

Microbial contamination of Groundwater under Agricultural Fields – Sources and Pathways

Michael J. Goss & Adrian Unc...

University of Guelph
Ontario Canada

New Mexico State
University

mgoss@uoguelph.ca

aunc@nmsu.edu

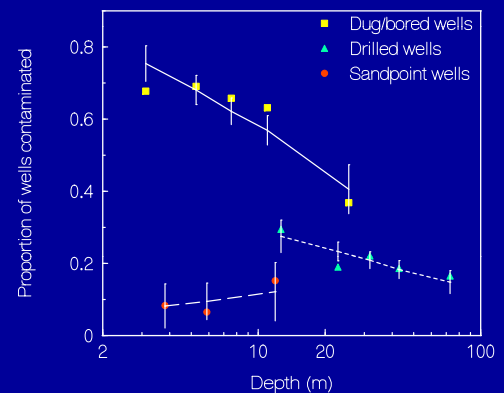
Synopsis

1. Agricultural sources
2. Overview of processes that govern the movement of microorganisms in soil - surface and subsurface
3. Incorporation of this knowledge into practices to counter contamination

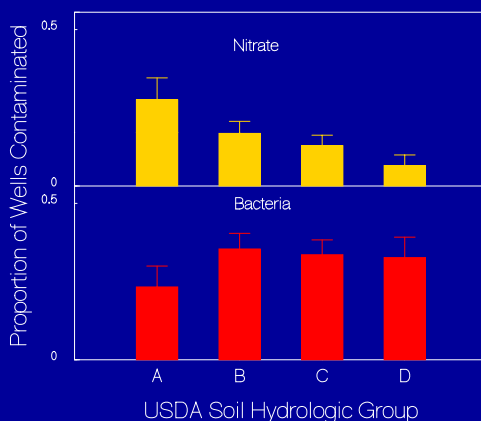
On-farm sources

- Confined
 - Manure storage tanks
 - Walled storage for sold manure
 - Septic tanks
- Unconfined
 - Manure piles
 - Grazing animals – domestic and wildlife
 - Land applied manure
 - Land applied organic amendments
 - Sewage biosolids
 - Composted urban waste

Bacterial Contamination in Ontario Farm Wells 1991-92



Effect of soil type



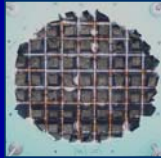
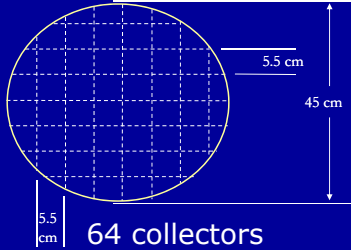
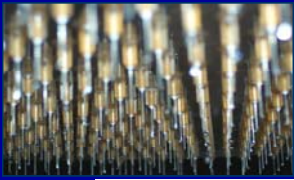
Factors that govern movement of bacteria through soil

- Flow characteristics
 - Pore size, shape and continuity
 - Particle size distribution of the porous medium
 - 3D organization of particles held together by various cohesive forces:
 - van der Waals,
 - coulombic,
 - cationic bridges,
 - cementation: chemical, organic colloids, metal oxides, carbonates
- Adsorption and adhesion of bacteria on soil mineral and organic particles.

