Microbiological Parameters: current shortcomings and possible approaches

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Microbiological safety in EU-DWD

General obligation about water fit for human consumption without potential danger to human health….

…translated into water quality targets

(Health) basis for pathogens

Absence of faecal indicator bacteria (FIB)
- No *E. coli* in 100 mL
- No intestinal enterococci in 100 mL
- Monitoring of finished water/consumer’s tap

*Article 4*

**General obligations**

1. Without prejudice to their obligations under other Community provisions, Member States shall take the measures necessary to ensure that water intended for human consumption is wholesome and clean. For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it:

(a) is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health, and

(b) meets the minimum requirements set out in Annex I, Parts A and B;
Shortcomings

1. End-product testing for FIB is reactive check, not proactive control of microbial safety based on understanding and control of hazards (pathogens) in water sources, treatment and distribution.

2. End-product testing for FIB is too late: warns about health risk when water is already consumed

3. Viruses/Cryptosporidium/Giardia cause drinking-waterborne outbreaks in absence of FIB, also in EU

4. Non-enteric pathogens (Legionella) not covered by FIB (waterborne (warm water systems) approx. 6000 confirmed cases of legionellosis in EU, mortality 10%, estimated cases 10-15X higher)
Implication of shortcomings

End-product testing of drinking-water for faecal indicator bacteria and HPC testing provide insufficient safeguards to public health.

With the current state of knowledge about microbiological safety of drinking-water, the view that the general obligation of Article 4 of the EU-DWD is fulfilled with only the current point-of-compliance testing requirements for E. coli, enterococci and HPC cannot be maintained any longer.
# Recognized by EU-MS and others

<table>
<thead>
<tr>
<th>Country</th>
<th>Regulation</th>
<th>Additional requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Surface Water Treatment Rule, 1989</td>
<td>Bacteria, Giardia, viruses, Legionella</td>
</tr>
<tr>
<td>USA</td>
<td>(Long term 2) Enhanced Surface Water Treatment Rule, 2006</td>
<td>Cryptosporidium</td>
</tr>
<tr>
<td>Canada</td>
<td>Guidelines for Canadian Drinking Water Quality, 2012</td>
<td>Enteric viruses, enteric protozoa (Cryptosporidium, Giardia), treatment performance</td>
</tr>
<tr>
<td>Australia</td>
<td>Australian Drinking Water Guidelines, 2011</td>
<td>Preventive risk management approach</td>
</tr>
<tr>
<td>England &amp; Wales</td>
<td>The water supply regulation, 2001</td>
<td>Cryptosporidium risk assessment (no longer in force)</td>
</tr>
<tr>
<td>Scotland</td>
<td>Cryptosporidium directions, 2003</td>
<td>Cryptosporidium risk assessment</td>
</tr>
<tr>
<td>England &amp; Wales</td>
<td>Water supply (water quality) regulations, 2016</td>
<td>Risk assessment, Drinking Water Safety Plans</td>
</tr>
<tr>
<td>Germany</td>
<td>DVGW recommendations W 1000, 1001, 1002</td>
<td>Water Safety Plans</td>
</tr>
<tr>
<td>Germany</td>
<td>Recommendations by the Environment Ministry, 2014</td>
<td>Risk assessment of enteric viruses and protozoa</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Drinking Water Decree, 2011</td>
<td>Risk assessment of enteric bacteria, viruses, protozoa, Legionella</td>
</tr>
<tr>
<td>France</td>
<td>Guidelines for public warm water systems, 2010</td>
<td>Legionella</td>
</tr>
<tr>
<td>Germany</td>
<td>Trinkwasserverordnung, 2001</td>
<td>Legionella, risk assessment</td>
</tr>
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</table>
WHO Guidelines

“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.”
Key principles

• A system / **risk assessment** to determine whether the drinking-water supply (from source to treatment to point of consumption) as a whole can provide safe water.

• **Operational monitoring** of the Critical Control Points: control measures in the drinking-water supply that are of particular importance in securing drinking-water safety.

• **Management plans** documenting the system assessment and monitoring plans and describing actions to be taken in normal conditions and incident conditions, including upgrade and improvement, documentation and communication.
Overall approach: risk assessment

Know pathogen (b, v, p) sources and transport dynamics in catchment

Know pathogen contamination level at water intake (peak events)

Know the distribution network hazards/events

Know pathogen removal by critical water treatment processes (events)

Know hazards/events in plumbing systems

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Overall approach: control

Catchment protection

Intake protection (peak events; operational monitoring)

Protect the distribution network: operational monitoring

Control critical water treatment processes: operational monitoring & action plans (events)

Control plumbing systems: operational monitoring

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Guidelines’ approach towards assessing and managing microbial hazards in drinking-water fills the gaps in the EU-DWD.

