

Dairy Manure Field Applications—How Much is Too Much?

by Amber Moore and Jim Ippolito

Applying dairy manure to agricultural fields has been shown to increase crop yields, improve the water-holding capacity of the soil, and enhance soil fertility. However, when manures are applied to fields at high rates over a period of several years, nutrients can accumulate, causing eutrophication in drainage waterways; degradation of drinking water; nutrient toxicities in plants; nutrient deficiencies in plants; disruptions in soil microbial populations; and nutritional imbalances for grazing animals. Growers and dairy producers also run the risk of violating state and federal regulations designed to avoid these issues.

In this publication, we will help you understand the reasoning behind laws that limit the application of specific nutrients in dairy manure. We will also provide a few general recommendations on how to avoid overloading fields with nutrients, and how to reclaim a field once you have exceeded these thresholds. The recommendations presented in this paper are suggestions, and do not have any regulatory implications. However, to enjoy the benefits of dairy manure applications instead of the pitfalls, please take note.

Phosphorus

Phosphorus (P) tends to be the nutrient of greatest concern when it comes to animal manure field applications. When dairy manure is

applied based on the nitrogen (N) needs of the crop, P is typically applied at 3 to 6 times the amount of P that the crop can use.

“Eutrophication” can occur if P enters waterways through soil erosion and runoff. Eutrophication—excessive aquatic plant growth and decay from increased P and N concentrations—can cause dissolved oxygen concentrations to decrease so much that aquatic plants and animals suffocate. In order to avoid eutrophication, the Total Maximum Daily Load (TMDL) for total P in the southern Idaho waterways is only 0.075 parts per million (ppm) as established by EPA Region 10.

Phosphorus that accumulates in soil can contribute to eutrophication. Therefore, in Idaho, regulations for soil test P are in place to prevent the accumulation of P in soils, since this excess P can run off into surface water. The NRCS Conservation Practice Standard—Idaho Statute Code 590 establishes the Idaho Phosphorus Threshold (IDPTH) at 40 ppm when using the Olsen soil test P (at a 0-12” soil depth) on fields that have surface water runoff exiting the field.

Another problem with excessive phosphorus accumulations in soils is the potential for phosphorus leaching from the soil into the groundwater. This was originally thought to be a non-issue, since P binds strongly to calcium, soil particles, and organic matter. However, more and more researchers are finding that phospho-

rus does leach into the groundwater in areas that have received manure applications for long periods of time.

Because the calcium in free lime binds strongly to phosphorus, phosphorus leaching will likely be less prevalent in Idaho than other regions of the U.S. due to the high lime content of our soils. Still, if more P is applied than can be chemically bound, leaching can occur. Sandy soils are particularly vulnerable to P leaching. At this time, there seem to be more questions than answers in terms of phosphorus leaching and Idaho soils.

To lower the risk of P leaching into groundwater, the IDPTH for fields with subsurface water drainage (groundwater) is 20 ppm using Olsen soil test P (18-24" soil depth) if the field has a water table less than 5 feet below the soil surface, and 30 ppm with a water table more than 5 feet below the soil surface. For more information on Code 590, go to:
<http://efotg.nrcs.usda.gov/references/public/ID/590.pdf>.

If your soil test P exceeds the IDPTH, dairy manure can still be applied, but you must not exceed the P uptake of the succeeding crop. In other words, whatever P you apply must be fully used up by the crops.

Fertilizer guides from the University of Idaho and from other universities in the western region of the U.S. can help growers determine how much P will be needed by their crops.

Zinc (Zn) deficiency in plants is another concern with excessive P in the soil. Phosphorus and zinc interact in the root. Excessive concentrations of P in the root hinder Zn from being transported to leaves to support growth. The good

news is that Zn deficiency is less common on manured soils, as the Zn in manure is chelated to organic compounds and readily available to plants. That said, Zn deficiencies could still occur, as Zn deficiencies on manured soils have not been extensively researched or investigated.

If your soil tests exceed the maximum legal levels of P, you may want to consider stopping applications of P until the P level decreases. Some people may worry that their crop yields will suffer if they do not fertilize with P. If your soil is already high in P, this should not be an issue. Most crops will not show an increased yield when Olsen soil test P concentrations exceed 20 ppm.

While P in the soil will decrease naturally over time, one of the most common methods for removing P from soils is crop removal. Crops such as corn grown for silage, alfalfa grown for hay, and triticale, can be useful for lowering P concentrations. "Mitigating High-Phosphorus Soils" (Bulletin 851) contains a wealth of information on lowering P concentrations related to dairy manure applications:
<http://info.ag.uidaho.edu/pdf/BUL/BUL0851.pdf>.

