"Comparison of Solid, Liquid and Storage Runoff Manure on Tile Drain and Groundwater Quality."

Final Report

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DISCLAIMER

This project has been prepared for the Agricultural Fund Program, Ontario Ministry of the Environment Southwest Region (OME-SWR) in fulfilment of their requirements. The views expressed are those of the author and do not necessarily reflect the views and policies of the Ontario Ministry of the Environment.

ABSTRACT

Two manure applications of solid manure, liquid manure, and runoff containment were monitored following land application to compare the relative bacterial and nutrient loading to tile drains. These spreading events took place in September and October of 1992.

In both the September and October manure applications the liquid manure and runoff containment resulted in tile drain contamination. The spreading of liquid manure resulted in the greatest level of bacterial and nutrient loading, the bacterial biotracer concentrations were approximately 7 times greater than those monitored following the application of the runoff containment. The application of the runoff containment also resulted in bacterial and chemical contamination in the tile drain water, although the level of contamination was less significant than that of the liquid manure. Solid manure application did not result in tile drain or groundwater contamination. Soil bacteria analysis indicated movement of the bacterial biotracer within the soil profile to a depth of 70-75 cm following liquid manure application in both trials.

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INTRODUCTION

Previous research conducted by the Ausable Bayfield Conservation Authority in 1989 and 1990 revealed that the land application of manure can rapidly degrade tile water quality under normal farming practices. Of the twelve manure spreading events that were monitored, eight resulted in water quality degradation within 20 minutes to 6 hours. It was concluded that the rate of manure application (L/ha) had little bearing on whether or not tile drain contamination occurred; that no or very low tile drain flow resulted in least contamination; and that macropores appeared to be the main pathway for manure components to travel through the soil column and enter the receiving water. Studies by Patterson *et al.* (1974) and Evans and Owens (1972) found contamination in the field tiles after the application of swine slurry within 30 minutes and 2 hours respectively. Soil macropores were thought to be the main pathway for manure components to reach tile drains. In agreement with this, Chandler *et al.* (1981) found that the contamination of subsoils following an application of piggery effluent occurred at a rate far in excess of the infiltration capacity of the soil suggesting flow of effluent through soil cracks.

Many studies have dealt with surface runoff from solid manure storage, feedlots and grazed pasture (Springer *et al.* 1983; Doran *et al.* 1981; Coate and Hore 1977; Loehr 1970). A study by Patni *et al.* 1985 involving bacterial runoff from manured cropland stated that hydrological conditions greatly affect bacterial concentrations in runoff. The management practice of dry weather manure application followed by immediate plowdown on mostly level topography resulted in relatively better water quality of manured cropland runoff compared to other studies. They also reported that long term stored manure had a lower indicator bacteria concentrations compared to relatively fresh manure. This suggested a lower potential for pollution from land application. No studies could be found relating bacterial and nutrient loading from applications of solid manure to field tile drains.

Timing is also an important factor to consider when discussing the spreading of manure, as the movement through the soil column is strongly related to soil moisture content. Bacteria must move within the saturated zone because they lack a hyphal system to bridge air spaces in soil (Hagedorn *et al.*, 1978). Reddy *et al.* (1981) established that the capacity of soil to remove organisms increases with soil moisture content.

STUDY OBJECTIVES

The objective of this study was to compare solid manure, liquid manure, and runoff from a solid manure storage combined with milkhouse wastes (runoff containment) on their relative bacterial and nutrient loading to the tile drain and groundwater.

METHODS

Description of Study Area

The manure application trials were conducted on a four hectare field approximately 20 kilometres southwest of Exeter, Ontario on imperfectly drained Perth clay loam soil. It is a systematically tiled field with 15 metre tile spacings, and has been in a corn/bean/cereal rotation under conventional tillage for a number of years. A soil profile description is included in Appendix A. Figure 1 is a detailed sketch of the study area.

