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CONTAMINATION OF SUBSURFACE DRAINAGE SYSTEMS DURING MANURE SPREADING

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SUMMARY:

A field scale research project was carried out to assess the relative impacts on tile drainage water quality of spreading liquid manure under different management techniques. Tile drainage effluent was analyzed for various parameters prior to and following manure application. Manure was applied during December '91, May '92 and June '92 to a field in southwestern Ontario. During each spreading 4 treatments were examined (including a control). Loadings of NH_4-N were used as an indicator of manure entry into tile drains.

KEYWORDS:

macropore flow, preferential, slurry

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BACKGROUND

There have been many on-farm observations in Ontario of recently spread liquid manure gaining access to tile drainage systems. This phenomenon has been documented by various researchers. Dean and Foran (1991) suggested that liquid manure was gaining quick access to subsurface tile drains through soil macropores. Fleming and Bradshaw (1991) applied liquid manure to undisturbed soil columns in the laboratory. They found that most of the effluent emitted from the bottom of the soil columns occurred during the first five hours. They also found that significant levels of bacteria passed through the soil columns which received manure. Fleming and Bradshaw (1992) blew smoke into tile drains to demonstrate that there were direct connections between the soil surface and the tile drains. In this study, the affected area was approximately 2 metres wide on the ground surface above the tile drain.

Soil macropores are large continuous openings in field soils. They typically are formed by soil fauna, by plant roots, by cracks and fissures, and natural soil pipes (Beven and Germann, 1982). Macropores are generally considered to have an equivalent pore diameter of greater than 1,000 μm.

Dean and Foran (1991) suggested that by tilling the field prior to manure spreading, the loading of manure to tile drains could be greatly reduced. Their study, however, did not measure the total loading of various manure parameters into the tile drains.

The objectives of this study have evolved from the problem that liquid manure spread onto farm fields is gaining access to tile drains and farmers are asking what they can do to prevent this from happening. This study then, is an attempt to:

1. Investigate alternative practices for applying liquid manure to farmland that would minimize the amount of manure gaining access to subsurface drainage systems.

2. Measure the total loading of various manure-derived parameters for each of the treatments used.

PROCEDURE

Selection of farm - The farm that was selected met the following criteria: a) systematic subsurface tile drainage system, b) fairly level or gentle grade, c) cropping system compatible with the selected treatments, d) soil type where rapid migration to the tiles would be expected to occur, e) interested and co-operative farmer, and f) convenient supply of liquid manure.

The farmer involved was very interested in the study and quite co-operative. The soil type on this farm was a Guelph loam. During 1991 the crop grown in this field was winter wheat. It was harvested in the summer of 1991. The proposed crop for 1992 was corn.

Monitoring setup - The location of the tile drains used in this study is shown in Figure 1. The tile spacing was approximately 18 metres.

