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PLUGGING TILE DRAINS TO REDUCE MANURE CONTAMINATION

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ABSTRACT:

The second phase of an experiment was performed to assess the feasibility of plugging a drainage outlet to reduce or eliminate any harmful impacts to surface water after application of liquid manure on farmland. Two flat fields were divided so that, in each, two separate drains could be monitored. At one farm, observation wells were installed on the header tile to monitor flow and water quality. Manure was spread and one of the drains was blocked. Seven days after manure application the blocked drain was released. In the other field, one of the outlet pipes was blocked, for a shorter period. Total loadings of nitrate, ammonium, coliform bacteria, phosphorous and potassium were compared.

KEYWORDS: controlled drainage, pollution, water quality, slurry

Plugging Tile Drains To Reduce Manure Contamination

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Background

Subsurface drainage systems have the potential to transport pollutants to streams, rivers and lakes. One of the possible contaminants is livestock manure, especially liquid manure, due to the presence and mobility of nutrients and bacteria.

Recent research has indicated that land application of liquid manure can contribute to bacterial contamination of surface waters. Increased bacteria levels have been found in tile drainage effluent following liquid manure application. Evans and Owens (1972) found that the concentration of bacteria in tile drainage effluent increased by 30 to 900 fold within two hours of liquid swine manure spreading. Dean and Foran (1990) found that manure can travel through the soil to the tile drains, and that significant concentrations of bacteria are evident to a depth of 70 cm in the soil. Laboratory experiments also demonstrate bacterial movement through the soil. Smith et. al. (1985) found that up to 96% of the bacteria irrigated onto a soil column 280 mm deep were recovered in the effluent.

Manure parameters have been observed exiting tile drains after field application. Fleming and Bradshaw (1992) found that shortly following liquid manure applications, ammonia exited tile drains in high concentrations. Evans and Owens (1972) reported that 2 hours after spraying swine waste over a pasture, bacterial populations in tile water increased. Evidence of manure contamination in tile drainage water was reported by Dean and Foran (1990) in as little as 20 minutes following liquid manure applications.

The transport of liquid manure parameters at elevated concentrations through the soil to tile drains only lasts for a relatively short period of time following application. The concentrations of faecal bacteria discharged from tile drains following manure application returned to background levels over a period of 2 to 3 days (Evans and Owen, 1972, Dean and Foran, 1990). Patterson et. al (1974) found that after a period of 24 hours contamination of drainage water caused from the application of swine waste to a ploughed field had disappeared. A laboratory liquid manure spreading study using soil columns conducted by Fleming and Bradshaw (1991) found that as little as 17 hours after application, manure flow through the columns was nearly terminated.

Researchers believe that soil macropores are responsible for transporting liquid manure to tile drains. A macropore is a large crack, channel or passageway in the soil through which water and its constituents can travel. These large pores can be formed by plant roots, soil fauna, and swelling and shrinkage of clay soils (Beven and Germann, 1982). The previous studies observe rapid and short duration flow of manure to tile drains as well as the soil's inability to filter the bacterial component of manure. These observations are typical of flow through soil macropores.

Several methods have been proposed and tested for reducing the rapid macropore flow of manure. These methods include:

a) Pre-cultivation - tillage prior to manure application
b) Selection of spreading system - injection vs. surface application
c) Avoid spreading prior to a heavy rain or, if possible, when tile drains are running
d) Controlled drainage - outlet control to prevent discharge from drains during certain periods

Bacterial contamination and nutrient loading of surface waters caused by land application of liquid manure may be mitigated by controlled drainage. This technique requires blocking the drainage outlets during and after spreading for a fixed period of time. McLellan et al (1993) carried out a study which involved plugging a tile drainage outlet for one week following manure application. One drain was allowed to flow freely during this time period. The manure application to the field caused an elevation in levels of bacteria and NH_4-N in the drains. The blocked drain had markedly lower maximum concentrations and total loadings of NH_4-N, Cl, and three species of bacteria. Because the technique showed promise for use by farmers, it was felt that additional trials were needed to refine the method. This 1993 study was the first phase of the study that is the subject of this paper.

