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Phosphorus Best Management Practices for Biosolids and Other Organic Residuals

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Biosolids in this publication are defined as organic residuals from any waste treatment process, including sewage sludge, food processing waste and sludge from treatment lagoons. Current regulations controlling land application of biosolids have few required management practices for phosphorus. Missouri previously limited biosolid applications only when the agronomic soil test level (based on the Bray-I procedure) exceeded 800 pounds of phosphorus per acre. Recommended management practices suggested obtaining permission from the Missouri Department of Natural Resources (MDNR) before applying to land that exceeded this limit.

Movement of phosphorus from agricultural land to surface waters is a complex process affected by a wide range of localized field conditions and management practices. In the past decade, understanding of phosphorus loss from agricultural fields has increased significantly. We have also developed new tools and recommended practices to help reduce the contribution of phosphorus loss from agricultural land to water quality problems.

The objective of this guide is to update the recommended practices for managing phosphorus in biosolids to reflect these recent advances. Many of the recommendations for animal manure apply to other biosolids because of the similarities between animal manure and biosolids. Other publications (see the suggested reading list at the end of this guide) describe phosphorus loss processes from agricultural land and the impact of phosphorus on water quality. These guides provide more in-depth descriptions of the key concepts of phosphorus loss and management. This guide will focus on the recommended practices for managing phosphorus with particular attention to the unique recommendations for biosolids.

Why are we concerned about phosphorus?

Phosphorus is typically the most limiting nutrient in most Missouri lakes and streams. Increasing the amount of phosphorus reaching a freshwater body typically will stimulate growth of aquatic vegetation. This process can lead to reduced water clarity, depletion of oxygen in the water, changes in fish populations, and in extreme situations, growth of toxic algae.

The sensitivity of water resources to increases in phosphorus loading have led to extensive efforts to limit phosphorus reaching lakes and streams.

- Some wastewater treatment facilities have been required to meet stricter effluent limits for phosphorus.
- The new revised regulations for concentrated animal feeding operations include new requirements for assessing phosphorus loss from fields receiving manure and phosphorus limits on manure application on permitted operations.
- An increasing number of producers make voluntary use of phosphorus loss assessment tools and phosphorus limits on manure application on all agricultural land.

Phosphorus loss from agricultural fields is a major focus of efforts to improve water quality. Agriculture is listed as the primary source of impairment for Missouri streams in the *National Water Quality Inventory Report* published in 2002 by the U.S. Environmental Protection Agency.

The Ozark region of Missouri is particularly sensitive to increased phosphorus loading of its surface waters. Native soils in this region of the state have very low available phosphorus levels, and streams in the region have historically been clear with low phosphorus concentrations.

Phosphorus best management practices for biosolids

A nutrient management plan should be developed for all fields receiving biosolids. A nutrient management plan details the rates, timing and placement of all sources of nutrients over the course of a plan, typically five years. Comprehensive nutrient management planning additionally integrates into the plan conservation planning, operation and control requirements for land application activities and emergency spill plans.

There are software packages available to facilitate

many of the activities of nutrient management planning, including mapping land application setbacks, calculating application rates and calculating nutrient balances. Most software has been developed for manure management but is useful for nutrient management planning for biosolids. Visit the Web site http://nmplanner.missouri.edu for more information on nutrient management planning software and for other resources helpful for nutrient management planners.

The following elements of a nutrient management plan address phosphorus management issues.

1. Phosphorus loss assessment is recommended on all fields receiving biosolids.

- Phosphorus-based rates are recommended on fields with a high rating
- No biosolid applications are recommended on fields with a very high rating.

In Missouri there are two tools for assessing phosphorus loss from agricultural fields:

1. Agronomic phosphorus
2. Missouri phosphorus index

Use either of these tools to obtain a rating for the field. There are five rating categories from "very low" to "very high." The agronomic phosphorus assessment uses soil test results and agronomic response interpretations to place the field into one of the five categories. The phosphorus index assessment integrates multiple pieces of information to assess the long-term probability of phosphorus loss from a field. Information required for using version 0.2 of the phosphorus index includes:

- Soil test phosphorus (assume Bray-I extraction and 6- to 8-inch sampling depth)
- County
- Tillage (no till or forage vs. tilled)
- RUSLE-2 estimate of erosion (component of an NRCS conservation plan)
- Soil cover (description of cropping practices)
- Soil hydrologic group (from the soil survey, based on soil type)
- Distance from target water body

This information is entered into a spreadsheet available at http://nmplanner.missouri.edu. The spreadsheet will determine the phosphorus index rating for that field.

