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Comparative Study of Renewable Energy Based Water Disinfection Methods for Developing Countries

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Abstract: This study was carried out to compare three renewable energy based water disinfection methods (boiling, solar disinfection and granular activated carbon filtration) for developing countries, in order to estimate which is cost effective. A very large segment of the world's population is without microbiologically safe water supply. Obtaining clean drinking water is a constant challenge in many countries. Often the only water available is rife with disease-causing bacteria and must be disinfected to make it safe. The lack of money needed to develop the elaborate drinking water infrastructure in addition to the difficulty or impossibility associated with importing materials and expertise necessary for sustainable operation of such facilities demand techniques capable of eliminating or neutralizing water-borne pathogens using little or no external input such as capital, material, expertise etc. The water samples for this study were collected from Aso River and a borehole both in Nsukka into two containers. These water sources are used by the villagers. The control and treated samples were collected and analysed for coliform and total viable count, using modified method of Miles and Misra. The results showed that the best means of water disinfection is boiling which destroyed all the coliform in the water samples while the use of solar could be considered a cheaper alternative although it did not eliminate completely the microbial load impeding suitability for drinking. However, granular activated carbon filtration should be discouraged, as it had a negative effect of increasing the microbial load of the water samples.

Key words: Borehole, boiling, filtration, pathogen, coliform, countries

INTRODUCTION

Water is a chemical substance that is essential to all forms of life. It is employed by man for several purposes such as in the industry as solvent, in agriculture for irrigation, for recreation, travel, commerce and as regards this study-domestic uses. To meet the above needs, it must satisfy certain requirements. The major sources of water in developing countries are rain, streams, well, boreholes etc (Health Canada, 2008). A very large segment of the world's population is without microbiologically safe water supply. It is estimated that in Latin America more than 40% of the population is utilizing water of dubious quality for human consumption. This value is probably even higher in Africa and areas of Southeast Asia (Reiff *et al.*, 1996). Obtaining clean drinking water is a constant challenge in many countries. Often the only water available is rife with disease-causing bacteria and must be disinfected to make it safe (IDRC, 1998).

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Water disinfection means the removal, deactivation or killing of pathogenic microorganisms. It is one of several interventions that can improve public health. Water-borne disease in developing countries leads to millions of deaths and billions of illnesses annually (Burch and Thomas,1998). It is also necessary to eliminate pathogens, as many horticultural products are to be consumed raw and in regions with high values of solar radiation it can be used for this purpose (Tripanagnostopoulos and Rocamora, 2007). Some waterborne pathogenic microorganisms spread by water can cause severe, life-threatening diseases. Examples are typhoid fever, cholera and Hepatitis A or E. Other microorganisms induce less dangerous diseases. Often, diarrhea is the main symptom. Many people in most developing countries suffer from the inadequacy or hazardous condition of public water supplies (WHO, 1985). Also, total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm and cold-blooded animals. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being *Escherichia coli* (Kotoski, 1997). Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. It is also used as an indicator to show that other potentially harmful bacteria may be present. Disease-causing microbes (pathogens) in these wastes can cause cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children and people with severely compromised immune systems (EPA, 2008). A wide variety of known waterborne diseases, including those associated with children's diarrhea, are rampant (WHO, 1987). Improper management of abattoir wastes and subsequent disposal either directly or indirectly into river bodies portends serious environmental and health hazards both to aquatic life and humans (Omole and Longe, 2008).

There are available methods to disinfect water. There is no ideal disinfection method; each has it advantages and limitations. Choosing a disinfection technique involves accepting the advantages and living with the limitations. Water can be disinfected by boiling it, by adding oxidizing agents like chlorine or iodine, or by exposing it to ultraviolet light etc. (Eubank *et al*., 1995). The lack of money needed to develop the elaborate drinking water infrastructure in addition to the difficulty or impossibility associated with importing materials and expertise necessary for sustainable operation of such facilities demand techniques capable of eliminating or neutralizing water-borne pathogens using little or no external input such as capital, material, expertise etc. This study was therefore carried out to compare three renewable energy based water disinfection methods for developing countries, in order to estimate which is cost effective.

