Health risk assessment resulting from the presence of *Legionella* bacteria in domestic hot water in public buildings – the results of a pilot study

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Abstract: The aim of the study was to assess the risk posed by *Legionella* bacteria in a public building in Krakow. An old building with internal installation risers of different ages, as well as draw-off points of different types, was selected for testing. Samples were collected during two campaigns. In one sample of the first series of tests, no bacteria were found. During the second series of tests, no *Legionella* bacilli were found in just one sample and in one sample only 4 colony-forming units were detected. At the remaining draw-off points (water taps), the bacteria count detected were greater than the maximum threshold allowed by legal regulations (admissible threshold for public utility buildings – 100 cfu/100 mL). No morphological differences were observed with respect to the occurrence of specific serogroups. In 14 samples, *Legionella pneumophila* serogroups 2–14 were found, while the *Legionella pneumophila* serogroup 1 was only found in one sample. The risk assessment was also carried out based on a semi-quantitative risk matrix approach and as a quantitative microbial risk assessment. The risk matrix approach was successfully implemented for the recognition of the potential risk associated with the *Legionella* occurrence in a water system. The calculated annual cumulative risk is high. The research shows that even if the weekly inhalation exposure dose (and therefore the calculated risk) is high, the number of *Legionella pneumophila* illness cases found can be equal to zero. This is probably due to the large uncertainty associated with QMRA determination. The size of the room in which the contaminated water is used also affects the possibility of infection.

Keywords: *Legionella pneumophila*, tap water, public building, quantitative microbial risk assessment, risk matrix

INTRODUCTION

The first observed cases of the disease caused by *Legionella* bacteria occurred in 1976 during a congress of the American Legion in Philadelphia, U.S. At that time, as many as 221 people fell ill and 34 died (Garret 1994). *Legionella* bacilli owe their name to that outbreak, and the disease they cause has been called legionellosis.

Legionella is gram-negative, aerobic rod-shaped, motile, and non-spore-forming bacteria (Rasilainen et al. 2005). The number of recognized *Legionella* species and serogroups is constantly growing. Currently, there are over 60 known species and 80 serogroups. Several *Legionella* species can cause human diseases such as Legionnaires' disease and Pontiac fever. *Legionella pneumophila* still causes the most community-acquired infections and nosocomial infections (Helbig et al. 2002, Yu et el. 2002, Amemura-Maekawa et al. 2010, 2018, Miyashita et al. 2020). Eighty to eighty-five percent of infections caused by *Legionella* have been related to *Legionella pneumophila*. Serogroups 1 and 6 are responsible for two-thirds of all reported *Legionella* infections (Yu et al. 2002). This is why most detection methods have been developed to identify *Legionella pneumophila* (Miyashita et al. 2020).

Natural *Legionella* habitats include freshwater bodies (rivers, streams, lakes), groundwater, geysers, highly eutrophic saline waters, municipal and industrial waterworks, public buildings, soils, sewerage systems, air-conditioning installations and biofilms on the surface of water bodies (Huang et al. 2011, Benhammou et al. 2012, Walczak et al. 2013a, 2013b, 2016, Liguori et al. 2014, Kmiecik et al. 2017, Mika et al. 2019). The transport of *Legionella* and their introduction into other environments occur by means of air and water spray (aerosols). Such an aerosol is produced by many devices in doctor's offices, at swimming pools, in public spaces (showers, fountains), public toilets, and air-conditioned spaces in which periodic inspections are carried out (US EPA 1999). Human infection only occurs by aerosol inhalation (Rafiee et al. 2014, Walser et al. 2014). Over the last few years, the number of outbreaks has increased strongly (Delgado-Viscogliosi et al. 2005).

The Polish Regulation of the Minister of Infrastructure (Rozporządzenie 2002) includes provisions envisaging the protection of hot water distribution systems in buildings against the growth of *Legionella* bacteria. According to the Regulation, hot water distribution system should be capable of producing water at water draw-off points with a temperature no less than 55°C and no more than 60°C. Hot water distribution systems should allow continuous or periodical chemical or physical disinfection (including the periodic application of the thermal disinfection method) without reducing the durability of the system and the products it includes. For thermal disinfection purposes, it must be ensured that the water temperature at draw-off points is no less than 70°C and not higher than 80°C. However, this provision only applies to newly designed buildings.

