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The Value of Field Occurrence Studies of Fecal Contamination in Aquifers and Wells

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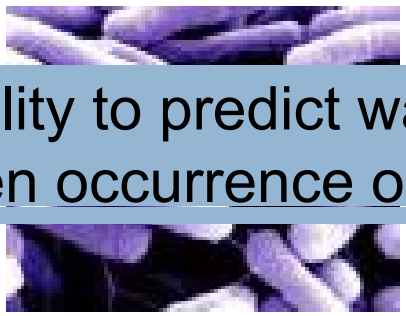
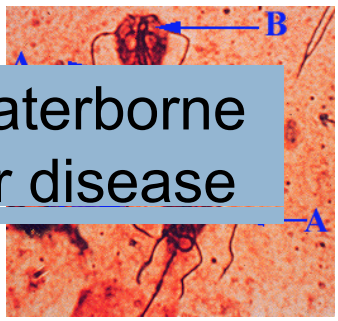
Outline

- The need for field-scale occurrence studies and "case histories" of pathogens & fecal indicators
- Examples from a field study in Bangladesh
  - Testing the main hypothesis
  - Serendipitous findings
- Summary

Pathogens in Groundwater

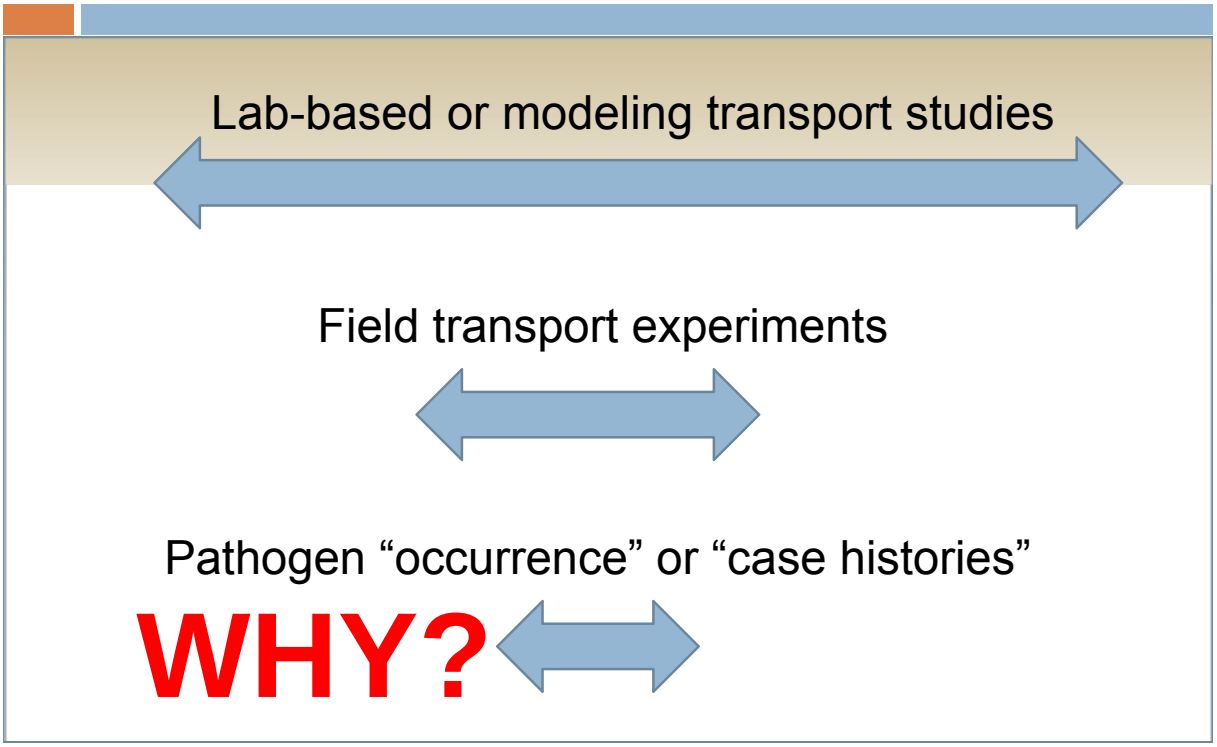
- Wide variety of pathogen types & inputs
- Variable correlation with other fecal microbes
- Strong influence of environmental factors
  - Hydrogeologic setting, precipitation, well type, sewage treatment, population density, etc.





