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Ceramic Filters Coated with Green Ag-Nanoparticles for Drinking Water Treatment in Rural Households of Nigeria

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ABSTRACT: A ceramic water filter (CWF) coated with plant-based nanoparticles was used as household water purifier in a rural community. Silver nanoparticles (AgNPs) were produced from the stem bark of *Bridelia ferruginea* plant, and their efficacy to enhance the physical, chemical, and microbial quality of raw stream water sample was determined using analytical probes and pour-plate techniques, respectively. The pH of the filtered water sample ranged 7.6 to 8.1, which is within the WHO permissible limit for drinking water, and the electrical conductivity values were also reduced from 110 to 70 μS/cm. The CWF coated with AgNPs (CWF-AgNPs) removed *Klebsiella pnuemoniae, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Entamoeba histolytica* from the stream water sample. The highest percentage of coliform reduction in the CWF and CWF-AgNPs were 93.18% and 99.64%, respectively. The raw data showed that the CWF-NPs enhanced the quality of the stream water. The surface and internal structure of the CWF-AgNPs can be modified by varying the concentration of the composite materials, so as to determine the most effective combination. The improved CWF-AgNPs will enhance achieving United Nations Sustainable Development Goal #6, which focuses on clean water and sanitation.

PLAIN LANGUAGE SUMMARY: Ceramic water filter (CWF) coated with the stem-bark of *Bridelia ferruginea* plant was used as household water purifier in a rural community. The efficacy to enhance the physical, chemical, and microbial quality of raw stream water sample was determined using standard methods. The CWF improve the quality of the tested water and removed bacteria from the water samples. The CWF can be used for water treatment in rural households, as this will enhance achieving the United Nations Sustainable Development Goal #6, which focuses on clean water and sanitation.

KEYWORDS: Ceramic water filter, Water, Silver nanoparticles, ***Bridelia ferruginea***, Nigeria

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Introduction

Diarrhea, cholera, dysentery, typhoid fever, and some other neglected tropical diseases (amoebiasis, intestinal worm infection, and schistosomiasis) are major health issues in many developing countries, and this can be attributed to the consumption of unsafe water, poor sanitation, and hygiene (WASH).[1-3] Global reports have shown that more than 771 million people lack access to basic water services, of which 50% are in sub-Saharan Africa.[4] Water-related disease is responsible for millions of deaths annually,[3] and an estimated 1.7 billion cases of diarrhea infection are recorded every year, of which about 525,000 children die before they turn 5 years old.[5] Diarrhea has been reported to be the second leading cause of children's morbidity in the world, and this can be abated by an adequate supply of safe water, appropriate hygiene, and sanitation.[5,6]

In 2015, it was reported that water supply via pipes was reduced from 43% to 33% in urban centers across Sub-Saharan Africa.[7] So many people in these poor resource countries will have to depend on surface and ground water for their main water supply. Many rural households in developing countries will have to collect their water for domestic uses from streams and/or hand-dug wells, which are usually far away from their homes. The water collected from these unprotected sources is often contaminated or prone to contamination during collection, transport, and storage, and this has increased the incidence of waterborne infections.[8,9]

Chlorine and alum, commonly used in household water treatment (HWT), have been linked to certain health risks.[10] However, the use of ceramic water filters (CWF) as HWT technology is becoming more popular. It can be made from inexpensive and locally available materials.[11,12] The CWFs as a POU treatment option will filter out contaminants during the collection and storage of water.[13,14] In places where there are no piped water systems, CWF can be very helpful because of its efficient filtration process, as reported in many studies.[12,15,16] A CWF was designed in Guatemela, Central America, by Fernando Mazariegos in 1981 so as to make clean water accessible to everyone. Since 1998, Potters for Peace, a non-profit organization, has been engaged in the production of low-cost silver-enhanced ceramic purifiers throughout the world to make safe water available to everybody. Several studies have also reported the manufacture of CWF by combining clay, water, grog (previously fired clay), and burnout materials (such as rice husk, flour, and sawdust) in different proportions.[15-17] The combination is usually pressed to form a frustum shape and subsequently heated in a kiln.[12] The tiny pore size of the burnout material allows the infiltration of water through the filter. In recent times, CWFs have been coated with silver nanoparticles (AgNPs), which serve as a bactericidal agent and prevents the formation of biofilms.[18] Silver nanoparticle are tiny particles of silver with size range of 1 to 100 nm. The CWF coated with AgNPs (CWF-AgNPs) has the combined effects of size exclusion, disinfection, and prevention of recontamination.[13,19]

Many municipalities in Nigeria do not have access to central drinking water treatment facilities, and this can be attributed to limited financial resources. Like many other developing countries, over 50% of Nigerians do not have potable water. While hand-dug private wells are the major water sources in urban areas, streams and rivers are the main sources in the majority of the rural areas.[20-23] These water sources are often contaminated with agricultural run-off and fecal waste, and this may account for the high incidence of waterborne diseases in some parts of the country.[24-26] Ceramic water filters could be a promising option in these disadvantaged communities.

