Introduction to water-related infectious diseases

Module 1.1
Overview

• The Protocol on Water and Health and requirements relating to water related disease surveillance and outbreak management

• International Health Regulations (IHR) core requirements:
  • Definition of water related infectious disease (WRID)
  • Pathogens transmitted through drinking-water
  • Drinking-water systems as a source of WRID
  • Burden of WRID in the European Region
  • The need to strengthen WRID surveillance and outbreak management capacity
Protocol on Water and Health

• Article 8:
  • Establish and maintain surveillance and early warning systems
  • Develop national and local contingency plans for responding to outbreaks, incidents and risks
  • Strengthen response capacity

• Article 6.2:
  • Establish and publish targets to reduce WRD outbreaks and incidents

• Article 13:
  • Strengthen transboundary cooperation on early-warning and response systems
## IHR Core Capacity Requirements

<table>
<thead>
<tr>
<th>Core Capacity</th>
<th>Component</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance</td>
<td>Indicator-based surveillance</td>
<td>Early warning function for the early detection of a public health event</td>
</tr>
<tr>
<td></td>
<td>Event-based surveillance</td>
<td>Established and functioning</td>
</tr>
<tr>
<td>Response</td>
<td>Rapid response capacity</td>
<td>Public health emergency response mechanisms are established and functioning</td>
</tr>
<tr>
<td>Risk communication</td>
<td>Policy and procedures for public communication</td>
<td>Mechanisms for effective risk communication during a public health emergency are established and functioning</td>
</tr>
</tbody>
</table>

2030 Agenda for Sustainable Development

- **Ensure healthy lives and promote well-being for all at all ages**
  - **Target 3.3**: By 2030, (...) combat hepatitis, water-borne diseases and other communicable diseases
  - **Target 3.9**: By 2030, substantially reduce the number of deaths and illnesses from (...) water and soil pollution and contamination

- **Ensure availability and sustainable management of water and sanitation for all**
  - **Target 6.1**: By 2030, achieve universal and equitable access to safe and affordable drinking-water for all
  - **Target 6.2**: By 2030, achieve access to adequate and equitable sanitation and hygiene for all (...), paying special attention to the needs of women and girls (...)
Quiz

How are water-related infectious diseases transmitted?
What are water-related infectious diseases?

• Water-related disease
  • adverse effect on human health caused by the condition of water
  • Infectious or non-infectious

WRID may be transmitted via:

- the gastrointestinal tract, by ingestion of contaminated water (drinking or recreational water)
- the respiratory tract, by inhalation or aspiration of aerosols
- the skin, mucous membranes or eyes, by contact during recreational water use or bathing
## Classification of WRID

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-borne</td>
<td>Ingestion of pathogens in contaminated water</td>
<td>Typhoid, legionellosis, poliomyelitis</td>
</tr>
<tr>
<td>Water-washed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Skin and eyes</td>
<td>Poor hygiene / lack of access to safe water</td>
<td>Scabies, trachoma, bacillary dysentery</td>
</tr>
<tr>
<td>b) Diarrhoeal diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Skin penetration</td>
<td>Infection by agents that spend part of their life-cycle in water</td>
<td>Schistosomiasis</td>
</tr>
<tr>
<td>b) Ingested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-related vectors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Biting near water</td>
<td>Spread by vectors that breed or bite near water</td>
<td>Malaria, West Nile Fever</td>
</tr>
<tr>
<td>b) Breeding in water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Primary agents of infectious waterborne outbreaks

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Viruses</th>
<th>Protozoa</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>Hepatitis A virus</td>
<td><em>Balantidium coli</em></td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>Norovirus</td>
<td><em>Cryptosporidium spec.</em></td>
</tr>
<tr>
<td><em>Helicobacter pylori</em></td>
<td>Rotavirus</td>
<td><em>Cyclospora cayetanensis</em></td>
</tr>
<tr>
<td><em>Legionella spec.</em></td>
<td>Adenovirus</td>
<td><em>Entamoeba histolytica</em></td>
</tr>
<tr>
<td><em>Leptospira spec.</em></td>
<td>Enterovirus</td>
<td><em>Giardia spec.</em></td>
</tr>
<tr>
<td><em>Mycobacterium spec.</em></td>
<td>Astrovirus</td>
<td><em>Naegleria fowleri</em></td>
</tr>
<tr>
<td><em>Salmonella enterica</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Shigella spec.</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vibrio cholerae</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2. Pathogens transmitted through drinking-water