Poor ability to predict waterborne pathogen occurrence or disease

Pathogen/surrogate Papers in Hydrogeology



Case against occurrence/case histories

- Expensive, time consuming, messy, unconstrained, seasonal, irreproducible, local relevance, etc.
- Viewed by some as a public health topic, not a hydrogeological topic
- Not attractive to hydrogeological funding agencies or journal editors

Case for occurrence/case histories

- Distinguish what “is” from what “might be”
- Insights into transport processes
- Aid in experimental & modeling design
- Water management & public health
- Can lead to serendipitous discoveries

Medical Case Histories are highly respected, so why are hydrogeological Case Histories discouraged?

Examples from Bangladesh Study

- Funded by NIH
- Investigate relationship between fecal bacteria & arsenic in rural wells
- Collaboration with
  - Columbia Univ.
  - Barnard College
  - Dhaka Univ.
  - Univ. of North Carolina

Bangladesh Arsenic & Pathogens

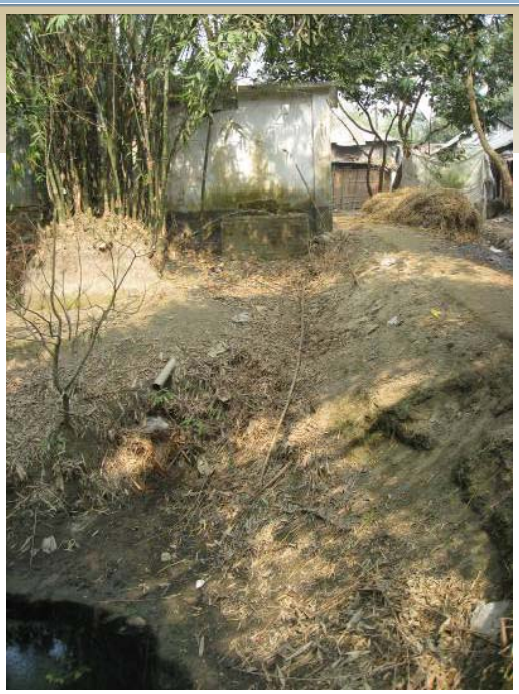
- Children drinking from shallow wells that are high in arsenic are less likely to have diarrhea than children drinking from wells low in arsenic
- Can this be explained by a geologic control?

Bangladesh Hypothesis

- Sandy sediments near ground surface
  - Short resident time & rapid transport of pathogens
  - Oxic conditions favor sorbed arsenic
- Clayey sediments near ground surface
  - Longer residence time & slow pathogen transport
  - Reducing conditions favor dissolved arsenic

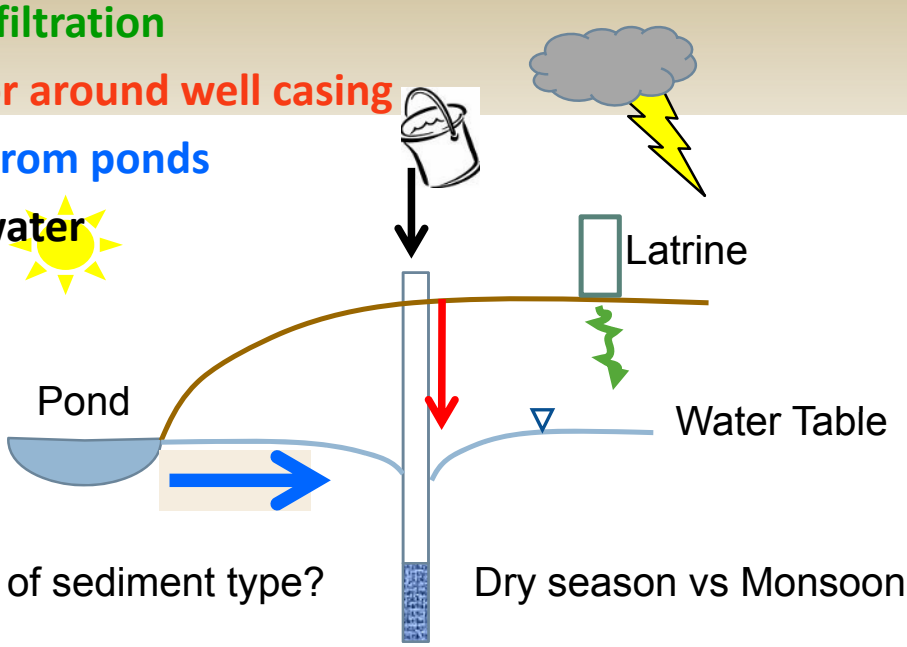
Revised Conceptual Model

- Latrines and wash water typically discharge into excavated pits
- These ponds act as sources of recharge to aquifer



