Using Biosolids As a Source of Phosphorus

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Biosolids and other organic fertilizers, like manure, have significant amounts of phosphorus — a nutrient necessary for plant growth. This fact sheet will discuss the role biosolids can play in improving a soil deficient in phosphorus.

The role of phosphorus (P) in a plant is to store and transfer energy produced by photosynthesis for use in growth and reproductive processes. Adequate phosphorus levels encourage vigorous root and shoot growth and promote early maturity. These effects often increase water use efficiency and potential grain yield. Phosphorus deficiency stunts plant vegetative growth and grain development.

Phosphorus-deficient plants are stunted, have thin, short stems, purplish leaves, and delayed maturity. Deficiencies often occur in soils with finely-textured clay soils because P adheres to the clay particles and becomes unavailable for use by plants. Phosphorus deficiencies also occur in eroded or excavated soils because, when the topsoil is lost, P is often lost as well.

About 20–30% of Nebraska soils are deficient in phosphorus. Many cooperators in Lincoln's Biosolids Land Application Program are using biosolids primarily as a source of phosphorus for their P-deficient soil. One advantage to using biosolids (or manure) as a source of P, is that, unlike other P fertilizers, most of the P in biosolids is immediately available for use by plants.

Table 1. Phosphate removal for the crops grown in Southeast Nebraska

CROP	AMOUNT OF PHOSPHATE REMOVED
Corn	0.35 lb per bushel (grain)
Soybean	0.88 lb per bushel (grain)
Alfalfa	10 lb per ton (hay)
Sorghum	0.42 lb per bushel (grain)
Wheat	0.63 lb per bushel (grain)

Phosphorus is found in significant quantities in biosolids and manures because animals do not need high levels found in plants and the excess phosphorus is excreted. Phosphates are added to many laundry detergents to improve their cleaning ability in hard water — biosolids also contains phosphates from detergents.

Corn is often the first crop planted following an application of biosolids. Based on nitrogen (N) concentrations in Lincoln's Theresa Street biosolids, the agronomic N application rate for field corn is about 40 yd^3/acre (28 tons/acre). When 40 yd^3/acre is applied, there will be about 286 lb of elemental phosphorus applied per acre. This 286 lb of P is equivalent to about 644 lb of phosphate (P_2O_5) — the form of P fertilizer crop producers are most familiar with. Eventually, all the 644 lb of P_2O_5 will act just like P_2O_5 applied from commercial fertilizer, like 11-52-0.

About 90% of the 644 lb of P_2O_5 /acre will be immediately available for plant use — about 580 lb P_2O_5 / acre. In Lancaster County soils, 15 lb of P_2O_5/acre (from any source) will increase the Bray and Kurtz #1 P soil test about 1 ppm. This means a single application of biosolids at 40 yd^3/acre can raise the Bray and Kurtz #1 P soil test about 39 ppm. (580÷15 = 39)

From Table 1, you will see corn removes 0.35 lb phosphate per bushel. Therefore, a 150 bushel/acre yield will remove 52.5 lb. P_2O_5/acre. (0.35 lb P_2O_5/bu x 150 bu/acre = 52.5)

Soybeans will remove 0.88 lb. P_2O_5 per bushel. A 50 bushel crop will remove 44 lb. P_2O_5/acre. (0.88 lb P_2O_5/ bu x 50 bu/acre = 44)

Using these crop removal rates and a corn-soybean rotation, an average 48 lb. phosphate is removed/ year. Therefore, it will take about 12 years to get back to the same soil P level after just one application of biosolids (at 40 yd^3/acre). Calculation: 580 lb. P_2O_5/acre ÷ 48 lb. P_2O_5 removed/acre/year = 12 years.

As a source of immediately available phosphorus, there is nothing better than biosolids or manure. It is no surprise, given the cost of phosphate fertilizers, most farmers in the Biosolids Land Application Program are using biosolids primarily as a source of P.

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Even though phosphorus is essential for plant growth, amounts over about 25 ppm in the soil do not improve plant health or increase yields of field crops typically planted in southeastern Nebraska. Even though there is no yield response, there is also no scientific evidence high soil P levels (even up to 1,000 ppm Bray and Kurtz #1 soil P) causes any plant toxicity or reduces crop yield.

Environmental Concerns

There are two different aspects that cause environmental concern with excessive phosphorus loading of the soil. The first is when the soil becomes saturated with phosphorus (about 150 ppm Bray and Kurtz #1 soil P). At levels lower than about 150 ppm, P will adhere to soil particles and not move through the soil, but once the saturation level is reached, P can move down into the soil profile.