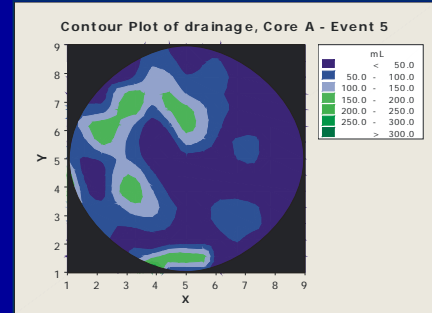


Monolith studies

Rainfall simulator



Preferential flow through unsaturated soil



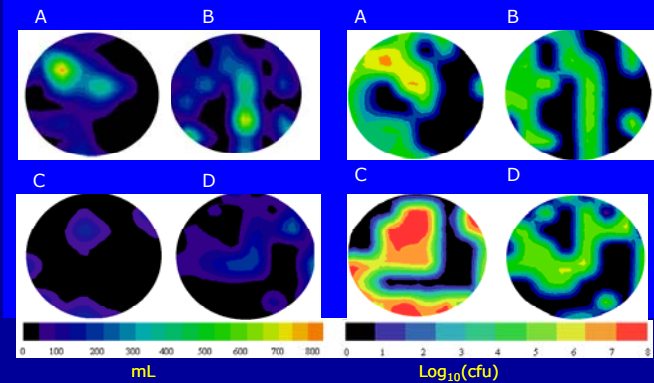
Flux density distribution

Drainage water

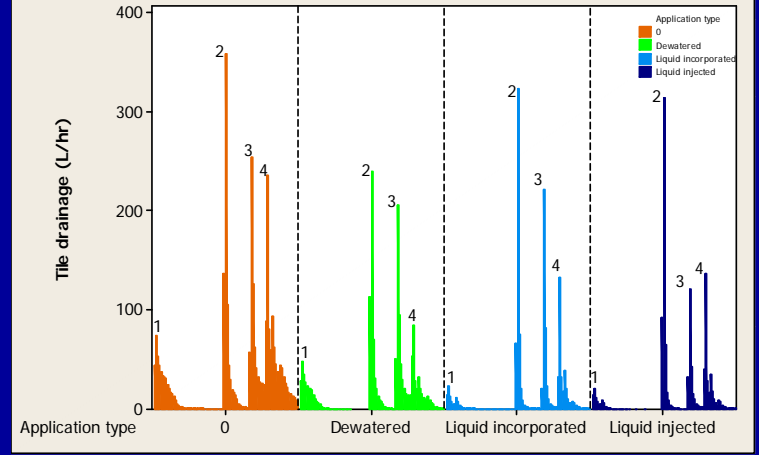
Faecal bacteria

Liquid manure swine

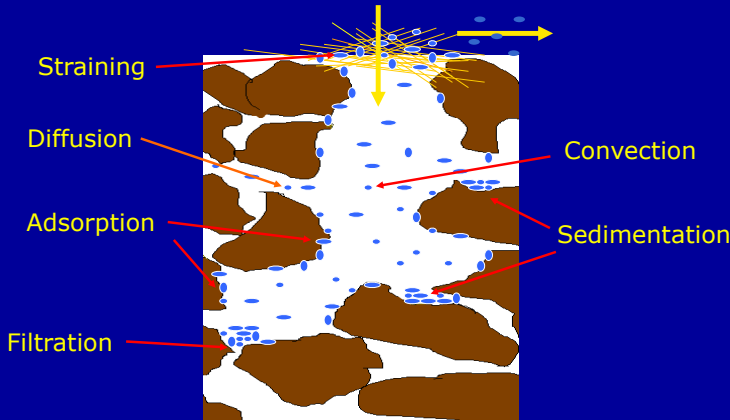
Solid Manure beef



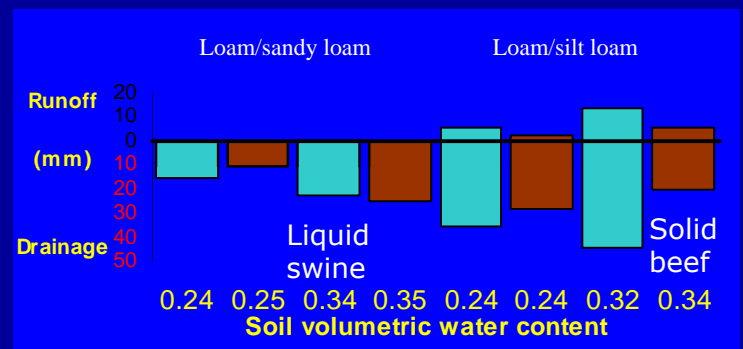
Tile drainage vs Application type



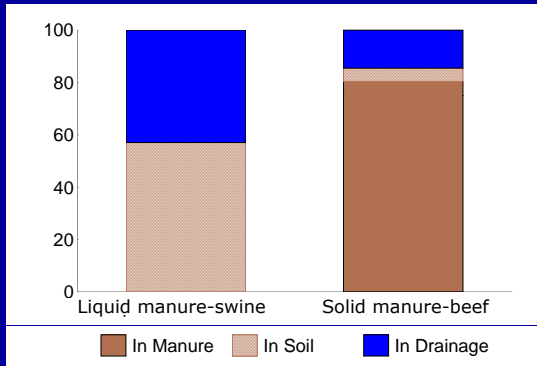
Factors that constrain movement of bacteria through soil



