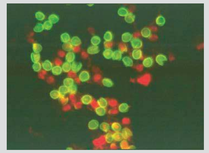
Assessment of Dairy Manure Management Practices to Reduce Pathogen Runoff Losses from Agricultural Watersheds



Contamination by bacteria and other microorganisms is a leading cause of impairment of US waters. Runoff from animal waste applied to agricultural land frequently delivers indicator bacteria and pathogens to surface waters, contributing to violations of water quality standards and presenting a potential risk to public health. Improved manure management practices of known effectiveness are needed to reduce export of pathogens from agricultural land, but specific practices to control export of microorganisms to surface waters have not been widely developed, tested, or applied.

Project Goals

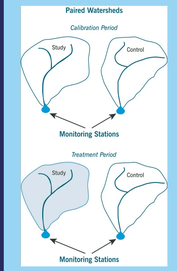
1. Characterize microbial pathogen and indicator bacteria levels in dairy manure in Vermont over a full seasonal cycle.
2. Quantify runoff losses of pathogens and indicator bacteria from cropland receiving manure.
3. Assess the effectiveness of several management practices in reducing runoff losses of pathogens and indicator bacteria under field conditions.

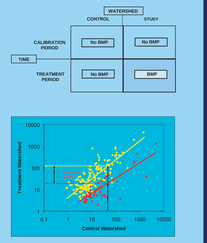
Study Approach

- Analysis of fresh and stored liquid dairy manure for *E. coli* and pathogens, monthly for one year
- Storm-event monitoring of field-sized watersheds in corn and hay production for runoff quantity and microorganism content under present management
- Storm-event monitoring following management changes:
  - Delay between manure application and rainfall
  - Manure incorporation on cornland
  - High vegetation on hayland

Paired Watershed Design

In the paired-watershed design, two or more watersheds – control and treatment – and two time periods – calibration and treatment – are used to evaluate the effect of a change in management.





The calibration period began in May 2007 and was completed in August 2008 with the monitoring of 19 storm events. During this period, management was identical for the two hayland watersheds and for the two cornland watersheds. During the treatment period, a change in management will be applied to the treatment watersheds, while the control watersheds will remain in the original management. We will use analysis of covariance (ANCOVA) to evaluate changes in microorganism levels in runoff in response to treatment.

Manure Sampling Sites

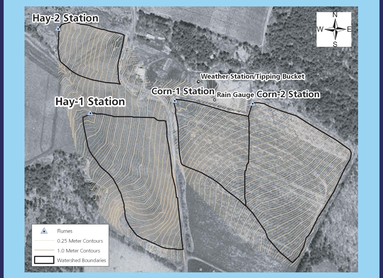
Fresh and stored manure was sampled at three working dairy farms in central Vermont over an annual cycle. One of the participating farms (Farm A) also manages the fields used in the runoff experiment.

Fresh and stored manure was sampled from these locations

Experimental Watersheds

Study fields have runoff prone soils (hydrologic group C or D) and moderate slopes (5-10%). The runoff monitoring stations were constructed at the natural drainage outlet of each field.

Experimental watershed location



Methods

1. Stored manure was sampled monthly by compositing multiple subsamples from each storage structure. Fresh manure was sampled from a sump below the barn or from a paved loafing area.

2. Soil infiltration rates were measured.

3. Soil cores were collected for physical/chemical analyses.

4. Monitoring stations with H-flumes were constructed at the outlets of the four experimental watersheds, April 2007.

5. An autosampler, flowmeter, and sample tank are housed next to each flume.

6. An on-site weather station records air and soil temperature, precipitation, solar radiation, and relative humidity.

7. Manure spreading on Corn-2 watershed in May 2007.

8. Paint -tray liners are placed randomly around the fields prior to manure application to collect samples of manure as applied.

9. Flow-proportional bulk composite samples collected in the tank are subsampled and analyzed for *E. coli*, *Salmonella*, *Cryptosporidium*, and *Giardia* by Analytical Services, Inc. of Williston, Vermont.

Results of Manure Analysis

E. coli O157:H7 organisms were never detected in any manure samples. *Giardia* cysts were detected at least once in manure from all three farms, but at low numbers (Fig. A). With one exception, *Cryptosporidium* oocysts were found only in manure from Farm B (Fig. B). Levels of both protozoa appeared to peak in late summer. *Salmonella* were routinely analyzed only in samples from Farm A, where they were found at moderate levels in fresh (66 - >1300 organisms/g) and stored (50 - 470 organisms/g) manure.

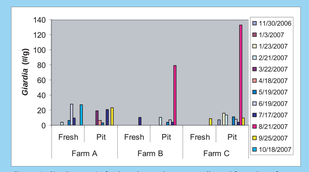


Figure A. *Giardia* cysts in fresh and stored manure collected from three farms.

