

Pathogens in Runoff following Surface Application of Animal Manure to Frozen Ground

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Introduction

Land application of animal manures and process wastewaters are among the most documented sources of wet-weather water pollution causing degradation of streams, rivers and lakes in the U.S. The most prominent of these manure pollutants include pathogenic microorganisms and nutrients. Application of manure to frozen soil can exacerbate runoff, and has been linked to contamination of private drinking water wells and fish kills from excessive oxygen-demanding organic wastes. Vegetative filter strips, unmanured setbacks, and nutrient-limited manure application are widely used management practices for mitigating the movement of manure pollutants to surface waters. However, little information exists regarding their performance when frozen. An improved understanding of pollutant transport following application of manures to frozen soil will aid in finding appropriate solutions regarding the winter application of livestock manures that may reduce both manure storage costs and the risks of environmental degradation. We present data following year two of a multi-year effort.

Objectives

Using recommended best management practices, measure the concentrations of fecal indicator bacteria, bacterial pathogens, antibiotic resistant bacteria, and oxygen-demanding organic materials in overland flow from areas that have received surface-application of manure while the ground was frozen. Data on the runoff concentrations of fecal bacteria will be used in conjunction with that acquired in parallel studies on the survival of these organisms in soils to improve our ability to model their fate in agroecosystems. Data on the reduction of oxygen demanding organic materials will be used to improve the scientific foundation for guidance regarding winter application of manure to land when the soil is frozen (Managing Manure Nutrients at Concentrated Animal Feeding Operations, EPA-821-B-04-006, Appendix L). USDA-ARS collaborators assessed nutrient runoff in parallel studies.

Current Recommendations

- Among the recommendations by the Ohio NRCS for manure application to frozen ground:
 - Limit of 22.4 wet Mg/ha (10T/Ac) for solid manure (>50% moisture)
 - Apply to land with a minimum of 90% surface residue cover
 - A minimum setback distance of 61 m (200 ft) from grassed waterways, surface drainage ditches, streams, and water bodies
 - Additional criteria apply when slopes exceed 6%
- U.S. EPA, Region 5 guidance for manure application to frozen soil can be found in Appendix L of "Managing Manure Guidance for Concentrated Animal Feeding Operations (CAFOs)"

Materials and Methods

Watershed Design

- Six small, continuous no-till corn watersheds with manure applied at the annual agronomic N-rate for an estimated 18 Mg/ha corn yield
- Two watersheds received swine manure (2.5% solids) and two received turkey litter (52.5% solids)
 - 30 m setback from the bottom of the watershed
 - Manure applied to frozen, snow-covered ground on February 21 and 22, 2007, and again on January 22 and 23, 2008
 - Nitrogen fertilizer (181 kg N/ha) was applied to the setbacks prior to planting
- Two control watersheds received nitrogen fertilizer at 181 kg N/ha prior to planting



Figure 1. Swine manure application

Plot Design

- Six plots, each with a 61 x 12 m manure application area and an average slope of 10%
 - Four plots received beef cattle manure slurry (9% solids); 22 Mg/ha in 2007, 11.2 Mg/ha in 2008
 - Manure applied to frozen, snow-covered ground on February 21 and 22, 2007, and January 29, 2008
 - Two plots have a 61 m filter bed, two plots have a 30 m filter bed
- Two control plots (61 m filter bed and 30 m filter bed) received no manure.

Runoff samples were collected in "dust pan" sample collectors placed at the down-slope end of the manure application area, 11 m down-slope of the manure application area, and in Coshocton wheel samplers at the down-slope end of the filter beds.