Partitioning of precipitation into surface runoff and drainage



Partitioning of *E. coli* 36 h after manure application - clay loam soil

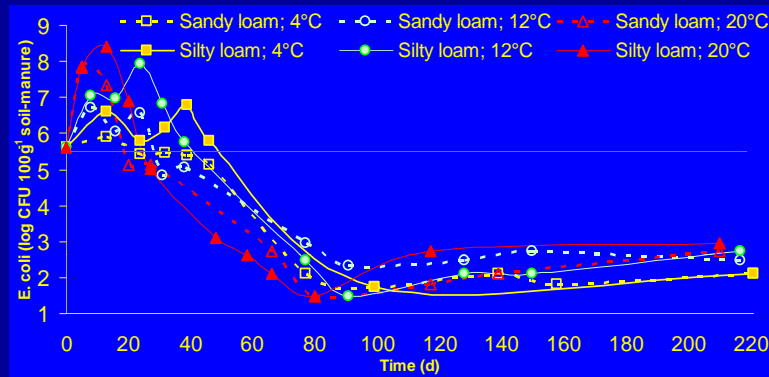


Factors affecting survival of microbes from manure after application to soil

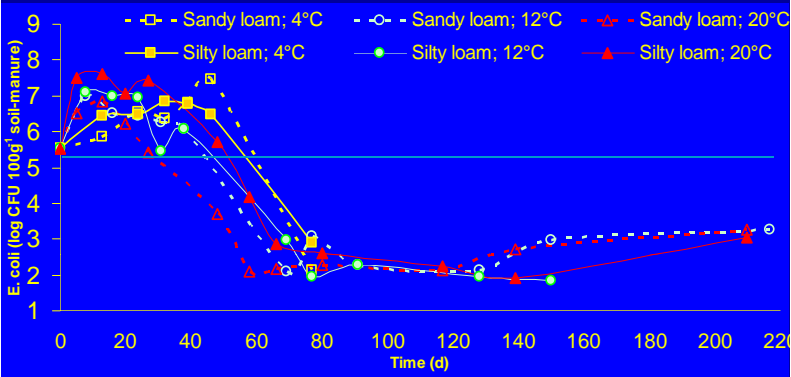
- Environmental factors:
 - UV radiation
 - pH
 - Temperature
 - Moisture (soil water holding capacity)
 - Indigenous soil organisms » competitive interactions.
- Manure impact on the soil microorganisms:
 - Additional nutrients and carbon » increase in the soil microbial activity?
 - NH₃



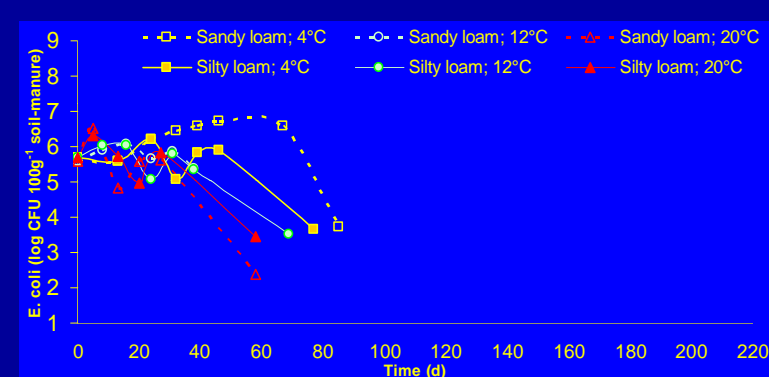
Variation in numbers of *E. coli* in sterilized soil after solid manure (beef) added



Variation in numbers of *E. coli* in sterilized soil after liquid manure (swine) added



Variation in numbers of *E. coli* in fresh soil after liquid manure (swine) added



Matrix components likely impact the factors governing movement of bacteria through the soil.