While many researchers have focused on the application of AgNPs coated ceramic filters to wastewater and laboratory spike water,[27-33] only very few reports are available on its applicability to natural drinking waters. And despite the long use of CWF in many countries, its knowledge and use in rural Nigeria are still very limited. Although CWFs coated with AgNPs have been reported to be effective in water treatment technology, the AgNPs are usually produced using chemicals. These chemicals are expensive because they are imported from developed countries and can be hazardous to the environment. However, local production of AgNPs from plant materials will reduce the cost of production and is not deleterious to the environment. Msoka et al.[34] synthesized nanoparticles using *Commelina maculata* leaf extract. The nanoparticles were immobilized on silica sand and the report showed up to 95% *E. coli* reduction in water. Also, Moustafa[35] applied green synthesized nanoparticles to remove pathogenic bacteria from wastewater and he reported a 97.3% to 98.5% reduction. In a similar study, Apea et al.[36] investigated the use of ceramic filter pot coated with colloidal silver to filter water samples from dam and municipal tap water. Their finding indicated coliform reduction of 2.31% to 76.97%.

Bridelia ferruginea is a medicinal plant belonging to the family Euphorbiaceae. It is a shrub tree about 15 m tall, fire-resistant, and termite proof.[37] It is commonly found in the Savannah forest of Africa and has a long use in folk's medicine.[38] The stem bark has a long historical use for milk coagulation during the production of local cheese and serves as a coagulant in wastewater treatment.[39]

The chemistry of natural water could be quite complex compared to laboratory water. Therefore, utilizing CWF on natural water is paramount to understanding the efficacy of the CWF in prior field trial studies. The aim of this study was to determine the effectiveness of CWF coated with green-AgNPs for the treatment of drinking water in rural households of Nigeria.

Materials and Methods

Fabrication of ceramic water filters

The CWFs used for this study were fabricated at the Atamora Pottery in Ikire, Osun State, Nigeria. Kaolitic clay was got from a natural deposit, and sawdust was collected from a local sawmill, both in Osun State, Nigeria. Sawdust was used as the combustible material in this study because it is readily available in Nigeria and more effective when compared with rice husk.[40] The clay, sawdust, and grog were sundried, pulverized, and mixed in a ratio of 5:2:1 by dry weight to make up the total weight of the CWF (62.5% clay, 25% sawdust, and 12.5% grog). This combination was chosen because it has been tested at the Atamora clay factory to be effective in purifying water. Grog was added to the mixture to prevent it from shrinking while drying and to enhance the flow rate.[15] Water was added to the mixture until a pliable paste was formed.[16] The paste was formed into a frustum-shaped pot using a hydraulic press. The filters were air-dried and fired in the furnace at 850°C for 8 hours. The CWF was allowed to cool until needed. The inner diameter of the top of the filter was 25 cm, the bottom diameter was 19 cm, the depth was 20 cm, and the wall thickness was 1.3 cm (Figure 1).

Preparation of the plant material

The healthy stem-bark of *B. ferruginea* used in this study was collected from a forest in the suburb of Iwo, Osun State, and authenticated by a plant taxonomist in the Pure and Applied Biology Programme, Bowen University, Iwo. The plant was dried at room temperature (25°C) for 21 days and pulverized to a fine powder using a mechanical grinder. Ten grams of the powder were added to 1000 mL of deionized water, and the solution was heated in a water bath for 15 minutes at 60°C, allowed to cool, and filtered using a Whatman No. 1 filter. The filtrate was preserved at 4°C until further use.

