Chapter 2
Nanotechnology for Filtration-Based Point-of-Use Water Treatment:
A Review of Current Understanding

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ABSTRACT

With significant infrastructure investments required for centralized water treatment, in home treatment technologies, known as point-of-use, have become a popular solution in the developing world. This review discusses current filtration-based point-of-use water treatment technologies in three major categories: ceramics, papers and textiles. Each of these categories has used silver for added antimicrobial effectiveness. Ceramics have had the most development and market infiltration, while filter papers are a new development. Textiles show promise for future research as a cheap, socially acceptable, and effective method. Also, a new method of silver incorporation in ceramics is explored.

INTRODUCTION

Approximately 1 billion people worldwide do not have access an "improved water supply", which is defined by the World Health Organization (WHO) as "a household connection or access to a public standpipe, a protected well or spring, or a source of rainwater collection"(Cosgrove & Rijsberman, 2000). This definition also requires that at least 20 liters per person per day are available within 1 km of a person's home. Because this definition does not refer to water quality, reliability of service, or even cost, it is estimated that an additional 2-3 billion people also have unsafe water supplies, at least for part of the time (Hutton & Haller, 2004). Studies have also shown that numbers reported by the Joint Monitoring

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Programme of the proportion of drinking water coming from improved sources are likely substantial overestimations when water quality data is included (Bain et al., 2012). Access as well as quality is key.

The dangers of consuming unsafe water are substantial, particularly for children. The WHO estimates that consuming unsafe water causes the deaths of over 4 million people per year, with more than 1.5 million of these deaths being children under the age of 5. This is about equal to having 10 jumbo jets crashing every day with 90% of the passengers being children (Dillingham & Guerrant, 2004). Not included in this figure are the added health burdens on children who experience cognitive impairment and growth stunting as a result of gastrointestinal infections caused by consumption of water with pathogenic organisms like Shigella, pathogenic strains of *Escherichia coli*, *Vibrio cholerae*, and *Cryptosporidium parvum (Dillingham & Guerrant, 2004)*. People living with AIDS are particularly susceptible to infections from waterborne pathogens because of their weakened immune systems (Dillingham et al., 2006). In many parts of sub-Saharan Africa, there is an unfortunate confluence of low-quality drinking water and high rates of HIV infection. Providing safe water to our global population has been identified as one of the Grand Challenges of Engineering by the National Academy of Engineering.

In most cities and suburban areas of the developed world, water is treated at centralized water-treatment plants and delivered directly to homes through distribution systems with chlorine residual. About 3-4 billion people receive this high level of service, which generally prevents gastrointestinal infections by waterborne pathogens. This service is usually not available in the developing world or even in some suburban and rural areas of the developed world. These regions cannot economically sustain centralized water treatment plants that meet the full demands of the population. A centralized water treatment facility is a very large investment not feasible for many communities. The treatment plants plus the distribution system is not practical in developing rural areas due to the financial and structural requirements for safe treatment and delivery of water. The WHO has suggested that one possible solution is to take a more decentralized approach to water treatment, wherein people treat their water in their households immediately before consumption. This idea, often referred to as point-of-use (POU) water treatment, has the potential to significantly improve the microbial quality of household water and reduce the risk of diarrheal disease and death, particularly among children (Thomas Clasen, Nadakatti, & Menon, 2006). Table 1 shows a summary of some point-of-use systems currently in use and their effectiveness against *Escherichia coli* (*E. coli*).

Ideally, local markets can ideally drive the proliferation of these technologies without reliance on government interventions and/or subsidies. Peter-Varbanets, et al. divides current point-of-use treatments being used into three general categories: heat and UV-based systems (boiling with fuel, solar radiation, SODIS, combined action of heat and solar UV, and UV lamps), chemical treatment methods (coagulation, flocculation and precipitation, adsorption, ion exchange and chemical disinfection), and physical removal processes (sedimentation or settling, filtration, including membranes, ceramic and fiber filters, and granular media filters, including sand filters and aeration).

Rural areas of developing countries have been unable to implement centralized drinking water treatment because it is expensive. This leads to using untreated natural water sources (rivers, lakes, groundwater or rain) (Peter-Varbanets, Zurbrugg, Swartz, & Pronk, 2009). Without centralized treatment and direct piping into the home, there are many steps before consumption including collection from the source, storage, contamination, and treatment (J. E. Mellor, Smith, Learmonth, Netshandama, & Dillingham, 2012). There are three types of conventional methods for treatment including physical, chemical, and biological (Praveena & Aris, 2015). Common practices for point of use water treatment not utilizing filtration include boiling, chlorination, or solar disinfection. Membrane systems for use in the home