Modelling exposure to *Legionella* spp. with experimental measured aerosol data

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Introduction

Current quantitative microbial risk assessment (QMRA) frameworks applied simple volumetric estimation or partitioning coefficient approaches for exposure assessment (Blanky et al., 2017)(Hamilton et al., 2019)(Sharaby et al., 2019)(Weir et al., 2020)

$$Dose = \sum_{i=1}^{10} C_{aer,i} \cdot V_{aer,i} \cdot C_{leg} \cdot Br \cdot t$$

$$Dose = P \cdot C_{leg} \cdot Br \cdot t$$

$C_{aer,i}$—Concentration of aerosol of size i (#/m3) $V_{aer,i}$—Volume of aerosol of size i (L)
C_{leg}—Concentration of *Legionella* spp. (CFU/L) Br—Inhalation rate (m^3/min) P—Partitioning coefficient (CFU/L^{-1}/CFU m^{-3}) t—Exposure duration (min)

Limitations

- Limited aerosol data for shower
- Constant aerosol size distribution over time
- Unknown environmental conditions

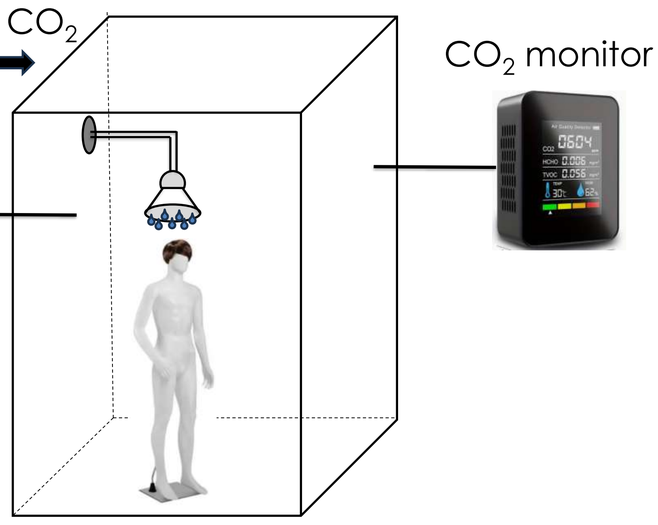
Objective

- Dynamic aerosol size distribution data
- Size-resolved aerosol emission rate
- Inform intervention strategies

Methods

1. Measurement of aerosol size distribution

Aerodynamic particle sizer



Sampling time: 5 min background, 10 min shower and 5 min after shower

2. Model development and calibration

Aerosol concentration

$$V \cdot \frac{dC_i}{dt} = G - (\lambda_{ventilation} + \lambda_{deposition} + \lambda_{other}) \cdot C_i$$

Exposure dose estimation

$$Dose = \sum_{i=1}^{10} \int_0^t C_{leg} \cdot C_i \cdot V_i \cdot Br \cdot DE_i \cdot F_i \cdot dt$$

C_{leg}—Concentration of *Legionella* spp. (CFU/L)
C_i—Concentration of aerosol of size i (#/m^3)
V_i—Volume of aerosol of size i (L)
Br—Inhalation rate (m^3/min)
DE_i—Deposition efficiency of aerosol of size i
F_i—Fraction of *Legionella* spp. partitioning into aerosol of size I
G—Aerosol generation rate (#/min)
$\lambda_{ventilation}$—Ventilation rate (1/min)
$\lambda_{deposition}$—Deposition rate (1/min)
λ_{other}—Aerosol removal rate through evaporation, condensation, coagulation and other process (1/min)

Risk assessment

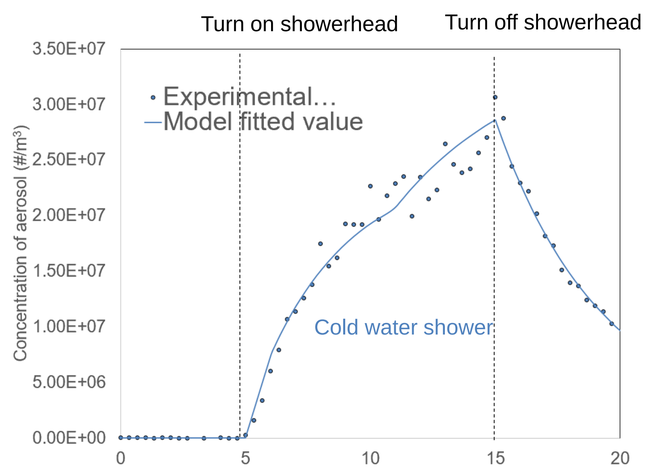
$$P_{inf,daily} = 1 - e^{-r \cdot dose}$$

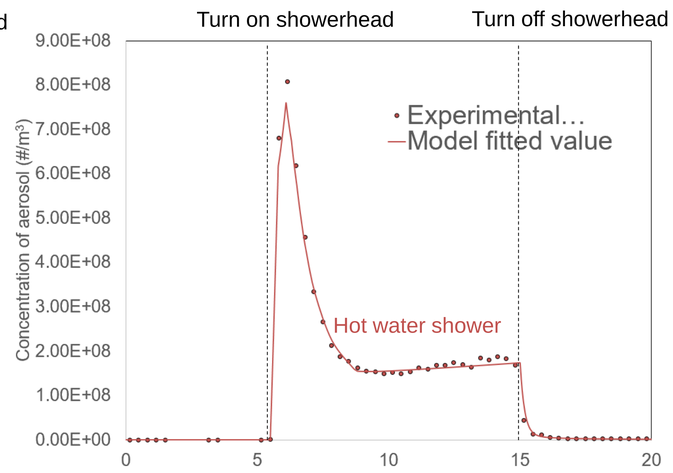
$$P_{inf,annual} = 1 - \prod_1^n (1 - p_{inf,daily})$$

$P_{inf,daily}$—Daily risk of infection
$P_{inf,annual}$—Annual risk of infection
n—Exposure frequency
r—Dose-response model parameter for *Legionella* spp.