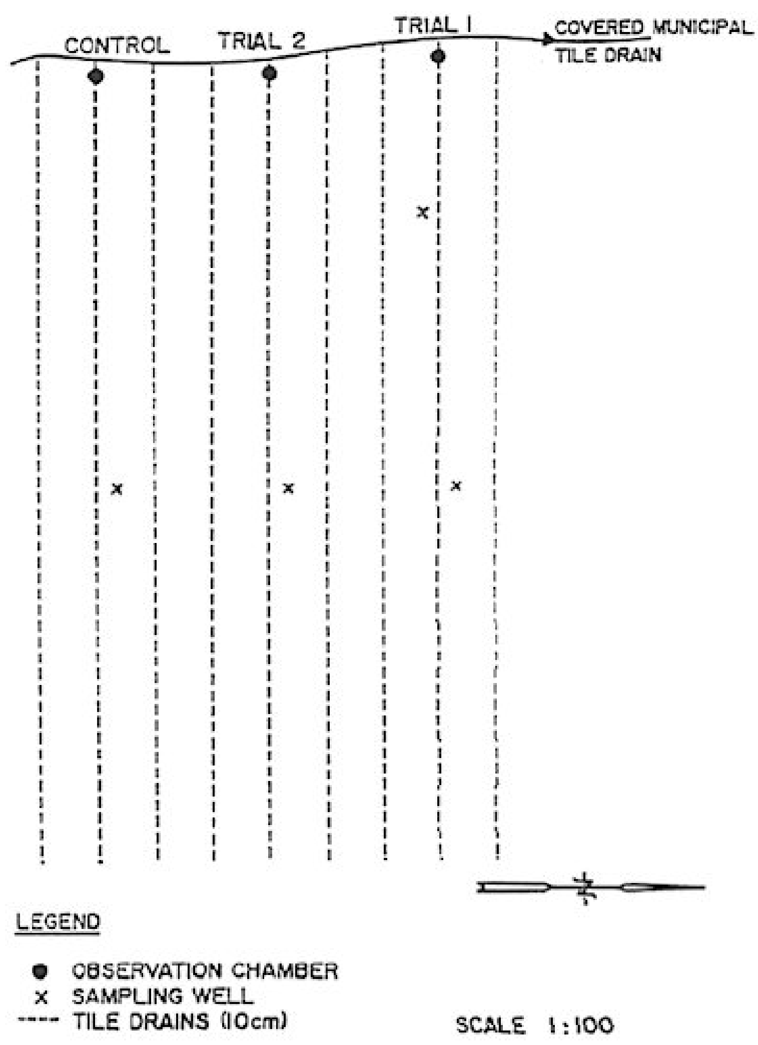

Figure 1: Detailed Sketch of Study Area

Three observation chambers (Figure 2) which are located at each trial site on the study location were positioned to allow water samples and discharge measurements to be taken from each of the tile drains. Four sampling wells (Figure 3) which vary in depth from 2.2 to 4.1 metres were installed to enable monitoring of groundwater quality, and levels.

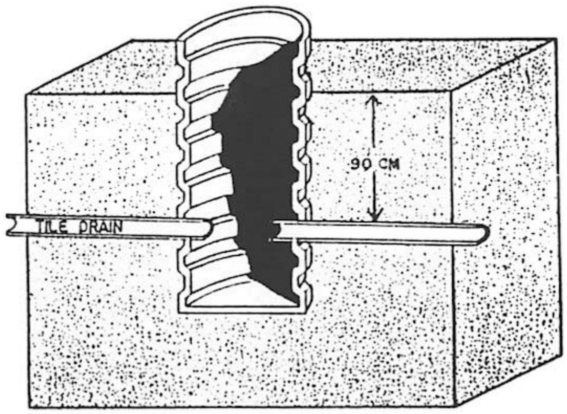

Figure 2: Cross Section of Observation Chamber

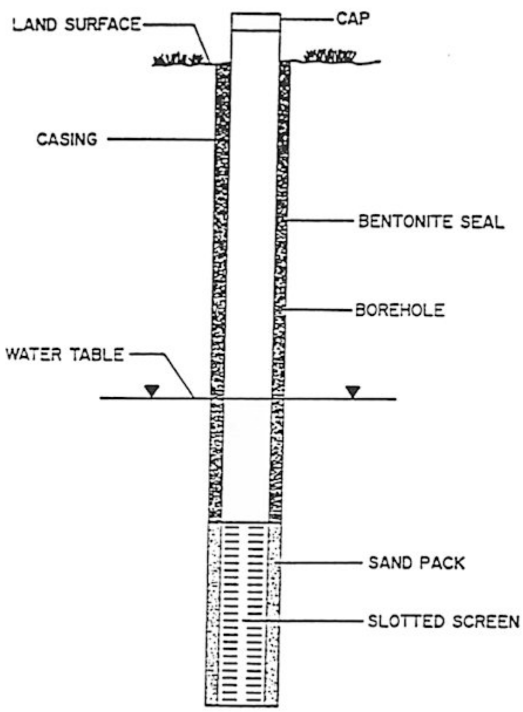

Figure 3: Cross Section of Sampling Well

Water and Manure Sampling and Analysis

The liquid manure, runoff containment, and solid manure samples were obtained from the storage areas prior to manure application. Samples from the tanker and box spreader during the time of spreading were taken using collection pans. A minimum of 3 bacteria and 2 chemical samples were taken from the storage, and at the time of spreading so that an average calculation of concentration could be obtained. The collection pan samples were used as an indicator as to whether or not changes in concentrations occur as a result of manure transport or application. Samples collected from the solid manure storage were also analyzed for nitrogen, phosphorus, and potash content at Agri-Food Laboratories in Guelph, an Ontario Ministry of Agriculture and Food (O.M.A.F) accredited laboratory.

Tile drains were monitored weekly for a one month period prior to the scheduled manure application. Intensive water sampling took place on the day of manure application, followed by daily samples for a 5 day period following the spreading event. Measurements of tile drain discharge were taken at the time of sampling by measuring the specific time it takes to fill a container of a measured volume.

