Climate change and waterborne infectious diseases from an aspect of regional sustainable development

Tatsuo Omura
Professor
Graduate School of Engineering
Tohoku University, Japan

CONTENTS
1. Infectious diseases enhanced by climate change must be global issues for regional sustainability
2. Regional sustainability and health risk of infectious diseases
3. Infectious risk evaluation in water utilization system in Mekong watershed (from RR2002 project)
4. Regional sustainable development through water utilization system in consideration of climate change
5. Conclusion

International Efforts for Issues on Water Resources & Health
Adoption at the Environment & Development Summit (2002, South Africa)

- Water resources
  - 25–40% of underground & river water resources are wasted through irrigation
  - To create national action plans for water resource management considering ecosystem preservation
  - To achieve 5% higher efficiency in using agricultural water
  - To achieve 10% higher efficiency in using agricultural water

- Health
  - 6000 children/day are dying due to unsafe drinking water in developing countries
  - To reduce number of disease cases owing to unsafe water by 35%
  - To reduce number of disease cases owing to unsafe water by 70%

Causes of death in 1998

Source: WHO (1999)

99.8% of death associated with unsafe water, sanitation and hygiene are in developing countries (WHO, 2002).
**Infant mortality rates in 2004**
(Unit: death per 1,000 live births)

- **Lao PDR**: 65
- **Republic of Korea**: 5
- **Japan**: 3
- **Philippines**: 26
- **China**: 8
- **Thailand**: 18
- **Vietnam**: 17
- **Cambodia**: 97
- **Malaysia**: 10
- **Singapore**: 0
- **Indonesia**: 30
- **Timor-Leste**: 64


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**Waterborne pathogens (bacteria)**

- **Shigella spp.**
- **V. cholerae**

**Waterborne pathogens (protozoa)**

- **Giardia**
- **Cryptosporidium**

**Waterborne pathogens (viruses)**

- **Norovirus**
- **Rotavirus**
- **Hepatitis A virus**
- **Adenovirus**
Societal/climate changes and risk of waterborne infectious disease in the future

Keywords for societal and climate changes

- International society
- Climate change
- Overpopulated society

Outbreak of imported infectious diseases
Outbreak of infectious diseases due to the lack of water resources
Acceleration of water reuse and reclamation (water shortage)

Increase of risk of infectious diseases

Effect of Water shortage due to climate change on health risk

Additional millions of people at risk of increased water shortage

Temperature increase (°C)

Prediction in 2080


Simulation of Dispersion of total coliforms due to flooding in Cambodia in 2002

Water depth

Conc. of total coliforms

Estimated impacts of climate change in 2000, by WHO-region

Summary

- Infectious and parasitic diseases related to water utilization are the main causes of death in developing countries.
- Risk of infectious diseases would be increased with societal and climate changes in the future.
- It is critical to elucidate the transboundary movement of pathogens with climate change in order to avoid the prevalence of infectious diseases.

Sustainable development limited due to high risk of infectious diseases

- Poverty
- Lack of human resources
- Lack of infrastructures
- Slow economic development
- Shortage of clean water resources
- High mortality of children
- Poor sanitation
- Climate change enhancing
Economy and health risk

<table>
<thead>
<tr>
<th>Gross National Income per capita (US$)</th>
<th>Probability of dying due to diarrheal diseases under 5 years (per 10^6 live births)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>10^0</td>
</tr>
<tr>
<td>1,000</td>
<td>10^1</td>
</tr>
<tr>
<td>10,000</td>
<td>10^2</td>
</tr>
<tr>
<td>100,000</td>
<td>10^3</td>
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<td>1,000,000</td>
<td>10^4</td>
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<td>10^5</td>
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<td>100,000,000</td>
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<td>1,000,000,000</td>
<td>10^7</td>
</tr>
<tr>
<td>10,000,000,000</td>
<td>10^8</td>
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</tbody>
</table>

n = 152, r = -0.86 (p<0.01)


Summary

- High risk of waterborne infectious diseases is a factor to limit sustainable development.
- Risk of infectious diseases has been characterized with societal factors such as GNI, population, infrastructure and so on but relationship between climate change and health risk has not been investigated sufficiently.

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Study area

- Groundwater with high salinity
- Relatively low precipitation
- Low percentages of population with access to safe water sources and improved sanitation
- Flooding
- Complicated canal systems
- Intrusion of seawater to rivers and canals

Surveyed in rainy season
Surveyed in dry season
Surveyed in both seasons
Water utilization and diseases

Annual deaths due to infectious diarrhea
- Worldwide: 1.8 million
- Southeast Asia: 0.5 mil.
Unsanitary water attributes to 90% of the deaths.

<table>
<thead>
<tr>
<th>Safe water sources</th>
<th>Unsafe water sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap (piped) water</td>
<td>River water</td>
</tr>
<tr>
<td>Rainwater</td>
<td>Lake water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mortality for children &lt; 5 yrs [%]</th>
<th>Access to safe water source [%]</th>
</tr>
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<tbody>
<tr>
<td>Cambodia 13.3</td>
<td>34</td>
</tr>
<tr>
<td>Lao PDR 13.3</td>
<td>43</td>
</tr>
<tr>
<td>Thailand 2.3</td>
<td>85</td>
</tr>
<tr>
<td>Vietnam 3.5</td>
<td>73</td>
</tr>
</tbody>
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Main drinking water source in each study area

<table>
<thead>
<tr>
<th>Rainy season</th>
<th>Dry season</th>
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<tbody>
<tr>
<td>Lao PDR</td>
<td></td>
</tr>
<tr>
<td>Urban area</td>
<td>Tap water / Bottled water</td>
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<tr>
<td>Rural area near rivers</td>
<td>River water (rainwater)</td>
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<tr>
<td>Rural area far from rivers</td>
<td>Well water (rainwater)</td>
</tr>
<tr>
<td>Cambodia</td>
<td></td>
</tr>
<tr>
<td>Rural area far from rivers</td>
<td>Well water</td>
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<tr>
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<td></td>
</tr>
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</table>
Procedure of risk evaluation for infectious diarrhea associated with drinking water

Field survey
- Detections of total coliforms & E.coli

Interview survey
- Estimation of E.coli conc.