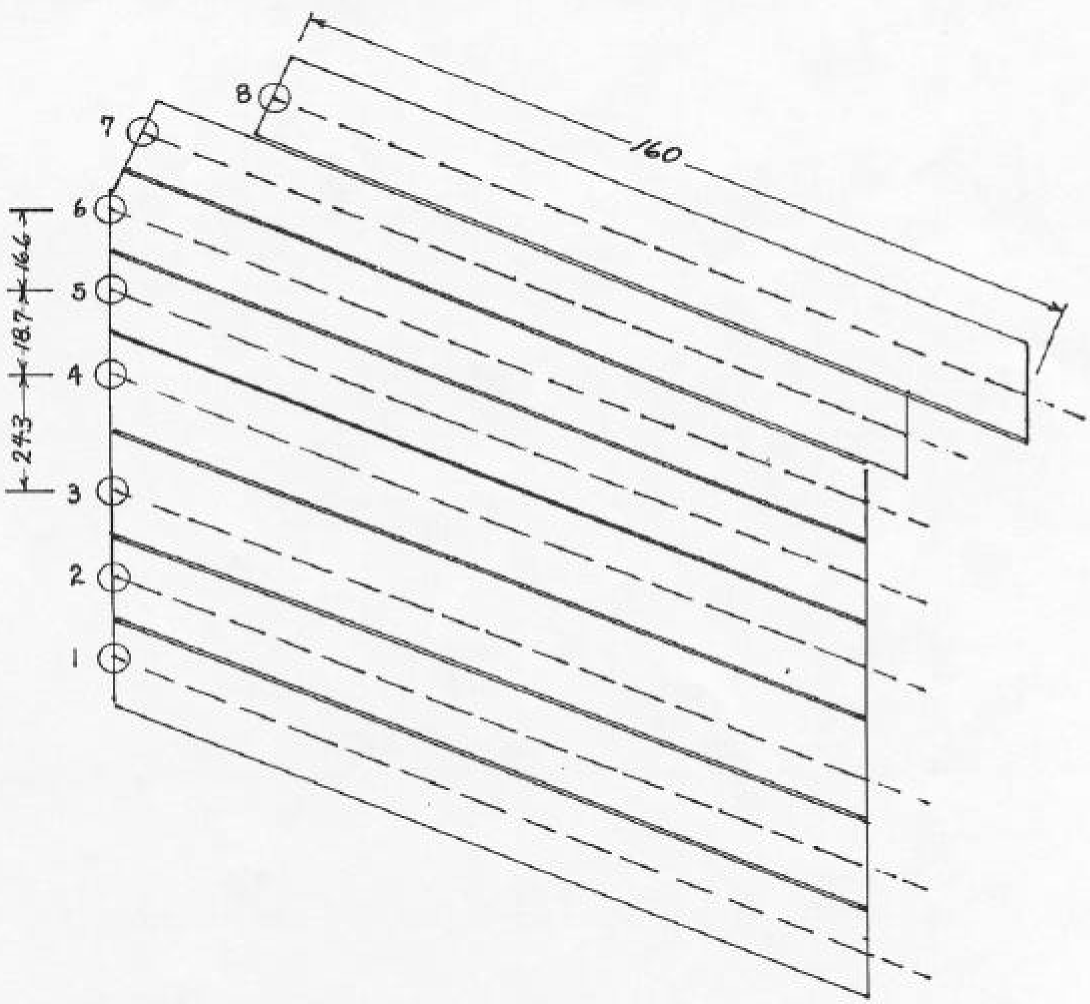

Figure 1 Field Layout

Corrugated plastic pipes, having a diameter of approximately 910 mm and a length of approximately 2 metres, were used as sampling sites. These were installed vertically in the ground. The existing subsurface drainage system consisted of 100 mm plastic tubing, installed at a depth of approximately 750 mm.

To measure flow rate from the tiles, the water was first evacuated from the bottom of the stand pipe. Flow rate was measured using a stopwatch and a container of known volume. Water samples were then taken following a preset schedule of sampling. Samples were taken for several days prior to manure application in order to establish background levels of selected parameters. On the day of application a more intensive sampling was carried out for up to 24 hours. Following this, a daily sampling was again followed to ensure that the readings had dropped to background levels again.

Timing of spreading - The intention was to spread manure at times and rates that would be encountered under typical situations. Unfortunately, adverse weather prevented this from happening. In the fall of 1991, the weather was dry enough that most farmers were able to spread manure well before the end of November. Dry conditions, however, prevented the tile drains from flowing until approximately the end of November. The manure spreading date in 1991 was December 3. The second spreading date was May 14, 1992. This was chosen to represent a time before corn planting. The third spreading date was June 9, 1992. In this case, manure was applied between corn rows. The corn rows were parallel to the subsurface drainage system.

Manure application - The 8 tile drains were divided into 2 groups of 4 and the treatments were randomly assigned within these two groups (i.e. there were two replications of each treatment). For the December 3 spreading, Treatment 1 involved no manure application. Treatment 2 involved manure broadcast from a tank spreader directly onto the surface of the ground. Treatment 3 was similar to Treatment 2 except that the land was chisel plowed the day before manure applicjation. On Treatment 4 the manure was injected into untilled ground. The injection was to a depth of approximately 15 mm with a narrow-tooth injector.

For the May 14 spreading, Treatment 1 consisted again of no manure application. Treatment 2 involved manure broadcast onto the surface of the soil. Treatment 4 again involved injection into untilled ground. Treatments 1, 2, and 4 were randomly assigned to plots. However, Treatment 3 involved broadcasting manure onto land that was chisel plowed in December. Because of this, the same two plots that were used in December were again used for Treatment 3.

