Characterization and Quantification of Microbial Risks: Rainwater/stormwater

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Technologies & Innovative Solutions for Harvesting and Non-Potable Use of Rain & Stormwater in Urban Settings
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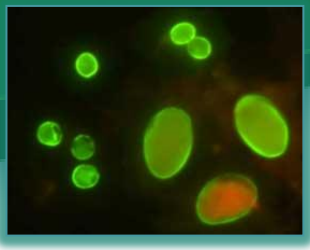
Problems with water monitoring

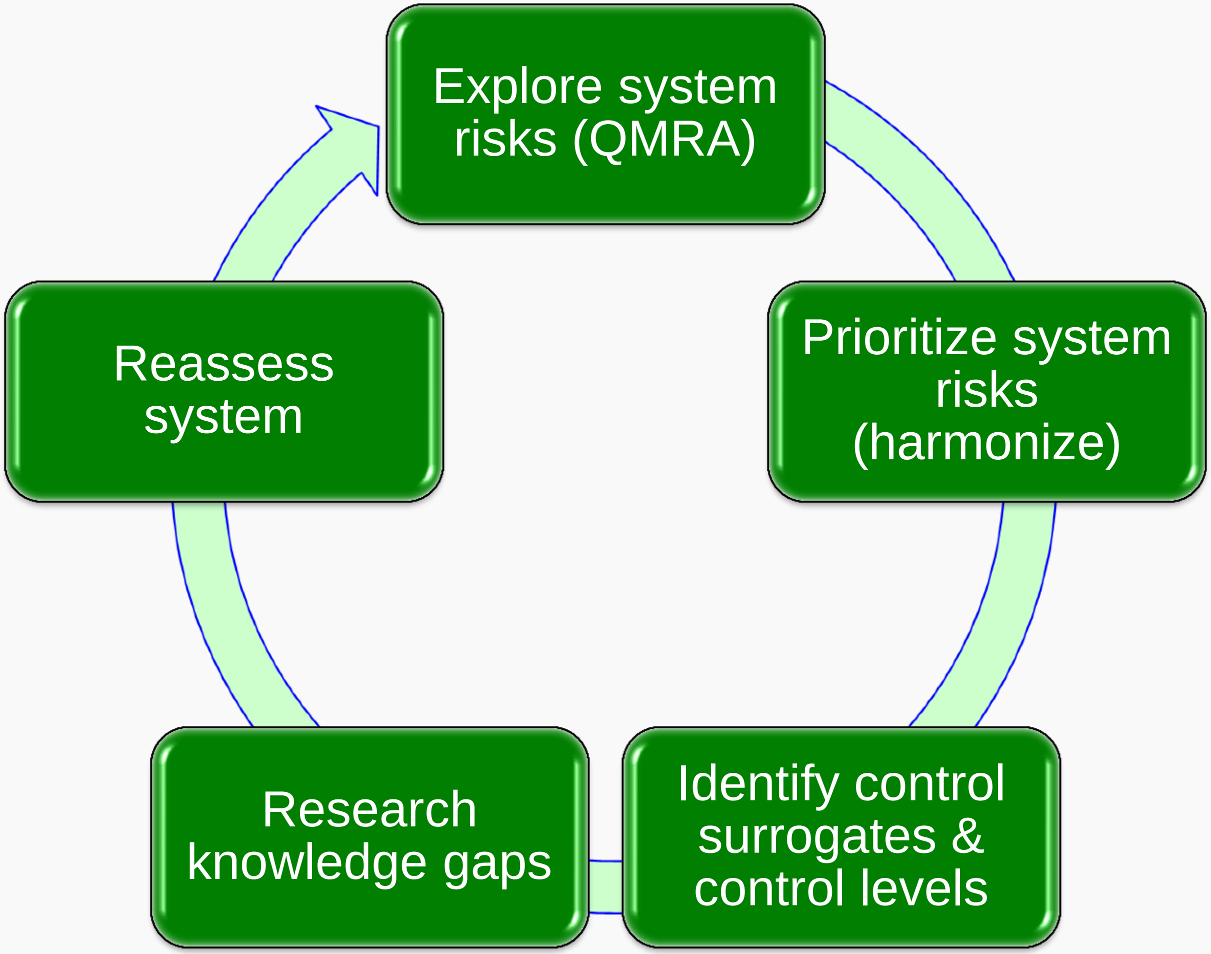
- Tests results received after water used
- Too many parameters for frequent testing & the only microbial indicator included is *E. coli*
  - But *E. coli* is a poor indicator for viral and protozoan pathogen removal/inactivation & does not indicated presence of environmental pathogens (e.g. *Legionella*)
- For many hazards there is no suitable test

