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Microbiological water quality and derived health risks from exposure to ornamental water fountains in the city of Hannover

Autorinnen:

Estefania Carpio Vallejo
Dr. Urda Düker,
Prof. Regina Nogueira
Institut für Siedlungswasserwirtschaft und Abfalltechnik Hannover

Kurzbeschreibung des Einzelkapitels

This study assesses the microbial water quality of four ornamental water fountains (Blätterbrunnen, Körtingbrunnen, Klaus-Bahlsen, and Marstallbrunnen) and performs a quantitative microbial risk assessment (QMRA) using E. coli, Enterococci, and Salmonella non-typhoid to quantify the probability of gastrointestinal illnesses and Pseudomonas aeruginosa to quantify the risk of dermal infections. Samples were collected fortnightly in two campaigns between 2020 and 2021 and processed to determine bacterial concentrations. Data for time of exposure was obtained during field observations on the selected fountains, 499 people were observed from which 30 % were children. Mean concentrations ranged from 1.6×10^1 - 6.1×10^2 MPN/ 100mL for E. coli, 1.2×10^1 - 1.2×10^3 MPN/ 100mL for Enterococci, 8.6×10^3 - 3.1×10^5 CFU/ 100mL for Salmonella non-typhoid, and 2.5×10^3 - 3.2×10^4 MPN/ 100mL for P. aeruginosa. Monte Carlo simulations were performed and compared with the US Environmental Protection Agency (USEPA) illness rate of 36 NGI/ 1000. Results demonstrated that the illness rate was exceeded for Enterococci at the Körtingbrunnen and Klaus-Bahlsen-Brunnen fountains as well as Salmonella non-typhoid and P. aeruginosa at the Körtingbrunnen. The scenario analysis gives an overview of how water quality monitoring could improve microbiological quality minimizing the risks of illness and infections.

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1 Introduction

Besides offering aesthetic properties and recreational opportunities to their surroundings, ornamental fountains play a key role in enhancing human well-being and creating refreshing microclimates thanks to evaporative cooling processes (Seputra, 2018). Different water sources such as groundwater, rainwater, surface or tap water can be used to fill up these water features. Many of the ornamental fountains in the city of Hannover are fed by the public drinking water supply, where water is constantly recirculated through pumps after being sprayed into the air (Freyer and Hanning, personal communication, June 5, 2020). These water features encourage people, especially children, to have direct contact with the water by playing, walking through, and/or touching the water (Man et al., 2014a).

Microbiological pollution of ornamental fountains fed with drinking water can occur through human and animal contact with water, runoff from paved surfaces or growth of microorganisms in water; thus, posing an emerging risk of infection/illness to the individuals exposed to the water through ingestion, inhalation, and dermal contact (Man et al., 2014b).

Fecal indicator bacteria, such as *E. coli* and Enterococci, are commonly used as indicators to identify the potential presence of pathogenic microorganisms which can cause gastroenteritis and other gastrointestinal infections (Modrzewska et al., 2019); also, the presence of Pseudomonas aeruginosa in water can result in skin rashes such as folliculitis when there is dermal exposure. For that reason, maintaining a safe water quality in ornamental fountains, as well as developing a risk analysis has become an important issue to be addressed (Man et al., 2014a). In Germany, there are established guidelines for the planning, construction, and operation of air humidification devices, such as fountains and water walls in public buildings defined by the Verein Deutscher Ingenieure e.V. (VDI 6022); however, there are no specifications on hygienic requirements for fountains and water features in public spaces.

Quantitative Microbial Risk Assessment (QMRA) is one of the tools used to quantify the health risks caused by human exposure to waterborne pathogens (Haas, 2014; Ortells Sales, 2015). A QMRA study requires several sources of data, such as microorganism concentration (e.g MPN/100mL), the exposure rates to which people are subject to (e.g. mL/min), the exposure duration (e.g. min/day), and the dose-response model provided for the microorganism of interest. Due to lack of studies focusing on these water features, there is limited exposure-data information regarding low water-contact recreational activities that take place in ornamental water fountains. Moreover, temporal and spatial variability of water contact and bacterial concentrations are also important factors that make it difficult to relate recreational water exposure with specific health outcomes (Sunger & Haas, 2015). QMRA allows testing different scenarios and obtaining insights regarding measures to be applied to prevent outbreaks of infectious illnesses (Ortells Sales, 2015).

The aims of this study were (i) to determine the presence of potentially pathogenic bacteria in ornamental fountains fed with drinking water, (ii) to perform a QMRA of the selected ornamental fountains for the selected reference bacteria, and (iii) to evaluate and compare the health risk implications for the population exposed to these recreational sites.

