C3) Hot water systems  Legionella infection risk reduction

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Abstract

Sporadic cases of Legionnaires' disease continue to occur. No doubt many of people have impaired defence against such bacterial infections and the medical attention has so improved in recent years that the case-fatality ratio is now very low. But the presence of Legionella pneumophila in hot and cold water systems inside any building is to be expected. Hotels and hospitals abroad, particularly those located in old buildings, represent a major source of risk for Legionnaires' disease due to the high frequency of Legionella contamination. The most vulnerable individuals are normally the elderly, or those already weakened by sickness or disease. The subject of the paper is our Legionella contamination investigation of hot water in a cross-sectional survey in Kosice, the second biggest city of the Slovak Republic.

Keywords

Legionella, hot water system, contamination, thermal disinfection

1 Introduction

Legionellosis is a collection of infections that emerged in the second half of the 20th century, and that is caused by Legionella pneumophila and related Legionella bacteria. Water is the major natural reservoir for Legionella, and the bacteria are found worldwide in many different natural and artificial aquatic environments, such as cooling towers; water systems in hotels, homes, ships and factories; respiratory therapy equipment; fountains; misting devices; and spa pools. About 20% of the cases of legionellosis detected in Europe are considered to be travel-related; these cases present a particular set of problems because of difficulties in identifying the source of infection. The severity of legionellosis varies from mild febrile illness (Pontiac fever) to a potentially fatal form of pneumonia (Legionnaires’ disease) that can affect anyone, but
principally affects those who are susceptible due to age, illness, immunosuppression or other risk factors, such as smoking [1].

**Figure 1 - The outcome of illness for all cases with onset in 2007**

The first evidence of the association between water for human consumption from shower and nosocomial legionellosis was reported more than 20 years ago [2], and the hot water system is thought to be most frequent source of case or outbreaks within a hospital [3], where patients may be at higher risk for a severe infection [4]. Relatively little is known about sporadically occurring cases of community-acquired legionellosis, which accounts for most infection [5], although correlation analyses suggest that a substantial proportion of these cases may be residentially acquired and associated with bacteria in hot water distribution system. Absolute exclusion of these particular bacteria from building water systems may not be possible, or necessary. Outbreaks of disease have generally occurred when the concentrations in water systems have been high and aerosol has been produced. The aim therefore is to minimize the possibility for infectious doses to be produced as a result of operation of water systems. It is important that appropriate measures are taken to guard against conditions which may encourage Legionella multiplication.

The chain of causation that must exist for Legionnaires' disease to be acquired, involves:

- an environmental reservoir – naturally occurring;
- opportunity for multiplication – stagnation, temperature increase above ambient, nutrients;
- a mechanism for dissemination – devices generating aerosols;
- virulence of the organism – not all strains affect humans;
- inoculation of an infectious dose – inhalation;
- host susceptibility – some people are more susceptible than others.

This chain must be broken to ensure a system is safe.
2 Legionnaires’ disease and Pontiac fever

Legionnaires’ disease lacks characteristic symptoms or signs — there is no typical syndrome, and not everyone exposed to the organism will develop symptoms of the disease (Yu et al., 1982; Macfarlane et al., 1984; Granados et al., 1989; Roig et al., 1991; Sopena et al., 1998; Ruiz et al., 1999; Gupta, Imperiale & Sarosi, 2001). However, several clinical signs are classically associated with Legionnaires’ disease rather than with other causes of pneumonia.

Legionnaires’ disease is often initially characterized by anorexia, malaise and lethargy; also, patients may develop a mild and unproductive cough. About half of patients develop pus-forming sputum, and about one third develops blood-streaked sputum or cough up blood (haemoptysis). Almost half of patients suffer from disorders related to the nervous system, such as confusion, delirium, depression, disorientation and hallucinations. These disorders may occur in the first week of the disease.

Pontiac fever is an acute, self-limiting, influenza-like illness without pneumonia (that is, it is “non-pneumonic”). Unlike Legionnaires’ disease, Pontiac fever has a high attack rate, affecting up to 95% of exposed individuals (Glick et al., 1978).

For main characteristics of Legionnaires’ disease and Pontiac fever see Table 1 [1].