According to *European technical guidelines* (ESGLI 2017), the pipework and any components should be easy to inspect so that the thermal insulation and temperature monitoring can be checked.

In the Regulation of the Minister of Health (Rozporządzenie 2005), *Legionella* bacterium is classified as a so-called harmful biological agent. This is the fundamental legal act that governs the protection of employees against harmful biological factors such as *Legionella* in Poland.

The obligation to test for the presence of *Legionella* in domestic hot water was introduced by the Regulation of the Minister of Health (Rozporządzenie 2015a). The latter Regulation established the obligation to test domestic hot water in multi-apartment residential buildings and public buildings for *Legionella* where air and water spray (aerosol) is generated during use (permissible number of microorganisms: <100 in 100 mL of water). The Regulation also stipulates the recommended method of testing for *Legionella* sp., which is described in the ISO standard no. 11731:2017 (ISO 2017). Another method may be used as well provided that its equivalence with the aforementioned method is documented.

The revised Drinking Water Directive (Directive 2020) includes a new provision on the risks associated with domestic distribution. Article 10 introduces the obligation to monitor for the

presence of *Legionella* when assessing the risk associated with domestic distribution systems. *Legionella* has been found by the WHO to cause the highest health burden of all waterborne pathogens in the European Union. In addition, it is also recommended by the European Centre for Disease Prevention and Control (ECDC 2017) to apply regular checks and appropriate control measures to man-made water systems as a means to prevent cases of Legionnaires' disease at tourist accommodation sites, hospitals, long-term healthcare facilities or other settings where sizeable populations at higher risk may be exposed (Directive 2020). For the purposes of Articles 10 and 14, the parametric value for *Legionella* is set as <1000 cfu/L. Actions provided for in those Articles could be considered even when the value is below the parametric value, e.g., in cases of infections and outbreaks. In such cases, the source of infection should be confirmed and the species of *Legionella* identified.

Poland is in the group of countries with a relatively low level of incidence. Unfortunately, however, this may result from difficulties in diagnosing this disease correctly. It should be recognized that associated severe pneumonia cases are too rarely associated with *Legionella* infection, which results in the delayed administration of appropriate therapy and a failure to detect environmental sources of infection (Stypułkowska-Misiurewicz & Czerwiński 2016).

In this context, the objective of the study was to assess the risk posed by *Legionella* bacteria in a public building in Krakow. An old building with internal installation risers of different ages, as well as draw-off points of different types, was selected for testing.

MATERIALS AND METHODS

Sampling points locations

An experiment was conducted in order to assess the risk posed by *Legionella* bacteria in a public building in one of the districts of Krakow (Poland, Lesser Poland Voivodeship). An old building with internal installation risers of different ages, as well as draw-off points (taps/showers) of different types (no-touch infrared sensor and classical taps), was selected for testing. Two sampling series named

A and B were made. The first campaign (series A) was performed as a preliminary test to recognize if the problem with *Legionella* occurred. The locations of sampling points are summarized in Table 1, while their characteristics are presented in Table 2.

Table 1

Water sampling locations and their names

Floor no.	Water supply riser				
	1	2	3	4	5
−1	A1/B1*$_S$	B2$_S$	B3$_C$	A2$_C$	–
0	B4$_S$	B5$_S$	–	B6$_S$	B7$_S$
+1	–	B8$_S$	–	B9$_S$	B10$_S$
+2	B11$_S$	B12$_S$	–	B13$_S$	B14$_S$
+3	–	–	–	B15$_C$	A3/B16*$_C$

Sampling series: A and B; types of tap: S – sensory, C – classic, * equivalent points in both test series.

During the first sampling, the following samples were collected: sample A1 – from the shower using a disinfected funnel and samples A2 and A3 – directly from taps (Tab. 1).

During the second sampling, samples were collected from taps in the bathrooms, in different water supply risers. The taps were both no-touch infrared sensor and conventional (classical) ones. During this test stage, 16 water samples were collected (samples B1–B16) (Tab. 1).

