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Managing Phosphorus from Animal Manure

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Applying animal manure to farmland is an appropriate and environmentally sound management practice for livestock and poultry producers. Land applications recycle nutrients from manure to soil for plant growth and add organic matter to improve soil structure, tilth, and water holding capacity. As with other nutrient sources, improper use of manure can result in environmental damage. One of the major concerns associated with manure application is the buildup of phosphorus (P) in soils, and the subsequent impact of P on surface water quality. This fact sheet provides basic information on manure P and some options for better management of P from animal manure.

What is the Nature of Manure Phosphorus?

Phosphorus occurs in animal manure in a combination of inorganic and organic forms. In general, 45 to 70 percent of manure P is inorganic. Organic P constitutes the rest of total P. Essentially, all inorganic P is in the orthophosphate form, which is the form taken up by growing plants. Much of the organic P is easily decomposable by soil microorganisms to the inorganic form. Factors such as temperature, soil moisture, and soil pH affect the P mineralization rate.

The availability of P from manure ranges from 80 to 100 percent, compared to 100 percent availability in commercial fertilizers. When nutrient application is based on P, 90 percent availability normally is used for application rate calculations. In other words, the total P in manure should provide nearly the same effect as an equal amount of P from commercial fertilizers, as far as crop response is concerned.

How Much P is Present in Manure?

Nutrients in manure vary greatly from operation to operation, depending on animal species, the size of animals, and the ration fed. Manure P, like other nutrients, is normally not uniform even in the same storage facility, depending on various factors such as the amount of bedding, the amount of moisture entering the system, and how the manure is handled and stored. Therefore, the first step in developing an effective manure application plan is to determine the amount of nutrients in the manure. It is strongly recommended that the nutrient content of manure be determined by laboratory analysis annually or when manure handling procedures change. Table 1 shows the average of major nutrients in different types of manure generated in Oklahoma. Broiler litters are relatively high in all three major nutrients, especially phosphorus.

Table 1. Average nutrient analyses of major types of manure in Oklahoma.

Manure Type	Total N	P_2O_5	K_2O	N:P Ratio
	lb/ton			
Stockpiled Feedlot Manure	24	21	25	1
Broiler Litter	58	61	47	1
	lb/1000gal			
Lagoon Effluent	4.2	1.0	5.0	4

What Happens to P after Manure is Applied to Soil?

Manure contains organic and inorganic phosphate compounds. The inorganic P initially is quite soluble and available; however, when it comes in contact with soil, various reactions begin to take place. Those reactions make phosphate less soluble in water and less available to plants. The rates and products of these reactions are dependent on soil pH, moisture, and the minerals already present in the soil.

Generally, phosphate ions react with soil in two ways:

1. Adsorbing onto soil particles
2. Chemically combining with elements in the soil such as calcium (Ca), aluminum (Al), and iron (Fe), forming compounds that are solids (precipitates).

The adsorbed phosphate and the newly formed compounds are only slowly available to plants. The easily dissolved compounds of phosphate form more insoluble compounds that cause the phosphate to become fixed and unavailable to plants. The texture of soil affects its capacity to hold P by adsorption. Most fine-to-medium textured soils have larger capacities to adsorb phosphate than coarse-textured soils. On the other hand, soil pH determines the kinds of phosphate compounds formed when P precipitates. Calcium phosphates

EXHIBIT 5

form in neutral and alkaline soils, while aluminum and iron phosphates form in acid soils.

As adsorbed and precipitated P increases, the P in soil solution (water held in the soil matrix) also increases, due to an equilibrium between solid and dissolved forms of P. Soil solution P is subject to runoff loss during storm events. More P will be subject to loss when soil P approaches saturation or over-saturation. Saturation means that all the sorption sites on soil particles are occupied by P, and all Ca, Al, Fe and other elements capable of precipitating P are used up. Therefore, the soil P holding capacity is a function of clay and organic matter content, soil pH, and the amount of calcium carbonate and aluminum or iron oxides of a particular soil.

Why Does Soil P Increase?

In many areas of intensive livestock and poultry production, manure normally is applied at rates designed to meet crop nitrogen (N) requirements. This often results in a buildup of soil test P (STP) above sufficient amounts for optimal crop yields. This is because the amount of P in manure is considerably greater than the amount removed in harvested crops. For example, the N:P ratio of most poultry litter and feedlot manure is close to 1:1 (see Table 1), but most crops require an N to P ratio of 8:1. While N gets used, P builds up in the soil. Long-term research, conducted at the OSU Agricultural Experiment Station at Lahoma, documents soil-P depletion and enrichment from 27 years of annual applications of zero to 80 lb/acre fertilizer P for winter wheat production (Figure 1). Change in the soil test P index is well correlated with net P input or removal. About 14 lb P_2O_5/acre is required to raise or lower the STP by 1.0 unit for this silt loam soil. The amount of P_2O_5 needed to change STP may vary with soil texture, pH, and other soil properties. There may also be differences between inorganic P fertilizer and organic P sources, such as animal manure and biosolids. When manure is surface-applied, as in pasture and hayland systems, STP may increase faster than in cropping systems where manure is incorporated, or mixed well, with soil.