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Legionnaires’ disease</th>
<th>Pontiac fever</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incubation period</td>
<td>2–10 days, rarely up to 20 days</td>
<td>5 hrs–3 days (most)</td>
</tr>
<tr>
<td>Duration</td>
<td>Weeks</td>
<td>2–5 days</td>
</tr>
<tr>
<td>Case–fatality rate</td>
<td>Variable depending on susceptibility; in hospital patients, can reach 40–80%</td>
<td>No deaths</td>
</tr>
<tr>
<td>Attack rate</td>
<td>Attack rate 0.1–5% of the general population 0.4–14% in hospitals</td>
<td>Up to 95%</td>
</tr>
</tbody>
</table>

Sources: Woodhead & Macfarlane, 1987; Stout & Yu, 1997; Yu, 2000; Akbas & Yu, 2001; Mülazimoglu & Yu, 2001

3 AIMS AND METHODS

To assess the potential public health impact of Legionella colonization at a domestic level, as well as public level, a descriptive multicentric study was undertaken to identify and qualify the levels of the microorganism in a substantial number of Slovak domestic and public hot water samples.

We addressed three specific aims:
1. To estimate the frequency of Legionella colonization and severity of contamination at different levels;
2. To identify potential the risk factors for contamination relative to distribution systems and water characteristics;
3. And to define a relative role of each risk factor and suggest possible remediation.
4. Lastly, risk for legionellosis will retrospectively evaluated by collecting information about pneumonia symptoms recorded by residents at buildings.

3.1 Thermal disinfection

The subject matter is periodic rising of temperature per specific time in the whole hot water (HW) network including outlet points with a certain time of flushing these points at increased temperature. It is important to take into consideration the temperature level and flushing time of the outlet points. US CDC (Center for Disease Control and Prevention) recommends thermal disinfection at 71° C (160° F) flushing network outlets for 5 minutes. The original method design considered 30 minutes flushing which is financially and technically very difficult, although very efficient – positivity % decreased to zero. The name of the method is "Superheat and flush" and essential is to keep the temperature level and time of flushing the network outlets. The effect is short-lasting and must be repeated periodically to avoid recolonization of Legionella. In practice there are also other thermal disinfection procedures performed, e.g. periodical temperature increasing in HW systems above 70° C with 10 minutes network outlets flushing by water above 60° C. This process decreases percentage of network outlets positivity to zero and recovery of the contamination percent to the previous level in 30 up to 60 days.

WHO, 1996, Health criteria, Vol. 2, recommends to operate HW at temperature above 60° C as one of measures leading to Legionella prevention in potable water distribution network. The German document DVGW (Deutscher Verein des Gas- und Wasserfaches e. V.) W 551 and W 552 states that operating and technical measures in potable water distribution systems lead to successful results, unless water temperature in a whole system falls under 55° C. Pre-heating systems must be heated up to 60° C once a day, periodically (e.g. once a week) thermally disinfected, i.e. set heaters above 70° C so that 70° C hot water flows out of network outlets for a minimum of 3 minutes. Another barrier to effective thermal disinfection is the present legislation, STN 83 0616 – Quality of hot service water standardizes HW temperature in the range of 45 up to 60° C. This fact means that HW distribution systems do not have to be sized for temperatures above 70° C. The system of "self-regulating trace heating elements" represents a technical solution for controlling bacterial colonization at network outlets (mixing faucets, shower roses, etc.). Keeping a constant temperature of 50±1.5° C at these outlet points is recommended even if temperature in circulation pipeline decreases to 45° C (this should not occur in adjusted systems – although practice shows opposite)[9].

3.2 Hot water adjustment influence on Legionella elimination.

Adjusted systems satisfy certain thermal and pressure features providing disinfection spreading (e.g. thermal disinfection) into all points of distribution network in a certain time period, namely concentration depending on time. In distribution network areas not reached by disinfection, there remain a contamination source in the network then serving as a place where contamination is newly spread from. Non-adjusted distribution systems do not provide keeping disinfection neither for a required period nor in a required quality. Non-adjustment of systems leads to fast
spreading of legionella in distribution systems. Long-term monitoring shows that legionella contamination regenerates very quickly, usually after 1-2 months.

3.3 Sample collection

From February through October 2006, a total of 46 water samples were collected from private homes, hospitals and boiler houses of Kosice, the representative of Eastern Slovakia. Selection was made on the basis of the water distribution systems inside the town and buildings and heater types in each area. After we identified each building, we asked a random family, or work collective to participate in the study, i.e. to complete our questionnaire and give informed consensus for water collection. Laboratory examinations and Legionella analyses were made by Regional health office – referential centre for potable water in Kosice.

