Module 8: Water-borne diseases
Key messages in Module 8

- Water-borne diseases are mostly faecal-orally transmitted diseases
- Climate can influence waterborne diseases in different ways depending on the local environment & population
- Mitigation & adaptation will be enhanced by understanding the ecology of pathogens
Module 8 outline

1. Water quantity & quality
2. Burden of diarrhoeal diseases
3. Effects of climate on diseases
4. Addressing water- & food-borne diseases
Water quantity & quality
Water quantity & quality issues
Examples of current vulnerabilities of freshwater resources

Source: IPCC (2007)
54% of India Faces High to Extremely High Water Stress
<table>
<thead>
<tr>
<th>Category</th>
<th>Transmission</th>
<th>Disease examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-borne</td>
<td>Ingestion of water contaminated by human or animal faeces or urine containing</td>
<td>Gastroenteritis, enteric hepatitis, amoebic &amp; bacillary dysentery,</td>
</tr>
<tr>
<td></td>
<td>pathogenic bacteria, viruses or parasites</td>
<td>cholera, leptospirosis, poliomyelitis, typhoid/paratyphoid fever</td>
</tr>
<tr>
<td>Water-washed</td>
<td>Skin, ear or eye contact with contaminated water &amp; poor personal hygiene</td>
<td>Conjunctivitis, trachoma, intestinal helminth infections, leprosy,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>scabies</td>
</tr>
<tr>
<td>Water-aerosol disease</td>
<td>Inhalation of water aerosol containing pathogen</td>
<td>Legionellosis, phiesteria</td>
</tr>
<tr>
<td>Water-based</td>
<td>Parasitical worm infections (parasites found in intermediate organisms living</td>
<td>Dracunculiasis, schistosomiasis, (tricho)bilharziasis</td>
</tr>
<tr>
<td></td>
<td>in water)</td>
<td></td>
</tr>
<tr>
<td>Water-related arthropod</td>
<td>Insect vectors breeding in water or biting near water</td>
<td>Dengue, lymphatic filariasis, malaria, onchocerciasis, trypanosomiasis,</td>
</tr>
<tr>
<td>vector</td>
<td></td>
<td>yellow fever</td>
</tr>
</tbody>
</table>
Diarrhoeal disease pathways: Fecal-oral transmission

Source: Prüss-Üstün et al. (2008)
Burden of diarrhoeal diseases
Burden of water-borne disease

- 1.8 million deaths - 4 million cases in 2004 due to gastroenteritis (WHO)
- 88% due to unsafe water & poor sanitation

Source: Prüss-Üstün et al. (2008)
Burden of diarrhoeal diseases related to WSH

In 2016, water, sanitation and hygiene was responsible for 829,000 annual deaths from diarrhoea and 1.9% of the global burden of disease (DALYs).

Improvements related to drinking-water, sanitation, hygiene and water resource management could result in the reduction of almost 10% of total burden of disease worldwide.
DALYs due to Diarrhoeal Diseases, India
In addition to diarrhoea, an important share of the following diseases could be prevented if adequate water quality and quantity, sanitation facilities, hygiene behaviour, as well as water resource management interventions were implemented:

- Malnutrition
- Intestinal nematode infections
- Lymphatic filariasis
- Trachoma
- Schistosomiasis
- Malaria
- Other infectious diseases
Diseases with largest water, sanitation & hygiene contribution (% global disease burden) (2002)

Source: Prüss-Üstün et al. (2008)
No. of additional deaths from diarrhoea in 0-15 years of age, worldwide

Source: Kovats & Lloyd (WHO) (2014)
How climate & weather affects water-borne disease
## How climate influences waterborne disease trends

| **Local temperature** | • Replication in the environment or associated with food products  
| | • Persistence  
| **Local rainfall** | • Loading into the environment (contamination)  
| | • Increased concentration of contaminants (drought)  
| **Changes in hydrologic cycle** | • Increased drought  
| | • Increased storm intensity  
| **Change in frequency of ‘extreme events’** | • Hurricanes  
| | • Ocean-atmosphere oscillations: ENSO, IOD, others  
| **Sea level rise** | • Influx of marine pathogens  
| | • Flooding (storm surge), contamination, loss of infrastructure  

How climate & weather affects food- & water-borne disease: *Seasons*
Seasonal trends in Rotavirus infections

Source: Patel et al. (2013)
Seasonal patterns of Salmonellosis

Source: Kovats et al. (2004)
How climate & weather affects food- & water-borne disease: Temperature
3% increase of diarrhoea for each 1°C increase in the previous month

Source: Singh et al. (2001)
Correlation of temperature & water-borne diseases in Lao PDR

**Severe diarrhoea**

- **National**: 0.12048, 0.3134
- **Northern region**: 0.13393, 0.262
- **Central region**: 0.20952, 0.0773
- **Southern region**: -0.01009, 0.933

**Dysentery**

- **National**: 0.26601, 0.0239
- **Northern region**: 0.29679, 0.0114
- **Central region**: 0.36591, 0.0016
- **Southern region**: 0.12709, 0.2874

**Typhoid fever**

- **National**: 0.30992, 0.0081
- **Northern region**: 0.32278, 0.0057
- **Central region**: 0.31133, 0.0078
- **Southern region**: 0.07596, 0.526

Source: Fengthong et al. (2005)
How climate & weather affects food- & water-borne disease: Precipitation

Source: Bennett et al. (2012)
Local rainfall influences levels of pathogens in water & exposure risk to humans

- Run-off
- Flooding
- Drought
Flooding: Risk factors

• Direct contact with contaminated water
  – Skin
  – Respiratory
  – Ear & eye infections

• Ingestion of contaminated water (wells etc.)
  – Gastroenteritis

• Insufficient water treatment (i.e. problem at the tap)

• Additional secondary spread
Climate change & flooding

(A) World map showing flood frequency with color indicating increase or decrease over time.

