Does Land Application of Biosolids Pose Health Concerns for Grazing Livestock?

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Introduction

Biosolids are solid, semi-solid, or liquid materials resulting from treatment of domestic sewage sludge (see "Wastewater Treatment Processes," http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_Wastewater.pdf). Biosolids and their land application are regulated on the federal level by the U.S. Environmental Protection Agency, or U.S. EPA, and on the state level by the Virginia Department of Environmental Quality (DEQ) and the Virginia Department of Health (VDH) to ensure that the biosolids have been sufficiently processed to permit safe and beneficial land application (see "How and Who Regulates the Use of Biosolids," http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_WhoRegulates.pdf).

Biosolids consist mainly of partially decomposed organic matter and essential plant nutrients. These products provide considerable yield and quality benefits to pastures (Figure 1), hayfields, and row crops (see "Biosolids Use for Row Crop, Forage, and Hay Lands," http://www.virginiabiosolids.com/wp-content/uploads/2019/02/Biosolids-Use-for-Row-Crop.pdf) because they supply significant amounts of plant nutrients (see "Nutrient Content, Value, and Management of Biosolids,"

http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_NutrientContent.pdf). They also supply organic matter that improves physical, chemical and biological properties of soil (see "Benefits of Organic Matter in Biosolids," http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_Benefits.pdf), as well as biostimulants (see "Biostimulant Benefits from Biosolids,"

http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_Biostimulant.pdf).

Figure 1. Tractor-drawn manure spreader applying biosolids onto a Virginia pasture in early May.

Despite the well-documented benefits of the use of biosolids in agriculture, the presence of undesirable constituents such as trace inorganic and organic constituents and pathogens has elicited some concern among the general public, farmers, and regulatory agency staff regarding their use. (See "Inorganic Trace Elements," http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_TraceElements.pdf; "Trace Organic Compounds,"

http://www.virginiabiosolids.com/wp-content/uploads/2018/10/VBC_TraceOrganic.pdf; and "Pathogens and Biosolids," http://www.virginiabiosolids.com/wp-content/uploads/2019/01/VBC_Pathogens-Biosolids-2.pdf.)

Land Application: Risks and Benefits

Under Part 503 (U.S. EPA 1995), land application of sewage sludge shall not exceed the agronomic rate, which is "the application rate designed to provide the crop nitrogen (N) requirement and minimize the amount of N that passes below the root zone" and into ground water. The agronomic rate requires knowledge of the crop N requirement, the available N in the biosolids, and soil conditions at the site. To prevent phosphorus (P) pollution of surface water, the Virginia Department of Conservation and Recreation (DCR) and the Virginia Department of Environmental Quality (DEQ) have included P-based nutrient management plans for biosolids application. For lime-stabilized biosolids, the agronomic rate must also ensure that soil pH does not rise excessively.

The contents of organic matter, nitrogen, phosphorus, and other macro- and micronutrients make biosolids valuable as a fertilizer and soil conditioner. Forages grown on land amended with biosolids have been used by grazing ruminants, principally beef cattle, while grain crops fertilized with biosolids have been fed to both monogastric and ruminant species. No detrimental impacts on animal health have been observed in livestock grazing on or fed biosolids-amended forages and hay.

Nonessential (for plants and animals) trace metals in biosolids occur in chemical forms that have low availability and uptake, even when biosolids are consumed directly by animals (Cottenie, Satoh, and Winteringham 1984). A mechanism called the "soil-plant barrier" (Logan and Chaney 1983) reduces toxic metal uptake and accumulation due to processes such as soil immobilization or antagonism with other elements. An example of the soil-plant barrier is reduced cadmium (Cd) absorption by plants due the ample quantities of soil zinc. Another protective mechanism is "phytotoxicity," by which some metals (e.g., copper, Cu; nickel, Ni; and zinc, Zn) will stunt plant growth before the plant can accumulate enough of the element to be toxic to feeding animals.

Biosolids can contain numerous trace organic chemicals, which are legitimate concerns when applying biosolids to soils to produce feed for livestock. However, a risk assessment conducted by the U.S. EPA has demonstrated that bioavailability of trace organic compounds to plants and animals is low, especially at the rates at which biosolids are applied to land (U.S. EPA 1993; National Research Council 1996).

Research at sites whose biosolids application history pre-dates the Part 503 regulations provided useful data for assessing the risk of biosolids to grazing livestock. Three such sites include the former Lowry Bombing Range operated by the City of Denver (Baxter et al. 1983), a site in Fulton County, Ill., operated by the City of Chicago (Lue-Hing et al. 1986), and the Rosemont Watershed study managed by the University of Minnesota (Knuteson et al. 1988). At the Fulton County site, cattle were allowed to graze for up to eight years on pastures on which anaerobically digested biosolids were applied annually. Cows on both control and biosolids treatments calved normally without complications. Zinc, copper, and cadmium increased in the livers of cows in treatment herds but remained below tolerable levels for food products. Negligible amounts of trace elements were assimilated and concentrated by crops grown on biosolids-amended soils at the Rosemont and Denver sites. Numerous studies from the 1970s and 1980s have shown accumulation of trace elements (especially cadmium) in the kidney and liver but not in the muscle of cattle grazing sludge-amended pastures (National Research Council 1996). However, the concentrations of biosolids-borne trace metals prior to the promulgation of the 503 Rule were considerably higher than found in currently permitted biosolids. An improvement in the quality of biosolids over the years has occurred due to pretreatment and pollution prevention programs (Shimp et al. 1994).

