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Leaching of Phosphorus Fractions Following Manure or Compost Application[#]

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ABSTRACT

Phosphorus (P) leaching in manure-amended soil can be influenced by the P fractions added when manure or composted manure is applied. This study was conducted to determine leaching of different P fractions following beef cattle feedlot manure or compost application. Manure and composted manure were applied to meet the nitrogen (N) or P needs of corn (*Zea mays* L.) for either a one or two-yr period. Fertilized plots and unfertilized control plots were also used. The P-based treatments also received additional N fertilizer. Soil P fractions were determined for various soil depth increments. After 4 years of manure and compost applications, leaching of plant-available P was observed to a soil depth of 30 cm. The differences among treatments for total and inorganic P were significant only at the 0 to 15 cm soil depth increment. Greater

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concentrations of total, available, and inorganic P fractions were observed for the N-based manure and compost treatments as these management strategies received more P than P-based. More than 70% of beef cattle manure or composted feedlot manure P was inorganic. Water-soluble P was a small fraction of total P in beef cattle feedlot manure or composted manure (<13%). Leaching of plant-available P following manure and compost applications can pollute the ground water if P comes in contact with ground water, especially in areas with shallow and/or fluctuating ground water and in areas with till drainage.

Key Words: Cattle manure; Eutrophication; N-based; P-based; P movement; Water quality.

INTRODUCTION

Phosphorus from long-term manure or fertilizer application or from heavy loading of manure, can leach into ground water in areas with shallow water tables or coarse-textured soils. Phosphorus leaching to a soil depth of 1.8m was observed with long-term (>50 yr) beef cattle feedlot manure application.^[1] They found leaching of P from chemical fertilizer to be shallower than similar loading of manure P ($\sim 84 \text{ kg P ha}^{-1} \text{ year}^{-1}$). It was hypothesized that manure contained P fractions that were not susceptible to adsorption by a calcium carbonate layer in this soil and would thus be more likely to leach deeper into the soil than fertilizer P. Land application of cattle feedlot manure resulted in increased soil levels of total, inorganic, organic, and available P, and decreased P sorption capacity to a depth of 0.3 m.^[2] Mozaffari and Sims^[3] found P movement to a depth of 0.4m in soils receiving poultry manure. Sims et al.^[4] reported an extensive review of P loss in agricultural drainage when manure or fertilizer was applied to different soils and found significant leaching of P following manure application. When P leaches through soil, it can eventually reach the ground water. In many cases, ground water emerges as surface water and thus can contribute to eutrophication if it contains sufficient P.

Manures from different animal species differ in their composition, which influences their environmental impacts. Chemical fractionation techniques have been used to identify the various forms of P in soils receiving wastewater,^[5] municipal sludge,^[6,7] cattle feedlot waste,^[2] and poultry litter.^[8] These P fractions can have different effects on the environment.

Applying manure or compost to meet corn N requirements can greatly increase soil P level as compared with P-based applications.^[9] This is because the N:P ratios of manure and composted manure are significantly

smaller than N:P uptake ratios of most crops. This unused P can be transported in runoff or leach further into the soil profile. Soil P fractions following manure and compost applications can have a significant effect on the amount of P leached or lost in runoff. The objective of this study was to fractionate P in manure, composted manure, and soil receiving annual or biennial applications of N or P-based manure and compost to assess P leaching.

MATERIALS AND METHODS

A field experiment was initiated in 1992 on a Sharpsburg silty clay loam soil (fine, smectitic, mesic Typic Argiudoll) under rainfed (dryland) conditions at the University of Nebraska Agricultural Research Center near Mead, NE. The Sharpsburg series consists of deep, moderately well drained soils formed in loess on uplands and high benches. Permeability is moderately slow in the upper part and moderate in the lower part. Selected soil characteristics are given in Table 1. Additional information regarding soil properties during four years of manure and compost applications is given in Eghball.^[10] The experimental design was a randomized complete block with four replications. The ten treatments included annual or biennial manure or compost applications based on N or P removal of corn (151 kg N ha⁻¹ and 25.8 kg P ha⁻¹ for an expected yield level of 9.4 Mg ha⁻¹)^[11] and fertilized and unfertilized checks. Fertilizer application was made in the spring each year. If necessary, the P-based treatments (annual or biennial application) also received N fertilizer as ammonium nitrate (34-0-0, N-P-K) in the spring so that a total of 151 kg N ha⁻¹ was available to the crop.