Weekly grab samples of water from the wells were taken for one month proceeding the scheduled manure spreading event. Approximately 3 days prior to the scheduled event the sampling wells are bailed. For 5 days following manure application the samples continue on a daily basis. Well depth is measured prior to each sample using a water sensor. The samples are obtained by lowering a sterilized copper tube.

Bacterial parameters analyzed in the water and manure included; fecal coliform, fecal streptococcus, *Escherichia coli* and the biotracer, nalidixic acid resistant *Escherichia coli*. The biotracer was introduced into the manure prior to application so that the bacterial movement through the soil could be traced through the soil column and into the receiving waters. The tracer organism was originally isolated from the environment by G. Palmateer, Ontario Ministry of the Environment Southwest Region (OME-SWR). The *E. Coli* (NAR) is non entero-pathogenic, is easily recovered from the soil and water and is not commonly present in the natural environment. The tracer bacteria was injected in concentrations that are approximately equal to the concentrations of indigenous bacteria found in the liquid waste.

Water and manure samples were analyzed for the chemical parameters; suspended solids, free ammonia, total kjeldahl nitrogen, nitrate, nitrite, total phosphorus, potassium, conductivity and pH.

The water and manure samples were stored on ice immediately and transported to OMESWR for microbiological and chemical analysis which was performed within approximately 24 hours. Laboratory methods used by the microbiology and chemistry departments were those outlined by the Handbook of Analytical Methods of Environmental Samples (OME 1984b). In addition the microbiology department used the Standards Methods for the examination of Water and Wastewater (APHA) 1985.

Soil Sampling and Analysis

Soil samples for bacteria analysis were taken a few days prior to and within three hours following the application of the manure. Soil samples were taken at 5-10 cm, 30-35 cm, and 7075 cm depths in the soil column using a sterilized coring device. Soil samples were collected in sterile jars, stored on ice, and analyzed within 24 hours. The same bacterial parameters described for in the manure and water were examined in the soil samples. These samples were also analyzed at the OME-SWR. The multiple tube fermentation technique was used to determine the bacterial concentrations in the soil (APHA) 1985. Results of the examination using replicate tubes and dilutions were reported in terms of the Most Probable Number (MPN).

Soil Moisture

Soil samples were collected to obtain the soil moisture content so that the relationship between bacterial movement in saturated soil and soil moisture could be determined. The methods and procedures used for obtaining the soil moisture content are those outlined in Methods of Soil Analysis, Gardner 1965.

RESULTS AND DISCUSSION

Climatic Conditions

Appendix B includes the mean hourly temperature, relative humidity and wind velocity for each of the days on which the manure spreading events took place. Daily records of the rainfall data from July 1, 1992 to Dec 30, 1992 are also available in Appendix B. The climatic data was obtained from a weather station at Centralia College, Huron Park. The rainfall received in the study area was greater than normal and was accompanied by unusually low temperatures. The first event was scheduled to take place on August 24, 1992, but had to be delayed due to the cool and wet conditions, and several rain delays. The first spreading event did not take place until September 14, 1992. The rainfall received in September was nearly 70 mm more than the 30 year average. October rainfall also exceeded the 30 year average. Field tiles remained flowing throughout September and October.

Summary of September 14/92 Spreading Event

On May 7, 1992 the research plot was planted in spring oats and underseeded with red clover. The oats were harvested on September 2, 1992 with the straw being chopped and spread back on the field. Surface residue on the day of spreading was approximately 96% on the study site. The soil moisture before the manure application at the following depths 5-10 cm, 30-35 cm, and 70-75 cm were as follows 22%, 18% and 15%, respectively.

Table 1. contains a description of the September 14, 1992 manure spreading comparison including tile flow rates, manure type, application method and rate, surface residue, surface conditions, and time taken to apply the manure. The source of the solid beef manure was located at the research farm and three spreader loads were applied to Trial 1. The runoff containment consisted of milkhouse waste and runoff from a solid manure stack, combined in a covered storage tank. The liquid swine manure was from a farrow to finish hog operation with a covered tank. Both the liquid swine manure and runoff containment were transported approximately 2.5 kilometres to the plot area.

Five tanker loads (60,160 L/ha) using an 1100 gallon tanker were applied to Trials 2 and 3, which explains the longer length of time taken to apply the liquid manure and runoff containment. As well, a pump breakdown was experienced while the runoff containment was being spread causing further delay.