OBJECTIVES

The objectives of this study were:

1) to demonstrate and further refine a simple technique to stop tile flow and to measure the resultant increase in head;

2) to compare the difference in total loading of indicator parameters in the effluent of two header tiles underneath two similar fields, treated with surface applied manure , where one side was subjected to a flow interruption for one week, and the other one was allowed to flow freely; and

3) to investigate the importance of "time of year" on the success of this technique.

PROCEDURE

A - Farm Selection - Two farms were used in this study, both owned by the same farmer and both receiving manure from the same swine operation. Site A was the subject of a study carried out in the fall, 1994. Site B received manure in spring, 1995.

Site A consisted of a 4.9 hectare field, planted to winter wheat and under-seeded with red clover. The wheat had been harvested in the summer of 1994 and all of the wheat residue was left in the field. There was an excellent stand of red clover, about 30 cm tall at the time of the experiment.

The soil was described as a heavy texture till (silty clay) with poor drainage, from the Brookston series. The topography was essentially level with a rise of about 60 cm towards the back of the field (south side). The farm had an open ditch along the west side of the field into which the tiles drained.

The drainage system at Site B drained about 41 hectares. This land was divided into two fields - a field of winter wheat and a field that had been plowed the previous fall. This field was to receive manure before being planted into soybeans. In all, there were four drain outlets, but only three of these were used due to logistical problems. The soil at this site was similar to that at Site A. Like Site A, the entire field was systematically drained.

B- Monitoring Setup - Figure 1 shows the layout of the field at Site A. A non-perforated 150 mm plastic tile was installed as a by-pass header, thus splitting the field leaving six laterals feeding int each header. Two observation wells were installed, one serving each side of the field, to allow sampling and observations.

The observation wells were constructed from 2 m lengths of 1 m diameter corrugated plastic pipe. Both observation wells had the first 2 meter section of the influent perforated drain tubing replaced by smooth PVC tubing. The downstream side also had PVC pipe installed to prevent sagging of the tile in the disturbed soil around the observation wells. Joints were sealed with concrete and geotextile material. This was required to create a leak-proof joint so that both sampling wells could be effectively blocked. A PVC tee was pressed on to the tube and a vertical standpipe installed on both sampling wells. A threaded cap was screwed onto the tee on the east side when we blocked the tile. This provided a mechanism by which the water flow could be interrupted just prior to the manure application, while allowing for removal of samples (with a pump) and measurement of the head throughout the experiment.

These simple catch basins afforded easy access by one person, and after pumping the water in storage to below the inlet level, they also provided for easy measurement of flow rate and withdrawal of samples.

At Site B, the setup was less elaborate. It was intended to be operated more in line with how a farmer might plug the drains. Flow rates were measured and samples collected right at the outlet pipe in the ditch. To block the one drain, a simple and low-cost method was tried - it consisted of stuffing plastic and burlap bags into the tile and using the rodent guard to hold them in place.

Soil samples were collected at each site in order to get background soil nutrient levels and to determine the soil texture.

C -Manure Application - Swine manure was obtained from the co-operating farmer's liquid manure storage located near Site A. It was pumped into a liquid manure spreader.

At Site A, manure was spread on Nov. 22, 1994. The spread pattern was at 90 degrees to the laterals and the manure was broadcast onto the clover crop. One load covered two passes across the field. No manure was spread over the main tiles or areas with disturbed soil.

Manure was applied over the entire field at the approximate rate of 47,900 litres per hectare. Four samples of manure were obtained from four different levels in the manure tank during agitation, and they were analysed for ph, nitrogen, phosphorous, potassium, ammonium, dry matter, and E. coli. The first six parameters were analysed at the Department of Land Resource Science at the University of Guelph, Ontario, and the latter one was analysed at the Fusarium Laboratory, Ridgetown College of Agricultural Technology, Ridgetown, Ontario.