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Type species/genus/group</th>
<th>Health significance</th>
<th>Persistence in water supplies</th>
<th>Resistance to chlorine</th>
<th>Relative infectivity</th>
<th>Important animal source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkholderia</td>
<td>B. pseudomallei</td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>C. coli</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>C. jejuni</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Escherichia coli -</td>
<td></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>diarrhoeagenic²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E. coli - enterohaemorrhagic</strong></td>
<td>E. coli O157</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>Francisella</td>
<td>F. tularensis</td>
<td>High</td>
<td>Long</td>
<td>Moderate</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>Legionella</td>
<td>L. pneumophila</td>
<td>High</td>
<td>May multiply</td>
<td>Low</td>
<td>Moderate</td>
<td>No</td>
</tr>
</tbody>
</table>
Campylobacter spp

- Important cause of acute gastroenteritis worldwide and in the European region.
- C. jejuni, C. coli, C. laridis and C. fetus
- Incubation period: 2-4 days; illness duration 3-7 days
- Symptoms: abdominal pain, diarrhoea (sometimes bloody), vomiting, chills and fever
- Reactive arthritis, meningitis and Guillain Barre syndrome
- Reservoir: Poultry, wild birds, cattle and pets.
- Waterborne outbreaks
  - Faecal contamination of water storage reservoirs with bird faeces
  - Consumption of inadequately treated surface water
Shigella

• *S. dysenteriae*, *S. flexneri*, *S. boydii* and *S. sonnei*.
• Abdominal cramps, fever and water diarrhoea; bacillary dysentery is characterized by bloody diarrhoea.
• Incubation period: 24-72 hours
• Faecal-oral transmission through person-to-person contact, contaminated food, water and flies
• Waterborne outbreaks are occurring more frequently due to faecally contaminated drinking-water.
• Control of Shigella in drinking-water is of special public health importance
• Sensitive to disinfection
Legionella

• *L. pneumophila* is responsible for most human infections: Legionellosis
  • Legionnaires’ disease
  • Pontiac fever

• Infection through inhalation of aerosols containing the bacteria (showers, jacuzzi, sinks and cooling towers etc.)

**In rare cases transmitted by aspiration**

• Risk management strategies in high-risk settings:
  • Temperature control (in cold water systems <20°C; in hot water systems >55°C)
  • Disinfection
  • Minimise biofilm growth
Hepatitis A virus

- Highly infectious with a low infectious dose
- Average incubation period 28-30 days
- Mostly asymptomatic, disease severity increases with age
- Hepatitis A / infectious hepatitis – sudden onset, fever, malaise, nausea, anorexia, abdominal pain, jaundice and liver damage – prolonged illness
- Mortality <1%
- Source: faecally contaminated food and water
- Person to person and faecal oral transmission most common
- Strong evidence of waterborne transmission
- Highly resistant to disinfection

E. coli or thermotolerant coliforms are not a reliable indicator of the presence/absence of HAV in drinking-water supplies.
Hepatitis E

• Much less widespread and mostly confined to tropical and subtropical areas. It has caused large waterborne outbreaks
  – Recent evidence indicates that HEV might also be prevalent at a low level in Europe.

• Infection can be more severe than HAV, increased mortality in pregnant women
Norovirus

- **90% of epidemic nonbacterial outbreaks** of gastroenteritis worldwide
- Usually self-limiting - severe illness is rare
- Transmission:
  - Faecally contaminated food or water
  - Person-to-person
  - Aerosolization of vomited virus and subsequent contamination of surfaces
- Outbreaks often occur in closed communities
  - Long-term care facilities, overnight camps, mass gatherings, hospitals, schools, prisons, dormitories and cruise ships
Cryptosporidium

- 13 species – C. hominis and C. parvum predominant in humans
- Self-limiting abdominal pain and diarrhea (1 week on average); can be prolonged and severe in immunosuppressed
- Large waterborne outbreaks, and outbreaks associated with visiting farms and contact with animals
- Oocysts shed in faeces can survive for weeks or months in fresh water
- Faecal oral and person to person transmission; consumption of contaminated food and water and transmission from animals.
- Highly infectious – 10 oocysts
- Resistant to disinfection
- E. coli or thermotolerant coliforms are not a reliable indicator of their presence/absence.
- UV radiation inactivates oocysts.
Giardia