Table 1. Summary of September 14/92 Spreading Event

Event	Trial	Tile Flow Rate (L/s)	Manure Type	Appl'n Method	Appl'n Rate	Appl'n Time (hours)	Surface Residue %	Surface Conditions
Sept. 14	1	0.018	solid beef	solid spreader	19.7 t/ha	2	95	- very few 1 mm cracks - many 1 min dia. pores
	2	0.010	dairy runoff	tanker	60,160 L/ha	4	97	- very few 1 mm cracks - few 1 mm pores
	3	0.010	liquid swine	tanker	60,160 L/ha	1.5	96	- few 1-1.5 mm cracks - some 2 mm pores

Bacterial Analysis

Within one hour following the application of the liquid manure containing the *E. Coli*(NAR), the bacterial biotracer was evident in the tile drain water. Loading remained high for the first 40 hours but had decreased significantly within 70 hours. *E. Coli*(NAR) concentrations of over 100 bacteria per 100 ml were still found in the tile drain water for seven days.

For Trial 2, which received the runoff containment, *E. Coli*(NAR) was evident in the tile drain water within two hours. The loading had dropped off considerably within 48 hours time. Concentrations decreased to less than 100 bacteria per 100 ml within 4 days.

Trial 1, which received the solid manure contaminated with *E. Coli* (NAR) showed no sign of the biotracer in the tile drain water in the first 70 hours following application. Soil bacteria data indicated that the *E. Coli* (NAR) was present at the 30-35 cm depth, 3 hours after application. A 25 mm rainfall occurred the sixth day following the manure application. A very low concentration of the biotracer was found in the tile drain water seven days after the spreading, but the concentrations were less than 100 bacteria per 100 ml.

Figure 4 indicates the *E. Coli*(NAR) loading to the tile drains for 48 hours following the application of the runoff containment and the liquid manure.

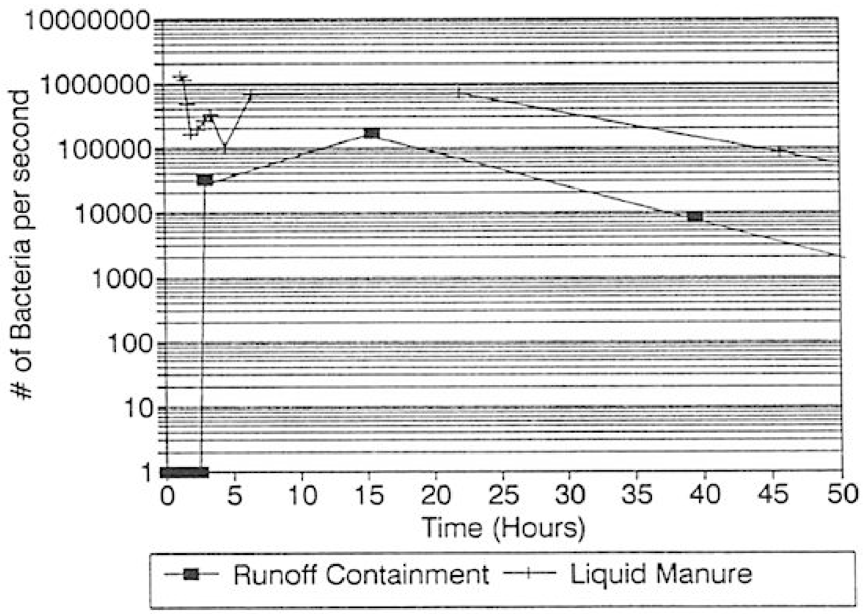

Figure 4: *E. Coli* (NAR) Loading September 14, 1992

Chemical Analysis

Figure 5 represents the Total Kjeldahl Nitrogen (TKN) loadings to the tile drains in the first 48 hours following the application of the liquid manure and the runoff containment. The site receiving the liquid manure (Trial 3) had a much higher loading of TKN than the runoff containment site. The peak loading was within 2 hours of spreading on the liquid manure site, and although the loading was significantly reduced within 70 hours, the levels did not return to the background concentrations until four weeks following the spreading event. The degree of loading to the tile drain was very minimal in Trial 2. No increases in nutrient levels resulted from the application of the solid manure.

