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Microbiological effectiveness of mineral pot filters as household water treatment in the coastal areas of Bangladesh

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ABSTRACT

Mineral pot filters (MPFs) are commercially produced household water purifiers, used by millions of people in Bangladesh and other Asian countries. The effectiveness of the filters in reducing microbial indicators and other potential pathogens under realistic household usage conditions has not been previously investigated. A total of 75 filters were distributed among rural households in two coastal areas of Bangladesh and their performances were monitored in four cycles in an interval of about 1.5 months. The results showed a median $\log_{10}$ reduction of *E.coli* from 1.8 to 2.7 in four monitoring cycles. For pond water, *E.coli* reduction $> 2 \log_{10}$ was observed. The filters also removed *Vibrio cholerae* non-O1/non-O139. The number of filtered water samples satisfying the WHO no risk level increased significantly. The turbidity of the filtered water was found to be less than 1 NTU (Nephelometric Turbidity Unit). The results suggest that MPFs are effective in reducing indicator bacteria substantially from the available water supply options. However, the performance of the filters was found inconsistent and was not sufficient to consistently meet the WHO guidelines for drinking water. More evidence based data obtained under laboratory and household usage conditions are necessary to further verify the filter performance and also to recommend the filter as household water treatment device for the population with unreliable water supply.

1. Introduction

Access to safe, reliable sources of drinking water is a long-standing problem among rural people in developing countries. A recent study has estimated that about 1.2 billion people lack access to microbiologically or chemically safe drinking water (Onda et al. 2012). Waterborne diseases such as diarrhea, cholera, enteric fever, and hepatitis cause 1.6 million deaths annually and children under 5-years old are especially vulnerable (WHO/UNICEF 2006). Inadequate access to safe water contributes to the massive global burden of disease and death especially of children in lower-income countries (Blakely et al. 2005).

In the coastal areas of Bangladesh, where about 28% of the country's total population live, people have to depend on water from rain-feed ponds, pond sand filters (PSFs) and rainwater harvesting systems (RWHs) for drinking water supply. Several recent studies (Islam et al. 2011; Karim 2010; Ahmed et al. 2005) showed that water from rain-feed ponds, PSFs and RWHs is microbiologically unsafe. The fecal coliforms (FC) counts in PSF water were found to vary from zero to over 4000 per 100 mL (Islam et al. 2011; Kamruzzaman and Ahmed 2006) and FC was found in about 97% samples (Ahmed et al. 2005). Rain-feed pond waters are highly polluted due to unhygienic sanitation in and around the pond, indiscriminant usage and lack of protection of the ponds. The FC and *E.coli* counts were found to vary from 12 to 10.000 and zero to 3000 per 100 mL (Islam et al. 2011), respectively, together with the presence of several pathogenic bacteria. Several studies (Islam et al. 2011; Karim 2010; Howard et al. 2006; Ahmed et al. 2005) in Bangladesh showed that the rooftop harvested rainwater was also microbiologically contaminated to a great extent, which may cause significant health risks of the rural people. Studies from other countries (Despins et al. 2009; Sazakil et al. 2007; Meera and Ahammed 2006) also reported microbial contamination of harvested rainwater and consumption of the water may cause a variety of infectious diseases around the world (Lye 2002).

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Evidence has shown that household water treatment (HWT) or point-of-use (POU) water treatment is effective in improving the microbiological quality of drinking water and in preventing diarrheal disease (Clasen et al. 2007; Sobsey 2002). In a recent review, WHO concluded that point-of-use water treatment technologies constitute simple, socially acceptable and low-cost interventions with significant potential to reduce global waterborne disease and death (Clasen et al. 2006). In a follow-up meta-analysis, it was found that water interventions at the individual household level are more effective in improving water quality and substantially reducing diarrheal illness than source-level interventions and that they may be more cost-effective over time than centralized systems (Clasen et al. 2007). As the water from the available water supply options in the coastal area is unsafe, the incidence and prevalence of water borne diseases are higher and an appropriate strategy needs to be undertaken to deliver safe drinking water to the coastal communities. Recently both in-house and field based interventions like household filtration, chlorination and solar based UV disinfection have been demonstrated by NGOs to treat the water for microbial safety. In urban areas in Bangladesh, HWT using mineral pot filters (MPFs) is very popular and common to treat the untrusted supply water and this may be one of the promising options to deliver safe water to the coastal communities. During the field survey for this study in 2013, several households were found to use MPFs to treat water from ponds, PSFs and others. Although, the ceramic water filters were supported by a number of published studies indicting microbiological effectiveness (Murphy et al. 2010; Brown and Sobsey 2010; Vinka et al. 2008; Van Halem 2006), adequate evidence base for microbial effectiveness of the MPFs under daily usage conditions is not available. Brown et al. (2012) conducted laboratory challenge experiments following the WHO recommended performance test protocols for MFPs in Cambodia. The results indicated that MFPs were highly effective in reducing *E.coli* ($>4\ \log_{10}$), moderately effective in reducing bacteriophage MS2 ($> 2\ \log_{10}$), and somewhat effective against *Bacillus atrophaeus*, a spore-forming bacterium used as a surrogate for protozoa ($< 1\ \log_{10}$). The test results also suggested that commercially available MFPs are at least as effective against waterborne pathogens as other filters like ceramic pot filters or boiling. Several recent studies also demonstrated the effectiveness of various commercial filters in removing microbial impurities from water in India and other countries (Bhathena et al. 2014; Mwabi et al. 2012; Clasen and Menon 2007).

