Statistics of Flow and the Scaling of Ceramic Water Filters

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Abstract: According to the World Health Organization (WHO), there was an increase in the number of people that have access to safe drinking water between 2006 and 2010. Such trends can be accounted for partly by the increasing usage of ceramic water filters that can remove microbial pathogens from water. However, the initial flow rates in such filters are often limited to ranges between 1 and 3 L/h. In this paper, six frustum-shaped ceramic water filters of the same clay:sawdust composition were tested. Each ceramic water filter was filled with water and allowed to filter 20 times. Each time, the flow rate and water level were measured for a consecutive 12 h. Permeability values were estimated for each run of the ceramic water filters. Statistical analysis was performed on flow rates (in the first hour), mean flow rates, and estimated permeability values. The flow rate values (in the first hour) for the six ceramic water filters were found to be between 1.4 and 3.0 L/h. An effective permeability was obtained for ceramic water filters with a range of microscale and nanoscale pore sizes. The statistical variations in the flow rates and effective permeabilities were elucidated along with the potency of a multiple ceramic water filter system for scale-up studies in serving communities that need portable water. **DOI: 10.1061/(ASCE)EE.1943-7870.0000862.** *© 2014 American Society of Civil Engineers.*

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Introduction

It is estimated that 1.8 million deaths per year and 61.9 million disability-adjusted life-years are attributed to the drinking of unsafe water and poor sanitation (WHO/UNICEF 2000). The WHO also suggests that over 99.8% of the deaths are caused by unsafe water, sanitation, and hygiene in developing countries (WHO/UNICEF 2000). Furthermore, in developing countries, most of the childhood mortality occurs in children who are less than 5 years old (WHO/UNICEF 2004).

Those who have access to improved water may also experience contamination between the source and the point of use. Hence, the key is to ensure that people have access to improved water at the point of use. This is crucial for the achievement of the Millennium Development Goals (MGDs) of halving the number of people without access to improved water supply and sanitation by the year 2015 (WHO/UNICEF 2004). To achieve this target, it is important to explore point-of-use water purification methods (Murcott 2006; Sobsey 2002) that can improve the health and well-being of people in rural/urban areas in the developing world.

Several point-of-use treatment systems (Murcott 2006; Sobsey 2002) can be used to provide microbiological, chemical, or physical water treatment. They include (1) disinfection [chlorination, solar disinfection (SODIS), solar pasteurization, ultraviolet irradiation with lamps, and boiling] (Liu and Fitzpatrick 2010), (2) particle filtration (cloth fiber, ceramic filter, biosand, and other slow sand filter technologies) (Heather et al. 2010; Yakub et al. 2013), (3) adsorption media (granular activated carbon and activated alumina or clay) (Liu and Fitzpatrick 2010; Yakub and Soboyejo 2013), (4) combined system (combined flocculation and disinfection or filtration) (Liu and Fitzpatrick 2010; Preston et al. 2010), and (5) other approaches (plain sedimentation settling, safe storage, flocculation with iron or alum salts, and membrane processes) (Preston et al. 2010; Davies et al. 2010). Within the range of possible water treatment methods, water filters are one of the most highly rated systems for the removal of turbidity (Van Halem et al. 2009; Brown et al. 2009; Brown and Sobsey 2010), fluoride removal (Yakub and Soboyejo 2013), and bacteria inactivation (Van Halem et al. 2009; Brown et al. 2009; Brown and Sobsey 2010; Oyanedel-Craver and Smith 2008; Yakub et al. 2013). Filters are advantageous because they are relatively inexpensive (Van Halem et al. 2009; Brown et al. 2009).

Ceramic water filters are produced from a mixture of clays and sawdust. The mixtures are then molded into pot shapes using steel molds that are subjected to hydraulic pressure. After drying, the green bodies are treated at approximately 850°C (Yakub and Soboyejo 2013; Yakub et al. 2013; Van Halem 2006). During the heating process, the carbonaceous materials are burnt at temperatures between 400 and 500°C and sintered between 800 and 900°C (Yakub and Soboyejo 2013; Yakub et al. 2013; Van Halem et al. 2009; Brown et al. 2009; Brown and Sobsey 2010; Oyanedel-Craver and Smith 2008; Van Halem 2006). They are then furnace-cooled (to minimize thermal shock) and dipped in water for 24 h. After dipping to saturation, the filters are soaked in colloidal silver or silver nitrate (Yakub and Soboyejo 2013; Yakub et al. 2013; Van Halem et al. 2009; Brown et al. 2009; Brown and Sobsey 2010; Oyanedel-Craver and Smith 2008; Van Halem 2006) to

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