- Giardiasis – G. intestinalis/G. lamblia or G. duodenalis
- Diarrhoea, abdominal cramps and malabsorption deficiencies
- Self-limiting illness, but prolonged illness can occur
- Asymptomatic carriage is common
- Cysts are shed in faeces; prolonged survival of cysts in fresh water
- Infectious dose <10 cysts
- Person to person transmission, contaminated drinking-water, recreational water and food
- Well established source of waterborne outbreaks
- Resistant to disinfection

E.coli or thermotolerant coliforms are not a reliable indicator of their presence/absence.
Drinking-water systems as a source of WRID

### Hazardous events at different points of the water supply system

<table>
<thead>
<tr>
<th>Point of contamination</th>
<th>Examples of hazardous events</th>
</tr>
</thead>
</table>
| Source water (surface or groundwater) | • Runoff of animal and human waste and sewage during wet weather  
  • Leakage of faecal matter from on-site sanitation or damaged sewers |
| Treatment system | • Inundation of filtration beds with contaminated water during flooding  
  • Failures in treatment (e.g. coagulation, filtration and/or disinfection processes) |
| Distribution system | • Ingress of contaminated water from the environment through cracked or eroded pipes, especially during pressure drops  
  • Cross-contamination of drinking-water systems with wastewater, rain water etc  
  • Unhygienic conditions of containers carrying water from source to home |
| Storage system | • Faecal contamination of water stored in reservoirs and storage tanks |

**The water treatment and distribution process**

Source: https://interestingengineering.com/dirty-clean-how-water-treatment-plant-works
Drinking-water systems as cause of WRID outbreaks

Water safety plans

• Best way to ensure a safe drinking-water supply
• Identify hazards and events (e.g. technical defects, malpractices, accidents, natural causes) that pose a risk to the supply system or fail to remove them

• Multi-barriers to contamination
  – Preventing hazards entering to water system (catchment)
  – Removing hazards from the water (treatment)
  – Preventing re-occurrence (storage and distribution)
Burden of WRID in the European Region

• Estimated 2700 deaths due to WASH related diarrhoea in 2016 which indicates 7 people die every day (WHO, 2019)

• The diseases with the highest number of reported outbreaks are shigellosis, E. coli diarrhoea, hepatitis A and cryptosporidiosis*

• Available data do not allow to distinguish the transmission routes (water, sanitation or food)

• Under-reporting of outbreaks to insufficient surveillance and outbreak investigation capacity

*Global Infectious Disease and Epidemiology Online Network, data for 2010-2021 https://www.gideononline.com/
Waterborne outbreaks in Europe, 2000 - 2013

<table>
<thead>
<tr>
<th>Disease</th>
<th>Outbreaks linked to water</th>
<th>Number of outbreaks</th>
<th>Proportion linked to water (%)</th>
<th>Countries</th>
<th>Most common sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionellosis</td>
<td>37</td>
<td>100</td>
<td>37</td>
<td>15</td>
<td>Drinking-water, water heater, cooling tower, spa</td>
</tr>
<tr>
<td>Gastroenteritis – viral</td>
<td>24</td>
<td>206</td>
<td>12</td>
<td>12</td>
<td>Drinking-water, swimming area, spa</td>
</tr>
<tr>
<td>Cryptosporidiosis</td>
<td>20</td>
<td>50</td>
<td>40</td>
<td>6</td>
<td>Drinking-water, swimming pool</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>18</td>
<td>155</td>
<td>12</td>
<td>8</td>
<td>Drinking-water, sauna</td>
</tr>
<tr>
<td>Campylobacteriosis</td>
<td>14</td>
<td>45</td>
<td>31</td>
<td>11</td>
<td>Drinking-water</td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>13</td>
<td>21</td>
<td>82</td>
<td>8</td>
<td>Drinking-water, outdoor recreational area</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>10</td>
<td>37</td>
<td>27</td>
<td>7</td>
<td>Drinking-water</td>
</tr>
<tr>
<td>Shigellosis</td>
<td>9</td>
<td>64</td>
<td>14</td>
<td>8</td>
<td>Drinking-water, fountain</td>
</tr>
<tr>
<td>Typhoid and other enteric fever</td>
<td>9</td>
<td>38</td>
<td>24</td>
<td>4</td>
<td>Drinking-water</td>
</tr>
<tr>
<td>Tularemia</td>
<td>8</td>
<td>42</td>
<td>19</td>
<td>4</td>
<td>Drinking-water</td>
</tr>
<tr>
<td>E. coli diarrhea</td>
<td>5</td>
<td>100</td>
<td>5</td>
<td>4</td>
<td>Drinking-water, swimming pool</td>
</tr>
<tr>
<td>Giardiasis</td>
<td>5</td>
<td>14</td>
<td>36</td>
<td>5</td>
<td>Drinking-water</td>
</tr>
</tbody>
</table>

