Assessing the Quality of Traditionally Manufactured Ceramic Water Filters, Limpopo, South Africa

Jabulani R. Gumbo, Asivhanzhi I. Munarini, Ndishavha Khangale

Abstract**—**The traditional clay pot can be modernized by including sawdust to produce a ceramic water filter. Ceramic water filters are known to improve the quality of drinking water by inactivating waterborne pathogens. Here we report on the quality of traditionally manufactured ceramic water filter in improving the chemical and microbial quality of drinking water. The sources of drinking water were Mambedi dam and the Luvuvhu River. The water from Luvuvhu River was then filtered with ceramic water filter (CWF). The mean pH values of Luvuvhu River and purified water ranged from 6.20 to 6.56 and 7.79 to 7.91 respectfully. The electrical conductivity of Luvuvhu River and purified water ranged from 210 to 224 µS/cm and 229 to 284 µS/cm respectfully. The temperature of Luvuvhu River and purified water ranged from 21.3 to 23.5 °C and 23.1 to 25.5°C respectfully. The turbidity mean value of Luvuvhu River and purified water ranged from 1.67 to 4.38 NTU and 0.31 to 0.64 NTU respectfully. The CWF was effective in the removal of some metals Cr, Sr, and Ba and there was no leaching of metals As and Ni. The total coliforms and faecal coliforms in the purified water were 3 cfu/100 ml and 36 cfu/100 ml respectfully. Thus at household level, the ceramic water filter may be used to improve the chemical and microbial safety of the Luvuvhu river.

Keywords**—**traditionally made ceramic water filters, drinking water, rural communities, waterborne diseases.

I. Introduction

South Africa is one of the water-stressed countries [1]. Freshwater is our most limiting natural resource. South Africa receives an annual rainfall of 492 millimeters whereas the other country receives 985 millimeters which is around half the average rainfall of other countries. These make the water availability now and in the future to be heavily dependent on climate, water use and management and also the land-use practices availability as we find rainfall in 3 months of the whole year [2].

Many households still lack safe drinking water. They use unsafe drinking water for a variety of reasons such as they are not yet connected by the municipal water supply, cannot afford the connection tariffs and if the municipal water supply is availability and reliability are erratic. Having a water source or supply point near the home does not necessarily mean that the water is suitable for consumption and safe for drinking. It may be that the water is not treated at all or is not treated well or that the source is not bacteriological safe due to groundwater contamination [3]. Household water treatment can lead to the dramatic improvement in drinking water quality and makes the immediate differences to the lives of those who rely on water from polluted rivers, dams and unsafe wells or water supplies [4].

Several technologies have been developed and deployed in communities without access to safe public drinking water to treat water in their home. The most well studied methods of point-of-use (POU) sterilization via Ultraviolet Radiation (UV) through clear plastic container (SODIS), ceramic water filtration and biosand filtration [5].

Ceramic water filtration is one of the household water treatment options in currently used in developing country, the filters are manufacture by mixing of combustible material such as rice and saw dust, the clay is then fired to create the pore space through which the water is being filtered. The ceramic water filter is one of the low-cost water filters since is made up of cultural clay soil and saw dust and eliminate the use of chemicals in the treatment of water the ceramic water filter may design in two different strictures which are the ceramic water filter without filter and the other one with silver enhanced [6].

The ceramic water filter which is enhanced by the silver have low flow rate as compare to the one without sliver as results of the one with silver have very tint pores while the one without silver have big pore which lead more flow rate. Therefore, the ceramic water filter which is coated with silver is more effective to remove the bacteria up to 99% with the pore size of 0.6-3 microns (such as *E coli*) in water than the one without silver [6]. The silver enhances also serve as the disinfectant by inactivation through solid silver suspended in the ceramic filter solution and serve as antibacterial properties which lead to the removal of up to 99.9%ofthe most common water borne bacteria [6].

