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Efficacy of Ceramic Candle Filters in the Removal of Bacteria and Enteroparasites

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ABSTRACT
This study aimed to evaluate the efficacy of ceramic candle filters (CCF) used for domestic purification of water. They are considered cheap and in the past were very popular in Brazil. The efficiency of this system to remove *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, and eggs and cysts of nine different enteroparasites (helminths and protozoa) was investigated using three different conditions of contaminated water. The microbial samples were suspended in tap water and filtered using quadruple CCF. The experiments were carrying out for eight days by taking two samples at intervals of 24 h from the top (raw water) and bottom (filtered water) units. Bacterial and parasitological analyses were performed according to current methods often used for drinking water quality monitoring. The experiments confirmed that CCF was very efficient to guarantee water free from *P. aeruginosa*, *E. coli*, and enteroparasites. We concluded that CCF can be used as a household method to provide safe drinking water with the advantage of being an affordable and culturally acceptable solution as well as sustainable and particularly indicated for low-income communities where the access to safe water, sanitation and healthcare are limited.
Keywords – Ceramic candle filter, *Escherichia coli*, enteroparasites, *Pseudomonas aeruginosa*.

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I. INTRODUCTION

More than one billion of people worldwide still do not have access to potable water, particularly people in the developing world, rural areas and low-income communities [1]. Contaminated water contributes to global illnesses, seriously increasing the number and severity of infectious diseases due to pollutants. Potable water must be freed from chemical and biological contaminants, as well as presenting an acceptable appearance [2].

Water quality is generally defined in terms of its physical, chemical and biological components [3]. Nevertheless, millions of people do not have access to drinking water [4]. Microbial, chemical, and radiological contamination can occur at the source of the water both from the surface and in the ground. Additionally, in a distribution system after water has been cleaned in a water treatment plant, there are additional opportunities for drinking water contamination, including pipes not successfully protected from contaminants as well as improper storage [5].

The lack of drinking water is even more serious in the semiarid regions of developing countries because in those areas there is no adequate means of supply or distribution. The main sources of water supply for the local population are: dams, weirs, runoffs, shallow wells, springs and rainwater. All of these are susceptible to contamination by water borne diseases. In addition, drinking water problems in semi-arid regions are also related to long periods of drought and inadequate use of rainfall storage [6].

According to the Brazilian Ministry of Health, when investigating the presence of coliform bacteria, it is essential to define the microbiological standard of water quality. In other words, the presence of Escherichia coli, faecal coliform, in water is a basic test to determine faecal contaminated water or contaminated food, which means that other pathogenic organisms such as helminths, protozoa and enterovirus could also be present [7].

Studies in the literature have proposed household water treatment as part of the solution to provide safe drinking water [8]. Filtration systems appear to be an alternative affordable to low-income communities and easy to operate at the household level to provide acceptable quality drinking water for domestic purposes [9]. Several ceramic pot filters were tested in order to demonstrate their efficacy with regard to the production of safe drinking water [10]. The rapid filtration device showed inefficient bacterial retention [11] while the silver-impregnated porous pot filter resulted a high-quality water due to the bactericidal property of silver [12].

The effectiveness of ceramic pot filters is also related to the ceramic candle filter (CCF). It has been documented that CCF may decrease high levels of bacterial, especially *E. coli* as well as reducing water turbidity, making it a preferential device in terms of household drinking water treatments [13]. The aim of the present study, then, was to evaluate the efficacy of CCF in the removal of biological contamination.

II. MATERIAL AND METHODS

2.1 Biological retention assay

We used São José brand ceramic filter pots – CFP (Fig. 1), traditionally manufactured by the Brazilian industry. These consist of a dome-shaped candle filter, a tap, and two containers, generally made of baked clay. On the top is a 6L unit for receiving tap water and on the bottom, a 6L unit to store the filtered water. Connected to the two units, there is a porous ceramic candle, protecting an inner layer of colloidal silver, covering a compartment containing activated carbon, with a minimum flow of 0.5 L/h (Stéfani, Jaboticabal, Brazil).

Prior to use, all the CFP were washed thoroughly with a water:ethanol solution (30:70) and rinsed several times with distilled water. Three conditions were tested: F1 – water contaminated with *P. aeruginos*a ATCC 27853; F2 – water contaminated with *P. aeruginosa* ATCC 27853 and *E. coli* ATCC 25922; and F3 – water contaminated with *Ascaris lumbricoides*, *Trichuris trichiura*, *Taenia* sp. and *Ancylostoma* sp. eggs, and *Blastocystous* sp., *Giardia* sp., *Entamoeba coli*, and *Entamoeba histolytica* cysts. A control without contamination was also tested for comparison (F4). Bacterial suspensions were adjusted to 1 McFarland turbidity standard and diluted in 3L of tap water to achieve an initial concentration of 10^3 cells/mL. An enteroparasite infectant dose was also prepared by adding 10 mL of 4% formalin containing eggs and cysts of helminths and protozoa from faeces samples, which were provided by the Parasitology Department of UFPE. The experiments were running out for a period of eight days at 25 ºC. Each interval of 24h, samples of 100 mL were aseptically collected from the top and from the bottom units.

Fig. 1. São José Ceramic filter pots

2.2 Microbial and parasitological analyses

P. aeruginosa was enumerated by the Most-Probable-Number (MPN) technique. *E. coli* enumeration was determined through the Multiple Tube Fermentation technique, using Fluorocult broth, which indicates the presence of total coliforms and E. coli by change of colour and fluorescence under 366nm UV lamp, respectively. The MPN/mL was calculated by MacCrady Table [14]. For the enteroparasite detection, water samples were centrifuged at 2500 rpm for 5 min, according to Faust method [15]. Microscopy observations with the samples stained with lugol were performed by Hoffman method [16]. Tests were conducted in triplicate.