Sampling methodology

The water samples with a volume of 650–750 mL were collected into sterile 1000 mL polypropylene bottles which contained sodium thiosulphate in order to fix the sample. The samples were collected aseptically using sterile gloves, observing all safety and hygiene principles related to the samples so as not to contaminate the sample with any substances which could affect the test results. The air left in the bottle (250 mL) allowed the mixing of water samples and provided microbial organisms with access to oxygen. Thiosulphate (sodium or potassium) is necessary to inactivate disinfectants. Culture method can return false negative results if the bottles used to collect chlorinated tap water samples do not contain a neutralising agent to immediately inactivate residual halogen biocides (Wiedenmann et al. 2001). Directly before the water samples had been collected, the water temperature was measured

using a calibrated mercury thermometer. The water samples were transported as soon as possible to the accredited Wessling Poland laboratory in Poznań (PCA No. AB918).

Analysis methodology

Water samples were tested for the presence of *Legionella* bacteria within 24 hours of their collection, using the reference method described in the ISO standard no.11731:2017(ISO 2017). The detection/quantification limit for *Legionella* using this method was 1 cfu/100 mL.

Results are given in the form of an estimated number of colony-forming units (cfu) of *Legionella* bacteria in a 1000 mL water sample (often as cfu/100 mL).

Additionally, in the samples collected during the second series of tests, serotyping was carried out to distinguish the following strains: *Legionella pneumophila*serogroup 1 and serogroups from 2 to 14 and *Legionella* spp.

Risk analysis methodology

In the semi-quantitative risk matrix approach, the likelihood (*L*), frequency (*F*), and severity of consequence (*S*) of selected hazard events which can occur in a scale from 1 to 5 were taken into account during the risk (*R*) assessment. The risk was calculated by multiplying likelihood or frequency by severity. In the presented work, the risk levels were divided into low (a risk score below 10), medium (a risk score between 10 and 19), and high (a risk score above 20) as proposed by other researchers (Papadakis et al. 2018).

RESULTS AND DISCUSSION

The results of the research are presented in Table 2.

Table 2
Microbiological characterization of the collected samples

Sample no.	Sampling point type	Water temperature [°C]	Number of bacteria [CFU/100 mL]	*Legionella pneumophila* serogroup
Sampling A (Kmiecik et al. 2017)				
A1	S/men's bathroom	27.0	1.6×10^3	not analysed
A2	C/shower tap	24.4	1.2×10^3	
A3	C/men's bathroom	26.3	not found	
Sampling B				
B1	S/men's bathroom	38.2	2.0×10^3	2–14
B2	S/women's bathroom	29.1	1.4×10^3	2–14
B3	C/co-ed bathroom	21.4	2.9×10^3	2–14
B4	S/men's bathroom	19.3	9.8×10^2	2–14
B5	S/men's bathroom	27.0	2.1×10^3	2–14
B6	S/women's bathroom	37.9	4.4×10^3	2–14
B7	S/women's bathroom	41.8	3.5×10^3	2–14
B8	S/disabled bathroom	36.0	2.7×10^2	2–14
B9	S/women's bathroom	30.2	2.4×10^3	2–14
B10	S/men's bathroom	20.5	8.2×10^2	2–14
B11	S/men's bathroom	16.1	4.0×10^0	1
B12	S/women's bathroom	20.0	7.0×10^3	2–14
B13	S/women's bathroom	31.1	3.6×10^3	2–14
B14	S/men's bathroom	22.3	1.8×10^3	2–14
B15	C/men's bathroom	18.9	not found	–
B16	C/men's bathroom	27.8	5.6×10^2	2–14

Types of tap: S – sensory, C – classic.

In one sample (A3 – a tap in the men's bathroom of a public utility building with an old water distribution system), no bacteria were found; in the remaining samples, *Legionella* colonies were identified (Fig. 1) in numbers exceeding admissible thresholds for public utility buildings (100 cfu/100 mL). In most samples (excluding A3, B4, B8, B10, B11, B15, B16), the parametric value from Directive (2000) was also exceeded.

The presence of *Legionella* rods in the A2 sample (a rarely used shower in a public building) is probably caused by the deposition of sludge and biofilm in a system that is not used.

De Filippis et al. (2018) opined that the presence of biofilm increases the survival and development of *Legionella* by protecting the bacteria from the effects of disinfection. In the case of sample A1 (men's bathroom in a public building, new water distribution system, infrared sensor tap), the problem may be insufficiently high water temperature. The automatic infrared sensor tap is activated for about 30 seconds after the infrared beam is interrupted, and the maximum instantaneous water temperature does not exceed 45°C, so this system may be susceptible to bacterial colonisation. In the case of this water draw-off point, its frequent use does not protect the system against contamination in any way.

