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A Comparative Review of the Traditional and Modern Methods of Water Treatment

Abayomi Olusegun Adeniyi[1*]

[1]*Department of Technical Education, Osun State College of Education, Ila –Orangun, Nigeria.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Artificial pollution of groundwater may arise from either point or diffuse sources. Several different means to improve the microbial quality of water and reduce waterborne diseases have been documented around the world. Traditional methods of water treatment include Filtration through winnowing sieve (used widely in Mali), Filtration through cloth (commonly used in villages in India, Mali and the southern part of Niger), Filtration through clay vessels (used in Egypt), filtration through plant material (commonly used in Tamil Nadu and Kerala, India) and Jempeng stone filter method (used in Bali, Indonesia). Modern methods of water treatment include Solar Water Disinfection (SODIS), LifeStraw, Nanofilter, Ceramic water filter, Bio-sand filter and Kanchan Arsenic filter. Comparatively, traditional methods of water treatment employ crude methods which have proved to be effective in relation to filtration but the modern methods make use of newer research technologies in the elimination of pathogens and toxic chemicals to make drinking water more potable and safe.

Keywords: Filtration; winnowing sieve; water treatment; solar water disinfection; lifestraw; nanofilter; ceramic water filter; bio-sand filter; kanchan arsenic filter.

**Corresponding author: E-mail: dnyolusegun@gmail.com;*

1. INTRODUCTION

Access to water can be from two sources namely surface water in the form of rivers, lakes, smaller reservoirs, natural or man-made (dams), and groundwater. Rain is the main determinant in the output of these sources and it contributes majorly to the uneven distribution of water in the planet as evident in some areas having much more quantity of water than they need (high rainfall intensity) thereby exposing such areas to floods while some other areas do not have enough water especially in dry regions where there is little rainfall [1]. Surface water that has been stable and uncontaminated for decades can change with a single storm, a drought or the degradation of the pipes, such as a water main break [2].

Artificial pollution of groundwater may arise from either point or diffuse sources. Some of the more common sources include domestic sewage and latrines, municipal solid waste, agricultural wastes and manure, and industrial wastes (including tipping, direct injection, spillage and leakage [3]. Contaminants, such as agricultural chemicals may spread over large sections of the aquifer recharge area, take decades to appear in the groundwater and perhaps longer to disappear after their use has ceased making the process of contamination a bit more complex [4]. Pollutants that are fully soluble in water and of about the same density (such as chloride-contaminated water from sewage) will spread through the aquifer at a rate related to the groundwater flow velocity, pollutants that are less dense than water will tend to accumulate at the water table and flow along the surface while dense compounds such as chlorinated solvents will move vertically downwards and accumulate at the bottom of an aquifer [5].

Several different means to improve the microbial quality of water and reduce waterborne diseases have been documented around the world which include common physical treatment methods like boiling, heating, settling, filtering, UV disinfection from sunlight, and UV disinfection with lamps and chemical treatment methods like coagulation-flocculation and precipitation, adsorption, ion exchange and chemical disinfection with germicidal agents such as chlorine but however, these treatment methods are laced with limitations that make many of them inaccessible to users in certain regions of the world [6,7].

This paper tends to review the various traditional and modern methods of water treatment in order to examine and compare their effectiveness.

2. MATERIALS AND METHODS

2.1 Traditional Methods of Water Treatment

Traditional methods of water treatment include the following:

2.1.1 Filtration through winnowing sieve

This type of filtration is used when the water source is polluted by wind-borne impurities such as dry leaves, stalks, and coarse particles. The raw water is passed through a winnowing sieve, and the impurities are filtered. This type of filter is widely used in villages of the Bamaka area, Mali.

2.1.2 Filtration through cloth

Thin white cotton cloth or a discarded garment is used as the filter medium. This method of filtration can filter raw water containing such impurities as plant debris, insects, dust particles or coarse mud particles and is commonly used in villages in India, western Nigeria, Mali and the southern part of Niger.

