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Phosphate distribution in animal waste slurries

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SUMMARY

Results obtained previously on distribution and behaviour of phosphate between organic and inorganic forms in pig slurries are extended to slurries from wastes of hens, cows and calves. Organic P in the slurries varied from about 1 to 15% of total P, with slurries from veal calves having the lowest content of organic P. In all slurries roughly half of organic P in solution had a high molecular weight (50000 and higher) and is therefore potentially mobile in soils.

INTRODUCTION

Phosphate in animal waste slurries is present in both inorganic and organic compounds. The nature of these compounds in pig slurries and their role in the phosphorus cycle in slurry and in soil on which slurry is spread has been explained in previous papers (Gerritse, 1978, 1981). Here data on the distribution of phosphate between organic and inorganic forms are given for slurries from wastes of laying hens, pigs, dairy cows and veal calves.

MATERIALS AND METHODS

For each animal species slurries were sampled from slurry tanks or pits of two representative large battery units. In addition, samples of slurries of cows (twice) and pigs (once) were taken from anaerobic digestion plants. The samples (5 l) were taken after thoroughly mixing the slurry in the tank by pumping it round at high speed. Inorganic P in the slurries was determined after diluting with HCl to a dry-matter content of about 1% and a molarity of 1·5 M for added HCl in a final volume of 50 ml (Salomons & Gerritse, 1981). This corresponded to a 5–40 ml sample of the original slurry. The well-mixed slurry was sampled fourfold. Variability between samples was less than 5%. Total P was determined as orthophosphate after destruction with a mixture of concentrated HNO_3 and H_2SO_4 (1:1 by volume). Orthophosphate was determined colorimetrically as the phosphomolybdate complex after reduction with ascorbic acid (Murphy & Riley, 1962). Organic P was taken as the difference between total and inorganic P. Solution phases of the slurries were obtained after centrifuging at 40000 *g* for 1 h. Gel permeation of the slurry solution through Sephadex G-100 (Pharmacia) was used to separate high-molecular-weight organic phosphate (MW 50000) from lower molecular weight organic and inorganic phosphate (Gerritse, 1978); 0·01 M-KCl was used as eluant in order to prevent charge exclusion (Gerritse, 1978). Organic P in the eluate within a partition coefficient range on the gel column of 0–0·3 was termed high-molecular-weight P (HMW). Dry matter was determined after drying at 105 °C for 18 h. Organic matter was determined after subsequent ashing at 600 °C for 3–4 h, without correcting for the presence of carbonate. Total N was determined by the Kjeldahl method and ammonia-N was determined after addition of MgO and steam distillation, both after appropriate dilution of the samples. Chloride was determined potentiometrically (after dilution), titrating with $AgNO_3$.

RESULTS AND DISCUSSION

Table 1 gives some chemical characteristics of the slurries. Organic-matter content of the slurries from veal calves was too low for a proper determination.

Table 2 gives the concentrations of soluble organic and inorganic P in the slurries, obtained by analysing the eluate fractions from the gel-permeated slurry solutions for total and inorganic P. Data in brackets are for the analysis of the slurry solution after centrifuging but before gel permeation. Fractions obtained after gel permeation contain either mainly organic P or inorganic P. This

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Table 1. *Characteristics of the slurries*

Slurry from	Dry matter (%)	Organic matter (%)*	NH_4-N (%)*	Organic N (%)*	NH_4-N (% of total N)	pH	Cl^- (mg/l)
Hens							
1	10·4	72·6	7·0	2·0	78	6·9	1470
2	13·2	67·4	5·7	1·6	78	6·8	1630
Pigs							
1	10·8	68·9	4·8	2·4	67	7·2	1700
2	5·3	65·7	7·4	2·3	76	7·2	1270
3†	5·6	58·7	9·8	2·8	78	7·8	1620
Cows							
1	9·7	71·5	3·3	2·1	61	7·5	1970
2	9·2	68·6	3·6	1·6	70	7·7	2850
3†	8·2	69·9	4·2	2·6	62	7·7	2170
4†	7·3	66·5	4·9	2·3	68	7·8	3380
Calves							
1	1·0	—	9·6	2·4	80	7·8	1270
2	0·9	—	14·9	1·6	90	8·1	2030

* Of oven-dry matter. † After anaerobic digestion.

