Manure component release and partitioning between surface runoff and infiltration: a simulation study

Ryan A. Blaustein[1,2], Robert L. Hill[1] , Yakov A. Pachepsky[2], Dan Shelton[2], Gene Whelan[3], Thanh Dao[4]

[1]University of Maryland, College Park; [2]USDA-ARS Environmental Microbial and Food Safety Laboratory, ANRI;

[3]U.S. EPA, Ecosystems Research Division, NERL; [4]USDA-ARS, Environmental Management and Byproduct Utilization Laboratory, ANRI

Background

- Microorganisms, as well as other manure components, are released from land-applied manures during precipitation and irrigation events.
- Upon release, manure-borne microorganisms are transported in suspension with surface runoff or infiltrating water and have the potential to contaminate surface water and groundwater sources.
- Many illness outbreak incidents have been linked to contamination of water supplies by pathogens that had originated from agricultural lands.
- Concentrations of indicator bacteria, such as *E. coli*, enterococci, fecal coliforms, and total coliforms, are often measured, simulated, and regulated to represent potential fecal contamination in the environment.
- The initial manure concentration (C_0) depends on how it is defined and used:
  - Many predictive release models simulate the ratio of the concentration of bacteria released over time to the effective initial concentration of bacteria in manure (C/C_0), where C_0 is defined by the bacteria content in manure divided by the manure water content.
  - Results of predicted release models are typically reported as the concentration of bacteria released over time to the initial concentration in the initial release from the manure (i.e., eluate) (i.e., C/C_0).
- Information is scarce about the relationship between concentrations of manure components in runoff and infiltration water and the contents of those components that can be inferred from preliminary manure analyses.
- A better description of the release process and the establishment of procedures to determine C_0 are needed to improve microbial fate and transport models.
- The objectives of this work were to compare contents of *E. coli*, enterococci, total coliforms, fecal coliforms and total organic carbon in two types of manure to the initial concentrations of these components in runoff and infiltration water during rainfall simulations using partitioning boxes.

Methods

- Sectioned partitioning boxes (70cm x 70cm) were built to contain a top support frame, a middle mesh frame with a 185-micron opening, and the bottom frame with an impenetrable base.
- The boxes were designed to have manure applied on the mesh-covered frame, and to have both runoff and infiltration collected from troughs level with the mesh and below the lower frame, respectively, during a simulated rainfall event.
- Manure from a dairy CAFO and manure from grazing cattle were collected and used in this study.
- Manure was applied to the mesh layer of each box at the rate of approximately 60 ton/ha with three replicates used for each manure type.
- The partitioning boxes were positioned under a rainfall simulator on a 20% sloped hill at the USDA Beltsville Agricultural Research Facility.
- Rain gauge jars were placed around each box-plot to measure total precipitation during the rainfall event.

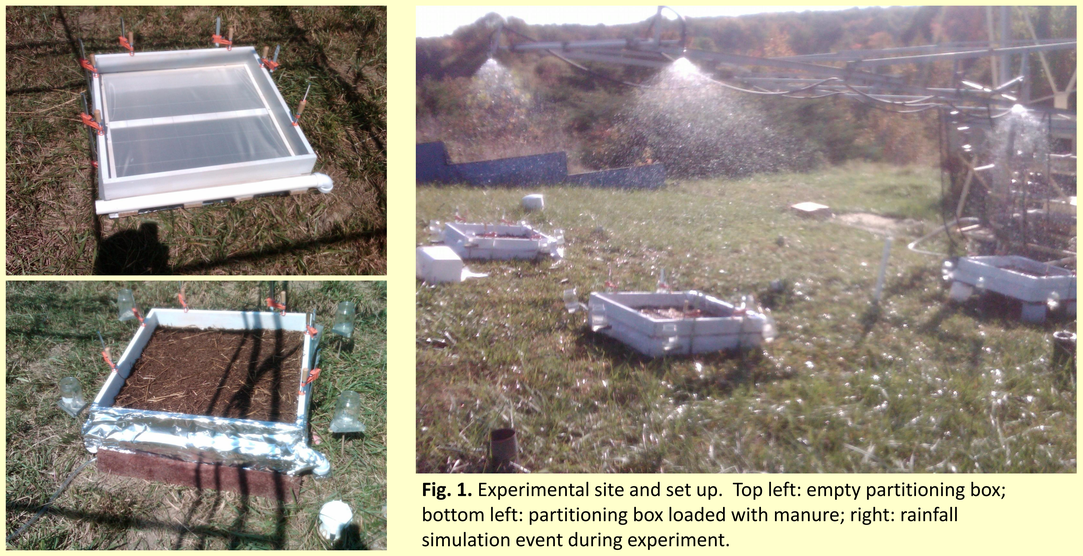


Fig. 1. Experimental site and set up. Top left: empty partitioning box; bottom left: partitioning box loaded with manure; right: rainfall simulation event during experiment.

- The rainfall simulation began after two samples of manure were collected from each box.
- Runoff and infiltration samples were collected upon their initial release (time 0) and then subsequently at 1, 2, 4, 8, 16, 32, and 64 minutes.
- The manure, runoff, and infiltration samples were processed with Colilert (IDEXX), Enterolert (IDEXX), and MacConkey agar (Remel) to enumerate *E. coli* and total coliform MPN/ml, enterococci MPN/ml, and fecal coliform CFU/ml, respectively.
- The samples were also processed with the Phoenix 8000 UV-Persulfate TOC Analyzer (Teledyne Tekmar) to measure total organic carbon.