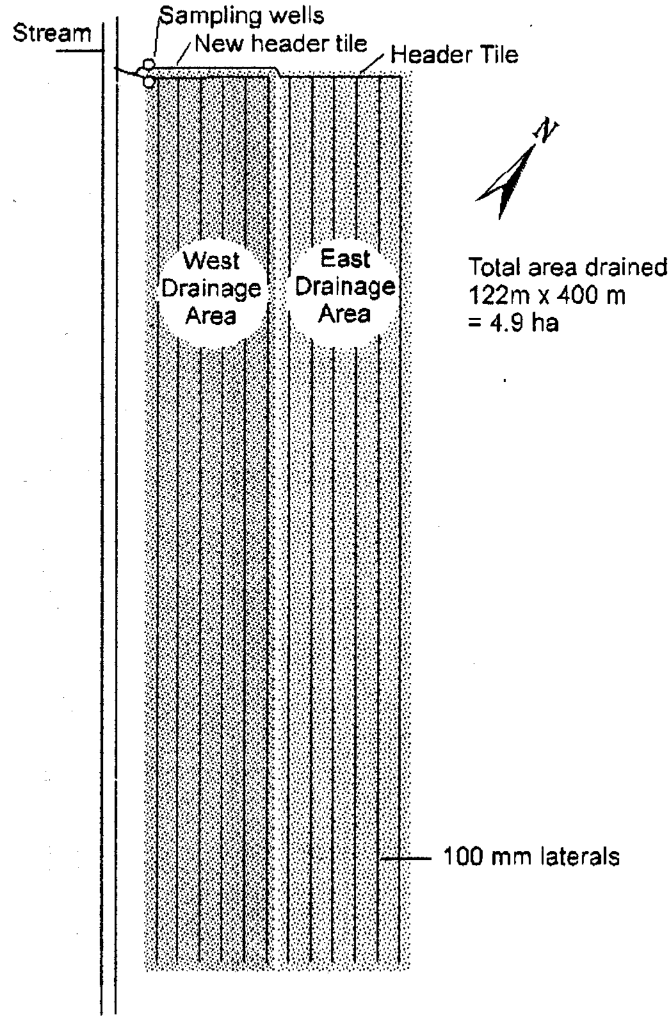

Figure 1 Field layout at Site A

Manure was spread at Site B on May 8 and 9, 1995. The field had been cultivated on May 4 and the soil surface was dry and loose. Once again, manure was broadcast onto the field. The spreading rate was uniform across the field and was maintained at about 15,200 L/ha.

D - Water Sampling - The flow rate in the various header tiles was measured by collecting a specific volume of water in a graduated container from underneath the lip of the inlet tube, and timing the collection with a stop watch. November 27, 28 and 29, flow volumes were determined by using a bilge pump connected to a data logger that logged the time at which the bilge pump started and stopped. The refill time was used to determine the flow rate of the open tile. The flow in the blocked tile when released on November 29, was determined by gradually releasing the water into the sampling well and pumping this water out onto the surface using an electric utility pump. The temperature was measured by a hand held probe inserted into the flowing water.

Precleaned, autoclaved, sample bottles, were held under the flowing water and filled in order to obtain samples for analysis. Water samples were analysed for E. coli at the Fusarium Laboratory, Ridgetown College, and the pH, total salts, nitrate, ammonium, phosphorous, and potassium at the Agricultural Laboratory Services, Ridgetown College.

RESULTS AND DISCUSSION

To help put the results from this phase of the study into perspective, selected results from the initial study (McLellan et al, 1993) are included in the analysis. These will be referred to as the 1992 project.

Site A - General - Sampling of background conditions at Site A was started on November 14, 1994. With limited precipitation and very dry soil conditions, background samples could only be collected on the few days of light precipitation. Samples were collected Nov. 14 (east and west tiles) and Nov. 21 (east only). Manure application was delayed as long as practical, hoping for adequate rainfall to produce a tile flow, but it did not occur. Manure was applied on the morning of November 22, 1994, between 9:30 am and 4:00 pm.

