Microbial Risk Analysis 4 (2016) 1–6

Contents lists available at ScienceDirect

Microbial Risk Analysis

journal homepage: www.elsevier.com/locate/mran

Giardia and *Cryptosporidium* infection risk by simultaneous exposure to drinking water

Maria Tereza Pepe Razzolini[a,*], Marcelo de Souza Lauretto[b], Elayse Maria Hachich[c], Maria Inês Zanoli Sato[c], Adelaide Cássia Nardocci[a]

[a] *Faculdade de Saude Publica, Universidade de Sao Paulo, Av. Dr Arnaldo 715 1o andar, São Paulo, SP 01246-904, Brazil*
[b] *EACH – Escola de Artes, Ciências e Humanidades, Universidade de Sao Paulo, R. Arlindo Bettio, 1000, São Paulo, SP 03828-000, Brazil*
[c] *CETESB – Companhia Ambiental do Estado de Sao Paulo, Av. Prof. Frederico Hermann Jr, 345, São Paulo, SP 05459-900, Brazil*

ARTICLE INFO

Article history:
Received 4 September 2015
Revised 12 January 2016
Accepted 23 January 2016
Available online 17 February 2016

Keywords:
Drinking water
Cryptosporidium
Giardia
Risk

ABSTRACT

The fecal contamination of water sources represents a health risk for the population consuming drinking water from Water Treatment Plants (WTP) supplied by these sources. *Giardia* and *Cryptosporidium* protozoa pose major risks because they are excreted at high densities, survive for long periods in the environment and can remain infectious. Considering the relevance of both parasites in waterborne outbreaks, the objective of this study was to assess the probability of infection by both parasites in a population supplied by drinking water contaminated with *Giardia* cysts and *Cryptosporidium* oocysts using the Quantitative Microbial Risk Assessment (QMRA) approach. The model of dose-response used for estimating the risk for children and adults was the same but with a lower ingestion rate of water for children. Results showed that the annual risks of infection for adults and children exposed by direct consumption of drinking water and indirect consumption during bathing were higher than the tolerable annual risk of 1/10,000 issued by the US EPA. The risk of infection by *Giardia* was the major determinant for the combined risk. The results obtained in this study showed DALY values ranging from 5.2×10^{-6} to 6.5×10^{-6} ppy, elevated levels according to WHO recommendations. The QMRA approach is strategic for determining the acceptable level of treatment by WTPs and information on the efficiency of sanitary barriers.

Introduction

The fecal contamination of surface water and groundwater sources represents a health risk for the population consuming treated water from these supplies. Despite technological advances in the elimination of waterborne pathogens, protozoa occurrence in source waters remains a challenge for environmental surveillance and water treatment companies. This global problem has a heavier impact on low-income countries, where a lack of sanitary infrastructure coupled with an expansion in peri-urban areas persist (Regional Office for Latin America and the Caribbean, 2010). According to the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística – IBGE), approximately 38% of Brazilian cities collect and treat their sewage (IBGE, 2010). Thus, raw sewage from the majority of cities runs “*in natura*” directly into water bodies, contaminating water sources and exposing the supplied population to fecally transmitted waterborne pathogens.

These waterborne pathogens, which pose major risks, are excreted at high densities in the feces of infected humans and animal, survive for long periods in the environment where they remain infectious (Smith 1998; Rosen 2000). The pathogenic protozoa *Giardia* and *Cryptosporidium* are a typical example of such organisms. To being resistant to the standard disinfection process by chlorination carried out by Water Treatment Plants (WTPs) and are infectious at low doses. The presence of *Giardia* cysts and *Cryptosporidium* oocysts in water sources has been reported in numerous studies (Hachich et al., 2004; Leal et al., 2009; Vernile et al., 2009; Razzolini et al., 2010; Fernandes et al., 2011; Gallas-Lindemann et al., 2013, Burnert et al., 2014). The occurrence of protozoa in watersheds and also in drinking water poses a threat to human health, as shown by previous studies. In the United States, both parasites were associated with more than 50% of waterborne outbreaks in the 1986–2000 period (Karanis et al., 2007; Arnone and Walling, 2007; Baldursson and Karanis, 2011). According to Karanis et al. (2007), out of 325 outbreaks reported between 1986 and 2000, 32% (104) were associated with drinking water

* Corresponding author. Tel.: +55 1130617888.
E-mail addresses: razzolini@usp.br (M.T.P. Razzolini), marcelolauretto@usp.br (M.d.S. Lauretto), ehachich@sp.gov.br (E.M. Hachich), misato@sp.gov.br (M.I.Z. Sato), nardocci@usp.br (A.C. Nardocci).

http://dx.doi.org/10.1016/j.mran.2016.01.001
2352-3522/

contaminated by *Giardia lamblia* and 23.7% (77) by *Cryptosporidium parvum* or *Cryptosporidium* spp. In a study with more recent data, Bardulsson and Karanis (2011) reported that *Giardia* and *Cryptosporidium* were the most prevalent parasites in 199 waterborne outbreaks that occurred worldwide between 2004 and 2010.

In Brazil, cryptosporidiosis and giardiasis are major causes of morbidity among children under five (Uchôa et al., 2001; Carvalho-Almeida et al., 2006; Gonçalves et al., 2006). The study conducted by Teixeira et al. (2007) revealed a giardiasis prevalence of 18 % in children from a poor area of Juiz de Fora City (MG). In the state of Maranhão (MA), Silva (2009) studied the prevalence of giardiasis in children aged between 0 and 10 years old in Chapadinha City and found that 102 (16.4%) out of 623 stool samples were positive for *Giardia lamblia*. The author indicated that the 2–6 year-old age group was the worst affected.

