Influence of Hog Manure Application on Surface Runoff Water Quality

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Abstract

This paper describes some preliminary results from a field-scale study of the effect of field application of hog manure by injection on surface runoff water quality. In the study, manure injection at rates of 7,000 and 10,000 gal ac^{-1} are compared to an inorganically fertilized control at sites near the Bear Hills Pork Producers barn at Perdue and the new Prairie Swine Centre at Elstow. Surface runoff water quality is assessed during snowmelt and by rainfall simulation. Analysis of the preliminary data from Perdue indicates that concentrations of total and ortho P and NH_3 in snowmelt runoff from the basin receiving 10,000 gal ac^{-1} of hog manure increased relative to background measurements and the control basin. Concentrations of NH_3 also appeared to increase in snowmelt runoff from the basin receiving 7,000 gal ac^{-1} of hog manure. Although the rainfall simulation data were less conclusive, nutrient concentrations in runoff from the plots receiving hog manure appeared to increase relative to the control. There was no indication that hog manure application led to increased coliform counts in runoff water.

Introduction

Increasing numbers of hogs in Saskatchewan and a trend to larger-scale hog operations have raised environmental concern about the impact of hog manure on water quality. Hog manure is a valuable source of nutrients and its application to fields as fertilizer is an environmentally-sustainable solution to a waste disposal problem. However, with increasingly large amounts of manure produced in a single location and prohibitively high transportation costs, manure applications to fields close to hog operations may exceed environmentally sustainable rates. If nutrients are applied in excess of crop requirements they may be transported to surface water through runoff or to groundwater through leaching. While the organic C and micro-organisms in manure can be beneficial to soil, dissolved organic C, bacteria and parasites may pollute water resources. Research is required to confirm that hog manure can be applied to agricultural fields without negatively impacting the environment and to establish sustainable rates of manure application.

We have undertaken a field-scale study that is designed to assess the impact of hog manure application on soil and water quality by comparing two rates of manure application with an inorganically fertilized control and by comparing two methods of manure injection. This paper describes the methodology for the surface water quality component of the study and presents some preliminary results.

Methodology

Sites and Treatments

The research is being conducted at two sites; the first, near Perdue, receives manure from the Bear Hills Pork Producers barn, while the second, near Elstow, is supplied by the new Prairie Swine Centre. At both sites, two rates of manure (7,000 and 10,000 gal ac^{-1}) are applied every second year and compared to a control that is fertilized inorganically. At the Elstow site conventional and low disturbance injection will be used for both rates to give 5 treatments but at Perdue only low disturbance injection is used giving 3 treatments. Each treatment is studied at the landscape scale in a defined drainage basin. The basins range in size from 1 to 7 ha. Manure was applied in the fall of 1999 at the Perdue site but the first manure application at Elstow will not be until the fall of 2001.

The Perdue site is located in steeply rolling topography with slopes ranging up to 20%. The soils are Dark Brown Chernozems of the Keppel association with clay loam texture and organic C ranging from 1.4 to 2.7%. Since the site is externally drained with water flowing in well defined runways, weirs are installed each fall at the outflow of the basins to measure snowmelt runoff and provide a location for the water quality samplers. The Elstow site is more gently sloping (generally >2%) and is internally drained. Since runoff water accumulates in depressions on the landscape, runoff rate can be measured by monitoring the depth of water in the potholes and water quality samples can be taken from the potholes. The basins selected for this study all contain temporary pothole wetlands that only hold water for a few weeks after snowmelt. Soils at Elstow belong to the Elstow association of Dark Brown Chernozems and with silty clay loam textures they are slightly heavier than the Perdue soils and have less variable organic C (2.3 - 2.9%).

Snowmelt runoff water quantity and quality is measured each year and rainfall simulation is used to determine the impact of a runoff-producing storm. Rainfall simulations were conducted after harvest in late September to early October of 1998 and after seeding in late May to early June of 2000. Rainfall is simulated at 3 landscape positions (shoulder, footslope and backslope) in each basin. In 1998 the rainfall rate was 50 mm h^{-1} with a large droplet size but the simulator used in 2000 produced a rainfall rate of 70 mm h^{-1} with a small droplet size.