The east tile was blocked at 8:30 a.m., prior to manure application. It remained blocked for 7 days and one sample was removed during this time. There was no water in the tile until a 14.8 mm rainfall on Nov. 27. The water level in the stand pipe of the east tile rose to 35 cm above the invert of the tile (on Nov. 27) . The water level in the stand pipe dropped to 33 cm on Nov. 28 and 20 cm Nov. 29. On November 29, 1994, 1:10 p.m., the cap on the tee in was removed and the water in storage (approximately 1348 L) was drained away. The entire volume of water was pumped out of the sampling well using an electric utility pump calibrated for a flow rate of 57 L/min.. Water samples were collected to establish nutrient and bacteria levels. The remaining samples were collected on an "event" basis since tile flow stopped by Nov. 30. The last samples were collected on December 9, 1994.

Site A - Manure Application - Table 1 gives a summary of manure characteristics for the study at Site A (Fall 1994) as well as Site B (Spring 1995) and the 1992 study. These numbers are typical for swine manure. It is also evident that the nutrient levels for the same farm are similar from one sampling date to the next.

Table 1: Summary of Manure Analysis Results

Parameter	Fall 1992	Fall 1994	Spring 1995
Type	swine	swine	swine
No. samples	6	4	2
%N	0.30	0.45	0.44
%P	0.07	0.13	0.12
%K	0.14	0.30	0.21
NH_4-N mg/kg	1490	3645	3030
% Dry Matter	1.83	2.91	2.21
E. Coli	$6.96(10)^6$	$5.36(10)^5$	-
Fecal Coliform	$9.20(10)^6$	-	$7.75(10)^6$
pH	-	7.5	7.15

Site A - Water Quantity and Quality - The cumulative volumetric flow over the study period for the east observation well (blocked) was 1.12 times greater than the west observation well, and drained a slightly smaller area (2.36 ha vs 2.48 ha). The flow volumes are summarized in Table 2.

Table 2: Summary of Cumulative Loadings

Water Quality Parameter	East Blocked	West Not Blocked	Ratio E:W
Ammonium-N (g)	4.4	6.9	0.63
Nitrate-N (g)	48.8	16.1	3.04
Phosphorus (g)	2.9	5.7	0.51
Potassium (g)	25	36	0.69
E.Coli*	$7.20(10)^7$	$2.42(10)^8$	0.30
Cumul. Flow (L) (Nov. 14 to Dec.9)	4227	3761	1.12
Drainage Area (ha)	2.4	2.5	.0.96

*Total Number of organisms

Ammonium-N

Inorganic nitrogen in manure is mostly in the form of ammonium. Ammonium in the soil can also come from the initial decomposition of nitrogen-fixing organic matter. Background levels of ammonium concentrations ranged from 0.1 to 0.2 mg/L. During the rain of November 27, an increase in ammonium concentration was observed in the west observation well. The maximum value observed was 9.4 mg/L. In the east observation well, the maximum value was 2.4 mg/L, observed 6 days after the removal of the plug.

In Figure 2, cumulative mass loading is plotted against time for the west and east observation wells. This graph shows that the flow interruption resulted in a lower total amount of NH_4-N leaving the drain (63%). The west well produced 7 g of ammonium, whereas the east well produced 4 g (see Table 2). The corresponding ratio in the 1992 study was 41%.

