SPATIAL AND TEMPORAL PROPAGATION OF *CRYPTOSPORIDIUM* AND *GIARDIA* AT VARIOUS SCALES IN A DRINKING WATER RESERVOIR

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Aims

Cryptosporidium and *Giardia* are emergent protozoan parasites of faecal origin causing diarrhoeal diseases throughout the world. Their impact on public health is closely linked to the management of water resources and both pathogens are continuously released in the environment by punctual and diffuse faecal pollution sources. With the amendment of the Water Safety Plans published by the World Health Organization in 2005, the assessment of the public health risk associated with the presence of both parasites has extended to watershed scale.
In Luxembourg, the Upper-Sûre reservoir provides 50% of the population of the country with drinking water. The presence of both *Cryptosporidium* and *Giardia* in surface water within the catchment area has been documented earlier. The aim of this study was therefore to understand the propagation of both protozoans within the catchment area over time and space. Integrated into a risk assessment-based approach, the results are intended for establishing an efficient monitoring strategy. Currently, no such strategy is available for water utilities. Though it is a crucial tool for improving the management of drinking water resources because it should alert responsible authorities in case of high contamination risk and prevent from possible waterborne outbreaks.

Methods

For the study of the spatial and temporal dynamics of *Cryptosporidium* and *Giardia* within the catchment area, a multi-compartment approach was adopted. For this purpose, the Upper-Sûre watershed was broken down into three interconnected compartments that display different hydrological behaviours (see figure). The first one regroups four sub-catchments of various sizes and land use characteristics, encompassing a variety of potential point and diffuse sources of faecal pollution. The second compartment is represented by the Sûre River which is the main tributary of the Upper Sûre reservoir. The reservoir itself constitutes the third compartment which extends to the inlet of the drinking water treatment plant, located at the dam wall.
Sampling was performed over two years and focused on the prevalence season (from October to April) defined in a previous work. It was further adapted to the hydrological behaviour of each compartment. Following this methodology, water was sampled with an autosampler at the outlet of each of the four sub-catchments in order to evaluate the contamination load that exits the compartment. For both the Sûre River and the reservoir, transects were performed under base-flow and flood conditions and the propagation of the contamination load was followed over time and space. Also, the distribution of both *Cryptosporidium* and *Giardia* within the water column was further examined at fine spatial scale in the reservoir. Eventually, background contamination was monitored at the inlet of the drinking water treatment plant on a bi-monthly basis.
For *Cryptosporidium* and *Giardia* analyses, samples (volumes ranging from 20 to 100 L) were processed by filtration and immunomagnetic separation according to ISO15553 standard protocol and split in two equal parts, one for immunofluorescence detection, one for PCR detection. Further analyses were performed at each sampling occasion, including physico-chemical parameters (T°, pH, conductivity, oxygen level, turbidity, total suspended matter and stable isotopes) as well as faecal bacteria indicators (*E. coli* and total coliforms).