For the June 9 spreading date, Treatment 1 again consisted of no manure application. For Treatment 2, manure was simply dropped onto the soil surface between corn rows. The manure was run through the injectors but the injectors were raised to aboveground level. A special modified tank spreader was used for this spreading. It came equipped with a tool bar, ahead of the injector teeth at the back of the spreader. On this tool bar were cultivator teeth. Treatment 3 consisted of cultivating the soil to a depth of 125 mm using these cultivator teeth then injecting manure to a depth of 75 mm into this tilled soil. Treatment 4 involved simply injecting the manure of a depth of 100 mm into land that had not been previously worked. The injector for this spreading date was a slightly different design, in that it used the wide sweeps on the teeth. This meant that the manure entered the soil in more of a horizontal than a vertical band.

Water analysis - In all cases, the water samples were refrigerated prior to chemical analysis. For the December, 1991 spreading, the following parameters were measured: NH_4-N, $N0_3$-N, Cl, Ph, and total suspended solids. These samples were analyzed at the Department of Land Resource Science, University of Guelph, Guelph, Ontario. The elapsed time between sampling and analysis was less than 2 weeks.

For the May and June spreading dates, water samples were analyzed at Centralia College. Parameters measured included: NH_4-N, $N0_3$-N, conductivity, and pH.

Manure sampling and analysis - Samples of liquid manure were removed from each spreader load. These were mixed and a sample was extracted and refrigerated. A more extensive sampling was done in December than in May or June. The May and June samples, however, were composites including manure from each spreader load. Manure samples were analyzed for levels of NH_4-N, $N0_3$-N, Cl, pH, and dry matter.

Soil sampling and analysis - For the December spreading date, a total of 6 soil samples were taken from the soil in each of the 8 plots. Soil was taken from 3 depths - 75 mm, 300 mm, and 530 mm. Soil was sampled at 2 locations in each plot of land. Also, the soil was sampled before manure application and again following application. The soil parameters measured included: NH_4-N, $N0_3$-N, Cl, pH, and percent soil moisture. The soil samples were refrigerated prior to analysis. In the May and June spreadings the soil analysis was far less extensive. It consisted of checking the soil moisture at various locations in the field on the day of spreading.

RESULTS AND DISCUSSION

Spread date - December/91 - On the 6 plots which received manure, the manure was applied to an area of land approximately 15 metres wide by 156 metres long. The application rate was equivalent to 52.6 m^3/ha (4690 gal/ac). This represents a typical rate of application for livestock producers with liquid manure.

Table 1 gives a summary of the average manure analysis values for the 3 spreading dates. For the December application, the mean NH_4-N concentration was 3056 mg per kilogram. In calculating the actual nutrient application rates, a manure density of 1000 kg/m^3 was assumed.

Table 1: Manure Analysis Summary

Spread Date		NH4-N (mg/kg)	N03-N (mg/kg)	Cl (mg/kg)	pH	D.M. (%)
Dec./91	mean	3056	10.6	767	7.3	3.2
	S.D.	124	2.5	48.9	0.1	0.1
	Number	18	18	18	18	18
May/92	mean	2890	0.073	-	-	2.54
	S.D.	743	0.027	-	-	1.15
	Number	6	6	-	-	6
June/92	mean	3520	164	-	-	5.43
	S.D.	-	-	-	-	-
	Number	2	2	-	-	2

Since the majority of inorganic nitrogen was in the NH_4 form, NH_4-N was selected as an indicator that the manure was entering the tile. Figure 2 shows the average NH_4-N concentrations in the 2 tile drains receiving Treatment 2 (i.e. manure broadcast onto the surface of the ground). At a time corresponding to 300 hours after the start of sampling, a shock loading of ammonia was added to the tile drain. This load quickly dropped off and within approximately 12 hours was very near to background levels again.