2.1.3 Filtration through clay vessels

Clay vessels with a suitable pore size are sometimes used to filter highly turbid water. Turbid water is collected in a big clay jar and allowed to settle down as the water in the jar trickles through the porous clay wall of the jar. This trickled water is collected in a vessel (usually a clay pot) by placing it at the bottom of the porous clay jar. This method is used in Egypt.

2.1.4 Filtration using plant parts

Highly turbid water with fine suspended and colloidal particles are first coalesced and settled out using the nuts of a locally available plant, in some of the southern districts of Tamil Nadu, Kerala, India, which is then filtered using cloth filters. Studies have found that the nuts excrete coagulant chemicals upon soaking which does the job. Similarly, wiry roots of the rhizomes from the ‘ramachham’ (*Vetiveriazizanoides*) are placed in a clay jar, which has tiny holes in its bottom. Raw water is poured into the jar and the water is allowed to filter thorough this layer of roots. The water then trickles through the tiny holes at the bottom of the jar and is collected at the bottom of the jar.

2.1.5 Jempeng stone filter method

This type of water filtration method is developed in Saringan batu Jempeng, Bali, Indonesia. A small artificial pond or a by-pass channel is cut by the side to an irrigation canal, which carries muddy water. Jempeng stone filter units are placed in the artificial ponds. The filter unit is carved out of a porous material called ‘cadas’. This unit has an average height of 60 cm, a diameter of 50 cm, and a wall with a thickness of 10–12 cm. This unit is placed on the top of a stone-supporting gravel bed. Muddy water filters through the porous wall of the filter unit and gets collected inside.

2.2 Modern Methods of Water Treatment

Modern methods of water treatment include the following:

2.2.1 Solar water disinfection (SODIS)

This is one of the methods of removing microbiological organisms associated with waterborne diseases using solar water disinfection, more commonly known as SODIS (Plate 1). The premise functions by inactivating waterborne microbes as a result of exposure to UV-A radiation and heat (pasteurization) when water of low turbidity (<30 NTU) is placed in clear PET plastic or glass bottles and exposed to direct sunlight for several hours (the official SODIS website recommends 6 hours so that it becomes sufficiently heated and exposed to UV radiation, both of which inactivate microbes in the water.

2.2.2 Life straw

LifeStraw is an invention by the Vestergaard Frandsen Group, shaped like a straw and a few centimeters thick (Plate 2). It uses halogenated resin to kill bacteria and virus as water is drunk straight through the straw. Halogenated resin compositions are prepared without using halogen acids by combining at least one silicone intermediate, with an optional silane, an organic halogen-containing ingredient having functional groups selected from the group consisting of hydroxyl amine, and carboxyl groups, and a resin selected from the group consisting of hydroxy- and epoxy-functional resins.

2.2.3 Nanofilter

Researchers at Stanford University developed the Nanofilter that kills bacteria with an electric field (Plate 3). The filter is an ordinary cotton fabric coated with highly conductive carbon nanotubes and silver nanowires as silver has long been known to have chemical bacteria-killing properties. The coated cotton is layered to about 2.5 inches thick and the pores of this filter are much larger than conventional filters, allowing water to flow through up to 80,000 times faster. Electricity passing through the filter kills the bacteria as electrons pass very smoothly over the filter due to the very small size of the nanoparticles that requires only a few milliamperes of current. The silver helps prevent ‘biofouling’ which is the buildup of bacteria caught in a filter, because any bacteria that lag behind will be killed by the silver nanowires.

2.2.4 Ceramic water filter

The ceramic water filter also known as PFP filter (Plate 4), developed by Potters for Peace is a simple bucket 11 inches wide, 10 inches deep made of local terracotta clay, mixed with a combustible fibre, such as sawdust or old rice-husks and coated with colloidal silver, known for its anti-microbial properties.

