Impact of the Use of Compost on the Quality of Drainage Water

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Introduction

For a variety of reasons, a number of livestock farmers are seriously considering treatment systems to alter the properties of their livestock manure. One of the systems being considered is composting. This is not a new process and has been used on farms for years. However, with the development of systems to compost liquid manure, there is a renewed interest in the technology. Compost is produced by the aerobic breakdown of livestock manure. Water vapour, carbon dioxide and heat are given off during composting. The resulting material is a valuable soil conditioner and source of plant nutrients. Composting has the potential to reduce the impact of a manure system on the environment by: reducing odours, reducing emissions of greenhouse gases, reducing the potential for preferential flow to subsurface tile drains (possible with liquid manure under certain spreading conditions), and reduce the amount of energy needed to spread the compost on the land (due to reduced mass).

While some information is available on the availability of compost nutrients to crops, there are questions remaining about the potential for leaching of nutrients when compost is spread onto fields. A project was set up at Ridgetown College - University of Guelph, during June and July, 2002, to have a preliminary look into the leaching potential.

The objective of the study was to compare the potential for nutrient leaching between compost, liquid manure and inorganic fertilizer in a typical soil situation.

Project Setup

The study was designed to be a lab-scale experiment and was conducted in the Engineering Building at Ridgetown College. Ten small bins were used in the test. There were five treatments and two replications. Once the first run was completed, the bins were emptied and the study was repeated.

a) Bin construction

The bins were clear plastic storage bins, with a capacity of about 110 L (length: 0.79 m, width: 0.48 m). In the bottom of each bin, an outdoor plumbing tap was installed. It was attached below the bin to allow for easy access to open and shut the valve. Clear silicon caulking was added around the fixture to ensure a leak-proof installation. New paving bricks were laid in the bottom of the bin and new plastic mesh animal caging was cut to fit into the bin on top of the bricks. A geotextile material was laid on top of the mesh and the soil was eventually placed on top of the geotextile. Its purpose was to ensure all of the soil remained in place during the tests and to allow the water to freely pass through.

b) Experimental procedure

Treatments

- Soil was placed into each bin, to a depth of 0.20 m. The soil was sandy loam and it was well-mixed. Soil from the same source was used for all tests - this soil has not received manure applications for the previous several years.
- When all of the soil was in place and spread evenly, the soil in each bin was saturated using tap water (from a municipal water supply - assumed to be free of bacteria and having negligible nitrate concentration). The drain was closed and water was added until it pooled on the soil surface.
- The soil was allowed to soak for two or three days.
- The tap on each bin was then opened and excess water was drained from each bin. A composite sample of this initial drain water was collected and sent for analysis.
- After 24 hours, when the surface of the soil had dried somewhat, the soil surface was shaped so that it was slightly lower in the centre and slightly higher around the edges - to ensure there was no preferential flow at the sides (see Figure 1).

Figure 1 Preparing soil surface in test bins

- The bins were divided randomly into two groups of five, and each bin was randomly designated one of the treatments.
- The various treatments were applied to the bins. The four nutrient additions were chosen to provide similar amounts of nutrients, at rates that would be typical of on-farm applications (the target application rate was 50 kg/ha of phosphate):
  - 2.22 L of liquid hog manure
  - 1.38 kg of solid beef manure
  - 866 g of compost (made with tree leaves and liquid hog manure)
  - 8.32 g of 10-25-25 fertilizer and 6.47 g of 34-0-0 fertilizer
  - control - no nutrient additions
- The nutrient additions (in the various forms) were incorporated into the soil surface, using a hand held gardening tool. The surface of the soil in the control bins was also worked up to give a similar soil surface appearance. The tillage tool was rinsed in clean water

between bins.