Beef cattle manure was collected from the feedlot pens in late spring each year and composted for about 4 months using active composting (with turning). Beef cattle feedlot manure (collected in the autumn) and

Table 1. Selected characteristics of the soil in 1996 following four years of manure, compost, and fertilizer applications (averaged across treatments) at Mead, NE.

Soil depth (cm)	Total C	Total N	pH	EC (d S m ⁻¹)	Bulk density (Mg m ⁻³)	Sand	Silt	Clay
	(g kg ⁻¹)					(%)		
0–15	22.3	2.0	6.3	0.32	1.26	8.3	66.9	24.8
15–30	18.7	1.6	6.3	0.23	1.39	8.0	68.8	23.1
30–60 [†]	–	–	6.7	0.24	1.38	9.0	67.9	23.1
60–90 [†]	–	–	6.5	0.37	1.47	7.4	57.7	34.9

[†]Total C and N were not determined.

Figure 1. Total P in dry beef cattle feedlot manure or composted manure as determined by the Nitric-Perchloric,^[13] Ignition,^[12] and X-ray^[14] methods. The dotted line is the 1:1 ratio.

composted feedlot manure were applied in the autumn of 1992 based on the assumption that 40, 20, 10, and 5% of the N and P in manure or compost would become plant-available in the first, second, third, and fourth yr after application, respectively, based on a modification of the decay series given in Gilbertson et al.^[11] The first yr N availability assumption from compost was found to be too high, therefore availability assumptions were changed to 20, 20, 10, 5% in the first, second, third and fourth yr for compost applications made in 1993, 1994, and 1995. The N availability assumptions used in 1992 (40, 20, 10, 5%) were used for manure in the other three years. Phosphorus availability assumptions from manure and compost were

Table 2. Composted and non-composted manure dry weights and P applications in four years at Mead, NE.

Treatment	Dry weight				Phosphorus				Total
	1992	1993	1994	1995	1992	1993	1994	1995	
	Mg ha ⁻¹				kg P ha ⁻¹				
Manure for N [†]	46.9	18.5	12.1	14.5	104	74	42	36	256
Manure for P	28.3	6.4	6.6	2.7	63	25	23	7	118
Manure for N/2 y	93.9	—	36.3	—	208	—	127	—	335
Manure for P/2 y	56.4	—	19.8	—	125	—	69	—	194
Compost for N	34.6	49.5	25.1	36.4	141	112	104	139	496
Compost for P	15.5	10.3	5.3	2.9	63	23	22	11	119
Compost for N/2 y	69.4	—	75.2	—	282	—	312	—	594
Compost for P/2 y	31.0	—	15.9	—	126	—	66	—	192
Fertilizer	—	—	—	—	26	26	26	26	104

[†]N and P indicate applications to meet N or P needs of corn, respectively. 2y indicates biennial application.

changed to 60, 20, 10, 10% in the first, second, third, and fourth yr for applications made in 1993, 1994, and 1995. Biennial manure or compost applications were made to provide 151 kg N ha⁻¹ for N-based and 25.8 kg P ha⁻¹ for P-based rates in the second yr after application based on the assumptions given above. Residual N and P values from previous years were considered when manure or compost was applied.

Manure or compost application was made in late autumn after corn harvest. Manure and compost were applied by hand to plots 12.2m long and 4.6m wide (6 corn rows). All plots were disked to a soil depth of 10cm in the autumn within one or two days after manure and compost applications and in the spring following fertilizer application. Continuous corn system was used from 1993 to 1996. The amounts of manure, compost, and P applied for each treatment are given in Table 2. Total P in manure and compost was determined using the Ignition method.^[12] When Ignition method was compared with the Nitric-Perchloric^[13] and X-ray^[14] methods, it resulted in similar total P as the Nitric-Perchloric, but less than that for X-ray method (Figure 1). X-ray method seems to overestimate total P in cattle feedlot manure or compost.