Sample Analyses

Samples were analyzed for:

- Pathogens (U.S. EPA)
 - *E. coli* and *Enterococci*
 - Antibiotic-resistant *E. coli* and *Enterococcus* spp.
 - *E. coli* O157:H7 and *Salmonella* spp.
- Oxygen-demanding organics (ARS)
 - Total COD
 - Nonsetttable COD
- Nutrients (ARS)
 - NH₄⁺, NO₃⁻, and Org. N
 - PO₄⁻³

Figure 2. Experimental plot design

Table 1. Watershed characteristics and manure application rates for 2007 and 2008

Watershed & Treatment	Size		Slope ¹	Dominant Soil	Area		Manure Application ²	
	Hectares (Acres)	%			Hectares (Acres)	Rate		
WS 118 Swine Manure	0.79 (2.0)	11	11	Coshocton Sil	0.73 (1.8)	181 (160)	195 (174)	195 (174)
WS 127 Swine Manure	0.67 (1.7)	10	10	Coshocton Sil	0.58 (1.4)	181 (160)	295 (274)	295 (274)
WS 109 Turkey Litter	0.68 (1.7)	12	12	Rayne Sil	0.51 (1.3)	181 (160)	181 (160)	181 (160)
WS 123 Turkey Litter	0.55 (1.4)	6	6	Keene Sil	0.55 (1.4)	181 (160)	181 (160)	181 (160)
WS 113 No Manure	0.59 (1.5)	10	10	Coshocton Sil	---	---	---	---
WS 115 No Manure	0.65 (1.6)	8	8	Coshocton Sil	---	---	---	---

¹ Rayne = fine-loamy, mixed, mesic Typic Hapludal; Keene = fine-silty, mixed, mesic Aquic Hapludal; Coshocton = fine-loamy, mixed, mesic Aquic Hapludal

² Approximate

³ Manure was not applied within 30 m of the flume.



Preliminary Results

Manure application and runoff

Application of manure in both 2007 and 2008 was to snow-covered frozen ground. The first precipitation event following application in 2007 was only a few days post-application, although snow-melt resulting in runoff occurred within a day. The first post-application runoff of 2008 occurred at 10 days. There was approximately 30% more runoff from the treated watersheds following manure application in 2008 than in 2007 (Feb 22 – December). Runoff was greater during the first 10 days following manure application in 2007 for the swine manure treated watersheds. There was no consistency in this regard for the other watersheds.

Oxygen-demanding organics

Figure 3 shows COD measured at the various sampling points in the watersheds and plots relative to the no application controls for 2008. COD runoff occurred rapidly, primarily in the first month post-application. Later runoff coincided with that detected in the control plots and watersheds. Flow-weighted average COD in runoff from manured plots and watersheds were significantly greater than their unmanured counterparts in both years 2007 (Table 2) and 2008.

Table 2. Flow-weighted average fecal indicator bacteria and COD in discharge in 2007

Watershed/Plot	Runoff (mm)	Flow-Weighted Average		Flow-Weighted Average	
		<i>E. coli</i> (MPN/100 mL)	<i>Enterococci</i> (MPN/100 mL)	Total COD (mg/L)	Nonsetttable COD (mg/L)
Plot, grassed buffer, beef manure	---	---	---	---	---
30 m filter - 1	13.8	1309	1333	408	414
30 m filter - 2	3.8	305	3552	155	169
61 m filter - 1	15.2	1723	2023	370	366
61 m filter - 2	12.3	2851	130345	372	392
30 m filter - control	27.0	38	1576	46	43
Watershed, unmanured setbacks, swine or turkey manure	---	---	---	---	---
Turkey - 1	25.5	1672	132602	232	241
Turkey - 2	209.5	1514	34884	101	99
Swine - 1	146.7	305	32740	151	131
Swine - 2	197.4	445	88127	171	157
Control - 1	99.5	3509	16745	47	43
Control - 2	9.5	208	497	36	30

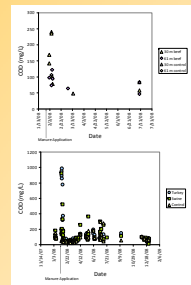


Figure 3. Total COD measured in plot and watershed runoff

Bacterial Pathogens and Fecal Indicators

Fecal indicator bacteria in runoff are shown in Table 2. Manured plots yielded larger populations of fecal bacteria than their unmanured counterparts in 2007 (Table 2). Data for 2008 were similar, and are not shown. More than 400 isolates of *E. coli* and *Enterococcus* spp. have been selected from the runoff to test for antibiotic resistance. Nearly one quarter of the isolates have been tested to date (Tables 3 and 4), and several have exhibited multidrug resistance. Although multidrug resistance was on average greater in isolates of manured plots, there was no significant difference between the populations ($\alpha=0.05$). *Salmonella* spp. have been detected infrequently in runoff from both manured and unmanured land. Although several putative *E. coli* O157 have been isolated, the virulence markers stx1, stx2, or eaeA have not been detected in any of the isolates. Further monitoring is required to better characterize potential differences in manured versus unmanured plots and watersheds.

