendations for agriculture service professionals are as follows:

Nutritionist – monitor forage copper levels

- Reduce unneeded supplementation
- Monitor changes in forage copper levels

Agronomist – monitor soil and manure copper levels

- Manage manure applications
- Reduce/eliminate copper fertilization
- Maintain soil pH

Veterinarian – protocols for efficient footbath use

- Concentrations of copper sulfate and footbath frequency
- Consider alternating or replacing copper sulfate
- Maintain hoof-trimming schedule
- Spot treat rather than the whole herd

The results of the survey provide a baseline for future monitoring of soil, manure, and forages on Wisconsin dairy farms. It is important to remember that once copper is in the soil, it will remain there until plants use it. Different plants have different copper tolerances, which may impact forages and herd health in the long run. Judicious use of footbaths on the farm and maintaining a regular hoof trimming schedule will help control DD, therefore potentially needing to use footbaths less.

*Developed by UW–Madison Division of Extension Regional Dairy Educator Aerica Bjurstrom.*
*References are available upon request.*