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Bacteria and virus removal effectiveness of ceramic pot filters with different silver applications in a long term experiment

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ABSTRACT

In 2012 more than 4 million people used a ceramic pot filter (CPF) as household water treatment system for their daily drinking water needs. In the normal production protocol most low cost filters are impregnated with a silver solution to enhance the microbial removal efficiency. The aim of this study was to determine the role of silver during the filtration and subsequent storage. Twenty-two CPFs with three different silver applications (non, only outside and both sides) were compared in a long-term loading experiment with *Escherichia coli* (K12 and WR1) and MS2 bacteriophages in natural challenge water under highly controlled laboratory circumstances. No significant difference in Log Removal Values were found between the filters with different silver applications. The results show that the storage time in the receptacle is the dominant parameter to reach *E. coli* inactivation by silver, and not the contact time during the filtration phase. The hypothesis that the absence of silver would enhance the virus removal, due to biofilm formation on the ceramic filter element, could not be confirmed. The removal effectiveness for viruses is still of major concern for the CPF. This study suggests that the ceramic pot filter characteristics, such as burnt material content, do not determine *E. coli* removal efficacies, but rather the contact time with silver during storage is the dominant parameter to reach *E. coli* inactivation.

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1. Introduction

1.1. Ceramic pot filters

Ceramic Pot Filters (CPF) are widespread around the world as point-of-use water treatment systems. In 2009 there were 35 ceramic pot filters factories in 18 countries worldwide with a monthly production of 20,175 filters (Rayner et al., 2013). It is estimated that in 2012 more than 4 million people use their more than 700,000 ceramic pot filters (Fig. 1) as a household water treatment system for their daily drinking water needs.

The ceramic filter systems are the most effective household water treatment system to reduce illness compared to other systems such as a Biosand, Solar Disinfection (SODIS) and chlorination, especially on the long term, as stated in a meta-study by Hunter (2009). An overview of the bacterial and viral testing of low-cost Ceramic Pot Filters (CPF), as presented by Simonis and Basson (2011), gives an average Log Reduction Value (LRV) of 2.0 (99% reduction) for *Escherichia coli* over the listed 15 laboratory and field studies. This complies with the performance target indicated as 'Protective' as set by the WHO (WHO, 2011) for bacteria. The removal effectiveness of the CPF is good and is one of the reasons why these filters are so widespread around the globe.

Yet, the variability in the documented performance of the filters with regards to *E. coli* removal is large as Simonis and Basson (2011) report a LRV range between 0.9 and 6.8. Although efforts have been made to come to standardized procedures by the 'Ceramics Filter Manufacturing Working Group' (Lantagne et al., 2009; Rayner et al., 2013), a recent overview of the current practices shows 'that manufacturing processes vary widely both between and within factories, including the consistency of materials, manufacturing methods, and quality control practices' (Rayner et al., 2013).

Virus removal by CPF has been tested with Bacteriophages such as MS2. Van Halem found LRVs for MS2 of 0.6–0.9 after 5 weeks, which increased to 1.1 to 1.8 after 13 weeks (Van Halem et al., 2007) with silver impregnated filters. Tests with deionised water showed a low LRV by CPF of 0.21 and 0.45 for MS2 Bacteriophages (Salsali et al., 2011). Others (Brown and Sobsey, 2010) using rain water and drinking water found a LRV of 1.2 for MS2 on the long term (after filtering 100 L). In a study using virus sized microspheres of 0.02 and 0.1 μm the LRV was highly variable ranging between 0.43 and 2.4 (63–99.6%) for six filters (Bielefeldt et al., 2010). Virus removal efficiency of ceramic pot filters does not meet the WHO standards for being 'Protective' (LRV $\geq$ 3; WHO, 2011). No critical parameter is yet found to enhance the virus removal efficiency.

Different factors in the production process and performance assessment influence the reported removal effectiveness (Table 1). The local craftsmanship and materials, typical for the production process of these ceramic pot filters, have an inherent variability in itself. The type of clay used, burnt materials as poreformer, temperature and place in the kiln, the way and type of silver that is applied, wet or dry season and many more parameters all have their influence on the performance of the filter. Another variable is the way the filters are used. Some families treat mostly rain water, others treat local surface water with a high turbidity which can have a direct effect on performance and on cleaning practice. Finally the research method used to assess the performance can have a large impact on the reported efficacy. The type of bacteria and viruses, their culture techniques, the number of duplicates and laboratory or field conditions all influence the performance of the filter and the accuracy of the assessment. The variability creates concern about the consistency of the removal effectiveness of the CPF. For a water treatment technique which is used to supply more than 4 million people such uncertainty should not be acceptable. It also shows that suggestions for optimization are only valuable when they are based on thorough and solid research, since it might influence the water supply of millions of people.

1.2. Role of silver

In this study the role of silver, as additive to enhance bacterial disinfection, is investigated, since the influence of silver impregnation on the microbial performance is still poorly understood. In some studies the (re)application of silver has an immediate effect on the removal efficiency with regards to *E. coli* (Bielefeldt et al., 2009). The research and modelling by Bielefeldt et al. (2009) showed that bacterial efficacy increases

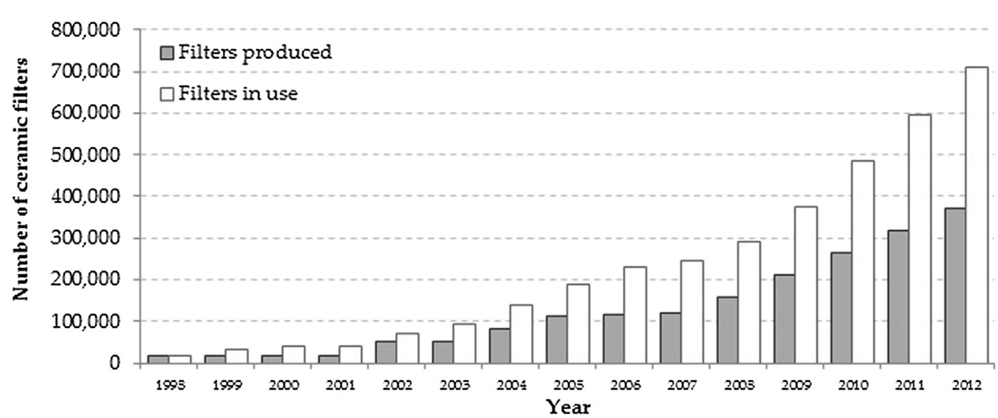

Fig. 1 – Estimation of the total number of ceramic pot filters worldwide, based on information provided by Rayner et al. (2013) and assuming 5 new factories per year since 2009 with each 1000 filter pots per month production capacity, a failure rate of 12% at the factory (Rayner et al., 2013) and a disuse rate of 2% a month at the users (Brown, 2007).