Nitrogen

Idaho Statute Code 590 allows for manures to be applied based on nitrogen needs on soils with Olsen P concentrations that do not exceed the IDPTH. In this case it is assumed that the crop uses the majority of the N from manure. While this is generally true, the amount of manure N remaining at the end of the season depends on the manure and its application rate relative to crop N requirements. For example, manures that overwinter on fallow soils contain organic N and ammonium compounds that will slowly mineralize to form nitrates, which might be taken up by the following crop, or might move further down into the soil, beyond root systems, and leach into groundwater.

Nitrate, an inorganic and plant available form of N, is highly mobile and can therefore easily move into shallow groundwater resources when not utilized by plants. The movement of nitrates into drinking water and into waterways can pose serious environmental and health threats. Nitrates can also cause eutrophication in lakes and streams. Nitrates in drinking water from groundwater wells can cause blue baby

To prevent accumulations of P in the soil, you should closely monitor:

- 1)** the amount of P that you are applying to your soils;
- 2)** soil test P concentration; and
- 3)** the P requirements for your crop.

syndrome (methemoglobinemia), a human disorder in which nitrate replaces oxygen in hemoglobin, causing a suffocation effect in the bloodstream that can turn skin pigment a gray or bluish color.

As a prevention measure, the Environmental Protection Agency (EPA) limits nitrate concentrations in drinking wells and in waterways to 10 ppm nitrate-N. The Idaho Department of Environmental Quality well monitoring program has shown an increase in groundwater wells exceeding 10 ppm nitrate-N in agricultural areas. While it is difficult to say whether dairy manure, fertilizers, septic systems, or another source is to blame, it is recommended that all agricultural entities employ conservation practices to prevent nitrate from contaminating groundwater and surface waterways.

Many growers make the assumption that the slate is wiped clean every year as far as nitrogen accumulation in their soils. However, stable organic N compounds in manure continue to accumulate in soil with annual manure applications. Stable organic nitrogen compounds can take as long as 5 years or longer to mineralize into the ammonium and nitrate forms available to plants. Continued application of manures can

build up these reserves, thus contributing more nitrogen to the soil than the plants can use.

For information on N availability and manures, refer to “Estimating Plant-available Nitrogen from Manure” (EM 8954-E), <http://extension.oregonstate.edu/catalog/pdf/em/em8954-e.pdf>, and “Fertilizing with Manure” (PNW0533), which can be accessed at: <http://cru.cahe.wsu.edu/CEPublications/pnw0533/pnw0533.pdf>.

Copper

Experts are becoming concerned about the accumulation of copper (Cu) in the soil because of the application of dairy wastes to agricultural fields. Copper sulfate (CuSO_4) from cattle foot baths is washed out of dairy barns and into wastewater lagoons. The addition of CuSO_4 baths increased Cu concentration significantly in manure slurry from 4.8 g/1000 L to 88.6 g/1000 L (Miner Institute, 2006). The copper-enriched dairy waste is then applied to agricultural crops, thus raising concerns about how soils and plants are impacted by these Cu additions.

Because soluble Cu binds strongly to soils and organic matter in alkaline soils (soil pH > 7), very little of the applied Cu is plant-available in southern Idaho. Overall, the potential for Cu toxicities in plants is relatively small given the amount of Cu applied through dairy waste.

Preliminary results from the USDA ARS in Kimberly, Idaho, showed that DTPA-extractable Cu concentrations ranging from 1 to 154 ppm in a calcareous soil had no effect on alfalfa or corn silage biomass yields. At concentrations of 323 ppm and greater, plant survival was drastically impeded (Ippolito and Tarkalson, unpublished data). However, these high concentrations greatly exceed rates typically seen for dairy manure applications.

In a similar study in New York, Flis et al. (2006) applied copper sulfate at 0, 6.3, and 12.6 lbs Cu/acre to corn silage, orchardgrass, and timothy grass, using Cu rates equivalent to those typical of 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.

To prevent nitrate leaching, and to prevent costly over-applications of supplemental N fertilizers, you can:

- 1) determine total N, ammonium, and nitrate content in manure;
- 2) determine ammonium and nitrate concentrations in the soil prior to planting;
- 3) apply manure in fall on fields with plant residue;
- 4) apply dairy lagoon water during periods of high nutrient uptake;
- 5) grow winter cover crops after fall manure applications; and
- 6) account for available N in manure when estimating N fertilizer amounts to avoid over-application of N.

While these results are encouraging, repeated applications of dairy wastes could potentially raise Cu concentrations to levels toxic to plants. Once this happens, there is very little a grower can do to reclaim the field. A small number of fields in Idaho that have received frequent applications of lagoon water have shown evidence of Cu toxicity. Because Cu is so tightly bound by the soil, and so little is removed by crops, it is very difficult to quickly lower soil concentrations. If you wait until Cu plant toxicity symptoms occur (including plant death), you will continue to see Cu toxicities on that field for an indefinite period of time.

