Variability in the nutrient, metal, and minor element composition of hog manure over the pump-out cycle of several manure stores in Manitoba

D.F. Malley[1] and P.D. Martin[2]

[1]PDK Projects, Inc., 365 Wildwood Park, Winnipeg MB R3T 0E7; Tel: 204-284-8047; Fax: 204-475-6090; Email: dmalley@pdkprojects.com; Web site: www.pdkprojects.com

[2]PDK Projects, Inc. #2 - 12 McGillivray Place, Winnipeg, MB R3T 1N4; Tel: 204-452-7842; Fax: 204-452-7883; Email: pdmartin@pdkprojects.com

ABSTRACT

This study showed that manure sampled from three types of manure stores from 13 hog operations was inherently variable for a number of constituents, including ammonium-N, and dissolved P. Organic nutrients, N and P, bound to particles were most variable because of the high variability of particulate content from sample to sample. Due to variable particulate content, particulate P varied 230-fold over pump-out and total P varied 20-fold. Because of variable particulate content, the N:P ratio in manure can vary widely during pump-out, and therefore significantly affect the application of manure as a fertilizer.

INTRODUCTION

Hog manure is recognized as a valuable source of plant-available N. Nevertheless, it is highly variable in composition within a manure store. This makes it difficult to apply nutrients to land at desired loadings.

Few data exist on the variability in composition of the manure during pump-out of manure stores for application to land. This presentation describes variability in nutrients, metals, and minor elements among manure stores and during actual land application.

METHODS

Sampling

For a study of the feasibility of analyzing hog manure rapidly with near-infrared spectroscopy, 121 manure samples were collected from 13 hog operations in the vicinity of Winnipeg MB between 28 September and 4 November 2000. All but two of the 13 operations held the manure in earthen stores, one in a slurry store and a secondary lagoon, and one in above ground storage. Six of the operations were visited once, and seven were visited from two to seven times during pump-out from agitated lagoons. Several of these were visited at the start and finish of pump-out, as well as periodically in between. At most sites, a grab sample was taken from the drop-out valve on the umbilicus during actual field application. The manure was divided into four 1-L subsamples immediately.

Chemical Analysis

Samples were analyzed by the Freshwater Institute Analytical Laboratory for pH, conductivity, density, ammonium-nitrogen (NH_4-N), total dissolved nitrogen (TDN), particulate nitrogen, dissolved phosphorus (dissolved P), particulate P, and particulate carbon (particulate C, i.e., a measure of the particular organic matter). Eighty of the 121 samples of manure were analyzed for 31 metals and minor elements by inductively coupled plasma spectrometry, and for % moisture by Norwest Labs. Some or all of the values for Ag, As, Bi, Pb, Sb, Se, Sn, Ti and V were below the limits of detection for the method. These are not considered further.

Table 1. Average chemical composition of the 121 hog manure samples analyzed in this study

Constituent	Range	Median	CV	Constituent	Range	Median	CV
CHEMICAL				HEAVY METALS			
Moisture, %	88.5 - 99.7	98.8	2.9	Aluminum,µg/L	1.20 - 199.0	19.1	116.9
pH	6.6 - 8.1	7.7	4.7	Cadmium, µg/L	0.01 - 0.27	0.03	121.7
Conductivity, mS/cm	6.8 - 27.2	15.3	31.3	Cobalt, µg/L	0.05 - 0.43	0.08	75.1
Density, g/mL	1.002 - 1.049	1.002	1.0	Chromium, µg/L	0.01 - 2.10	0.11	156.0
NUTRIENTS				Copper, µg/L	0.65 - 175.5	10.91	165.7
Ammonium-N,g/L	0.56 - 5.54	1.95	51.0	Iron, µg/L	4.2 - 513.6	46.5	121.3
Suspended N, g/L	0.014 - 4.08	0.31	132.7	Magnesium, µg/L	10 - 38745	152	146.3
Total N, g/L	0.6 - 10.1	2.5	62.9	Manganese, µg/L	0.22 - 118.0	6.2	160.3
Total dissolved P, g/L	.0.6 - 3.86	0.38	123.3	Molybenum, µg/L	0.01 - 1.23	0.17	113.0
Suspended P, g/L	0.003 - 2.650	0.125	150.9	Nickel, µg/L	0.09 - 3.19	0.36	124.9
Total P, g/L	0.055 - 6.512	0.579	132.0	Tin, µg/L	0.21 - 1.36	0.42	63.3
Suspended C, g/L	0.09 - 54.60	2.4	164.0	Strontium, µg/L	0.16 - 11.56	0.89	136.9
Potassium, g/L	0.0007 - 2.8	0.001	36.8	Vanadium, µg/L	0.03 - 2.91	0.5	108.8
Sulfur, µg/L	15 - 235	77.5	61.6	Zinc, µg/L	2.3 - 590.3	27.9	171.5
MINOR ELEMENTS				Zirconium, µg/L	0.01 - 0.36	0.05	96.4
Boron, µg/L	2.85 - 15.43	6.4	35.2				
Barium, µg/L	0.20 - 6.92	0.63	118.3				
Beryllium, µg/L	0.01 - 0.0	0.02	69.5				
Calcium, µg/L	60 - 5370	307	147.5				
Lithium, µg/L	0.04 - 0.33	0.11	53.7				
Sodium, µg/L	221 - 573	394	20.0				
Silicon, µg/L	33 - 442	120	63.5				

