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REVIEW

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Efficiency of common filters for water treatment in Tanzania

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Abstract

Background: Approximately 69% of population in Tanzania lacks better sanitation, while 45.6% lacks access to clean and safe water. To leverage this shortage, several technologies have been used for purifying water from various sources; however, there is still persistence of waterborne diseases.

Main body: This article reviewed the efficiency of common water filters in removing water contaminants such as *Escherichia coli*, fluoride, TSS, turbidity, nitrate, virus, BOD, COD, fecal coliform and color. Common water filters available in Tanzania markets include slow sand filter, ceramic filter, bone char, membrane purifier and bio sand filter. The effectiveness of each technology was evaluated in terms of its ability to remove water contaminants. Ceramic filter was found to be less expensive technology compared to the rest. Ineffectiveness of common water filters can be linked to persistence of waterborne diseases in Tanzania.

Conclusion: Ability of water filters in viral removal is of greater concern. This study suggests a ceramic filter as the best filter among all common filters available in Tanzania. Ceramic filters can be synthesized by locally available materials such as clay, saw dust, rice husk ashes and flour which make it efficient in removing all water contaminants, especially viruses.

Keywords: Waterborne diseases, Filters, Water contaminants, Tanzania

Background

Water is very important to all organisms where it acts as the main solvent to many substances and essential for the existence and development of life. According to World Health Organization (2017), inadequate sanitation is a major source of sickness in the world. UN (2017) affirmed that about 90% of diarrheal deaths are due to contaminated water, poor sanitation and poor hygiene. A report from joint monitoring program for water supply and sanitation by WHO and UN (2017) revealed that 4.5 billion people lack access to good sanitation. This shows that people are susceptible to waterborne diseases (Sullivan et al. 2017; Kilungo et al. 2018; Mukaratirwa-Muchayenyereyi et al. 2020). Additionally, the UN report released in 2019 indicated that 2.1 billion people throughout the world still lack access to clean drinking water. As a result, 2.2 million people die each year from waterborne diseases of whom majority of them are children under the age of five years (UN 2019). Aside from the human cost, the World Bank estimated that lack of access to safe water and good sanitation costs the global economy about $ 260 billion per annum (WHO 2017). Therefore, water has been a great issue to be considered all over the world and the various strategies should be envisaged to ensure equitable access to clean and safe water (Ajibade et al. 2014; Ugya et al. 2018).

Most of the developing countries lacks municipal water treatment systems to facilitate provision of adequate clean and safe water. Streams, ponds and rivers are their main source of drinking water which are susceptible to contamination by pathogens and chemicals. About 80% of wastewater is discharged into the environment without being treated or repurposed (UNESCO 2017). The

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problem of inadequate access to safe and clean water in developing countries is a major concern. According to the 2019 UN World Water Development Report, safe water and good sanitation are critical for eradicating poverty and building peaceful communities. In underdeveloped nations, the prevalence of gastrointestinal sickness is a typical sign of poor water quality and one of the primary causes of morbidity (UN 2017). Households have been using various point-of-use water treatment systems to obtain safe and clean drinking water (Mohamed et al. 2016). Despite the existence of such water treatment technologies, there is still persistence of waterborne diseases to those who cannot afford them. Tanzania in particular, faces challenges toward accessing safe and clean water due to pollution of surface and groundwater. Therefore, most of people in Tanzania are vulnerable to waterborne infections (TDHS 2010; Kiagho et al. 2016; Ainea et al. 2019).