2 Results and Discussion

2.1 Field observations

Field observations were held during clear-sky days with temperatures that ranged between 20 and 32 °C, as these water features are visited by many people during warm days. 499 people were observed between the four ornamental fountains from which 30 % were children assumed to be below 16 years old. Moreover, 70 % of the people were observed among the Marstallbrunnen and Körtingbrunnen, both located in busy areas with many restaurants, cafes, and shops. Most of the children at these two fountains were seen having direct water contact; conversely, most adults had either no contact or indirect contact through animals or another person.

At the Blätterbrunnen only few people were observed, they were mainly sitting around the fountain and relaxing, nearly all of them had no water contact. On the other hand, adults who visited the Klaus-Bahlsen-Brunnen had mostly no or indirect water contact, while nearly all the children observed there had direct water contact (Fig. 4a). People observed having direct water contact at the fountains were 151 in total, from which 70 % were children and 30 % adults. From these data, it can be inferred that children are the population under higher risk at the selected fountains, as most of them had direct contact with water at the ornamental fountains (see Fig 4a), which is why the risk of illness/infection due to ingestion and dermal exposure was calculated only for children.

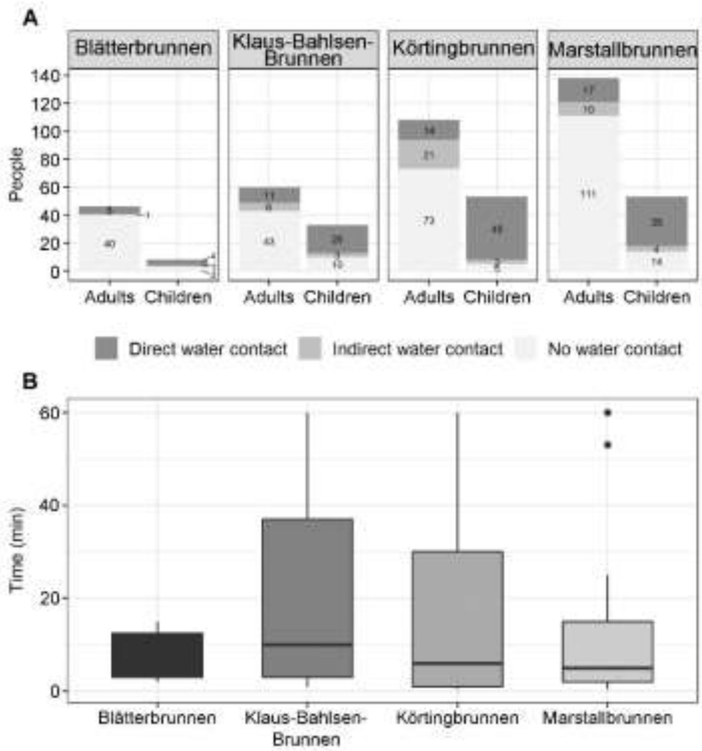

Figure 1: a) Number of people observed per place and type of exposure. b) Boxplot for the time of exposure of people who had direct water contact at each fountain a) Number of people observed per place and type of exposure. People having direct water contact are defined as those who had hand immersion in water, hand to mouth contact after water contact, water droplets falling in face or mouth, and drinking mouthfuls of water. Indirect water contact refers those who had contact with water through another person, animal, or object and no water contact refers as those who were in the surroundings of the

fountain but did not have any observed interaction with water b) Boxplot for the time of exposure of people who had direct water contact at each fountain. Line inside the box represents the median value, box represents the interquartile range (25 – 75 percentiles), black dots outside box represent the outliers, and whiskers show the maximum and minimum values.

The total time of exposure (t) of people who had direct water contact varied depending on the fountain (Fig. 4b). However, the mean time of exposure at each fountain was not significantly different (p-value > 0.05). The data collected from field observations was used to fit a Beta distribution, which was afterwards used as input for the Monte Carlo simulation. The parameters found for each fountain can be found in Table 3.

Fountain	Parameters of the probability distribution	
Blätterbrunnen	$\alpha = 0.35$	$\beta = 0.66$
Klaus-Bahlsen-Brunnen	$\alpha = 0.34$	$\beta = 0.70$
Körtingbrunnen	$\alpha = 0.30$	$\beta = 0.69$
Marstallbrunnen	$\alpha = 0.32$	$\beta = 1.22$

Table 1: Parameters describing the Beta probability distribution of the time of exposure at each fountain

2.2 Hazard identification

To determine the water quality of the ornamental fountains, the studied bacteria were *E. coli*, Enterococci, *Salmonella non-typhoid*, *Vibrio cholerae*, *Listeria monocytogenes*, *Campylobacter spp*. and *P. aeruginosa*. However, concentrations of *Vibrio cholerae*, *Listeria monocytogenes, Campylobacter spp*. were always below the limit of detection (LOD). Bacterial concentrations were highly variable at each location during the monitoring (Table 4). The highest concentrations of the selected bacteria were observed at the Körtingbrunnen and the lowest at Blätterbrunnen, except for *P. aeruginosa*, where the lowest concentrations were found at Klaus-Bahlsen-Brunnen.