Researchers have fed biosolids directly to beef and dairy cattle at 10%-20% of their diet with no negative health results (Baxter et al. 1983). Other studies also show that there is not a significant health risk to beef or dairy cattle from consuming feed grown on biosolids-amended soils (Dowdy et al. 1984). The use of best management practices reduces the potential for direct ingestion of biosolids while grazing cattle on biosolids-amended pastures.

Dorn et al. (1985) conducted a three-year epidemiologic study on 47 farms receiving annual applications of biosolids (average of 2–10 dry metric tons per hectare per year) and 46 control farms in three geographic areas of Ohio. There were no differences in disease occurrence in livestock between farms that used or did not use biosolids.

A workshop on emerging infectious disease agents and issues associated with biosolids, animal manures, and other organic byproducts (Smith, Millner, and Goldstein 2005) summarized the knowledge on this topic, as follows. Note that authors use the term "sewage sludge" instead of "biosolids," currently preferred when discussing sludge that has undergone treatment and meets federal and state standards.

There are currently available treatment technologies that per se adequately disinfect sewage sludge of existing and emerging pathogenic microorganisms to a degree that has consistently resulted in no clinically-documented outbreaks of illness that were associated with land application of treated sewage sludge .

The current sewage sludge and animal manure treatment technologies can be expected to affect antibiotic resistant as well as nonresistant strains of bacteria equally. Furthermore, after land application the inherent capacity of these bacteria to maintain antibiotic resistance can be expected to diminish as the concentrations of corresponding antibiotics decrease in the soil environment.

Knowledge about the origin and treatment of biosolids applied to soils for forage or crop production will remain important. Numerous research trials and long-term experience with soil application of biosolids to forage and crop lands have shown that natural soil-plant-animal barriers act to minimize risks from toxic trace elements, organic compounds, and pathogenic organisms in biosolids. Stringent analysis and control of these potentially toxic factors in biosolids at the treatment sites will avoid problems.

In addition to the requirements mandated by the regulations to protect the environment and the health and safety of the public and the farmer, livestock farmers can adopt several practices to ensure that biosolids application is safe. Below are some potential problems that could arise from the use of biosolids and what steps farmers can take to prevent them.

Potential problem: Liquid biosolids application to pastures may increase the risk of toxic intake of inorganic trace elements and organic trace compounds by grazing livestock.

Most biosolids currently generated are dewatered to limit the mass that must be transported to an application site. Dewatered biosolids (usually containing 25%-30% solids) applied onto pastures are dry enough so as not to adhere to the vegetation. The solids from dewatered biosolids fall onto the soil surface as the plant grows and comprises a low percentage of the diet (usually less than 2.5%). Such low biosolids ingestion rates pose insignificant risk to the livestock when time-dependent access restrictions are followed (i.e., 60 days for lactating dairy cattle, 30 days for all other cattle). However, liquid biosolids that are sprayed onto pastures adhere to the leaf surface and usually comprise a greater portion of the diet of the livestock than estimated in the risk assessment. Pollutants (e.g., heavy metals, organic chemicals) are more likely to be ingested by livestock grazing on pastures fertilized with liquid sludge than dewatered sludge.

Solution: To minimize the risk of ingestion of pollutants and pathogens, 1) graze livestock on pastures fertilized with dewatered biosolids; or 2) ensure that pasture or hay vegetation has been mowed to less than 4 inches before the liquid biosolids application, thereby allowing enough time for the vegetation to grow to a height that adequately dilutes the adhering biosolids.

Potential problem: Molybdenum (Mo) and sulfur (S)-induced copper (Cu) deficiency.

Molybdenosis, or Mo-induced Cu deficiency in ruminants, is caused by an imbalance in dietary molybdenum, copper and sulfur. Lime-treated biosolids may exacerbate this health problem by increasing plant availability of soil Mo and reducing the availability of Cu, both situations which are promoted at higher (e.g., greater than 7) soil pH. Research in Florida (O'Connor et al. 2001) has demonstrated that under a very narrow set of conditions, the concentrations of molybdenum in forages could be raised to levels that might cause a Mo-induced Cu deficiency; however, the combined set of conditions (e.g., excessive uptake rate of Mo by plants, high feeding rate/proportion of biosolids-amended grain and forage in animal diet, and extremely low Cu availability in certain soil types without the typical practice of supplementing trace elements to the livestock) are highly improbable. This scientifically peer-reviewed research was employed as the basis for establishing safe molybdenum concentration and application rate standards.