Calculation of infectious risk

Area and drinking water source for risk evaluation

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<thead>
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<th>Dry season</th>
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<tr>
<td>Rural area</td>
<td>Rainwater</td>
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</tr>
</tbody>
</table>

Procedure for risk evaluation based on GIS data (1)

(1) Determination of drinking water source

<table>
<thead>
<tr>
<th>Data sets</th>
<th>Land use</th>
<th>River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinking water source</td>
<td>Urban area</td>
<td>Tap water</td>
</tr>
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</table>

(2) Estimation of the contamination of drinking water with total coliforms

<Based on multiple regression model>

Well water: $X = 0.50 \text{ POPD} - 0.72 \text{ SANI} + 36$

(N = 6, $R^2 = 0.69$, $p = 0.17$)

where,

$X$ : Concentration of total coliforms [CFU/mL]

$\text{POPD}$: Population density [person/km²]

$\text{SANI}$: Access to improved sanitation based on population [%]
Risk factors for the contamination of well water

Access to adequate sanitation based on population (%) vs. Population density [person/km²]

Well water:
\[ X = 0.50 \text{ POPD} - 0.72 \text{ SANI} + 36 \]
\( N = 6, R^2 = 0.69, p = 0.17 \)

Procedure for risk evaluation based on GIS data (2)

(2) Estimation of the contamination of drinking water with total coliforms

Based on multiple regression model

Well water: \( X = 0.50 \text{ POPD} - 0.72 \text{ SANI} + 36 \)
\( N = 6, R^2 = 0.69, p = 0.17 \)

where,

\( X \) : Concentration of total coliforms [CFU/mL]
\( \text{POPD} \) : Population density [person/km²]
\( \text{SANI} \) : Population with access to adequate sanitation [%]

Based on the average of measured data

Tap water from PWS: \( X = 9 \) (S.D. = 10)
Tap water from VWS: \( X = 32 \) (S.D. = 44)
River water: \( X = 36 \) (S.D. = 55)

Risk of infectious diarrhea in dry season

Possible scenarios on risk reduction in the Mekong watershed

Scenario A.
Improvement of tap water quality in urban area.

Scenario B.
Promotion of drinking rainwater in rural area.
**Scenario A. Improvement of tap water quality in urban area**

**Initial**
- Savannahkhet

**Case 1**
- Savannahkhet

**Case 2**
- Savannahkhet

- Reduction of infected persons by chlorine disinfection of tap water: 562
- Reduction of infected persons by strict quality management of tap water: 610

**Scenario B. Promotion of drinking rainwater in rural area**

**Initial**
- Annual infected person: 4,540,000

**Case 1**
- Annual infected person: 2,120,000 (47% of the initial)
  - If promoted to provinces: 6 in Lao PDR and 7 in Cambodia.

**Case 2**
- Annual infected person: 1,130,000 (25% of the initial)
  - If promoted to provinces: 12 in Lao PDR and 14 in Cambodia.
Summary

- Source of drinking water and its contamination with indicator bacteria in the Mekong watershed were clarified.
  - Tap water and bottled water are drunk in urban area. Total coliforms are sometimes detected from the drinking waters.
  - River water and well water with high concentration of indicator bacteria are used for drinking in rural area.

Summary (cont’d)

- Risk of infectious diarrhea associated with drinking water was evaluated in Lao PDR and Cambodia.
  - The risk was quite high in rural area surrounding capital cities.
  - Introduction of rainwater as drinking water source is more effective for reducing the risk of infectious diseases.
  - Model developed will be the powerful tool in evaluating the risk of infectious diseases.

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Continent

Regional sustainable development through water utilization system in consideration of climate change

International society, Climate change, and Overpopulated society

Present society with high infectious risk in the region

Regional sustainable development

Future society with minimized infectious risk in the region

Pollution of water resources
Risk evaluation
Characteristics of water utilization

Change of water utilization
Risk reduction
Control of water pollution

Technology for water & wastewater treatment

Transboundary movement of pathogens

Risk evaluation methodology
Studies of culture, economy, society, etc.

Recent sustainable development

Future sustainable development

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Conclusion

In order to materialize the regional sustainable development, we need to develop the innovative methodology on the regional sustainability toward the resolution of issues caused by climate change in the context of preventing the prevalence of infectious diseases.

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- Thammasat University
- Mahidol University
- Khon Kaen University

CAMBODIA
- National Malaria Center
- Department of Drugs and Food, Ministry of Health

LAO PDR
- National Institute of Public Health
- National Center for Laboratory and Epidemiology

VIETNAM
- Southern Institute of Water Resources Research
- National Institute of Hygiene and Epidemiology

and, other counterparts in southeast Asian countries.

Simulation of Dispersion of total coliforms due to flooding in Cambodia in 2002

Water depth
Conc. of total coliforms

Evaluation of seasonal infectious risk

Thank you very much for your kind attention.
In case of small flood, infectious risk is locally very high with small flood area. Infectious risk decreases with increase of flood area due to dispersion of pathogens.