Therefore use a risk management approach






QMRA – Analytic Framework



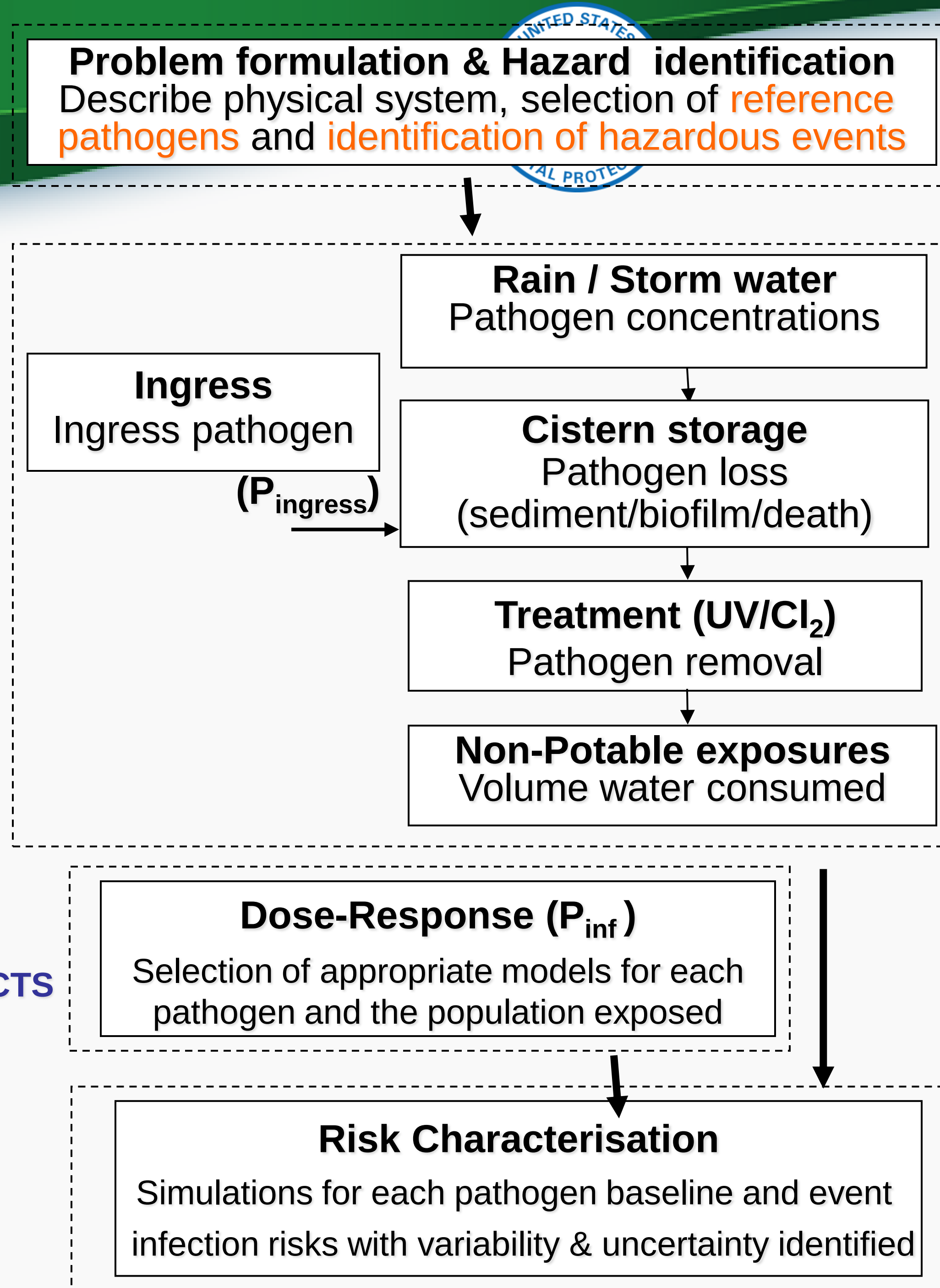
Quantitative microbial risk assessment (QMRA)

