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Copper and Zinc Accumulation in Manured Soils

E. Brock, Q.M. Ketterings, and M. McBride

Department of Crop and Soil Sciences

Considerable research in the past 5-10 years has focused on how manure applications affect soil nitrogen (N), phosphorus (P), and potassium (K) levels, both from plant nutrition and environmental perspectives. However, manure consists of more than just N, P and K. A recent survey of the trace metal content of dairy manure in New York State showed levels of copper (Cu) and zinc (Zn) that were elevated compared to all other trace metals analyzed (McBride and Spiers, 2001). Similar trends were seen in Vermont by Jokela and others (2005). Both Cu and Zn are added to most dairy rations as part of a mineral mix; however the highest concentrations result when hoof-bath treatment solutions containing copper or zinc sulfate are disposed of in the manure stream. An average corn silage crop will remove about 0.014 lbs of Cu and 0.016 lbs of Zn per ton of silage (35% dry matter). Given current average manure Cu and Zn data for New York, as described by McBride (2001), and a yield of 17 tons of silage per acre, an application of more than 700 gallons of liquid dairy manure per acre will result in more Cu being added than removed with harvest. Similarly, 160 gallons per acre of this manure will be enough to apply the amount of Zn and average corn crop will remove. These calculations show that on our dairy farms even the lowest manure application rate will result in the addition of more Cu and Zn than required by the crop. Copper and Zn are not as mobile as nitrate due to their high affinity for sorption to organic matter so these elements tend to accumulate in the soil. The question remains: is this a problem for our current farming systems?

Case study

We analyzed soil profiles from a case study farm in Steuben County with over 40 years of dairy and/or poultry manure addition. With this study we wanted to determine the long-term effects of manure application on Cu and Zn accumulation in the plow layer, its distribution over the soil profile and bioavailability in the soil. The soils of the farm are classified as either Wellsboro or Oquaga channery silt loams. We do not have accurate historical manure spreading records or analyses over the past 40 years so we used the total P content of the soils as an estimate of manure history (higher total P concentrations representing longer durations of manure application or higher loading rates). Agronomic soil tests such as Mehlich-3 and Morgan can not reliably predict when copper or zinc toxicity might occur to plants or microbes (interpretations have mostly been limited to identification of deficiency situations), but they can be used to monitor soils for evidence of increased Cu and Zn accumulation over time. As the farm's historic fertility program includes Mehlich-3 soil tests, we report on trends in Mehlich-3 soil test data but similar trends would be observed if the Cornell Morgan test was used.

Cu and Zn accumulation in the plow layer

The Cu and Zn content of the 0-7 inch plow layer were both accumulating with manure application (i.e. as total P levels increased). Copper accumulation was higher in the dairy manure amended fields while Zn accumulated more rapidly in the fields that had a history of poultry manure addition. The increased Cu accumulation in dairy manure amended soils could be attributed to $CuSO_4$ used in hoof bath treatments. The higher Zn accumulation in poultry manure amended fields was due to higher loading rates of manure and higher concentration of Zn in poultry manure compared with dairy manure. The elevated Zn levels in poultry manure were most likely due to sloughing of the cage plating over time. Also when we plotted farm soil fertility records over time for individual fields, a clear and gradual increase in both Cu (dairy manure amended fields) and Zn (fields with poultry manure history) could be seen. This is similar to trends that were observed and reported on by Ev Thomas at the Miner Institute (Thomas, 2001).

Distribution over depth

Because the accumulation of Cu and Zn in the surface layer of the soil was evident, we wanted to examine whether any of the accumulated metal was moving down through the soil profile. Soil samples were collected every 2 inches down to a depth of 20 inches and analyzed for Mehlich-3 extractable Cu and Zn. Figure 1 shows that there is little evidence of any downward movement of Cu past the plow layer. The only exception was the field with the longest history of poultry manure application that showed slightly elevated Zn levels up to a depth of 12 inches. While analysis of the soil profile suggests there is no Cu or Zn translocation through soil, it is possible that some metal could move via preferential flow paths as a complex with organic molecules. However, when analyzing leachate samples taken from 30 inch deep intact soil cores from these fields, we saw no appreciable increase in Cu or Zn loss in leachate from manure amended soils compared to the fields that received no manure. In short: currently, Cu and Zn accumulation on the fields of this farm is mainly restricted to the surface soil layers.