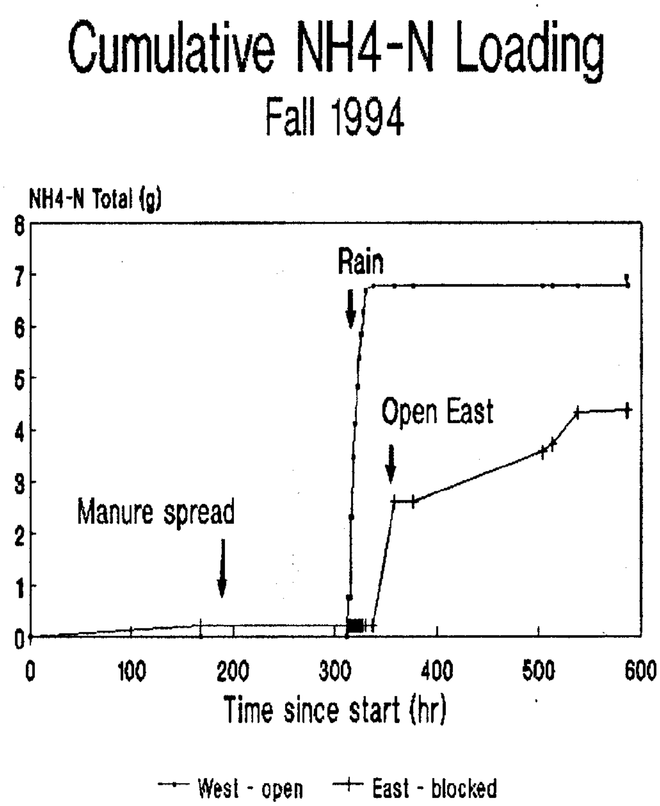

Figure 2 NH4-N form the blocked and unblocked drains

Nitrate-N

Most nitrogen resident in agricultural soils is in the form of nitrate, derived from either chemical fertilizers, animal wastes, or the ultimate breakdown of nitrogen fixing legumes. Land application of liquid manure did not produce a peak in nitrate-N concentration in this study. The highest concentrations observed in the east and the west wells were 24.1 and 10.8 mg/L respectively, independent of the manure application.

The total mass from the east field was 48.8 g, and 16.1 g from the west field (see Table 2). This is consistent with the lack of impact on nitrate from the manure application. The nitrate numbers were similar to those observed in the 1992 study. It is unclear why the east side should contribute three times as much nitrate as the west. What is consistent with other studies is the fact that the majority of N leaving a tile drain is in the nitrate form.

Bacteria

Water samples were analysed for E. coli bacteria. The results shown in Table 2 suggest that blocking the tile was most effective at reducing bacteria levels. The blocked drain had only 30% of the bacteria that flowed from the unblocked drain.

The peak concentration of E. coli was observed to be 12,500 organisms per 100 mL in the west well, and 9,500 organisms per 100 mL in the east well. Before commencing manure application, no bacteria was measured in the drains. The elevated levels of bacteria in the drains coincided with the rainfall shortly after manure application. The cumulative loading of bacteria is displayed in Figure 3. This graph helps to demonstrate the significance of the timing of the rainfall on bacteria loadings in the drains.

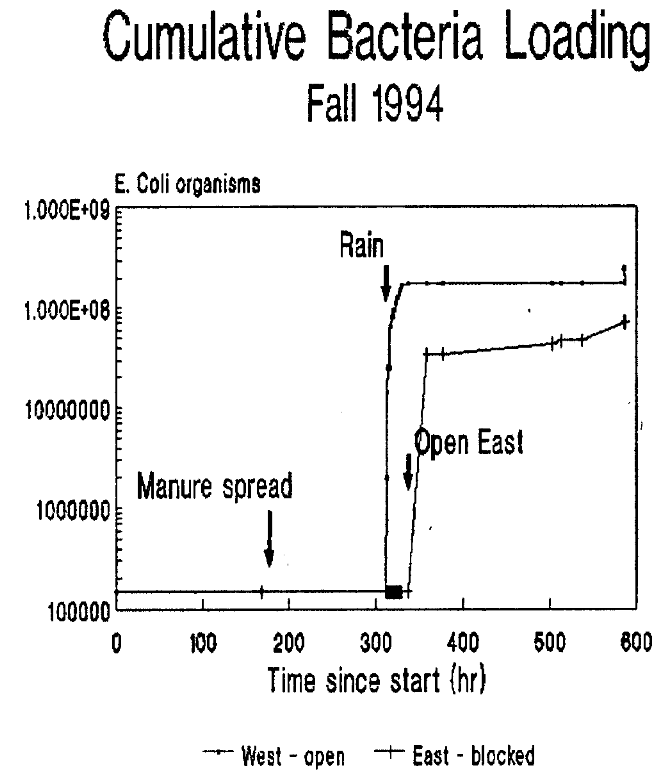

Figure 3 Loading of E.Coli bacteria from the blocked and unblocked drains

Other Parameters

Phosphorus is a relatively immobile element in the soil. Background levels of phosphorous were 1 to 1.75 mg/L in the west tile and 1 to 1.5 mg/L in the east tile. The maximum value observed was 7.4 mg/l in the west tile during the rain of Nov. 27, and 1.4 mg/L in the east tile following the removal of the flow blockage.

