Predicting Soil Phosphorus Sorption Capacity (PSC) for Manure and Biosolid Amended Soils of the Inner and Outer Bluegrass Regions in Kentucky

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Introduction

Increased phosphorus (P) saturation of agricultural soils is associated with P enrichment of water bodies (Sharpley et al., 1996). Soils in the Inner and Outer Bluegrass regions of Kentucky have a higher than average soil test P (STP), resulting in restricted P recommendations based on STP levels or seasonal plant uptake. However, manures are often land applied in these regions as a nitrogen source resulting in incidental P enrichment of these inherently high P soils.

Two soils from the Outer Bluegrass and two soils from the Inner Bluegrass, with STP levels ranging from 48 to 485 mg/kg, were selected as representative agricultural soils. These soils had no recent history of P amendment applications. The selected soils were amended with cattle manure, horse manure, or municipal biosolids for 108 days at 25ºC. Over the course of the incubation, soil phosphorus capacity was estimated by the soil phosphorus index (PSI) calculated from a single P adsorption isotherm followed by four sequential desorptions (Penn et al., 2005).

Objectives

- The aim of this study was to determine the effect of manure and biosolid amendment application on the sorption behavior of four soils with high STP.
- Determine the potential for P losses as a result of land application of animal manures or municipal biosolid wastes.

Methods

Basic Characterization:

- Soil samples were analyzed for pH, OM, and Mehlich 3 extractable P (soil test P), Fe and Al.
- Clay percent was determined by the pipette method.
- Mineralogy was determined using XRD and TGA (Karathanasis and Hajek, 1982).
- Water soluble P (WSP) was measured on a 1:25 ratio soil to deionized water sample shaken for two hours, centrifuged and filtered through a 0.45µ filter. Inorganic PO4-P in the filtrate was analyzed by the modified Malachite Green method (D'Angelo et al., 2001).

Incubation:

- Air dried, 2mm sieved, soil samples were pre-incubated at 25 ºC for 7 days at approximately 45% gravimetric water filled pore space.
- Nutrient composition of horse manure, cattle manure, and biosolid amendments was determined by LECO combustion and ICP. Dried and ground sample were added to the pre-incubated soils based on 150 lb N/acre recommendation.
- Centrifuge tubes were lightly packed with 7g soil +distilled water+amendment, and monitored every 3 days to maintain water content and ensure air exchange.
- Destructive sampling occurred on days 0, 3, 7, 14, 28, 58, and 108, and samples were oven dried at 65 ºC for analysis.

Adsorption/Desorption:

- Soil phosphorus sorption index (PSI) from the single point P sorption isotherm (Brock et al., 2007). The PSI involved mixing 34mL 0.01M $CaCl_2$, 6mL of 100mg P L^{-1} KH_2PO_4, and 0.4g of soil to 50mL centrifuge tubes. After shaking for 24hr. samples were centrifuged and filtered. The percent of P adsorbed by the soil was calculated as the difference between P added and P remaining in solution (Penn et al., 2005).
- Samples remaining from the single point adsorption isotherm were sequentially desorbed four times by adding 40mL of 0.01M $CaCl_2$. The amount of P desorbed was used to calculate the percent of P retained from the P adsorbed following the equation:

$$\frac{Adsorbed\ P\ after\ four\ desorptions}{P\ adsorbed\ from\ a\ single\ point\ isotherm} * 100 \quad [1]$$

- PSI was calculated from the single point adsorption isotherm as:

$$PSI = \frac{(P\ retained)(Solution\ Volume)}{Soil\ Weight} \quad [2]$$

Results

- X-ray diffraction and TGA analyses determined the dominate mineralogy to be HIV/V > K > MI > INT = Q

Table 1. Amendment sources and nutrient composition. Amendments were added to soils at a rate of 150 lbN/acre. The control was un-amended, with only deionized water added.

Amendment	Source	Moisture %	C %	N %	P %	K %
Biosolid	Paris KY WWS Treatment, anaerobically digested and pressed	84	35.7	5.9	1.8	0.5
Horse	University of Kentucky, Fayette County Main Chance Horse Unit	67	42.7	1.8	0.9	1.0
Beef	University of Kentucky, Woodford County Beef Unit	81	47.1	1.7	0.6	1.4

*Concentrations on dry wt basis

Table 2: General soil characteristics of dry soil samples prior to incubation.