MATERIALS AND METHODS

The study took place from the November to December 2009 at the National Centre for Energy Research and Development (NCERD) University of Nigeria Nsukka. Nsukka is located at (6.9°N, 7.4°E) and 445 m above sea level. The materials used for the study were Polyethylene tephthalate (PET) bottles, activated charcoal, funnel, filter paper, kettle and heater, autoclave, incubator, oven, Electronic balance, water bath, colony counter, hot plate, bunsen burner, test tubes, petri dishes, pipettes.

Sampling

All containers were washed with 1:1 HCL. The water samples were collected from Aso River and a borehole both in Nsukka into two containers. These water sources are used by the villagers (Okoye, 2005).

Procedure

Boiling

Seven hundred and fifty milliliter each of the two water samples were measured separately into a kettle and boiled for 15 min. It was left to cool and transferred into container (Brouhard, 2009). Another 750 mL each of the two water samples were measured separately into a kettle and boiled for 1 h, 30 min. It was left to cool and transferred into container.

Solar Disinfection

Seven hundred and fifty milliliter each of the two water samples were measured separately into PET bottles, put out in the sun on top of a roof for six hours and left to cool (Anonymous, 2009).

Granular Activated Carbon (GAC) Filtration

A filter paper was folded properly into a funnel and activated charcoal was poured into it. Seven hundred and fifty milliliter each of the two water samples were separately passed through the activated charcoal and filtrate collected into a container (Turner, 2009).

Analysis

The samples were sent to the lab for analysis immediately after disinfection.

The water samples without any treatment were used as control. The control and treated samples were analysed for coliform and total viable count, using pour plate technique described by Okaka (2005) as follows:

Total Viable Count

One milliliter of the water sample in 9 mL of ¼ Ringer solution was mixed with the Nutrient Agar that has been cooled to 45 to 50°C and poured in a petridish. After incubation, the colonies that developed were counted and the concentration of the micro-organism in the original suspension was estimated. This was done in duplicates and the average taken in counts mL^{-1} Okaka (2005).

Coliform Count

One milliliter of the water sample in 9 mL of ¼ Ringer solution was mixed with the MacConkey's Agar that has been cooled to 45 to 50°C and poured in a petridish. After incubation, the colonies that developed were counted and the concentration of the micro-organism in the original suspension was estimated. This was done in duplicates and the average taken in counts mL^{-1} Okaka (2005).

RESULTS

As shown in Table 1, the Total Viable Count (TVC) of the water samples were 4.50×10^4 and 8.10×10^4 cfu mL^{-1} while for the disinfected samples, it was between 4.00×10^2 to 2.87×10^5 cfu mL^{-1}. As shown in Table 2, the coliform count of the water samples were 1.08×10^3 and 3.00×10^3 cfu mL^{-1} while for the disinfected samples, it was between 0.00×10^0 to 2.72×10^4 cfu mL^{-1}. The borehole sample had higher TVC and coliform count than that of the river sample. Total viable count and coliform count of the control samples were higher than that of the boiled (for 1 h 30 min) and solar disinfected samples. But the TVC and coliform count of the filtered samples and the boiled (for 30 min) were higher than that of the control samples.

Table 1: Results of total viable count of the water samples

Water samples	Total viable count (cfu mL^{-1})
Boiled (borehole) for 15 min	1.40×10^5
Boiled (river) for 15 min	6.50×10^3
Boiled (borehole) for 1 h 30 min	4.00×10^2
Boiled (river) for 1 h 30 min	6.10×10^2
Filtered (borehole)	2.87×10^5
Filtered (river)	2.02×10^5
Solar (borehole)	2.00×10^3
Solar (river)	5.00×10^3
Control (borehole)	8.10×10^4
Control (river)	4.50×10^4

Table 2: Results of coliform count of the water samples

Water samples	Coliform count (cfu mL^{-1})
Boiled (borehole) for 15 min	1.00×10^4
Boiled (river) for 15 min	3.60×10^4
Boiled (borehole) for 1 h 30 min	0.00×10^0
Boiled (river) for 1 h 30 min	1.00×10^0
Filtered (borehole)	2.72×10^4
Filtered (river)	4.60×10^3
Solar (borehole)	8.00×10^0
Solar (river)	1.00×10^0
Control (borehole)	3.00×10^3
Control (river)	1.08×10^3

