NUTRIENT MOVEMENT FROM A WINDROW OF DAIRY BEDDING/LEAF MULCH COMPOST

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Abstract. To evaluate movement of nutrients from compost windrows, a test bed was designed to capture the runoff from and effluent leaching (leachate) through a moderate size compost windrow. For six natural rain events, discharge volume over time was measured for leachate and runoff from a windrow created on top of the test bed along with rainfall intensity. Samples from leachate and runoff were analyzed for chemical constituents of nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, dissolved phosphorus and pH. Nutrient concentrations from the compost effluents varied greatly for the six rainfall events. Nitrate-N concentration in leachate varied from 1.8 to 120 mg/L for the rainfall events. Nitrate-N concentrations from runoff ranged from 0.1 to 6.7 mg/L. Phosphorus concentrations were consistently higher in the leachate than in the runoff. The concentration of the nutrients in the leachate for some of the rain events were high enough to warrant concern for the pollution potential of large windrows placed directly on soils.

INTRODUCTION

There is little to no data available on the effects of rainfall on nutrient movement from composting windrows. Large uncovered windrows placed directly on soil surfaces or where runoff is not controlled can be a source of pollution from nutrients leaving the windrows in runoff or leachate infiltrating into soil during and after a rain event.

Composting is a recommended practice for dairy waste solids and for municipal leaf waste. Because the composting organic material has a high level of nutrients, the compost windrows may create a potential pollution problem from runoff and water leaching below the compost windrow into subsurface soils. For actively composting materials in a given setting, the amount of nutrients and mechanisms for movement of nutrients during rain events is poorly understood. Thus, the potential for pollution from composting windrows is unknown.

Without a better understanding of nutrient movement from compost windrows, improved practices to prevent the loss of nutrients from windrows cannot be sensibly recommended. A study was designed to measure nutrient movement from composting windrows due to natural rainfall. Samples of runoff and leachate were taken from composting windrows of dairy bedding (manure, urine and wood shavings) and municipal leaf waste. Chemical constituent concentrations of the effluent samples were measured, and the hydrology of the water movement through and over the windrows was quantified.

BACKGROUND AND RELATED WORK

Field studies to measure movement of nutrients from composting windrows have looked at different composting mixtures and constituents. In a study of different composting windrow mixtures of manure and straw, Ulen (1993) found elevated nitrogen (N) concentrations in leachate and increased concentrations of other nutrients such as phosphorus (P) and potassium (K) in runoff. Richard and Chadsey (1990), took water samples with suction lysimeters at various depths below municipal leaf waste composting in windrows. Nitrate and potassium levels in the soils below the compost site were higher than surrounding soils. Warman and Termeer (1996) studied leachate from various mixtures of composting racetrack manure, grass clippings and municipal biosolids. They concluded that the grass clippings contain elevated nitrates due to lawn fertilization and when the grass cell walls rupture during decomposition, the nitrates could quickly leach from the windrow. Elevated macronutrient levels were observed only for the windrows containing grass clippings. Controlling excess losses of nitrate and phosphorus would require either decreasing the quantity of grass clippings or adding more of some other substrate with a higher C:N ratio. Eghball et al. (1997) sampled effluent from a concrete pad that held composting dairy manure and found the runoff from the windrows could contribute nutrients in concentrations high enough to pollute surface and ground waters.

METHODS

The study was set up at a farm composting facility on the Witter Farm in Old Town, Maine. A test bed with dimensions of 3.3 m X 15.2 m was established for the study. The test bed consisted of a gravel filled trench with an impermeable barrier below the gravel and a tile drain pipe at the bottom of the trench to capture the leachate coming out of the compost. The impermeable barrier was attached to PVC pipes cut in half and placed like gutters around the perimeter of the bed to capture runoff.

Runoff and leachate flow through the pipes were measured by ISCO flow meters. The flow meters also signaled ISCO automated samplers to take samples during the rainfall events according to the volume of water passing by the flow meters. Samples were taken at 50 L intervals during rainfall events. Samples were removed at the end of a rainfall event. Hydrologic data and effluent samples were collected from four different windrows that were established consecutively on the test bed. The number of samples varied from event to event and ranged from two samples to eight samples taken during an event. There were a total of six measured events.

Each sample was analyzed for nutrient concentrations. Chemical concentration results presented are the averaged concentrations of all samples taken for each event. Samples were filtered through a 2 micron filter. Chemical analysis of the filtrates included nitrate-N, ammonium-N, total Kjeldahl nitrogen (TKN), total dissolved phosphorus and pH for both the leachate and runoff. The detection limit for the TKN was 60 mg/L. For the nitrate-N and ammonium-N the detection limits were 0.05 mg/L.