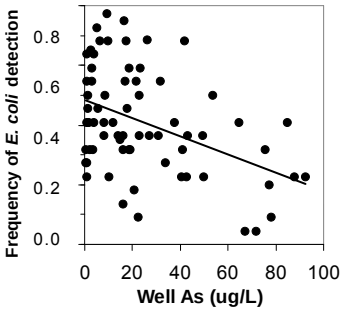
Many transport pathways

- **Latrine infiltration**
- **Leaks in or around well casing**
- **Seepage from ponds**
- **Priming water**



Primary Results

- Geology is a major control on both arsenic and *E. coli* (GW 2010) and there is an inverse correlation between As & *E. coli* (ES&T 2010)
- Consumers switching to low Arsenic wells in villages can increase risk of diarrhea (In-review)



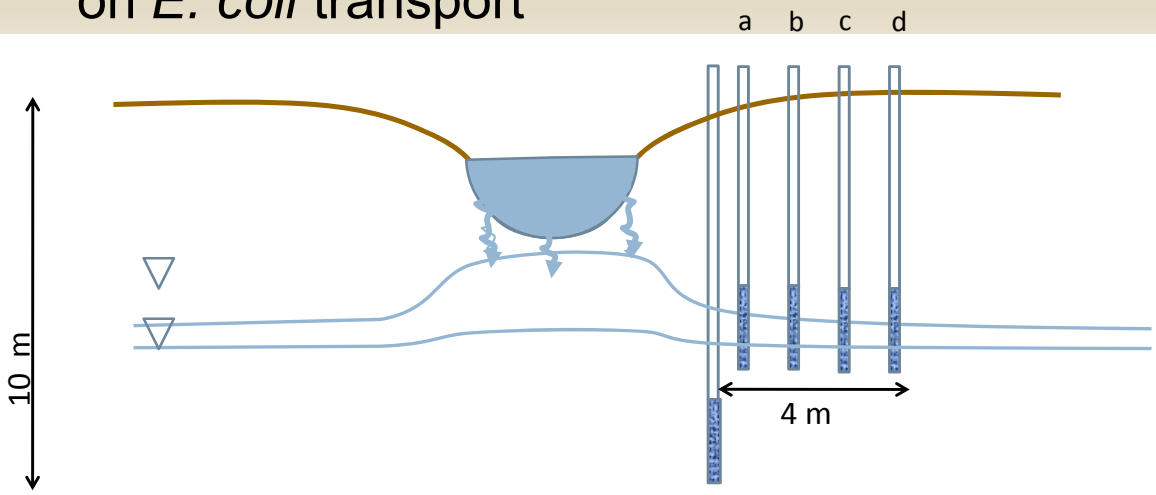
Secondary (often serendipitous) Results

- **Role of ponds as fecal sources (ES&T in-review)**
- **Cast iron hand pumps as reservoirs of microbial contamination (J. Water & Health in-press)**
- Improved sampling methods and influence of pumping on *E. coli* concentration (GW 2010)
- Influence of human population density on *E. coli*
- Comparison of field-scale and column-scale transport
- Molecular *E. coli* correlation with pathogens
- Comparison of well pathogens with those detected in clinical disease studies

Transport from pond experiments
(Knappet et al.)

