Risk of Infectious Diseases during Flood and Drought

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Self-introduction

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2010 - present  Associate Professor, Faculty of Agriculture, Yamagata Univ., Japan
2009 - 2010  Project Assoc. Prof., Environ. Science Center, Univ. of Tokyo, Japan
2008 - 2009  Visiting Assistant Prof., Drexel Univ., USA
1998 - 2008  Assist. Prof., Graduate School of Eng., Tohoku Univ., Japan

Research interests:
- Quantitative microbial risk assessment (QMRA)
- Development of mathematical model for QMRA
- Water-related infectious diseases
What is QMRA?

**Microbial contamination in environment**
- Water, air, soil, foods, etc.

**Exposure assessment**
- Fate of pathogens and human behavior

**Risk estimation**
- Calculation with dose-response model

Field investigation (Sampling & lab analysis)

Environmental modeling & simulation
Project on risk assessment of infectious disease attributed to drinking water (2003-2006)

Thailand
Lao PDR
Vietnam
Cambodia

Investigated in rainy season
Investigated in dry season
Investigated in both seasons

Lao PDR
Mekong River
Thailand
Cambodia
Vietnam

Questionnaire survey
Detection of fecal indicator bacteria in drinking water
## Description: Drinking water

### Primary drinking water in the Mekong watershed

<table>
<thead>
<tr>
<th>Area</th>
<th>Drinking water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lao PDR</td>
<td></td>
</tr>
<tr>
<td>Urban area</td>
<td>Tap water</td>
</tr>
<tr>
<td>Rural area close (&lt;1km) to rivers</td>
<td>River water</td>
</tr>
<tr>
<td>Rural area away from rivers</td>
<td>Well water</td>
</tr>
<tr>
<td>Cambodia</td>
<td></td>
</tr>
<tr>
<td>Urban area</td>
<td>Tap water, Bottled water</td>
</tr>
<tr>
<td>Rural area close (&lt;1km) to rivers</td>
<td>River water, Rainwater</td>
</tr>
<tr>
<td>Rural area away from rivers</td>
<td>Well water, Rainwater</td>
</tr>
<tr>
<td>Vietnam</td>
<td></td>
</tr>
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</tr>
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<td>Thailand</td>
<td></td>
</tr>
<tr>
<td>Urban area</td>
<td>Tap water</td>
</tr>
<tr>
<td>Rural area</td>
<td>Rainwater</td>
</tr>
</tbody>
</table>

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![Water bottles](image1.png)  ![Water source](image2.png)  ![Traditional water storage](image3.png)  ![Vietnam](image4.png)  ![Thailand](image5.png)
Estimation of fecal contamination of drinking water in Lao PDR, Cambodia and Vietnam by multiple regression analysis

Dependent variables: Mean concentrations of total coliforms in tap, well, river and rain water in each province

Independent variables: Provincial population, population density, rural population, poverty rate, access to safe drinking water and access to adequate sanitation
Significant regression equations were obtained for...

**In rainy season**
- **Well water:** \( C = 0.93PD + 0.57WT - 1.4SN + 41 \)  \((R^2 = 0.69, p = 0.01)\)
- **Rainwater:** \( C = 0.36RR - 0.81PV - 0.31WT - 0.25SN + 49 \)  \((R^2 = 0.74, p = 0.02)\)

**In dry season**
- **Well water:** \( C = 0.73WT - 0.57SN + 13 \)  \((R^2 = 0.58, p = 0.08)\)
- **River water:** \( C = 0.86PD + 20 \)  \((R^2 = 0.70, p = 0.006)\)
- **Rainwater:** \( C = -0.99PV + 172 \)  \((R^2 = 0.98, p = 0.07)\)

*where,* \( C \): Concentration of total coliforms [CFU/mL]  
\( PD \): Population density [\#/km\(^2\)]  
\( RR \): Rural population [%]  
\( PV \): Poverty rate [%]  
\( WT \): Access to safe drinking water [%]  
\( SN \): Access to adequate sanitation [%]  

Data from GIS (1km grid)
Results: Annual risk of infectious diarrhea

- High population density without access to adequate sanitation
  Annual risk: 0.1 to 1

