COPPER SULFATE HOOF BATHS AND COPPER TOXICITY IN SOIL

Copper sulfate hoof baths are used on many dairies in Pennsylvania as part of their overall hoof hygiene program. On most dairies spent hoof baths are dumped into the manure pit or lagoon so the copper ultimately gets spread on production ground with the manure. Recently there have been several reports in the dairy press regarding copper accumulation in soils from this practice. It is possible that after several years copper could accumulate in soil to levels that become toxic to soil microbes and crops. This could slow organic matter decomposition and nutrient cycling in soil (especially conversion of organic nitrogen to plant available nitrogen) and crop production could be reduced because of direct toxic effects of copper on the plants as well as reduced soil fertility. Copper accumulation in soil and forage could become toxic to sheep, whose tolerance for copper is much lower than that of dairy cattle.

The potential for accumulation of toxic levels of copper in soil is a critical issue because there is no practical way to reverse the problem if it occurs. On the other hand it is a problem that will take many, many years to develop and can easily be avoided. Copper is an essential element for all living organisms so plants and microbes need a constant small supply. All soils naturally contain some copper and it is only when the availability of soil copper becomes too large that toxicity could result. Thus two important questions for dairies that use copper sulfate hoof baths are: (1) How much copper can be added to soil before it reaches the toxic threshold, and (2) How long will it take to reach that threshold? Unfortunately there are no simple or clear answers to those questions. In this article we will look at factors that affect copper availability in soil and provide some guidance for dairies on how to deal with this issue.

The toxicity of copper in soil depends more on the *available* concentration of copper than it does on the *total* concentration. Available means that the copper is in a form that can be taken up by plants, microbes, or animals. For example, copper pipes are almost pure copper but are not toxic because the copper is not in a form that is available to living organisms. When water flows through the pipes, tiny amounts of copper dissolve in the water and that copper is available. The same holds true for copper in hoof baths, manure pits, and soil. Copper sulfate hoof baths are normally made as a 10% solution so the water contains about 25,000 parts per million (ppm) of copper. All of this dissolved copper is available, and at this high concentration is toxic to fungi and bacteria (intentionally so). As soon as the bath is dumped into the manure pit its toxicity decreases dramatically for two reasons. First, there is a huge dilution as a bath of a few gallons is mixed into thousands of gallons of manure. We have analyzed liquid manure from dairies using copper sulfate and found copper concentrations of 20-60 ppm, or about a 1,000-fold dilution. Secondly, copper becomes strongly bound to the organic matter in the manure pit. We have found that in liquid dairy manure about 90-95% of the copper is held on organic matter. When copper is bound to organic matter its availability is vastly reduced. Nevertheless, hoof baths do add a lot of copper to the manure — up to 1,000 ppm on a dry weight basis (sewage sludge normally has 300-500 ppm copper on a dry weight basis).

Ultimately all the copper ends up in the soil. Surface soils in Pennsylvania normally have total copper concentrations in the range of 15-30 ppm (mg/kg), or 30-60 lb/acre. When high copper manure is spread on the soil, copper is added to this natural background level. In the soil copper is strongly bound to soil organic matter and to clay particles. A lot of the copper gets bound so

tightly that it is not available to microbes or plants and thus has no effect on toxicity. Copper availability is lowest at near neutral soil pH (6.5-7.5), but as pH decreases copper availability increases. Thus when high copper manure is added to soil, we would expect a greater increase in copper availability in a light textured soil with low organic matter and somewhat low pH than in a heavier textured soil with moderate organic matter and near neutral pH. In all soils, however, almost all added copper stays right where it is placed. Thus spreading high copper manure in soil year after year will steadily increase the total amount of copper in the topsoil. At one PA dairy that used a lot of copper sulfate we found total copper in the soil was 3-5 times higher than the normal range for topsoil in Pennsylvania. But corn growth on that field was excellent and the silage contained normal levels of copper suggesting there had been little increase in copper availability.

Another indicator of copper availability is how much copper is taken up by crop plants. Most agronomic crop tissues (leaves and stems) normally contain copper in the range of 5-30 ppm. The average copper content of corn silage in Northeast US is 7 ppm. If crop tissues contain copper at the high end of this range or above, this is evidence of increased copper availability, though not of toxicity. The classic foliar symptom of copper toxicity is interveinal chlorosis (pale green striping in corn leaves). The problem of crop tissue analysis as an indicator of copper toxicity is that copper will also stunt root elongation and development and may never be taken up into the above ground part of the plant. Thus a copper problem in the soil may not be seen above ground.

So we come back now to the question of how much copper can be added to soil before toxicity problems might arise? While almost no research has been conducted with high copper dairy manure, investigations of high copper swine manure and sewage sludge provide some guidance. Based on this research, if copper is added gradually (<10 lb of copper per acre each year) it appears that at least 150 lb of copper per acre could be added to light textured, low organic matter soils without causing crop toxicity. Heavier textured soils with moderate to high organic matter levels could likely receive at least 3-5 times as much copper without showing any crop toxicity. However, adverse effects on soil microbes might occur with smaller additions of copper. Unfortunately, no simple soil test has been developed that can reliably predict when copper toxicity might occur to plants or microbes. Thus, dairy farmers using copper sulfate hoof baths should determine how much copper they are adding to their fields each year, and should monitor their soils and crops for evidence of increased copper availability.

There are two ways to calculate how much copper is added to soil each year. One is based on the total pounds of copper sulfate used in a year for hoof baths. This total must be divided by 4 since the copper sulfate is ¼ copper by weight. Now divide that result by the number of acres the manure is spread on to get pounds of copper per acre per year. This calculation will give a good estimate of how much copper is being added to a field. However, since there are other sources of copper in the manure (from feed and water) a more precise method is to have the manure analyzed for copper. Then multiply the concentration of copper in the manure (lbs/ton or lbs/1,000 gal) by the application rate used (tons/acre or 1,000 gal/acre) to get lb of copper added per acre with each manure application. We have done these calculations at 4 PA dairies and found copper additions ranging from 2 up to 11 lbs of copper per acre per year. If the amount of copper added is less than 2 lb per acre, the buildup in soil will be extremely gradual (crop harvest

will likely remove about ½ lb of copper per acre) and unlikely to cause a problem. Farms with annual copper addition of more than 5 lbs per acre should analyze soils and crops for copper every 5 years or so to monitor for any increases. Soils should be analyzed for *total* copper (strong acid digestion). The Agricultural Analytical Lab at Penn State can do these soil and tissue analysis as well as many other service laboratories. Farms where annual copper addition is 10 or more lbs per acre should attempt to reduce the amount of copper being used. This can be done by reducing the frequency of hoof bath use to the minimum needed to control hoof diseases, decreasing the concentration of copper sulfate used in the baths from 10% to 5%, and by placing a water bath ahead of the copper sulfate bath so that the copper sulfate bath will not need be changed as often. Dairies could also investigate alternative treatments to copper sulfate. Zinc sulfate baths are one alternative, but with long-term use zinc could accumulate to toxic levels just like copper.

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