Results

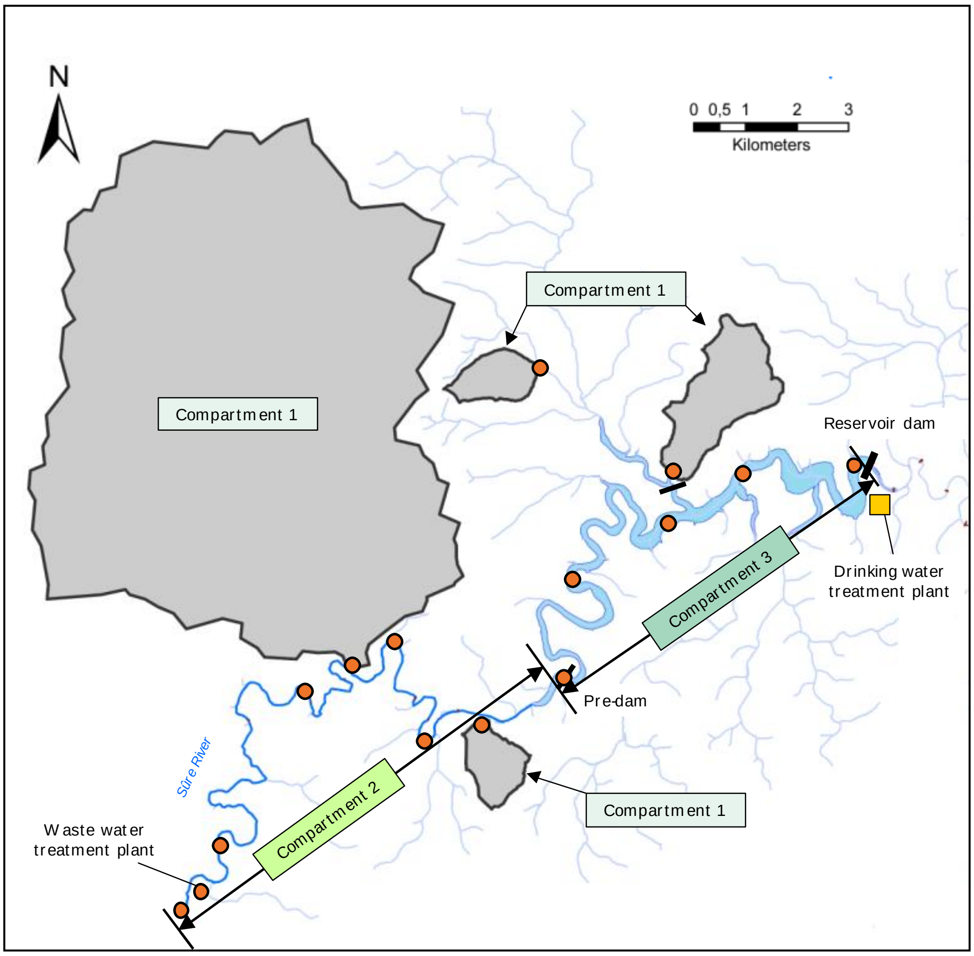
Our results outline the heterogeneous character of both *Cryptosporidium* and *Giardia* occurrence in surface water. In accordance with other studies, we observe a higher prevalence of *Giardia* compared to *Cryptosporidium*. When comparing the contamination load at the outlet of the first compartment, namely the sub-catchments, it appears that land use characteristics are not sufficient to explain the pollution load produced by the respective catchment area. Instead, hydrological and meteorological parameters appear to be a key component to take into account jointly with land use characteristics.

The heterogeneous distribution of *Cryptosporidium* and *Giardia* is further illustrated in both the Sûre River and the reservoir. For the river, the presence of a wastewater treatment plant at the upstream part of the study area greatly impacts the density of *Giardia* at downstream sites and the fate of this load through the river greatly varies according to hydrological conditions. The occurrence of peaks of contamination with *Cryptosporidium* on downstream sampling sites suggests that other sources may contribute to the contamination of the river.

The fate of the contamination load is more difficult to assess in the reservoir since hydraulic processes are more complex and spatio-temporal scales are larger. Nevertheless, after periods of heavy rainfall, we could record peaks of contamination moving towards downstream sampling stations, ultimately reaching the inlet of the treatment plant. The fine spatial distribution at the scale of a reservoir section is heterogeneous but there is a clear trend towards higher parasite concentrations in the upper layers of the reservoir.

Conclusions

We present here a compartment-based approach for the assessment of the propagation dynamics of *Cryptosporidium* and *Giardia* at a watershed scale. Such an approach is helpful when studying complex systems because it enables to break them down into smaller, yet interconnected systems. Our results claim for a high heterogeneity in the propagation dynamics of the parasites, both in time and in space. Clear trends have been observed and the results put emphasis on the key role of the hydrological parameters for the understanding of the propagation dynamics. Further species-specific genotyping will give insights into the pollution sources and more accurately inform on the risk associated with the presence of *Cryptopsoridium* and *Giardia* in the watershed. Ultimately, it should help in developing monitoring strategies for water utilities in order to control and to contain the microbial risk in the framework of drinking water supply.



Figure

Map of the study area showing the three compartments as well as sampling stations (orange dots).