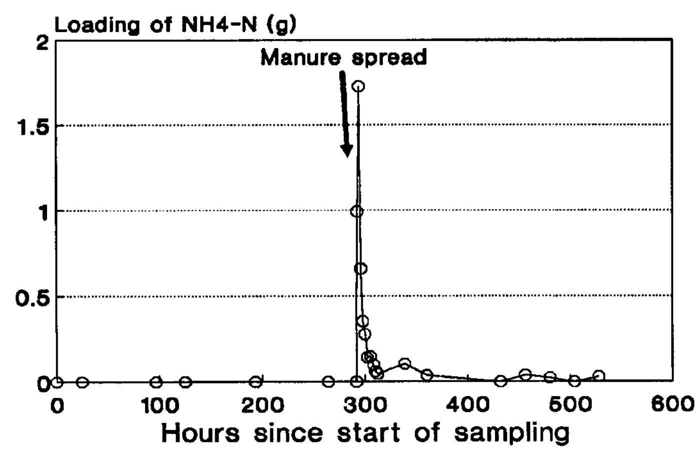

Figure 2 Loading of NH_4-N over time for Treatment #2, December 1991

A cumulative graph was used to better show the total loadings of NH_4-N to the tile drains. Figure 3 shows these cumulative loadings over time. The sharp rise in loading of NH_4-N to the drains corresponds to the spreading time of the liquid manure. Treatment 1 (i.e. no manure applied) resulted in nearly a zero loading of NH_4-N. In Treatment 3 where the land was chiselled plowed before the manure was broadcast onto the surface, very little NH_4-N reached the tile drain. Where manure was broadcast onto unworked ground, the cumulative loading of NH_4-N totalled 4.76 g. Where the manure was injected into the ground, the highest loading occurred. These same numbers are shown in a different way in Figure 4. Here the average value is shown, as well as the individual loadings from the 2 tile drains involved for each treatment number. The greatest variability in entry to tile drains occurred with the injection.

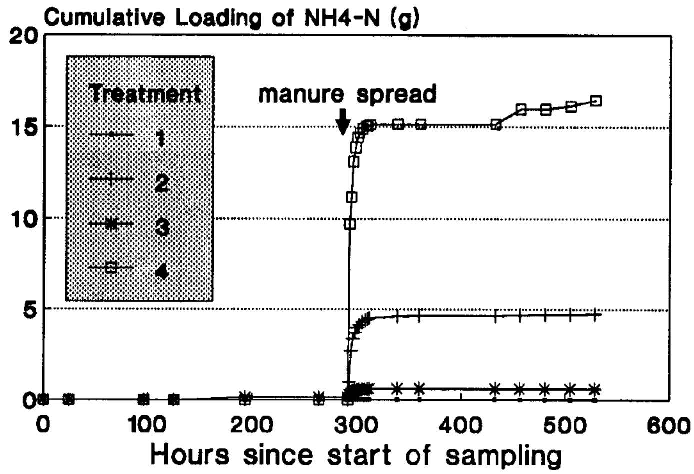

Figure 3 Loadings of NH_4-N for various treatments, December 1991.

The tile water levels of NO_3-N, Cl, and TSS did not respond to the manure spreading in the way that the NH_4 levels did. The cumulative loadings of NO_3-N are shown in Figure 5. Figure 6 shows the levels of Cl and Figure 7 shows loadings of total suspended solids. These parameters much more closely mirrored the total flows from the system. Cumulative flow from each of the different treatment systems is shown in Figure 8.

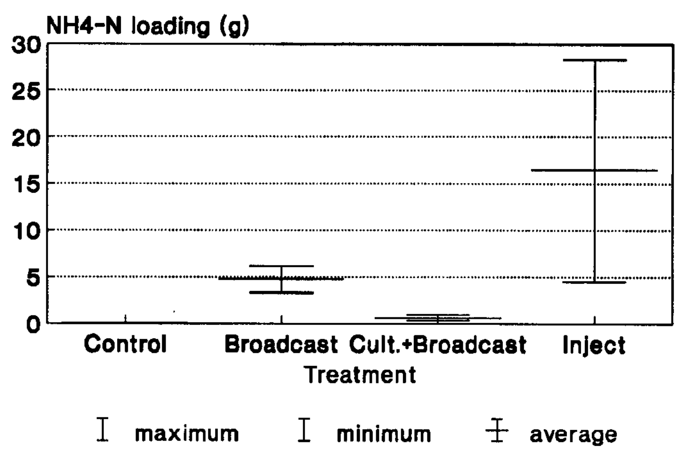

Figure 4 Spreading 1-total NH_4-N loadings for the various manure spreading options.

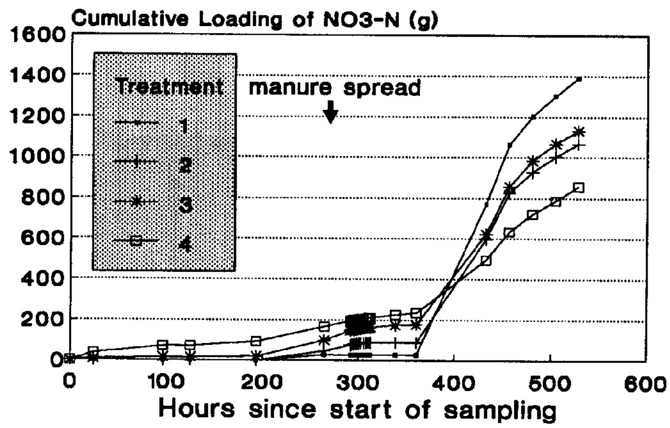

Figure 5 Loadings of NO_3-N for various spreading options, December 1991.