Water Sampling and Analysis

Automated water samplers were installed on the weirs at the Perdue site during snowmelt and programmed so that the runoff water was sampled every hour and composited over each 24-hour period to give daily water samples. Since the potholes at Elstow provided a natural composite sample, grab samples were taken each day during runoff from the centre of the pothole at mid depth. All samples were analysed for Total P, ortho P, nitrate (NO_3^-), ammonia (NH_3), dissolved organic C (DOC), coliforms and chloride (Cl^-). Nutrient analysis was performed at the Environment Canada Water Quality Laboratory in Saskatoon, coliforms were counted at the Saskatchewan Research Council Laboratory in Saskatoon and an ion-specific electrode was used to measure Cl^-.

Prior to snowmelt in each year, snow surveys were conducted to determine the snow water equivalent (SWE) in the snowpack of each basin and snow samples were collected and analysed for the nutrients listed above.

During rainfall simulation, water samples were collected at 5, 15 and 25 minutes after the start of runoff. All of the samples were analysed for total P and the 15 minute sample was analysed for the same parameters as the snowmelt runoff samples.

Manure samples were taken from the injection tanks and digested using sulphuric acid to determine total N and P. All samples were duplicates and samples were taken from the full tanks and again when the tanks were nearly empty.

Results

The N content of the manure in the injection tanks did not vary much and the low manure application rate was calculated to be 220 (± 10) kgN ha^{-1} while the high rate corresponded to 315 (± 15) kgN ha^{-1}. Phosphorus content of the manure samples varied considerably with samples from the empty tanks containing only half as much P as samples taken when the tanks were full. The low manure application rate corresponded to 60 (± 20) kgP ha^{-1} while the high rate was 90 (± 30) kgP ha^{-1}. Since all the watersheds received manure from more than one injection tank, the average values of N and P content are likely close to the actual applications.

Nutrient concentrations in the snowpack at Perdue in 1999 and 2000 are shown in Table 1. Total P, ortho P and NH_3 concentrations in the snowpack were greater in 2000 than in 1999. The greatest increases in total and ortho P were measured in the basin receiving the high rate of manure application and may partly reflect movement of nutrients from soil to the snowpack. However, the differences in ammonia concentration between the years were not likely due to the field application of manure since concentrations increased more on the control basin than in the basins that received manure. The ammonia in snow may reflect local deposition of emissions from the hog barn which was fully stocked in the winter of 1999/2000 but not in the winter of 1998/1999. It is also unlikely that differences in snowfall between the two years affected nutrient concentrations in snow since the concentration of NO_3^- was similar in both years and the difference in concentrations of the other nutrients was relatively greater than the difference in snowpack.

Table 1. Nutrient concentrations in the snowpack at Perdue in 1999 and 2000.

Year and Treatment	Total P	Ortho P	NO_3^-	NH_3
		mg L^{-1}		
1999				
All Basins	0.038	0.005	0.325	0.251
2000				
7,000 gal/ac	0.082	0.019	0.309	0.454
10,000 gal/ac	0.132	0.056	0.280	0.485
Control	0.092	0.016	0.423	0.644

In 1999, the average snow water equivalent in the basins was 75 mm at the start of melt while only 50 mm was present in 2000. The combination of a smaller snowpack and a slower melt in 2000 resulted in runoff volumes during snowmelt that were 3 and 4 orders of magnitude lower than those measured in 1999 (Table 2). Most of the runoff in 1999 occurred on March 26 when the temperature rose higher than 10 ºC after a number of days of above 0 ºC temperatures which had allowed the snowpack to ripen.

Table 2. Snowmelt runoff volumes from three basins at Perdue in 1999 and 2000.