Table 2. *Composition of the solution phase of the slurries (mg P/l)*

Slurry from	Total inorganic P		Total organic P		P_{HMW}
Hens					
1	39	(34)	15	(10)	5
2	5	(17)	18	(13)	10
Pigs					
1	237	(240)	22	(20)	13
2	38	(38)	20	(10)	8
3*	330	(310)	6	(10)	3
Cows					
1	1	(12)	38	(22)	15
2	10	(11)	44	(32)	22
3*	2	(8)	45	(23)	16
4*	10	(6)	36	(32)	25
Calves					
1	28	(26)	5	(1)	1
2	198	(187)	5	(3)	2·5

* After anaerobic digestion.

Data in parentheses were determined directly in the slurry solution; other data were determined after gel permeation of the slurry solutions.

P_{HMW} = organic P in the high-molecular weight fraction of the slurry solution.

improves both accuracy and precision of the P analysis. Also the easier destruction of the gel permeate fractions and absence of turbidity when analysing for inorganic P improves accuracy.

Table 3 gives the total organic and inorganic P, and soluble inorganic, organic and high-molecular-weight (HMW) organic P in the slurries, as a percentage of oven-dry matter. Organic P in the various animal waste slurries ranged from less than 0·1 to 0·3 % (Table 3) of dry matter, or from about 1 to 15 % of the total P. The concentration of dissolved organic P varied from a low of 5 mg P/l in veal calf slurry to a high of 50 mg P/l in cow slurry (Table 2). About 50 % of the dissolved organic P was of high molecular weight (Table 3). In previous research (Gerritse, 1981), only this HMW-P was

Table 3. *Phosphate distribution in animal waste slurries* (% *of oven-dry matter*)

Slurry	Total inorganic P	Total organic P	Inorganic P in solution	Organic P in solution	P_{HMW} in solution
Hens					
1	2·6	0·2	0·03	0·01	0·005
2	2·4	< 0·1	0·01	0·01	0·006
Pigs					
1	2·2	0·3	0·2	0·02	0·01
2	2·1	0·1	0·07	0·035	0·015
3*	3·2	0·15	0·55	0·01	0·005
Cows					
1	1·2	0·1	0·01	0·035	0·015
2	0·8	0·1	0·01	0·04	0·02
3*	0·9	0·15	0·01	0·05	0·015
4*	0·6	0·1	0·01	0·045	0·03
Calves					
1	4·5	< 0·1	0·27	0·05	0·01
2	3·0	< 0·1	2·1	0·055	0·03

* After anaerobic digestion.
P_{HMW} = organic P in the high-molecular-weight fraction of the slurry solution.

found to be potentially mobile in soils. On this basis, and considering the results in Table 3, it can be said that of the order of 0·2 to 2% of total P in animal waste slurries is potentially mobile in soils. The concentration of dissolved organic P in animal waste slurries is unaffected by storage time (Gerritse, 1981). The concentration of total organic P in slurries, expressed as a percentage of oven-dry matter, also remains fairly constant with time (Gerritse, 1981). Fresh slurries, however, may have very high concentrations of organic P, decreasing to a more or less constant concentration within a few weeks (Gerritse, 1978, 1981). The variation in total and dissolved inorganic P in the slurries is much larger than in organic P (Table 3). This reflects the mineral composition of the feeds and thus of the slurries (Gerritse & Zugec, 1977). The concentrations of Ca and Mg in solution, and pH, will strongly affect the concentration of dissolved inorganic P (Gerritse & Eksteen, 1978).

The small number of samples makes it difficult to generalize the results of this work and draw definite conclusions on differences in amounts of organic P that may be leached from various slurries in soils after spreading. However, comparing these results with previous ones (Gerritse, 1978, 1981; Gerritse & Zugec, 1977; Gerritse & Eksteen, 1978), and taking into account the care spent on selection and sampling of the slurries, they may indicate a more general pattern.

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