The ratings derived from either assessment method (agronomic phosphorus or phosphorus index) are interpreted the same way (Table 1). Nitrogen-based application rates are allowed on fields rated very low to high. However, sustainable management would recommend phosphorus-based management except when the agronomic soil test recommends raising soil test phosphorus to improve productivity.

Table 1. P assessment ratings and interpretations.

P assessment rating	Interpretation
Very low	Nitrogen-based applications okay
Low	Nitrogen-based applications okay
Medium	Nitrogen-based applications okay
High	Phosphorus-based applications recommended
Very high	No applications recommended

Phosphorus-based application is typically implemented using a rotation approach where up to five years of phosphorus is applied in a single application and then no further phosphorus applications are allowed until subsequent crops remove the excess phosphorus. A multiple-year phosphorus application should not exceed the nitrogen need of the current crop. See the next section for more information on field nutrient balance.

The nutrient management planner has the option of choosing the method of assessment. The agronomic approach typically is more conservative, resulting in more limits on phosphorus application than the Missouri phosphorus index.

2. Calculate a phosphorus nutrient balance for every field receiving biosolids.

A field nutrient balance for phosphorus sums all sources of phosphorus applied to a field and all exports of phosphorus in harvested crops. Phosphorus inputs include biosolids and commercial fertilizers. Exports typically are based on yield goals for the crops in the planned rotation using book values for nutrient concentrations in the harvested crops.

The phosphorus balance for the field is then calculated as:

Phosphorus inputs
– Phosphorus exports
Phosphorus balance

A positive phosphorus balance implies that phosphorus soil test levels will increase in the field over the course of the planning window. A rough "rule of thumb" is that soil test phosphorus will increase one pound per acre for every 10 pounds of phosphate applied per acre. This is a conservative estimate; on some fields 10 pounds of phosphate per acre will result in greater increases in soil test phosphorus.

Caution must be used in interpreting nutrient balances. In some cases the nutrient balance will be positive even when using a phosphorus-based application strategy. For example, a field may receive a phosphorus-based application rate to provide three years of phosphorus. If the application is applied in year one of the plan and then again in year four of a five-year plan the phosphorus balance will be positive because the removal window for the second application extends beyond the planning window of the five-year plan.

3. Phosphorus balance for a five-year plan should not exceed 600 pounds phosphate per acre.

Some biosolids have a low ratio of plant-available nitrogen to phosphorus, substantially lower than most animal manure sources. Table 2 shows the estimated plant-available nitrogen to phosphate ratio for selected biosolids. It also shows the amount of phosphate applied when biosolids are applied to provide 150 pounds per acre of plant-available nitrogen.

Nitrogen-based application rates with low plant-available nitrogen to phosphate ratios materials can result in large rates of phosphorus being applied at one time (Table 2). In some cases the phosphate application rate with sewage sludge can be 10 times or more than the highest rates associated with typical animal manures. A single application of this magnitude can raise soil test phosphorus hundreds of pounds per acre in a single application. The resulting soil test level will be many times the agronomic optimum after a single application no matter what the initial soil test phosphorus level. A single application with this type of material can move a field from a low phosphorus loss assessment to a high or very high loss assessment.

Biosolids such as sludge materials from sewage treatment and animal lagoons need greater restriction on application rates than typical manure products because of the potential for extreme imbalance in the ratio of nitrogen to phosphate. Animal manure and sewage sludge applications can still exceed crop need by 600 pounds per acre in a five-year period with these restrictions. This can lead to at least a 60-pound-per-acre increase in soil test phosphorus, sufficient to raise any soil in the low phosphorus soil test category to high. Ideally biosolid application should not exceed the phosphorus removal capacity of the crop rotation except as recommended by soil testing.

Table 2. Estimated plant-available nitrogen (PAN) to phosphate ratio for selected biosolids and the phosphate rate applied when the material is applied at a rate to provide 150 pounds per acre PAN.

Biosolid	Estimated PAN:phosphate ratio	Phosphate applied at 150 lb nitrogen rate (lb/acre)
Poultry litter	0.80	190
Pig slurry manure	0.68	220
Sewage sludge #1	0.18	820
Sewage sludge #2	0.15	1,020
Sewage sludge #3	0.06	2,640

Note: Plant-available nitrogen is the fraction of total nitrogen that has fertilizer value. These estimates are for demonstration purposes only.

4. Maintain separation distances between land application areas and water resources.

Separation distances or setbacks from the edge of land application areas and water resources are an important tool for protecting water quality. Setbacks that are maintained in permanent vegetative cover are the most effective buffers. Setbacks reduce phosphorus movement to surface waters by serving as a trap for soil particles eroded from a field. Soluble phosphorus in runoff can also be reduced as runoff passes through a setback through water infiltration into the soil and by sorption of phosphate ions to the soil and plant material. Table 3 includes some of the recommended setbacks for biosolid land application.