It is made by pressing the clay mixture in a mold of aluminium and then firing at 860° C, the simplest such press can be is a hand-operated hydraulic truck jack. This bucket is kept in a plastic or ceramic receptacle with a tap at the bottom and a lid. A filter rate of 1.5-2.5 litres/hour can be expected, depending on the clay/fibre mixture and firing temperature. A bucket can be expected to last about 40 months before having to be replaced. Colloidal silver is a solution of silver cations (negatively charged ions) in water. For use in filters, protein, such as xanthium gum, is added to keep the highly concentrated silver cations from separating from the water. Colloidal silver can kill bacteria by inactivating their metabolic enzymes, or attaching to the cellular membrane, causing the cell to grow too much and die.

2.2.5 Bio-sand filter

The Biosand filter (Fig. 1), is an adaptation of the slow sand filter. It has been proven to be just as effective as slow sand filters though laboratory and field tests. It is smaller than a traditional slow sand filter and more adapted to intermittent use, making it suitable for small-scale family use. It can be contained in concrete, plastic or other waterproof, rust proof and non-toxic material. Typically a cylindrical shape about 0.9 m tall and 0.3 m in diameter with the sand and gravel layered inside. Treated water collects at the base and is propelled by its own pressure to a spout at the top of the filter. The filter has a diffuser which is a perforated plate above the sand layer to dissipate the initial force of the water poured into the filter to allow evenly flow through the biolayer. A lid completes the system.

Plate 1. SODIS Bottles on a Roof [8]

Plate 2. Lifestraw demonstration [8]

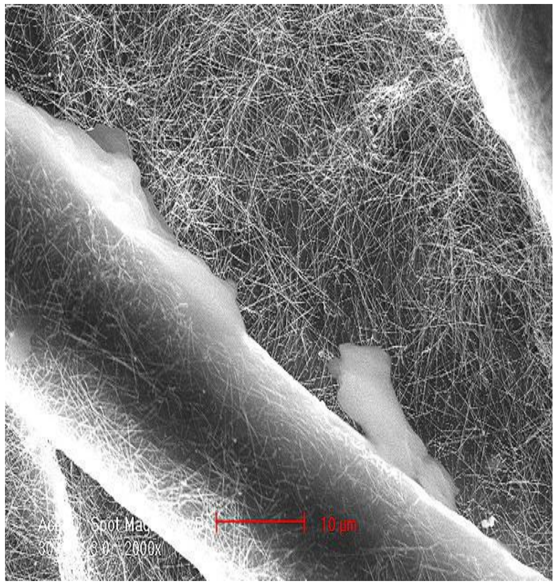

Plate 3. Section through a NanofilterPlate [6]

Plate 4. Ceramic Water Filter [6]

2.2.6 Kanchan arsenic filter

The Kanchan Arsenic filter (Fig. 2) works just the same as the Biosand-filter, but a layer of ungalvanized nails is added on the diffuser plate to filter out arsenic, a carcinogen. The nails filter arsenic by the principle of iron hydroxide adsorption; arsenate ions in water are quickly attracted by the iron oxide on the rusty nails and form bigger particles. These particles then dislodge and are filtered out by the sand-filter.

3. RESULTS AND DISCUSSION

3.1 Traditional Methods of Water Treatment

The method of Filtration through Winnowing Sieve cannot be used when the raw water is highly turbid or muddy, since the sieve cannot filter fine suspended particles in raw water [10].

Filtration of suspended particles present in water may not be achieved to a large extent under the method of Filtration through Cloth and therefore, this type of water treatment is not suitable for highly turbid water. It is most suitable for filtration of well water [11].

The method of Filtration through Clay Vessels is common in Egypt but the disadvantage is the inability to remove all pathogenic contaminants [12]. Usually, filtered water is very clear and has a pleasant smell when the method of Filtration using Plant Parts is adopted.

The method of Jempeng Stone Filter can only be adopted as a rural water treatment unit. Even though it can treat even highly turbid water, the main feature of this unit is that the only cost involved is the investment cost. Practically, there is no operational or maintenance cost for cleaning [13].

