Leaching losses of nutrients from farmyard manure pits in Central India

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Abstract
Nutrients in cattle manure and other inputs, components of farmyard manure (FYM), are important for sustained crop production in India, but little quantitative data exists on nutrient fluxes. Mass balance studies were conducted on a representative FYM pit in Geelakhedi village, Madhya Pradesh, India to determine the inputs and outputs of N, P and K. Cattle dung was the main component of FYM (67%) followed by cattle shed wastes (20%); household wastes, ash and vegetable wastes were minor components. A total of 3.70 t of FYM was produced from the 5.76 t of materials that were put into the pit. Importantly, 39% of the N, 20% of the P, and 32% of the K inputs were lost during the preparation of FYM by conventional methods. Ion exchange resin core studies showed that at least 20% of the N, 30% of the P and 50% of the K were lost through leaching, but failed to quantify this loss accurately. Further studies are needed to quantify the fluxes of other nutrients and to establish losses through other mechanisms (e.g. volatilization, runoff).

Key Words
Farmyard manure, nutrient mass balance, nutrients loss, leaching, ion exchange resin

Introduction
In India and in many other countries, farmyard manure (FYM) incorporation into soil as a source of nutrients and organic matter is an integral part of traditional crop production. Farmers produce the FYM by putting materials such as cattle dung, cattle shed wastes, kitchen wastes, ash, and house sweepings into the pit on a daily basis. This occurs both during the monsoon season and thereafter. These manure pits which are 1-1.5 m deep are exposed to rains as they are not covered. The quality of FYM produced is poor, containing only 0.5-1.0%N, 0.2-0.3%P and 0.5-1.0%K (Reddy *et al*., 2005). The leaching loss of nutrients, particularly N, not only reduces the quality of FYM but also causes pollution in nearby wells and waterways. The NO_3^--N concentration of village well-water is higher than that of wells located in agricultural fields, often exceeding WHO standards. The higher concentration of NO_3^--N in village well waters has been attributed to leaching from manure pits into nearby wells (Singh and Sekhon, 1977; Singh and Reddy, 2003; Biswas, 2008). While much research on nutrient balances has been done in developed countries (Sommer and Boller, 2000; Hao *et al*., 2001), there is little data on the mass balance of nutrient inputs and outputs of FYM production or on leaching losses of nutrients from manure pits. This study, therefore, focussed on the mass balance of nutrients and leaching losses of major nutrients from a representative, traditional FYM pit in Geelakhedi village, Rajgarh district, Madhya Pradesh, Central India. This followed group discussions with farmers which revealed that there are five main materials added to FYM pits, viz., cattle dung, cattle shed waste and straw, vegetable waste, ash and household wastes.

Methods
Nutrient inputs and outputs
A FYM pit, about 1.5 m deep, of Mr. Hukum Singh was selected for simple mass balance studies because he is representative of those in the village, owning two buffaloes, two bullocks and one young stock. The FYM pit was also typical, being in a vertisol. Community workers in the village sampled the fresh weight of each material once a week from July 1, 2006 to March 31, 2007, and samples of these materials were also collected for chemical analysis, including moisture content to express quantities on dry weight basis. The dried samples of each type of material were pooled on a monthly basis to obtain composite samples which were ground and analysed for total N, P and K. The weighted nutrient concentrations of the different types of materials and total amounts of each nutrient input into the FYM pit were computed at the end of the 9 month period. The FYM pit was emptied in May 2007, at which time the total weight of the field moist FYM produced from the pit was recorded, and FYM samples were collected for the laboratory analysis. The dry weight of the FYM was recorded after adjusting for the moisture content. The total amounts of nutrients in the FYM were computed, and their recovery and apparent loss determined.

Ion exchange resin studies
Resin cores constructed of PVC tubing with 10 cm diameter and 10 cm length contained one volume of a combined cation-anion exchange resin mixed with two volumes of acid washed sand. The mixture was well compacted in the cores (Lehmann *et al*., 2001). Both ends of the cores were closed with a wire mesh. Two cores 0.5 m apart were installed vertically at the bottom of the FYM pit by removing the overlying soil with a ring auger. At the time of emptying FYM pit, the resin cores were collected, each core was cut into three layers, 0-3, 3-7 and 7-10 cm, and resin collected from the layers analysed for inorganic N, P and K. Since there was little difference in nutrient concentrations in the layers, the mean nutrient concentrations were computed and used to estimate the leaching losses.

Chemical analyses
Total N was determined by digesting sub-samples of organic materials and FYM using a semi-Kjeldahl method. For the determination of P and K, sub-samples of organic materials and FYM were digested in 3:1:1 HNO_3:$HClO_4$:H_2SO_4 mixture. Total P and K were determined in digests using the vanadomolybdate yellow colour method and by flame photometer, respectively.

Resin samples were extracted with 1 M KCl for 2 hours on an agitator to estimate inorganic N. Inorganic N in extracts (NO_3^- and NH_4^+) were determined photometrically with a continuous flow analyser. Phosphorus in resin samples was extracted with 0.5 mol/L $NaHCO_3$ and P determined in the aliquots by the ascorbic acid method. Potassium in resin samples was estimated by flame photometer in 1 M neutral ammonium acetate extracts.