Synthesis of silver nanoparticles (AgNPs)

The AgNPs were prepared by a green reduction method as described by Lateef et al.,[41] in which 0.017 g of $AgNO_3$ was added to 100 mL of distilled water. Five milliliters of the plant filtrate were added to the $AgNO_3$ at room temperature (25°C), and observed for a color change from light yellow to dark brown, depicting the formation of AgNPs. The solution was centrifuged at 4000 rpm for 15 minutes and washed with deionized water until black particles were obtained. It was necessary to determine the size of the AgNPs, so as to ensure that the particles are within the nano-size range (1-100 nm), and this was done by placing 0.1 mL of the particles on a copper grid and observed using a scanning electron microscope (SEM). In 10 mL of deionized water, 0.1 g of the AgNPs was added. This was applied to the interior of the CWF using a clean paint brush, allowed to dry for 2 hours and labeled as

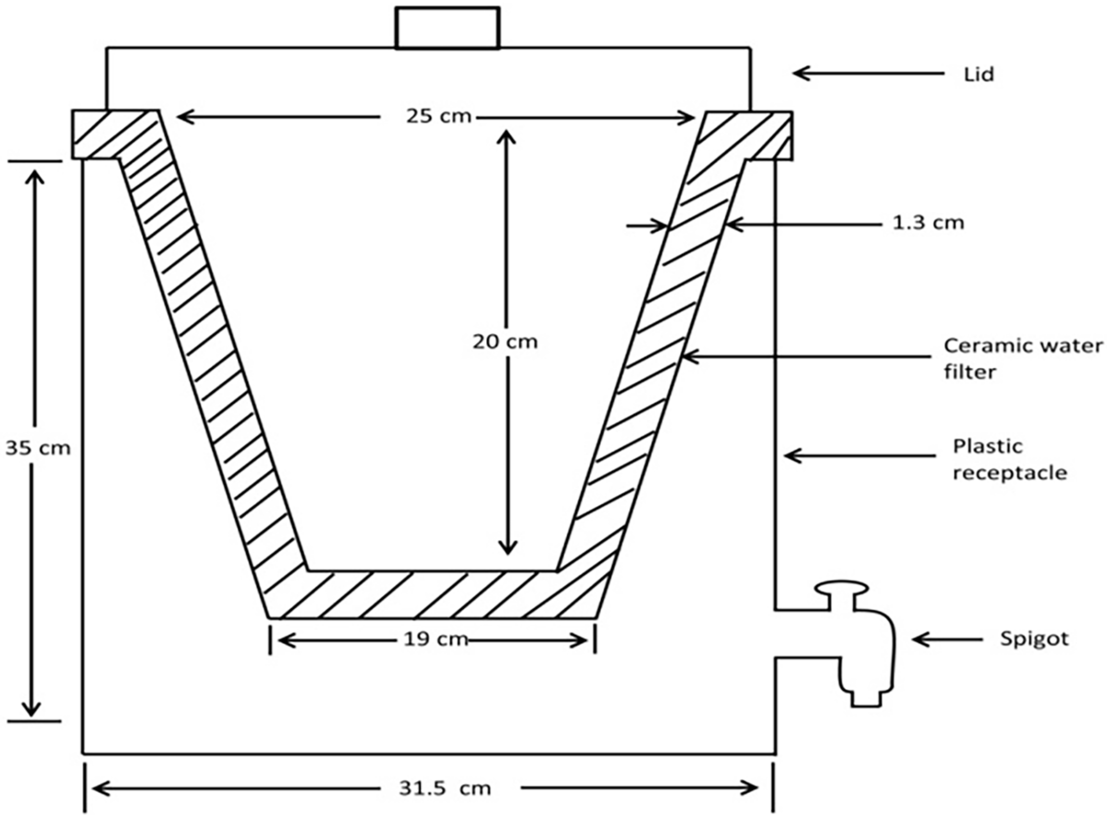

Figure 1. Schematic diagram of ceramic water filter.

"ceramic water filter coated with AgNPs" (CWF-AgNPs) and the filter without AgNPs as "ceramic water filter" (CWF).

Pollutant Removal Performance of the Ceramic Water Filter

Sample collection

The water sample used for this study was collected from Onlete stream in Iwo, Osun State, southwest Nigeria, located at latitude 7°41′04″N and longitude 4°11′18″E (Figure 2). Onlete stream was chosen for this study because of its proximity to the laboratory and because it serves as a domestic water source for the residents of Onlete village and neigbouring communities around the village. The temperature around the study area ranges between 21°C and 31°C, with an annual rainfall of about 1750 mm.[9] Water samples were collected into 3 sterile 20-L plastic containers using the grab method and the lids were carefully replaced. The samples were collected at users' fetching points, transported immediately to the Biology Laboratory of Bowen University, Iwo, and analyzed within an hour of collection.