- Using a small garden watering can, clean water was applied to each bin, to simulate rainfall. An amount equivalent to 6 mm of water (2.42 L) was applied to each bin at 15 minute intervals, for a total of four applications (i.e. 9.68 L total per bin).
- The bins were left for 24 hours, with the drain taps closed.
- After the 24 hour period, the tap was opened and a nutrient and a bacteria sample were collected from each bin. The total drainage volume from each bin was measured.
- The taps were closed and leachate was allowed to accumulate for another 24 hours.
- The volume of any new leachate was measured - no samples were collected.
- The bins were cleaned out (new filter cloth and soil were used - all other components were thoroughly pressure-washed) and the entire test was repeated.

c) Sample collection

- For each leachate sample that was collected, two separate clean sample bottles were used. One was used for the nutrient analysis. The bottle used for the bacteria analysis was autoclaved prior to use.
- The sample bottles were immediately placed into a refrigerator (stored at < 5 ^{o}C).
- The bottles were delivered to the lab (Laboratory Services Division, University of Guelph) within 24 hours.
- Nutrient analysis: total N, P, K, NO_3-N, NH_4-N, and pH
- Bacteria analysis: total coliform and *E. coli*

Results and Discussion

a) Background sampling

Samples of the soil and the various nutrients sources were analyzed for nutrients and for bacteria. The results are given in Tables 1 and 2. The tables show the variation in values between materials. The compost had been tested previously (as part of another study) and found to be free of bacteria. These samples, however, contained measurable amounts (even though the densities were three orders of magnitude lower than raw manure).

Table 1 - Nutrient content of nutrient materials and soil

	N (% as is)	P (% as is)	K (% as is)	NO_3-N (mg/kg)	NH_4-N (mg/kg)	pH
Liquid swine manure	0.40	0.19	0.31	0.65	2000	7.1
Solid dairy manure	0.57	0.11	1.20	416	853	8.5
Compost	0.85	0.27	0.43	362	6.4	7.5
Soil	0.24	0.08	0.13	77.4	5.2	6.1

Table 2 - Bacteria densities in the raw materials used in the study

	Total coliform bacteria	E. coli
Liquid swine manure	2.40×10^6 cfu/100 mL	9.00×10^5 cfu/100 mL
Solid dairy manure	2.40×10^6 cfu/g	2.40×10^6 cfu/g
Compost	1.50×10^3 cfu/g	1.50×10^3 cfu/g
Soil	1.50×10^3 cfu/g	4.0×10^1 cfu/g

b) Leachate volume

The total volume of leachate was similar for all treatments, as shown in Figure 2. Each bar on the graph represents an average of the results from the four individual tests. Nearly all of the leachate volume was collected during the first 24 hours after addition of the water, with a small amount occurring in the second 24 hour period. The leachate totals were very close to the total volume of water applied. As expected, the volume of leachate was higher for the liquid manure, since it represented an additional "liquids" application.

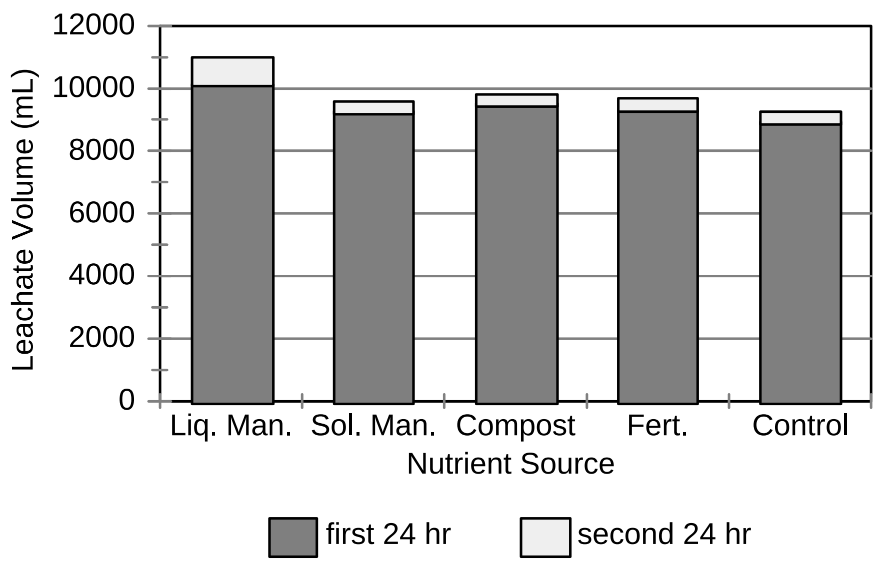

Figure 2 Average total volumes of leachate for the various treatments

c) Nutrients

There was a significant difference in the amount of ammonium-N leached in the study (P=0.01). The concentration in the leachate was significantly higher for the soil where liquid swine manure was applied. This is shown in Figure 3. This might be expected, since NH_4-N typically represents more than half of the nitrogen in liquid swine manure. There was no significant difference between the leachate concentrations for the other treatments.