Fountain	Parameters	*E. coli*[a]	Enterococci[a]	*Salmonella**[b]	*P. aeruginosa*[a]
Blätterbrunnen	Samples	13	12	13	13
	GM	2.6×10^0	2.6×10^0	4.0×10^2	2.9×10^2
	95 %	7.3×10^1	4.9×10^1	4.2×10^4	1.5×10^4
Klaus-Bahlsen-Brunnen	Samples	9	9	11	8
	GM	2.2×10^2	4.1×10^2	1.2×10^4	7.3×10^2
	95 %	1.8×10^3	2.2×10^3	1.2×10^5	6.9×10^3
Körtingbrunnen	Samples	9	9	10	9
	GM	1.9×10^2	2.7×10^2	5.6×10^4	5.1×10^2
	95 %	1.8 x103	3.8×10^3	1.3×10^6	1.5×10^5
Marstallbrunnen	samples	9	9	10	9
	GM	1.4×10^2	1.2×10^2	7.3×10^3	2.4×10^2
	95 %	7.8×10^2	1.5×10^3	9.5×10^4	2.5×10^4

a: MPN/ 100 mL, b: CFU/ 100 mL, *non-thypoid, MPN: Most Probable Number. CFU: Colony Forming Units

Table 2: Geometric mean (GM) and 95th-percentile (95 %) of bacteria concentration in water from the ornamental fountains

The USEPA recommends in their RWQC 2012 that the geometric mean of a water body should not exceed 3.5×10^1 CFU/ 100 mL for Enterococci and 12.6×10^1 CFU/ 100 mL for

E. coli in any 30-day interval, these concentrations correspond to an estimated illness rate of 36 NGI per 1000 primary contact recreators. Based on these criteria, the Blätterbrunnen was the only fountain for which *E. coli* and Enterococci concentrations were below these thresholds (Table 4). This could be explained by the retention basin that the Blätterbrunnen has, which can work as a barrier for dogs, mice, and other animals as well as a protection from surface runoff, which can introduce bacteria to the water; conversely, the other fountains are open and offer free access for vectors and surface runoff that might bring microbial pollution to the water.

At the Körtingbrunnen and Marstallbrunnen, many people walk through the fountains with dogs and several birds were seen during field observations (cats and rats cannot be excluded during the night). Both fountains have similar construction and even though the Marstallbrunnen has an automatic chlorine disinfection system, a high faecal contamination regarding *E. coli* was observed in both fountains (Table3I). Our results are consistent with those found by Man et al. (2014b) where 30 % of the studied water features fed with tap water exceeded the standards for fecal indicators in recreational waters according to the USEPA RWQC 2012.

In this study, concentrations of *Salmonella non-typhoid* were much higher than those found by Goh et al. (2015) at the Marina reservoir, which is used as fresh water recreational site and potable water source. Also, Ahmed et al. (2010) found a concentration range of *Salmonella spp*. of 6.5×10^1 to 3.8×10^2 per 1000 mL in roof-harvested rainwater, in our study, this range was exceeded in three of the four water fountains, except at the Blätterbrunnen. This could be explained by the bacterial pollution brought through birds (observed during field observations), as well as the bacterial load collected when water washes down the surrounding surface of the fountains and is continuously recirculated (Table 4).

For *P. aeruginosa*, critical concentrations and outbreaks data related to this bacterium in recreational sites are lacking in the literature (Rasheduzzaman et al., 2019; Roser et al., 2015). From the review made by Roser et al. (2015), 1×10^6 CFU/ 100 mL is considered the minimum concentration to constitute a hazard for skin infections, which is much higher than the concentration we found in the studied water fountains (Table 4). Moreover, the concentrations obtained in our study, were consistent with the results reported in the study from Akturk et al. (2012), who also found *P. aeruginosa* in different sections of a drinking water pipeline, confirming that the presence of these bacteria in drinking water can have its origin in biofilm formed in pipelines.

E. coli and Enterococci have been used as microbial indicators of fecal pollution both in marine and freshwater systems (Jang & Liang, 2018); nonetheless, a study carried out in German drinking water networks showed that most of the Enterococci species found in drinking water systems were not assigned to the intestinal strains, suggesting that it could be introduced to the water by invertebrates (Technologiezentrum Wasser, 2019). As mentioned before, three of the four studied fountains have open access, allowing not only people to have contact with the water but also domestic animals, birds and other vectors which can bring fecal pollution to the water; thus, to confirm the origin of these bacterial pollution, microbial source tracking, which allows discrimination between human and nonhuman fecal sources, should be performed in the future.

