Optimizing water sampling in large building premise plumbing for the detection of opportunistic pathogens

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Opportunistic pathogens in large buildings water distribution systems

Favorable growth conditions:

- ✓ Temperature (20 – 50 °C)
- ✓ Stagnation
- ✓ Small diameter = ↗ S/V
- ✓ Biofilm and amoeba
- ✓ Materials
- ✓ Dead legs
- ✓ Absence of disinfectant
- ✓ Renovation & construction

Ideal growth conditions:

+ exposition
+ vulnerable patients

= high risk of infection
Factors to consider when defining sampling plan in a large building

1) Understanding the system:
   • Water distribution system design and architecture
   • Data to locate risk areas: historical data, hydraulics, temperatures at point of use, user complaints
   • Type of devices and impact water quality

2) Defining sampling parameters:
   • Sampling objectives
   • 1st draw or flushed samples
   • Sampling volume to maximize recovery
   • Detection method: culture or molecular methods
Understanding the system: Large Building Water System

Horizontal subordinate flow and return loop

Vertical subordinate flow and return loop

Tertiary loop and return

Main distribution pipe

Main recirculation pipe

Hot Water Production Unit

Wall

0.01-0.05 L

0.13 L (1 m)

0.28 L/m

Recirculation

Hot water (HW)

Sampling Point

Tertiary terminal end

Bédard et al. 2015
Understanding the system: Hot Water Distribution System

**WING A**

- **Floor 10**
- **Floor 9**
- **Floor 8**
- **Floor 7**
- **Floor 6**
- **Floor 5**
- **Floor 4**
- **Floor 3**
- **Floor 2**
- **Floor 1**

Hot water unit Wing A

Recirculating hot water

**WING B**

- **Floor 4P**
- **Floor 11J**

- **Floor 6**
- **Floor 5**
- **Floor 4**
- **Floor 3**
- **Floor 2**

Hot water unit Wing B

Recirculating hot water
Understanding the system: Differences between floors

<table>
<thead>
<tr>
<th>Floor</th>
<th>7:30 am</th>
<th>11:30 am</th>
<th>6:30 pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>58.7</td>
<td>58.5</td>
<td>58.9</td>
</tr>
<tr>
<td>9</td>
<td>58.6</td>
<td>58.7</td>
<td>58.7</td>
</tr>
<tr>
<td>8</td>
<td>59.1</td>
<td>59.1</td>
<td>59.2</td>
</tr>
<tr>
<td>7</td>
<td>58.3</td>
<td>58.3</td>
<td>58.3</td>
</tr>
<tr>
<td>6</td>
<td>56.2</td>
<td>56.6</td>
<td>56.5</td>
</tr>
<tr>
<td>5</td>
<td>58.8</td>
<td>58.9</td>
<td>58.9</td>
</tr>
<tr>
<td>4</td>
<td>58.5</td>
<td>58.6</td>
<td>58.9</td>
</tr>
<tr>
<td>3</td>
<td>56.1</td>
<td>56.3</td>
<td>56.4</td>
</tr>
<tr>
<td>2</td>
<td>58.9</td>
<td>58.9</td>
<td>58.8</td>
</tr>
<tr>
<td>1</td>
<td>56.1</td>
<td>56.3</td>
<td>56.1</td>
</tr>
</tbody>
</table>
Consumer complaints in Wing 3 – unable to get hot water

Understanding the system: Temperature distribution

Table:

<table>
<thead>
<tr>
<th>Wing</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Cuis.</td>
<td>58</td>
</tr>
</tbody>
</table>

Diagram:
- Infeed to wing 1 to 9
- Manifold
- Principal loop
- Hot water heater
- Tertiary loop
- Secondary loop
- Point of use
- <50°C
- 52.9°

Results:
- Hot water production at $T \geq 60^\circ C$ BUT
- Deficient hydraulics

Risk areas for opportunistic pathogens

Bédard et al. 2016
Diagnostic flowchart to interpret temperature diagnostic results

- Step approach starting from the main recirculation system that indicates the overall system risk level,
- Progressively to the subordinate return loops to identify large building areas or sectors at risk
- Finally to the tertiary terminal ends, to identify local issues with defective faucets or showers
- Staged response in terms of corrective and preventative actions, including $L_p$ monitoring.

Bedard et al. 2015
System investigation:

- Recirculation pumps
- Temperature monitoring for each wing
- Identify hydraulically deficient areas (T°)
  - Dead legs
  - Usage pattern change
  - Customer complaints
- Identify the type of devices in the system (faucets, showers, heat exchangers)
Understanding the system:
Type of faucets

Manual
One-lever
Two-lever

Foot-operated

Electronic

= Mixing zone location
**Understanding the system: Type of faucets**

% *Pseudomonas aeruginosa* positivity at the faucet in a multi-hospital study

<table>
<thead>
<tr>
<th>Types of faucet</th>
<th>Nb sampled</th>
<th>Nb positive for Pa</th>
<th>% contaminated</th>
</tr>
</thead>
<tbody>
<tr>
<td>E faucets</td>
<td>92</td>
<td>13</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>4</td>
<td>31%</td>
</tr>
<tr>
<td>Manual</td>
<td>90</td>
<td>13</td>
<td>14%</td>
</tr>
<tr>
<td>Pedal activated</td>
<td>14</td>
<td>4</td>
<td>29%</td>
</tr>
</tbody>
</table>

Charron et al. 2015
Understanding the system: Showers

Upper shower

Lower shower

Temperature (°C)

Recirc temp.