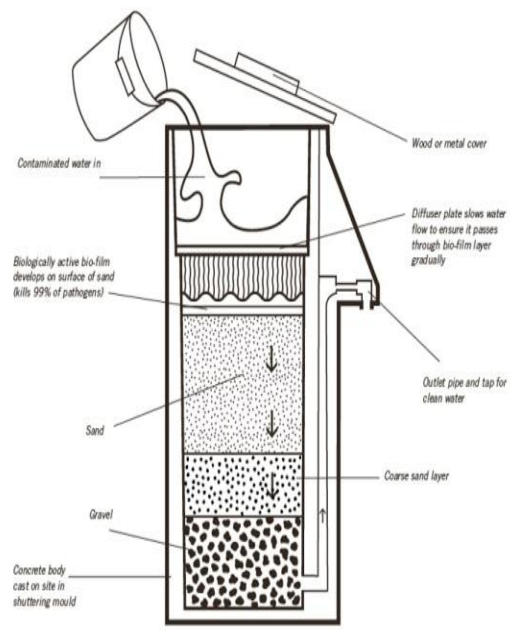

Fig. 1. Biosand Filter [9]

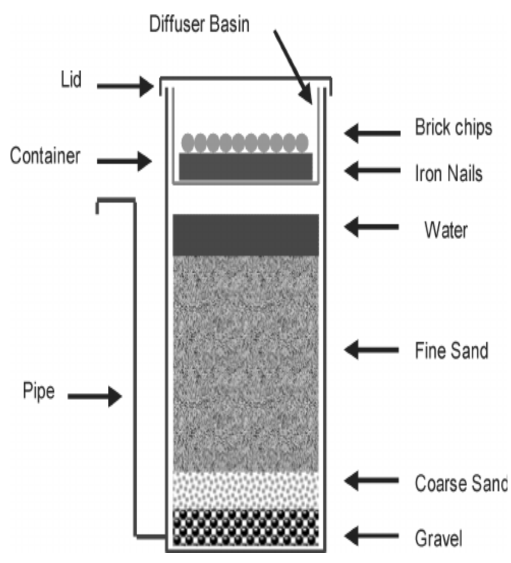

Fig. 2. Kanchan Arsenic filter [9]

3.2 Modern Methods of Water Treatment

The SODIS method of water treatment is simple, easy to use, and very effective at deactivating waterborne microorganisms but the limitations are:

a. Determination of the duration of time of exposure of water to the sun's radiation especially sometimes when the weather changes.
b. To ensure the effectiveness of this method, turbid water must first undergo filtration
c. To avoid recontamination, treated water must be drunk or used up quickly as plastic water containers are very notorious for bacteria growth.
d. There will be an increase in the temperature of water in the SODIS container and drinking warm water is not always very enjoyable especially if resources are not available to cool.

LifeStraw could reduce levels of iodine and silver to below toxicity but however, it does not remove heavy metals such as Lead (Pb) or Flouride (F) even though there is one version available that can filter Arsenic. The LifeStraw is an expensive filter, but may well save lives in connection with natural disasters where quick, short-term relief is needed.

Results from the Nanofilter tests revealed that 98% of *E. coli* bacteria were killed when subjected to 20 Volts of electricity during several seconds in the filter. Cotton is easily accessible and little electricity is needed but the nanomaterial will still be a difficult issue in developing countries. Notwithstanding, if materials are accessible, killing bacteria with an electric current will be much faster than conventional methods of filtering and disinfection with UV-light.

Field experience and clinical test results using Ceramic water filter have shown that the filter removes 99.88% of most water-borne disease agents. Bio-sand filter is smaller than a traditional slow sand filter and more adapted to intermittent use, making it more suitable for small-scale family use.

Field test results of the Kanchan Arsenic filter show 90-99% reduction of iron in the water and 85-95% reduction of Arsenic. The Arsenic filter is also better than the ordinary bio-sand filter in the reduction of high levels of iron.

4. CONCLUSION

In comparison, it can be seen that the traditional methods of water treatment employ crude methods which are very efficient to filter and produce clean water as evident in their construction but the modern methods have gone steps further to present newer refined systems that make use of research technologies in the elimination of pathogens and toxic chemicals to make drinking water more potable and safe.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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