The coefficient of variability (CV) is the (SD/mean)*100. It is a measure useful for comparing the variability of concentrations from one constituent to another. The larger the C.V., the greater the variability for these samples. To convert g/L to lbs/1000 gal: 1 g/L = 8.345925 lbs/1000 gal

RESULTS

Composition

- Hog manure is a complex mixture
- Manure was 88.5 to 99.7 % water
- Nutrients were present in solution and as particles
- Nitrogen was mostly dissolved and present as ammonium-N (Table 1)
- Phosphorus (P) was both dissolved and particulate (Table 1)
- Sodium, calcium, magnesium, silicon, and sulfur were the most concentrated of the minor elements (Table 1)
- Iron, zinc, aluminum, and copper were the most concentrated metals (Table 1)
- Non-essential, potentially-toxic metals, cadmium and lead were present in low concentrations (Table 1)

Variability over Operations

- Ammonium-N varied from 0.6 - 5.5 g/L and total N from 0.6 - 10.1 g/L in the samples in this study (Table 1)
- The particulate content was highly variable among samples from a manure store and from one store to another. Particles contain N and P and other constituents.
- This results in high variability in particulate (organic) P and N and, therefore, in total N and total P (Table 1)
- Variable particulate content contributed to the highly variable N:P ratio among samples (Fig. 1)
- Potassium varied less than ammonium-N (Table 1)
- Other variable constituents were chromium, copper, manganese, and magnesium, with zinc being the most variable constituent (Table 1)

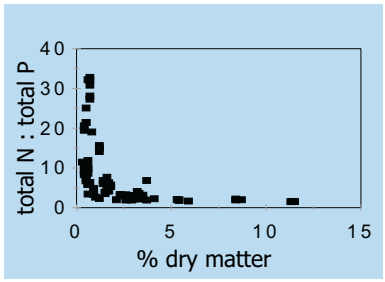

Fig. 1. In this sample set, the N:P ratio was highly variable, ranging from 1.5 to 4 for manure with sustantial particulate, up to 33 for manure containing little particulates. Thus, manures having a high particulate content (high % dry matter), had N:P well below agronomically desirable values

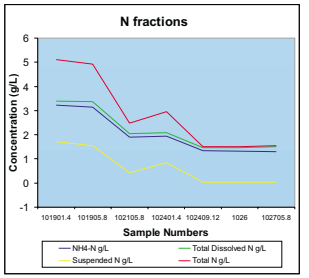

Fig. 2. Changes in concentrations of fractions of N during the 8-day pump out of an agitated two-celled earthen manure store (1 g/L = 8.345925 lbs/1000 gal)

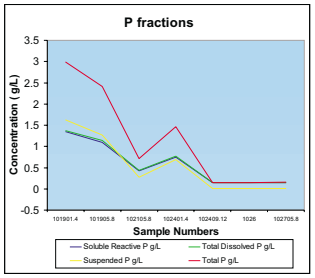

Fig. 3. Changes in concentrations of fractions of P during the 8-day pump out of an agitated two-celled earthen manure store (1 g/L = 8.345925 lbs/1000 gal)

Variability over Pump-out of a Two-cell Earthen Store

- Concentrations in manure followed over the 8 days of pump out of an agitated lagoon:
  - Ammonium-N varied over 2.4-fold during pump-out, particulate N varied 38-fold, and total N ranged over 3.5-fold.
  - Most extreme was the variation in P during pump-out. Dissolved P varied 9.5-fold; particulate P, 230-fold; and total P varied 20-fold
  - Potassium varied little
  - Most variable of the minor elements and metals were Al, Ba, Ca, Cr, Cu, Fe, Mg, Mn, Sr, and Zn

DISCUSSION

The data presented on the variability of manure composition during pump-out are for one of the 13 manure stores in this study and may not necessarily represent the extreme values for that case. Other stores were visited less frequently and, in most, manure composition was less variable during pump-out than the case shown. These results show that frequent sampling during pump-out cycles of representative manure stores is needed to better evaluate how variable the composition is in general.

The practice of measuring ammonium-N by gas bottle at the start of land application may over or under estimate the amount of this nutrient by several fold. Potassium was least variable of the macronutrients and may be adequately measured by a point-in-time sampling of the manure store before pump-out. The most important variability is that for P where these results suggest that dissolved and total P may vary over an order of magnitude and particulate P over two orders of magnitude.

CONCLUSIONS

These results indicate that a number of constituents, most importantly N and P, can vary considerably over the pump-out of a manure store, even when it is agitated. Current measurement practices do not adequately describe this variability.

These conclusions have implications for meeting regulatory requirements for the management of P as they become established by jurisdictions. They also have implications for the uniformity of nutrient loading to the land base to meet crop requirements for N andP.

There is increasing need for the capability of continuous monitoring of the composition of hog manure during the land application. This, combined with GPS/GIS mapping, could allow for variable rate application of manure and monitoring of the actual loadings of nutrients, metals, and minor elements to fields. Manure could be applied to land to meet the requirements for N or P. The N:P ratio could be brought into the desirable range for the crop by a second pass with inorganic fertilizer or by amending the manure with inorganic fertilizer in a patented process[1].

[1] (Guyot: US 5,907,925; CA 2,192,898; EP 0846408 A1)

ACKNOWLEDGMENTS

This study was funded by 1) Western Economic Diversification and the Canadian Climate Change Action Fund (Technology Early Action Measures, TEAM) through the Western Canadian Hog Manure Management Strategic Initiative of CETAC-West, and by 2). the Manitoba Livestock Manure Management Initiative Inc. Assistance with sampling was provided by Ecolagra Inc. and Ag Waste Management Corp.