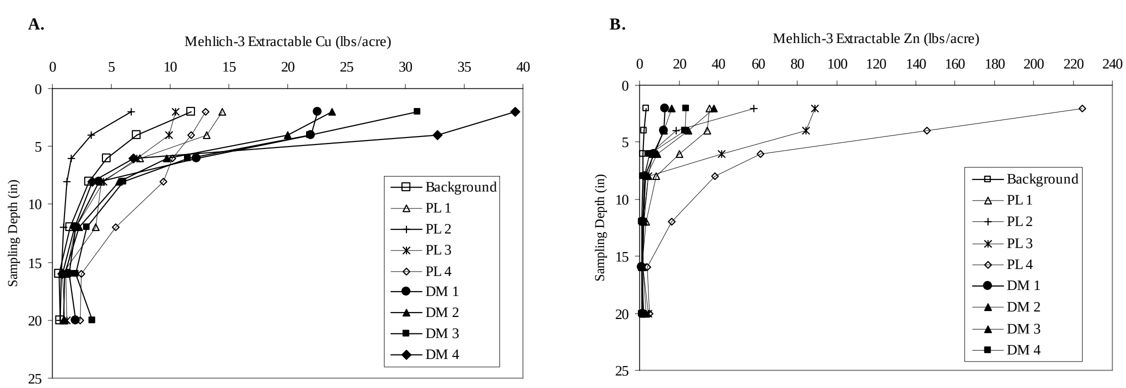

Figure 1. Mehlich-3 extractable Cu (A) and Zn (B) distribution over depth in four dairy manure amended fields, four poultry litter amended fields, and a background field on a farm in Southern New York State.

Availability/Toxicity

If Cu and Zn are accumulating in the surface layer, should we be concerned with plant toxicity? Analyses of the soil samples for bioavailable Cu and Zn using the hot 0.01 *M* $CaCl_2$ extraction showed that even in the fields with the highest accumulation of Cu and Zn, bioavailable Cu and Zn levels were still ten fold below levels that could be of concern with regards to plant toxicity. It should be noted that the soils at the case study farm ranged in pH from 5.8 and 7.4. At high pH, metals will be tightly bound to soil organic matter and Fe and Al oxides in soil. These metals become more available when soils become more acidic. Thus, it will be important to maintain the soil pH at agronomic optimum levels for field crops in fields with elevated soil Cu and Zn levels in order to prevent potential toxicity problems.

What it means to you

Fields with a long-term history of manure application on the case study farm showed elevated Cu and Zn in the surface soil layer. We found no evidence of either leaching of these metals through the soil profile or levels in the rooting zone that would lead to corn, grass or alfalfa toxicity issues. While the levels of Cu and Zn in the manure from our case study farm are representative of those found by others in NY State, very few fields in the state (at most only the typical "field behind the barn") will have the elevated P levels of the fields selected for our study. The NY P Runoff Index discourages manure addition to soils with a very high P index so manure applications will be restricted because of risk of loss of P long before Cu and Zn levels have had a chance to reach levels of concern in these soils. In addition, crops like corn and alfalfa do not show a clear correlation between accumulation of Cu and Zn in soils and plant tissue concentrations or crop yield, mainly due to limited translocation of these elements from the roots to the shoot (Mantovi, 2003; Warman and Cooper, 2000).

Although Cu and Zn accumulation on dairy farms may not be a problem in the short-term, it is important to analyze manure and soils for Cu and Zn over time. At present, no soil extraction method has been sufficiently tested to accurately predict plant availability or solubility of metals in a wide range of soil types. However, a bulk of research has been done to correlate total soil metal concentrations, as determined with an acid digestion, to plant toxicity effects. Rough guidelines given by Murray McBride suggest that total soil Zn of 200 ppm and total soil Cu of 100 ppm may cause toxicity effects on our field crops given they are kept at the agronomic optimum pH. At lower soil pH, toxicity effects could occur at lower total Cu and Zn levels. We recommend that soils be analyzed for total metals (acid digestion) every five years to monitor the impact of current management practices on Cu and Zn accumulation. If soil test levels increase to levels that could impact crop growth, changes in management practices should be made.

For more information

A good article on copper sulfate foot baths by Rick Stehouwer and Greg Roth can be found in Penn State's Dairy Digest of March 2004: http://www.das.psu.edu/user/dairy/newsletter/fullStory.cfm?newsID=376.

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