Soil Series	WSP	STP	Meh3 Al+Fe	pH	Clay	OM	PSI
	----------mg/kg----------				---------%-------		mg/kg
Lowell	3.2	48.0	953	6.5	14.9	3.4	195
Sandview	31.7	485.0	1468	6.0	22.7	2.2	76
Bluegrass	8.4	135.0	1153	6.2	16.8	3.4	104
Maury	17.9	198.5	1063	6.0	15.7	4.3	204

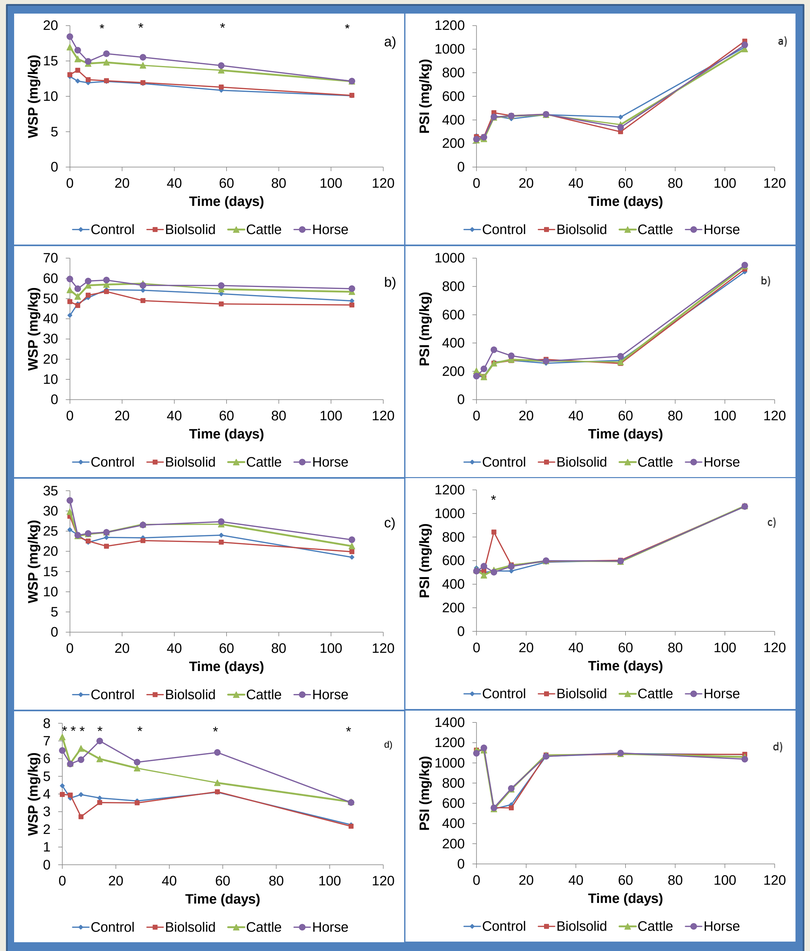

Figure 1. Changes in WSP (left) and PSI (right) over the course of the incubation, a) Bluegrass soil b)Sandview soil c) Maury soil d)Lowell soil. (Statistical significance between one or more treatments on a given sampling day indicated by, *, p<0.1.)

Discussion

- Initial soil analysis showed a positive linear relationship (r^2=0.96) between STP and WSP, suggesting that the Sandview and Maury soils would have the highest overall WSP measurements throughout the incubation experiment. In both the Sandview and Maury soils there was no significant difference between treatments . This suggests that the higher WSP values from day 0 for these soils is simply a result of the additional P added and that the water soluble fraction is quickly redistributed to other P fractions.
- The Bluegrass soil had a significant difference between the cattle and horse manure treatments and the biosolid and control for days 14, 28, 58, and 108 (Figure1). At day 7, both the manure amended soils showed a decrease in WSP that approached the control, likely the result of sorption transformations and possible microbial immobilization. The PSI at this time showed a slight decrease which suggests more P is being adsorbed. At day 14 there was an increase in WSP from the manure amendments, possibly due to transformations from other P forms in the manure.
- The Lowell soil which had the lowest STP level (Table 2) showed significant differences in at least one treatment from the control at every sampling event. The horse and cattle manure amended treatments were significantly higher at all sampling days except for day 58 for cattle manure. The PSI for the Lowell was similar across treatments with the only variance occurring at days 7 and 14, presumably the result of transformations between P fractions or forms.
- The Biosolid treatments, for all four soils showed no significant variation from the control, and at some occasions lower WSP than the control. Possible explanations could be the high levels of Fe (11621 ppm on a dry weight basis) that might encourage the immobilization of WSP fraction to Fe-phosphate forms.
- The PSI for all soils except the Lowell, had a significant increase from day 58 to day 108. While there was no evidence of treatment effects, this may suggest an increase in P adsorption as added P sources are immobilized or transformed to other P forms.

Conclusions

1. The amendment type had little effect on the PSI. Given enough time the adsorption will reach a maximum capacity regardless of P source.
2. The lower the initial STP the greater the likelihood that organic amendments will significantly increase the WSP pool.
3. P losses appear to be most likely in high STP soils during the first week of application.

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