The second series of tests was conducted in 2019. This consisted of collecting water samples from taps in bathrooms which were connected to specific taps in different water risers. The taps were no-touch infrared sensor ones (13 samples) and conventional ones (3 samples). The results of *Legionella* bacteria counts are listed in Table 2 and Figure1.

When the results of the second series of tests were analysed, no *Legionella* bacilli were found in just one sample (B15), while in the B11 sample only 4 colony-forming units were detected. At the remaining draw-off points, the bacteria number detected were greater than the maximum threshold allowed by legal regulations.

In four cases (B4, B8, B10, and B16 points), the number of bacteria was in the range of 10^2–10^3 cfu/100 mL. The remaining twelve samples were found to contain 10^3–10^4 cfu/100 mL. The literature reports describe the occurrence of *Legionella* bacilli in tap water (Sabrià et al. 2001, Lesnik et al. 2016, Donohue 2021). The number of bacteria indicated is greater than the health-based targets for *Legionella* in piped water systems in selected European countries, which is set as a maximum 1000 cfu/L in France and Germany and 100 cfu/L in the Netherlands and United Kingdom (Bartram et al. 2007).
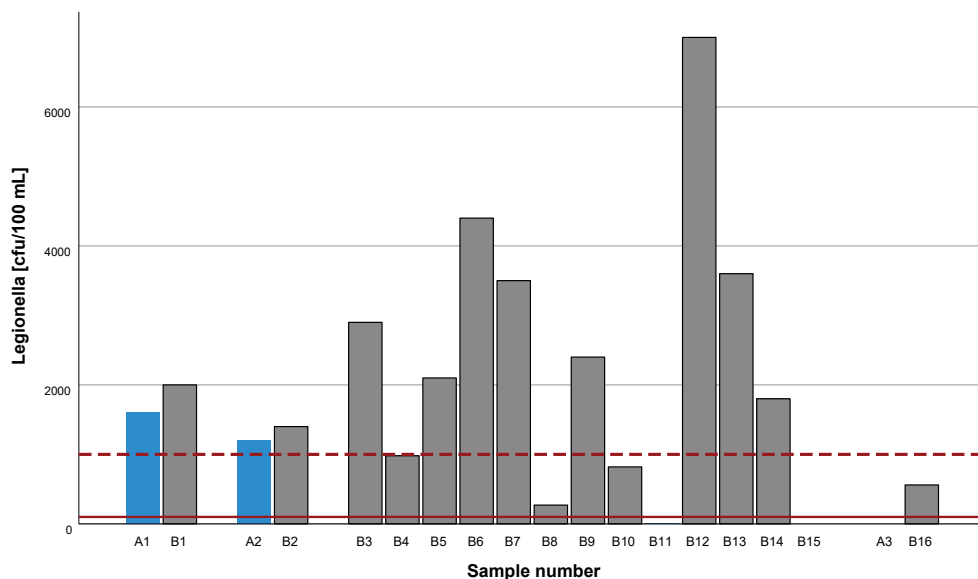