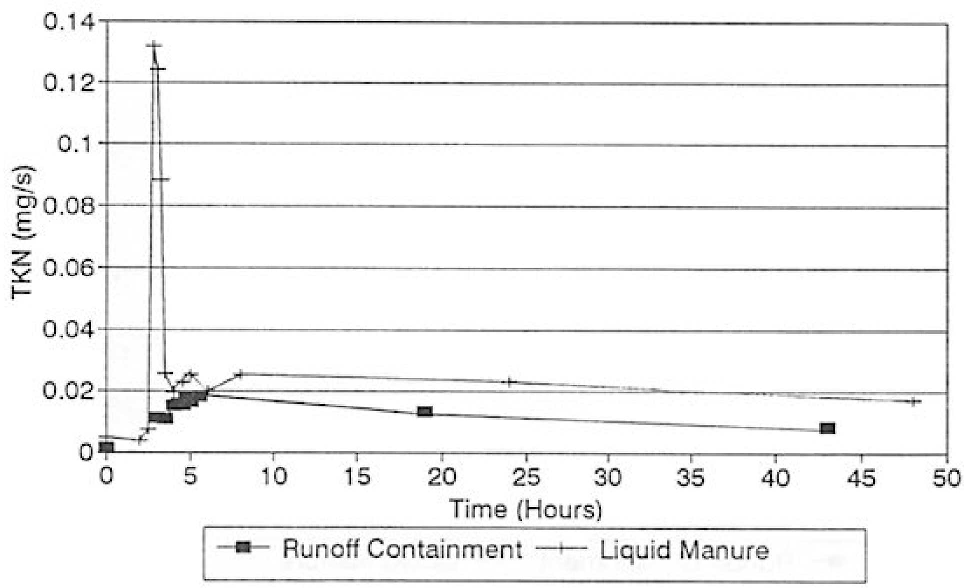

Figure 5: Total Kjeldahl Nitrogen (TKN) Loading - September 14, 1992

Figure 6 shows the loading of potassium in the tile drains following the manure applications. Trial 2 indicated the highest concentration of K at 8.4 mg/L, which was an increase of 2.3%. Trial 3 actually represented a higher degree of loading, an increase of approximately 5.4% over background levels.

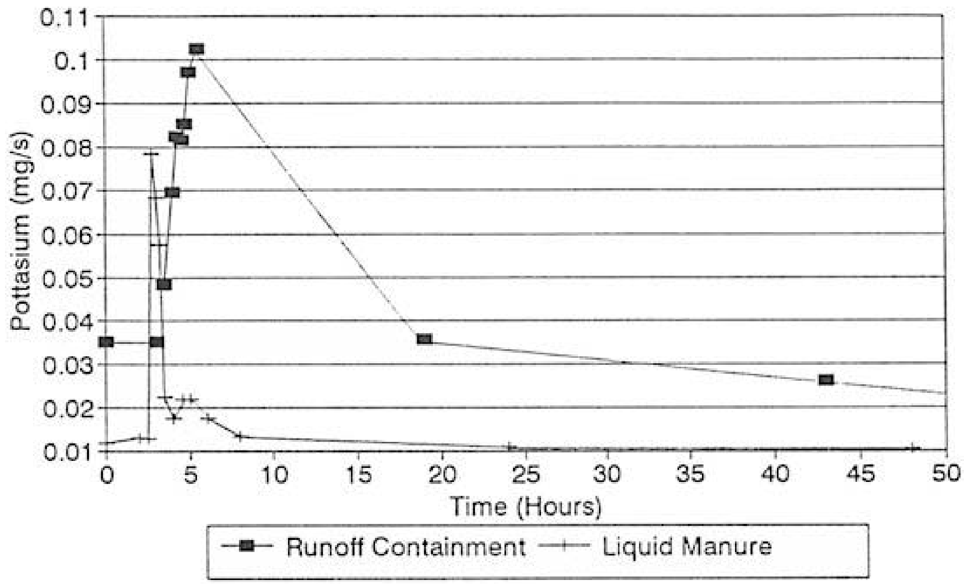

Figure 6: Potassium Loading September 14, 1992

Table 2 shows the average loads of *E. Coli*(NAR), TKN, TP, and K discharging from the field tile drains in the first 48 hours following manure application, as well as the percent loads which reached the tile drains. For all measured bacteria and nutrients, Trial 3 which received the liquid manure indicated a greater magnitude of loading.

Table 2. Loads of Bacteria and Nutrients to Tile Drains for 48 Hours Following Application

Site	Loads From Isolated Tile				Loads				% Applied			
	#/48hr	- - - - g/48hr - - -			g/ha/48hr							
	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K
Solid	-	-	-	-	-	-	-	-	0	0	0	0
Runoff	1.1662×10^7	0.32	0.18	0.22	2.9382×10^7	0.81	0.45	0.55	0.006	5.3×10^{-3}	0.01	0.02
Liquid	8.1996×10^7	0.83	0.14	0.10	2.0659×10^8	2.10	0.35	0.25	0.01	1.8×10^{-3}	2.5×10^{-3}	3.8×10^{-4}

Soil Analysis

Bacterial soil data (Figure 7) indicates the movement of the *E. Coli*(NAR) biotracer to the 70-75 cm depth within the soil column after the application of the liquid manure. The application of the runoff containment and the solid manure resulted in *E. Coli*(NAR) being present at the 30-35 cm depth.