2.3 Exposure assessment

When performing a QMRA, it is important to consider the microorganisms' distribution in the water. Bacteria are discrete variables which concentration can vary on each event; therefore, bacterial statistics should be characterized to acknowledge the risks differences from diverse concentration exposures (Haas et al., 2014).

The bacterial concentration results obtained from the lab analysis were used to identify the probability distribution that was a best fit to each bacterial concentration. The distribution that returned the highest Loglikelihood and the lowest AIC value provided the best fit. As a result, the concentration of *E. coli* in three of the fountains was described by a Gamma probability distribution. However, in the case of the Blätterbrunnen, the concentration was described by a log-normal probability distribution. Regarding Enterococci, the concentrations fitted a Weibull distribution for the Blätterbrunnen, Klaus-Bahlsen-Brunnen and Marstallbrunnen, while for the Körtingbrunnen a Gamma distribution was the best fit. *Salmonella non-typhoid* concentrations fitted a Gamma distribution for all the fountains, and, except for the Blätterbrunnen, the α-parameter was similar between the other locations, whereas the ß-parameter shows variation between the four fountains. Furthermore, the probability distribution for *P. aeruginosa* concentrations at the Blätterbrunnen and the Klaus-Bahlsen-Brunnen followed a Gamma distribution, while for the Körtingbrunnen and Marstallbrunnen a Weibull-distribution showed the best fit (Table 5).

Fountain	Parameters	*E. coli*	Enterococci	*Salmonella**	*P. aeruginosa*
Blätter-brunnen	Samples	13	12	13	13
	probability distribution	Log-normal	Weibull	Gamma	Gamma
	parameters	μ = -3.65 σ = 1.75	k = 0.55 λ = 0.06	α = 0.23 β = 0.002	α = 0.28 β = 0.008
Klaus-Bahlsen-Brunnen	Samples	9	9	11	8
	probability distribution	Gamma	Weibull	Gamma	Gamma
	parameters	α = 0.62 β = 0.10	k = 0.84 λ = 8.15	α = 0.50 β = 0.02	α= 0.50 β= 0.02
Körting-brunnen	Samples	9	9	10	9
	probability distribution	Gamma	Gamma	Gamma	Weibull
	parameters	α = 0.53 β = 0.08	α = 0.56 β = 7.71	α = 0.53 β = 0.08	k = 0.28 λ = 44.58
Marstall-brunnen	samples	9	9	10	9
	probability distribution	Gamma	Weibull	Gamma	Weibull
	parameters	α = 0.68 β = 0.21	k = 0.63 λ = 3.03	α = 0.54 β = 0.002	k = 0.34 λ = 13.12

**non-thypoid*

Table 3: Best fit probability distributions and parameters used for bacterial concentration

2.4 Risk assessment

A point estimate calculation of the risk of illness/infection is a widely used approach in QMRA; however, in our study a probabilistic approach was applied because it allows to consider the variability and the uncertainty within each input parameter. Thus, as input for the dose-response model, the probability distributions of bacterial concentration, exposure rates and time of exposure were used.

To analyze the risk of GI illness due to ingestion of *E. coli*, Enterococci, *Salmonella non-typhoid*, as well as dermal infection due to *P. aeruginosa*, Monte Carlo simulations were ran considering the respective dose-response model of each bacterium and the results are displayed in box-and-whisker plots (Fig. 5). Considering that recreational activities do not take place every day of the year, the risk of illness and infection is measured in units per day, eliminating the dependency on the days and assuming that a person is exposed to one recreational event per day (Haas et al., 2014). For the risk assessment in this study, it was assumed that no bacterial decay happened during water transport and exposure.