Determination of heavy metals in the raw and filtered water samples

Physico-chemical analyses were carried out on the stream water sample before and after the filtration processes. The parameters considered were pH, electrical conductivity (EC), and the presence of heavy metals (Pb, Cu, Zn, Cd, and Fe) using the standard method for water analysis.[42] Potential of hydrogen (pH) of water shows the level of acidity or alkalinity of a water sample. Electrical conductivity (EC) represents the concentration of charged ions (dissolved salts) in a water sample. The EC value above 400 µS/cm in drinking indicates that the water is polluted and not fit for drinking. The pH and EC were determined using an analytical probe (pHep, HANNA Instruments). The heavy metals were determined using PG 990 atomic absorption spectroscopy (AAS) (PG Instruments Ltd, UK) and the presence of silver (Ag) was determined using an inductively coupled plasma-mass spectrophotometer (ICP-MS) at the Institute of Hygiene and Public Health, University of Bonn, Germany.

Bacteriology of the raw and filtered water samples

Bacteriological analysis was carried out on the raw stream water sample before and after the filtration processes, and the water was left to settle down without filtration (SWF). Isolation of bacteria from the stream water sample was achieved by the pour plate technique. Biochemical tests were carried out on the isolates, and the identities were confirmed with online software, https://www.microrao.com. Bergey's Manual of Systematic Bacteriology was also employed in the identification process.

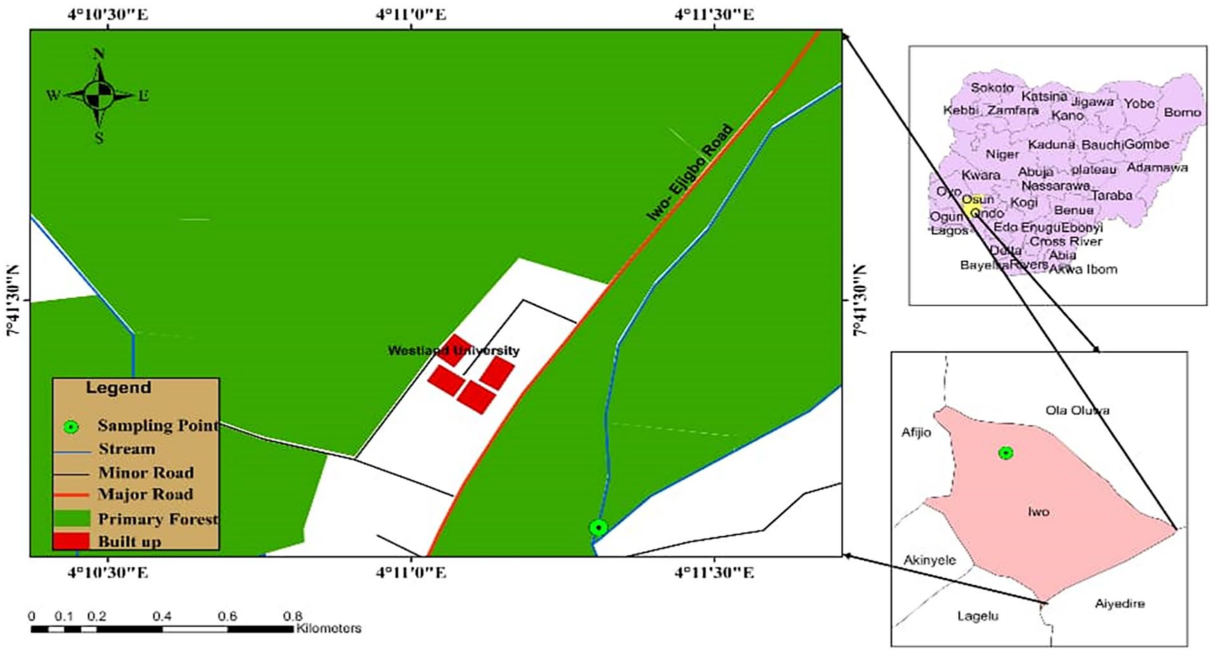

Figure 2. Map showing Onlete stream in Iwo, Osun State, Nigeria.

The enumeration of bacteria in the water samples was determined as described by World Health Organization (WHO) scheme to evaluate household water treatment technologies.[43] The analysis was carried out for a 10-day period, and water samples were collected for bacteriological analysis on days 1, 3, 6, 7, 8, and 10. The water samples were plated in triplicate on plate count agar (PCA), and the plates were incubated in an inverted position for 18 to 24 hours at 37°C. The geometric mean of the number of colonies was calculated, and the result was expressed as log reduction values (LRV). Log reduction is a mathematical expression that can be used to represent the number of microorganisms that are eliminated in a water treatment process. It is usually calculated using a logarithmic (log) reduction scale.