Soil P testing is a management practice that is used to predict the amount of P needed in a fertilizer or manure program for optimum yield. When soil testing shows a low to medium P index, a yield response to applied P should be expected. If the soil test P index is high or excessive, there is normally no added benefit from additional P; however, there is an increased potential for P leaving the field and entering water bodies (Figure 2). Science-based fertilizer recommendations used by Oklahoma State University, based on decades of field and laboratory research, show a STP value of 65 is adequate for production of most crops. Recent research indicates a field-average soil test of 120 (based on 15 to 20 cores per field) can be used to ensure that 95 percent of the area of a field has sufficient P with soil test levels of 65+ and to prevent any localized deficiencies due to soil variability. Therefore, nutrient utilization standards that are protective of the environment would require that animal manure applications do not result in soil test phosphorus levels that exceed 120.

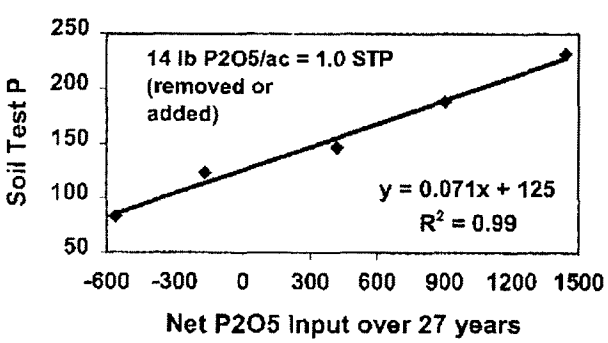

Figure 1. Changes in soil test P resulting from 27 years of fertilizer input and wheat grain removal at Lahoma, Okla.

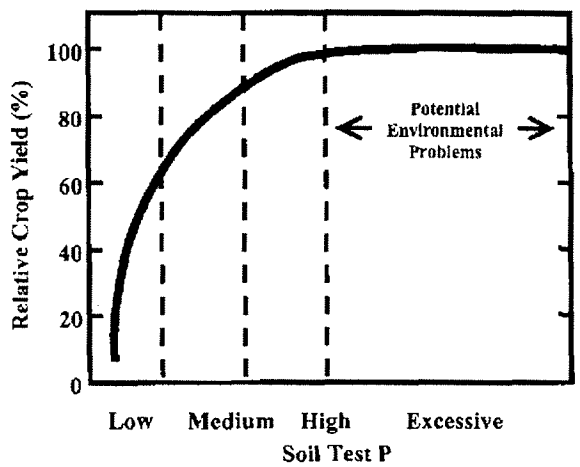

Figure 2. Relationship between soil test P levels, relative crop yield, and the potential for environmental problems.

How Does Soil P Affect Water Quality?

Most soils have a large capacity to retain P. Even large additions of P will be mostly retained by soils provided there is adequate contact with the soil. However, increasing the amount of P in soils results in increased levels of P in soil solutions (Figure 3). Generally, this will result in small, but environmentally important, increases in the amount of dissolved P in water that passes over or through soils.

Adsorbed and precipitated phosphates are associated more with fine soil particles than with coarse particles. When soil erosion occurs, and soil particles and organic matter are carried to a stream or lake, this sediment-bound P becomes a source of P in water. These two main mechanisms for transport of P to water resources are illustrated in Figure 4.

Excessive levels of P in water often promote eutrophication and cause water quality problems. These problems limit water use for fisheries, recreation, industry, and drinking due to the increased growth of undesirable algae and aquatic weeds, and shortage of oxygen. Lake water P concentrations at around 0.05 ppm are considered critical; at values above this, eutrophication is accelerated.

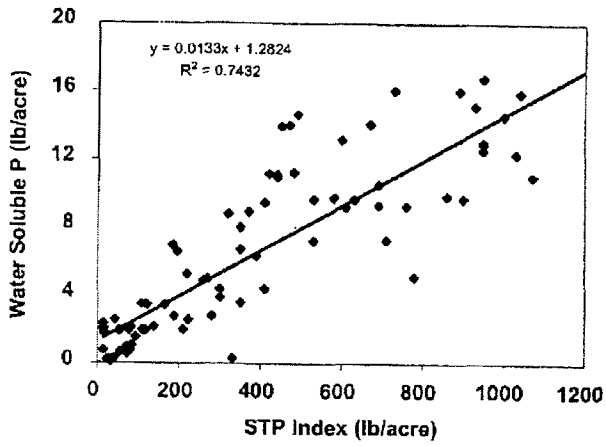

Figure 3. The relationship between soil test P index (Mehlich 3 extractable) and water soluble P.

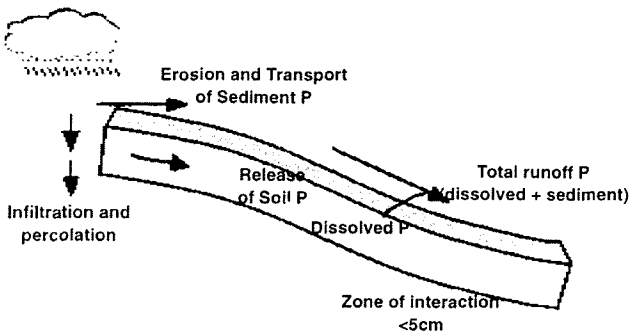

Figure 4. Mechanisms of phosphorus transport over landscape: erosion and runoff.

