Determination of *Enterovirus*, *Giardia* and *Cryptosporidium* Limits in Reclaimed Domestic Wastewater for Unrestricted Urban Reuse

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INTRODUCTION

Strategies to minimize public health risks associated with the reuse of treated municipal wastewater have been a challenge for authorities in developing countries. In metropolitan regions, like Sao Paulo city, where there is a high demand for water and water resources are each day more scarce, the urban reuse of wastewater is already a reality. Street washing is one of the most common urban reuse in the city of Sao Paulo; however there is no Brazilian regulation establishing quality standards for this use.

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OBJECTIVES

Our purpose was to develop an approach to determine maximum concentration limits for *Enterovirus*, *Giardia* and *Cryptosporidium* in treated wastewater, based on tolerable infection risks for workers involved in the street washing activity.

METHODOLOGY

The approach used for risk assessment is described in Table 1. The determination of pathogen concentrations limits were calculated considering different scenarios of tolerable annual risk (T_a). For a given T_a, the corresponding tolerable daily risk (T_d) and concentration (C) were computed by simple inversion of equations presented in Table 1, substituting P_a by T_a and P_d by T_d: $T_d = 1 - (1 - T_a)^{1/WD}$, Dose = $P^{-1}(T_d)$ and C = Dose / (D x F x T x A x IF x R). Monte Carlo simulations resulted in a collection $C_1, C_2 \ldots C_K$ of concentrations, each one yielding a different risk distribution. In order to choose the most suitable of these concentrations, besides the parameter T_a, we also took into account the desired confidence level (q) such that $P_a^q(C) < T_a$. Given the pair (T_a, q), which we denoted by T_a^q, the upper limit for the q-quantile concentration, denoted by C^q, was the maximum value of C among $C_1, C_2 \ldots C_K$ such that $P_a^q(C) < T_a$. For example, if $T_a^{0.5} = 1\text{x}10^{-4}$ (meaning that the median tolerable risk 1 x 10^{-4}), the upper limit for the median concentration should be $C^{0.5} = \max_C \mid P_a^{0.5}(C) < 1 \times 10^{-4}$. For each scenario, we defined $T_a^{0.5}$ and $T_a^{0.95}$ in order to compute the upper bounds for 0.5 and 0.95-quantiles of pathogen concentrations in treated wastewater ($C^{0.5}$ and $C^{0.95}$). Three scenarios were considered, in descending order of conservativeness:

(1) $T_a^{0.5} = 1 \times 10^{-4}$ / $T_a^{0.95} = 5 \times 10^{-4}$;
(2) $T_a^{0.5} = 1 \times 10^{-4}$ / $T_a^{0.95} = 1 \times 10^{-3}$;
(3) $T_a^{0.5} = 5 \times 10^{-4}$ / $T_a^{0.95} = 5 \times 10^{-3}$.

RESULTS

Table 1 - Procedure for calculating risk of infection.

Description	Notation	Value	Obs / Reference
Worker exposure parameters			
Human respiration intake (m^3/h)	R	0.830	(2)
Daily exposure time (hours/day)	T	2	-
Work days per year	WD	242	11 months, 22days/month
Plume model parameters			
Water flow rate (15m^3/h)	F	15±3	Normal distribution[a]
Efficiency of aerossolization	A	0.001, 0.003, 0.018	Triangular distribution[b] (1)
Impaction factor	IF	0.8, 1.0, 1.2	Triangular distribution (3)
Distance worker and water flow (m)	d	4.0, 5.0, 6.0	Triangular distribution
Distance worker and spray plume centerline in cross-wind direction (m)	y	0,0	(2)
Worker's height (mouth/nose) (m)	z	1.6	
Height of plume formation (m)	H	0.4, 0.5, 0.8	Triangular distribution
Wind velocity (m/s)	u	2.0, 3.0, 4.0	Triangular distribution (2)
Dispersion	D		Gaussian plume model (2)
standard deviation in y-axis	s_y	1.437	s_y: a x^b , a=0.36, b=0.86
standard deviation in z-axis	s_z	0.878	s_z: c x^d , c=0.22, d=0.86
Dose-response parameters			
Enterovirus - Beta-Poisson[c]			
Alpha	alpha	1,06	(4)
N_{50}	N_{50}	921,94	
Giardia - Exponential Model	r	0.01982	(5)
Cryptosporidium - Exponential Model	r	0.00467	(6)
Daily risk of infection	(P_d)		
Dose	CxDxFxTxAxIFxR		C= PFU/L or (oo)cysts/L
Exponential Model	$P(d) = 1 - \exp(-r \times \text{Dose})$		
Beta-Poisson Model	$P(d) = 1 - [1+\text{Dose}((2^{(1/\alpha)} - 1))/N_{50}]^{-\alpha}$		
Annual risk of infection (P_a)	$P_a(C) = 1 - [1-P_d(C)]^{WD}$		K=100,000 Monte Carlo simulations
Quantile estimation of $P_a(C)$	$P_a^q(C)$		

[a]Normal distribution notation: Normal(mean, std dev) ; [b] Triangular distribution notation: min, mode, max; [c] *Echovirus parameters* ;(1) Camann (1980); (2) Hoglund et al (2002); (3) Petterson&Ashbolt (2005); (4) Haas et al (1999); (5) Rose et al (1991) ; (6) Haas et al (1996).

Table 2 - Limits of pathogens concentration according to the three tolerable risks scenarios considering 50% and 95% percentiles

Pathogens	Limits for pathogen concentrations ($C^{0.5}$ / $C^{0.95}$)		
	A	B	C
***Enterovirus* (PFU/L)**	0.375 / 0.750	0.375 / 1.501	1.877 / 7.520
***Giardia* (cysts/L)**	0.020 / 0.040	0.020 / 0.080	0.101 / 0.403
***Cryptosporidium* (oocysts/L)**	0.085 / 0.171	0.085 / 0.341	0.427 / 1.709

A = $T_a^{0.5} = 1\text{x}10^{-4}$ / $T_a^{0.95} = 5\text{x}10^{-4}$; B = $T_a^{0.5} = 1\text{x}10^{-4}$ / $T_a^{0.95} = 1\text{x}10^{-3}$, C = $T_a^{0.5} = 5\text{x}10^{-4}$ / $T_a^{0.95} = 5\text{x}10^{-3}$

CONCLUSIONS

These data should be considered preliminary, since some issues regarding model assumptions, particularly the Gaussian plume model, must be further addressed. Nonetheless, the proposed approach tried to offer intuitive quality standards to comply with risk criteria, considering the uncertainties involved in this process. This study aimed to be a contribution to the urgent need of setting minimum standard for quality of treated wastewater to protect workers' health as well passers-by and neighborhoods during the street washing process.

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