The Log_{10} reduction value (LRV) was calculated as described by Karim et al.,[44] using the formula:

$$\begin{aligned} \text{Log}_{10}\text{reduction value} &= \text{Log}_{10}B_{rw} - \text{Log}_{10}\text{B}_{\text{fw}} \\ &= \text{Log}_{10}\left(\text{B}_{\text{rw}} \ / \ \text{B}_{\text{fw}}\right) \end{aligned}$$

where B_{rw} is the geometric mean of bacteria in the raw water; B_{fw} is the geometric mean of bacteria in the filtered water.

The multiple-tube fermentation technique was utilized to estimate coliforms in the water samples. Five hundred milliliters of lactose broth (Lab M) was prepared according to the manufacturer's specification, and 10 mL was introduced into 3 sets of test-tubes containing inverted Durham's tubes. The first and second sets contain a single strength of lactose broth, while the third set contains a double strength of lactose broth. Each set received varying quantities of water sample (0.1, 1, and 10 mL) and the test-tubes were incubated at 37 ± 2°C for 24 to 48 hours. Tubes with visible growth and gas production by air displacement in Durham's tubes were regarded as positive for the preliminary test. The coliforms present in the water samples were estimated by using the most probable number (MPN) statistical table, and the result presented as colony forming unit per milliliter (CFU/mL).

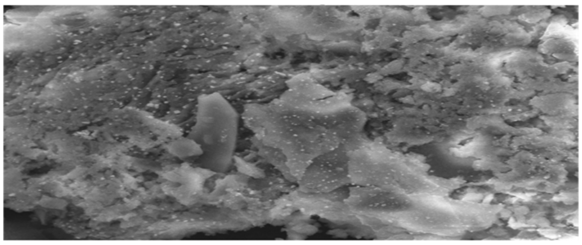

Figure 3. Scanning electron micrograph of green-synthesized AgNPs.
Abbreviations: AgNPs, silver nanoparticles

Statistical analysis

Data were analyzed using descriptive statistics, and results were presented as mean and standard deviations. A Mann-Whitney test was used to determine the significant difference between the ceramic water filters.

Results

The result of the SEM analysis revealed that the green-synthesized AgNPs were within the nano-size range (Figure 3). The nanoparticles were spherical in shape, with an average size of 5 nm.

The pH and EC of the raw and filtered water samples are presented in Figure 4. While the pH of the stream water sample at collection ranged from 7.0 to 7.2, the sample left to settle without any filtration (SWF) was 7.6 to 8.0 and the pH after

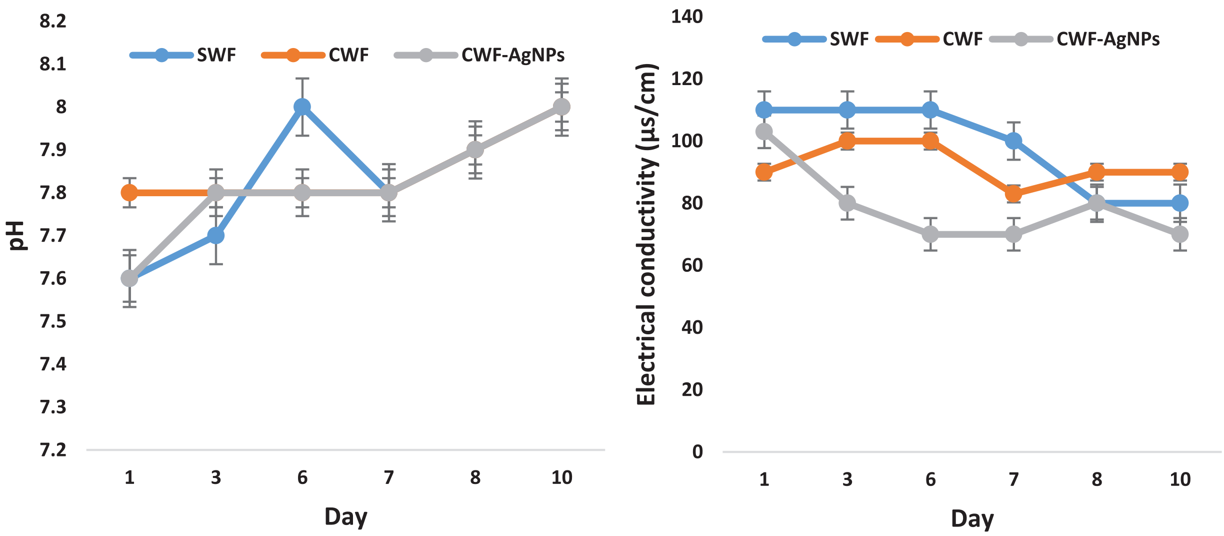

Figure 4. pH and EC of the raw and filtered water samples.
Abbreviations: CWF, filter without nanoparticles; CWF-AgNPs, filter coated with nanoparticles; SWF, settled water without filtration.