In terms of regulation, there is an existing EPA 503 “worst case scenario” standard that limits annual loading of Cu from biosolids to 66 lbs Cu/acre, and lifetime loading to 1,339 lbs Cu/acre. 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 and Illinois have set lower lifetime loading limits for Cu at 75 and 250 lbs/acre, respectively, to avoid the potential of irreversible toxic accumulations of Cu in the soil.

While more studies are needed to develop an official threshold for Cu in Idaho soils, based on what we know, it would be advisable to cease Cu additions to soils with greater than 50 ppm DTPA-extractable Cu. To determine if you currently have a Cu accumulation problem in your soil, or to identify a developing accumulation, request an analysis for DTPA-extractable Cu

every 2 to 3 years from a soil testing laboratory accredited by the Idaho State Department of Agriculture.

Mario de Haro Marti with the University of Idaho is also investigating the use of electrolysis for removing soluble copper from dairy lagoon water.

Soluble salts

Accumulations of sodium (Na), potassium (K), calcium (Ca), and/or magnesium (Mg) salts do not pose any serious human health or environmental threats (that we know of), and therefore soluble concentrations of salts in soils and waterways are not regulated by federal, state, or local government agencies.

However, salt accumulations can cause toxicities in plants, induce water stress, seal soil surfaces, and lower crop yields. Also, if there is an imbalance in the concentrations of calcium, potassium, and magnesium cations, a deficiency can occur due to cation competition. For example, if there are high concentrations of potassium in the soil, whether from manure, potassium fertilizer, or another source, the plant can take up a disproportionate amount of potassium cations in comparison to calcium and magnesium cations, thus triggering calcium and/or magnesium deficiencies in the plant.

Forage plants, such as alfalfa, will increase their uptake of K as concentrations in the soil increase, thus increasing K concentrations within the plant tissue. This can be of great concern for beef and dairy cattle grazing. Excessive animal intakes of K can cause grass tetany from a lack of magnesium absorption (which can lead to udder edema). Milk fever has also been linked to high forage K tissue concentrations. Potassium concentrations in forages used for grazing should not exceed 2.0% on a dry weight basis.

If you frequently apply manures and/or other salt sources to your fields, we recommend analyzing your soil for electrical conductivity, sodium, potassium, magnesium, and calcium concentrations on a yearly basis. Guidelines for soil analysis, interpretation, and reclamation of salt-affected soil are listed in the publication “Managing Salt-affected Soils for Crop Production” (PNW 601-E), which can be found at: <http://extension.oregonstate.edu/catalog/pdf/pnw/pnw601-e.pdf>

Copper concentrations can be lowered in dairy waste by:

- 1) reducing the amount of copper sulfate used in foot baths;
- 2) reducing the overall frequency of foot baths;
- 3) improving hoof trimming and stall surfaces; and
- 4) disposing of the Cu waste in an alternative location to the lagoon.

To reap the benefits of manure applications without the worry of overloading your soils, follow these basic guidelines:

- 1)** Know the environmental, regulatory, plant nutrition, human health, and animal consumption limits for P, N, Cu, and soluble salts.
- 2)** Stay on top of soil, plant tissue, manure, groundwater, and stream analysis for key nutrients within your cropping system.
- 3)** Know the signs of nutrient overloading.
- 4)** Reclaim overloaded soils earlier rather than later.
- 5)** Develop manure application rates that are based on common sense, and not just on regulations.

References

Flis, S. A., C. S. Ballard, M. A. LeVitre, R. M. Conant, and E.D. Thomas. 2006. Changes in Copper Sulfate Use on Northeastern New York and Vermont Farms Between 2002 and 2005. Abstr. #T76. J. Dairy Sci. Suppl. 1 vol. 89.

Miner Institute. 2006. The effect of CuSO_4 from dairy manure on the growth and composition of cool season forage grasses and corn. Miner Institute Research Report 06-4. Available online at: <http://www.whminer.com/Research/WHM-06-4.pdf>

About the authors

Amber Moore is an assistant professor of soil science at the University of Idaho's District III Cooperative Extension in Twin Falls. **Jim Ippolito** is a research soil scientist at the USDA Agricultural Research Service Northwest Irrigation and Soils Research Laboratory in Kimberly.

University of Idaho
Extension

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Charlotte V. Eberlein, Director of University of Idaho Extension, University of Idaho, Moscow, Idaho 83844. The University of Idaho provides equal opportunity in education and employment on the basis of race, color, national origin, religion, sex, sexual orientation, age, disability, or status as a disabled veteran or Vietnam-era veteran, as required by state and federal laws.