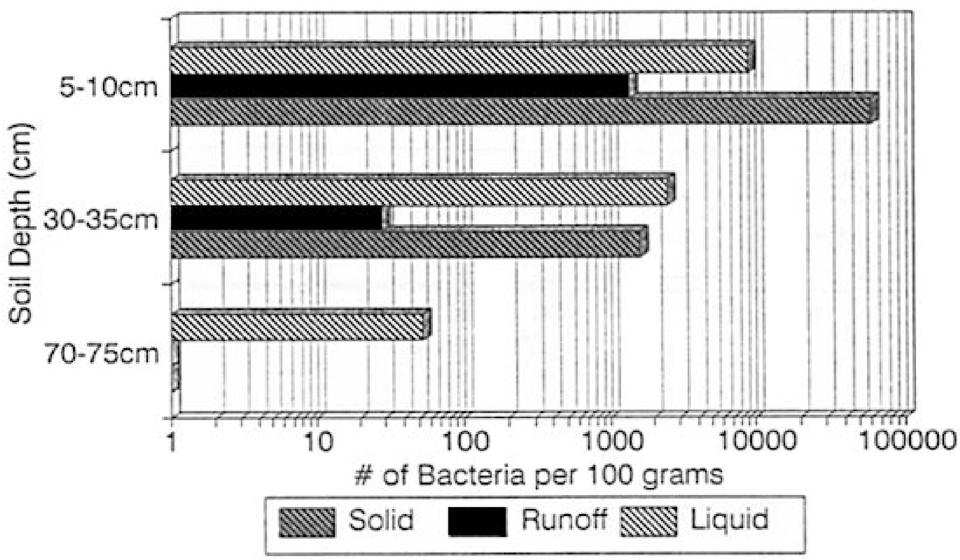

Figure 7: Soil *E. Coli*(NAR) Concentrations September 14, 1992

Groundwater Analysis

E. Coli(NAR) contamination was found in the piezometer samples four days following the application of liquid manure. No *E. Coli*(NAR) increases in the groundwater samples were detected from the runoff containment or solid manure application trials.

Summary of October 26, 1992 Spreading Event

Table 3 describes the study area on October 26, 1992. The field had very heavy residue coverage (98%). The average mass soil moisture prior to spreading for the entire area for the depths 5-10 cm, 30-35 cm, and 70-75 cm were as follows; 25%, 29%, 22%. Very few cracks were present in the soil, although there were many pores. The solid beef manure and runoff containment were obtained from the same operations as the previous spreading event, but the liquid manure was transported from a feeder pig operation with an open manure tank. The box spreader was used to spread the solid beef manure, and a larger (2200 gallon) tanker was used to apply the runoff containment and liquid manure, in an effort to reduce the application times, once again equipment failure delayed the spreading of the runoff containment on Trial 2.

Table 3. Summary of October 26/92 Spreading Event

Event	Trial	Tile Flow Rate (L/s)	Manure Type	Appl'n Method	Appl'n Rate	Appl'n Time (hours)	Surface Residue %	Surface Conditions
Oct. 26	1	0.015	solid beef	solid spreader	19.7 t/ha	1	96	- very few cracks <1 mm some 1 mm dia. pores
	2	0.011	dairy runoff	tanker	37,000 L/ha	3	100	-very few I mm cracks -some 1 mm dia. pores
	3	0.011	liquid swine	tanker	37,000 L/ha	1.25	96	-few cracks 0.5 - 2 min -many 1 mm dia. pores

Bacterial Analysis

Trial 3 which received the liquid manure applied at a rate of approximately 37,000 L/ha (4000 gal/acre), *E.Coli*(NAR) accumulations were detected in the tile drain water in less than one hour following initial application. Levels peaked at greater than 2,700,000 bacteria per 100 ml approximately 180 minutes (2½ hours) following the application of the contaminated manure. Elevated levels continued for 48 hours, but had declined substantially within 70 hours. Heavy rainfall on the already saturated soil did not allow sampling of the tile drains, but a sample obtained from the catchbasin on November 2, 1992 (one week following manure application) indicated levels in excess of 14,000 bacteria per 100 ml.

The application of the runoff containment injected with *E. Coli*(NAR) resulted in tile drain contamination within 2 hours following initial application. *E. Coli* (NAR) remained high for 70 hours, but had decreased significantly within 96 hours. Concentrations decreased to less than 100 bacteria per 100 ml two weeks following manure application.

Solid manure application did not result in the detection of the biotracer in the field tile until one week following the spreading event, the plot received nearly 25 mm of rain. Due to the saturated soil conditions the tile flow was too fast to allow bailing of the catchbasin, so samples were taken from the water contained within the catchbasin. Elevated concentrations were monitored on November 2, 1992 but had returned to background levels within one week time.