Fig. 1. *Results of the tests. Red line indicates admissible thresholds for public utility buildings, the red dotted line indicates the parametric value from Directive (2020)*
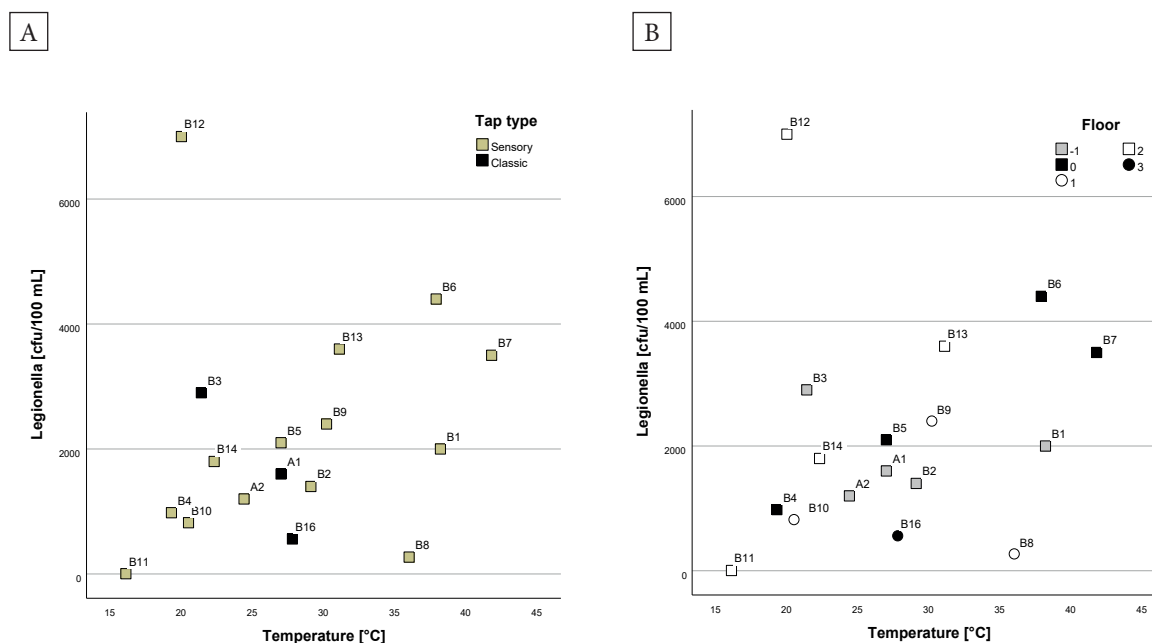
Fig. 2. Legionella bacteria in the samples analysed depending on water temperature. Data divided by the type of tap (A) and building floor (B)

In Figure 2, the results on scatter plots with breakdown by the type of tap (A) and building floors (B) are presented.

From the results obtained, it cannot be concluded that the presence of *Legionella* bacteria in water is related to the use of infrared sensor taps, since these bacteria were also found in conventional taps (connected to the same water supply riser). According to the tap manufacturers information, they equipped no-touch taps with thermal disinfection systems. This process consists of flushing the tap with hot water (about 70°C for 3–4 minutes), which destroys bacterial cells (Dur 2017), but the procedure is only effective if it is activated and the appropriate temperature of water in the water distribution system is ensured.

In Figure 3 the correlation between temperature and the number of bacteria in water risers is presented.

The method and frequency of using water from each riser have the greatest influence on the occurrence of *Legionella* in tap water, but it is not possible to give a straight answer on the correlation between each water riser and the number of *Legionella* bacteria.

The water temperature within risers changes between individual floors. In general, it decreases with height, although the opposite trend can sometimes be observed between floor 1 and floor 2. The smallest temperature difference between the floors was recorded in water riser 4 (women's bathrooms). In water risers 1, 4, and 5, an increase in *Legionella* bacteria count is observed as the water temperature rises, while in water riser 2 the trend is the opposite.

At the points which were sampled during both measurement series (A1 & B1 and A3 & B16), the number of bacteria increased over time, which may indicate favourable conditions for *Legionella* bacteria growth. The relatively constant number of colony units confirms that the system is not disinfected at regular intervals and suggests that *Legionella* has reached its maximum growth potential under the prevailing conditions (temperature, water distribution infrastructure, etc.).