The windrows were built to cover the entire collection pad with dimensions of 15.2 m X 3.3 m X 1.22 m. A tractor with a bucket formed the windrows. After the windrow was formed, a windrow turner mixed the substrates further.

The dairy manure was a heterogeneous mixture of manure and wood shavings used as animal bedding. This material was used in all windrows so the term 'manure' is used to describe the above mixture.

The yard waste was material collected from the University of Maine Campus and five surrounding municipalities and delivered to the composting site. This material was comprised primarily of fallen leaves (> 95% by volume), though there was some cut brush and other organic residuals. To provide proper C:N ratio (35:1) and moisture content (50 %) for composting, a volumetric ratio of 3:1, yard waste to manure was determined for the composting mix.

Each windrow was on the test bed for only 28 days. This length was chosen to focus on the initial composting phase because this is when the most rapid organic breakdown occurs during composting (NRAES 1992).

Temperature changes were used to determined when the windrow needed turning and mixing. The temperature was measured with a probe inserted into the center of the cross section of the windrow at three locations along the length of the windrow. The temperature was checked twice a week, and the windrow turned if the temperature reached or exceeded 66^o C or when the temperature declined below 32^o C. If neither of these conditions were met the windrow was turned 14 days from the last turning. The turning was carried out with a windrow turner attached to the side of a tractor.

RESULTS

Table 1 provides summary runoff and leachate discharge and rain data for the six events. The number of rain events and the amount of data collected were limited by a drought during the months the study was conducted. However, the results provided valuable information on some aspects of the hydrology and nutrient movement from the composting windrows. The observed characteristics were a unique combination for each rainfall event. The average rainfall intensity for an event ranged from 1.8 to 8.2 mm/hr. The duration of the rain events

Table 1. Summary of the rainfall, leachate and runoff data and the number of days since the compost windrow was established until the particular rainfall event occurred

Date and Pile ID	Total Time*	Age of Compost#	Cumulative Volume mm			Ratio of Effluent to Rain %		Rain in Windrow %	Max Rain mm/hr	Ave Rain mm/hr
			Rain	Leachate	Runoff	Leachate /Rain	Runoff/ Rain			
5/20/99-A	11:15	17	19.1	10.1	2.3	52.8	12.3	34.8	6.1	2.3
5/24/99-A	9:00	21	9.9	9.1	6.7	92.2	68.4	----	8.1	2.4
6/7/99-B	10:30	2	30.8	10.5	7.5	34.1	24.3	41.6	49.8	8.2
6/8/99-B	14:15	3	18.1	7.9	4.5	43.6	24.7	31.7	9.1	2.6
7/10/99-C	3:15	1	6.0	1.0	5.4	16.0	89.9	----	3.0	1.8
8/10/99-D	22:45	4	57.2	26.1	19.0	45.6	33.2	21.3	26.4	7.3

*Format of time interval is hours:minutes.

Age of compost is the number of days between when the pile was first established and the rainfall event occurred.

ranged from 3 hours and 15 minutes to 22 hours and 45 minutes.

On the gravel test bed, the percentage of rainfall that permeated the windrows was higher than the percentage that ran off the outside of the windrow for all but the lowest intensity event. The ratios of leachate to rain and runoff to rain were not related to average or maximum intensities of the rainfall. For all rain events, more of the total rainfall became runoff or leachate than was and held in the windrow mixture.

Unexpectedly, there were two events where the volumes of runoff and leachate together exceeded the volume of rainfall measured. The two rain events on May 24 and July 10 had the lowest total precipitation and were low intensity events, but there was more total volume of leachate and runoff from the windrow than the total volume of rainfall that fell on the windrow.

On May 24, 60 % of the total of the effluents was leachate. This excess leachate was due to the antecedent moisture conditions of the windrow, the windrow temperature and the ambient weather conditions just before and during the rain event. Just 3 days previously, on May 20, there had been rain that had left the windrow saturated. This windrow had been in place for 21 days and was past the hottest part of the composting process. There was little to no heat within the windrow to drive evaporation of the excess water from the windrow. Because it was late May and weather was overcast between May 20 and 24, the ambient conditions would not have created much evaporation from the windrow either for those three days. In this case, the runoff and leachate volumes together were 160 % of the estimated total rainfall volume that fell on the windrow.