Solution: To prevent molybdenosis, (1) maintain soil pH within the optimum range of 5.8 to 6.5, especially on sandy coastal plain soils; (2) do not feed livestock a diet comprised entirely of biosolids-fertilized forage; and (3) provide supplemental trace elements for livestock.

Potential problem: Grass tetany.

Grass tetany is a magnesium (Mg) deficiency (hypomagnesia) of ruminants usually associated with their grazing of cool-season grasses during the spring. Hypomagnesia is often observed in pastures grown on soils that contain high concentrations of soil potassium (K) relative to soil magnesium. In biosolids-amended pastures, hypomagnesia may be exacerbated by other factors because biosolids typically contain low concentrations of potassium that must be supplemented with synthetic fertilizer. Lime-stabilized biosolids are produced with quicklime (CaO) rather than with a mixed Ca-Mg liming product. Repeated applications of lime-stabilized biosolids without supplementation with a magnesium-containing product can reduce soil Mg concentration to low levels. High rates of nitrogen (N) that may be applied in biosolids may also exacerbate this condition.

Solution: 1) Have soil tested annually if using lime-stabilized biosolids and apply magnesium if soil Mg is low; 2) alternate lime-stabilized biosolids and dolomite as a liming source; 3) use other biosolids sources that are not lime-stabilized (e.g., anaerobically digested, heat dried); or 4) producers can feed livestock a magnesium-fortified supplement. Splitting the biosolids application can reduce the risk of hypomagnesia by providing less nitrogen at any one time.

Potential problem: Micronutrient deficiency of forage.

The repeated use of a lime-stabilized biosolids can raise soil pH to levels above the agronomically optimum range (i.e., 5.8 to 6.5) if biosolids are applied based on crop N rather than soil pH limitations. Soil texture can affect the degree of this problem; for example, pH of coarse-texture (i.e., sandy) soils is apt to rise higher and more rapidly in response to liming agent application than in fine-textured (i.e., clayey and silty) soils. Furthermore, plants grown in coarse-textured soils are more susceptible to deficiencies of copper, manganese (Mn), and zinc at high soil pH because high soil pH limits the availability of these nutrients, which are usually in lower concentrations that in fine-textured soils.

Solution: To avoid micronutrient deficiencies of Cu, Mn, and Zn, ensure that the rate of a lime-stabilized biosolid is applied to maintain soil pH within the ideal agronomic range. Use a soil testing lab that measures soil buffer pH to calculate the exact liming rate required to adjust the soil pH appropriately. Where the pH of the soil is already high, do not use lime-stabilized biosolids. Crops showing deficiencies of Mn, Cu, or Zn can be treated with foliar applications of these elements to ensure vigorous plant growth.

Potential Problem: Nitrate toxicity.

Toxicity in livestock that consume excessive concentrations of nitrates in forages has been well-documented. Nitrates can accumulate in plants heavily fertilized during or just after a drought; during cool, cloudy weather; or following a frost. Sudangrass, sorghum-sudan hybrids, pearl millet, corn, wheat, and oats are among plants known to have considerable potential to accumulate toxic levels of nitrates. Certain weeds (e.g., pigweed, smartweed, ragweed, lambsquarter, goldenrod, nightshades, bindweed, Canada thistle, and stinging nettle) may also accumulate toxic levels of nitrates.

Nitrate N is the main form of plant-available N taken up by crops. Under optimum environmental conditions (i.e., full sun, adequate soil moisture), the nitrate assimilated by plants is converted to protein. Environmental conditions that limit plant growth (e.g., drought, shade) limit the conversion of nitrate to protein and cause nitrate to accumulate in vegetative tissues. Nitrate accumulation is most prevalent where high rates of N are applied regardless of whether the N source is commercial fertilizer, animal manure, biosolids, or green manure crops. For this reason, nitrate testing of forages during drought is a commonly recommended practice, even where biosolids have not been applied.

Biosolids MAY pose a greater risk of nitrate toxicity than fertilizer due to the following factors:

1) Biosolids are often applied to pastures and hayland at rates designed to supply an entire year's worth of N. This could result in more N than the crop uses following adverse environmental conditions.

2) Mineralization rates used to estimate N availability of any organic material (i.e., biosolids, manure, plant residue) vary with climate; thus, more (or less) nitrate than anticipated may actually become available for crops during the growing season when the amendments are applied.

3) The variability in the concentration of N in biosolids may result in higher (or lower) than expected concentrations of nitrate in some fields. The concentration of N in biosolids used to calculate the amount of plant available N is estimated from a series of samples, some of which may have been collected as much as six months before the biosolids are actually applied. In most cases, the concentrations of N in biosolids are fairly constant, but normal variability will nearly always result in nitrogen concentrations somewhat higher or lower than that actually being applied.

Solution: To reduce the risk of accumulating high concentrations of nitrate during deleterious climatic conditions (i.e., before frosts or during droughts), biosolids rates should be applied to forage and hay crops based on well-designed nutrient management plans that include split applications.

Summary

The land application of biosolids to crops consumed by livestock, either indirectly or directly, is safe when regulations are followed. Additional wise agronomic and livestock practices can further reduce risk.

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