Research Note

Environmental Impacts from Land Application of Digestate

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Introduction

The anaerobic digestion of manure provides a number of environmental benefits. Methane (CH_4) emissions are reduced from storage reservoirs and nitrous oxide (N_2O) emissions are reduced from land application. Anaerobic digestion reduces volatile fatty acids (VFAs) in the digestate resulting in decreased odours. Reduced pathogen numbers in digestate can reduce risk of pathogen migration to surface and ground waters compared to untreated manure. The removal of carbon through the digestion of organic compounds results in the ionization of nutrients (e.g. Org-N → NH_4^+; Org-P → o-PO_4^{3-}), making these nutrients more readily available for crop uptake and ultimately increasing crop yields. A multi-year, multi-partner research study was conducted to quantify the environmental impacts associated with the land application of digestate, with particular emphasis on measuring air quality (N_2O, NH_3 and odour emissions), nitrogen and pathogen migration through soil to subsurface drains and crop yields.

Nitrous Oxide and Ammonia Emissions

N_2O and ammonia (NH_3) emissions were measured from the land application of raw manure and digestate on clay-loam fields. The AAFC researchers used a closed-path single optical pass tunable diode laser to measure N_2O gradients [1]. Table 1 presents the emission factors from both fall and spring applications. When raw manure and digestate were surface applied in the fall of 2005, the N_2O emission factor was only slightly higher (1.2 times higher) in the field receiving digestate. However, the NH_3 emission factor was much higher (1.7 times) in the field receiving digestate but only lasted until the digestate was soil incorporated. The higher NH_3 emission factors could be due to the higher content of inorganic ammonium nitrogen (NH_4^+-N) which is typical of digestate. In spring 2007 the land application of raw manure and digestate resulted in similar N_2O and NH_3 emissions factors.

Credit: ORWC

Figure 1. N_2O & NH_3 Emission Measurements at Land Application of Raw Manure and Digestate (Dr. Pattey and AAFC staff)

Table 1. N_2O & NH_3 Emission Factors following the Application of Raw Manure and Digestate

	Digestate (2005/2006[1])	**Raw Manure** (2005/2006[1])	**Digestate** (Spring 2007)	**Raw Manure** (Spring 2007)
NH_3 Emission Factor (kg NH_3-N/kg NH_4^+-$N_{applied}$)	0.39	0.23	0.25	0.22
N_2O Emission Factor (kg N_2O-N/kg $N_{applied}$)	0.031	0.026	0.021	0.025

[1] Gas emission is total from fall 2005 and spring 2006, with land application occurring in fall 2005.

Odour Emissions

Lab simulation studies were conducted to determine surface odour fluxes, expressed as odour units per m^2 per second ($OU/m^2{\cdot}s$), from the land spreading of raw manure and digestate. Standard flux chamber and wind tunnel protocols and odour measurements were applied [2]. Raw dairy manure and digestate (fresh and aged for 28 days) were used in the study. Table 2 presents the average odour emission concentrations and odour fluxes from the various manure types using the flux chamber method.

Table 2. Odour Concentration and Odour Flux Using the Flux Camber Method

Manure Type	Average Odour Concentration (OU/m^3)	Odour Flux ($OU/m^2{\cdot}s$)
Fresh Raw Manure	2527	1.62
Aged Raw Manure (for 28 days)	1834	1.18
Digestate	683	0.44
Aged Digestate (for 28 days)	298	0.19

The data demonstrates that the odour emission concentrations and odours fluxes are significantly lower in the land application of digestate compared with raw manure. Typically odour emissions were found to be more than 3 times lower with digestate.

Pathogen and Nitrogen Migration to Subsurface Drains

Land application trials were conducted at the Campus d'Alfred experimental plots in both spring and fall to investigate the migration of nutrients and pathogens in soil to sub-surface drains. Each of the hydraulically isolated experimental plots is 0.15 ha in size and composed of heavy clay, with drainage tiles running 1 m below the soil surface. Plots were treated with either raw manure or digestate at rates of 1x (140 kg N/ha) and 2x (280 kg N/ha) agronomic rates [3]. Grain corn was grown on each plot. Two plots received no treatment and were considered the control plots for the duration of the project.

Credit: ORWC

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Figure 2. Land Application of Digestate on Experimental Plots at Campus d'Alfred and Collection System for Subsurface Drains

Table 3 summarizes flow-weighted geometric log mean *E.coli* and *Salmonella* counts in subsurface drains at 15-days, 30-days and 60-days after land application of raw manure and digestate. After the first 15-days following land application of the two manure types the mean *E.coli* and *Salmonella* counts in the subsurface drains were similar to those found in the controls plots (no treatment). During this 15-day period there was less than 12 mm of precipitation accumulation. As rain events increased bacteria numbers in the subsurface drains increased proportionally. 30-days after land application, with 62.5 mm of precipitation, mean bacteria counts were 1 log higher than the control plots.