What Are the Options for Managing Manure P?

The main factors affecting P losses from manured fields include soil test P levels and the movement of P to surface water. Therefore, the most effective management practices for preventing P loss are managing P sources and reducing runoff and erosion.

A. Phosphorus Source Management

1. Reducing off-farm inputs of P in feed

Manipulation of dietary P intake by livestock has received a lot of attention lately. Enzyme additives, such as phytase, for animal feed may increase the availability of P from plant sources during digestion and therefore reduce the need for mineral P addition. Use of low-phytate grains in feeds would have a similar effect.

2. Soil P management

Many soils in Oklahoma are high in P. Once soil test P (STP) levels become excessive, further applications of P will increase the potential for P movement and do not provide any potential agronomic benefits. The Soil, Water and Forage Analytical Laboratory at Oklahoma State University uses the Mehlich 3 method to assess soil P availability. Research has shown that when STP reaches 65, it is 100 percent sufficient for all crops. Soil testing can help identify low P fields on your farm. Fertilization of soils susceptible to P loss or close to P- sensitive water bodies should be based on soil test recommendations (agronomic rates) when applying any source of P, to prevent P buildup in soils and to minimize P loss to surface water.

Accumulation of P in the surface soil (top one to two inches) occurs when manure is broadcast without incorporation on pasture or no-till fields. Testing has shown that STP from the zero to two-inch depth can be four times as high as that from two to six-inch samples. This may increase P loss in runoff because the near-surface horizon is the most reactive zone during a storm event. Subsurface placement of manure and periodic plowing of no till soils, if possible, would distribute surface P throughout the upper root zone, decrease exposure to surface runoff and increase crop uptake.

Forages with a high yield potential can be used to remove P from high P fields, but it is a slow process. Bermudagrass and certain warm-season annual grasses have the potential to produce large amounts of hay under Oklahoma conditions and thus remove relatively large quantities of P. Bermudagrass contains about 0.2 percent of P; thus, it can remove 20 lbs. of P (or 46 lbs. of P_2O_5) per year if five tons/acre is harvested. However, this would only reduce soil test P by about three. It will take about 30 years to reduce soil test P index by 100 units. P removal from high-P fields is more efficient if a combination of both warm- and cold-season forages is used.

3. Manure management

All manure has beneficial values in crop production. Manure analysis, combined with soil testing, is needed to determine the nutrient value and decide where and how much to apply. Manure should be applied where needed most, based on soil test results, not just to the fields nearest the barns. Preferably, the application rates are based on soil and crop P requirements instead of N needs. Additional N fertilizer should be used to meet crop N needs. If a manure market is available and economically viable, producers should consider selling manure to other farms where manure nutrients can be utilized. Manure buyers whose fields test below sufficiency in STP may consider applying two to three crop years' worth of manure-P at one time, based on soil test recommendations and N needs, to save on application costs or to take advantage of manure market considerations. Commercial N would be applied in the following seasons.

B. Phosphorus Transport Management

1. Control erosion and runoff

Phosphorus loss via erosion and runoff may be reduced by conservation tillage, buffer strips, riparian zones, terracing, contour tillage, and cover crops. Impoundments or small reservoirs can help capture or delay runoff and sediment from manured fields and feedlots.

- **Manage the soil for maximum water infiltration and storage:** maintain crop residues on the soil surface. On soils that are subject to erosion, use a winter cover crop to reduce erosion and take up nutrients.
- **Maintain vegetation on ditch banks and in drainage channels:** try not to disturb vegetation in drainage channels such as ditches and grassed waterways. Leave a buffer strip along drainage ways.
- **Slow water flow:** use contour tillage, diversions, terraces, sediment ponds, and other methods to slow and trap runoff.
- **Maintain buffer strips:** vegetated buffer strips have been shown effective in trapping nutrients in runoff. Leave buffer areas between farmland and environmentally sensitive areas. The amount of buffer needed varies with the farming activity and the nature of the adjacent area.
- **Do not apply manure on slopes with a grade of more than 15 percent or soils less than 10 inches deep;** do not apply manure on frozen or snow covered ground.

2. Fence animals away from streams, drains, and critical areas

Pastured large animals such as cattle, horses, and sheep randomly deposit manure, making nutrient management more difficult. Livestock should not be allowed free access to streams and ponds to prevent direct deposition of manure into water. Alternative water supplies should be provided by diverting or pumping water to livestock, or restricting the size of the access area. Feed, water, and lounge areas, where animals congregate, should be located so that runoff is filtered through vegetative buffer strips.

Conclusion

In general, animal manure contains more P than crops require if the application rate is based on N needs. Therefore, continuous manure application to meet crop N requirements will result in higher soil test P and water soluble P, and higher potential runoff P. Proper management of P sources and P transport over the landscape can reduce negative impacts of P on water quality.

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