

Copper Sulfate Foot Baths on Dairies and Crop Toxicities

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Environmental Issues for Land Applying Copper Sulfate

A rising concern with the application of dairy wastes to agricultural fields is the accumulation of copper (Cu) in the soil. Copper sulfate (CuSO_4) from cattle footbaths is washed out of dairy barns and into wastewater lagoons. The addition of CuSO_4 baths can increase Cu concentration significantly in manure slurry, from approximately 5.0 grams per 1,000 liters to 90.0 grams per 1,000 liters. The Cu-enriched dairy waste is then applied to agricultural crops, thus raising concerns about how soils and plants are impacted by these Cu additions.

Once added to the soil, the Cu^{+2} from CuSO_4 can:

1. remain in the soluble form of Cu^{+2} which is available to plants;
2. adsorb to organic matter;
3. adsorb to clay particles; or
4. be converted to less available mineral forms.

Typically, the majority of Cu strongly adsorbs to soil organic matter and clay surfaces. In fact, Cu binds to organic matter more strongly than any other micronutrient. Dairy manure is rich in organic matter and will naturally have greater Cu adsorption than dairy lagoon water which is low in organic matter. In soils with pH values greater than 7.0, soluble Cu^{+2} will react with water to form either $\text{Cu}(\text{OH})_2$ or associations with Fe-oxides. Thus, almost all Cu added to soil typically stays in soil. For more information regarding soil Cu reactions, read [Copper Deficiency in Cereal Grains](#).

The potential for groundwater contamination, via enhance downward Cu transport, will be greater in sandy, acidic soils or under irrigated conditions. And although increasing soil organic matter content will increase Cu adsorption, Cu associated with dissolved organic phases could also be transported downward. However, most studies suggest that soluble Cu transported through soils does not exceed the national drinking water standard of 1.3 mg/L. For more information regarding Cu transport, read [Kinetics of copper desorption from soils as affected by different organic ligands](#).

Research Findings for Land Applying Copper Sulfate

With the strong binding of soluble Cu to soils, very little of the applied Cu is plant-available. Overall, the potential for Cu toxicities in plants is relatively small given the amount of Cu that is added through dairy-waste application. Preliminary results from the USDA-ARS in Kimberly, Idaho, showed that extractable soil Cu concentrations ranging from 1 to 154 parts per million (ppm) in a calcareous soil had no effect on alfalfa or corn silage biomass yields, while plant survival was drastically impeded at concentrations greater than 323 ppm.

Copper application rates used in this study to achieve reductions in yields and plant survival greatly exceeded rates typically seen for dairy manure applications. In a similar study in New York, Flis et al. (J. Animal Science, 2006, 84:184-185, supplement 1) applied CuSO_4 at 0, 6.3 and 12.6 pounds Cu per acre to corn silage, orchardgrass, and timothy grass using Cu rates equivalent to those typical to dairy waste applications. Corresponding soil Cu concentrations were 11, 13 and 18 ppm, respectively. The varying Cu application rates had no effect on grass or corn silage yields, although tillering and regrowth rates were significantly reduced for the grasses.

While these results are encouraging in the short-term, repeated applications of dairy manures could potentially raise Cu concentrations to levels toxic to plants, with very limited possibilities for remediation. A few fields in Idaho that have received frequent applications of lagoon water have shown evidence of Cu accumulation. Because Cu is so tightly bound by the soil, it is very difficult to remove. Succeeding crops can only remove 0.1 pound Cu per acre per year. As it stands now, if a grower waits until Cu plant toxicity symptoms occur (including plant death), they will continue to see Cu toxicities in that field for an indefinite period of time.



Corn growing in various copper- treated soils. Inset photo: Corn two days following a 1,000 ppm soluble Cu treatment. Photo courtesy Jim Ippolito.

In terms of regulation, there is an existing EPA 503 “worst case scenario” standard that limits annual loading of Cu from biosolids to 66 pounds Cu per acre and limits lifetime loading to 1,339 pounds Cu per acre (limits are based on biosolids land application). For more information read [Land Application of Biosolids](#). Reaching these limits is almost impossible with dairy waste applications, and would devastate most agricultural crops long before the lifetime loading limits were met. New York has set lower lifetime loading limits for Cu at 75 pounds per acre to avoid the potential of irreversible toxic accumulations of Cu in the soil. (For more information, see Table 5 in [Composting Facilities](#).)

Recommendations for Land Applying Copper Sulfate Hoof Baths

While more studies are needed to develop an official threshold for Cu in alkaline Idaho soils, based on what we know thus far, it would be advisable to cease Cu additions to soils with greater than 50 ppm extractable Cu. This value is advisable for producers raising alfalfa for dairy cow consumption in order to avoid Cu accumulation above National Research Council recommendations. To determine if you currently have a Cu accumulation problem in your soil, or to identify a developing accumulation, request an analysis for diethylenetriaminepentaacetic acid (DTPA) extractable Cu every two to three years from an accredited soil testing laboratory.

Recommended Reading

- Rick Stehouwer and Greg Roth with the Department of Crop and Soil Sciences at Penn State University produced a similar document, [“Copper sulfate hoof baths and copper toxicity in soil”](#), which describes hoof bath use, accumulation and toxicity in soils.
- Mike Rankin with the University of Wisconsin Extension wrote [“Agronomic and Environmental Issues with Foot Bath Solution Land Spreading”](#)
- Joe Harrison & Lyn VanWieringen wrote [“Copper Sulfate Footbaths and Soil-Crop Levels of Copper”](#), again targeting issues similar to those presented in this webpage.
- Kevan Klingberg from the UW Discovery Farms Program prepared [“Copper Sulfate Foot Bath Treatment for Animal Health: Impact on Manure Nutrient Content, Crops, Soil and the Environment”](#) which answers some important dairy producer questions.
- ZINPRO animal nutrition outlined [“Foot baths – Key Points”](#). This site contains follow-along calculations for determining the quantity of CuSO_4 needed to create solutions of various concentrations and volumes.

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