DISCUSSION

Total Viable Count (TVC) of the borehole sample was 8.5×10^4 cfu mL^{-1} which was higher than that of the river sample with concentration of 4.5×10^4 cfu mL^{-1}. The TVC is a basic test for drinking water quality. The test gives a reading for all bacteria present. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water might have been contaminated by pathogens or disease producing bacteria or viruses which can also exist in fecal material. The result obtained seems to be contrary to the fact that water from borehole is considered safer for drinking than river water. However, it should be made clear that as the river water is the main source of water for drinking in the area of study, activities such a washing and indiscriminate disposal of waste will be curbed as much as possible. As already established, contaminants can find their way into ground water through activities like industrial discharges, seepage of municipal landfills, septic tank effluents etc. (Okuo *et al*., 2007). The major contributions to pollution of the rivers are the households that throw their waste materials into the rivers and those whose waste water eventually end up in the river (Ogbonna *et al*., 2008).

The water from borehole in the process of being transferred into a water tank might have been contaminated and the seepage from drainage tanks around the area including farmlands is another possible source of contamination. Infact, many of the small premises do not have access to any disposal system other than allowing waste to soak into the ground. Industrial contaminants can also gain access to the local aquifer either via interaction with the surface water bodies or directly through infiltration (Yusuf, 2007). However, with disinfecting through boiling and solar disinfection, the TVC of the water samples reduced. But with disinfecting through granulated activated charcoal filtration, the TVC ended up increasing (Table 1).

The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Some waterborne pathogenic diseases as a result of this include typhoid fever, viral and bacterial gastroenteritis and hepatitis A (Kotoski, 1997). The coliform count of the borehole sample which was 3×10^3 cfu mL^{-1} was also higher than that of the river sample which was 1.08×10^3 cfu mL^{-1}. However, this was totally removed after boiling for 1 h 30 min and also after only solar disinfecting. The results show that the best means of water disinfection is boiling for as long as one hour thirty minutes. The water that was allowed to boil for about 15 min did not show any considerable reduction in the microbial load. Boiling may concentrate any harmful contaminants that do not vaporize as the relatively pure water vapor boils off. The solar disinfection method is also good as it completely eliminated the microorganisms. The filtration method which employed the use of activated charcoal was found to further contaminate the water from 8.10×10^4 to 2.87×10^5 cfu mL^{-1} for the borehole sample and from 4.50×10^4 to 2.02×10^5 cfu mL^{-1} for the river sample. The findings reveal that GAC filters, by themselves, can not remove bacteria as also stated by Johnson (2005). For surface waters with heavy levels of fecal or sewage contamination, filters should not be used as the sole means of disinfection. One rational use of filtration is to clear the water of sediment and organic debris, allowing more accurate, lower doses of halogens. Filters are mainly useful as a first step to remove parasitic and cryptosporidium organisms that have high resistance to halogens (Backer, 1995).

A benefit of all home filtration systems is that they are passive. That is, they require no electricity to filter the water and normal home water pressure is used to force the water though the filter. The only routine maintenance required is periodic replacement of the filtration element. If the filter holes are large enough, disease organisms can get through. Of special concern are viruses, which are small enough to penetrate a number of the common water filters in the market today (Anonymous, 2010). Granular Activated Carbon (GAC) are particles of carbon that have been treated to increase their surface area and increase their ability to adsorb a wide range of contaminants. The GAC filters do not require electricity, nor do they waste water. If a bed of charcoal that traps an occasional bacterium, picks up a bit of organic material and removes the chlorine from the water, one can see how these filters might become breeding grounds for the bacteria they trap (Johnson, 2005).

Comparing the results obtained from this study with the EPA (2008) standard of coliform count for drinking water, the boiled and solar disinfected water samples were okay as they were both zero as recommended. Whereas the filtered water samples were 2.72×10^4 and 4.60×10^3cfu mL^{-1} for the borehole and river respectively which were even higher than 1.08×10^3 and 3.00×10^3cfu mL^{-1} of the control samples.

Examining the cost for the different disinfection methods, many people boil with kerosene or electricity and to boil water for 1 h 30 min for disinfection will cost a lot while solar disinfection does not cost anything as the source of disinfection is the sun. However, granular activated charcoal is expensive but the method is a bit cumbersome as there is the need for a filter, careful set up and constant monitoring.

CONCLUSION

The results show that the best means of water disinfection is boiling while the use of solar could be considered a cheaper alternative although it does not eliminate completely the microbial load impeding the suitability for drinking. However, granular activated carbon filtration should be discouraged, as it increases the microbial load of water.

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