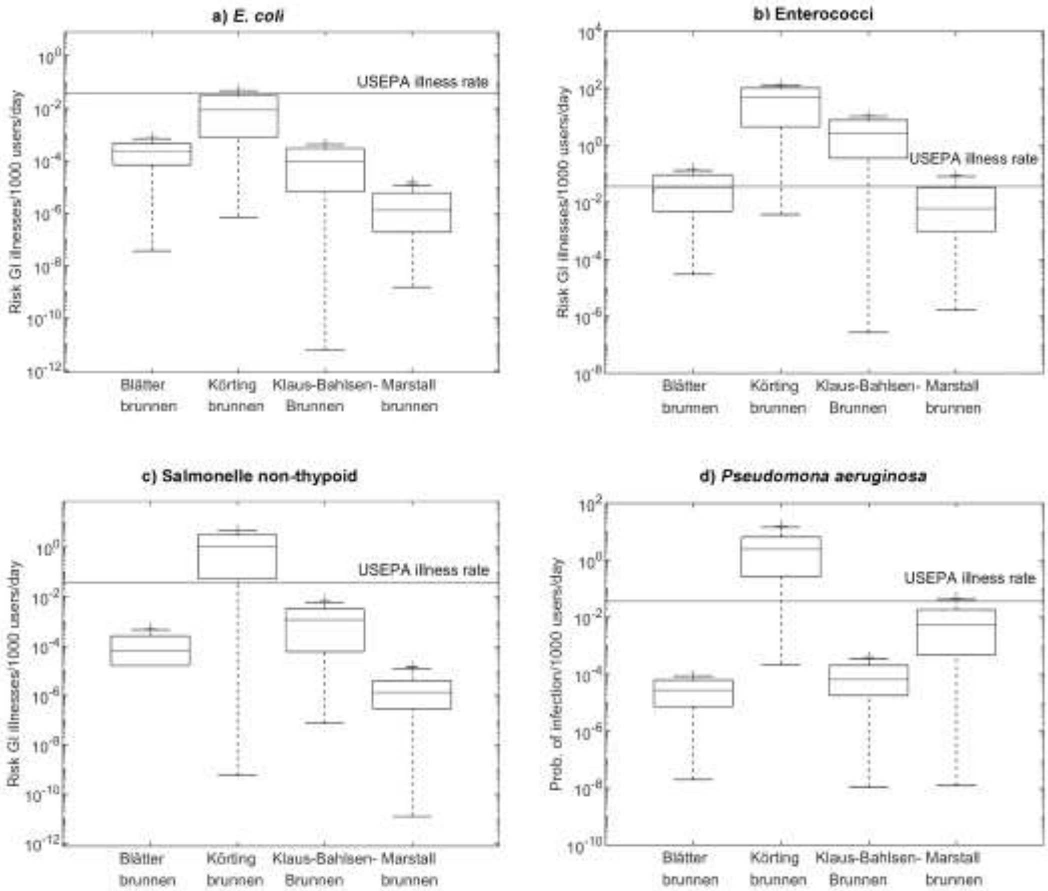

Figure 2: Risk of illness/infection per 1000 users per day at each ornamental water fountain due to exposure to a) E. coli, b) Enterococci, c) Salmonella non-typhoid and d) P. aeruginosa obtained from the Monte Carlo simulations. Horizontal line represents USEPA mean illness rate of 36/ 1000 users. Line inside the boxes represents the median value, box represents the interquartile range (25 – 75 percentiles), crosses outside box represent the outliers, and whiskers show the maximum and minimum values.

The results show that the risk of GI illness due to *E. coli* are below the USEPA mean illness rate at all the studied fountains (Fig. 5a). On the contrary, the risk of GI illness due to Enterococci (Fig. 5b) at the Körtingbrunnen, Klaus-Bahlsen-Brunnen and Blätterbrunnen fountains is above the USEPA benchmark. And at the Marstallbrunnen, the simulated values above the 75th percentile also exceed the USEPA mean illness rate. Soller et al. (2014), in their QMRA study assessed human health risks derived from exposure to multiple sources of fecal indicator bacteria and concluded that recreational waters affected by *E. coli* and Enterococci from non-human sources have reduced risks to human health compared to recreational waters that are impaired by human sewage sources. However, it should be kept in mind that this study considers a “worst case scenario” and assumes that all *E. coli* and Enterococci found in the samples are pathogenic as mentioned before.

The risk of GI illness due to *Salmonella non-typhoid* and the risk of infection for *P. aeruginosa* are below the benchmark for three of the four fountains; however, both risks exceeded the benchmark at the Körtingbrunnen fountain. This could be explained by a higher exposure time and volumes at this fountain, due to observed ingestion of mouthfuls of water, and higher bacterial concentrations found during lab analysis. Goh et al. (2015) also performed a QMRA for *Salmonella spp.* and Enterococcus in a freshwater reservoir and its feeders in Singapore used for recreational purposes and concluded that the illness risk derived from *Salmonella* was under the acceptable benchmark, which coincides with the results of three of the ornamental fountains in the present study; however, high concentrations of these bacteria and high ingestion rates might be of concern for the public health at the Körtingbrunnen. Bollaerts et al. (2008) modeled dose-illness relationships with data from *Salmonella* outbreaks considering normal and susceptible subpopulations. They concluded that the normal population showed immunity to these bacteria, however, susceptible population, which includes new-borns, young children, pregnant woman, elderly, and immunocompromised persons, showed a higher probability of getting ill at low dose levels. This should be bear in mind as the present study did not consider difference in host susceptibility (Bollaerts et al., 2008).