STEP 1
SETTING

STEP 2
EXPOSURE

STEP 3
HEALTH EFFECTS

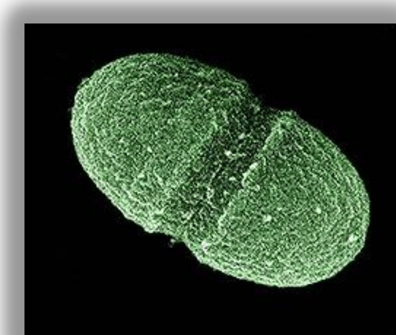
STEP 4
RISK

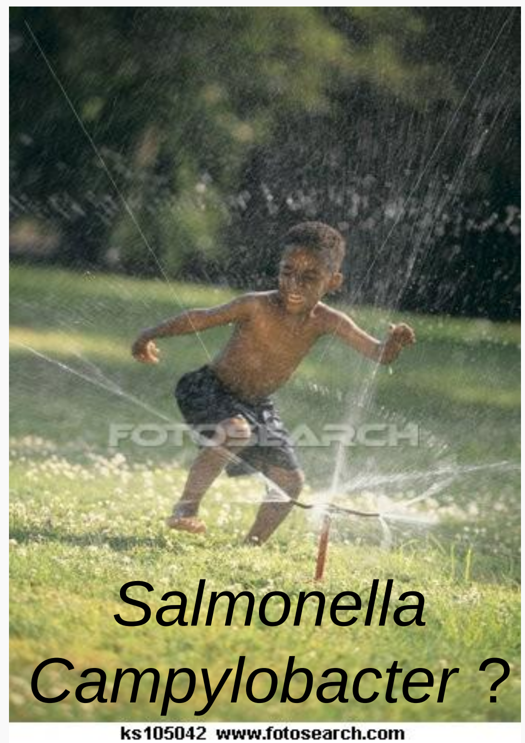


Hazard identification & characterization
Describe physical system, selection of reference pathogens and identification of hazardous events

Grounding from epi studies

Indicator? ⟵ Exposure ⟵ Outcome



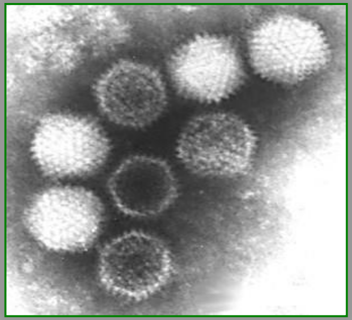


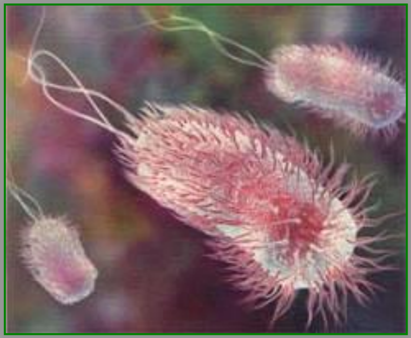
Dean & Hunter (2012) Env Sci Technol 46(5), 2501-2507
Rodrigo *et al.* (2011) Amer J Pub Health 101(5), 842-847
} No

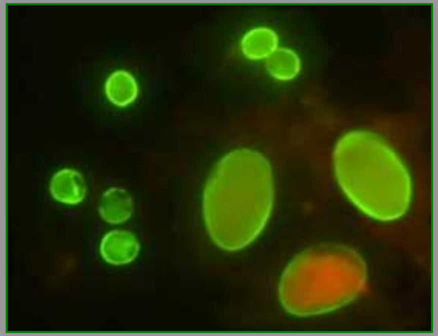
Hazard identification & characterization
Describe physical system, selection of reference pathogens and identification of hazardous events

Epi provides disease data – Limited on pathogens

- Gastroenteritis
- Respiratory
- Skin, eye infections
- Neurological
  - Other sequellae







Including non-GI disease requires a common metric (DALY)
Focus now on exposure reconstruction (saliva, sera etc.)