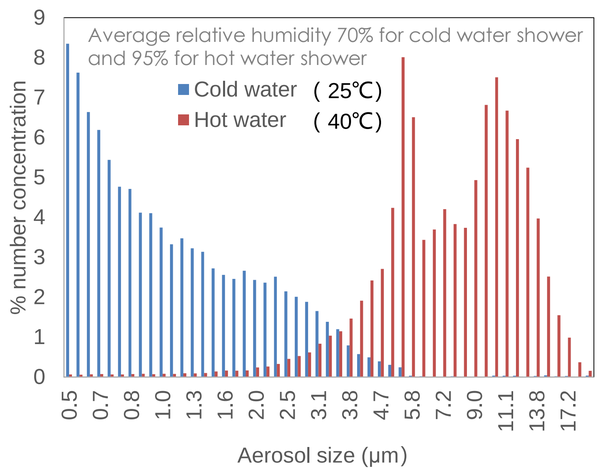
Results

Concentration of aerosol over time (1~10 μm)

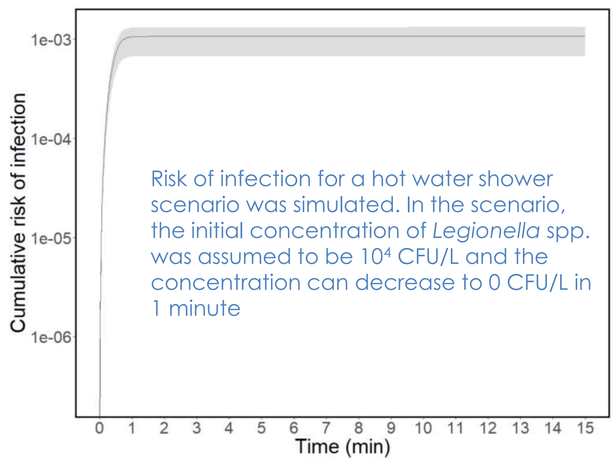




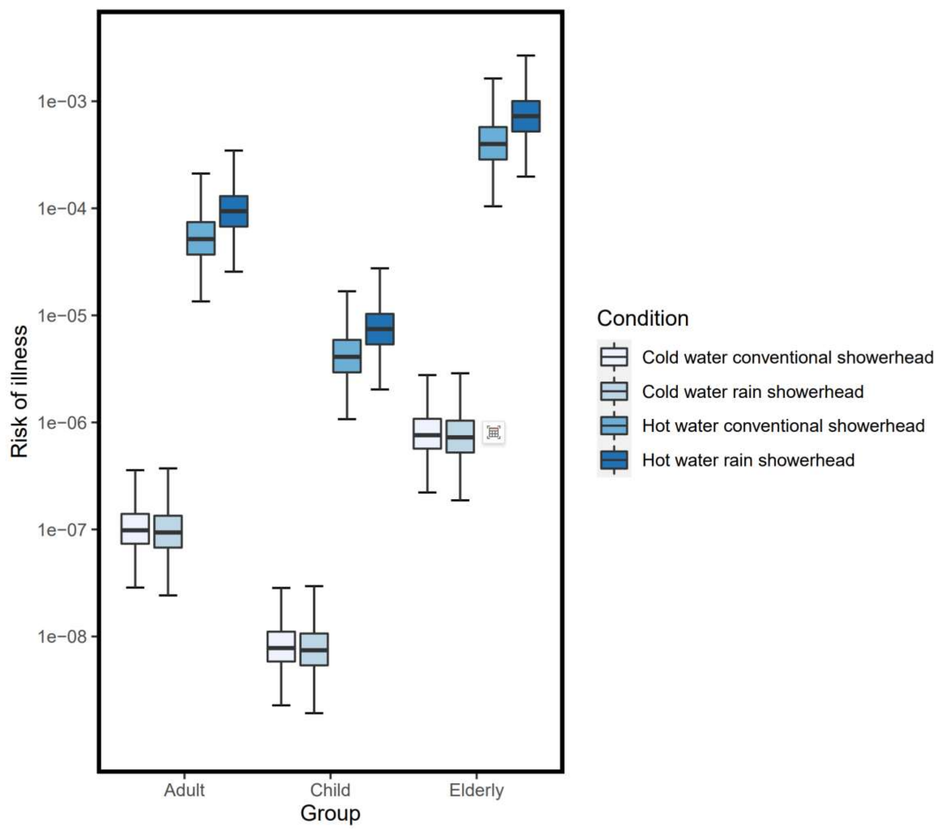
Aerosol size distribution when t=10 min



Cumulative annual risk of infection



Annual risk of illness for different groups of people considering different morbidity ratios



Conclusion

- Count median size of aerosols for hot shower is 6 μm for hot shower and 1 μm for cold shower
- Risk is higher when taking hot water shower compared to cold water shower (3 orders of magnitude)
- Combined with concentration profile of bacteria during flushing , high risk can be reached within the first 1~2 minutes due to peak concentrations of both aerosols and bacteria in this period