filtration with CWF and CWF-AgNPs ranged from 7.6 to 8.0 and 7.6 to 8.1, respectively. The EC of the stream water sample was 110 µs/cm, and the EC was reduced in the filtered water samples. The heavy metal concentrations in the water samples before and after filtration with the CWF-AgNPs are presented in Table S1. The heavy metals (Pb, Cu, Zn, Cd, and Fe) found in the water samples were below the World Health Organization (WHO) maximum permissible limit in drinking water. Although Fe was found to be 0.72 mg/mL in the raw water sample and 0.81 mg/mL in the filtered sample, this is still below the WHO maximum limit of 5 mg/L in drinking water. Silver was below 0.002 mg/L in the filtered water samples.

The microbial analysis showed that there was a diversity of bacteria in the raw stream water sample. This includes both Gram-negative and Gram-positive bacteria. The bacteria isolated from the stream water sample were *Serratia marcescens*, *Citrobacter* sp., *Escherichia coli, Enterobacter aerogenes, Pseudomonas* sp., *Klebsiella pnuemoniae*, and *Staphylococcus aureus* (Table 1). The number of bacteria in the raw water sample ranged between 1.70×10^7 and 6.20×10^7 CFU/mL. *Serratia marcescens* was the most frequent bacteria isolated from the raw water sample, with a percentage occurrence of 25%, followed by *K. pnuemoniae, Citrobacter* spp., *and S. aureus. Entamoeba histolytica* was also detected in the raw water sample. These microorganisms were absent in the filtered water.

The LRV of the SWF ranged from 0 to 0.7 (mean 0.3), while the LRV of the CWF and CWF-AgNPs ranged from 0.8 to 3.5 (mean 2.5) and 1.8 to 3.5 (mean 2.7), respectively (Figure 5).

Coliform shows the sanitary quality of the water samples (Table 2). The filtered water samples were grouped based on the WHO guideline: conform (<1 CFU/mL); low (1-10 CFU/mL); intermediate (11-100 CFU/mL); and high (100 CFU/mL).[45] While the coliform count was >1100 for the SWF, the CWF-AgNPs was able to achieve a "conformed" sanitary quality of <1 CFU/mL for 3 batches of the filtered water samples. The descriptive box plots (Figure 6) and the Mann-Whitney tests (Table S2) revealed that there was no significant difference in bacterial removal between CWF-AgNPs and CWF ($P = .407$, $P > .05$), while SWF was significantly different from the filters ($P = .000$, $P < .05$).

Discussion

Green synthesis of metal nanoparticles is usually simple, cost-effective, and non-toxic, when compared with the chemical method of synthesis.[46,47] The efficacy of a ceramic water filter coated with green Ag-nanoparticles for improving the quality of Onlete stream in rural Nigeria was considered in this study. The nano-sized silver particles (5 nm) were efficient in reducing the bacterial load by 92% to 99.64%. In a similar study, Wang et al.[48] synthesized FeNPs from the leaf extract of eucalyptus for wastewater treatment and reported a high removal of inorganic contaminants. Small-sized nanoparticles have the advantage of increased reactivity and affinity for contaminants, due to their unique small sizes.[17,49]

While pH values represent the acidity or alkalinity of a water sample, EC measures the amount of ions in the water. The pH and EC of the filtered water samples in this study were within the WHO permissible limits for safe drinking water (pH 6.5-8.5; EC < 400 µs/cm). Zereffa and Bekalo[50] reported a pH range within 7.0 to 8.0 and EC within 90 to 140 µs/cm in water filtered through CWF in Ethiopia, which concurs with the present study. Water meant for drinking should be within the standard pH range, as acidic water could cause a sour taste.[51] A high level of EC in water indicates high concentrations of dissolved ions, such as sodium. Increased sodium concentration in the body could result in some health issues, such as hypertension, and cardiovascular diseases.[52]

Table 1. Biochemical characteristics of bacteria isolated from Onlete stream.