Efficient purification systems can be used to suppress waterborne diseases. To date, there are several water filtration technologies available in the market. Water filters are essential in removing contaminants such as sediments, unwanted taste and odor, hardness and bacterial impurities from water for industrial and domestic use. Point of use (POU) water filtration systems are potential options for providing clean drinking water to the rural communities (Murphy et al. 2010a, b; Farrow et al. 2014; Mellor et al. 2014; Berg 2015). Ceramic water filters, membrane purifiers, bone char, slow sand filters, and bio sand filters are most common water filters found in Tanzania markets (Murphy et al. 2010c; Kiagho et al. 2016). The current review assesses the efficiencies of common water filters available in Tanzania. The performance of water filters in filtering water from various sources such as rivers, streams and ponds is presented. This study provides a general understanding on the water treatment technologies available in Tanzania markets to researchers, communities especially rural dwellers, policymakers, and market sellers. This will essentially strengthen the efforts to combat the existing problem of inadequate access to safe and clean water to reduce the persistence of waterborne diseases.

Main text

General water supply in Tanzania

Provision of clean and safe water is the basic human right. Several efforts have been envisaged to enhance water treatment at point of use to ensure the availability of clean and safe drinking water (Bartram et al. 2005; Mohamed et al. 2016). It has been reported that about 69% of population in Tanzania lacks better sanitation. People use water originated from rivers, streams and ponds as their main sources of drinking water. These sources are susceptible to contamination by pathogens and chemicals. In 1990, 45% of rural dwellers in Tanzania had access to safe and clean water. In 2015 the access to safe and clean water was reported to be 46% (TDHS 2010; Kilungo et al. 2018). 54.4% of the rural population had access to clean water (Kilungo et al. 2018). Health and demographic survey showed that about 17% of deaths are associated with diarrhea. Further reports revealed that 22% of urban residents and 9% of rural residents had access to better sanitation (Kilungo et al. 2018). This demonstrates that strategies to improve the quality of water are of a great demand. According to an economic analysis of the municipal water system, the cost of delivering centralized water for 10 years is roughly $221 per family. For the same period, the adoption of water treatment technology such as a ceramic filter costs around $63 (Ren et al. 2013). This suggests that using water technologies is more cost-effective and affordable than using municipal water treatment systems.

Problems associated with water systems available in Tanzania

Water systems can help people obtain clean water. However, several challenges associated with water systems force people to use untreated water that affect health of individuals (Klug et al. 2018). For example, high levels of iron in water are caused by corrosion of older hand pumps (Furey 2014). It has been reported that water systems that have been used for more than five years do not function effectively. Maintaining functional and sustainable water services is hence another challenge (Amjad et al. 2015). The functionality of water systems differs from one another depending on the type of water system. Table 1 summarizes the functionality and general limitations associated with water systems.

Table 1 Functionality and general limitations of water systems (Foster 2013; Bonsor et al. 2015; Cronk and Bartram 2017; Sweya et al. 2017)

Type of water system	Functionality (%)	Limitations
KSB	54.1	Age of the system
Afridev	67.2	Absence of user fee collection
Gravity	70.9	Poor treatment technologies
Cemo	64.2	Lack of access to external technical support
India Mark II	65.1	Seawater intrusion
India Mark III	48.9	Low storage capacities
Nira	74.1	System interdependency
Mono	48.9	Unbalanced investment

Table 1 indicates that the functionality of water systems is susceptible to various limitations. This information reveals that water obtained using these systems must be treated to remove contaminants. This can exquisitely be achieved using water purification systems such as slow sand filter, ceramic filter, bone char, bio sand filter and membrane purifier (Kiagho et al. 2016).

Common water treatment technologies available in Tanzania market

It has been reported that the common water treatment technologies for water treatment in Tanzania are slow sand filter, ceramic filter, bone char, bio sand filter and membrane purifier (Kiagho et al. 2016). Among them, ceramic filter has reportedly to be less expensive technology hence, it has been used in many countries (Brown et al. 2008; Farrow et al. 2018; Gupta et al. 2018).

Slow sand filter

A slow sand filter is a basic method for pathogen and particle removal (Lengbanch et al. 2009a, b). Larger bacteria are unable to pass through the pores of the slow sand filter (Thompson 2014). Physical, chemical and biological means of removing bacteria and suspended particles in raw water can be done by using slow sand filter (Lengbanch et al. 2009a, b; Bauer et al. 2011a, b; Ijadunolaet al. 2011). Slow sand is very effective in removal of turbidity and TSS than other water contaminants. Nevertheless, slow sand filter is poor in removing color. Routine cleaning can harm the bio layer and decrease the effectiveness of the filter. But also when using a slow sand filter, there's a sudden change in flow rate (Kiagho et al. 2016).