Table 3. Recommended separation distances for land application of biosolids.

Type of sensitive setback area	Separation distance
Wells, abandoned wells, sinkholes, caves and losing streams[1]	300 ft
Permanently flowing and intermittent streams	100 ft
Privately owned impoundment (ponds) not used as a water supply	100 ft
Property lines[1]	50 ft
Neighboring houses or public use areas[1]	150 ft

[1] Required by Missouri regulations (Department of Natural Resources, Clean Water Commission Chapter 8 Design Guide (10 CSR 20-8.020)).

5. Surface applications should be avoided when runoff events are likely before phosphorus has reacted with the soil.

- No application on saturated, snow-covered or frozen ground.
- Avoid applications when rainfall that could produce runoff is likely.
- Avoid surface application on land prone to flooding.

Research has shown that runoff events that occur soon after a surface phosphorus application can carry very high phosphorus concentrations. After a surface application the phosphorus in the biosolids will react with the soil, reducing the vulnerability to loss in runoff. Research with animal manure indicates that potential losses are most acute in the first one to two weeks after application. Light rains that help move the phosphorus into contact with the soil speed the reaction process. Injecting phosphorus sources below the soil surface eliminates this concern. This can be a beneficial practice if injection minimizes potential erosion, another important source of phosphorus in runoff.

Application onto saturated, snow-covered and frozen soils is not allowed under water quality regulations. These conditions prevent phosphorus from reacting with the soil and promote phosphorus losses in runoff. Surface application of high-phosphorus materials in fall or spring onto land prone to flooding increases the potential that these materials could be washed directly into flooding rivers and streams.

Example: Phosphorus nutrient balance

A municipality has arranged with a neighboring farmer to make a one-time application of sewage sludge to a 100 acre field that is in a corn-soybean rotation. The application is to take place in spring before planting corn.

- Yield goals are 150 bushels of corn and 40 bushels of soybeans per acre.
- The corn nitrogen recommendation is for 110 pounds of nitrogen per acre.
- The current phosphorus soil test level in the field is 45 pounds per acre and the recommended phosphate application rate is equal to crop removal.
- Crop removal of phosphate for corn is 0.45 pounds of phosphate per bushel and for soybean is 0.84 pound per bushel.
- The sludge material has 15 pounds of total nitrogen per 1,000 gallons, of which 4 pounds is plant-available nitrogen. The nitrogen-based application rate is 27,500 gallons per acre.
- The sludge material has 27 pounds phosphate per 1,000 gallons.

Planned phosphate application rate

27,500 gal/1,000 gal $\times$ 27 lb phosphate per 1,000 gal $=$ 740 lb phosphate/acre

Planned phosphate crop removal

Corn removal rate =

3 years $\times$ 150 bu/acre/year $\times$ 0.45 lb phosphate/bu $=$ 203 lb phosphate/acre

Soybean removal rate =

2 years $\times$ 40 bu/acre/year $\times$ 0.84 lb phosphate/bu $=$ 67 lb phosphate/acre

Total crop removal potential $=$ 203 $+$ 67 $=$ 270 lb phosphate/acre

Phosphate nutrient balance

740 lb phosphate applied per acre
– 270 lb phosphate removed/recommended per acre
470 lb phosphate excess per acre

The amount of phosphate applied substantially exceeds the phosphate removal capacity of the crops in the five-year planning window. Soil test phosphorus levels will increase substantially on this field. The imbalance is less than the five-year limit of 600 pounds of phosphate per acre, so it is an allowable application.

Also from Extension Publications - (800) 292-0969

The following publications provide supplemental information that will help you better understand and implement the recommendations presented in this guide.

G9181 *Agricultural Phosphorus and Water Quality*
G9182 *Managing Manure to Protect Water Quality*
G9215 *Soil Sampling Pastures*
G9217 *Soil Sampling Hayfields and Row Crops*
G9219 *Setback Distances for Land Application of Manure*
G9220 *Strategies to Minimize Phosphorus Loss From Your Farm*
G9221 *Nutrients and Water Quality for Lakes and Streams*
NCR187 *Agricultural Phosphorus Management and Water Quality Protection in the Midwest*
WQ426 *Best Management Practices for Biosolids Land Application*
WQ429 *Interpretation of Laboratory Analysis of Biosolids Samples*

This guide was reviewed by members of the Interagency Technical Working Group, an advisory group on issues related to agriculture and water quality. The group includes representatives from the USDA Natural Resources Conservation Service, Missouri Department of Natural Resources and University of Missouri Extension.

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