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Quantitative Microbial Risk Assessment in onsite sanitation systems: influence of sewage infiltration on water quality from shallow wells

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Highlights:

- We assessed health risks associated with ingesting contaminated groundwater by the soil infiltration of sewage.
- Contamination of groundwater was detected with *E. coli* concentrations until 3.7m depth and distant 15m to the sewage infiltration.
- The probability of annual infection by the bacteria within a radius of 15 m from the infiltration trench was zero.
- The risks were higher for the simulation of Rotavirus, with 31% annual PI at 15m distance and 3.7m depth,

Keywords: QMRA; onsite sanitation; subterranean water.

INTRODUCTION

Groundwater is 96% of the total available on the planet and is widely used in Brazil. In Brazil, Federal Law Nº 9,433/1997, State Law Nº 9,748/1994, and State Decree Nº 4,778/2006 provide groundwater for single-family consumption. However, less than 2% of the more than 2.5 million tubular wells in Brazil meet the regulation requirements (HIRATA et al., 2019). The lack of technical criteria in the construction and analysis of water quality represents a risk to human health, by possible sewage contamination.

Because of the low coverage of the sewage collection network in Brazil, the onsite sanitation systems are widely used in both, urban and rural communities (IBGE, 2020). Among these solutions, the septic tank is widely used and considered adequate (BRASIL, 2019). In addition to system efficiency, climate, water table depth, as well soil and effluent composition, affect groundwater quality. Brazil is estimated to have 2.5 million tubular wells, and less than 2% meet the regulation requirements (HIRATA et al., 2019). This study sought to evaluate the health risks associated with the ingestion of potentially contaminated groundwaters by the soil infiltration of sewage in onsite sanitation systems, using data from the Florianópolis, SC case study (PHILIPPI, 2009).

METHODOLOGY

The study was conducted with real data from the Basic Sanitation Research Program Report, PROSAB (PHILIPPI, 2009), in a household in Florianópolis/SC coastal region in southern Brazil. The residence's sewage treatment consists of a septic tank (ABNT, 1993) followed by a sand filter and infiltration ditches (ABNT, 1997). From top to bottom, the local soil profile was classified as sandy, sandy-clayey, and clayey-sandy. The water table level is 3.1 m.

Escherichia coli was measured as an indicator of fecal contamination, and the probability of infection from consuming contaminated water was calculated considering 8% of pathogenic strain. Rotavirus (RNA virus of the Reoviridae family, Rotavirus genus) was measured as one of the main viral agents causing acute diarrheal diseases in the world. Rotavirus concentration was simulated considering the excretion rate, and inactivation in the treatment and soil percolation (HAAS; ROSE; GERBA, 2014). For *E. coli* analysis, 100 mL samples were incubated for 24 hours at 37oC in Quanti Tray® with Chromogenic Substrate Colilert®.

The reduction of bacteria *E. coli* during water percolation was obtained by the difference between the final and initial concentrations, at the collection points. For this, groundwater was sampled in four monitoring wells (points 1, 2, 3, and 4) at three heights: 2.70 m, 3.70 m, and 4.70 m. The wells were made far from the infiltration unit with points (1) at 1.0 m, (2) at 1.7 m, (3) at 3.6 m, and (4) at 1.7 m. Samples were also collected in the supply well, 15 m away from the effluent infiltration trench.

For QMRA, it was considered the intake of 2 L of water per person per day. The Beta-Poisson dose-response model was adopted for pathogenic *E. coli* and Rotavirus, calculating for each scenario and point estimate of microbiological risk. For *E. coli* was adopted α of 0.050 and β of 1.001 (HAAS; ROSE; GERBA, 2014). For Rotavirus was adopted α of 0.26 and β of 0.42 (REGLI et al., 1991).

RESULTS AND CONCLUSIONS

According to Consolidation Ordinance 5 of 2017, for human consumption, *E. coli* must be absent in 100 ml of water (BRASIL, 2017). Only at a depth of 4.70 meters at points 2 and 4 was the concentration of *E. coli* zero.

E. coli concentrations were reduced with increasing depth due to natural filtration and adsorption in the unsaturated zone during soil percolation. This reduction was relatively small compared to the initial concentration in treated wastewater. The greater adsorption in the most superficial layer, from 2.7 m to 3.7 m, than from 3.7 m to 4.7 m, is due to the groundwater level at 3.1 m.

Point 3 showed the highest concentration of *E. coli* at 3.7 meters, even at the greatest horizontal distance from the infiltration ditch. This may have occurred because this point is directly in the direction of the water flow from the groundwater, receiving a greater flow of contaminated water.

From the measured points, 1.7 m away horizontal from the infiltration site and 2.7 m deep, we detected the highest concentration of *E. coli*, which was 1.6×10^3 MPN/L.

The probability of annual infection by the bacteria within a radius horizontal of 15 meters from the infiltration trench, was zero. The probability of annual Rotavirus infection was zero only at 222

meters horizontal, considering chlorination in the water before consumption (simulated scenario, not measured).

The simulations for Rotavirus show a decreasing probability of infection with increasing distance between the system and the wells. At 15 meters away horizontally from the infiltration unit, with 99% inactivation by effluent treatment, the annual probability of infection was 31.11%. At 222 meters horizontal, considering a treatment efficiency of 99%, the annual probability was 0.05%, still above the WHO acceptable risk (WHO, 2016) of 0.01%.

In this study, the distance between the bottom of the infiltration ditch and the average groundwater level did not reach 1.5 meters, as required by NBR 13.969/1997. The infiltration rate applied was 0.09 m^3/m^2.day, 3.75 times higher than that predicted in the standard. Both influence the risk of contamination, as the higher the rate, the greater the chance of organisms being transported over greater distances.

The results of this work highlight the problem of implementing on-site sewage treatment systems in conjunction with the water collection system for consumption. Over the years, systems built improperly or without maintenance become inefficient in controlling pathogens and increase the risk to human health. In many households, the distances between wastewater treatment and water collection for consumption are unfeasible.

It is worth noting that these results are related to sandy soil conditions, which are common in coastal regions like the study site. The importance of preventive measures against health risks is highlighted with basic hygiene habits, such as correctly washing hands and food. In addition to complementary research to elucidate the dynamics of pathogens in different situations and different climate and soil conditions.

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