It ensures that drinking-water will also be safe with regards to enteric viruses and protozoa and towards opportunistic pathogens that may grow in distribution/plumbing systems.
Key elements

Risk assessment

The objective of the Risk assessment is to
- describe the water supply system from catchment to consumer
- identify hazards and risks
- evaluate whether the control measures (from engineered barriers to hygiene protocols) are able to adequately control these risks

Monitoring

The objective of Monitoring is “to verify that the measures in place to control risks to human health throughout the water supply chain from the catchment area through abstraction, treatment and storage to distribution are working effectively and that water at the point of compliance is wholesome and clean” (EU-DWD).
- Operational monitoring to verify that all critical elements of the catchment to tap chain are working effectively (generally non-microbiological)
- Verification monitoring to verify that water is wholesome and clean (generally microbiological)
How to implement this in the EU-DWD?

*Legionella pneumophila*

Include requirement for risk assessment for warm water systems in public buildings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Role in risk-based approach</th>
<th>Priority for inclusion</th>
<th>Monitoring requirement</th>
<th>Quality requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legionella pneumophila</td>
<td>Risk assessment: reference pathogen for pathogens that are able to grow in water distribution networks or plumbing systems in EU.</td>
<td>High</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
How to implement this in the EU-DWD?

*Legionella pneumophila*

Include requirement for risk assessment and monitoring for warm water systems in public buildings

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<td></td>
<td></td>
</tr>
<tr>
<td><em>Legionella pneumophila</em></td>
<td>Risk assessment: reference pathogen for pathogens that are able to grow in water distribution networks or plumbing systems in EU.</td>
<td>High</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><em>Legionella pneumophila</em></td>
<td>Verification of distribution/plumbing control.</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>INDICATOR PARAMETERS (ANNEX I PART C)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colony count 22°C</td>
<td>Verification of distribution/plumbing control against growth of micro-organisms, including opportunistic pathogens</td>
<td>High</td>
<td>Yes</td>
<td>Yes, relative (no abnormal change)</td>
</tr>
</tbody>
</table>
Legionella pneumophila risk assessment

Assess risk factors

- water temperature of 25–50 °C
- presence of biofilms (and amoeba)
- aerosol production (showerheads, nebulizers, etc.)
- poor removal of nutrients for growth of microbes
- distribution system stagnation, dead zones
- construction materials that contribute to microbial growth
- inefficient or ineffective disinfection (biofilms)
Legionella pneumophila risk assessment

Evaluate control measures

- cold water <25, warm water >50-60 °C
- limit presence of biofilms (and amoeba) by adequate removal of nutrients for growth of microbes
- design to limit stagnation, dead zones
- construction materials code: no support microbial growth
- biofilm disinfectants (chloramine)
**Legionella pneumophila monitoring**

**Operational monitoring**
- water temperature, ideally continuously in warm water systems
- disinfectant residual
- turbidity
- treated water nutrient content (biodegradable organic matter)
- inspect (plumbing) system design

**Verification monitoring**
- *Legionella pneumophila*
- point of compliance/aerosolization
- <100 - <1000 / litre
### Legionella pneumophila

**Table 11.** Reported culture-confirmed cases of Legionnaires' disease and *Legionella* isolates by species, EU/EEA, 2014

<table>
<thead>
<tr>
<th>Species</th>
<th>Culture-confirmed cases</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. pneumophila</em></td>
<td></td>
<td>777</td>
<td>95</td>
</tr>
<tr>
<td><em>L. longbeachae</em></td>
<td></td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td><em>L. micdadei</em></td>
<td></td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td><em>L. bozemanii</em></td>
<td></td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td><em>L. maccachernii</em></td>
<td></td>
<td>1</td>
<td>&lt;1</td>
</tr>
<tr>
<td><em>L. sainthelensi</em></td>
<td></td>
<td>1</td>
<td>&lt;1</td>
</tr>
<tr>
<td><em>L. other species</em></td>
<td></td>
<td>6</td>
<td>&lt;1</td>
</tr>
<tr>
<td><em>L. species unknown</em></td>
<td></td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>819</td>
<td>100</td>
</tr>
</tbody>
</table>

ECDC, 2016
How to implement this in the EU-DWD?

Enteric pathogens

Include requirement for risk assessment (surface water supplies)

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>B: Campylobacter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V: enterovirus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P: Cryptosporidium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Enteric pathogens: risk assessment

Assess risk factors

- Contamination of source water with excreta from man, livestock, wildlife
- Contamination of source water with (treated) domestic sewage, run off of manure, leaching of septic tanks and manure storage
- Events leading to peak contamination of source waters, such as heavy rains, snowmelt and flooding
- Insufficient treatment, treatment failure or periods of suboptimal or poor treatment performance, allowing breakthrough of pathogens
- Accumulation of pathogens in the treatment chain (such as via filter backwash water)
- Ingress of pathogens via open storage or openings, leaks etc. in the treatment plant
- Ingress of pathogens in storage reservoirs or the piped network (leaks, low/no pressure events, repairs, cross-connections etc.)
Enteric pathogens: risk assessment

