Water-related Infectious Diseases

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September 16, 2008
Outline

• Background
  – Global impact of infectious diseases (IDs)
  – Transmission of IDs
  – Water-related IDs

• Water and Emerging IDs

• Remote Sensing and IDs
Environmental Effects on Infectious Disease

• Why infectious disease?
  – … still leading causes of deaths and disability worldwide
  – New threat from emerging & re-emerging diseases

• Why environmental effects?
  – Environmental change is occurring worldwide at varying scales
  – Discoveries that emerging and re-emerging pathogens have their origin in environmental change
<table>
<thead>
<tr>
<th>Disease</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrhea</td>
<td>4 billion cases &amp; 1.8 million deaths/year, 95% are children under 5, 88% of disease burden attributed to unsafe water supply, inadequate sanitation and hygiene; primarily in developing countries</td>
</tr>
<tr>
<td>Malaria</td>
<td>1.3 million deaths/year, 90% are children under 5; 396 million episodes/year; intensified irrigation, dams &amp; other water related projects contribute importantly to this burden; primarily in Africa</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>200-300 million people affected, tens of thousands of deaths/year; unsanitary excreta disposal &amp; absence of nearby sources of safe water, man-made reservoirs &amp; poorly designed irrigation are drivers</td>
</tr>
<tr>
<td>Trachoma</td>
<td>500 million people at risk, 146 million threatened by blindness, 6 million people visually impaired by trachoma; strongly related to lack of face washing, most often due to absence of safe water</td>
</tr>
<tr>
<td>Intestinal helminthes</td>
<td>133 million people suffer from high intensity infections, leading to severe consequences such as cognitive impairment, massive dysentery or anaemia; at least 9400 deaths/year</td>
</tr>
</tbody>
</table>

Source: WHO, 2008
TABLE 2.1 WORLD POPULATION BY REGION (IN MILLIONS) ¹

<table>
<thead>
<tr>
<th></th>
<th>Africa</th>
<th>Asia</th>
<th>LA &amp; C Oceania</th>
<th>Europe</th>
<th>N. Amer.</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>615</td>
<td>3,180</td>
<td>441</td>
<td>26</td>
<td>722</td>
<td>282</td>
</tr>
<tr>
<td>2000</td>
<td>784</td>
<td>3,683</td>
<td>519</td>
<td>30</td>
<td>729</td>
<td>310</td>
</tr>
<tr>
<td>% Increase</td>
<td>27.5</td>
<td>15.8</td>
<td>17.7</td>
<td>15.4</td>
<td>1.0</td>
<td>9.9</td>
</tr>
<tr>
<td>Global</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,055</td>
</tr>
</tbody>
</table>

¹ Source: (10).

Figure 2.1 Distribution of the global population not served with improved water supply, by region

Total unserved: 1.1 billion

Figure 2.2 Distribution of the global population not served with improved sanitation, by region

Total unserved: 2.4 billion

Source: WHO
Environmental Determinants of Infectious Disease

- Transmission cycle grouping – The EnvID Study
  (six transmission groups that each relate the environment in distinct ways)
  - I. Directly transmitted diseases
  - II. Vectorborne diseases
  - IIIa,b. Environmentally mediated diseases
  - IVa,b Zoonotic diseases
Transmission groups

- The impact of proximal environmental characteristics on disease burden is mediated through transmission cycles

![Table showing transmission groups](image)

*Source: Eisenberg, Liang et al., 2007*
Civet – origin of SARS?
Global distribution of malaria transmission risk (WHO, 2003)
Water-related Infectious Diseases

• What pathogens can be found in water?
  – Virus, bacteria, and parasites

• How does water support them?
  – Waterborne
    • Contamination of water by human or animal feces or urine infected by pathogens via fecal-oral route (e.g. cholera)
  – Water-based
    • Water provides the habitat for intermediate host organisms or insect vectors in which some pathogens pass part of their life cycle (e.g. dengue, schistosomiasis)
• **Water-associated**
  – Pathogens could exist in a wide array of environmental media including water, soil, or air (e.g. influenza A)

• **Water-dispersed infections**
  – Infections whose pathogens can proliferate in freshwater and enter the body through the respiratory tract (e.g. some freshwater amoebae, Legionella)
Global trends in emerging infectious diseases

Kate E. Jones, Nikkita G. Patel, Mai & Peter Daszak

Figure 1 | Number of EID events per decade. EID events (defined as the temporal origin of an EID, represented by the original case or cluster of cases that represents a disease emerging in the human population—see Methods) are plotted with respect to a, pathogen type, b, transmission type, c, drug resistance and d, transmission mode (see keys for details).
Water & ID Project

• Construction of global database
  – About 1400 infectious organisms pathogenic to humans
  – In the past 60 years, 365 emerging ID events occurred
  – 139 (42%) of which are water-related
What are ‘environmental determinants’ of infectious disease?

