

## Analysis of Water Treatment Performance for *Giardia* Parasite by Quantitative Microbial Risk Assessment

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### INTRODUCTION

*Giardia* spp. is one of main protozoan parasites having world-wide distribution. Many of them have been established as infectious agents to the human population (Fayer, Santín et al., 2006; Robinson, Elwin et al., 2008). *Giardia* has been proposed as reference organism in water treatment systems by EPA. In this work, the performance of a water treatment plant (WTP) (Jalaliyeh WTP in Tehran) was examined using the Quantitative Microbial Risk Assessment (QMRA) tool.

### MATERIALS AND METHODS

**Sampling and pathogen detection.** Analysis of *Giardia* was performed using 1623.1 (U.S. EPA 2012). Sampling was performed by passing 50 L (raw water), 50 to 100 L (water passes through the clarifluculators) and 1000 L (finished water) samples through the filtration cartridges. The cartridges were processed with the automatic system (IDEXX Laboratories, Inc., Westbrook, ME, USA) and immunomagnetic separation was performed using Dynal reagents and equipment.

**Quantitative microbial risk assessment.** For conducting a quantitative microbial risk assessment, the density of *Giardia* at source water, its physical removal within treatment zones, its inactivation by chemical disinfection, the water consumption by different age of groups and dose-response models were taken into account. Monte-Carlo simulation was used to estimate the infection risk with a minimum of uncertainty.

**Density of *Giardia* in source water, its removal and inactivation.** The density of pathogen in source was assumed to be Gamma distributed and modelled with a Negative Binomial distribution. A mixed form of Beta distribution and Hypergeometric function was used to model the number of pathogen in the samples after passing through the treatment processes. The log of inactivation for compliance with the surface water treatment rule was calculated according to USEPA Disinfection Profiling and Benchmarking Guidance Manual (U.S. EPA 1999).

**Exposure estimation and risk characterization.** Exposure to the *Giardia* pathogen was estimated by incorporating the Monte-Carlo simulated data including pathogen density in source ( $C_{source}$ , cysts/L), recovery (R) of pathogen, log of reduction in treatment zones (from  $i=1$  to  $i=n$  zones) (RLog), total log of inactivation in disinfection segments ( $Tlog_{inact}$ ) and water ingestion rate (IR, L/day):

$$Dose = IRC_{source} \frac{1}{R} 10^{-TL_{0.2,200}} \prod_{i=1}^n 10^{-R_{i,log}} \quad (1)$$

The daily infection risk and the annual risk were determined as follows:

$$P_{inf, person, day} = 1 - {}_1F_1(\alpha, \alpha + \beta; -Dose) \quad (2)$$

$$P_{inf, person, year} = 1 - \prod_{i=1}^{365} (1 - P_{inf, person, day, i}) \quad (3)$$

where  ${}_1F_1$  – the confluent hypergeometric function. The risk of illness per year for an individual was estimated using following equation:

$$P_{ill, person, year} = P_{inf, person, year} \times S \times I \quad (4)$$

where  $S$  and  $I$  – the proportion of the population susceptible to infection and the proportion of individuals who develop symptomatic illness after infection, respectively.

The health burden (HB) of gastroenteritis resulting from infection with *Giardia* in drinking water in terms of DALY per case was calculated as follows:

$$HB (DALY/case) = YLD + YLL \quad (5)$$

YLL and YLD were calculated as follows:

$$YLD = \sum_{i=1}^n (OF \times DI \times SW) \quad (6)$$

$$YLL = \sum_{i=1}^n (OF \times [LE - AD] \times SW) \quad (7)$$

where  $OF$  – outcome fraction (0 to 1);  $DI$  – duration of illness (years);  $SW$  – severity weight of outcome (0 to 1);  $n$  – number of health outcomes;  $LE$  – life expectancy (years) and  $AD$  – age at death (years).

## RESULTS

The amounts of removal and inactivation of *Giardia* in Jalaliyeh WTP were determined to be 2.4 and 3.3 log, respectively. Out of fifteen monthly samples one sample was found positive for threatened drinking water. The estimated burden of disease due to the presence of *Giardia* in produced water for age groups of less than 2, 2 to 6, 6 to 16 and older than 16 years were  $1.91 \times 10^{-9}$ ,  $2.09 \times 10^{-9}$ ,  $4.93 \times 10^{-10}$  and  $5.24 \times 10^{-9}$  DALYs per person per year, respectively.

## CONCLUSION

Comparison of the estimated burden of disease with target show despite the detection of pathogen in treated water, there is no health concern about *Giardia* in the produced drinking water from Jalaliyeh WTP. Disinfection with chlorine had the main role for lowering the risk of infection in this system in spite of its possible roles in disinfection by-products (DBPs) formation. As the first QMRA study in Iran, this tool is able effectively to identify the vulnerabilities of system and to facilitate decision-making to improve water treatment performance. We argue that promoting the use and development of QMRA in conventional water treatment systems in Iran which in some cases are expose to more microbial pollutions and identifying their performance gaps to be filled in future are needed.

## REFERENCES

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