III. RESULTS

The CCF removed 100% of *P. aeruginosa* ATCC 27853 cells by day 8 in F1, as demonstrated in Fig. 2. This percentage was reached in F2 by day 2, however the values oscillated through the assay. Differently, the removal of *E. coli* ATCC 25922 reached nearly 100% in F2 (Fig. 3). It is important to say that on days 3 to 5 bacteria were detected. The percentage of the cell reduction was around 80%. All enteroparasite transmissible forms were confirmed as having been removed from the filtered water.

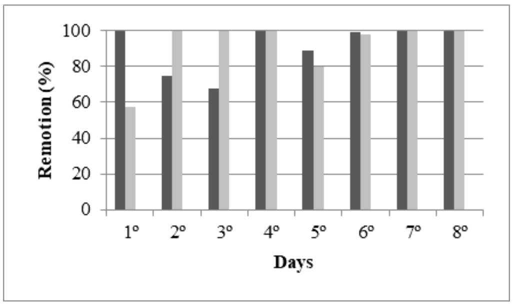

Fig.2. Percentage of *Pseudomonas aeruginosa* ATCC 27853 removal in F1 (dark gray) and F2 (light gray) over eight days

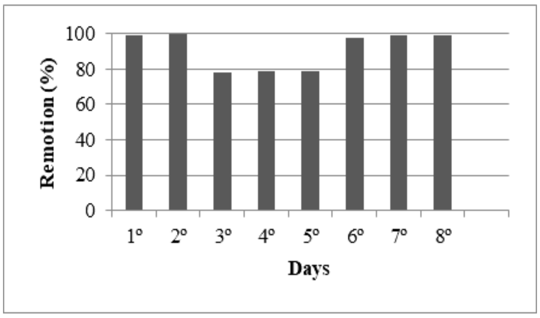

Fig.3. Percentage of *Escherichia coli* ATCC 25922 removal in F2 over eight days

IV. DISCUSSION

This study evaluated the CCF effectiveness for bacterial and enteroparasite removal from water samples. These results are in support of research data published demonstrating that the CCF is bacteriologically effective in reducing microbes to safe levels [1,17]. Moreover, there was complete removal of the non-enteroparasites during filtration since the porosity of the candle was able to retain 100% of tested cysts and eggs that ranged from 6 to 70 µm in diameter. It has already been documented that CCF may retain 100% of Giardia duodenalis cysts, with or without activated carbon, in candles with minimum of 0.5 µm of porosity [11].

These enteroparasites contribute to a rapid growth in waterborne disease outbreaks and affect a large number of people. Protozoa, such as *Giardia* spp., *Entamoeba* ssp., and *Blastocystis* ssp. are between the most common worldwide [18]. Giardiasis symptoms include diarrhoea and abdominal cramps in severe cases because of absorption deficiencies in the small intestine. Giardiasis has also been associated with drinking water for over 30 years [19].

It is important to note that the use of ceramic filters can prevent many waterborne diseases. In some regions there is a habit of storing water for consumption in tanks or vessels. A study carried out in a small, poor town in the Northeast of Brazil, analysed 132 water samples that had been stored in tanks or clay pots. Coliforms were detected in 87.1% of the water stored in tanks and 94.3% in clay pots. In addition, enteroparasite analysis from samples of stocked rainwater have shown that at least 34.8% presented one or more parasite, helminths or protozoan species, for example *Giardia* spp cysts; *Ascaris lumbricoides*, *Entamoeba coli* and *Entamoeba histolytica*/*E. dispar* [6]. Thus, results presented in this present study help to contribute to a greater dissemination of the use of these home filters as inexpensive options for water treatment, as well as to encourage the return to the use of these clay pot filters at home, guaranteeing the consumption of safer water [20,21,22,23].

The presence of *Escherichia coli* and other microorganisms are used worldwide as indicators of recent faecal contamination and the risks they may represent. These organisms are used as indicators due to their low pathogenic potential, high levels in sewage and faeces, and relationship to pathogen presence. However, these indicators have many limitations due to the great diversity of pathogens that are known to be present in sewage, including enteroparasites, such as helminths and protozoa [24].

The CCF were also completely efficient in removing *P. aeruginosa* ATCC 27853. Even though the test for *P. aeruginosa* is required by Brazilian regulations for bottled water [7], the literature has recognized its pathogenic importance and the risks for human health in terms of drinking water quality. P. aeruginosa competes for nutrients with *E. coli*, producing means to inhibit the growth of E. coli but not eliminate it, since favourable conditions may allow the regrowth of *E. coli*, which represents health risks [25]. A previous study has reported that pyocyaning-producing *P. aeruginosa* strains inhibited two enterobacteria adhesions on a ceramic surface but did not reduced planktonic cells suggesting that coliform cells under appropriate conditions may regrow, which highlights *P. aeruginosa* or its phenazinic pigment as a potential indicator in colimetric analyses [26].

Although the risks of contamination by pathogenic bacteria and enteroparasites transmitted by contaminated drinking water are greater in developing countries [27], we should also consider literature reports in the last decades of outbreaks of enteroparasites in developed countries, such as in Norway, the USA and the UK [28]. Given this, our study suggests that the use of the CFP should be widespread, not only in developing countries in order to ensure a better quality of water. This is always provided that proper care with regard to cleanliness of the units is observed, as well as the replacement of the CCF after its time of use.

V. CONCLUSION

Based upon our results, we conclude that effectiveness of CCF was observed in terms of the removal of pathogenic bacteria as well as infectant forms of enteroparasites. Pottery filter containers coupled with CCF provide an acceptable option for household drinking water treatment. In addition, they provide an affordable and sustainable solution particularly indicated for low-income communities where there is limited access to safe water.

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