	Control	7,000 gal ac^{-1}	10,000 gal ac^{-1}
		Runoff, L ha^{-1}	
1999 (excl. Mar 26)	290	745	480
March 26, 1999	7,250	7,250	38,420
1999	7,540	7,995	38,900
2000	0.5	2.3	35

The nutrient concentrations in snowmelt in 1999 and 2000 are shown in Figure 1. Runoff from the plot that received the high rate of manure application had higher total P, ortho P and NH_3 concentrations than runoff from the control and the low rate manure plot. In 2000, total and ortho P concentrations were slightly lower in runoff from the control basin and the basin that received 7,000 gal ac^{-1} manure than were measured in 1999 but the concentrations measured in runoff from the basin that received 10,000 gal ac^{-1} manure were much greater than measured before manure application. Total P concentrations in runoff from the 10,000 gal ac^{-1} basin were 4 times greater in 2000 than in 1999 while ortho P concentrations increased by an order of magnitude. Ammonia concentrations in runoff from the control basin were similar in 1999 and 2000 but there was a slight increase in NH_3 concentration in runoff from the 7,000 gal ac^{-1} basin from 1999 to 2000 and in runoff from the 10,000 gal ac^{-1} basin the NH_3 concentration increased by an order of magnitude. Nitrate concentrations in snowmelt runoff from all three basins were lower in 2000 than measured in 1999. Dissolved organic C in runoff was also slightly less in 2000 than 1999 while total coliform numbers and available ions were similar in both years.

The results for the rainfall simulations in Table 3 show that very different rain sources were used for the two sets of simulations. Both sources were low in phosphorus but the water for the 2000 had much more NH_3, NO_3^-, DOC and Cl^- than the 1998 source and coliforms were present in the 1998 source but were not detected in the rainwater used in 2000. The change in rainfall simulator and water source between 1998 and 2000 means that the data from the two years cannot be directly compared but we can compare the manured treatments to the control for each set of simulations. In 1998, before manure application, there was more total P, ortho P, NH_3, NO_3^- and DOC in runoff from the control treatment than from the treatments that would receive manure in 1999. However, in 2000, approximately 7 months after manure application, runoff from the control treatment had lower concentrations of total P, ortho P, NH_3, NO_3^- and DOC than the manured treatments. Chloride concentration was also lower in runoff from the control than from the manured plots in 2000 while in 1998 the Cl^- in the control had been intermediate between the 7,000 and 10,000 gal ac^{-1} treatment. Total coliforms counts were lower on the manured treatments than in the control in 1998 and 2000.