In 1996, soil samples to a depth of 1.2m were collected from all plots after corn harvest. The soil samples were divided into 0–15, 15–30, 30–60, 60–90, and 90–120cm increments and air-dried, crushed to pass a 1-mm sieve, and analyzed for plant-available P.^[15] The inorganic and total P fractions were determined on all soil samples, except the ones from the 90–120cm soil, using the Ignition method.^[12] The organic P fraction was the difference between total P and inorganic P. Water-soluble P in the depth fractions 0–15, 15–30, and 30–60cm soil was determined using the method described by Self-Davis and Moore.^[16] Total, organic, inorganic, and water-soluble P fractions were also determined on the air-dried and ground samples of manure and compost using similar methods as for the soil samples.

Analysis of variance was used to analyze the data using PROC MIXED of SAS.^[17] Depth increments were used as repeated measures in this analysis. A probability level ≤ 0.05 was considered significant.

RESULTS AND DISCUSSION

Phosphorus Fractions in Manure and Compost

Organic P was a small fraction of the total P in the applied manure and compost (Table 3). Averaged across four years, organic P accounted for 16% of total P in composted manure and 25% of total P in noncomposted

Table 3. Phosphorus fractions, EC and pH of beef cattle feedlot manure and composted feedlot manure applied in four years at Mead, NE.

Year and source	TP ⁱ		Water-soluble P		OP/TP		IP/TP		Soluble P/TP		EC [‡] d S m ⁻¹	pH
	TP ⁱ	OP	IP	g kg ⁻¹	OP/TP	IP/TP	%	Soluble P/TP	EC [‡]	pH		
<i>1992</i>												
Manure	2.220	0.480	1.740	0.246	22	78		11	4.6	7.3		
Compost	4.070	0.435	3.635	0.305	11	89		7	7.4	7.7		
<i>1993</i>												
Manure	3.972	0.763	3.209	0.482	19	81		12	5.2	8.8		
Compost	2.278	0.666	1.613	0.150	29	71		7	2.2	8.3		
<i>1994</i>												
Manure	3.493	1.419	2.074	0.168	41	59		5	5.4	8.2		
Compost	4.156	0.310	3.848	0.098	7	93		2	6.1	7.2		
<i>1995</i>												
Manure	2.489	0.442	2.048	0.100	18	82		4	3.8	7.3		
Compost	3.814	0.653	3.161	0.108	17	83		3	6.0	7.7		

ⁱTP is total P, OP is organic, and IP is inorganic P (all determined by the Ignition method, Olsen and Sommers^[12]).[‡]EC and pH were determined on 2:1 water to dry manure or compost ratio.

manure (Table 3). This indicated mineralization of manure organic P during composting process. Water-soluble P was a small fraction of total P in beef cattle feedlot manure or composted feedlot manure (<13%) (Table 3). Averaged across four years, water-soluble P accounted for 8% of total manure P and 5% of total compost P (Table 3). It seems that turning and mixing of manure during composting converted some of the soluble P to insoluble forms. Inorganic P was the largest fraction of manure and compost P (>75% of total P). Sharpley and Moyer^[18] also reported high inorganic P (>63% of total P) in composted and non-composted dairy manure, composted or non-composted poultry manure, and swine slurry. They concluded that dissolved inorganic P could be used to estimate the potential for land-applied manure or compost to enrich leachate and surface runoff P. The inorganic P is high in manure since the diet of these livestock species usually contains inorganic P.

Total, Inorganic, and Organic Phosphorus in Soil

There were significant treatments by soil depth interactions ($P < 0.0001$) for total and inorganic P in the soil. Manure and compost applications significantly increased total and inorganic P in the surface (0–15 cm) soil as compared with chemical fertilizer or no treatment check (Table 4). Annual or biennial N-based manure or compost application resulted in greater total and inorganic P in the 0 to 15cm soil than the check, chemical fertilizer, and annual P-based treatments (Table 4).

The differences observed among treatments for organic P in soil were not significant in all soil depths increments (Table 4). While there were sharp decreases for total and inorganic P with soil depth, organic P concentration was relatively constant for the top 60cm soil indicating high organic P content in this Mollisol. The small amount of organic P applied with manure or compost did not significantly increase soil organic P level as compared with the check or chemical fertilizer treatments (Table 4). Sharpley et al.^[2] reported increased total, inorganic, and organic P to 30cm soil depth following cattle manure application at application rates much higher than those of the N and P-based rates used in this study.