Time
Understanding the system: Energy recovery or saving devices

Example: Heat exchangers in hot water distribution system:

STAGNATION + TEMPERATURES + SURFACE

CONTAMINATED WATER

Example:

Heat exchangers in hot water distribution system:

STAGNATION:

- **DAY**
- **NIGHT**

TEMPERATURES:

- **Sortie**
- **Entrée**

SURFACE:

- **Danger**

CONTAMINATED WATER:

- **Municipal cold water supply**
- **Heat exchanger**
- **Pre-heated water**
- **Temperature Mitigating Valve**
- **Hot Water Distribution System**
- **Recirculating hot water**

Table:

<table>
<thead>
<tr>
<th>Description du prélèvement</th>
<th>Résultats L. monocytogenes (CFU/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frottis 1ère plaque</td>
<td>&lt; LD</td>
</tr>
<tr>
<td>Frottis plaque</td>
<td>++ Positif</td>
</tr>
<tr>
<td>Frottis eau d'étage</td>
<td>+++ Positif</td>
</tr>
<tr>
<td>Eau d'îlot</td>
<td>510 4600</td>
</tr>
<tr>
<td>Eau d'eau de l'échangeur</td>
<td>88 000 85 000</td>
</tr>
<tr>
<td>Eau purge de l'échangeur</td>
<td>5 000 22 000</td>
</tr>
</tbody>
</table>

Bédard et al. 2016
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Defining sampling parameters: 1st draw vs flushed

- #1 to #5 = 1st liter
- 15 mL #1
- 35 mL #2
- 200 mL #3
- 250 mL #4
- 500 mL #5
- 250 mL #6 after 2L of flow
- 250 mL #7 after 5L of flow
- 200 mL #8 after 10L of flow

Graphs showing:
- Cumulated Volume (L): 1h, 24h, 2d, 3d, 5d, 10d
- Hot Water
- HPC (CFU/mL)
- P. aeruginosa / 100 mL

Log scales for HPC and P. aeruginosa.
Defining sampling parameters: Sample volume

Cumulative HPC (CFU) vs. Sampling volume (mL)

- +500 mL
- +250 mL
- +200 mL
- +35 mL
- 15 mL

Monolever faucet
1st liter
Mixing Chamber
Defining sampling parameters: Sink and faucet sampling case study

- Detection of P. aeruginosa:
  - Culture (ISO 16266)
  - qPCR (gyrB)

28 sinks
Defining sampling parameters: Detection methods

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Aerator</th>
<th>Drain</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culture</td>
<td>7%</td>
<td>3.5%</td>
<td>57%</td>
<td>0%</td>
</tr>
<tr>
<td>qPCR</td>
<td>50%</td>
<td>64%</td>
<td>89%</td>
<td>21%</td>
</tr>
</tbody>
</table>

Positive at all 3 sites except 1 drain

Culture (+) = qPCR (+)

qPCR positivity > Culture
Low aerator positivity → metal & simple structure

Bédard et al. 2015
Defining sampling parameters: Detection methods

Culture vs qPCR:

- Low *P. aeruginosa* water contamination detected by culture based methods vs 50% by qPCR
- *P. aeruginosa* exposed to Cl$_2$ and Cu$^{2+}$ at drinking water concentration levels unlikely to be measured by standard culture methods or enzyme based assay
- Environmental strains may be stressed and require more time to grow on media
Defining sampling parameters: Detection method

Experimental study with longer incubation times (up to 10 days):

Swabs from drain, splash area and faucet
15 (n=60) confirmed positive samples:
8 drains (D), 4 splash areas (S) & 3 faucets (F)

- 40% of positive samples detected after 48h (ISO 16266 incubation)

Lalancette et al. 2017
Conclusions
Impact of sampling plan on results

Multiple studies, variable parameters:

- Type of sample – swab vs water
- Volume sampled – 50 to 250 mL
- Study context – outbreak vs prospective (after renovation or device replacement)
- Number of taps sampled
  - > 25 faucets → 0 to 18% positivity
  - ≤ 25 faucets → 58 to 100% positivity
- Technical information on the faucet and sink environment: mixing volume, connection material, length of connection, sink design, type of aerator, ...
Conclusions

➢ Understand the objectives of the sampling

➢ Understand the water distribution system architecture to identify hydraulically at risk sectors

➢ Select sampling points based on microbial risk:
  ➢ Consumer complaints (temperature, flow, drainage)
  ➢ Vulnerability of users
  ➢ Devices/areas favorable to microbial growth

➢ Select detection methods based on expected contamination levels, environmental stressors, target microorganisms and type of sampling (once OR routine monitoring)
Questions?

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