Bone char

Bone char plays an important role as an adsorbent in water pollution due to its outstanding physicochemical properties (Flores-Cano et al. 2016). It is widely used in the water deflouridation process (Medellin-Castillo et al. 2015). Bone char is very effective in removing. *Escherichia coli*, organic matter and turbidity. Bone char has been very effective in fluoride removal compared to other filters in India, Thailand and Tanzania (Mjengera and Mkongo 2003; Kaseva 2006; Kiagho et al. 2016). If the media of bone char is not well prepared it can produce odor and bad taste. In addition, the media need to be changed when the quality of produced water does not meet the acceptable standard level (Kiagho et al. 2016). There is a need to find an alternative way of preparing a bone char so that it can be effective in water treatment.

Bio sand filter

Bio sand filter is widely used in remote rural areas in Tanzania. Using bio sand filter can reduce diarrheal diseases by 50% or greater (Ngai et al. 2014; Stauber et al. 2009; Tiwari et al. 2009; Liang et al. 2010; Aiken et al, 2011). Bio sand filter shows best performance in *E. coli* removal than all common water filters. The ability of bio sand filter in turbidity removal is very high (Kiagho et al. 2016). The biggest challenge of bio sand filter is its inability to remove fluoride in water.

Membrane purifier

Membrane purifier is made up by activated carbon and other extra filter bags for lime, arsenic and heavy metals. Membrane purifier is very effective in removing *E. coli*, TSS and turbidity (Kiagho et al. 2016). The ability of membrane purifier in color removal is also very high than other common water filters but it has no ability to remove fluoride.

Ceramic filter

According to Agbo et al. (2017), ceramic filters are inexpensive and effective type of water filter that involve passing water through a permeable ceramic material. This ceramic-based water purification technology has been used in many countries in the world (Brown et al. 2008; Farrow et al. 2018; Gupta et al. 2018). Distinct reports have shown that ceramic-based purification system can be adopted in local communities. In Cambodia, Dominican Republic of India, and Sri Lanka, clay ceramic filters have been used for ensuring the provision of safe and clean water (Brown et al. 2008; Gupta et al. 2018). The technology has also been employed in providing clean water in rural China as well (Farrow et al. 2018). However, little has been practiced in Tanzania and the products lack practical validation under local conditions (Kiagho et al. 2016; Lemons et al. 2016).

Effectiveness of common water filters

The current review compares the effectiveness water filters to the standards set by WHO. The minimal health risk standard set by WHO is 99.9% removal of water contaminants signifying that a filter capable of removing water contaminants up to 99.9% seems to be most effective. Each common water filter was evaluated basing on its ability to remove several water contaminants. Customarily, the efficiency of common filters depends on the type of water contaminants to be removed. Studies show that there is no filter that can remove 100% of all water contaminants. Table 2 summarizes the efficiency of common water filters in Tanzanian market. It can be observed that bio sand filter is very effective in removing *E. coli* when compared to other common filters available in Tanzania market. Bone char filter is effective in removing fluoride in water. This is used mostly by people living in the Northern part of Tanzania due to the presence of

Table 2 Summary of the efficiency of common water filters in Tanzanian market on different studies (Kiagho et al. 2016; Lindgren and Overcrona 2016; Nigri et al. 2016; Mtavangu et al. 2017; Yaseen et al. 2019; Zachery and Oyanedel-Cravel 2022)