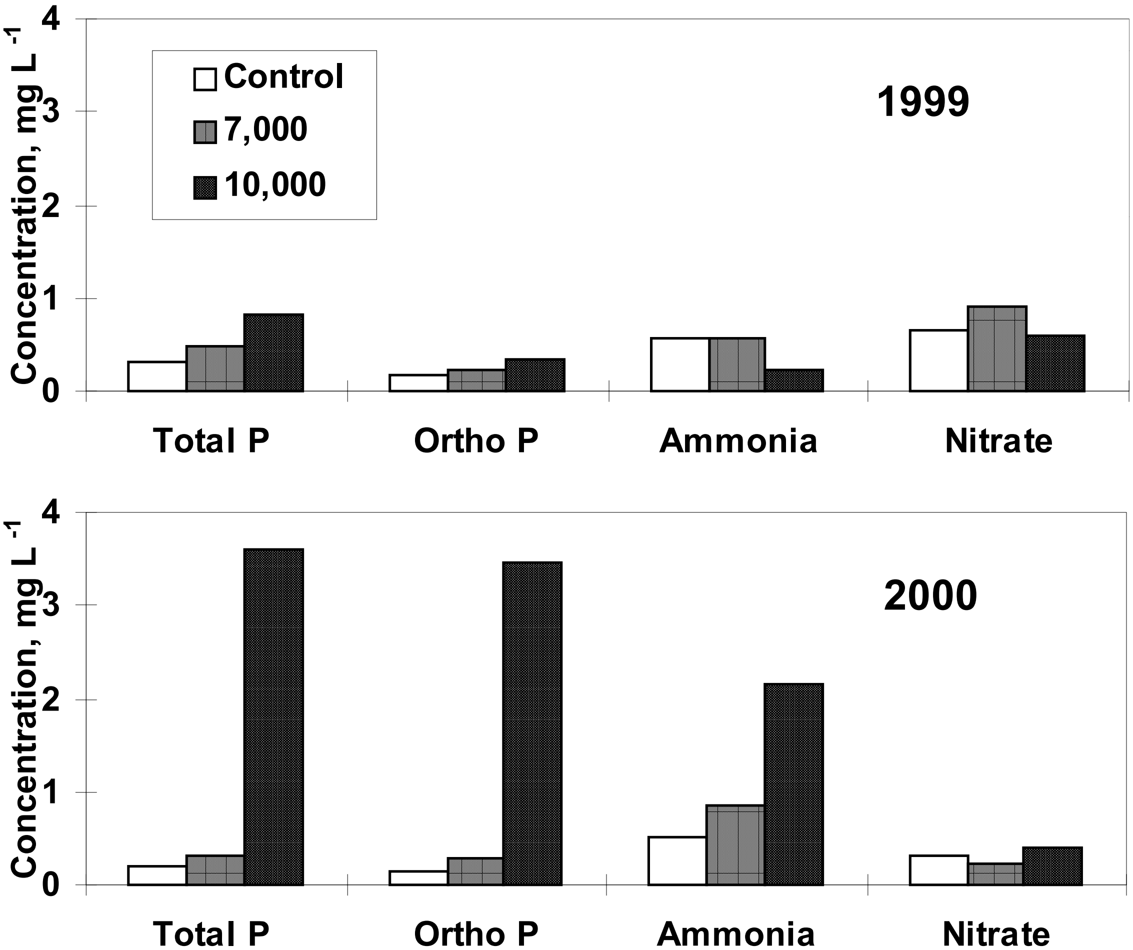

Figure 1. Average nutrient concentrations in snowmelt runoff water from the three basins at Perdue in 1999 (before manure application) and 2000 (after manure application).

Conclusions

Analysis of the preliminary data indicates that concentrations of total and ortho P and NH_3 in 2000 were greater in snowmelt runoff from the basin receiving 10,000 gal ac^{-1} of hog manure than they had been in snowmelt runoff prior to hog manure application. These concentrations were also greater than those measured in both the control basin and the basin receiving 7,000 gal ac^{-1} of hog manure. Concentrations of NH_3 also appeared to increase relative to background levels in snowmelt runoff from the basin receiving 7,000 gal ac^{-1} of hog manure. Nitrate concentration in snowmelt runoff were lower in 2000 than in 1999 on all treatments. Although rainfall simulation data from before and after manure application could not be compared directly, nutrient concentrations in runoff from the plots receiving hog manure appeared to increase relative to the control. There was no indication that hog manure application led to increased coliform counts in runoff water from snowmelt or rainfall simulation.

Table 3. Nutrient and coliform concentrations in runoff from rainfall simulations 15 minutes after the start of runoff.

Treatment	Total P	Ortho P	NH_3	NO_3^-	DOC	Cl^-	Total Coliform
			mg L^{-1}				ct/100 mL
1998							
Control	2.30	0.26	0.28	0.39	7.80	3.48	1700000
7,000 gal/ac	1.21	0.03	0.21	0.22	5.34	4.03	
10,000 gal/ac	1.85	0.03	0.13	0.09	5.15	3.21	26200
Rain	0.02	0.01	0.17	0.04	3.06	3.29	>24000
2000							
Control	0.61	0.04	0.42	0.75	6.24	25.39	249
7,000 gal/ac	1.98	0.94	1.76	5.16	9.21	29.94	17
10,000 gal/ac	0.88	0.23	0.69	3.62	6.77	34.27	127
Rain	0.01	0.00	0.44	1.50	4.85	31.20	<1

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