An application of this low-cost Ceramic Water Filter impregnated with silver will be important to the community because of its ability to produce sufficient quantities of microbiologically safe drinking water in a reasonably short period of time and the ability to treat water from different sources that may have high turbidity and organic content. This will lead to reduction of waterborne diseases especially diarrheal among the under 5 children and improve their health status. The main objective of this research is to assess the

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J.R. Gumbo is with the University of Venda, Department of Hydrology & Water Resources.

A.I. Munarini was with the University of Venda, Department of Hydrology & Water Resources .

N .Khangale was with the University of Venda, Department of Hydrology & Water Resources.

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quality of a traditionally manufactured Ceramic Water Filter impregnated with silver in improving the drinking water quality. The specific objectives were: to map the current sources of drinking water in Mambedi village; to determine the physico-chemical parameters of the raw and purified (filtered) water and to determine the leaching of metals from the processed clay material into the purified water and to assess the level of microbial quality of raw water and purified water.

II. Materials and Methods

A. Composition of the Ceramic Water Filter Impregnated with Silver

The ceramic water filters impregnated with silver was manufactured using the saw dust that was collected from a timber company in Levubu, the clay soil that was collected at Vhalufuli village and the silver nitrate AR. The saw dust was grinded using the Retsch RS 200 milling machine for milling for at least 4 min and also be sieved with a sieve machine of 250 µm (micrometer), the clay soil was grounded and mixed with the silver nitrate. The whole mixture was kneaded and pressed into a mold. The clay filters were sun dried and fired at around 890°C.

The procedure for the preparation of the ceramic water filter impregnated with silver is listed below:

- 8 cups of clay soil were grounded, 500g of grinded and sieved sawdust of the uniform size of 250µm (micrometer) and 1.2g of silver nitrate are mixed together.
- Water was added to the mix to obtain the correct consistency
- The filters were then formed by hands
- Filters were fired at 890°C in a brick kiln using wood
- Filters were allowed to cool
- Filters were soaked for 24 hours to saturate the filters before flow testing
- The flow rate of each filters was tested and the filters with cracks were discarded
- The filters were allowed to dry again and ready to be used.

B. Selection of Suitable Ceramic Water Filters/ Flow Rate

Five prepared ceramic water filters impregnated with silver were used to filter the deionised water. The filter pots were named using the alphabet. Each filter pot was filled with 1000ml of deionised water and the time was set as to see the duration that the filters took to filter 1000ml of deionised water. The flow rate of each filter pot was recorded. Filter pot E is the one chosen for this research as was not having cracks and the flow rate was reasonable.

C. Procedure for Water Samples Collection

The samples were collected from the two sources used by the communities for domestic purpose at Bernard village. The sources are water from the Mambedi dam and Luvuvhu River. Water were collected with two 25 litre buckets and taken to the school laboratory for the laboratory analyses. The co-ordinates of the area where the samples were collected were recorded using the GPS.

D. Physical Analysis of Water

The Multimeter mm41 was standardized by as per manufacturers instruction for determination of pH, electrical conductivity (EC) and total dissolved solids (TDS) of water samples in triplicate.

E. Microbiological Analysis of Water Samples

The water sample were analyzed total coliforms and feacal coliforms where the total coliforms were analyzed using the media called M-endo agar while the feacal coliforms were analysed using the M-FC agar.

F. Metal Analysis of Water Samples

The water samples were also sent to ARC Institute of Soil, Water & Climate in Pretoria for metal analysis. The metals were analyzed using the Thermofischer ICP MS Model X Series II. These metals were analyzed in triplicate.

G. Data Analysis

Microsoft Excel 2003 was used to analyze the raw data and compute the basic statistics. The differences between raw and purified water were analysed using single factor ANOVA at 95% at $p>0.05$

III. Results and Discussion

A. Manufacturing of Ceramic Water Filter

The ceramic water filter was composed of traditional clay soil together with saw dust from a timber processing company. A traditional clay potter was approached to produce the ceramic water filters and she was then given sawdust (250 µm particle size). She used her normal clay material and ratio was 12 cups of clay soil and 1 cup of saw dust. Each cup of material was 427.1 g.