To make this easier to understand, UNL Researchers, Steve Comfort and Bahman Eghball, have explained this movement using the concept of a "tipping bucket approach." The tipping bucket approach assumes each soil layer in the profile can hold only so much P. Once the bucket (soil layer) is full (~150 ppm), adding additional P will spill (move or leach) to the next layer below. This type of leaching has been documented in long-term studies with manure (over 40 years) and under abandoned feedlots. In addition, phosphorus movement has been observed in a Nebraska sandy loam soil even when the 150 ppm P-saturation capacity of the soil was not reached. The good news is that vertical movement is fairly slow and is dependent on continual applications of phosphorus. The most logical way to prevent further downward movement is to simply stop applying high-P fertilizers.

There is also concern runoff or soil erosion after applications of biosolids or manure can contaminate nearby surface waters with nutrients. The problem is not direct toxicity to aquatic organisms from P, but, like its effect on crop plants, phosphorus stimulates aquatic weeds and growth of algae in streams and lakes — the "algae bloom" phenomenon. "Hypoxia" is a term being used to describe a zone of oxygen-depleted water at the Gulf of Mississippi that is substantially depleted of aquatic animals. The algae overproduction eventually sinks to the bottom and decays, consuming the available oxygen in the bottom waters reducing it to levels lower than most aquatic animals can survive. Environmental scientists are concerned about this situation and, while there probably are multiple causes for this phenomenon, there is some evidence runoff into the Mississippi River watershed is a major contributor to this problem.

The problem of nutrient loading in surface waters is one reason farmers who use biosolids must adhere to setback distances near surface waterways, like streams, ponds, and rivers. Farmers who use biosolids are encouraged to use soil conservation practices, including terraces, filter strips, and minimum tillage to prevent soil erosion. Studies conducted by Bahman Eghball, UNL, and John Gilley, USDA-ARS, have shown cultural practices like incorporating manure and planting grass hedges can be useful in preventing P losses in runoff of sloped fields.

Phosphorus Fertilizer Value of Biosolids

The following calculations were used to determine how much phosphate is found in dewatered biosolids from Lincoln's Theresa Street Wastewater Treatment Plant in 2010.

Laboratory analysis shows P concentrations were given in parts per million (ppm) or mg/kg, dry weight.

Average elemental P value = 29,917 mg/kg, dry weight.
Percent solids = 16.49%
Percent moisture = 83.51%
Weight of one yd^3 of biosolids = 1,450 lb. Conversion factor of .725 = 1,450/2,000

1. Converting elemental P from mg/kg to lb/ton: 29,917 x .002 = 59.8 lb elemental P/dry ton
2. Convertion to lb/wet ton: 59.8 lb/ton x .1649 = 9.9 lb elemental P/wet ton
3. Conversion to lb/yd^3: 9.9 lb/wet ton x .725 = 7.15 lb elemental P/$yard^3$ (This step isn't needed if rate is express tons.)
4. If the application rate is 40 yd^3/acre, then 7.15 lb/yd^3 x 40 yd^3= 286 lb. elemental P/acre.
5. Next, convert P to P_2O_5. The molecular weight of the P is 32. P_2 = 64. The molecular weight of O is 16. So the molecular weight of P_2O_5 is (32 x 2)+(16 x5) = 144.64÷144 = 0.444.

   To convert elemental P to P_2O_5, divide 286 lb. elemental P/acre by .444 = 644 lb. P_2O_5/acre.
6. About 90% of the P_2O_5 will be readily available for plant use (644 x .9), which is 580 lb. P_2O_5/acre.
7. Adding 15 lb. P_2O_5/acre to Lancaster County soils raises the Bray and Kurtz #1 P soil test about 1 ppm. In this example, the addition of 40 yd^3 biosolids would increase the soil test about 39 ppm. [580 lb. P_2O_5/acre ÷15 lb. P_2O_5/acre = 39 ppm]
8. And finally, corn removes 0.35 lb. of P_2O_5 per bushel. A 150 bushel/acre yield will remove 52.5 lb. of phosphate/acre.

   Soybeans remove 0.88 lb. P_2O_5 per bushel. A 50 bushel/acre yield will remove 44 lb. P_2O_5 per year.

Averaging these phosphate removal rates for a corn-bean rotation, results in removal of 48 lb. P_2O_5/acre/year. It will take approximately 12 years to get back to the original soil P level. Calculation: 580 lb. P_2O_5/acre ÷ 48 lb. removed/acre/year = 12 years.