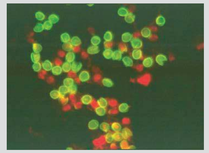
# Assessment of Dairy Manure Management Practices to Reduce Pathogen Runoff Losses from Agricultural Watersheds



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

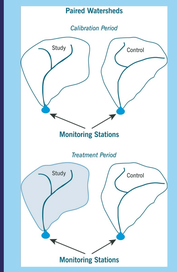
1. Characterize microbial pathogen and indicator bacteria levels in dairy manure in Vermont over a full seasonal cycle.
2. Quantify application rates and runoff losses of pathogens and indicator bacteria at dairy manure application sites.
3. Assess the effectiveness of several management practices in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

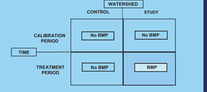
## Study Approach

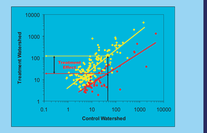
- Analysis of fresh and stored liquid dairy manure for *E. coli* and pathogens, monthly for one year
- Storm-event monitoring of field-sized watersheds in corn and hay production for runoff quantity and microorganism content under present management
- Storm-event monitoring following management changes:
  - 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.




We are currently in the calibration period. During the calibration period, management is 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. The primary statistical technique we will use to test changes in microorganism levels in runoff in response to treatment will be analysis of covariance (ANCOVA).

## Manure Sampling Sites

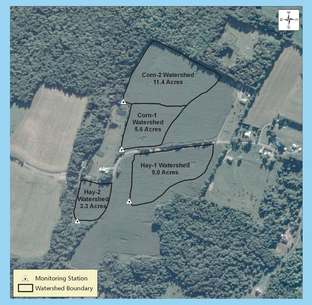
Fresh and stored manure was sampled at three working dairy farms in Central Vermont over an annual cycle. One of the participating farms (Farm A) also manages the fields used in the runoff experiment.

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.

Corn-1 watershed, June 2007




## Methods

1. Manure were sampled at five locations around each manure pit, monthly for one year (2006-2007).

2. Soil infiltration rates were tested.

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

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

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

6. Onsite weather station.

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

8. Paint tray liners are used to sample the applied manure

9. Sub-sampling the flow-proportional composite runoff sample (in the tank). Runoff is analyzed for indicator *E. coli*, Cryptosporidium, Giardia, and Salmonella by Analytical Services, Inc.

## 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.

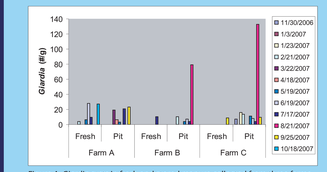



Figure A. *Giardia* cysts in fresh and stored manure collected from three farms.

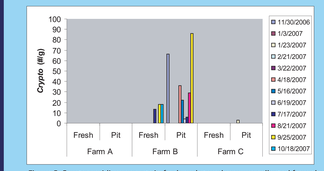



Figure B. *Cryptosporidium* oocysts in fresh and stored manure collected from three farms.

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). There seems to have been a trend toward lower *E. coli* counts in fresh manure during the summer months than in winter, a pattern not widely reported in the literature.

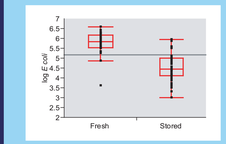



Figure C. Mean *E. coli* counts in fresh and stored dairy manure over an annual cycle (all farms).

## Results of Runoff Monitoring--To Date

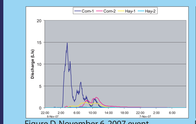



Figure D. November 6, 2007 event.

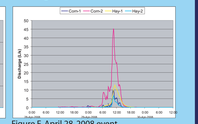



Figure E. April 28, 2008 event.

Runoff from 12 storm events has been monitored. The watersheds have characteristic event hydrographs. The larger Hay-1 watershed has a higher peak flow and total discharge and a longer recession curve than the smaller Hay-2 watershed. The event hydrographs of the corn watershed generally mirror one another, but the larger Corn-2 watershed typically has a higher peak flow and total discharge and a longer recession curve than the smaller Corn-1 watershed. The November 6, 2007 event (Fig. D) was an interesting exception. This event occurred one day following manure application at a time when the Corn-2 watershed had been incorporated and the Corn-1 watershed had not. The incorporated Corn-2 watershed yielded only 31% of the total discharge of the Corn-1 watershed and the flow rate peaked more than 7 hours after Corn-1. This pattern illustrates the hydrologic effect of soil incorporation. By the April 28, 2008 event (Fig. E), the effect of incorporation was no longer apparent.

| | | Corn | Hay |
|---|---|---|---|
| *E. coli* | mpn/100 ml | $10^3$ – $10^6$ | $10^2$ – $10^5$ |
| *E. coli* O157:H7 | | ND | ND |
| *Salmonella* | | ND – 120 | ND – 16 |
| *Giardia* | #/L | ND – 310 | ND – <10 |
| *Cryptosporidium* | | ND - <3 | ND – 10 |
| ND = none detected | | | |

Figure F. Summary table of *E. coli* and pathogen levels in runoff (to date).

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 *Giardia* and *Cryptosporidium* (maximum 10 oocysts/L) have been observed (Fig. F). Low numbers of *Salmonella* have been detected in runoff, although *Salmonella* analysis only began in mid-summer 2007. The highest levels of *E. coli* (3.4 x $10^6$ mpn/100 mL), *Giardia* (310 cysts/L), and *Salmonella* (120 organisms/100 mL) were present in runoff from Corn-1 on November 6, 2007, immediately after manure was spread without incorporation.

## 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 present management. *E. coli* O157:H7 to be analyzed only if detected in applied manure samples.
- Analyze generic *E. coli* export rates for 2007 and 2008 runoff events to determine when satisfactory pre-treatment statistical calibration between the paired watersheds has been achieved.
- After calibration of the paired watershed has been confirmed, implement field treatments with subsequent manure applications.
- Continue rountine site maintenance.

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

## Acknowledgements and Contact Information

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