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 a site near the Bear Hills Pork Producers barn at Perdue, SK. Surface runoff water quality is assessed during snowmelt and by rainfall simulation. Analysis of the preliminary data 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 the previous fall 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. Elevated P concentrations were also measured in runoff from the manured plots the following year. 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
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, SK, receives manure from the Bear Hills Pork Producers barn, while the second, near Elstow, SK, is supplied by the new Prairie Swine Centre. Since manure has yet to be applied at the Elstow site, this paper deals only with results from Perdue. At Perdue two rates of manure (7,000 and 10,000 gal ac^{-1}) are applied every second year using low disturbance injection and compared to a control that is fertilized inorganically. Each of the 3 treatments is studied at the landscape scale in a defined drainage basin ranging in size from 4 to 7 ha. Manure was applied in the fall of 1999.

The topography at Perdue is steeply rolling 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.

Snowmelt runoff water quantity and quality have been measured each year since 1999 and rainfall simulation has been 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, installed on the weirs at the Perdue site, were activated 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. 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 have increased from 1999 to 2001 (Table 1). Total and ortho P concentrations in 2000 and 2001 were highest on the treatment that received the high rate of manure application and may partly reflect movement of nutrients from soil to the snowpack. The increase in NH_3 concentration since 1999 may be due to local deposition of emissions from the hog barn which was fully stocked in the winters of 1999/2000 and 2000/2001 but not in the winter of 1998/1999. Ammonia deposition may also have affected NO_3 concentrations but since some of the NO_3^- is due to long-range transport in the atmosphere and deposition, the increased concentrations in 2001 may also reflect the smaller snowpack.

Table 1. Nutrient concentrations in the snowpack at Perdue from 1999 to 2001.

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
2001				
7,000 gal/ac	0.253	0.060	0.490	0.657
10,000 gal/ac	0.375	0.109	0.433	0.513
Control	0.222	0.057	0.504	0.555

In 1999, the average snow water equivalent in the basins was 75 mm at the start of melt while 50 mm was present in 2000 and only 33 mm was measured in 2001. The combination of a smaller snowpack and a slower melt in 2000 resulted in runoff volumes during snowmelt that were much lower than those measured in 1999. In 2001, snowmelt runoff

was only generated on 2 days because of the small snowpack and dry conditions in the fall of 2000. Total flows were considerably less than in 2000 on all treatments.
The nutrient concentrations in snowmelt in 1999, 2000 and 2001 are shown in Figure 1. In 2000, runoff from the plot that received the 10,000 gal ac^{-1} manure application had higher total P, ortho P and NH_3 concentrations than runoff from the control and the 7,000 gal ac^{-1} plot. Although the total and ortho P concentrations on the control and 7,000 gal ac^{-1} plot were comparable to those measured prior to manure application (1999), the concentrations

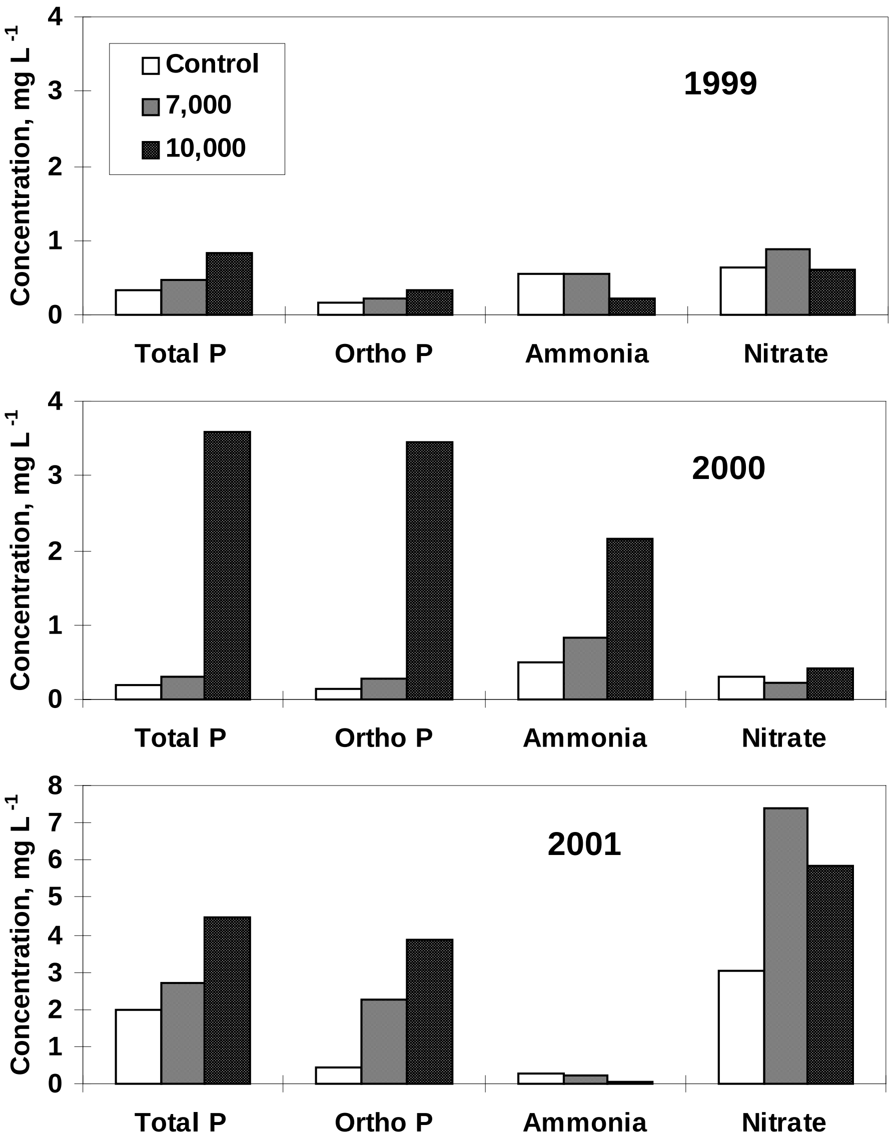

Figure 1. Average nutrient concentrations in snowmelt runoff water from the three basins at Perdue in 1999 (before manure application), 2000 (the spring after fall manure application) and 2001 (one year after manure application). Note that the scale on the concentration axis is different in 2001 than in 1999 and 2000.

measured on the 10,000 gal ac^{-1} plot in 2000 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.

In 2001, concentrations of total and ortho-P and NO_3^- were greater in snowmelt runoff than in previous years. This may be partially due to concentrating effect of the low runoff volume. Ammonia concentrations were lower in 2001 than in either 1999 or 2000. The differences in total and ortho-P concentration between the manured and control plots that were observed in 2000 were still discernible in 2001 but the effect of manure was no longer present in the NH_3 concentrations. Although manure application did not appear to affect NO_3^- concentration in runoff in 2000, there was more NO_3^- in runoff from the manured treatments than from the control in 2001.

The results for the rainfall simulations in Table 2 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

Table 2. 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

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.

Conclusions

Preliminary data analysis shows that a fall application of 10,000 gal $acre^{-1}$ of hog manure increased total and ortho P and NH_3 concentrations in spring snowmelt runoff. Elevated concentrations of total and ortho P in snowmelt from the manured treatments were still evident the following year but NH_3 concentrations were lower and no longer different from the control treatment. Nitrate concentrations in snowmelt runoff were similar for the manured and control treatments in the spring after application but the following year, NO_3^- concentrations in runoff were greater from the manured treatments than from the control. 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.

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