Drinking water public health costs

- CDC estimate waterborne disease costs > $970 m/y
  - Addressing giardiasis, cryptosporidiosis, Legionnaires' disease, *otitis externa*, and non-tuberculous mycobacterial (NTM) infections, causing over 40 000 hospitalizations per year

Disease	**$ /** hospitalization	**Total cost**
Cryptosporidiosis	**$16 797**	**$45 770 572**
Giardiasis	**$9 607**	**$34 401 449**
Legionnaires' disease	**$33 366**	**$433 752 020**
NTM infection/Pulmonary	**$25 985 / $25 409**	**$425 788 469/ $194 597 422**

Collier *et al.* (2012) Epi Inf 140(11), 2003-2013

Pathogens in source & Barrier removals
For nominal periods and hazardous events

Ahmed *et al.* (2012) Appl Environ Microbiol 78(1):219-226

Rainwater pathogen estimates

Reference Pathogen	Range (% +ve /#)
Salmonella enterica	0.9% /125 – 11% /27
Campylobacter jejuni	ND /125 – 45% /27
E. coli O157:H7	ND (not detected)
Cryptosporidium parvum	ND – 35% /17
Giardia intestinalis	ND /125 – 19% /21
Legionella spp. (few *L. pneumophila*)	ND /125 – 26% /27

Fecal pathogens all event driven, i.e. washed-in roof scats
Use culture & PCR data to bound credible ranges

Rationale for indicator qPCR vs pathogen detection – in stormwater (~ 100-fold)

- Target pathogen density (rec water 0.03 GI risk swim^{-1})
  - e.g. for one of the most numerous sewage pathogens:

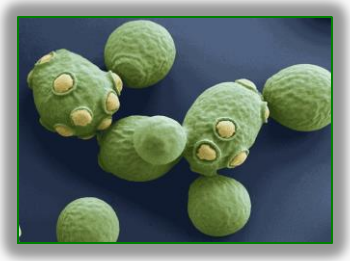
    9 *Norovrius* genomes L^{-1} of rec water ➡ 0.03 GI risk

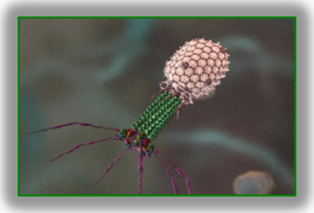
    Changing *Norovirus* morbidity based on infection from best estimate 0.6 to 0.1 increases target density **to 80 *Norovrius* genomes L^{-1}** (half to a tenth if recovery accounted for)
- *Bacteroides* HF183 target for same level of contamination from sewage to cause the benchmark (0.03 GI) illness:
  - **8600 *Bacteroides* HF183 genome copies L^{-1}**

Ashbolt *et al*. (2010) Wat Res **44:**4692-4703

Rain/Storm water fecal indicators

- Microbial source tracking markers
  - General & avian fecal markers
    - various *Bacteroidales* PCRs however, no avian targets
    - *Catellicoccus* PCR or cholesterol markers for avian excreta
  - Sewage-targeted (various *Bacteroides, e.g.* HF183)
- Surrogates for pathogen removals
  - Baker's yeast for *Crypto & Giardia* oo/cysts
  - Bacteriophages for human enteric viruses





Surrogates for stormwater treatment

- Three stormwater recycling systems evaluated*, which included biofiltration, storage tanks, UV disinfection, constructed wetland, retention ponds
- Barrier efficacy studied by MS2, yeast & *E. coli*
  - Over 12 mo under wet & dry conditions, e.g. biofilter log-reductions

Replicate	MS2 phage	*E. coli*	Yeast
1	1.5	1.8	2.9
2	1.2	1.6	2.3

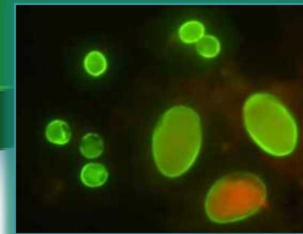
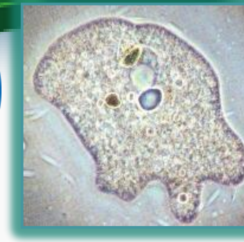
*Davies *et al.* (2008) Water Sci Technol 57(6):843–847

Clinical data for dose & health outcome
Used to estimate outcome by event-scenario

Rainwater reference pathogens Dose-Response data, and find…

- *Campylobacter* more important than *Salmonella*
- Toxigenic *E. coli* very infectious, but rare
- *Cryptosporidium* probably > *Giardia*
- Of the viruses, possibly bird flu of interest
- Of environmental pathogens, only *L. pneumophila* dose-response data available

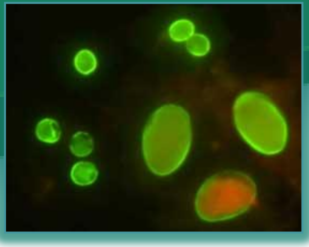


Hazardous events vs nominal

- **Enteric pathogen** risks depend upon:
  - **ID and control of short-duration hazardous events throughout the system; via**
  - **Surrogate target levels (at control points)**
    - **Rainwater: is disinfection on/functioning?**
    - **Stormwater: are barriers intact/functioning?**
- **Environmental pathogen risk is largely a function of chronic conditions**
  - Warm stagnant water/biofilms-nutrients