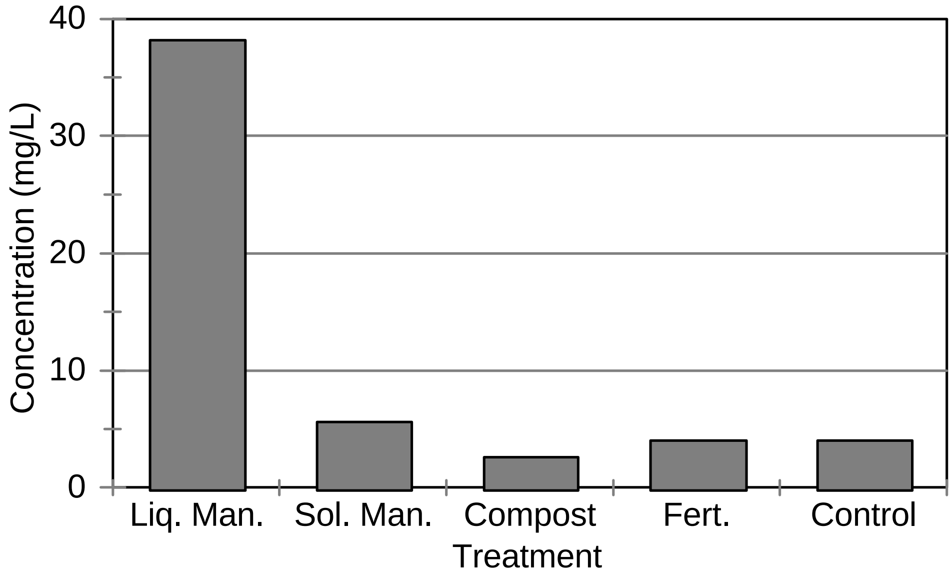

Figure 3 Average NH_4-N leachate concentrations

There were differences among treatments in the concentration of nitrate-N in the leachate. The average values are shown in Figure 4. This time, the concentration in leachate from the liquid swine manure was lowest. Using Fisher's least significant difference procedure (at the 95% level), the nitrate concentrations were significantly lower than the "inorganic fertilizer" or "control" situations. Why the control situation had such a high level of leached nitrate is unclear.

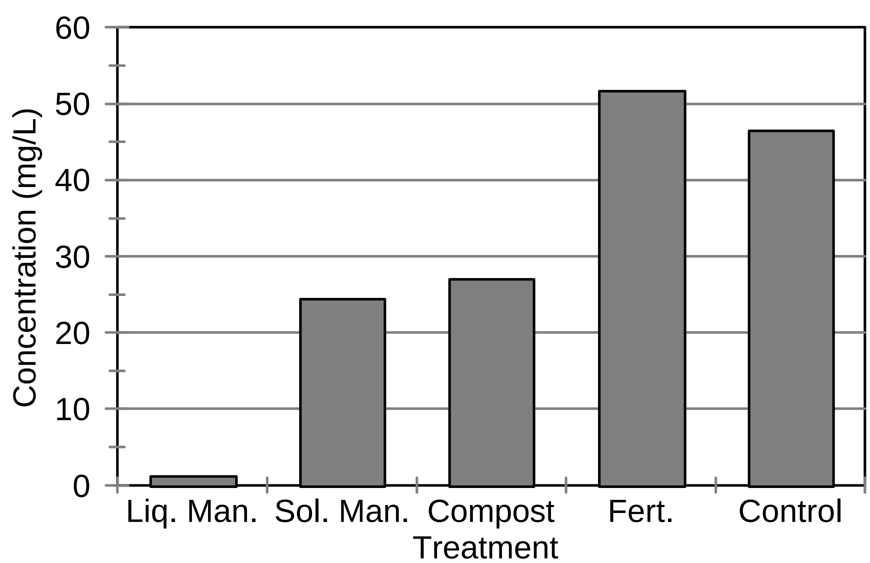

Figure 4 Average NO_3-N leachate concentrations

Levels of phosphorus were generally so low, they were not detected (i.e. less than 0.001 mg/L). This was the case in all but three of the four leachate samples for the liquid swine manure treatment. For each of these three samples, the concentration was 0.001 mg/L.