Evaluate controls

- Catchment protection measures (protected groundwater zones, safe setback zones, riparian buffer zones, sewer overflow diversion etc.)
- Source protection measures (intake stops/relocation, flow diversion, etc.)
- Treatment processes: set treatment performance target
- Pressure and integrity of distribution network
- Hygiene protocols for repair and maintenance works in treatment plants and distribution networks
Enteric pathogens: risk assessment

• Treatment performance target
  1. Establish reference pathogen level in source water
     • Using sanitary survey and *E. coli* monitoring
     • Pathogen monitoring for validation (optional)

  2. Set treatment performance target
     • = pathogen level source – safe pathogen level treated (=10^-6 DALY)

  3. Assess ability of treatment chain to remove reference pathogens
     • Using sanitary survey and operational monitoring
     • Surrogate (*E. coli*, coliphages, *Clostridium* spores) monitoring in source and treated water for validation (optional)
Enteric pathogens monitoring: operational

Operational monitoring of critical control points

- **Catchment**
  - River flow, turbidity

- **Treatment**
  - Chemical disinfection: dose and residual disinfectant, contact time (flow), temperature, (pH)
  - UV: UV irradiation, flow, UV transmittance
  - Filtration: turbidity (<0.3 NTU)

- **Distribution**
  - Inspection of works, monitoring of pressure, turbidity, (disinfectant residual)

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<th>Quality requirement</th>
<th>Monitoring site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>Operational monitoring of efficacy of physical removal by filtration processes</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
<td>Post-filtration</td>
</tr>
</tbody>
</table>
# Enteric pathogens monitoring: verification

<table>
<thead>
<tr>
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<th>Monitoring site</th>
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<tbody>
<tr>
<td>E. coli¹</td>
<td>Risk assessment: typing of source water contamination level, peak events</td>
<td>High</td>
<td>Yes</td>
<td>No</td>
<td>Source water</td>
</tr>
<tr>
<td>E. coli¹</td>
<td>Verification of treatment control for enteric bacterial pathogens</td>
<td>High</td>
<td>Yes</td>
<td>Yes (0/100ml)</td>
<td>Post-treatment</td>
</tr>
<tr>
<td>E. coli¹</td>
<td>Verification of distribution control against ingress of excreta</td>
<td>High</td>
<td>Yes</td>
<td>Yes (0/100ml)</td>
<td>Consumer</td>
</tr>
<tr>
<td>Clostridium perfringens, including spores³</td>
<td>Verification of treatment control for disinfection-resistant pathogens such as Cryptosporidium</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
<td>Post-treatment</td>
</tr>
<tr>
<td>Coliphages</td>
<td>Risk assessment: typing of source water contamination level, peak events (groundwater sources)</td>
<td>High</td>
<td>Yes</td>
<td>No</td>
<td>Groundwater</td>
</tr>
<tr>
<td>Coliphages</td>
<td>Verification of treatment control for enteric viruses.</td>
<td>High</td>
<td>Yes</td>
<td>Yes</td>
<td>Post-treatment</td>
</tr>
</tbody>
</table>
Enteric pathogens monitoring: no longer needed

<table>
<thead>
<tr>
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<td></td>
</tr>
<tr>
<td>Enterococci</td>
<td>Risk assessment: typing of source water contamination level, peak events</td>
<td>Medium</td>
<td>Yes</td>
<td>No</td>
<td>Source</td>
</tr>
<tr>
<td>Enterococci¹</td>
<td>Verification of treatment control for enteric bacterial pathogens</td>
<td>Medium</td>
<td>Yes</td>
<td>Yes (0/100ml)</td>
<td>Post-treatment</td>
</tr>
<tr>
<td>Enterococci</td>
<td>Verification of distribution control against ingress of excreta</td>
<td>Medium</td>
<td>Yes</td>
<td>Yes (0/100ml)</td>
<td>Consumer</td>
</tr>
<tr>
<td><strong>INDICATOR PARAMETERS (ANNEX I PART C)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coliform bacteria</td>
<td>Verification of treatment control</td>
<td>Low</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Coliform bacteria</td>
<td>Verification of distribution control</td>
<td>Low</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
Summary

- Current EU-DWD not adequate against viruses, protozoa and opportunistic pathogens (*Legionella pneumophila*).
- Risk assessment/risk management approach in WHO Guidelines can provide adequate protection.
- Key elements:
  - Risk assessment
  - Monitoring, operational & verification

Both elements already embedded in EU-DWD, implementation for new pathogens requires operational translation.
Summary

• Implementation in EU-DWD:
  – Legionella pneumophila risk assessment, operational and verification monitoring
  – Enteric pathogens risk assessment, operational and verification monitoring
  – Redefine role of existing parameters in light of risk assessment / risk management approach
  – Add (and remove) microbiological parameters to complete the approach