Global trends in waterborne infectious disease

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Content

1. Waterborne infectious disease
2. Prevention and Intervention
3. Global changes
4. Future perspective
Waterborne infectious diseases
Digital Wildfires in a Hyperconnected World

Critical systems failure
- Cyber attacks
- Mass attacks
- Cyber terrorism

Major systemic financial failure
- Severe income disparity
- Chronic labor market imbalances

Global governance failure
- Failure of intellectual property regime
- Backlash against globalization

Failure of climate change adaptation
- Food shortage crises
- Water supply crises
- Persistent extreme weather

The Dangers of Hubris on Human Health
- Vulnerability to pandemics
- Unmanageable inflation or deflation

Testing Economic and Environmental Resilience
- Failure of ecosystem services
- Mineral resource supply vulnerability
- Unmanageable migration

World Economic Forum 2013
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Global freshwater sources

Saline (oceans); 97.0%

Ground water; 30.1%

Icecaps, glaciers; 68.7%

Rivers; 2.0%

Swamps; 11.0%

Lakes; 87.0%
Water scarcity affects 3 billion
Improved sources often fecally contaminated
Safe drinking-water is essential to human health

Prüss et al 2008
Burden of disease due to inadequate WaSH

Approximately 1.8 million diarrhoeal deaths each year; large proportion due to unsafe drinking-water, sanitation and hygiene (WHO, 2013)
Prevention and intervention
Human right to water

- UN resolution 64/292 (August 2010)

“... Recognizes the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights...”
Safe drinking-water?
Concept of ‘safety’

- Is it safe to drink if standards are met?

- Is it safe to drink if appearance and taste of water is acceptable?

- Is it safe to drink if it is disinfected?

- Is it safe to drink if operators are qualified and know what to do?
‘Over-reliance’ on end-product testing

- Classical 'faecal indicators' have different sensitivity to disinfection and environmental conditions of viral or protozoan pathogens
- Outbreaks reported in absence of faecal indicators
- Limited early warning capability of microbial testing: water is distributed and drunk before test results are gained
- Water volumes tested are rarely statistically representative
- Limited capability to detect short-term fluctuations
Source water

Household water treatment and/or

Global supply of safe drinking-water

Prevention and intervention

Drinking-water treatment plant

Distribution system
Water Safety Planning!

What are the risks to my supply system?

How important are they?

How do I know that they are fixed?

How do I fix them?

Continuous cycle

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“The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. In these Guidelines, such approaches are called water safety plans.”
Established approaches in drinking water safety

- **Rigorous assessment** of biological, chemical, physical and radiological agents
- Health-based **guideline values** for more than 100 chemicals
- **Multiple-barrier principle**
- **Disinfection** must not be compromised
- **Faecal indicator** concept
- **Sanitary inspections**
Framework for safe drinking-water

**Health-based targets**  
(National regulatory body)

**Water Safety Plan**  
(Water utility)

**Independent surveillance**  
(Surveillance agency)

Rolling revision towards 5th ed. in 2020
Global changes
Water - Pathways and Pathogens

**Route of infection**
Sepsis and generalized infection may occur

**Ingestion (Drinking)**
- **Gastrointestinal**
  - **Bacteria**
    - *Campylobacter* spp.
    - *E. coli*
    - Pathogenic
    - *Francisella tularensis*
    - *Salmonella* spp. including
      - *S. Typhi*
      - *Shigella* spp.
      - *Vibrio cholerae*
  - **Viruses**
    - Adenoviruses
    - Astroviruses
    - Enteroviruses
    - Hepatitis A virus
    - Hepatitis E virus
    - Noroviruses
    - Rotaviruses
    - Sapoviruses
  - **Protozoa and helminths**
    - Cryptosporidium hominis/parvum
    - Cyclospora cayetanensis
    - Dracunculus medinensis
    - Entamoeba histolytica
    - Giardia intestinalis
    - Toxoplasma gondii

**Inhalation and aspiration (Aerosols)**
- **Respiratory**
  - Adenoviruses
  - Enteroviruses
  - *Legionella pneumophila*
  - Mycobacteria (non-tuberculous)
  - *Naegleria fowleri*

**Contact (Bathing)**
- **Skin** (especially if abraded), mucous membranes, wounds, eyes
  - Acanthamoeba spp.
  - *Burkholderia pseudomallei*
  - *Leptospira* spp.
  - Mycobacteria (non-tuberculous)
  - *Schistosoma mansoni*

WHO 2011
## Water–transmitted Infectious Diseases

Table 1 Water-transmitted infectious diseases divided into four categories according to their transmission route. Adapted from Bradley (1977)