The mineral pot filters (MPFs), locally known as ceramic water filters (CWFs) are commercial innovative HWT devices used by millions of peoples in Bangladesh and other Asian countries to treat water for drinking. As no local manufacturer produces MPF in Bangladesh, the filters are mainly imported from Malaysia, Thailand, South Korea and China. The price of MPFs in local markets ranges from US$20 to 40 in 2013 and they have a high demand both in urban and rural areas. The products are marketed by the private sector with a wide range of claims including high microbial efficacy, long service life, effectiveness in a wide variety of water conditions (temperature, pH, turbidity), improvement of water taste and minerals, etc. The filters are produced by several manufacturers, although the design and fabrication of the filter of each manufacturer is very similar. They have a porous ceramic filter at the top chamber, followed by a cylindrical granular media filtration comprised of an activated carbon filter and a four layer filter (silica sand, Zeolite and mineral sand and stone) at the bottom chamber as shown in Fig. 1. Raw water is poured at the top chamber, which passes through both the ceramic and granular media filters by gravity and gets collected at the bottom storage chamber. The treated water is dispensed via a tap attached at the storage chamber.

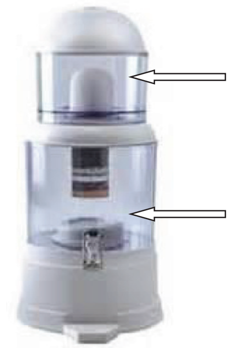

Fig 1. A typical picture of the MPF used in this study.

This paper studies the suitability and effectiveness of locally available MPFs as household water purifiers in removing microbial impurities from the water supply options and the resulting health burden reduction in the coastal areas of Bangladesh. The physio-chemical and microbial analysis of the randomly collected source water samples was performed to establish the baseline situation. The effectiveness of MPFs in reducing microbial level was evaluated under the daily household usage conditions. The results of this study can be used as a reference for the effectiveness of this commercial product in reducing microbial concentrations from unreliable water sources and its significance in reducing microbial health burden.

2. Materials and methods

2.1. Study area and sampling

This study was conducted in Dacope and Mongla areas of Khulna and Bagerhat districts, which is the same study area as reported by Islam et al. (2011), located in the southwest coastal areas of Bangladesh. People in these areas mainly depend on PSF, RWH and rain-feed pond water for drinking water supply. To assess the source water quality (baseline situation), a total of 39 water samples were collected from 18 rain-feed ponds, 6 PSFs and 15 RWHs on March 25, 2013 for physical, chemical and microbial analysis. Water samples were collected following the standard procedures (APHA 2012).

To evaluate the effectiveness of MPFs, a total of 75 filters from three well-known brands were purchased from the local market in Khulna. The devices were assembled according to manufacturers' instructions and were distributed among 75 preselected households. The households were selected in such a way that an equal proportion (about 25) of households belonged to each of the three water sources based on initial information on their available water sources, willingness to use the filter and readiness for operation and maintenance of filter.

Paired water samples (feed and filtered water) from each filter were collected during water sampling from May 2013 to November 2013 at an interval of 1.5 months in 4 monitoring cycles and samples were tested for physical, chemical and microbial parameters. The feed water sample was collected from the top chamber (first sampling point) and the filtered water sample was collected directly from the filter tap. For microbiological analysis, both feed and filter water samples were collected into 250 ml sterilized plastic bottles. All the samples were placed in an insulated box filled with ice packs immediately after sampling and transported to the Environmental Engineering Laboratory of IUT for Total Coliforms (TC), Fecal Coliforms (FC) and *Escherichia coli* analysis and to the Environmental Microbiology Laboratory of the International Center for Diarrhoeal Disease Research, Bangladesh (icddr,b) for