Plant-Available and Water-Soluble Phosphorus in Soil

There was significant treatment by soil depth interactions ($P < 0.0001$) for plant-available and water-soluble P in the soil. Leaching of plant-available P (Bray and Kurtz No. 1) was observed to the 15–30cm soil depth increment (Figure 2) following 4 yr of N-based manure [MN (manure application for corn N needs) and MN2Y (manure for corn N needs for 2 yr)]

Table 4. Soil depth by treatment interaction means for total, inorganic, and organic P fractions in 1996 following four years of manure, compost, and fertilizer applications at Mead, NE.

Treatment	Total P				Inorganic P				Organic P			
	0–15 [†]	15–30	30–60	60–90	0–15	15–30	30–60	60–90	0–15	15–30	30–60	60–90
	mg kg ⁻¹											
Manure for N [‡]	636 bc [#]	417 a	351 a	339 a	384 bc	160 a	107 a	179 a	273 a	258 a	244 a	160 a
Manure for P	479 ef	412 a	352 a	316 a	257 d	173 a	93 a	171 a	223 a	239 a	259 a	145 a
Manure for N/2 y	635 bcd	396 a	350 a	340 a	379 bc	173 a	122 a	199 a	257 a	223 a	227 a	141 a
Manure for P/2 y	575 cde	413 a	330 a	303 a	317 cd	148 a	77 a	169 a	258 a	265 a	253 a	134 a
Compost for N	700 b	423 a	327 a	316 a	453 b	207 a	115 a	188 a	246 a	216 a	213 a	128 a
Compost for P	511 ef	406 a	317 a	328 a	284 d	171 a	99 a	204 a	227 a	234 a	219 a	123 a
Compost for N/2 y	930 a	440 a	340 a	349 a	672 a	193 a	96 a	202 a	258 a	249 a	244 a	147 a
Compost for P/2 y	534 def	405 a	308 a	310 a	280 d	136 a	101 a	213 a	253 a	269 a	207 a	97 a
Fertilizer	488 ef	415 a	307 a	314 a	262 d	152 a	80 a	192 a	226 a	263 a	226 a	121 a
Check	455 f	406 a	312 a	320 a	230 d	169 a	91 a	204 a	225 a	237 a	222 a	117 a

[†]Soil depth increments in cm.[‡]N and P indicate applications to meet N or P needs of corn, respectively. 2y indicates biennial application.[#]Within each column, the values with different letters are significantly different at the 0.05 probability level based on LSD values.

Figure 2. Plant-available P in the soil in 1996 following four years of N and P-based manure and compost applications. The horizontal bars are standard errors, CN is compost for N, CP is compost for P, MN is manure for N, MP is manure for P, FR is inorganic fertilizer, CK is check, and 2Y is biennial application.

and compost [CN (compost application for corn N needs) and CN2Y (compost for corn N needs for 2 yr)] applications as compared with the fertilized plots or the check. The surface (0–15 cm) soil P level was the highest for the CN and CN2Y treatments, which also received the highest P application rates (Table 2). The annual P-based manure and compost treatments [MP (manure for corn P needs) and CP (compost for corn P needs)] resulted in similar soil P levels to that for the fertilizer application at all soil depth increments.

Water-soluble P was significantly different among treatments in the 0 to 15cm soil depth increment (Figure 3) with the N-based treatments resulting in a greater water-soluble P than the plots receiving chemical

Figure 3. Water-soluble P in the soil in 1996 following four years of N and P-based manure and compost applications. The horizontal bars are standard errors, CN is compost for N, CP is compost for P, MN is manure for N, MP is manure for P, FR is inorganic fertilizer, CK is check, and 2Y is biennial application.

fertilizer. The differences in water-soluble P among treatments were not significant in the 15 to 30 and 30 to 60cm soil depth increments. Water-soluble P remained in the surface layer of soil while plant-available P moved to the 15 to 30cm soil increment.

CONCLUSIONS

More than 70% of the P in beef cattle feedlot manure or composted manure was inorganic. The soil organic P concentration was relatively constant in the top 60cm soil reflecting the organic matter distribution in

this Mollisol. Phosphorus-based manure and compost applications resulted in much less soil build up of P fractions in the soil than N-based. Plant-available P leached to a soil depth of 30cm following N-based manure or compost application. Phosphorus leaching should be considered when manure or compost is applied to areas with shallow ground water, fluctuating ground water that moves close to the soil surface, and areas with till drainage. In most cases ground water eventually emerges as surface water and if it contains sufficient P can cause eutrophication. Sandy soils are especially prone to P leaching as these soils typically contain less adsorption sites than heavier soils.