<table>
<thead>
<tr>
<th>Category</th>
<th>Transmission</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterborne</td>
<td>Ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria, viruses or parasites</td>
<td>Gastroenteritis, enteric hepatitis, amoebic and bacillary dysentery, cholera, leptospirosis, poliomyelitis, typhoid/paratyphoid fever</td>
</tr>
<tr>
<td>Water-washed</td>
<td>Skin, ear or eye contact with contaminated water and poor personal hygiene</td>
<td>Conjunctivitis, trachoma, intestinal helminth infections, leprosy, scabies</td>
</tr>
<tr>
<td>Water-based</td>
<td>Parasitical worm infections, the parasites are found in intermediate organisms living in water</td>
<td>Dracunculiasis, schistosomiasis, (tricho)bilharziasis</td>
</tr>
<tr>
<td>Water-related</td>
<td>Insect vectors breeding in water or biting near water</td>
<td>Dengue, lymphatic filariasis, malaria, onchocerciasis, trypanosomiasis, yellow fever</td>
</tr>
</tbody>
</table>
Waterborne transmission routes

- Wash-off of animal manure
- Water recreation
- Leaking sewage tank/pipe
- Wildlife
- Meat from wildlife
- Ground water well
- Shellfish
- Animal contact
- Irrigated crops
- Biofilms

Sources
Exposure
Rate of discovery of emerging pathogens 1970-2000

Adapted from Desselberg, 2000
<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Disease Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>Rotaviruses</td>
<td>Infantile diarrhoea</td>
</tr>
<tr>
<td>1975</td>
<td>Astroviruses</td>
<td>Diarrhoea</td>
</tr>
<tr>
<td>1975</td>
<td>Parvovirus B19</td>
<td>Aplastic crisis in chronic anaemia</td>
</tr>
<tr>
<td>1976</td>
<td>Cryptosporidium parvum</td>
<td>Acute enterocolitis</td>
</tr>
<tr>
<td>1977</td>
<td>Ebola virus</td>
<td>Ebola haemorrhagic fever</td>
</tr>
<tr>
<td>1977</td>
<td>Legionella pneumophila</td>
<td>Legionnaires’ disease</td>
</tr>
<tr>
<td>1977</td>
<td>Hantaan virus</td>
<td>Haemorrhagic fever with renal syndrome</td>
</tr>
<tr>
<td>1977</td>
<td>Campylobacter spp.</td>
<td>Diarrhoea</td>
</tr>
<tr>
<td>1980</td>
<td>Human T-cell lymphotropic virus-1 (HTLV-1)</td>
<td>Adult T-cell leukaemia</td>
</tr>
<tr>
<td>1982</td>
<td>HTLV-2</td>
<td>Hairy T-cell leukaemia</td>
</tr>
<tr>
<td>1982</td>
<td>Borrelia burgdorferi</td>
<td>Lyme disease</td>
</tr>
<tr>
<td>1983</td>
<td>HIV-1, HIV-2</td>
<td>Acquired immunodeficiency syndrome</td>
</tr>
<tr>
<td>1983</td>
<td>Escherichia coli O157:H7</td>
<td>Haemorrhagic colitis; haemolytic colitis</td>
</tr>
<tr>
<td>1983</td>
<td>Helicobacter pylori</td>
<td>Gastritis, gastric ulcers, increased bleeding</td>
</tr>
<tr>
<td>1988</td>
<td>Human herpesvirus-6</td>
<td>Exanthema subitum</td>
</tr>
<tr>
<td>1989</td>
<td>Ehrlichia spp.</td>
<td>Human ehrlichiosis</td>
</tr>
<tr>
<td>1989</td>
<td>Hepatitis C virus</td>
<td>Parenterally transmitted non-A</td>
</tr>
<tr>
<td>1990</td>
<td>Human herpesvirus-7</td>
<td>Exanthema subitum</td>
</tr>
<tr>
<td>1990</td>
<td>Hepatitis E virus</td>
<td>Enterically transmitted non-A</td>
</tr>
<tr>
<td>1991</td>
<td>Hepatitis F virus</td>
<td>Severe non-A, non-B hepatitis</td>
</tr>
<tr>
<td>1992</td>
<td>Vibrio cholerae O139:H7</td>
<td>New strain associated with epidemics</td>
</tr>
<tr>
<td>1992</td>
<td>Bartonella henselae</td>
<td>CAT-scratch disease, bacillary peliosis</td>
</tr>
<tr>
<td>1993</td>
<td>Sin nombre virus</td>
<td>Hantavirus pulmonary syndrome</td>
</tr>
<tr>
<td>1993</td>
<td>Hepatitis G virus</td>
<td>Non A-C hepatitis</td>
</tr>
<tr>
<td>1994</td>
<td>Sabia virus</td>
<td>Brazilian haemorrhagic fever</td>
</tr>
<tr>
<td>1994</td>
<td>Human herpesvirus-8</td>
<td>Kaposi’s sarcoma</td>
</tr>
<tr>
<td>1995</td>
<td>Hendravirus</td>
<td>Castleman’s disease</td>
</tr>
<tr>
<td>1996</td>
<td>Prion (BSE)</td>
<td>Meningitis, encephalitis</td>
</tr>
<tr>
<td>1997</td>
<td>Influenza A virus</td>
<td>New variant Creutzfeldt-Jakob</td>
</tr>
<tr>
<td>1997</td>
<td>Transfusion-transmitted virus</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Enterovirus 71</td>
<td>Epidemic encephalitis</td>
</tr>
<tr>
<td>1998</td>
<td>Nipah virus</td>
<td>Meningitis, encephalitis</td>
</tr>
<tr>
<td>1999</td>
<td>Influenza A virus</td>
<td>Influenza (Hong Kong)</td>
</tr>
<tr>
<td>1999</td>
<td>West Nile-like virus</td>
<td>Encephalitis (New York)</td>
</tr>
</tbody>
</table>