- Water-supplied area (PWS system)
  Annual risk: Approx. $10^{-4}$

Approx. 12 million cases of diarrhea annually occur in the whole watershed.
### Scenario 1: Expansion of water-supplied area and strict management of tap water quality in Lao PDR, Cambodia and Vietnam

<table>
<thead>
<tr>
<th></th>
<th>Status quo</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water-supplied population (Percent in the 3 countries)</strong></td>
<td>3.2%</td>
<td>9.1%</td>
<td>13%</td>
</tr>
<tr>
<td><strong>Total coliforms [CFU/mL] in tap water (Rainy/Dry)</strong></td>
<td>PWS: 1 / 12 VWS: 93 / 105</td>
<td>PWS: 1 / 1 VWS: 1 / 1</td>
<td></td>
</tr>
<tr>
<td><strong>Annual risk of infectious diarrhea around Vientiane, Lao PDR</strong></td>
<td><img src="image" alt="Vientiane" /></td>
<td><img src="image" alt="Vientiane" /></td>
<td><img src="image" alt="Vientiane" /></td>
</tr>
<tr>
<td><strong>Annual cases of diarrhea</strong></td>
<td>11.8 million</td>
<td>- 15%</td>
<td>10.0 million</td>
</tr>
</tbody>
</table>
### Results: Scenarios for the risk reduction (2)

**Scenario 2: Promotion of drinking rainwater in Lao PDR, Cambodia and Vietnam**

<table>
<thead>
<tr>
<th>Case</th>
<th>Provinces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 provinces in each country</td>
</tr>
<tr>
<td>2</td>
<td>10 provinces in each country</td>
</tr>
<tr>
<td>3</td>
<td>All provinces (58 in total)</td>
</tr>
</tbody>
</table>

**Total coliforms in rainwater**

- Case 1: 46 CFU/mL
- Case 2: 2 CFU/mL
- Case 3: 0 CFU/mL

**Annual cases (million) of infectious diarrhea**

- Status quo: 12 million
- Case 1: 8 million
- Case 2: 6 million
- Case 3: 4 million

- Reduction: 72%
Water-related infectious diseases

Waterborne diseases

Are caused by pathogens that can be directly spread through contaminated water.
[Diarrhea, cholera, leptospirosis, shigellosis, typhoid fever, etc.]

Sanitation & hygiene-related diseases

Could be prevented through better access to adequate sanitation facilities (e.g. toilet and latrines) and better hygiene practices (e.g. frequent hand-washing, face washing, and bathing with soap and clean water).
[Scabies, ringworm, trachoma, etc.]

Vector or insect-borne diseases associated with water

Are spread by insects, such as mosquitos, breeding around water.
[Dengue fever, malaria, yellow fever, etc.]
Climate change and water-related infectious diseases

Climate change
- Rise in temperature
- Change in rainfalls

- Expansion of vectors’ habitat from tropical to temperate regions
- Enhancement of pathogens’ growth in water
- Frequent occurrence of flood & drought

- Difficulty to access to safe drinking water and adequate sanitation
- Risk of vector-borne diseases associated with water
- Risks of waterborne, sanitation and hygiene-related diseases
Freshwater availability in 2007

Source: FAO, Nations unies, World Resources Institute (WRI).

PHILIPPE REXACEWICZ
FEBRUARY 2008
Change in water availability

Change in water availability compared with average 1961–1990 (%) 2050 based on IPCC scenario A1

- more than 20
- 20 to 0
- 0 to −20
- −20 and more

Large flood events (1985-2007)

1985 - Global Flood Archive - Dartmouth Flood Observatory
Change in frequency of flood events from 1993 to 2003

Source: NIES, Japan
Risk of waterborne diseases during flood events

Flood water is probably contaminated by overflow from canals receiving domestic and industrial wastewater.

Risk of waterborne diseases would increase due to exposure to such a contaminated flood water.