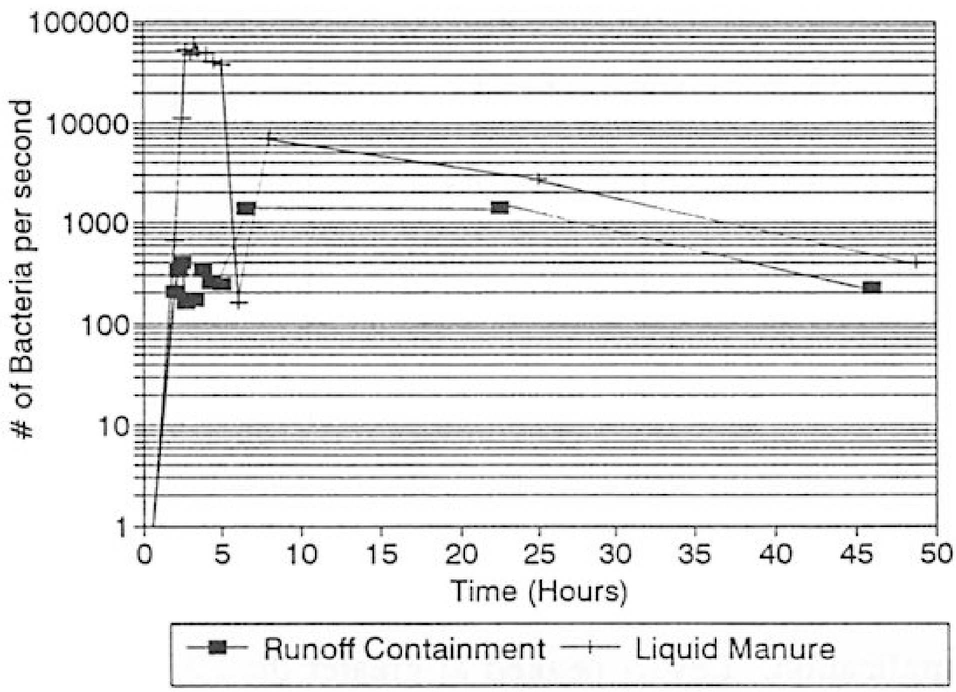

Figure 8: *E. Coli* (NAR) Loading October 26, 1992

Chemical Analysis

Total Kjeldahl Nitrogen (TKN) loadings in the October spreading event were significantly higher than those of the September spreading event. TKN loadings increased in less than 2 hours following application in Trial 2 and peaked within 4 hours. Trial 3 readings peaked at approximately 3 hours following the application of liquid manure. TKN levels decreased substantially after 24 hours in Trial 2, and within 70 hours following the spreading of the liquid manure (Figure 9). There was no chemical concentration increase following the application of the solid manure.

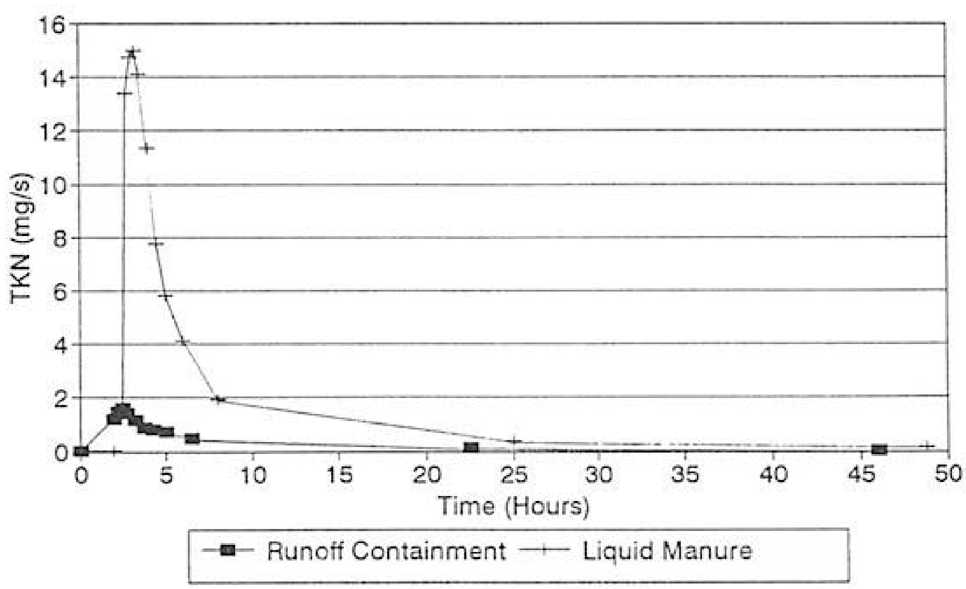

Figure 9: Total Kjeldahl Nitrogen (TKN) Loading October 26, 1992

Figure 10 shows the Total Phosphorus (TP) loadings to the tile drains for the first 48 hours after the application of liquid manure and runoff containment. Again the liquid manure application resulted in higher loadings to occur in the tile drains. Contamination was detected within 2 hours following spreading, and peaked at 2½ hours. Concentrations decreased substantially within 24 hours at Trials 2 and 3.