Potassium is a fairly soluble nutrient that is readily found in clay soils in southern Ontario. It is also available from chemical fertilizers and manure application. The background levels in the soil were 4.7 mg/L in the west field and 3.2 mg/L in the east field. In the west tile the maximum value observed was 3.1 mg/L during the rain on Nov. 27. The east tile maximum value was 9 mg/L observed on Dec. 9 when the drain was opened.

Site B - General - Background water sampling at Site B began on May 2, 1995. Water samples were taken from three of the four outlets. Tile #1 was a 300 mm pipe (all outlet pipes were corrugated steel) and drained 17.4 ha. Tiles #2, 3, and 4 were 150 mm pipes and drained areas of 6.7, 9.9, and 6.9 ha, respectively. On May 4, part of the field (approximately half of the field was already in winter wheat) was cultivated and on May 8 and 9, manure was spread. At spreading time, tile #1 was blocked. The largest of the outlet pipes was chosen for blocking even though it proved to be the hardest to seal. Various methods were tried and the best method at the time appeared to be stuffing the pipe with plastic and bags. This did not provide a complete seal, unfortunately.

The drains were all running, though not much. The amount of water leaking out of the blocked pipe was about equal to the flow from the field. On May 9, 15 mm of rain fell on the site. This was followed on May 10 with an additional 12.5 mm, and on May 11 with 4.4 mm. The soybeans had not been planted before the rains came. The flow rate increased and water pressure started to build in the plugged drain - to a maximum of 950 mm above the top of tile #1 (the soil cover over this tile was 1050 mm). Because the farmer still hadn't planted this field, and because the blocked tile was obviously slowing down the drainage in the field, the tile was unplugged on May 12.

Site B - Manure Application - Table 1 gives information about the nutrient content of the manure applied to Site B. The spreading rate was less than half of that used the previous fall on Site A. Also, soil macropores had been broken up by the cultivation of a few days previous to manure spreading. As expected, therefore, manure spreading did not cause any immediate impacts on water quality.

Site B - Water Quantity and Quality - Similar to Site A, flow rates were measured only at the time of sampling and flows between sampling times were estimated. This site was complicated by the fact that the drainage areas were not equal in size, and that only parts of the drainage areas received manure. Table 3 summarizes some of the cumulative loadings that help demonstrate the impact of partially blocking Tile #1.

Table 3 Summary of Loadings for Site B

	Tile #1 - Partially Blocked	Tile #2 - Open	Tile #4 - Open
Ammonium-N (mg)	72400	560	340
Nitrate-N (kg)	169	131	136
F.Colif (# organisms)	$8.9(10)^9$	$4.9(10)^{10}$	$5.4(10)^9$
Flow (m^3)	102	7.4	7.4
Drain Area (ha)	17.4	6.7	6.9

It is obvious that much more ammonium-N left the drain that was partially blocked that the drains that were open. One should keep in mind that, even though Tile #1 was blocked, it leaked so much that the flow still exceeded the other drains. Also, the drain was blocked for only 3 days from the start of the rains (which carried some manure constituents to the tile drains). It is not clear why the total nitrate-N loading from the open drains exceeded tile #1.

An attempt was made to remove water samples from behind the drain plug in Tile #1 to observe the change in bacteria density over time. Even though this drain leaked so much, the bacteria appear to die off as one might expect. The water temperature in the tile was in the range of 9 to 10 °C for the sampling period.