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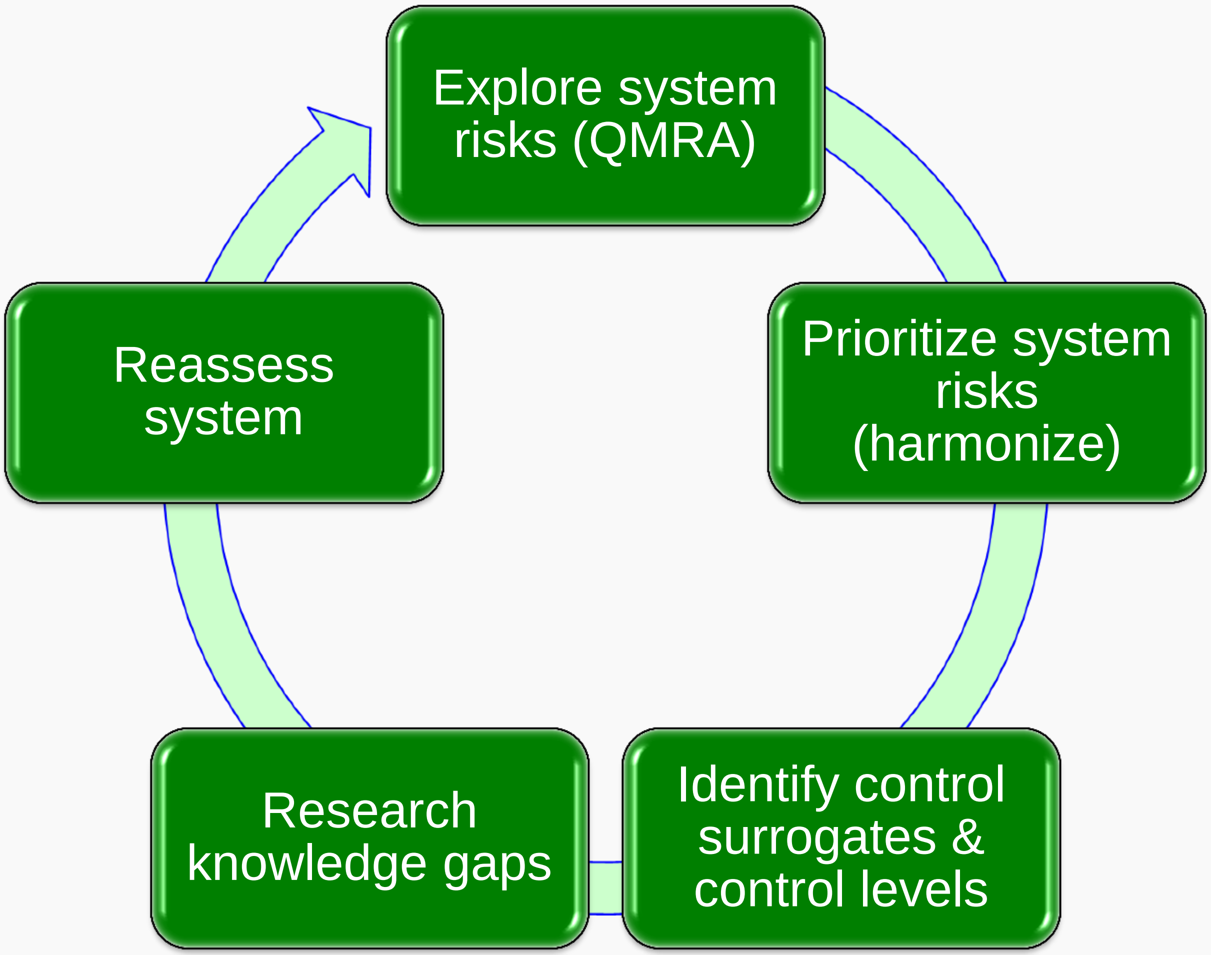

Conclusions: research gaps

- Need qPCR estimates of infectious pathogens and generally, precision estimates
- Need to correlate qPCR targets/surrogates to specific pathogens by environment type (fate)
- Hence, need to identify primary risks of concern and their control parameters for effective rain & storm water management