The rain event on July 10 had a total of runoff and leachate that was 6 % more than the measured volume of rainfall for the event. While the rain gauge for measuring the rain was within 3 m of the windrow test bed, rain intensity is spatially highly variable. This 6+ % discrepancy was some combination of instrument error for the discharge measurements and error due to spatial variability of rain intensity at the site.

For the events where the total of leachate and runoff volumes were less than the total rain volume, the longer the storm duration the higher the percentage of the rain that became leachate and runoff. The rain event duration had more effect on the percentage of rain that became effluents than the rain intensities which showed no correlation with the percentage of rain that became leachate or runoff.

Tables 2 and 3 show the nutrient concentrations for the runoff and leachate samples, respectively. Nutrient concentrations were much lower in the runoff samples than the leachate samples for all events. Nitrate-N was over the drinking water standard concentration of 10 mg/L in leachate for all events except the largest rainfall intensity event. Nitrate-N in runoff was never over the drinking water standard. Ammonium-nitrogen did not have consistently higher concentrations for either runoff or leachate samples. Phosphorus was higher in the leachate than in the runoff for all but the longest lasting storm.

DISCUSSION

Results indicated that nitrogen can move out of composting windrows at concentrations that exceed drinking water standards under some rain conditions. The high concentrations of nitrate-N results from water moving out of and through the windrow due to wetting from rain. This leachate can infiltrate directly into soil below a windrow or with impervious surfaces, it would become a part of the runoff. However, proper design of the surface area where large scale composting will take place can minimize or prevent this problem.

An impermeable liner or compacted clay placed at or below a composting facility surface would prevent the leachate from windrows from moving deeper into the soil. The liner or clay would need to have some additional materials such as gravel or woodchips on top to allow for capture and drainage of the surface so that heavy turning

Table 2. Nitrogen and phosphorus concentrations and pH of runoff samples from compost windrows for six rainfall events

Date	NH4-N mg/L	NO3-N mg/L	TKN mg/L	P mg/L	pH
5/20	2.1	0.1	<60	12.0	7.6
5/24	6.3	0.8	<60	7.4	8.2
6/7	10.6	6.7	430	15.0	7.7
6/8	5.1	4.8	<60	11.1	7.7
7/10	7.7	1.4	181	16.3	8.6
8/10	38.6	1.8	284	27.8	8.3

Table 3. Nitrogen and phosphorus concentrations and pH of leachate samples from compost windrows for six rainfall events

Date	NH4-N mg/L	NO3-N mg/L	TKN mg/L	P mg/L	pH
5/20	1.4	34.1	83	20.3	8.0
5/24	0.6	12.0	73	20.7	8.2
6/7	28.4	21.0	171	20.6	8.7
6/8	34.3	11.0	190	26.0	8.6
7/10	2.2	120	185	17.0	8.9
8/10	0.3	1.8	235	19.0	8.1

and loading equipment could move over the surface soon after rain events.

However, this would result in more water collected on the surface and an increase in runoff as well as an increase in the nutrient concentrations in the runoff. To prevent the increase in nutrient concentration in the runoff, windrows can be covered with impermeable covers. Care must be taken in doing this so that the covers do not inhibit the flow of air into the windrows to maintain oxygen levels for the composting process. Serious odor problems could arise if the covers prevented air movement into the windrows.

Alternatively, windrows could remain uncovered and the runoff from the composting area could be captured. The captured runoff could be re-applied to the windrows when they needed moisture or it could be treated through constructed wetlands or other natural means and allowed to flow into nearby streams after treatment.

RECOMMENDATIONS

The study presented was limited in duration and only dealt with one mix ratio of dairy bedding and leaf waste. Other mixtures and composting materials would have different nutrient concentrations and characteristics, so other compost substrates need to be evaluated in similar studies.

The study only looked at the first 28 days of the windrow composting process. NRAES (1992) states that the maturing phase of the compost process accompanies an increase in nitrate concentrations in the compost. Also, Inbar et al. (1991) found increasing concentrations of nitrates in compost occurred after the rapid phase of the composting process. This suggests that at later stages there would be higher nitrate concentrations in both runoff and leachate from windrows. This hypothesis needs to be investigated as well as further studies on the mechanisms of nutrient movement throughout the composting process.

Another poorly understood issue with the movement of nutrients from open composting windrows is how the soil microbiology below the windrows are affected. Knowledge of soil microbiology changes that occur under compost windrow facilities could provide insight into the movement of nutrients in the soil and subsoil below windrow facilities.

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