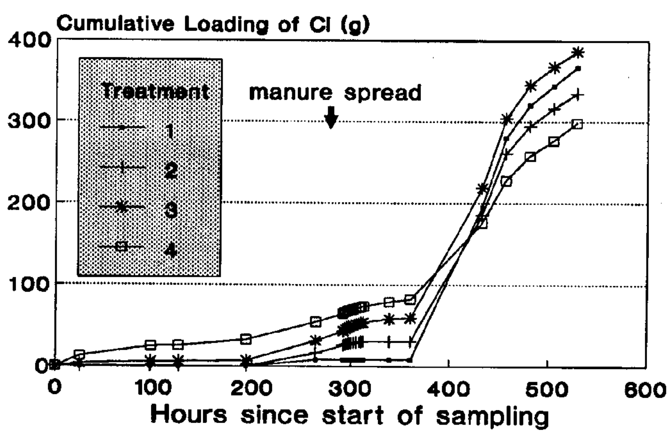

Figure 6 Loadings of chloride for the various spreading options, December 1991.

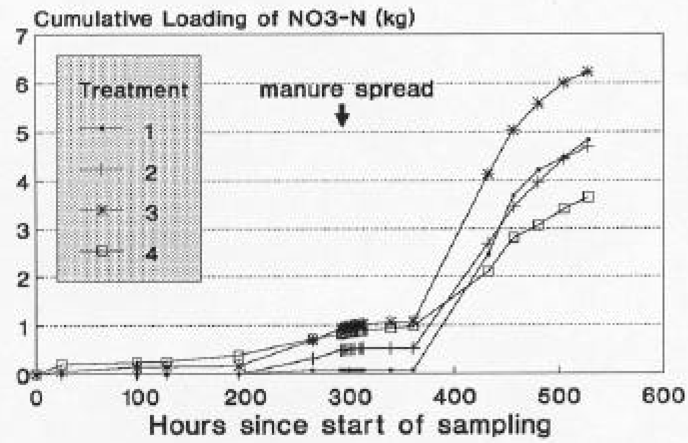

Figure 7 Loadings of total suspended solids for the various spreading options, December 1991.

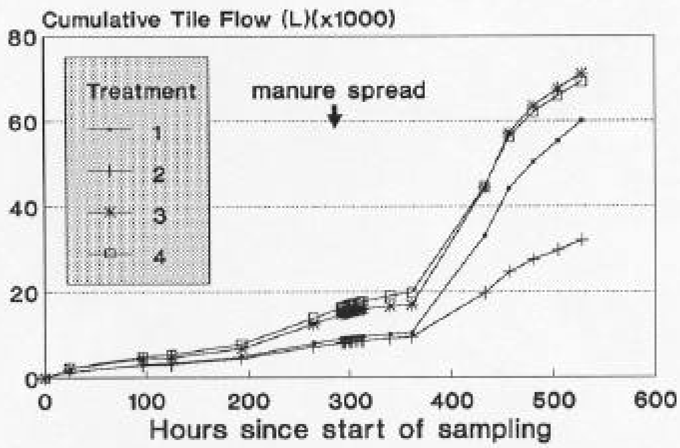

Figure 8 Tile flow totals under the various treatments, December 1991.

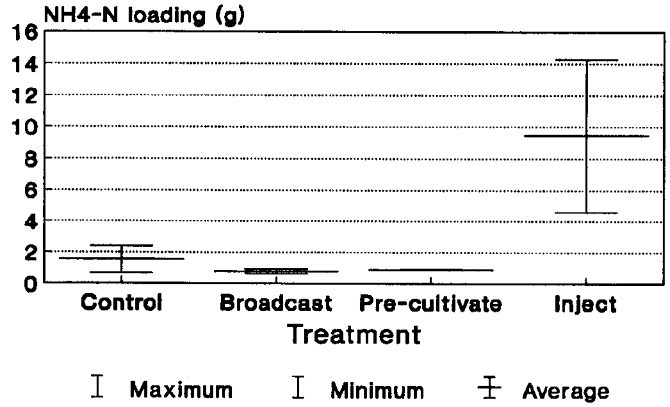

Figure 9 Total NH_4-N loadings for the various manure spreading options, May 1992.