Within both series, no *Legionella* bacteria were detected in the A3 and B15 samples, while in the second measurement series the number of *Legionella* bacteria at point B16 (the equivalent of A3) was already over 500 cfu/100 mL, which indicates intensified bacterial growth.
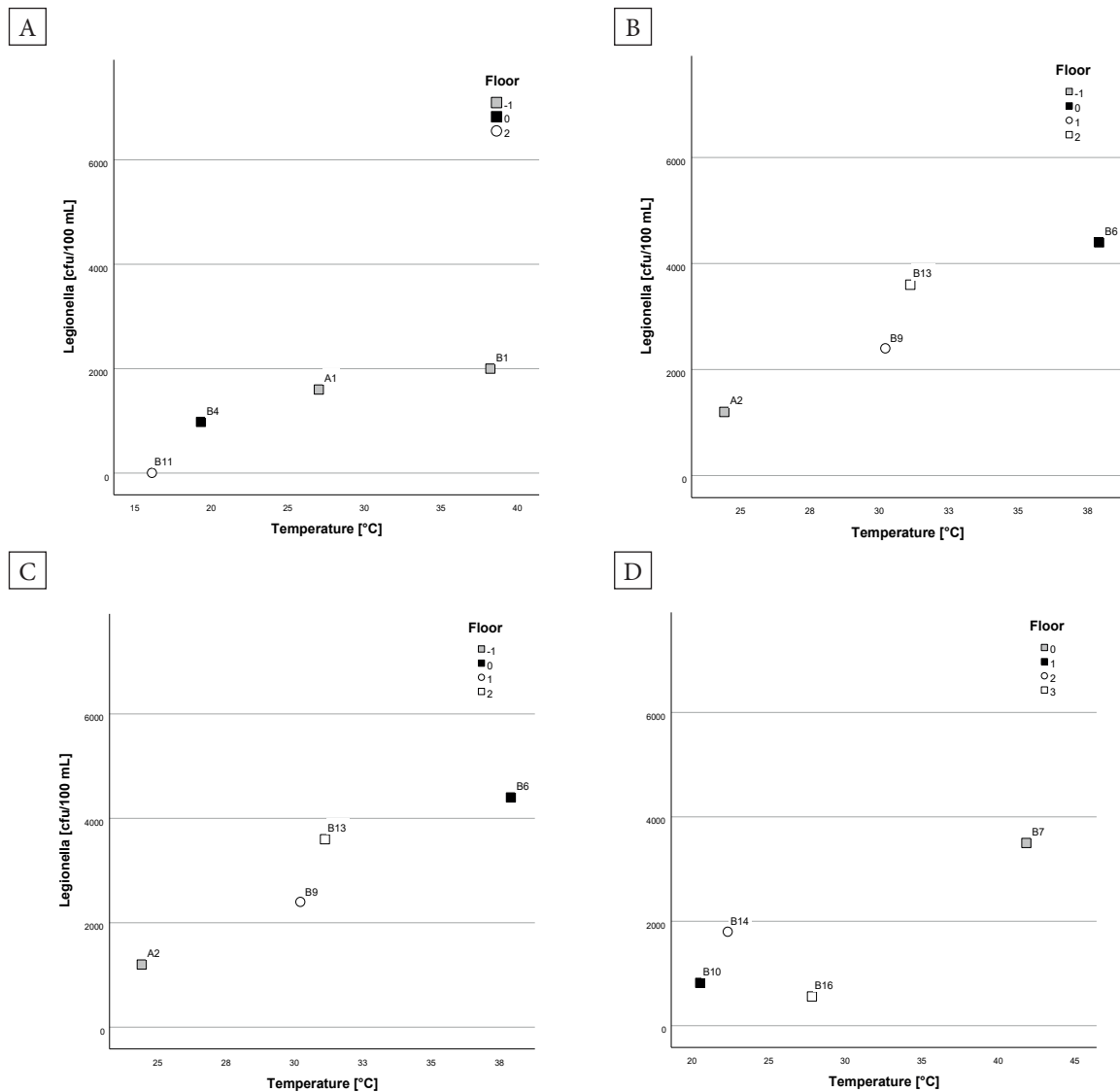
Fig. 3. *The correlation between temperature and the number of bacteria in water risers: A) riser 1; B) riser 2; C) riser 4; D) riser 5 (Tab. 1)*

The two draw-off points are located on different floors of a single building and are supplied by different water risers; they are used up to several hundred times per day. The fact that *Legionella* was identified at each of these points may suggest that the entire water distribution system in the building is contaminated with these bacteria.

In the samples in which *Legionella* bacteria were detected, serotyping was carried out to distinguish serogroups 1, 2–14 of *Legionella pneumophila*. The results are presented also in Table 2.

In the samples analysed, no morphological differences were observed with respect to the occurrence of specific serogroups. In 14 samples, *Legionella pneumophila* serogroups from 2 to14 were found, while the *Legionella pneumophila* serogroup 1 was only found in the P11b sample. The presence of a small amount of serogroup 1 within that tap may be caused by local external contamination of the tap itself. This result is somewhat dubious since the samples were collected from a single water distribution system riser and the rest of the water distribution system is free of this serogroup.

This serological group is very dangerous since it causes 67% of all disease cases (Fields et al. 2002).

In each case where the *Legionella* bacteria family is present, disinfection must be carried out, since despite the fact that the risk is lower for other groups compared to serogroup 1, humans may still be infected, which may result in morbidity and even death. The building administrator was informed of the test results and disinfection was carried out.