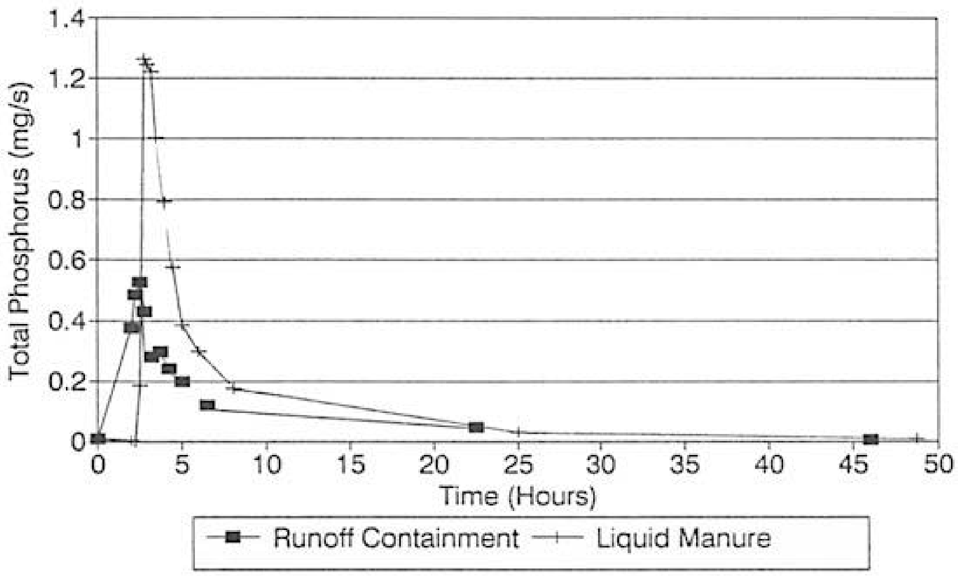

Figure 10: Total Phosphorus Loading October 26, 1992

Table 4 shows the average loads of *E. Coli*(NAR), TKN, TP, and K discharging to the tile drains in the first 48 hours following application, as well as the percent loads which reached the tile drains. Trial 2 which received the runoff containment shows a greater percentage of the nutrients applied actually reached tile drains.

Table 4. Loads of Bacteria and Nutrients to Tile Drains for 48 Hours Following Application

Site	Loads From Isolated Tile #/48hr	Loads From Isolated Tile - - - g/48hr - - -			Loads g/ha/48hr				% Applied			
	EC(NA}	TKN	TP	K	EC(NA)	TKN	TP	K	EC(NA)	TKN	TP	K
Solid	-	-	-	-	-	-	-	-	0	0	0	0
Runoff	$1.4863x10^8$	41.76	11.37	30.94	$2.6223x10^8$	73.68	20.08	54.59	0.01	0.845	0.812	0.324
Liquid	$8.7525x10^8$	221.85	17.58	120.15	$1.5442x10^9$	391.4	31.0	211.9	0.06	0.0028	0.0028	0.004

Soil Analysis

Soil bacteria samples indicated that *E. Coli*(NAR) was present at the 70-75 cm depth following the application of the liquid manure and the runoff containment. *E. Coli*(NAR) readings did not indicate that the tracer moved through the soil column following the application of the solid manure (Figure 11).

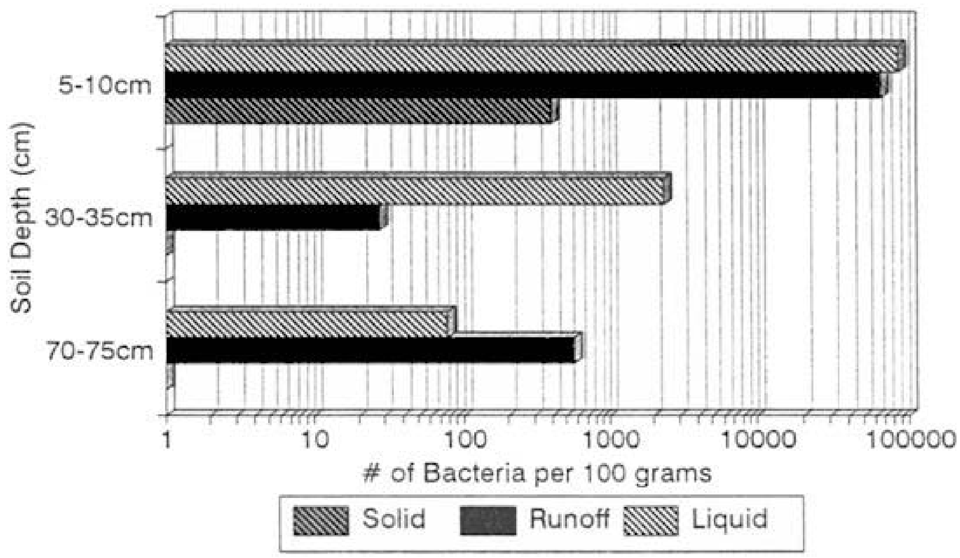

Figure 11: Soil *E. Coli* (NAR) Concentrations October 26, 1992

Groundwater Analysis

Piezometer samples did not indicate bacterial or nutrient contamination of the groundwater as a result of the October 26, 1992 manure applications.

CONCLUSIONS

Preliminary conclusions from the spreading events conducted would be that; the land application of liquid manure has a greater level of bacterial and nutrient loading to the tile drains as compared to the application of runoff containment; secondly that the increased time taken to apply the liquid manure and runoff containment resulted in a extended duration of tile drain contamination; and that the application of solid manure did not result in a significant level of contamination of the tile drain or groundwater. Further investigation into these manure applications should be studied for a better understanding of water quality impacts.

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