(Desselberg, 2000)

The distribution of emerging pathogens according to the main group of micro-organisms to which they belong. The figure shows that nearly half of all emerging pathogens are viruses or prions (adapted from Taylor, Latham & Woolhouse, 2001).
Viral Infectious Diseases

PV

HepV

ReoV

AIV

VV

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Drivers of global change

- Changes in pathogen
  - Natural selection
  - Biocides, antimicrobials
  - Zoonoses

- Changes in the environment
  - Climate
  - Urbanization
  - Transport
  - Disasters
  - Man-made systems

- Changes in men
  - Travel/ Migration
  - Import/ Export
  - Ageing
  - Displacement
  - Health care
    - Vaccination
    - Antibiotic use
    - Mental disorders
Changes in the pathogen

- Genetic changes
  - Mutations / Insertions / Deletions
  - Changes in virulence / pathogenicity

- Antibacterial resistance
  - The environment as transmission route of ABR bacteria and ABR genes, relative to direct contact with animals/humans and consumption of meat
  - Public health risks associated with exposure to ABR in the environment?
  - To what extent do different potential contamination sources contribute to ABR bacteria and genes in the environment?
  - In consideration of intervention measures

![Bacterial cultures and plates](image)
Changes in the host population

- Low income, homeless, displaced people
- Vulnerable subpopulations
  - Immunocompromised: age, pregnancy, infection, medication, genetic etc.
Conflict situations

- Rise in numbers of unvaccinated individuals against poliovirus
- Mopping up activities with live poliovirus vaccine may lead to reverted polioviruses
Changes in the environment

- Predominant *extreme water events* leading to waterborne infectious disease outbreak
  - Floods
  - Extreme precipitation
- Predominant waterborne pathogens associated with an *extreme water event*
  - *Vibrio cholerae*
  - *Leptospira* spp.
  - *Campylobacter* spp.
  - *Cryptosporidium* spp.
  - Pathogenic *Escherichia coli*
  - Norovirus
Cholera outbreaks

Cholera: Zimbabwe's 'worst crisis' 2008

92,000 ill
4,000 deaths [Mason et al 2010]

As of 30 November 2011, the cumulative number of reported cholera cases was 515,699, of which 279,077 (54%) were hospitalized and 6,942 persons had died [WHO, 2011].

Cholera outbreak Haiti after earthquake 2010
Technological advances

- Manmade environments such as drinking water distribution systems
  - Legionellosis

Schalk et al. 2013, 2014
Urbanisation

- Introduction into urbanised area
  - Ebola virus

Initial infection
Contact with animals
Consumption of contaminated food

Further spread
Close contact with sick people
Insufficient WaSH

Future perspective
Pathogen characteristics

- Size
- Numbers
- Morphology
- Charge
- Infectivity
- Pathogenicity

Size matters

Relative sizes of cells and their components

@ Click4Biology
Future perspective

- Determine effective drinking water treatment options
  - Also in light of emerging virus inactivation
  - And global changes
- Global WHO Water Safety Planning and Water Quality Monitoring
  - Capacity building
- Surveillance for emerging infectious diseases
  - Capacity building in hotspots e.g. Uganda

Water safety planning in Ethiopia

Source

Tap

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Questions?

Water quality

Washing

Irrigation

Cattle

Drinking