RISK ANALYSIS

The presented research focused on *Legionella* occurrence in tap water from a public building. The risk assessment was carried out based on a semi-quantitative risk matrix approach (WHO 2009, 2017; European Standards 2013, Papadakis et al. 2018) and as a quantitative microbial risk assessment (QMRA) based on the method proposed by Armstrong & Haas (2007a, 2007b), reviewed by Hamilton & Haas (2016) and implemented by other scientists (Hines et al. 2014, Sharaby et al. 2019).

The main hazards identified in the analysed examples were:
1) *Legionella* occurrence in a water system,
2) inadequate water disinfection system,
3) too low water temperature,
4) low flow of water in the system,
5) water stagnation,
6) corrosion of water supply system,
7) long exposure to water contaminated with *Legionella*.

The highest likelihood (4) was estimated in a case of 1) and 3) identified hazards due to similar episodes in the past – *Legionella* was already found in the system and the water temperature

is often much lower than 50°C. A medium likelihood (3) was assessed in terms of water stagnation in the pipe system and probably corrosion of the water supply system because of the age of the installation (above 10 years), hard water in the system and the periods when water is not used due to the absence of users (e.g. holidays) and low flow of water in the system due to the use of water, usually only for hand washing. For other identified hazards, the frequency was set as 1 or 2 because of the lack of such episodes in the past, the systematic disinfection of water system compliant with the requirements and recommendations, and the short exposure (water used mostly for hand washing). The severity was set as 3 (medium) for all of the selected hazards except an example with long exposure to water contaminated with *Legionella*.

In Table 3, a risk assessment is presented.

The risk was found to be low in most of the analysed hazardous events which were identified. In two cases the risk was classified as medium. They were associated with the *Legionella* occurrence in water system and too low water temperature. Inadequate water temperature at the point of use poses a risk for human health (Boppe et al. 2016). Faucets and toilets have been already identified as a source of *Legionella* (Hines et al. 2014, Prussin et al. 2017). However, in total the risk should be considered as low because of the specific use of the analysed water. The highest risk for human infection occurs by aerosol inhalation and this is produced in very small amounts during hand washing.

Results of quantitative microbial risk assessment (QMRA) are presented in Table 4.

Table 3
Risk matrix

Hazard	Likelihood or frequency	Severity	Risk score	Risk rating
Legionella occurrence in a water system	4	3	12	Medium
Inadequate water disinfection system	1	3	3	Low
Too low water temperature	4	3	12	Medium
Low flow of water in the system	3	3	9	Low
Water stagnation	3	3	9	Low
Corrosion of water supply system	3	3	9	Low
Long exposure to water contaminated with *Legionella*	1	4	4	Low

Table 4
Quantitative microbial risk assessment

Sample no.	Bacterial concentration in inhalable aerosol [cfu/m³] $C_{air} = C_{water} \times EF_{f/s}$	Inhalation exposure dose [cfu/week] IED = $C_{air} \times$ ED $\times$ RR $\times$ IR	Predicted risk given the weekly dose $R_w(d) = 1 - e^{(-\gamma IED)}$	Annual cumulative risk $R_A(d) = 1 - \Pi_{w=1}^{n}[1 - R_w(d)]$
A1	8.96	9.15×10^{-2}	5.47×10^{-3}	0.25
A2	4.08	2.50×10^{-1}	1.49×10^{-2}	0.54
A3	not found	not calculated		
B1	11.20	1.14×10^{-1}	6.84×10^{-3}	0.30
B2	7.84	8.00×10^{-2}	4.79×10^{-3}	0.22
B3	16.24	1.66×10^{-1}	9.90×10^{-3}	0.40
B4	5.49	5.60×10^{-2}	3.36×10^{-3}	0.26
B5	11.76	1.20×10^{-1}	7.18×10^{-3}	0.31
B6	24.64	2.52×10^{-1}	1.50×10^{-2}	0.54
B7	19.60	2.00×10^{-1}	1.19×10^{-2}	0.46
B8	1.51	1.54×10^{-2}	9.26×10^{-4}	0.05
B9	13.44	1.37×10^{-1}	8.20×10^{-3}	0.35
B10	4.59	4.69×10^{-2}	2.81×10^{-3}	0.14
B11	0.02	2.29×10^{-4}	1.37×10^{-5}	0.001
B12	39.20	4.00×10^{-1}	2.37×10^{-2}	0.71
B13	20.16	2.06×10^{-1}	1.23×10^{-2}	0.47
B14	10.08	1.03×10^{-1}	6.15×10^{-3}	0.27
B15	not found	not calculated		
B16	3.14	3.20×10^{-2}	1.92×10^{-3}	0.10