S/N	BIOCHEMICAL TEST	*Serratia marcescens*	*Citrobacter sp.*	*Escherichia coli*	*Enterobacter aerogenes*	*Pseudomonas sp.*	*Klebsiella pneumoniae*	*Staphylococcus aureus*
1	Gram staining	–	–	–	–	–	–	+
2	Catalase production	+	+	+	+	+	+	+
3	Indole production	–	–	+	–	–	–	–
4	Citrate utilization	+	+	–	+	+	+	+
5	Acid production	–	+	+	–	–	–	+
6	Production of acetylmethyl carbinol	+	–	–	+	–	+	+
7	Sugar utilization:							
	Glucose	+*	+*	+*	+*	+*	+*	+*
	Lactose	–	+*	+*	+*	–	+*	+*
	Sucrose	+*	+*	+*	+*	–	+*	+*
	Mannitol	+*	+*	+*	+*	–	+*	+*

Abbreviations: +, positive; –, negative.
*Fermentation with gas production.

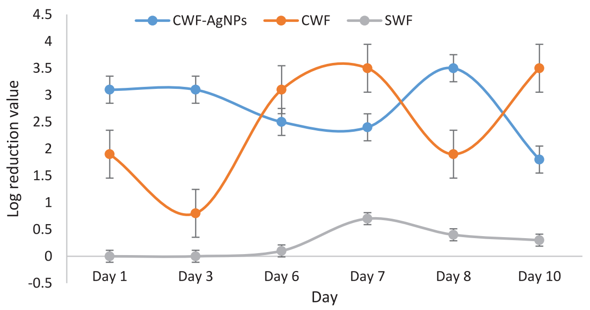

Figure 5. Log reduction values of the ceramic water filters.
Abbreviations: CWF, filter without nanoparticles; CWF-AgNPs, filter coated with nanoparticles; SWF, settled water without filtration.

Table 2. Estimated coliforms in the filtered water samples.

CERAMIC FILTER	BATCHES (MPN/100ML)					
	1	3	6	7	8	10
CWF-AgNPs	<1	<1	1-10	11-100	<1	11-100
CWF	11-100	11-100	>100	1-10	11-100	<1

Abbreviations: CWF, filter without nanoparticles; CWF-AgNPs, filter coated with nanoparticles; MPN, most probable number.

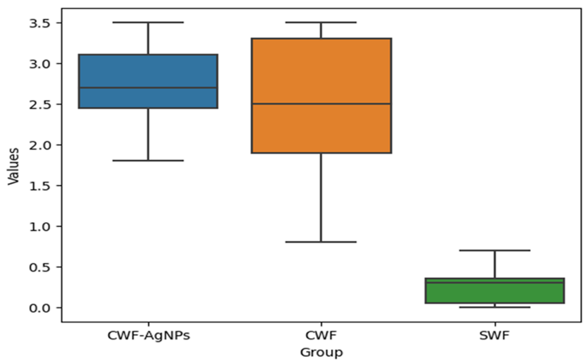

Figure 6. Box plots of the water filters and settled water without filtration.
Abbreviations: CWF, filter without nanoparticles; CWF-AgNPs, filter coated with nanoparticles; SWF, settled water without filtration.

The presence of heavy metals was below detection limits in the raw and filtered water samples except for the presence of Fe, which was 0.72 mg/L in the raw water sample but increased to 0.81 mg/L after filtration. The slight increase in the concentration of Fe in the water sample could be attributed to the dissolution of iron oxide from the clay material,[53] but this was still very far below the WHO permissible limit of 5 mg/L in drinking water. Silver metal was below 0.002 mg/L in the CWF-AgNPs filtrate, which signifies that Ag did not leach significantly from the CWF-AgNPs.

The presence of microbial pathogens, such as *K. pnuemoniae, P. aeruginosa, S. aureus*, and *E. histolytica* in the water sample indicated that the stream water is not safe for human consumption. Since the stream water is the main water supply in this community, many of the people are at high risk of waterborne diseases.[54,55] *Klebsiella pneumoniae* has been implicated in re-occurring urinary tract infections.[56] *Pseudomonas aeruginosa* is an opportunistic pathogen causing serious infections, especially in immunocompromized individuals.[57] *Escherichia coli* has been responsible for enteric diseases such as diarrhea and dysentery, and the toxigenic strains are the prominent cause of diarrhea in children in many developing countries.[58] *Staphylococcus aureus* causes abscesses of the skin and soft tissues,[55] and *E. histolytica* is responsible for amoebic dysentery. Suthar et al.,[59] Osieme et al.,[60] and Potgieter et al.[55] have reported the presence of enteric pathogens in surface water used for drinking purposes in some rural households in some developing countries, which is similar to the present findings. Illnesses arising from the consumption of microbially contaminated water cannot be undermined. Thus, there is an urgent need for the provision of low-cost and efficient household water treatment.