Environmental factors in which their changes have causal links to introduction, reemergence, intensification, and propagation (e.g., spatial) of infectious diseases.
Environmental Determinants

Current research – environmental/physical sciences

Distal Environmental Changes

Causal link

Proximal Environmental Characteristics

Changes in Disease Status
Current research – public health

Environmental Determinants

Distal Environmental Changes → Proximal Environmental Changes → Changes in Transmission Cycle → Changes in Disease Status

Causal link
A research priority in understanding environmental contribution to infectious disease
Remote Sensing & Infectious Disease

• Rationale
  – The distribution of many IDs is restricted geographically by landscape, climate, and anthropogenic factors

• Since the early 1970s, RS technology has proved to be a valuable tool for describing the Earth’s landscape, public health professionals/physical scientists have been exploring the use of RS to inform surveillance of IDs
## A partial list of studies that have used remotely sensed data for IDs

<table>
<thead>
<tr>
<th>Disease</th>
<th>Vector</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dracunculiasis</td>
<td><em>Cyclops</em> spp.</td>
<td>TM</td>
</tr>
<tr>
<td>Eastern equine encephalitis</td>
<td><em>Culiseta melanura</em></td>
<td>TM</td>
</tr>
<tr>
<td>Filariasis</td>
<td><em>Culex pipiens</em></td>
<td>AVHRR</td>
</tr>
<tr>
<td></td>
<td><em>Cx. Pipiens</em></td>
<td>TM</td>
</tr>
<tr>
<td>Leishmaniasis</td>
<td><em>Phlebotomus papatasi</em></td>
<td>AVHRR</td>
</tr>
<tr>
<td>Lyme disease</td>
<td><em>Ixodes scapularis</em></td>
<td>TM</td>
</tr>
<tr>
<td></td>
<td><em>I. ricinus</em></td>
<td>MSS</td>
</tr>
<tr>
<td></td>
<td><em>I. ricinus</em></td>
<td>TM</td>
</tr>
<tr>
<td>Malaria</td>
<td><em>Anipheles albimanus</em></td>
<td>TM</td>
</tr>
<tr>
<td></td>
<td><em>An. Albimanus</em></td>
<td>SPOT</td>
</tr>
<tr>
<td></td>
<td><em>An. Albimanus</em></td>
<td>TM</td>
</tr>
<tr>
<td></td>
<td><em>An. Spp.</em></td>
<td>AVHRR (Meteosat)</td>
</tr>
<tr>
<td>Onchocerciasis</td>
<td><em>Simulium</em> spp.</td>
<td>TM</td>
</tr>
<tr>
<td>Rift Valley fever</td>
<td><em>Aedes &amp; Cx. Spp</em></td>
<td>AVHRR</td>
</tr>
<tr>
<td></td>
<td><em>Cx. Spp.</em></td>
<td>TM, SAR</td>
</tr>
<tr>
<td></td>
<td><em>Cx. Spp.</em></td>
<td>SPOT</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td><em>Biomphalaria</em> spp.</td>
<td>AVHRR</td>
</tr>
<tr>
<td></td>
<td><em>Oncomelania</em> spp.</td>
<td>TM</td>
</tr>
<tr>
<td></td>
<td><em>Oncomelania</em> spp.</td>
<td>IKONOS</td>
</tr>
</tbody>
</table>
The Schistosomiasis Example

• Schistosomiasis is a water-based, tropical parasitic disease, caused by the digenetic trematode *Schistosoma*

• Five species affect humans, among them three have major public health impacts – *Schistosoma haematobium, S. mansoni*, and *S. japonicum*

• It is endemic in 76 countries, 80 million people are infected annually, 200 ~ 300 million people are at risk of infection
Global distribution of Schistosomiasis

**Senegal**
An epidemic of schistosomiasis along the Senegal river basin caused by water-resource development schemes continues unabated.

**Egypt**
Praziquantel chemotherapy coupled to a vigorous media campaign has resulted in a significant decrease in the morbidity and prevalence of schistosomiasis infection.

**Iran, Morocco, and Saudi Arabia**
Schistosomiasis control has been successful in those areas with elimination of the infection contemplated.

**China**
Schistosoma continues to be a major public health problem in the lake and marshy regions despite successful control in other endemic areas.

**Lao People’s Democratic Republic**
Schistosoma mekongi control has been successful around Khong Island with prevalence reduced from 42% to < 2%.

**Djibouti and Somalia**
Displacement of people by war and instability has introduced intestinal schistosomiasis to these countries.

**North-east Brazil**
Urban schistosomiasis now present in and around many major cities.

**Ghana**
Intestinal schistosomiasis has increased due to the construction of the Akosombo Dam and other much smaller dams.

**sub-Saharan Africa**
More than 85% of the estimated 200 million people globally with schistosomiasis and the majority of patients with severe disease live on this continent.

**Indonesia**
Schistosomiasis has been controlled in the Lindu region of Sulawesi such that the prevalence of infection is lower than 2%.

Source: WHO
• Seven provinces still endemic;

• An estimated 800,000 people are infected annually and ~60 -90 million people are at risk of infection.
Why this study...

• Global climate change
• The Three Gorges Dam
  • A number of studies underway …
  • Hotez et al. speculated that the formation of the lake behind the dam will generally increased both snail habitat and human disease transmission (1997);
  • Lessons learned form Africa – the Aswan Dam, dams in Senegal etc.
Schistosomiasis transmission in mountainous regions of Sichuan, China
Landsat TM – Classification of snail habitat
Land-cover Classification with IKONOS Imagery at Xichang

**Land Cover**
- Resid
- Road
- LoCrop
- LoTr
- UpCrop
- UpTr
- GHouse1
- GHouse2
- BareSl
- RivBed
- Lake
- FishPd
- Forest
- Shrub
- Grass
Estimated snail density against field surveyed snail density

Predicted vs. surveyed snail density
Snail Prediction of Xichang Study Site

The map shows the distribution of snail density across the study site. The snail density is color-coded as follows:

- **0.1 - 0.5** (Dark Blue)
- **0.6 - 1.0** (Light Blue)
- **1.1 - 1.5** (Teal)
- **1.6 - 2.0** (Light Green)
- **2.1 - 2.5** (Yellow)
- **2.6 - 3.0** (Orange)
- **3.1 - 5.0** (Red)

The map also highlights the lake area in black.