Bioeconomy Research Highlights Day: Opportunities for Innovation and Collaboration 2010
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Environmental Impacts from the Land Application of Raw and Digested Dairy Manure

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Project Overview

- Anaerobic Digesters:
  - Monitoring of 2 on-farm anaerobic digesters
  - Evaluate use of co-substrates for enhanced biogas production (pilot & full scales)
- Land Application Trials:
  - Land application trials for fate of nutrients and pathogens in soil and water

Benefits of Anaerobic Digestion

1. Production of renewable energy – biogas usually contains a methane content of approximately 60%, which can be stored and used on demand.
2. Permits the addition of various substrates to increase biogas production, known as co-digestion.
3. Odour reduction – can be in the order of 80 to 90%.
4. Reduction of pathogens of up to 1 to 2 logs depending on configuration.
5. Reduction of greenhouse gas emissions.
6. Improves the immediate fertilizer value of the manure.

Anaerobic Digesters

1. Fepro Farms (dairy operation) – Cobden, Ontario
2. Terryland Farm (dairy operation) – St. Eugene, Ontario

Monitoring Parameters

Digester System Performance	Environmental Impacts
Biogas production & CH_4 concentration	Volatile fatty acids (VFAs)
Electricity & heat production	*E.coli*
Organic Matter: COD, Volatile Solids	*Salmonella*
Nutrients: NH_4^+, Organic-N, o-PO_4^{3-}, TP	*C.perfringens*
pH	Enterococci
Temperature	CH_4 emissions

On-farm Anaerobic Digesters

Fepro Farm Digester

- Owned by Paul and Fritz Klaesi
- Mesophilic system (40ºC)
- 500 kW generator
- Co-digestion of dairy manure & grease
- Electricity production sold to grid
- Heat production used to heat digester, 2 homes, milking parlour

Terryland Farm Digester

- Owned by George and Linda Heinzle
- Mesophilic system (40ºC)
- 180 kW generator (soon to be 360 kW)
- Co-digestion of dairy manure & grease
- Electricity production sold to grid
- Heat production used to heat digester, pool, home, milking parlour and to dry silage

Electricity Production

Example: Terryland Farm Digester, St. Eugene, ON

	Average Biogas* (m^3/day)	Average Electricity with 180 kW Generator (kWh/day)	Average Biogas Yield (m^3/kg VS_{in})
Terryland Digester	1692	3917	0.67
STDEV	187	362	0.19

* Average methane content of biogas 62%

- Biogas production when 18% (by volume) of grease residue is added to digester
- Biogas production is over 4 times higher from when only manure was used as feedstock (415 m^3/day)
- Waste heat is used on the farm (potential of 730,000 Btu/h)

Odours

- Odours: ammonia (NH_3), volatile fatty acids (VFA), phenolic compounds
- 96 % reduction of VFAs

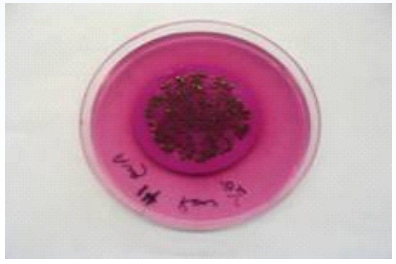
Example: Fepro Farm Digester, Cobden, ON

	Total VFA Concentrations (mg/L)							
	Raw Manure				Digested Manure			
	Acetic Acid	Propionic Acid	Butyric Acid	**TVFA**	Acetic Acid	Propionic Acid	Butyric Acid	**TVFA**
Average	4625	1521	884	**7030**	171	78	1	**250**
STDEV	1184	589	434	**2207**	94	22	1	**117**
% Red.					96	95	99.9	**96**

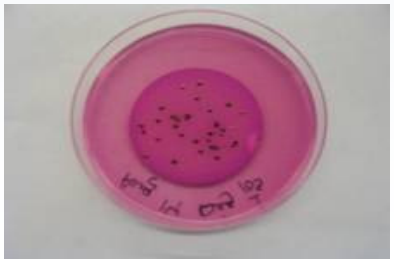
Pathogens

- 70-95% reduction in pathogens (~ 1-2 logs)