REFERENCES

1. Eghball, B.; Binford, G.D.; Baltensperger, D.D. Phosphorus movement and adsorption in a soil receiving long-term manure and fertilizer application. *J. Environ. Qual.* **1996**, *25*, 1339–1343.
2. Sharpley, A.N.; Smith, S.J.; Stewart, B.A.; Mathers, A.C. Forms of phosphorus in soil receiving cattle feedlot waste. *J. Environ. Qual.* **1984**, *13*, 211–215.
3. Mozaffari, M.; Sims, J.T. Phosphorus availability and sorption in an Atlantic coastal plain watershed dominated by animal based agriculture. *Soil Sci.* **1994**, *157*, 97–107.
4. Sims, J.T.; Simard, R.R.; Joern, B.C. Phosphorus loss in agricultural drainage: historical perspective and current research. *J. Environ. Qual.* **1998**, *27*, 277–293.
5. Cooke, J.G.; Stub, L.; Mora, N. Fractionation of phosphorus in sediments of a wetland after a decade of receiving sewage effluent. *J. Environ. Qual.* **1992**, *21*, 726–732.
6. Chang, A.C.; Page, A.L.; Sutherland, F.H.; Grgurevic, E. Fractionation of phosphorus in sludge affected soils. *J. Environ. Qual.* **1983**, *12*, 286–290.
7. Sui, Y.; Thompson, M.L.; Shang, C. Fractionation of phosphorus in a Mollisol amended with biosolids. *Soil Sci. Soc. Am. J.* **1999**, *63*, 1174–1180.
8. Mozaffari, M.; Sims, J.T. Phosphorus transformation in poultry litter-amended soils of Atlantic coastal plain. *J. Environ. Qual.* **1996**, *25*, 1357–1365.
9. Eghball, B.; Power, J.F. Phosphorus and nitrogen-based manure and compost application: corn production and soil phosphorus. *Soil Sci. Soc. Am. J.* **1999**, *63*, 895–901.

10. Eghball, B. Soil properties as influenced by phosphorus- and nitrogen-based manure and compost applications. *Agron. J.* **2002**, *94*, 128–135.
11. Gilbertson, C.B.; Norstadt, F.A.; Mathers, A.C.; Holt, R.F.; Shuyler, L.R.; Barnett, A.P.; McCalla, T.M.; Onstad, C.A.; Young, R.A.; Christensen, L.A.; Van Dyne, D.L. *Animal Waste Utilization on Cropland and Pastureland: A Manual for Evaluating Agronomic and Environmental Effects*, USDA Utilization Res. Rep. No. 6; US Governmental Printing Office: Washington, DC, 1979.
12. Olsen, S.R.; Sommers, L.E. Phosphorus. In *Methods of Soil Analysis, Part 2*, 2nd Ed.; Page, A.L., Miller, R.H., Keeney, D.R., Eds.; Agronomy, ASA and SSSA: Madison, WI, 1982; Vol. 9, 403–430.
13. Johnson, C.M.; Ulrich, A. *Analytical Methods for Use in Plant Analysis*; Bulletin, University of California, Agricultural Experiment Station: Berkeley, CA, 1959; Vol. 766, 26–78.
14. Knudsen, D.R.; Clark, R.B.; Dening, J.L.; Pier, P.A. Plant analysis of trace elements by x-ray. *J. Plant Nutr.* **1981**, *3*, 61–75.
15. Bray, R.H.; Kurtz, L.T. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.* **1945**, *59*, 39–45.
16. Self-Davis, M.L.; Moore, P.A., Jr. Determining water-soluble phosphorus in animal manure. In *Methods of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters*; Pierzynski, G.M., Ed.; Southern Cooperative Series Bulletin, 2000; North Carolina State University: Raleigh, North Carolina; Vol. 396, 74–76. A publication of SERA17, Online: http://www.soil.ncsu.edu/sera17/publications/sera17-2/p_methods2000.pdf.
17. Littell, R.C.; Milliken, G.A.; Stroup, W.W.; Wolfinger, R.D. *SAS System for Mixed Models*; SAS Institute, Inc.: Cary, NC, 1996.
18. Sharpley, A.N.; Moyer, B. Phosphorus forms in manure and compost and their release during simulated rainfall. *J. Environ. Qual.* **2000**, *29*, 1462–1469.