Table 3. Antibiotic resistant bacteria and *Salmonella* spp. detected in runoff from the plots.

Treatment	Buffer	Resistant spp.		Salmonella spp.	# pos.							
		<i>Enterococcus</i> spp.	<i>E. coli</i>									
		n	%	n	%							
Beef Slurry	0	14	6	2	1	14	8	1	0	0	44	2
Beef Slurry	11	2	1	1	1	1	0	0	0	42	0	
Beef Slurry	30	9	8	4	2	3	2	0	0	7	3	
Beef Slurry	61	12	9	5	3	0	0	0	0	7	1	
Total Manured	47	27	19	12	18	11	2	0	0	99	3	
No Application Control	0	10	1	1	1	1	0	0	0	22	1	
No Application Control	11	4	0	0	0	4	1	0	0	19	0	
No Application Control	30	13	10	4	1	5	3	2	2	2	1	
No Application Control	61	0	0	0	0	0	0	0	0	1	0	
Total Control	107	11	5	2	11	5	3	2	2	44	2	

Table 4. Antibiotic resistant bacteria and *Salmonella* spp. detected in runoff from the watersheds.

Treatment	Buffer	Resistant spp.		Salmonella spp.	# pos.					
		<i>Enterococcus</i> spp.	<i>E. coli</i>							
		n	%	n	%					
Turkey Litter	0	2	2	1	0	35	19	10	7	2
Turkey Litter	30	24	12	10	8	7	4	15	6	5
Swine Manure	0	2	2	0	0	43	28	15	10	5
Swine Manure	30	26	21	15	7	6	8	30	20	15
Total Manured	44	37	26	15	9	239	143	66	33	38
No Application Control	0	14	8	4	3	1	47	38	12	6
No Application Control	30	13	11	8	3	2	36	27	12	6
No Application Control	61	0	0	0	0	0	0	0	0	0
Total Control	27	19	12	6	3	101	65	24	12	7

Discussion

- From the first two years of data, several trends have emerged.
 - Manure application led to excess runoff of COD and bacteria during the first 7-30 days, after which the runoff was similar to that measured from unmanured land.
 - Rainfall and snow melt immediately following manure application resulted in a primary flushing of the systems. Insufficient data are available to fully characterize the impact.
 - For the manure plots, we were able to document a decrease in COD and fecal bacteria between the dust pan sample collectors and edge of the plots (post-filter strip) on the few occasions where samples from both locations coincided.
 - Fecal bacteria and COD in runoff from the grassed buffer strips were greater than that documented for the watersheds with corn cover and an unmanured setback; however, more data are needed to verify these observations before recommendations can be made.

Summary

The initial data suggest that the potential for manure runoff following application to frozen soil may be significant, but could potentially be controlled by a combination of more restrictive application rates and use of buffers, winter cover crops, and/or corn stover. The data are yet too limited to make firm recommendations on appropriate setback distances or application rates to reduce runoff potential. Studies will continue to monitor manure runoff following application to frozen soil and compare discharge to that following application in the spring when the soil is no longer frozen.

Additional Resources

- The NPDES Permit Writers' Guidance Manual and "Managing Manure Guidance for Concentrated Animal Feeding Operations (CAFOs)", are available online at <http://efpub.epa.gov/cgi-bin/afp/info.cfm?manure>
- The project quality assurance plan is available online at <http://www.epa.gov/region5/agriculture/pdfs/winter-manure-app-plan.pdf>

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