Pathogens	Geometric Mean Bacteria Concentrations (CFU/100mL)					
	Klaesi Digester			Terryland Digester		
	Raw Manure	Digested Manure	Log Reduction	Raw Manure	Digested Manure	Log Reduction
E.coli	6.00 E+07	2.90 E+05	2.32	1.21 E+07	3.03 E+05	1.60
Log STDEV	1.08	0.73		0.58	0.66	
Salmonella	6.51 E+04	8.84 E+03	0.87	1.27 E+05	3.48 E+04	0.56
Log STDEV	1.02	0.94		0.79	0.52	
C.perfringens	3.81 E+06	2.99 E+05	1.11	2.20 E+06	2.55 E+05	0.94
Log STDEV	0.48	0. 55		0.49	0.25	
Enterococci	9.11 E+06	7.29 E+05	1.10	4.86 E+06	3.19 E+05	1.18
Log STDEV	0.51	0.60		0.61	0.78	



E.coli in raw manure sample



E.coli in digested manure sample

Land Application Trials

- University of Guelph at Alfred – Monitoring of soil and water after land application of raw manure, digested manure and inorganic fertilizer.

- **Monitoring Parameters**

Water and Soil Samples	Air Measurements
Nutrients : NH_4^+, NO_3^-, o-PO_4^{3-}, TP, Organic-N	NH_3 & N_2O
E.coli	**Plant Samples**
Salmonella	Nutrients: Yield, Total-N, Total-P
C.perfringens	
Enterococci	

Characteristics of Digested Manure

- 70% reduction in volatile solids (VS)
- 61% reduction in chemical oxygen demand (COD)
- 29% increase in ammonium-nitrogen (NH_4^+-N)

Example: Terryland Farm Digester, St. Eugene, ON

Parameters	Raw Manure	Grease	Digested Manure
% Dry Matter	11.3	23.3	5.7
Total Solids (g/L)	113	233	57
Volatile Solids (g/L)	94	219	37
Chemical Oxygen Demand (g/L)	65	135	31
Total Nitrogen (g/L)	3.45	0.19	3.58*
Total Ammonium (g/L)	1.73	0.17	2.23*
Total Phosphorus (g/L)	0.71	0.10	0.61*

* Corrected for the dilution effects from addition of grease

Corn Yields

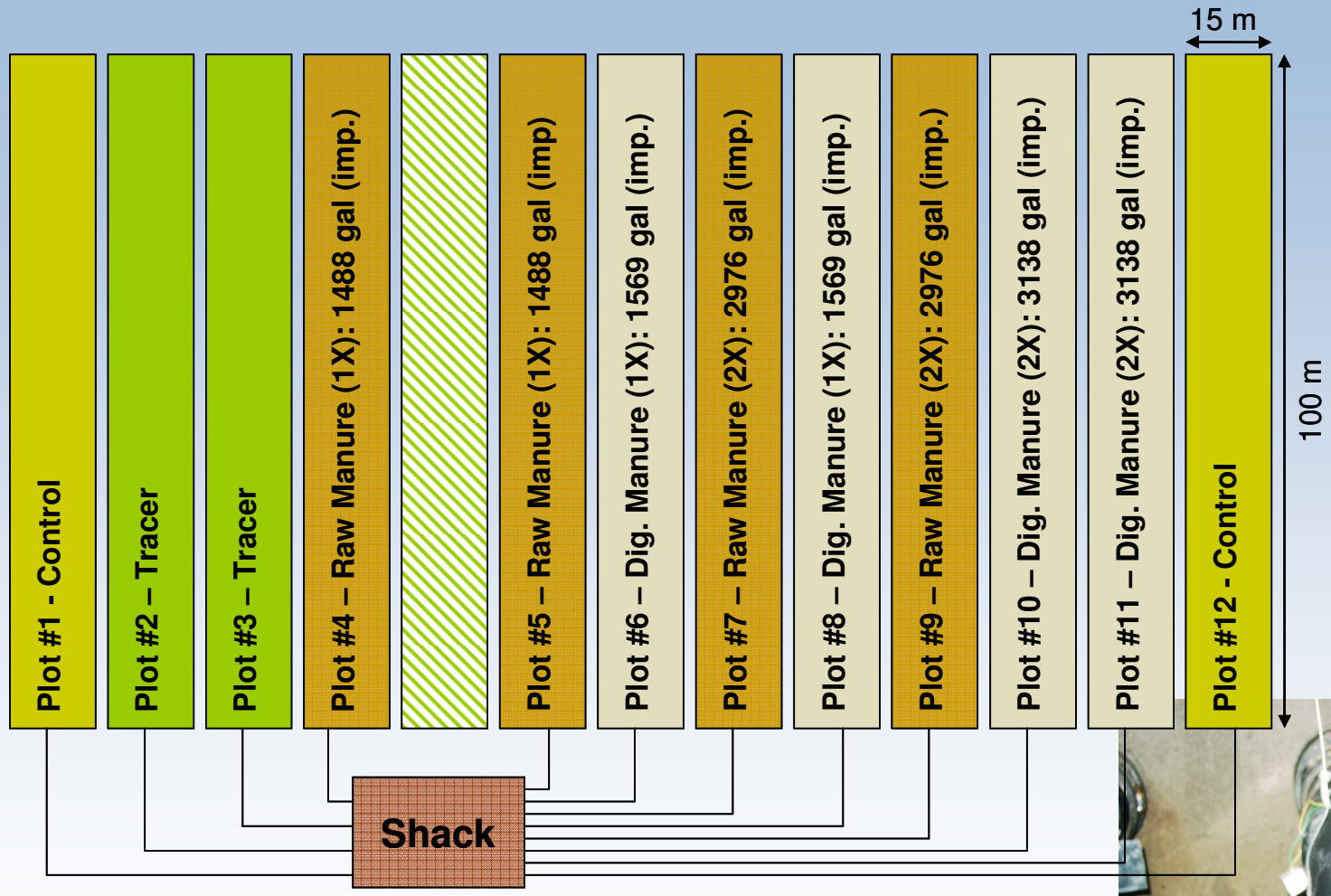
Application Rate (kg N/ha)	Corn Yield (bu/ac) *		
	Raw Manure	Digested Manure	Increase in Yield
2007 – 120 kg N/ha	128	196	53%
2009 – 140 kg N/ha	84	105	25%