Results

- The rainfall intensity was 14.2 ± 2.3 cm/hr and 15.3 ± 1.1 cm/hr during the trials using the CAFO manure and the grazing cattle manure, respectively.
- The microbial release kinetics followed a piece-wise, log-linear shape, beginning with a precipitous log-linear drop in concentration of released constituents during the first four to eight minutes of rainfall simulation, followed by a much slower log-linear release (Figure 2).
- The organic carbon release kinetics displayed exponential release for both manure types (Figure 2).
- The release rates of *E. coli*, fecal coliforms, and total coliforms, during the first four minutes of release, were significantly higher from the CAFO manure than from the grazing cattle manure.

Fig. 2. Constituent release (average concentration of infiltration and runoff) from CAFO manure (A) and grazing cattle manure (B). C_0 is the concentration in the very first portion released, and C is the concentration at sample collection times.

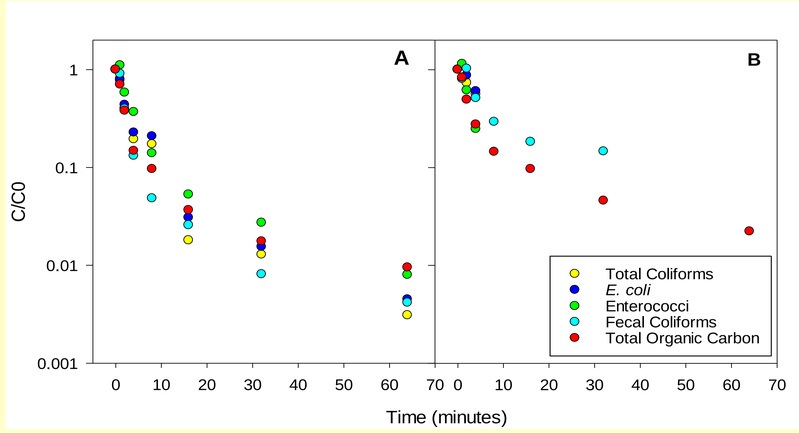
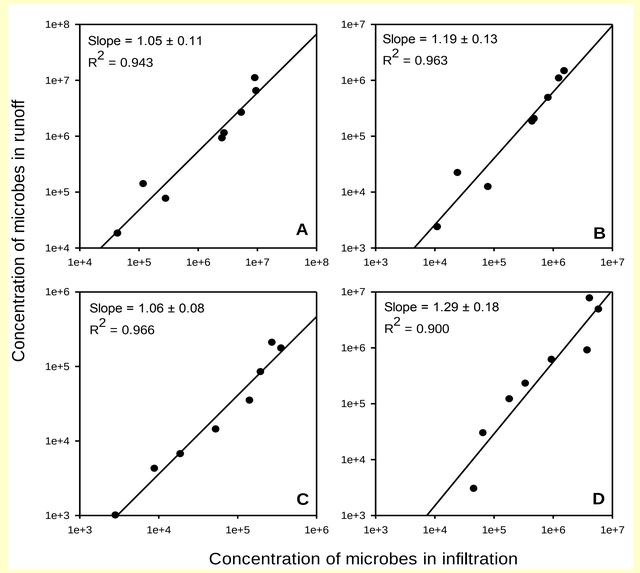


Table 1. Effective initial concentration in manure liquid phase (initial constituent content in manure / the manure water content) and concentration of constituents in the initial release (C_0). The unit for concentration is listed next to each manure constituent.

	CAFO Manure		Grazing Cattle Manure	
Manure Constituent	Effective initial concentration in manure liquid phase	C_0 from release data	Effective initial concentration in manure liquid phase	C_0 from release data
Total Coliform (MPN/ml)	5.98E+07	1.01E+07	3.07E+05	1.42E+04
E. coli (MPN/ml)	1.13E+07	1.51E+06	1.95E+05	6.17E+03
Enterococci (MPN/ml)	4.08E+06	2.41E+05	9.29E+04	1.98E+03
Fecal coliform (CFU/ml)	4.35E+07	5.92E+06	2.03E+05	6.83E+03
Total organic carbon (ppm)	5.60E+03	7.03E+02	7.22E+03	4.10E+02

- Initial microbial concentrations in runoff and infiltration were on average 0.7 and 1.1 log units less for CAFO manure and grazing cattle manure, respectively, than the effective initial concentrations in the manure liquid phase (Table 1).
- The ratios of 'time - log concentration' for the different microorganisms released from the same manure source did not significantly differ in most cases.
- The synchronous concentrations of microorganisms released from the CAFO manure into runoff and infiltration did not differ significantly (Figure 3).

Fig. 3. Ratio of total coliforms (A), *E. coli* (B), enterococci (C), and fecal coliforms (D) released from CAFO manure into runoff and infiltration over the course of the entire rainfall simulation. The computed values for slope and R^2 from linear regression are listed. The "±" sign separates the value and its standard error.



Summary

- Release rates of indicator bacteria appear to be different for CAFO manure and grazing cattle manure.
- Although the starting concentrations of microorganisms varied within manure, the different bacteria were released at similar rates from their common manure source.
- Manure-borne microorganisms were partitioned into runoff and infiltration at similar concentrations.
- In light of these preliminary results, manure release kinetic models may need to be re-evaluated to ensure that their formulations do not oversimplify bacteria release processes, which could lead to erroneous results.
- This research will be extended to advance the parameterization of C_0 in our attempts to improve microbial fate and transport models, which is critical for risk assessment of microbial contamination in the environment.

Disclaimer: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.