Table 2 gives summary statistics for all of the water quality parameters for all sites. The concentrations of NO_3-N show relatively little variability, compared to NH_4-N. These values are what one might expect from background levels where there has been no shock loading to the system.

Table 2: Tile Water Summary Statistics - [All drains combined]

	NH4-N (mg/L)	N03-N (mg/L)	Cl (mg/L)	T.S.S. (mg/L)	pH	Flow rate (L/S)
Mean concentration	2.24	22.3	10.5	118	7.53	0.025
Std. Dev.	9.30	4.72	7.56	85.8	0.209	0.037
Minimum	0	0.57	5.47	0	7	0
Maximum	88.2	36.0	88.5	1020	7.9	0.25
Number	167	167	167	167	167	192

Average values of NH_4-N in the soil both before and after the manure spreading are shown in Table 3. Generally, the average values are higher after manure spreading on those plots which received manure. However, there is no significant difference between levels of soil NH_4-N before spreading and after spreading (eg. at the 75 mm depth, $p = 0.15$).

The level of moisture in the soil remained fairly constant throughout the spreading and sampling period. Before spreading the percent dry matter in the soil was 77.2

(equivalent to a soil moisture[1] of 29.6%). The percent dry matter in the soil following manure spreading was 76.7 (soil moisture = 30.4%).

On the day of manure spreading the soil surface was covered with wheat stubble (except for the 2 plots that had been chiselled plowed the day before). During the night prior to manure spreading some snow and freezing rain had fallen. This did not appear to hold back the manure. It quickly melted through the snow and ice. The surface of the soil remained at a temperature above freezing. The air temperature fluctuated around the freezing mark for the rest of that day and the following few days. All of the soil samples taken following manure spreading were gathered on the 2 days after spreading.

Table 3: Soil levels of NH4-N (mg/kg) before and after manure spreading (each number represents the average of 4 numbers)

	75 mm Depth		300 mm Depth		530 mm Depth	
Treatment	**Before**	**After**	**Before**	**After**	**Before**	**After**
#1 - no manure	4.15	3.19	3.41	1.94	1.20	1.61
#2 - broadcast	7.11	20.97	2.78	3.83	1.88	2.78
#3 - till + broadcast	5.34	4.67	4.55	1.88	3.16	1.52
#4 - inject	5.82	12.00	3.41	6.25	2.98	5.30

Spread date - May/92 - Manure was spread on May 14, 1992. All 8 tile drains were running at the time of spreading. The average percent dry matter in the top 75 mm of soil was 81.0 (equivalent to 23.6% soil moisture).

The loading of NH_4 to the tile drains for the different treatments showed a similar pattern to those found in December 1991 (see Figure 9). Manure was spread at the same rate as in the December application. In May, however, the total loading to the tile drains was considerably less. Figure 10 shows the cumulative loading of NH_4-N to the tile drains. Over time it suggests that Treatment 4, injection, was the only treatment that responded to manure application. The other treatments show levels of NH_4-N that were not elevated above background levels. It is not clear why there were measurable background levels of NH_4 in the tile water. There may be some residual from the December spreading. Also, the levels may be due to a sampling inaccuracy. For the May and June studies, the ion specific electrode method was used to measure concentrations of NH_4-N and $N0_3$-N.

[1] Soil moisture = (water in the soil)/(dry weight of soil)

Spread date - June/92 - By the time manure was spread on June 9, the corn plants had reached a height of approximately 12 cm. The soil surface still showed signs of being recently worked up. There had been very little rainfall onto the soil surface since corn planting in the later part of May. Data on the soil moisture conditions is unavailable. The flow through the tiles was at a relatively low level during this period. The NH_4-N loadings in the tile drains are shown in Figure 11. They are an order of magnitude less than the loadings for the similar period in May. The results suggest that as the soil dried out and tile flow was reduced, spreading liquid manure at normal rates had a reduced impact on tile water quality.