The probability of infection by *Giardia* and *Cryptosporidium* associated with water consumption around the world has been published considering different scenarios (Hunter et al., 2011; Schijven et al., 2011; Xiao et al., 2013). Sato et al. (2013) estimated the infection probability for both protozoa in four regions of São Paulo State monitored for (oo)cysts concentrations over a 2-year period. The concentrations of *Giardia* cysts, according to the region, ranged from < 0.1 (Limit of Detection) to 97/L, while for *Cryptosporidium* oocysts concentrations ranged from <0.1 to 6/L. The estimated risk for all regions exceeded the 1/10,000 maximum tolerable risk issued by the USEPA. Sensitivity analysis revealed that the major contributors to the risk were the organism concentrations found in waters across all regions and scenarios considered.

Given the relevance of pathogenic protozoa in waterborne outbreaks, the objective of this study was to assess the risk of *Giardia* and *Cryptosporidium* infection by direct consumption of drinking water and indirect consumption during bathing in a population from São Paulo city supplied by a WTP previously evaluated for levels of both parasites (Razzolini et al., 2010). In this study, the DALY (Disability-Adjusted Life Year) approach – a measure recommended by the WHO – was used to evaluate the impact on health of exposure to poor water quality (WHO, 2009).

Method

The probability of *Giardia* and *Cryptosporidium* infection by water consumption was estimated using the Quantitative Microbial Risk Assessment (QMRA) approach. The exposure scenario was built based on drinking water concentrations of *Giardia* and *Cryptosporidium* from a previous study, an exponential dose-response model for both parasites, and different consumption rates for adults ($>$21 years old) and children ($<$5 years old).

Pathogen concentrations

The concentrations of *Giardia* cysts and *Cryptosporidium* oocysts were obtained from a previously published study (Razzolini et al., 2010). Briefly, 400 L of finished water from a Water Treatment Plant (WTP) with conventional treatment processes (coagulation with ferric chloride, flocculation, decantation, filtration - charcoal, gravel, sand, chlorination and fluoridation), were concentrated “in situ” monthly for a one-year period. The catchment point that feeds the WTP is located in a reservoir, which delivers drinking water to a population of 3.5 million, lies within a metropolitan area which is undergoing rapid population growth, with subnormal urbanization and inadequate sanitation facilities. The authors evaluated both parasites in drinking water samples using the USEPA 1623 method (USEPA, 2005).

Giardia and *Cryptosporidium* counts (N) in the 400 L sample ranged from 0 to 24 cysts and from 0 to 4 oocysts, respectively, and the limit of detection was 0.0025 (oo)cyst/L. For uncertainty analysis, counts data were modeled according to Haas et al. (2014, pp. 162–198). The first distribution to be considered was the Poisson distribution, constituting the baseline model under the assumption of homogeneous distribution of organisms in water. However, the likelihood-ratio test for goodness of fit indicated a poor model fit for Poisson (p-Value < 0.01). Therefore, a negative binomial distribution, which can be derived as a gamma mixture of Poisson distributions (Greenwod and Yule, 1920), was assumed. This distribution is more suitable than the Poisson family for microbial count data with overdispersion (i.e. data with variance greater than the mean), as was observed in the present study. Under this distribution, the probability that a sample contains x organisms (including $x = 0$) is given by Haas et al. (2014, p.197):

$$P(x|\mu,\ \beta) = \frac{\Gamma(x+\beta)}{\Gamma(\beta)x!}\left(\frac{\mu}{\mu+\beta}\right)^{x}\left(\frac{\mu+\beta}{\beta}\right)^{-\beta},$$

where the μ and β represent the mean and dispersion parameters, respectively. The maximum likelihood estimates, obtained using the R package “MASS” (Venables and Ripley, 2002), were: $\mu = 2.5,\ \beta = 0.186$ for *Giardia* and $\mu = 0.583,\ \beta = 244$ for *Cryptosporidium*. The recovery rate is not taken into account and all (oo)cysts were considered viable and infectious.

Dose-response model

The exponential dose-response model was used for both pathogens, where uncertainty in the dose-response parameter value r (organism-specific infectivity parameter) was considered as follows: for *Giardia, r* ranged with a triangular distribution with parameters (mode = 0.01982, min = 0.009798, max = 0.03582), corresponding to the average and 95% CI limits presented by Rose et al. (1991). For *Cryptosporidium, r* ranged with a triangular distribution with parameters (mode = 0.00419, min = 0.00220, max = 0.00852), obtained by the Center for Advancing Microbial Risk Assessment (CAMRA/WIKI – http://qmrawiki.canr.msu.edu) based on a study carried out by DuPont et al. (1995). The dose-response parameters used was based on WHO recommendation (Medema et al., 2009). We consider that this value is more appropriate for developing countries instead of EPA´s value which is conservative and more suitable for the USA or other high income countries. Besides, using EPA´s value could lead to high values of annual risk what could result in a non-realistic scenarios for public health measures.

Consumption rates

The water consumption rate for the Brazilian population in the southeast region of the country was estimated based on the study conducted by Kahn and Stralka (2009) that took into account water consumption by weight and age. This rendered it possible to discriminate different categories of age. Two age groups were considered: children ($<$5 years old) and adults ($>$21 years old). The group of children was assessed because it represents the sensitive population while the adult group represents the general population. For the present study, the best fit for this variable was a lognormal distribution with a mean and standard deviation (SD) of 0.44 L/d (SD 0.92 L/d) for children and 1.5 L/d (SD 0.8 L/d) for adults. Water consumption during showering was assumed to follow a gamma distribution with a rate of 0.45 mL and shape of 60 mL for adults, and rate of 0.64 mL and shape of 58 mL for children, based on the study carried out by Schets et al. (2011).