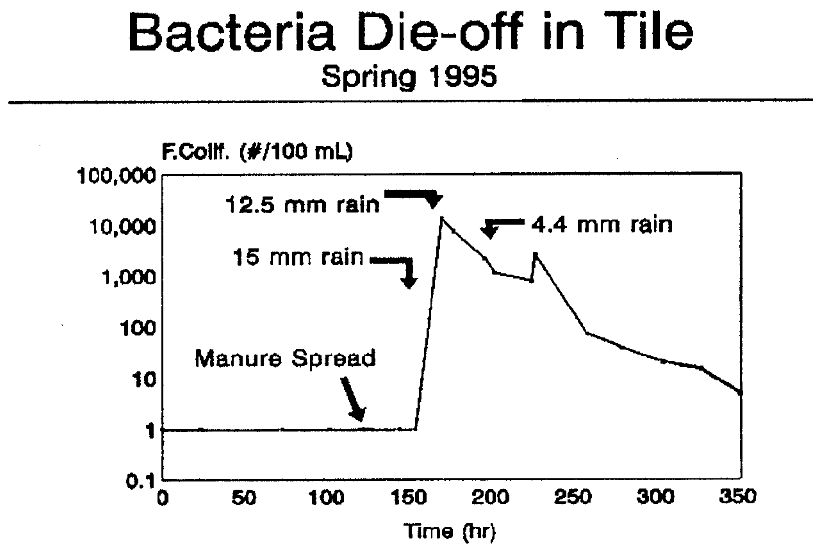

Figure 4 Density of fecal coliform bacteria in tile #1

General Discussion - For the technique of plugging drains to be used by farmers, it must be shown that there are low-cost, convenient methods of blocking drains. Efforts to use inner tubes and basketballs to plug drains failed in the field. Stuffing with plastic was not much better. A lab trial was performed to test various methods of plugging corrugated steel outlet pipes. A head of 1200 mm of water was used to test seals in 150 mm, 200 mm, 250 mm, and 300 mm diameter corrugated steel pipes. To seal the pipes, materials were either "stuffed in" or "inserted and inflated". The inflation technique proved much more effective. Inner tubes are not able to withstand the pressures. The most effective method involved a volleyball or a broom ball that could take the pressure. These needed to be wrapped with foam (eg. Packing foam, camp mattress, pool noodle) to seal inside the steel corrugations. The larger diameter pipes were much harder to seal than the two smaller sizes.

For farmers to consider plugging a drain tile, it should not interfere with farming operations. This was pointed out in the Site B study. Leaving the tile blocked for the desired period would have delayed soybean planting by several days. While this may be a necessary precaution on serious manure spills, it was not warranted at the test site, especially in light of the low spread rate and the soil conditions at manure spreading.

Table 4 is an attempt to put into perspective the loading of NH_4-N to surface water for each of the three similar studies discussed (ie fall 1992 study, fall 1994, spring 1995). The 1992 study was closest to a "worst-case" situation and the manure was spread only on top of the soil over the lateral tiles (ie in a narrow strip). While the shock loading of NH_4-N can be very harmful to a stream, this study has shown that the total amounts can be quite small under certain circumstances.

Table 4 - Comparison of Tile Blocking Tests

	Fall, 1992		Fall, 1994		Spring, 1995	
	open	blocked	open	blocked	open	blocked
NH_4-N applied as manure (kg)	50.3	50.3	440	420	281	313
NH_4-N from drain (g)	181	74	6.9	4.4	0.90	72.3
% of applied in drain	0.36%	0.15	0.0016	0.0010	0.0003	0.023

SUMMARY

Spreading liquid livestock manure can result in rapid flow of a portion of the manure to subsurface tile drains, and the subsequent movement to surface water. This phenomenon only happens under certain conditions, which unfortunately can be hard to predict. In one of the two trials reported on here, blocking subsurface drainage flow helped reduce the peak concentrations and the total mass of NH_4-N leaving the system. In the other trial, the tile could not remain plugged long enough to have a significant impact on water quality. Spreading manure did not have an effect on nitrate concentration.

This did not turn out to be a tidy, controlled study. The fall of 1994 was dryer than normal, thus the drains did not flow as normal. The spring study was changed due to heavy rains, Indeed, at both sites, it appears the manure application to the field would have had no impact on drain water quality if it hadn't rained.

The farms where blocking of tile drains should be considered include those that are flat and level, having livestock, where the subsurface drainage outlet is easily accessed. The ideal length of time that the drain remains blocked is still not known, but it appears that it must be in the order of one week to reduce NH_4-N and bacteria loadings.

A heavy rain shortly after manure application (up to a few days) can cause manure constituents to move from the soil surface into tile drains (albeit in small quantities).

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