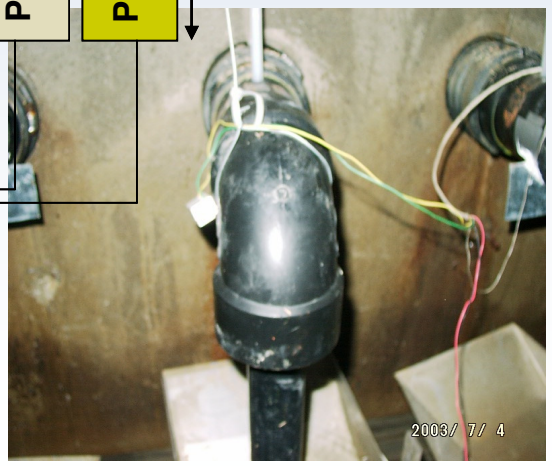
* Corn yields are standardized to 15.5% moisture and 56 lbs per bushel

Plot Trials at Alfred Campus

- Clay soil plots with surface and subsurface drains
- Twelve 0.15 ha plots (15 m x 100 m)
- Plots hydraulically isolated with liner between plots to a depth of 2 m
- Surface drains at 15 cm depth and subsurface drains at 1 m depth
- 3 m wells around plot perimeter
- Application of raw and digested manure in both spring and fall (spray broadcast and incorporated within 24 hrs)
- Low N loading: 120 kg N/ha
- High N loading: 240 kg N/ha
- Crop rotation barley/corn/corn

Alfred Plots – Layout of Clay Soil Plots





Both surface and subsurface water drainage are collected

Alfred Field Station

- All 24 drains run into basement of cabin
- Flow measured using tipping buckets (datalogged)
- Flow proportional composite samples are taken (tipping buckets control sampling pumps)

Nitrates in Subsurface Drains

Land Application Trials	Flow-weighted Mean NO_3-N Concentrations (mg/L) 60-day Period After Land Application	
	Subsurface Drains	Subsurface Drains
Spring 2008	1x Agronomic Rate (75 kg N/ha)	
Raw Manure	7.3	
Digested Manure	9.5	
Fall 2008	1x Agronomic Rate (75 kg N/ha)	
Raw Manure	4.2	
Digested Manure	3.9	
Spring 2009	1x Agronomic Rate (140 kg N/ha)	2x Agronomic Rate (280 kg N/ha)
Raw Manure	9.3	14.8
Digested Manure	13.1	16.9