We applied the raw stream water sample directly to the filters without dilution to present a natural condition. The filters effectively reduced the bacterial loads in the water, whereas the unfiltered water samples did not show any significant bacterial reduction. The main mechanism by which CWF removes pathogens is by physical removal of contaminants by size exclusion, and the presence of AgNPs inactivates the microbial cells by disrupting the bacterial DNAs.[61,62] Previous studies have shown that while the microorganisms in the water can be adsorbed on the surface of the coating material, the escaped microorganisms can be trapped within the pores of the CWF.[63] The CWFs were effective in removing bacteria in the stream water by up to 84% to 93.18% and 92% to 99.64% for the CWF and CWF-AgNPs, respectively.

The present study showed a decrease in the LRV of the CWF-AgNPs on day 10. This is comparable with previous literature. Bielefeldt et al.,[61], Perez-Vidal et al.,[64] and Huang et al.[65] reported reductions in LRVs in batch experiments using ceramic filters, and they observed a decrease in the efficiency of the filter over time. This was attributed to the leaching of the bacteria trapped in the previous cycles of filtration, but the efficiency can be recovered by cleaning the filters with boiling water before filtration.[65] Although, there was no statistically significant difference, the efficiency of CWF-AgNPs in pathogen removal was slightly higher than that of CWF. The little difference observed may be attributed to the low quantity of AgNPs that was applied to the filter. In a similar study exploring the use of nano ZnO to filtered laboratory spiked-water, it was observed that increased nano ZnO concentration resulted in an increase in *E. coli* removal efficiency.[65]

The CWF-AgNPs also has the advantage of preventing the formation of biofilms and biofouling.[66] In similar studies, Guerrero-Latorre et al.[67] and Lucier et al.[68] documented the use of CWF to purify spiked water samples. They reported bacteria log reduction of ⩾5, which was quite higher than what was obtained in this study. However, the present result conforms with Rivera-Sánchez,[69] who reported a range of 1.8 to 2.0 LRV for *E. coli* removal in spiked water using CWFs.

Aside the complexity of the natural water, the variation in bacteria log removal efficiencies of the clay could be ascribed to varying characteristics of clay from different regions.[17,69,70] The CWFs in the present study met the WHO protective protection requirement of ⩾2 LRV.[43] This implies that the filters can be used for more than 1 year to reduce the burden of the diseases associated with drinking water if they are used correctly and consistently.[43]

The presence of coliforms in water suggests fecal contamination. The point sources of the biological contaminants in Onlete stream may probably be the infiltration of human and animal wastes along the stream. The high concentration of coliforms (>1100 MPN/100 mL) in the Onlete stream exceeds the WHO recommendation of <1 coliform/100 mL of drinking water, indicating a potential health risk for residents and neighboring communities. The present report concurs with Zereffa and Bekalo[50] and Oyanedel-Craver and Smith,[13] who reported 80% to 97.5% and 97.8% to 100% coliform reduction in spiked-water samples filtered through CWF and CWF coated with nanoparticles, respectively. The CWF-AgNPs is estimated to be $0.85. This is relatively affordable in low resource countries.

The present study could not determine the efficacy and durability of the filter for over several years.

In this study, we made ceramic water filters using local clay from southwest Nigeria. The filters were coated with silver nanoparticles (AgNPs). The AgNPs were produced using a quick and affordable method involving the bark of the *Bridelia ferruginea* plant. The filters were tested using drinking water samples in rural area of Nigeria. The filters maintained the pH and EC of the water samples within the standard limits for safe drinking water. Bacterial removal of up to 93.18% and 99.64% were observed in the CWF and CWF-AgNPs, respectively. This indicates that the CWF-AgNPs were more effective than the CWF. The CWF-AgNPs achieved LRVs of 1.8 to 3.5 and reduced the coliform to the conformed standard for 3 batches of the filtered water. The surface and internal structure of the CWF-AgNPs can be modified by varying the concentration of the composite materials, so as to determine the most effective combination. The long-term study of the filter at the laboratory and field scale could be considered for future research. Also, the ability of the filter to remove chemical pollutants, the leaching behavior, and the safety of the nanoparticles before field application should be considered. The CWF-AgNPs will help to provide safe drinking water in rural and disadvantaged communities, where there is low/no access to potable water supply. This will help to reduce the burden of waterborne illnesses.

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Author Contribution

OA conceptualized and designed the study, collected and analyzed the data, and wrote the manuscript. TOO reviewed and revised the manuscript.

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Availability of Data and Materials

Data will be available upon request from the corresponding author.

Supplemental Material

Supplemental material for this article is available online.

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