(B) Graph showing historical and projected number of people exposed to floods with different return periods, comparing RCP8.5, RCP6.0, RCP4.5, and RCP2.6 scenarios.

Source: IPCC AR5 (2014)
Extreme precipitation & water-borne disease outbreaks

Source: Curriero et al. (2001)
E.g. Walkerton (Canada) rainfall, 2000
E.g. Walkerton (Canada) outbreak
Illness onset dates & precipitation

Cryptosporidiosis & precipitation

Source: Das et al. (2006)

C. hominis

Other Cryptosporidium spp.

Months A

Months B
Rainfall, run-off & pathogen contamination

• Building evidence for the association between diarrheal disease & increased precipitation, especially with heavy rainfall events

• In addition, several studies note increased pathogen loads related to floods, run-off, & heavy precipitation including:
  – Enteric viruses (e.g. enteroviruses, noroviruses, adenoviruses)
  – Protozoan parasites (e.g. Cryptosporidium, Giardia, others)
  – Enteric bacteria (e.g. Salmonella, Campylobacter, E. coli, fecal indicator bacteria)
Drought effects on water quality
Correlation between storage level & supplies with water quality issues

Source: CRCWQT (2005)
Drought & Shigellosis

Source: Modified from NICD data, Mongolia (2009)

$R^2 = 0.5393$
How climate & weather affects food- & water-borne disease: Sea level rise
Cities vulnerable to sea level rise

Source: Hallegatte et al. (2013)
India: Vulnerability to Sea Level rise

Source: TERI
Vibrio spp.

- *Vibrio* are commonly estuarine & marine bacteria & include at least 12 known pathogens to humans
  - *V. vulnificus*
  - *V. parahaemolyticus*
  - *V. cholerae*

- In general, this group replicates easily in natural waters & biota, especially under high temperatures
  - Directly related to increasing water temperatures
Cholera: South Asia

• Yearly epidemics correspond to natural environmental cycles & contamination
  – Influx of estuarine water
  – Plankton blooms
  – Monsoons
  – Warm temperatures

• Cycles can be modelled for year to year changes in outbreaks
Bay of Bengal: Sea surface height & sea surface temperature

Source: Lobitz et al. (2000)
Bay of Bengal: Cholera & sea surface height

Source: Lobitz et al. (2000)
Measures to address water- & food-borne diseases associated with climate change
Water-borne disease: summary

• Climate projections for increased warming & increased extreme events suggest water-borne diseases may increase

• Mitigation & adaptation will be enhanced by understanding the ecology of pathogens
  – What underlying factors provide the link to climate?
  – How do changing landscapes affect disease incidence under changing climate conditions?
The water tower of Asia
## The water tower of Asia

<table>
<thead>
<tr>
<th>River</th>
<th>Area sq km</th>
<th>Mean discharge (m³/s)</th>
<th>% of Glacier melt in river flow</th>
<th>Population x 1,000</th>
<th>Population density</th>
<th>Water per person m³/year</th>
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</thead>
<tbody>
<tr>
<td>Indus</td>
<td>1,081,718</td>
<td>5,533</td>
<td>44.8</td>
<td>178,483</td>
<td>165</td>
<td>830</td>
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<tr>
<td>Ganges</td>
<td>1,016,124</td>
<td>18,691</td>
<td>9.1</td>
<td>407,466</td>
<td>401</td>
<td>~2500</td>
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<tr>
<td>Brahma</td>
<td>651,335</td>
<td>19,824</td>
<td>12.3</td>
<td>118,543</td>
<td>182</td>
<td>~2500</td>
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<tr>
<td>Irrawaddy</td>
<td>413,710</td>
<td>13,565</td>
<td>small</td>
<td>33,097</td>
<td>80</td>
<td>18,614</td>
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<tr>
<td>Salween</td>
<td>271,914</td>
<td>1,494</td>
<td>8.8</td>
<td>5,982</td>
<td>22</td>
<td>23,796</td>
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<tr>
<td>Mekong</td>
<td>805,604</td>
<td>11,048</td>
<td>6.6</td>
<td>57,198</td>
<td>71</td>
<td>8,934</td>
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<td>Yangtze</td>
<td>1,722,193</td>
<td>34,000</td>
<td>18.5</td>
<td>368,549</td>
<td>214</td>
<td>2,265</td>
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<tr>
<td>Yellow</td>
<td>944,970</td>
<td>1,365</td>
<td>1.3</td>
<td>147,415</td>
<td>156</td>
<td>361</td>
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<tr>
<td>Tarim</td>
<td>1,152,448</td>
<td></td>
<td>40.2</td>
<td>8,067</td>
<td>7</td>
<td>754</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,324,800</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: ICIMOD (2008)
Measures to address water- & food-borne diseases

- The effects of climate change on water & foodborne diseases can be mitigated
  - Focus on public health response
  - Focus on basic infrastructure
  - Increased attention to treatment options

- We have the tools to address problems & prevent disease

- Understanding how climate may increase risk can be used to prioritize adaptation or rapid response measures
What we covered in Module 8

1. Water quality & quantity
2. Burden or diarrhoeal diseases
3. Effects of climate on diseases
4. Addressing water & food-borne diseases
Key messages in Module 8

• Waterborne diseases are mostly transmitted by faecal-orally transmitted diseases

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