Quantitative microbial risk assessment of waterborne infectious diseases

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Project research framework

Data collection and estimation
- Climate change
- Land use
- Population
- Master plan
- etc.

Model development
- Water quality model
- Inundation model
- Risk assessment model

Scenario analysis
- Simulation of future water environment

Benefit analysis
- Economic evaluation of improving water environment

Dissemination and outreach
- Database development
- Capacity development
- Publications
Facts about water and health

- In 2015, there were **2.4 billion** (32%) people who lacked access to an improved sanitation facility.
- An estimated **663 million** (9%) people do not use an improved source for drinking-water in 2015.
- **88% of cases of diarrhea** are attributable to unsafe water, inadequate sanitation or insufficient hygiene.
- These cases result in **1.5 million deaths** each year, most being the deaths of children.
- Almost **one tenth of the global disease burden** could be prevented by improving water supply, sanitation, hygiene and management of water resources.
  - Prss-Üstün et al., 2008
Top 10 causes of death in low-income countries
2012

- Lower respiratory infections: 91
- HIV/AIDS: 65
- Diarrhoeal diseases: 53
- Stroke: 52
- Ischaemic heart disease: 39
- Malaria: 35
- Preterm birth complications: 33
- Tuberculosis: 31
- Birth asphyxia and newborn problems: 29
- Protein energy malnutrition: 27

Deaths per 100,000 population

WHO, 2012
Quantitative Microbial Risk Assessment

- Health risk assessment
  - A method to qualitatively or quantitatively characterize and estimate potential adverse health effects (risks) associated with exposure of individuals or populations to hazards (materials or situations, physical, chemical and or microbial agents).
Quantitative Microbial Risk Assessment

• Health risks caused by microbial pathogens
• Pathogens of concern

**Viruses (<100nm)**
- Norovirus
- Enterovirus
- Adenoviruses

**Bacteria (~1μm)**
- Campylobacter
- Helicobacter
- *Escherichia coli*

**Protozoa (5-10μm)**
- Cryptosporidium
- Giardia
- Cyclospora
Quantitative Microbial Risk Assessment

- Is this hazardous?

I found a virus here!!
Case study: 2007 flood in Jakarta
2007 Jakarta flood

- The 2007 Jakarta flood was a major flood in Jakarta, the capital of Indonesia and affected several other areas around the city
  - Date: 2 February – 12 February 2007
  - Deaths: 80
  - Property damage: $400 million

- 1,066 patients treated by hospitals due to diarrhea and 329 due to dengue fever (Standard Newswire, 2007)
Study area

Greater Jakarta

Ciliwung river basin
Catchment area = 438 km²

Assessment area = 238 km²
Elevation: 9 to 403 m
Model development: noroviruses in flood water

Flood simulation results

Total coliform concentration

Convert to noroviruses conc.

Water ingestion

Norovirus concentration in flood water

Health risk (probability of infection)
Health risk of norovirus infection

- Flo-2D result = inundation depth in each grid at each time (hour)
  - 28,496 grids x 312 hours = 8.9 M data
  - 82% of the grids (23,228 / 28,496) had no flood = no risk

- Risk assessment
  - Norovirus as target pathogen
  - QMRA w/ Monte Carlo simulation (x 10,000 iteration)

- Results
  - Flooded grid showed relatively high risk of infection
    - 4,146 grids (72% of flooded grids) showed > 10^{-4} risk
Most flooded grids exceeded $10^{-4}$ risk

82% grids showed no risk
Conclusion

• The health risk assessment model using the QMRA approach can estimate potential health outcomes (probability of noroviruses infection) caused by being exposed to flood water
  ◦ 72% of flooded grids showed relatively high (> $10^{-4}$) risk

• The model can be used to estimate health risks in what-if scenarios
  ◦ Urban flooding in the future (population growth, climate change)
  ◦ Effect of flood control measures
  ◦ Effect of sewage management measures