As with *Salmonella non-typhoid*, we could observe a similar trend of *P. aeruginosa* showing the highest risk of infection due to dermal exposure at the Körtingbrunnen, which could be explained by higher concentrations of this bacterium found here compared to the other fountains as well as the distribution of the time of exposure.

Our results are comparable to those of Roser et al. (2015), who reported that concentrations of 104 CFU/ mL of *P. aeruginosa* could cause an outbreak to a very low extent and a minimum geometric mean of 1.8×10^7 CFU/ mL is needed for all the exposed population to get folliculitis. Concentrations of *P. aeruginosa* found during our monitoring study ranged between 1×10^{-3} and 2.4×10^3 CFU/ mL, which could represent a risk of infection for susceptible population at the Körtingbrunenn due to higher concentrations, as shown in Fig 5d. Nevertheless, a risk of infection does not necessarily mean development of an illness. Moreover, as reported by Vukić Lušić et al. (2021), the ubiquity of this bacterium does not represent a great concern for the general public.

2.5 Scenario analysis for different bacterial concentrations

The scenario analysis aimed to show how the microbiological water quality can influence the final risk of illness/infection during a recreational event. Given the wide possible range of bacterial concentrations that can be present in water, a scenario analysis was performed with different concentrations which ranged between 1×10^1 to 1×10^4 MPN/ 100 mL, including the criteria established by the USEPA for *E. coli*, 12.6×10^1 CFU/ 100 mL, and Enterococci, 3.5×10^1 CFU/ 100mL (USEPA, 2012).

In the scenario analysis we compared exposure at the Körtingbrunnen and the Blätterbrunnen, as the first one had larger exposure time and volumes due to ingestion of mouthfuls of water. Moreover, we considered the risk of GI illness and dermal infection as a function of the time of exposure (Fig. 6).