Computation of leaching losses
The bulk density of the FYM was determined by collecting core samples at depths of 0-50 cm, 50-100 cm and 100-150 cm. The mean bulk density of the FYM was 0.68 g/cm^3 which used to compute the weight of the FYM in the core having 1.5 m height (depth) and 10 cm diameter above the resin cores. The weight of dry FYM in this core was 8.0 kg. The N, P and K losses from this core portion of FYM was computed based on the percentage losses of these nutrients from bulk FYM obtained in the mass balance studies. It was assumed that the nutrients from this core of FYM were leached into the resin cores and trapped by the resin. Therefore, the amounts of N, P and K recovered by resin were expressed as percentage of their total loss from the FYM core, this percentage loss of N, P and K being considered as lost by leaching.

Results
Mass Balance of FYM
During the 9 month period, 3.87 t cattle dung, 1.15 t cattle shed wastes (straw mixed with urine), 0.019 t vegetable wastes, 0.587 t ash and 0.130 t household wastes were put into the FYM pit. Cattle dung was the main component of the FYM (67%) followed by cattle shed wastes (20%). At the end, 3.70 t FYM (output) was produced from the 5.76 t (input) organic materials that were put into the pit. These results showed that about 64% of the organic materials were recovered in the form of FYM.

Nitrogen
The average N concentration of materials put in the FYM pit ranged from 0.21% for ash to 1.72% for vegetable wastes (Table 1). Cattle dung contributed the highest amount of N (79%) input in the FYM followed by 17% from cattle shed wastes. Of the 57 kg N put into the FYM pit only 35 kg was recovered in the FYM indicating a loss of 39% during FYM production.

Phosphorus
The average P concentration was highest at about 0.2 % in the cattle dung, vegetable wastes and ash with by far the greatest amount of P (80 %) added as cattle dung (Table 1). Dry FYM contained 0.24% P resulting in a loss of about 20 % of the P put into the FYM pit.

Potassium
As expected, ash had the highest K concentration of the materials added to the FYM pit, but the greatest quantity of K arose from cattle dung (55%) followed by cattle shed wastes (21%) (Table 1). The K concentration in the FYM was 1.26%, with a K output in the dry FYM of 47 kg against the input of 69 kg. This showed that about 68% of K was recovered in the FYM and the remaining 32% K was lost during FYM production.

Table 1. Mass balance of N, P and K on a dry weight basis in FYM produced by farmers

Material	Nitrogen		Phosphorus		Potassium	
	Concentration (%)	Input (kg)	Concentration (%)	Input (kg)	Concentration (%)	Input (kg)
Cattle dung	1.17±0.06	45.3	0.23±0.021	8.83	0.98±0.12	37.5
Cattle shed wastes	0.83±0.10	9.55	0.092±0.04	1.07	1.23±0.09	14.2
Vegetable wastes	1.72±0.24	0.34	0.21±0.09	0.038	1.22±0.31	0.25
Ash	0.21±0.03	1.19	0.17±0.03	1.03	2.23±0.44	14.8
Household wastes	0.50±0.10	0.67	0.10±0.02	0.128	1.37±0.21	1.81
Total input (kg)		57.0		11.10		68.5
Total output in FYM (kg)		34.8		8.88		46.6
Recovery in FYM (%)		61		80		68
Loss (%)		39		20		32

Leaching losses

Based on the FYM composition, the total loss of nutrients from the 8.0 kg FYM above the resin core were 48 g N, 4.8 g P and 48 g K. This compared with 9.6 g N, 1.4 g P and 24 g K recovered in the resin core. However, the recovery of similar amounts of nutrient from each of the three layers within the resin core, indicates that the resin may have reached saturation (equilibrium with the leachate solution). Thus, following an initial period where nutrients were retained on the resin, leachate may have passed unaltered through the resin core. Longer cores, or ones containing a higher proportion of exchange resin, would need to be used to capture all of the nutrient leaching. Given this constraint, the resin core results can only be interpreted as showing that at least 20% N, 30% P and 50% K of the total nutrient loss was a result of leaching. Additional nutrient loss may have occurred through surface runoff during the monsoon season, and for N other loss pathways such as denitrification and volatilization may be important. Unfortunately, we are not able to quantify these losses on the basis of the data obtained in this experiment, and further research is needed to quantify losses of these and other nutrients.

Conclusions

Mass balance studies showed that the major component of the FYM was cattle dung followed by cattle shed wastes, these providing the major sources of dry matter and of N, P and K. There were considerable losses of nutrients, particularly N and K, during the preparation of FYM. Ion exchange resin studies showed that the leaching is an important pathway of nutrient losses from FYM pits on farmers' fields, but failed to quantify the loss. Phosphorus leached from the pit is likely to be retained in the first few cm of soil, and would be recovered in the commonly used practice of removing this soil layer with the compost. The more mobile nutrients, N and K, are likely to be lost to ground and surface waters, representing an economic loss to the farmer, and posing environmental and health risks.

Given the extent of loss from compost pits, there is considerable scope to improve the quality of FYM by reducing the leaching and runoff losses from FYM pits. Introducing simple and farmer-friendly modifications such as hybrid pits (both heap and deep pit), construction of earth bunds to protect pits from inundation with runoff water, or the use of pits with thatched roofs, would reduce nutrient loss through leaching and runoff improving nutrient retention in FYM production.

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