Type of filters	Turbidity (%)	TSS (%)	Color (%)	*E. coli* (%)	F (%)	F. C (%)	N (%)	Virus (%)	BOD (%)	COD (%)
BCF	66–100	70	64	87.9–100	0	96.8–100	47.4–97.2	70–99	52.6–93.3	45.1–89.1
SSF	98–100	95	31	75	0	85.7–100	45.9–95.4	85–90	43	52.62–93.3
CRF	100	100	32	68–99.9	0	94.7	–	96	53	–
BCF	100	99	5	96.5	73–98	–	–	–	50–83	79–83
MP	100	96	79	98.5	0	–	–	–	43.4	–

BSF, bio sand filter; SSF¸ slow sand filter, CRF, ceramic filter; BCF, bone char; MP, membrane purifiers; –, not reported

high fluorinated water. It was also observed that the ability of most filter to remove virus is low, hence a need for improving water filters to resolve that challenge.

Fabrication of ceramic water filter

The concept of ceramic-based water purification system has existed for a while and has been utilized in different forms. Contemporary ancient references approved that the existence of ceramic water filters with safe storage elements have been extensively used in Latin America for more than 100 years and have been produced in Britain since 1850 (Sobsey et al. 2008). Silver nanoparticles have been successfully used in water treatment applications (Haider et al. 2019, 2016; Hilonga et al. 2018; Dang et al. 2013). On the other hand, it has been discovered that the use of metal oxide is critical in the removal of organic contaminants from industrially contaminated water (Mutuma et al. 2015). Furthermore, adding hydroxyapatite or activated carbon to ceramic water filters can remove up to 93% of chemicals (Farrow et al. 2018). Interestingly, ceramic water filters with improved water purification properties can be prepared using locally available materials such as sawdust, rice husk ashes, flour and soil. The obtained water filter systems can be very essential in removing most of water contaminants, especially viruses which are very small in size.

Role of government in ensuring adequate water supply

Sustainable Development Goal 6 calls for provision of clean water and sanitation for all people. The impact of waterborne diseases can be very devastating if safe and clean water is not provided. Despite, the existence of vast water sources in Tanzania, the majority of people especially rural dwellers do not have access to safe and clean water. The global organizations such as UN set goals to halve population without sustainable access to safe drinking water and basic sanitation by 2015 (Thompson 2014). To date, there is inadequate access to safe water. The Tanzania Government supplied water in different areas through municipal systems. However, not all people have access to municipal system (Kilungo et al. 2018). There is a need for Tanzania government to increase efforts to combat the problem associated with waterborne diseases by investing in other water purification technologies.

Conclusions

The findings have shown that all common water filters are effective in removing certain water contaminants. The most common water filters used in Tanzania are very effective in removing turbidity. However, the ability of filters to remove fluoride and virus is still a big challenge. The usage of water filters that are poor at eliminating a variety of pollutants has made it more difficult to eradicate the problem of waterborne diseases. Increased efforts by the government, non-governmental organizations, policy makers, rural dwellers, and other stakeholders are needed to eradicate waterborne diseases. Several techniques are required, including fabrication of effective ceramic filters using locally accessible materials such as rice husk, sawdust, clay, and flour. Ceramic filters are less expensive than other water filtration technologies and may easily be embraced by the majority of people, particularly those who live in rural areas. The designing of ceramic-based water purification system capable of removing viruses and fluoride is in high demand, and the implementation of new designed ceramic filter is highly required.

Abbreviations

BOD: Biological oxygen demand; COD: Chemical oxygen demand; *E. coli*: *Escherichia coli*; F: Fluoride; F.C: Fecal coliform; KSB: Klein, Schanzlin & Becker; N: Nitrate; POU: Point of use; TSS: Total suspended solids; UN: United Nations; UNESCO: United Nations Educational Scientific and Cultural Organizations; WHO: World Health Organization.

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Author contributions

FEK participated in designing, writing, and submission of the manuscript. GNS Origination of the water purification systems idea, conducted research relating to the efficiency of common water filters and final approval of the version to be submitted. CF Organization of manuscript, editing of the manuscript and revised the manuscript critically for important intellectual content. EE Major Contributor in writing the manuscript and interpretation of the relevant literature. All authors proofread the work before submission. All authors read and approved the final manuscript.

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