Soil Copper Additions from the Use of Copper Sulfate Footbaths – Too Much of a Good Thing?

There is concern among dairy producers using copper sulfate footbaths regarding the fate of the copper in the footbath, specifically, copper applied to soil via manure, potential plant toxicity and ultimately animal copper intake.

Copper is an essential element to both plant and animal growth. With insufficient levels, deficiencies can affect plant and animal production. However, excessive amounts may also have detrimental effects. To determine the risk of copper toxicities, copper must be followed from the footbath, to the manure pit, to the soil, to the plant and finally to the animal. At each of these steps there are a number of factors affecting the availability of copper.

The concern is raised as producers are applying more copper to the soil than is being taken off by crops and as a result, soil copper concentrations increase. The real questions are: how much copper is too much, and how long will it take to reach critical copper soil levels? Unfortunately there are no easy answers but there are a number of clues that can help you determine whether or not copper levels on your farm may be a threat to crop and animal production.

Determine how much copper is being applied

It is first important to determine how much copper you are actually applying to your fields. This is fairly straightforward to do. Just keep track of how quickly you go through a bag of copper sulfate, and estimate how much copper sulfate you would use in a year. Then, knowing the weight of the bag you can calculate the total amount of copper sulfate purchased in a year. You need to divide this weight by 4 since copper sulfate is only 1/4 copper by weight. Now take this value and divide it by the number of hectares you apply manure to and you'll get your annual copper application rate per hectare. Alternatively, a more accurate estimation would be to test the manure directly since there will be additional copper in the manure that originated form cattle diets and water.

Guidelines to determine the likelihood of a potential problem

Soil scientists at Penn State University gives a few guidelines to help you determine if you're rate of application is going to lead to a potential toxicity[12]. As a general rule of thumb, they suggest if the amount of copper added annually is less than 2.25 kg per hectare, the buildup in soil will be extremely gradual and unlikely to cause a problem. Farms with copper addition of more than 5.6 kg per hectare per year should analyze soils and crops for copper every 5 years or so to monitor for any increases. Farms adding copper in access of 11.2 kg per hectare per year should be soil testing and should start to consider ways to reduce the amount of copper sulfate used. Researchers at Agriculture and Agri-food Canada recommend cumulative limits for copper application to crop land to be 140, 280 and 500 kg of copper per hectare for soils with a cation exchange capacity (which is reported on your soil test report as CEC) of less than 5, 15 and greater than 15 meq/100gm respectively[4].

However these are just guidelines and as we trace copper from the footbath to the animal, it will become clearer why these are just guidelines and predicting copper availability using these guidelines is not an exact science.

Manure affects copper availability

Right of the bat, when copper in the footbath is exposed to manure; the availability of copper is reduced. You've likely herd the mantra "keep your foot baths clean" and this is exactly why. The copper that has the antimicrobial effect on hairy heal warts will become tightly bound to the organic matter in the manure making it unable to do its job on the organism infecting your cows foot. Once the copper sulfate is added to the manure pit, it is exposed to more manure, and remaining available copper will become bound to the organic matter in the manure pit. It is estimated that 90-95 % of the copper sulfate will be bound to organic matter in the manure pit[12]. In addition, there is also quite a dilution effect once it reaches the manure pit.

Copper in the soil

When it hits the soil there are also a number of factors that will affect its availability. Soils with a high organic matter and clay content will hold on to copper more than sandy soils. In fact, soil organic matter binds copper more tightly than any other micronutrient[11] . In these high organic matter high clay content soils, copper tends to accumulate on the surface soil and it is unlikely copper will leach from the soil[9] . As a result, the copper that actually is in the soil solution and is plant available is a very small percentage of what you started with. Soil solution copper concentrations are generally extremely low, with more than 98% copper in solution bound to soluble organic matter, irrespective of pH[10].

Nevertheless, once it does reach the soil, perhaps the largest affect of elevated Cu levels are not on plants or animals but are on soil microorganisms. This makes sense, as the original purpose of the footbath was to take out the hairy heal wart bacteria on the cows foot but copper sulfate is not specific to just that organism and can affect many soil organisms. In fact, it was determined that if applications rates exceed 100 kg/ha a significant negative effect on microbial biomass can be measured after 20 days of application[1]. This far exceeds annual loading recommendations of Penn State University but if in time the cumulative copper additions exceeded 100 kg/ha there may be a detrimental affect on microbial populations. One sensitive organism in particular is Rhizobia[3]. Rhizobia is the bacteria that allows you to reduce your nitrogen fertilizer bills as it forms a relationship with legume plants and fixes nitrogen from the air at no cost to you other than perhaps some seed inoculants. This is certainly one organism you'd like to keep happy but it has been shown that excess soil levels of copper can have a detrimental effect on Rhizobia. Earthworms have also been shown to be effected by high copper levels where the number and burrowing length or worms decreased as copper levels increased[7].

Most labs using a Melich-3 soil extractant, including the Nova Scotia Department of Agriculture Soil Lab, suggest that soil copper levels of 3.1 ppm are high plus and levels of 20 and above are excessive. Soil copper levels in Nova Scotia between 1999 and 2007 have been reported to have a median level of 1.24 ppm but levels well above 20 ppm have been measured by the soil testing services lab from the total samples they receive for testing[6]. Pay close attention to your soil test report. It will report copper (Cu) levels in ppm and give you an indication of where you stand.