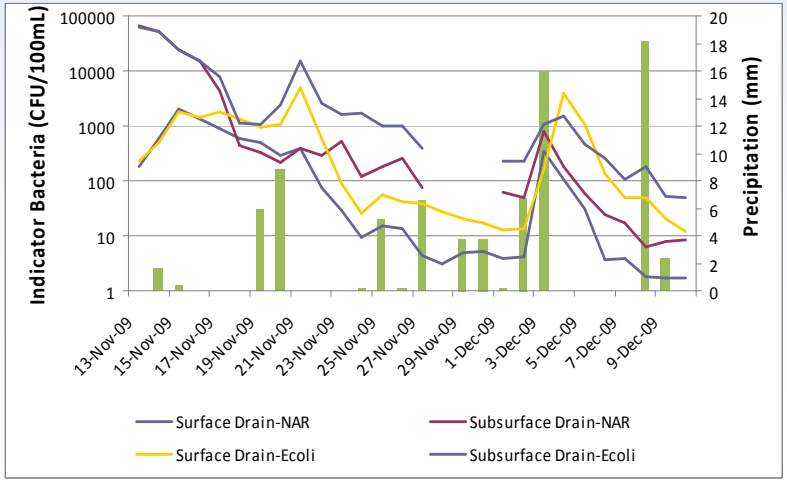
- Nitrate concentrations in control plots range from 1.9 to 3.7 mg/L
- Peak nitrate concentrations in subsurface drains observed 30 days after manure application:
  - * 9.6 mg/L (140 kg N/ha) & 15.5 mg/L (280 kg N/ha) in plots with raw manure
  - * 17.5 mg/L (140 kg N/ha) & 28.4 mg/L (280 mg/L) in plots with digested manure

Bacteria in Subsurface Drains

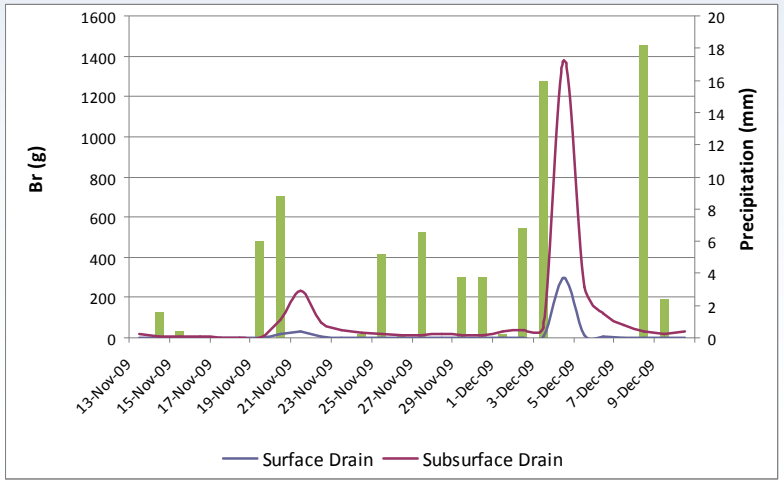
Geometric Log Mean of Pathogen Indicator Numbers in Subsurface Drains (log CFU/100 mL)

	E.coli	*Salmonella*	*E.coli*	*Salmonella*
2008	**1x Agronomic Rate (75 kg N/ha)**			
Raw Manure	1.8 ± 0.9	0.8 ± 0.8		
Digested Manure	1.7 ± 0.7	0.9± 0.7		
Control (no treatment)	1.8 ± 0.5	0.7 ± 0.4		
2009	**1x Agronomic Rate (140 kg N/ha)**		**2x Agronomic Rate (280 kg N/ha)**	
Raw Manure	2.8 ± 0.9	2.1 ± 0.9	3.1 ± 0.5	2.3 ± 0.8
Digested Manure	2.6 ± 0.*	2.0 ± 0.8	3.0 ± 0.3	2.0 ± 0.8
Control (no treatment)	1.6 ± 0.7	1.2 ± 0.6	---	---

E.coli NAR Tracer



Bromide Tracer



On-going Work

- Digesters:
  - Continue monitoring digesters for reactor performance and environmental impacts
  - Monitor increased biogas production at Klaesi and Heinzle digesters using co-substrates
  - Continue monitoring CH_4 emissions (AAFC)
- Land Application Trials:
  - Monitor NH_3 emissions from spring application of digested manure (AAFC)
  - Mass balance of nutrients and pathogens through soil to drainage waters

Project Partners

- Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)
- Agriculture and Agri-Food Canada (AAFC)
- University of Guelph
- University of Ottawa
- Organic Resources Management Inc. (ORMI)
- Dairy Farmers of Canada
- Fepro Farms – Klaesi Family
- Terryland Farms – Heinzle Family