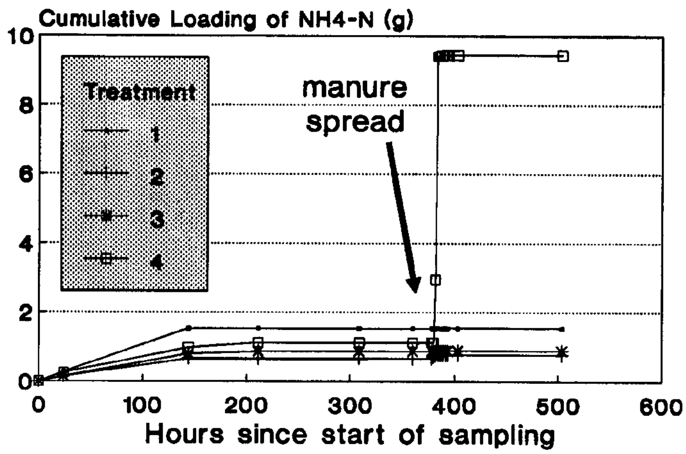

Figure 10 Cumulative NH_4-N loadings for the various spreading options, May 1992.

General observations - The focus of this study has been on the rapid movement of liquid manure through the soil and into tile drains. This can contribute a shock loading to the environment and contribute such contaminants as: NH_4, bacteria, and organic matter. In terms of the overall nitrogen loading to receiving waters however, it appears as though manure spreading has very little impact. The total of NH_4-N and NO_3-N is comprised almost totally of NO_3-N. These levels appear to be background levels coming out of the tile drains and exhibit no response whatsoever to application of liquid manure. The flow weighted mean concentrations of NO_3-N for all 3 study periods ranged from a low of 15.3 mg/L to a high of 37.8 mg/L. In contrast, the mean concentrations of NH_4 ranged from 0 to 0.11 mg/L.

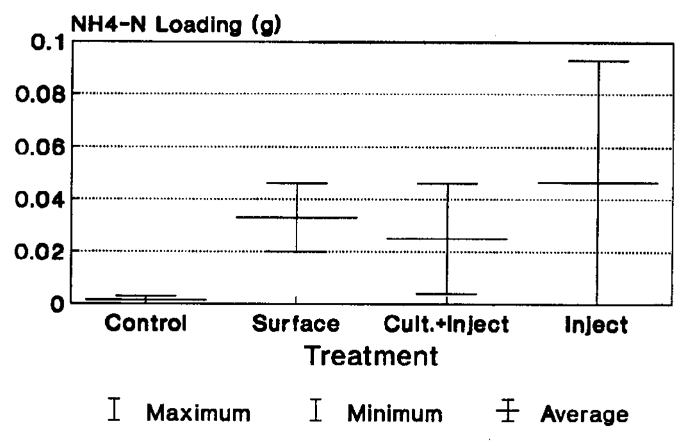

Figure 11 Total NH_4-N loadings for the various spreading options, June 1992.

If we assume that all of the NH_4-N in the tile drain in the December study came from the liquid manure that was applied, then the maximum amount in the tile drain was equivalent to 0.04% of what was applied to the surface of the soil. This manure was applied under conditions that should have lead to the highest possible flow of manure through the soil (i.e. high soil moisture conditions).

SUMMARY AND RECOMMENDATIONS

Liquid manure was spread on a farm field at 3 separate occasions between December 1991 and June 1992. Effluent from the tile drains was collected and analyzed to determine if liquid manure was gaining access to the tile drains. Various manure application methods were examined to assess their relative impact on tile water quality. For each spreading event, the 4 treatments were replicated twice. This study showed the following:

1. Manure constituents can enter tile drainage systems following land application of liquid manure.

2. If manure must be spread, it seems that the management technique to minimize potential flow to tiles is to work the soil prior to spreading.

3. While injection of manure may be an ideal way to minimize odour and losses of ammonia to the air, it appears that conventional systems for injecting manure contribute to tile water degradation at least as much or even more than simply broadcasting the manure onto the soil surface.

4. For the sampling periods studied, the loading of NO_3-N to the tile drains was considerably greater than the loading of NH_4-N.

A further recommendation to farmers should be to monitor tile drainage outlets during and after manure application. Manure entry to the tile drains in this study was fairly easily detected. The drainage effluent was no longer clear but instead became quite dark. Also, a noticeable odour could be detected in the drainage water.

ACKNOWLEDGEMENTS

This study would not have been possible without the enthusiastic cooperation of the farm owner, Richard Hiscocks.

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