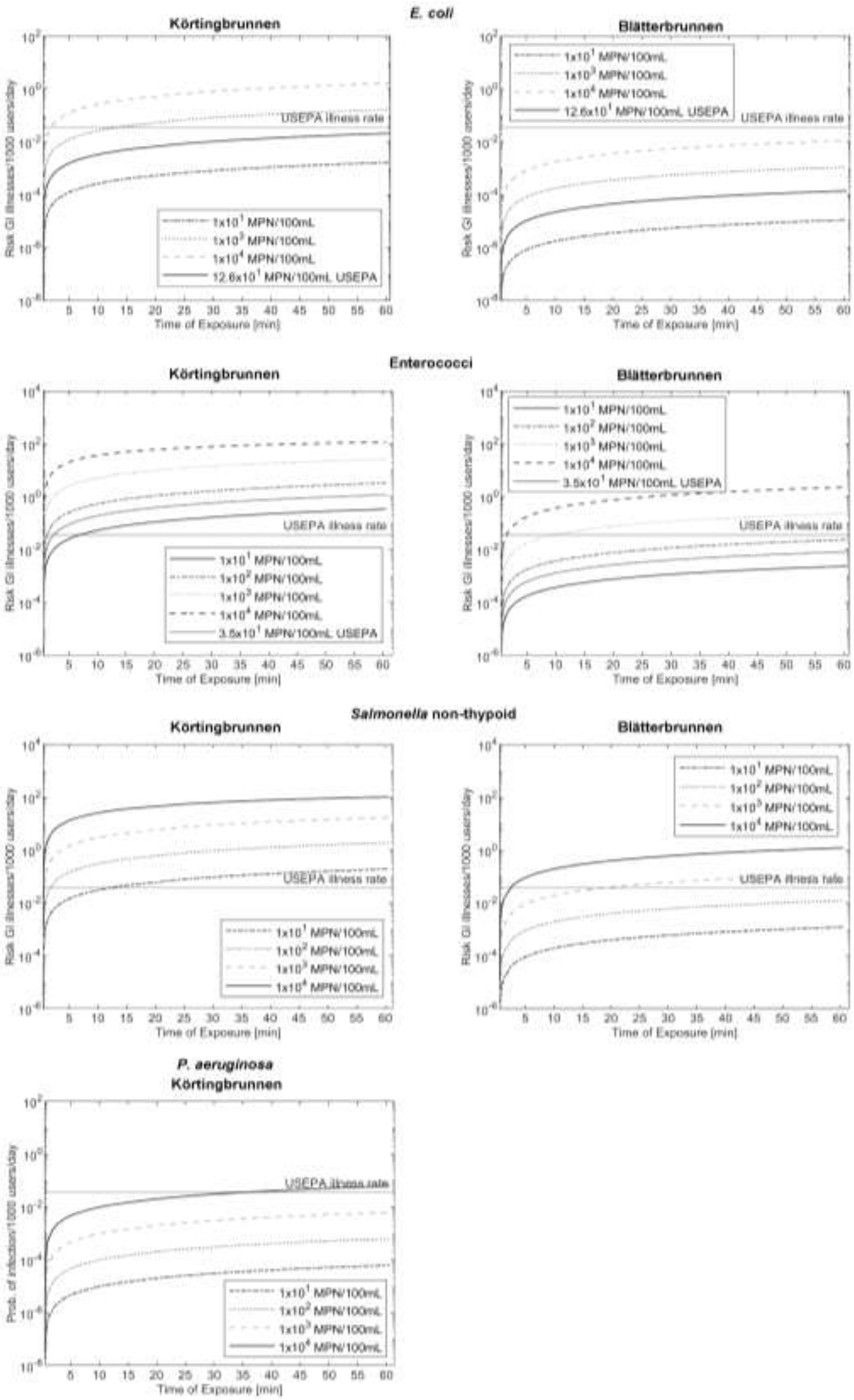

Figure 3: Scenario analysis for E. coli, Enterococci, Salmonella non-typhoid and P. aeruginosa at Körtingbrunnen and Blätterbrunnen.

Concentrations of *E. coli* at the Körtingbrunnen could be as high as the USEPA recommendation value of 12.6 x 10^1 CFU/ 100 mL for exposures up to one hour without exceeding the USEPA benchmark (Fig. 6 *E. coli* a). However, exposures above 10 min of duration to concentrations higher than 1 x 10^3 CFU/ 100 mL could entail a risk of illness above the USEPA benchmark of 36/ 1000 at this fountain. For the Blätterbrunnen, *E. coli* concentrations up to 1 x 10^4 CFU/ 100 mL during 60 min of exposure would not exceed the USEPA benchmark. This could be explained by the distribution of the time of exposure and higher ingestion rates at the Körtingbrunnen.

Concentrations of Enterococci at the Körtingbrunnen could be 1 x 10^1 CFU/ 100 mL for exposures up to 10 min without exceeding the mean illness benchmark, higher concentrations of this bacterium could involve adverse health outcomes to the exposed population. Conversely, at the Blätterbrunnen fountain, a concentration of up to 1 x 10^2 CFU/ 100 mL for exposures periods up to 60 min would not exceed the benchmark. These results are consistent with the values suggested by Wiedenmann et al. (2006) as reasonable estimates for no-observed-adverse-effect-levels which are 100 CFU/ 100 mL and 25 CFU/ 100 mL for *E. coli* and Enterococci, respectively. Nevertheless, they considered bathing exposures during a 10 min period with at least three head immersions in fresh recreational waters, which represent greater exposure volumes than those considered in our study as well as a different water source.

Regarding *Salmonella non-typhoid* a concentration of 1 x 10^1 CFU/100 mL for an exposure period up to 10 min can take place at the Körtingbrunnen without exceeding the USEPA benchmark; however, for longer exposure periods a concentration of 1 x 10^1 CFU/ 100 mL or below should be maintained to ensure lower risk of illness. At the Blätterbrunnen, concentrations of up to 1 x 10^2 CFU/ 100 mL and exposure periods up to 60 min would not exceed the USEPA mean illness rate. Again, this difference could be explained by ingestion of mouthfuls of water happening at the Körtingbrunnen as well as the distribution of the time of exposure. McBride et al. (2013) performed a QMRA from exposure to stormwater pathogens in recreational waters and despite of having different water sources, the concentrations obtained for *Salmonella non-typhoid* are similar with our study. We found that concentrations above 1 x 10^3 CFU/ 100 mL after 15 min exposure could represent high risk of infection, whereas they suggest that the incidence of probability of illness due to exposure to this bacterium was low in their studied locations.

Only one scenario analysis was performed for *P. aeruginosa* as the dermal exposure route was the same for all the studied fountains. This scenario analysis shows that even high concentrations of 1 x 10^4 MPN/ 100 mL within a period of 30 min exposure would not exceed the USEPA benchmark regarding the risk of getting a skin infection. This is in line with previous studies which concluded that the ubiquity of this bacterium in aquatic environments makes it of no great concern for the general public at these locations (Hardalo & Edberg, 1997; Vukić Lušić et al., 2021)

2.6 Sensitivity analysis

To estimate the human health risks related to recreational exposure, QMRA employs several parameters as input for the dose-response model, which are subject to uncertainty. Thus, a sensitivity analysis is performed to investigate how the final risk of infection is influenced when the parameters vary within their uncertainty range and which parameters have the greatest effect on the variance of the final risk outcome (Eregno et al., 2016).