Global Infectious Disease and Epidemiology Online Network, https://www.gideononline.com/
Viral gastroenteritis

**Example:** Prague experienced large waterborne outbreak of norovirus infection (estimated 11,000 to 12,000 cases) caused by cross contamination resulting from breakages of water and sewage pipes (2015)

**Number of people with vomit illness symptoms grows at 2018 Olympic Games**

Rachel Axon | USA TODAY Sports
Published 9:27 p.m. UTC Feb 7, 2018

**Norovirus sickens 39 in Spain with link to mussels**

By Joseph James Whitworth
16-Apr-2018 - Last updated on 16-Apr-2018 at 11:44 GMT
Burden of mortality

• Burden of disease ≠ burden of mortality
  - the burden of disease caused by pathogens transmitted by the faecal oral route is greatest, BUT
  - the burden of mortality may be caused by pathogens transmitted by other routes is greatest

• Legionella, pseudomonas and non-tuberculous mycobacteria
  - Caused 91% of WRID deaths in the USA between 2003 and 2009

• Germany: >3 deaths every day due to legionellosis

## Outbreaks of legionellosis in Europe, 2010 – 2021 (published data)

<table>
<thead>
<tr>
<th>Causes</th>
<th>Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling tower</td>
<td>29</td>
</tr>
<tr>
<td>Water supply system</td>
<td>11</td>
</tr>
<tr>
<td>Multiple</td>
<td>5</td>
</tr>
<tr>
<td>Spa, pool</td>
<td>4</td>
</tr>
<tr>
<td>Wastewater treatment plant</td>
<td>3</td>
</tr>
<tr>
<td>Fountain</td>
<td>2</td>
</tr>
<tr>
<td>Shower</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>10</td>
</tr>
</tbody>
</table>
Drivers of WRID in the pan-European region

• Emergence and re-emergence of pathogens: Cryptosporidium parvum and Legionella pneumophila

• Climate change and international travel
  - Geographic dissemination of WRID pathogens to new areas – Giardia lamblia

• Small scale and community operated water and sanitation systems
  - Vulnerable to environmental contamination
  - Untreated or insufficiently treated ground or surface water

• Changes in how water is used

• Increasing age and number of immunodeficient persons
Surveillance and outbreak management capacity in the pan-European region

- Passive surveillance of a limited number of pathogens
- Wide variation in number and types of pathogens, diseases and events under surveillance
- Variable sampling, laboratory testing and reporting protocols
- Limited routine testing of enteric pathogens; less testing of viruses and parasites
- Under-ascertainment of uncommon pathogens and those not covered by surveillance
- Limited laboratory capacity for testing
- Limited human and financial resources for surveillance and outbreak response
- Limited epidemiological capacity to investigate source of infection – cases not categorised as water-related
Surveillance and outbreak management capacity cont.

- Foodborne versus waterborne
- No standard definition of an outbreak and thresholds for outbreak detection not defined
- Inadequate early-warning and response systems
- Inadequate communication and coordination between public health agencies, water providers and those responsible for monitoring water quality
The need to strengthen WRID surveillance and outbreak management capacity

• Surveillance and outbreak response procedures need to be harmonised and strengthened in order to:
  - Generate more robust data on the true burden of WRID
  - Generate data on the causes of outbreaks
  → Inform investments in water supply systems
  → Inform public health action to control WRID
Useful references for further reading

**WHO (2017):** Legionella and the prevention of legionellosis.
https://apps.who.int/iris/handle/10665/43233

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