Hot water samples were drawn from the bathroom outlets in the case of residential houses (shower heads or bathroom tap) in the sterile 1-L glass battles after a brief flow time (to eliminate cold water inside the tap or flexible shower pipe). To neutralize residual free chlorine, sodium thiouosulphate was added in sterile bottles for bacteriologic analysis, whereas acid-preserved glass bottles were used for chemical determinations. Collection bottles were returned to the laboratory immediately after sampling for bacteriologic examination. We used concentration of samples by membrane filtration. Filters Millipore were used for 10 ml sample volumes. Adjusted samples were inoculated on the medium GVPC surface.

3.4 Positive Samples

Water and aerosols samples survey for Legionella presence according to their outcomes is connected with saprophytic and thermo-tolerant amebas presence monitoring. In waters for human consumption (potable water cold - PWC) volume of Legionella were detected, from sporadic colonies 20 CCU/200ml up to massive colonization in the quantity 6700 CCU/200ml of a sample. Legionella presence was detected in 8 samples of drinking water samples analyses. Positive findings were recorded in 8 samples of PWH (potable water hot).

![Figure 2 - Legionella results determination for potable water hot in Kosice](image-url)
Figure 2 presents water analyses results in chosen points of a hot water distribution system in Kosice. In waters for human consumption (potable water hot - PWH) volume of Legionella were detected, from sporadic colonies 200 CCU/200ml up to massive colonization in the quantity 14600 CCU/100ml of a sample. Legionella presence was detected in 8 samples of PWH samples analyses, i.e. in 17, 4 %.

3.5 Results

We repeat sampling after thermal disinfection in contaminated places. After 12 days the level of Legionella colonies was the same as before this measurement. See figure 3.

![Water analysis results](image)

**Figure 3 - Legionella results – positive samples**

Much worse results were obtained at similar survey in Italy or Germany [6]. In this case 36 - 68 % of samples were positive. In case that thermal disinfection in contaminated places was not done, the concentration of bacteria would have exponential character – would continually increase. By collecting the samples is verified that thermal disinfection is not a systemic solution and it is needed to find a new complex solution.

4. Material base

Researchers have monitored survival and growth of L.pneumophila in laboratory plumbing systems composed of materials typically found in hot water systems. After the trial period for one overseas study, the apparatus was dismantled and studied colonization was the heaviest on natural rubber components (tap washers), moderate on synthetic plastic tubing and lower on steel. The colonization was not apparent on copper surfaces. It was concluded that copper is able to produce a toxic effect on Legionella. This finding, no doubt, has implications for small hot water systems which, hitherto, have been predominantly constructed from copper-based materials. The increasing use
of plastic piping in main pressure hot and cold water systems may mitigate against the natural biocidal effects of construction materials. It is well known that Legionella occurs in all types of piping materials. The cited Dutch research project [7] was set up with new pipes under laboratory conditions – and, crucially, with water at 37 °C, the ideal temperature for Legionella.

The most important factor for the possible development of Legionella bacteria in tap water systems is the design and operation of the system. It is well known that Legionella thrives in water that is insufficiently flushed, and is allowed to remain stagnant for too long between the critical temperatures (20°C to 45°C). Regular, thorough flushing at 60°C or above permanently reduces the Legionella growth. These criteria are consistently reflected in guidelines and regulations developed in many individual countries for the design, operation and maintenance for tap water systems to avoid the growth of Legionella. An overview has recently been published by the European Working Group [8].

5. Conclusion

In conclusion, our results do not suggest specific new measures to control Legionella contamination except for the protective role of periodical temperatures of >60°C. Our observations suggest that Legionella species should be considered when examining environmental contamination, which is essential to better evaluate environmental risk factors and select the most appropriate prevention and control measures. We do not believe disinfecting measures at the domestic level are needed, considering that our retrospective study on pneumonia in residents did not show a relevant evidence of risk in colonized buildings.

Acknowledgments

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4 References


5 Presentation of Author

Zuzana Vranayová is the vice-dean at the Civil Engineering Faculty, Technical University in Kosice, Institute of Building and Environmental Engineering. She is a specialist on Building services, HVAC systems and Building Environment. Recently she has been concentrated on the field of hot water systems especially with the point of view of reducing the risk of Legionella contamination in distribution systems.