The assessed parameters were film thickness of water on hands (h), surface area of the hand that is mouthed (A), frequency of hand to mouth contact (fHM), volume of a water droplet (VD), frequency of ingesting water droplets (fD), volume of a mouthful of water (VM), frequency of taking a mouthful of water (fM), time of exposure (t), and bacterial concentration (C). The parameters α, β, N50 and k of each dose-response model are point estimates obtained from the literature, and they were not considered in the sensitivity analysis as they may vary from individual to individual (Perez-Rodriguez, 2021). For the sensitivity analysis (Fig. 7), only the dose-response for Enterococci at the Körtingbrunnen and Klaus-Bahlsen-Brunnen were considered as these were the bacterium and fountains which showed the highest risk of GI illness.

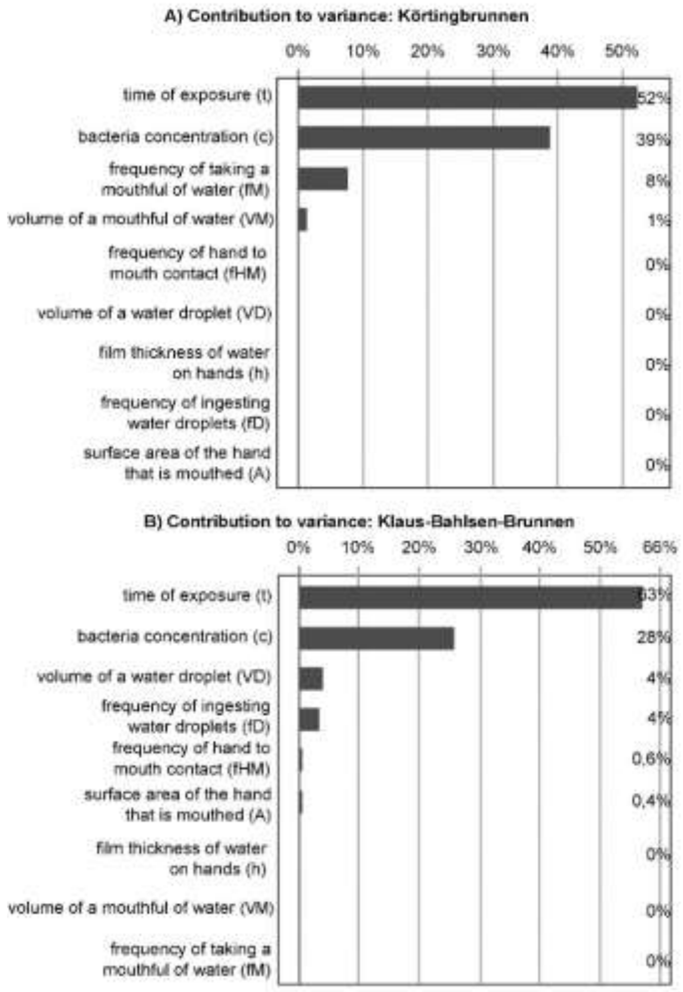

Figure 4: Sensitivity analysis expressed as contributions to variance of the final risk of infection due to Enterococci at a) Körtingbrunnen and b) Klaus-Bahlsen-Brunnen.

From the sensitivity analysis (Fig. 7), the parameter that has the greatest contribution on the variance of final risk of infection is the time of exposure (t), followed by the bacterial concentration (C). On the other hand, the parameters that have the lowest contribution on the variance of the final risk of infection were surface area of the hand that was mouthed (A) and the film thickness of water on hands (h). The studies performed by Wolfgang (2012) and Eregno et al. (2016), also reported that pathogen concentration defines the final exposure dose, and thus, dominates the final risk outcome of a person during a recreational event.

3 Conclusion

This study is the first QMRA performed for ornamental fountains fed with drinking water in Hannover city. While ornamental fountains are an excellent option to deal with the negative effects of global warming by providing refreshing environments within cities, the results of our study confirm the presence of potentially pathogenic bacteria in ornamental water fountains used for recreational purposes and fed with drinking water.

Although, the health outcome for most of the studied fountains did not exceed the USEPA mean illness rate, this dramatically changes when the microbiological water quality is deteriorated. Further microbial source tracking is needed to clarify the source of pollution. Preventative measures, such as warning signs discouraging people from drinking the water of ornamental fountains, can help reduce exposure volumes and thus, adverse health effects to the exposed population.

The high concentrations of *P. aeruginosa* found in the fountains suggests occurrence of water stagnation either in the fountain structures or in the water supply network, water aeration devices could be implemented to improve this aspect and lower the concentrations of these bacteria.

There are currently no water quality criteria established for water features in public places. Our study emphasizes the importance of such guidelines to be put in place to minimize health risks associated with exposure to ornamental fountains. The scenario analysis presented here can help with the development of water quality standards to be applied in these water features to protect public health. Thus, the scientific results presented in this paper can be of benefit for policy makers when launching new water quality standards and for implementation and operation guidelines of new urban recreational areas.

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