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A biological, chemical and pharmaceutical analysis of distillate quality from solar stills

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Abstract

As fresh and abundant water sources become increasingly scarce, desalination methods based on renewable energy emerge as a sustainable alternative. The solar still is one such method that has received notable revived attention recently. Research primarily focused on enhancing the productivity of the still with a very limited number of studies addressing the water quality issue of the distillate produced by the still, as it is often assumed that this distillate is safe to consume without proper analysis. In addition a very limited number of studies have examined the ability of the still to remove conventional and emerging contaminants such as pharmaceuticals. The objective of this paper is to address the bacteriological and chemical aspects of the distillate produced from a number of different water sources using several experimental setups. Results show that moderate temperature alone is not sufficient to kill bacteria hence the importance of ultra-violet light from solar radiation. It is also important that all parts of the still be accessible to sunlight to avoid bacterial breeding at shaded sections. Chemical quality parameters were found to be within the limits recommended by WHO standards for potable water. As for the pharmaceuticals considered, all three compounds that were spiked into the feed water were completely absent from the distillate, however, degradation products were found in the brine. The level of pharmaceutical degradation was influenced by the solar still configuration.

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Keywords: *Bacteria; Pharmaceutical; Solar Still; Water Quality*

1. Introduction

As fresh water resources become more limited, the search for sustainable water resources has grown to be an urgent need. An old sustainable water production tool is the solar still that has long been used as a presumably safe

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method to produce potable water. Its principle is simple: brackish or seawater is placed in a basin covered with transparent glass or plexiglass and subjected to sunlight. The water in the basin evaporates and hits the inclined cover of the still where it condenses and trickles down to be collected in a distillate channel as 'clean' water. The solar still is relatively easy to construct and operate and depends only on renewable energy. Recently, the solar still has received revived attention to improve its relatively limited productivity. These developments have continued unabated and several recent reviews (Ayoub and Malaeb, 2012; Kumar et al., 2015; Yadav and Sudhakar, 2015; Rufuss et al., 2016; Sharshir et al., 2016; Edalatpour et al., 2016) confirm the sustained interest in improving the yield of these devices. On the other hand, few studies discussed the quality of the distillate resulting from solar stills. In this context, contradictory results appear in the literature. Some studies report that the distillate produced by a solar still is totally disinfected and suitable for consumption (Qasim 1978; Medugu and Malgwi 2006; Flendrig et al., 2009; Schwarzer et al., 2009; Gude et al., 2010; Valenzuela et al., 2010; Eze et al., 2011). Whereas a number of other studies find that bacteriological contamination is present in the distillate (Balladin et al., 1999; Hanson et al., 2004; Chaibi and El Nashar, 2009; Malaeb, 2011; Kikuchi et al., 2012; Ahsan et al., 2014).

These inconsistent results shed doubts as to the health safety of distillates resulting from solar stills. Although studies that reported the presence of bacterial contamination in solar still distillate have not confirmed nor substantiated the sources of such contamination, a number of hypotheses may be cited as to the conditions that could have led to this contamination. One study attributed contamination to salinity and growth of algae and micro-flora that might affect the disinfection process in the still by sheltering microbial contaminants from UV radiation (Chaibi and El Nashar, 2009). Another group hypothesized that bubbles created by the turbulence of adding water to the basin could burst and form droplets on the cover, which contaminated the distillate (Hanson et al., 2004). Balladin et al. (1999) attributed their distillate bacterial findings to airborne microorganism contamination and low chloride concentration. In fact, a contaminated distillate could result in one of three events: (i) the reactor is contaminated and UV radiation is not available; (ii) in the presence of UV radiation but with parts of the reactor being shielded from such radiation thus creating locations for bacterial breeding with consequent transfer to the distillate; and/or (iii) where a specific bacteria transfer mechanism moves the bacteria from the contaminated feed water to the distillate. No studies have attempted to address these possibilities in detail in order to elucidate the primary cause of bacterial presence in the solar still distillate. Our group has suspected either possible cross contamination or a potential bacterial transfer mechanism (Malaeb, 2011; Dahdah, 2013; Ayoub et al., 2014) and has investigated whether bacteria in humid atmospheres can get transferred through water vapor only to the distillate in the dark. Results showed that bacteria got transferred with the vapor in the absence of solar radiation, with the number of colonies transferred being dependent on bacterial size, water type and temperature (Ayoub et al., 2014).

In addition to the biological side, studies on the chemical properties of the distillate from solar stills are also limited to a few number. Joseph et al. (2005) showed that chemical parameters of the distillate produced by a single-stage solar still system were within desirable standards using seawater as feed. Samee et al. (2007) found that pH, conductivity and total dissolved solids (TDS) of the distillate from a simple single basin still were within WHO limits. Similarly, Schwarzer et al. (2009) reported acceptable distillate quality parameters using both seawater and groundwater as feed. On the other hand, Ahsan et al. (2014) obtained a removal efficiency of 24, 80 and 99 % for salinity, pathogenic bacteria and arsenic respectively in a simple triangular solar still, whereas Velmurugan and Srithar (2010) noted that the distillate they obtained from a single basin still was very low in minerals and minerals have to be added before consumption. Furthermore, published data on the effectiveness of treatment of variously contaminated waters with emerging contaminants via solar stills is rare. Hanson et al. (2004) reported that stills showed mixed success as to the removal of volatile organic contaminants such as pesticides, depending on the volatility of the compound as given by Henry's law constant. In our research group, Baalbaki (2016) and Baalbaki et al. (2017) studied the transfer of five pharmaceuticals (ibuprofen, diclofenac, carbamazepine, ampicillin and naproxen) into the distillate of solar stills. Results showed that ibuprofen, was the only pharmaceutical that transferred via vapor into the distillate, most likely due to its relatively high volatility. Although naproxen and diclofenac did not undergo transfer to the distillate, their degradation byproducts did. For naproxen, ibuprofen, diclofenac and Carbamazepine, both high temperature and sunlight combined were required to observe noticeable degradation in the solar still; on the other hand, ampicillin was very stable exhibiting zero degradation.

Therefore, the solar still presents itself as a competitive alternative in terms of removing emerging contaminants that are difficult to remove by other methods. To illustrate, conventional water treatment processes such as coagulation, flocculation, and precipitation are reported to be largely ineffective in removing these emerging contaminants (Sharmin and Chowdhury, 2016). Ozonation can remove around 80% of caffeine, pharmaceuticals and