Plant responses to excess copper

So what happens to the approximately 5-10% the copper that not bound to organic matter in the manure pit?[12] Firstly copper is a micronutrient, meaning the plant really doesn't need a whole lot of it. It's estimated that most crops will remove 0.1kg Cu/ha per year[11]. When you compare that to removal of nitrogen by more harvested field crops, which can remove over 50 kg/ha, you quickly realize why copper is called a micronutrient. If copper levels in the leaves increase to levels of 20 -30 ppm, toxicity symptoms may appear including interveinal cholorsis (pale green stripes in corn leaves) and stunted root growth[5]. Since roots are largely affected by increase soil copper concentrations symptoms of copper toxicity may be difficult to detect above the ground. Plants range in their tolerance to high copper levels, where pasture grass and peas have a low tolerance, corn has moderate tolerance and alfalfa, barley, oats and wheat have higher tolerances[5]. Plant root growth may be suppressed with excess copper. Copper is about 5 to 10 times more toxic to roots than aluminum particularly in soils with a pH of less than 5.5[5]. In addition, often elements will interact with one another affecting each other's availability. This is the case with copper and iron where an excess of copper can induce an iron deficiency which also appears as interveinal cholorsis (figure 1).

Figure 1. Corn plant showing interveinal chlorosis.

Copper tends to accumulate in the root tissue with little translocated to the shoots[8] . If you consider that animal forage consists of above ground plant material (exclusive of roots), then you realize here is yet another filter that may lower the risk of copper toxicity to animals. However, not all plants respond the same to copper. Just as plants have different tolerances to high copper levels, they also have varying abilities to accumulate copper. For example, corn appears to be the least susceptible to high soil copper concentrations while yields of legumes may also not be affected but legumes appear to accumulate more copper into their plant tissues[2]. So it is likely that forage containing legumes will have a higher copper concentration than forage without.

Copper toxicities in cattle

Although it's not impossible, copper toxicities in dairy cattle are rare and usually occur because a cow gets access to concentrated substance not intended for her. However, it is important to remember that sheep are more susceptible to copper toxicity than cattle. If you are concerned about copper levels, a feed test including micronutrients will help you to determine if there is any real risk.

The twist in the story – observations from a few Nova Scotia dairy farms

One very important thing to keep in mind is that elements can interact effects each element's availability. Just as high copper can create and iron deficiency in plants, there are interactions with in the animal that may mask the real story. So despite concerns of potential toxic levels of copper, there have actually been reports of copper deficiencies in cattle. An obvious signs of copper deficiencies is a change in coat color. Black animals develop a reddish (figure 2) or gray tint to the hair and grayness develops around the eyes and red animals become more bleached. In the few cases in Nova Scotia of copper deficiencies, they have excesses levels of another element called molybdenum. Not only is molybdenum a bit of a tong twister, it has an antagonistic affect on copper rendering copper unavailable for adsorption in the digestive tract of animals. The tricky thing about molybdenum is that it is difficult to soil test for it therefore it is not reported on soil test reports. However, if you are seeing signs of copper deficiencies you can test your forage for levels of molybdenum. Any nutritionist should be able to help you through this. The good news is that with feed supplementation, it is an easy fix at the animal level. However, because soils are some complex and the interactions of elements within the soil are so complex, high molybdenum levels in the soil may be something you have to learn to live with.

Figure 2. Cow showing signs of copper deficiency

If there are any questions regarding soil copper levels you can contact your nutrient management planner or Amy Sangster, Soil Specialist, at Perennia.

For questions regarding molybdenum levels in forage and induced copper deficiencies, you can contact your nutritionist or Dan Mosley, Dairy Specialist at Perennia.

Amy Sangster, Soil Specialist
Perennia
(902) 896-0277
asangster@perennia.ca

Dan Mosley, Dairy Specialist
Perennia
(902) 890-9665
dmosley@perennia.ca

References

1. Bogomolov, D., S. Chen, et al. (1996). "An ecosystem approach to soil toxicity testing: a study of copper contamimation in laboratory microcosms." Applied Soil Ecology 4: 95-105.

2. Flis, S. A. (2008). The effects of high copper dairy manure on manure storage, soil, and plant growth and composition. The Faculty of the Graduate College. Burlington, University of Vermot. Doctor of Philosophy: 171.

3. Giller, K. E., E. Witter, et al. (2009). "Heavy metals and soil microbes." Soil Biology & Biochemistry 41: 2031-2037.

4. Gupta, U. C., W. Kening, et al. (2008). "Micronutrients in soils, crops, and livestock." Earth Science Frontiers 15(5): 110-125.

5. JB Jones Jr. (1998). Plant Nutrition Manual. Boca Raton, CRC Press.

6. LeBlanc, L. (2009). Soil Health of Nova Scotia. Soil Test Indicators of Soil Health in Agricultural Soils. Windsor, LP Consulting Limited: 154.

7. Ma, W. (1988). "Toxicity of copper to lumbricid earthworms in sandy agricultural soils ammended with Cu-enriched organic waste material." Ecology Bulletin 39: 53-56.

8. Marschner, H. (1995). Mineral Nutrition of Higher Plants. London, Academic Press.

9. McBride, M., B. Richards, et al. (1997). "Mobility and solubility of toxic metals and nutrients in soil fifteen years after sludge application." Soil Science 162: 487-500.

10. Sauve, S., N. Cook, et al. (1996). "Linking plant tissue concentrations and soil copeer pools in urban contaminated soils." Environmental pollution 94: 153-157.

11. Schulte, E. and K. Kelling (1999). "Soil and applied copper." University of Wisconsin Extension A2527.

12. Stehouwer, R. and G. Roth (2004). "Copper Sulfate Hoof Baths and Copper Toxicity in Soil." from http://www.das.psu.edu/news/dd200403-03.