Combined sewer system as “underground canal network”.
Life during flood in Hue, Vietnam

- Moving furniture
- Cooking
- Going to shops or work places
- Swimming & playing
Estimated risk of illness caused by *E. coli* in water

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Risk* (x10^-4)</th>
<th>Scenario</th>
<th>Risk* (x10^-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving furniture &amp; cleaning</td>
<td>2822</td>
<td>Eating raw vegetables at home</td>
<td>177</td>
</tr>
<tr>
<td>Cooking</td>
<td>1433</td>
<td>Eating raw vegetables at shop</td>
<td>59</td>
</tr>
<tr>
<td>Playing</td>
<td>916</td>
<td>Fishing</td>
<td>15</td>
</tr>
<tr>
<td>Going shopping</td>
<td>751</td>
<td>Swimming</td>
<td>9</td>
</tr>
<tr>
<td>Going to work</td>
<td>322</td>
<td>Drinking ice at shop</td>
<td>0.4</td>
</tr>
<tr>
<td>Eating raw vegetables at home</td>
<td>165</td>
<td>Drinking ice at home</td>
<td>0.2</td>
</tr>
<tr>
<td>Swimming</td>
<td>13</td>
<td>Total risk in normal time</td>
<td>258</td>
</tr>
<tr>
<td>Drinking ice at home</td>
<td>0.0001</td>
<td>*Estimated using averages of interview data (n=989).</td>
<td></td>
</tr>
</tbody>
</table>

Total risk in flood time                     | 4496           |
Leptospirosis: a waterborne zoonotic disease

Living in (infecting to) kidney of animals

Excreted with urine

Ingestion of contaminated water

Invasion through skin

Photo from National Institute of Infectious Disease, Japan
PHILIPPINES: Flood victims grapple with Leptospirosis

MANILA, 28 October 2009 (IRIN) - Weeks after back-to-back cyclones left nearly 1,000 people dead, the Philippines is grappling with an outbreak of a deadly flood-borne disease that has infected survivors from areas where dirty water has yet to subside, officials say.

In a report to emergency relief agencies, Health Secretary Francisco Duque said that as of 26 October, there were 2,158 confirmed cases of Leptospirosis infections, with 167 deaths reported by the National Epidemiology Centre.

With more than 120,000 people crammed into evacuation centres in Manila and outlying areas that are still submerged in putrid, stagnant water, Duque said the likelihood of more outbreaks was high.

The deaths linked to Leptospirosis - a bacterial infection caused by contact with water contaminated by rat and other animal urine - were in addition to the 929 people who died from devastation wrought by tropical storm Ketsana, which hit on 26 September, and Typhoon Parma, a week later. According to the National Disaster Coordinating Council (NDCC), more than nine million people were affected by the two storms.

"There is a surge in the number of hospitalized cases of Leptospirosis from among the victims of recent typhoons who have [lost] ... their homes," Duque said in a memorandum order issued last week to state-run hospitals to prioritize cases of the disease.

This report is available at http://www.irinnews.org/report.aspx?ReportId=86779
Risk of leptospirosis depending on number of invading cells

Dense population of mice especially in urban environment (e.g. sewer system)

Risk of cut on legs when walking in muddy flooded area

Lepto can easily invade human body through such a cut
Risk of water-related infectious diseases during drought

Waterborne diseases

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Cholera outbreak in Haiti after earthquake in January 2010
Schistosomiasis: a waterborne and neglected tropical disease

- **Snail: Intermediate host**
- **Egg**
- **Miracidium (1st stage)**
- **Cercaria (2nd stage)**
- **Adult worm living in portal vein**

The life cycle of Schistosomiasis involves a snail as an intermediate host and humans as the final host. The cycle begins with cercariae emerging from the snail and penetrating the skin of a human. The cercariae develop into miracidia, which infect the snail, developing into cercariae again. The cercariae penetrate human skin and develop into schistosomula, which migrate to the liver and eventually the veins of the intestines and liver, becoming adult worms.
Summary

Occurrence frequencies of flood and drought seem to be globally increasing probably due to climate change.

Flood and drought pose a higher risk of water-related diseases, such as diarrhea, leptospirosis and schistosomiasis, than normal time due to a frequent contact to contaminated water.

QMRA could help us understand whether or not outbreak of infectious diseases happens during flood and drought, where it dose, how large it is, and also how many cases of infectious diseases can be reduced with supposed countermeasures against flood and drought.