Table 3. Pathogen Indicator Numbers from Subsurface Drainage Waters during 2010 Study Period [Flow-weighted Geometric Log Mean (log CFU/100mL)]

2010	*E.coli*	*Salmonella*	*E.coli*	*Salmonella*
	1x Agronomic Rate		2x Agronomic Rate	
15-days after Land Application	Total Precipitation = 11.1 mm			
Raw Manure	1.1 ± 0.1	2.2 ± 1.1	1.2 ± 0.1	1.9 ± 0.9
Digestate	1.2 ± 0.1	1.6 ± 0.3	1.2 ± 0.1	1.6 ± 0.4
Control (no treatment)	1.2 ± 0.1	1.7 ± 0.6	N/A[1]	N/A
30-days after Land Application	Total Precipitation = 62.5 mm			
Raw Manure	2.4 ± 1.2	3.0 ± 1.8	2.7 ± 1.4	3.0 ± 1.8
Digestate	2.5 ± 1.3	3.0 ± 1.8	2.5 ± 1.4	2.6 ± 1.4
Control (no treatment)	1.1 ± 0.1	1.6 ± 0.3	N/A	N/A
60-days after Land Application	Total Precipitation = 160.7 mm			
Raw Manure	3.4 ± 2.0	3.6 ± 2.1	3.6 ± 2.1	3.6 ± 2.3
Digestate	3.0 ± 1.5	3.1 ± 1.5	3.4 ± 2.0	3.6 ± 2.2
Control (no treatment)	1.4 ± 0.1	1.7 ± 0.1	N/A	N/A

[1] N/A: Not Applicable

As more precipitation accumulated (over 160 mm total) the average bacteria counts in the subsurface drains of plots that received a manure treatment continued to increase with bacteria counts being 2 logs higher than the control plots. Generally, no significant differences in drainage water bacteria numbers were observed between raw manure and digestate applications onto the clay plots. However, drainage water bacteria numbers were observed to be up to 1.6 logs higher following a large rain event (~35mm) in plots having received 2x agronomic rates of either manure treatment compared with plots having received 1x agronomic rates of the manure type.

Table 4 summarizes the flow-weighted mean nitrate concentrations in drainage water 60 days after the land application of raw manure and digestate.

Table 4. Flow-weighted Mean Nitrate Concentrations in Subsurface Drains (60 days after land application)

Land Application Trials	Mean NO_3^--N Conc. (mg/L) in Subsurface Drains	
	1x Agronomic Rate	2x Agronomic Rate
Spring 2009[2]		
Raw Manure	5.1 ± 1.2	9.3 ± 2.1
Digestate	7.3 ± 1.9	13.1 ± 2.4
Spring 2010[2]		
Raw Manure	5.0 ± 2.1	6.1 ± 1.9
Digestate	5.6 ± 1.9	8.9 ± 2.4
Control	2.0 ± 0.3	N/A

1 N/A: Not Applicable
2 Land application trials to deliver 140 kg N/ha (1x agronomic rate) and 280 kg N/ha (2x agronomic rate)

Although the drainage water nitrate concentrations were observed to be typically below 10 mg/L, increased nitrate concentrations were observed in subsurface drains of plots treated with the 2x agronomic application rate (280 kg N/ha) of the raw and digested manures. In 2010 peak nitrate concentrations in the subsurface drains were observed between 30 and 40 days after land application (2x agronomic rates) where precipitation was over 100 mm, with concentrations of 10.3 mg/L and 14.4 mg/L for the raw and digested manure plots, respectively. In 2009 higher peak nitrate concentrations in the subsurface drains had been observed 30 days after manure application (2x agronomic rates) with concentrations of 15.5 mg/L and 28.4 mg/L for the raw and digested manure plots, respectively.

Crop Yields

Table 5 presents the grain corn yields from plots treated with raw manure and digestate. At application rates of 140 kg N/ha corn yields from the digestate plots had an overall 1.25 times higher yield than the plots treated with raw manure. These higher yields can be attributed to the higher concentration of inorganic nitrogen (NH_4^+-N) in digestate.

Table 5. Corn Yields from Tests Plots Treated with Raw Manure and Digestate

Application Rate	Corn Yield (bu/ac)		Increase in Yield
	Raw Manure	Digestate	
140 kg N/ha (2009 Season)	84	105	25%
140 kg N/ha (2010 Season)	81	103	27%

Credit: ORWC

Figure 3. Corn Plants on Plots Treated with Raw Manure and Digestate (center plot)

[1] Crolla, A., Kinsley, C., Pattey, E., Desjardins R., Ball-Coelho, B., Désilets, E., Sahota, T. 2008. *Assessment of the Production and Land Application of Anaerobically Digested Manure from Medium Sized Livestock Farms*. Final Report Submitted to Agriculture and Agri-food Canada. March 2008.

[2] Choinière, D. and Giard, D., 2010. Odour *Reduction Potential of Anaerobic Digestion on Dairy Manure*. Final Report Submitted to University of Guelph-Campus d'Alfred from Consumaj Experts Conseils June 2010.

[3] Crolla, A. and Kinsley, C. 2011. *Environmental Sustainability of On-farm Manure Anaerobic Digestion*, Final Report Submitted to the Ontario Ministry of Agriculture, Food and Rural Affairs. March 2011.

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