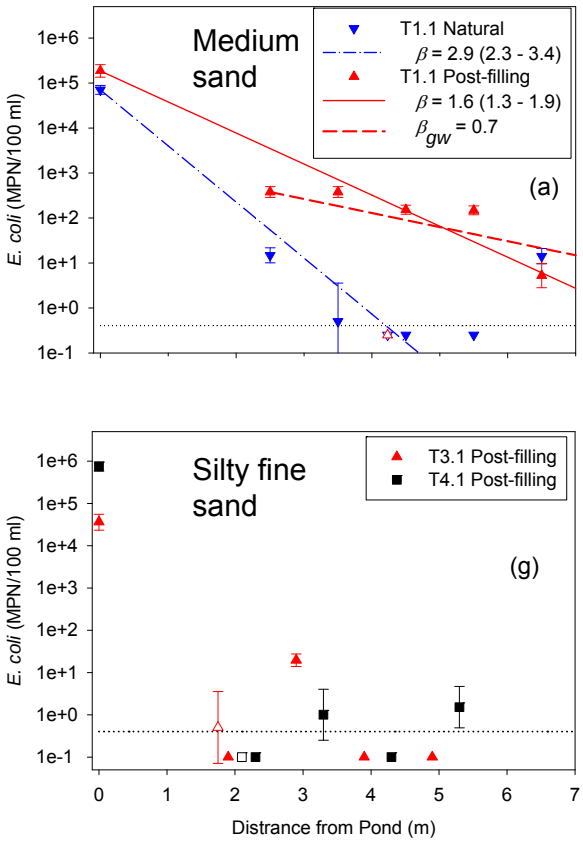
Pond Flooding Experiment

- Simulate influence of major rainfall event on *E. coli* transport



Results

- *E. coli* concentrations increase in transect near “sandy” pond, but not at “silty” pond
- Fitted β values’s indicated a 6-$\log_{10}$ (99.9999%) removal distance of < 5-12 m

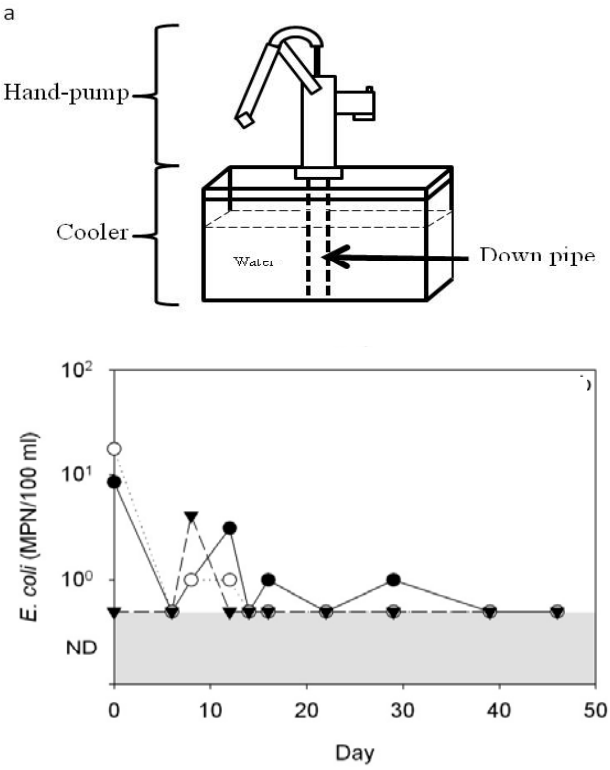


Hand pump experiment
(Ferguson et al.)

- Test whether pumps act as secondary reservoirs for contamination

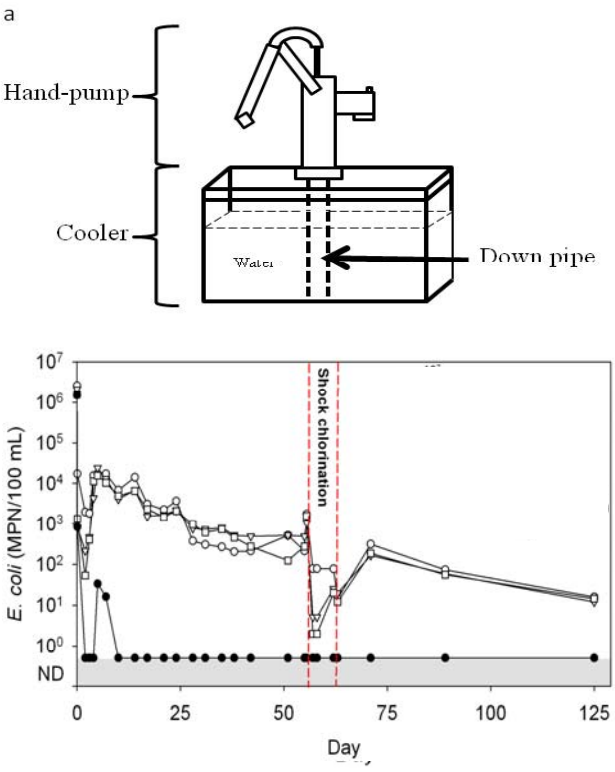
Results

- Added clean water to reservoir daily
- *E. coli* detected in discharge for 30 days



Results

- Added clean water to reservoir daily
- *E. coli* detected in discharge for 30 days
- Repeated experiment with higher C/Co
- Shock chlorination ineffective at removing *E. Coli* or coliform



Summary

- Field studies are needed to better understand causes & impacts of fecal contamination
- These studies often yield valuable unexpected insights