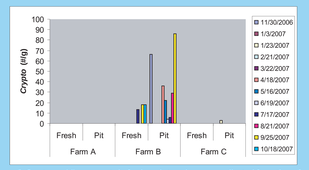


Figure B. *Cryptosporidium* oocysts in fresh and stored manure collected from three farms.

Generic *E. coli* were detected in manure samples at ~10^4 to 10^6 organisms/g, levels commonly reported in the literature. Bacteria counts in fresh manure always exceeded those in stored manure (Fig. C). *E. coli* counts were significantly higher in fresh manure than in stored manure (data from all farms and months combined). A tendency for lower *E. coli* counts in fresh manure during the summer months compared to winter was observed (Fig. D), a pattern not widely reported in the literature.

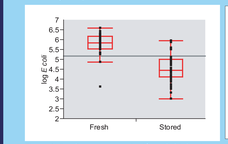


Figure C. *E. coli* counts were significantly higher in fresh manure (data from all farms and all months combined).

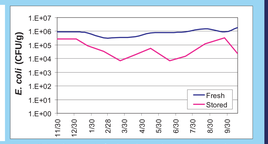


Figure D. *E. coli* counts in fresh and stored manure, November 2006 through October 2007.

Calibration Monitoring

Runoff has been monitored from 19 storm events since May 2007.

	Applied Manure	Corn	Hay
E. coli	10^3 - 10^5 MPN/g	10^2 - 10^6 MPN/100 mL	10^2 - 10^5 MPN/100 mL
E. coli O157:H7	ND	ND	ND
Salmonella	1 - 49 MPN/g	<4 - 120 MPN/100 mL	<4 - 38 MPN/100 mL
Giardia	ND - 30/g	ND - 310/L	ND
Cryptosporidium	ND - 26/g	ND	ND - 3/L
ND = none detected			

Figure E. Summary of microorganism data, calibration period.

As with manure, *E. coli* have been detected in runoff at typical levels (10^2 to 10^6 organisms/100 mL), while no *E. coli* O157:H7 and only low numbers of *Salmonella*, *Giardia* and *Cryptosporidium* have been observed (Fig. E). The highest levels of *E. coli* (3.4 x 10^6 MPN/100 mL), *Salmonella* (120 organisms/100 mL), and *Giardia* (310 cysts/100 mL) were present in runoff from the Corn-1 watershed in November 2007, during a major runoff event that occurred immediately after manure was applied without incorporation.

	Corn		Hay	
	Median	Mean[1]	Median	Mean[1]
Q_t (m^3)	127.6	90.4*	32.9	34.8*
RO (mm)	4.02	2.84*	1.69	1.55*
EC (MPN/100 mL)	4500	4903	2900	3656
EC Mass (MPN)	4.4 x 10^8	4.6 x 10^{9*}	2.0 x 10^9	1.4 x 10^{9*}
* = means differ significantly, $P \leq 0.05$				
1 = anti-log of log(Mean)				

Figure F. Event runoff quantity and *E. coli* data for calibration period.

Mean event runoff (both total flow (Q_t) and runoff depth (RO)) were both significantly higher ($P < 0.05$) from corn land than from hay land (Fig. F). Although *E. coli* counts tended to be higher from corn land than from hay land, the difference was not statistically significant. Because of the significantly higher runoff volume, *E. coli* mass export was significantly higher from corn land than from hay land ($P < 0.05$).

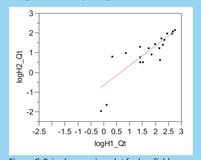


Figure G. Paired regression plot for hay fields log total event discharge.

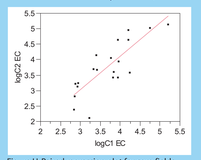


Figure H. Paired regression plot for corn fields log *E. coli* count.

Statistically significant regressions were obtained for both field pairs for event runoff (both total flow and runoff depth) and for *E. coli* count (Figs. G and H). Data for *Salmonella*, *Giardia*, and *Cryptosporidium* were too scant for use in this analysis.

Next Steps

- Continue collection and analysis of manure samples at application.
- Continue storm-event monitoring of experimental watersheds for runoff quantity and microorganism content under treatments through the 2009 field season.
  - Incorporation of manure applied to treatment corn field
  - High vegetation (~15 cm) on treatment hay field at manure application
- Continue to monitor agronomic and management variables.

Hay-1 watershed near the end of the November 6, 2007 event.

Acknowledgements and Contact Information

This project is funded by the National Research Initiative of the USDA Cooperative State Research, Education, and Extension Service, grant #2006-35102-17197.

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