Potassium levels were measured, and the average concentrations ranged from 0.007 to 0.014 mg/L, for the five treatments. Only one relationship was significant. The compost treatment had the lowest levels, and it was significantly less than the solid manure treatment (95% LSD).

c) Bacteria

Because the soil was not sterilized prior to this test, background soil bacteria were present in the leachate. In fact, these levels were relatively high, both for total coliform and for *E. coli* bacteria. The units reported were: colony forming units per 100 mL (cfu/100 mL). For total coliform, the lower detection level was 1.0 x 10^3 cfu/100 mL. In general, where the sample analysis was reported as less than the lower detection limit, a value of one half this level was assumed (rater than a value of 0). Total coliform densities for individual samples ranged from this lower level to a high of 1.4 x 10^9 cfu/100 mL. Because of this range of values it is common to use the geometric mean (based on the logarithm) rather than the arithmetic mean for bacteria densities (i.e. for statistical analysis, bacteria densities usually exhibit a log-normal distribution).

The geometric mean densities of total coliform bacteria were not significantly different between treatments. They ranged from 1.98 x 10^5, for the inorganic fertilizer treatment, to 7.41 x 10^6, for the solid manure treatment. There were significant differences in levels of *E. coli* in the leachate (95% LSD). The control treatment (at 6.85 x 10^3 cfu/mL) and the inorganic fertilizer treatment (at 1.66 x 10^4), were significantly lower than the solid manure treatment (at 5.01 x 10^6).

Because only four samples were taken for each treatment, and the fact that bacteria results tend to be quite variable, and the fact that the background soil levels were high, it is hard to draw meaningful conclusions from these results. It does appear, though, that *E. coli* levels in non-manured soils are lower than in manured soils. The likely reason is that the manure treatment (solid or liquid) involves adding bacteria to the soil. The compost treatment leachate levels were not significantly different from the other treatments for either bacteria tested. A greater number of samples would be needed to establish any relationship.

Summary

A small study was carried out at Ridgetown College - University of Guelph in the summer, 2002 to investigate the quality of drainage water from soil bins. The main objective was to compare the potential for nutrient leaching between compost, liquid manure and inorganic fertilizer in a typical soil situation. Plastic bins were used and a well-mixed sandy loam soil was added to each. In total, there were five treatments: liquid swine manure, solid beef manure, compost (composted liquid swine manure and tree leaves), inorganic fertilizer and a control (no nutrient additions). The soil was pre-wetted and allowed to drain. The nutrients were added (at typical application rates) and incorporated into the soil. Water was added, the leachate volume was measured and samples of leachate were analyzed. The main results:

! The total volume of leachate collected in 48 hours after application was virtually identical to the volume of water added to each soil bin.

! The concentration of NH_4-N in the leachate was highest where liquid manure had been applied - it was significantly higher than the other 4 treatments.

- In contrast, the level of NO_3-N in the leachate was lowest for the liquid manure application. The highest values were for inorganic fertilizer and the control.
- Total concentrations of N from these two sources were not appreciably different
- Concentrations of P were measured at low levels in three of the four samples from the liquid manure treatment. In all other cases, these levels were below the lower detection limit (of 0.001 mg/L).
- Bacteria levels in the leachate were relatively high, even for the control, indicating a high background level of bacteria in the soil that was used. The solid manure treatment resulted in higher leachate levels of *E. coli* than the control and inorganic fertilizer treatments.

To get a more precise description of the relative water quality impacts of using compost, a few improvements should be made to this study:

- the sample size needs to be bigger, especially for the bacteria sampling
- different soils could be tested - some would have lower background levels of bacteria - however, the use of sterilized soil would not be representative
- the testing could be carried out a field-scale, but this would be much more difficult and costly to set up