Water to air emission factor was set as 5.6×10^{-4} L/m³ for faucets (EF$_f$) and 3.4×10^{-4} L/m³ for showers (EF$_s$), weekly exposure duration (ED) was estimated 7 min for the shower (1 shower a week) and 70 seconds for faucets (2 times hand washing for about 7 seconds during 5 days) (Hines et al. 2014, Sharaby et al. 2019). The inhalation rate was set as 1.05 m³/h using specification of US EPA (2011). The fractional retention rate was estimated as 0.5 (Borchgrevink et al. 2013, Sharaby et al. 2019). Model parameter for *Legionella* infection risk (γ) was set as 0.06 1/cfu.

The weekly inhalation exposure doses calculated based on the results obtained vary from 2.29×10^{-4} (B11) to 4.00×10^{-1} cfu/week (B12). Appropriately, the lowest calculated annual cumulative risk is equal to 0.001 and the highest is 0.71. The mean annual cumulative risk was evaluated as 0.30. Even so, no case of Legionellosis was found in the tested public building. This may suggest that the risk found is overestimated due to the uncertainty of such evaluations and the degree of variability of *Legionella* in tap water during any given year (Lesnik et al. 2013, Hamilton et al. 2019).

The presented research proves that the number of bacteria in the same tap changed during the two conducted campaigns. A number of researchers have highlighted that the air-water partitioning coefficient is a major source of uncertainty in the *Legionella* QMRA process (Armstrong & Haas 2007a, 2007b, Schoen & Ashbolt 2011, Buse & Ashbolt 2012).

CONCLUSIONS

The presence of *Legionella* in public buildings is an immense problem. In such buildings, the responsibility for carrying out proper disinfection is divided between multiple functions and inspections are not carried out sufficiently frequently – the absence of a direct owner and user makes such prevention and disinfection measures rare or non--existent (Springston & Yocavitch 2017). According to estimates from the Polish literature, the prevalence of water contamination with *Legionella* in multi-apartment residential buildings in Poland may reach up to 65%. In Great Britain, it is 15%, while in Finland it is only 8% (Jamiołkowski 2020).

The contamination of water distribution systems may either be local and only involve some fittings (e.g., gasket or shower head) or it may extend to the entire water supply and distribution network, which is more likely in the case discussed here. At central points of large networks, there are often places where bacteria find their ecological niches in which they multiply and from which they are subsequently washed away (States et al. 1985). The metal parts of the pipe components and associated corrosion products can be also an important factor in the survival and growth of *L. pneumophila* in water systems (States et al. 1985, Martin et al. 2020).

When analysing the results of the tests performed, it was found that apart from favourable temperature conditions, there is no other factor that results in the increased occurrence of *Legionella* bacteria in any specific part of the water distribution system. Moreover, Rhoads et al. (2015) assessed temperature as a critical factor for *Legionella* development. Bacteria counts in taps and showers were similar and did not depend on the frequency of their use or the floor on which the sampling point was located.

Legionella bacteria do not pose a threat to users of hot water storage tanks heated by coal-fired boilers, since these tanks can be heated to temperatures of 70°C (Jamiołkowski 2020). Users of the district heating network do not have this opportunity, however, and thus this problem also concerns public buildings.

Proposals for a comprehensive solution to the *Legionella* problem (for both private users and public buildings) should be included in amended regulations concerning the quality of drinking water and water at swimming pools as well as the Construction Law (Główny Inspektorat Sanitarny 2014, Rozporządzenie 2015b).

With aging and increasingly immunocompromised populations, a better understanding of opportunistic pathogens including *Legionella* in household water systems will become more important (Borella et al. 2005, Collinset al. 2017) and the same is true for public buildings.

The results of health risk analysis indicate that the singular results coming from one grab sample can give an incorrect estimation of exposure and the likelihood of Legionellosis.

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