Impact of liquid manure on hydraulic properties of soil

- EC of manure liquid extracts up to 9.2 mS cm^{-1} (raw liquid manure) vs. EC of soil solution 0.3 to 1.2 mS cm^{-1}
 - » increased aggregate stability
- pH changes – more chemical dispersion as the soil departs from its point of zero charge
 - » reduced stability, crusting
- Wet soil aggregates more easily dispersed by raindrops
 - » crusting
- Reduced macroporosity diverts flow into the few pores that remain open
 - » increased preferential flow
 - » crusting

Impact of solid manure on hydraulic properties of soil

- EC of manure liquid extracts 1.9 mS cm^{-1} (solid manure)
 - » increased aggregate stability
- Mulch effect
 - » less runoff, more infiltration but less macropore flow
 - lowers the kinetic energy of raindrops
 - water-absorbing capacity of the bedding material
 - less mechanical soil dispersion, lowers the potential of water at the surface
- Manure mat at soil surface
 - » filtration of particulates

Surface properties of soil and bacteria

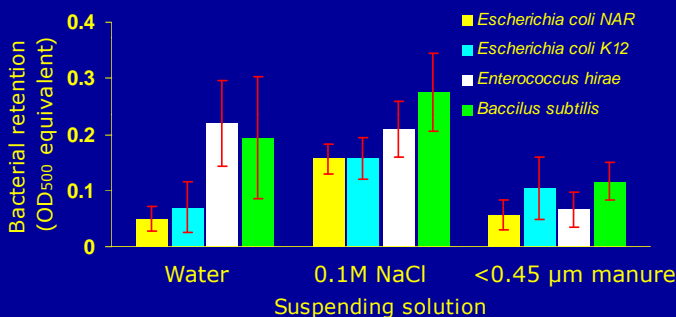
- Soil particles
 - negatively charged (e.g. clays, OM)
 - hydrophobic (e.g. OM)
 - positively charged (e.g. goethite)
- Microbial surfaces
 - Lipopolysaccharides, proteins, cell surface structures
 - Net negative charges
 - In the absence of charge the surfaces are hydrophobic

Manure impact on surface properties

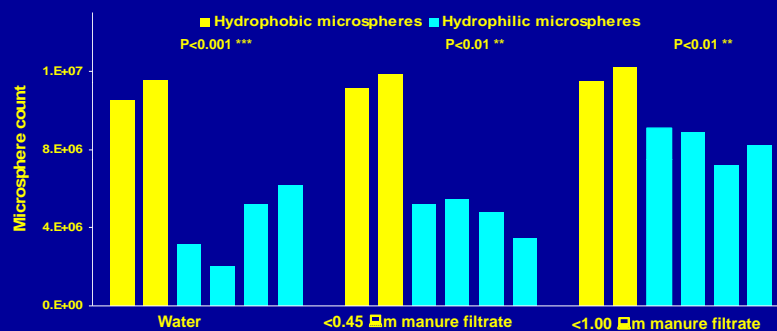
Impact of manure components

- Salts in solution
 - » reduced surface tension in suspension
 - » reduced hydrophobic effects
- Organic carbon compounds (charged and hydrophobic) soluble and colloidal
 - Colloidal matter » competition for retention sites?
 - Cell attachment to suspended colloids » more transport?
- Greater nutrient content of matrix
 - » bacteria having a more hydrophilic surface?

Impact of manure on retention of bacteria on soil aggregates



Retention of 0.7 - 2 μm microspheres on 1-2 mm diameter soil aggregates



Concerns for policy development

- Practices, such as no-till, developed to overcome soil erosion and contamination of surface waters increase infiltration, often by stimulating formation of preferential flow paths in soils
- Soils conducive of nitrate leaching are less likely to be associated with microbial contamination of groundwater
- Liquid manure systems pose a greater threat than solid manure handling