B. Selection of Ceramic Water Filter/ Filtration Rate

The results for the filter pot A was (2 h 56 min), filter pot B (1h), filter pot C (1h 5min), filter pot D (4h10 min) and filter pot E (2h30). Filter pot E is the one chosen for this research as was not having cracks and the flow rate was reasonable. But filter pot B and C were having cracks that is why they were not used to this research as they will allow the microbes to pass through and also filter pot A and D were slow in filtering water.

C. The Physical Analysis of Water

On the physical water quality parameters that were tested showed an improvement in the physical status of the purified water (Table 1). The water pH of all sites was in the range of 6.68 to 7.50. According to Mailula [7] the pH range from 3.0 to 10.5 could favors the growth of indicator and pathogenic microorganism. The pH of dam raw water were range from 7.28 and after ceramic water filter were 7.50 while the river raw water were range from 6.68 and the dam ceramic filter were 7.44. According to [8] has shown that the pH ceramic water may increase due to alkalinity dissolved in the from the clay based filter. The pH value of all ceramic water filtered comply with class 1 recommended operational limits of SANS 241 and the

ANOVA results show that ($p< 0.05$) in both river and dam water after ceramic water filter. For the effective disinfection with chlorine the pH should be 8 however the, lower pH is more likely to corrosive iron pipe [9].

TABLE 1: PHYSICAL WATER QUALITY DATA FOR RAW AND PURIFIED WATER

Parameters/ Sample site	Dam water, raw	Dam water, purified	River water, raw	River water, purified	SANS241 (2015)
pH	7.3±0.17	7.5±0.0	6.7±0.2	7.5±0.0	8-10
Electrical conductivity (µS/cm	213±0	221±0	147±0.0	195±0	150-370
Water temperature (°C)	25.9±0.0	26.4±0.1	26.3±0.1	26.3±0.1	---
Turbidity (NTU)	1.3±0.0	0.5±0.1	1.6±0.0	0.4±0.0	<1

Data is mean of triplicate.

D. Electrical Conductivity

The electrical conductivity of river raw water has increased from 147 to 194µS/cm after ceramic water filter and the dam range from for dam raw water 213 to 221µS/cm for the ceramic water filtered. According to [10] these value are above the recommended operational limits in class (i) but are suitable in class (ii) for maximum allowance duration time. The water temperature for all sample sites was between 25.9^{o}Cdam water raw and dam water filtered of 26.4 ^{o}C while the river raw water was 26.3 and the river water filtered 26.3.the recommended standard limits with no risk are less than 24 ^{o}C for domestic, aquatic ecosystem, agricultural water use and the recreation use [11].

E. Turbidity

The value of turbidity of dam raw water range from 1.25 NTU and the filtered water to 0.54 NTU while the river raw water start from 1.57 NTU and the filtered water to 0.36 NTU. According to [10] the turbidity of less than 1 NTU is recommended in the operational limit. The values of both river and dam water after ceramic filter are acceptable for drinking. The water with higher turbidity value is mainly associated with microbial survival due to particles mater in the water [11]. The South African Water Quality Guideline Standards limits for domestic use, aquatic ecosystem, agricultural use and the recreation are 1-5 NTU [12]. The research finding shows that the turbidity after ceramic filter reduced from1.25 to 0.54 NTU for the dam water and the river reduced from 1.57 to 0.36 NTU. The turbidity levels of the raw and purified water were significant different ($p<0.05$) indicating the effectiveness of the ceramic water filter. According to [13] ceramic water filter is more effective to remove turbidity in the surface water which have low turbidity since there is significant different of ($p=0.01$) as compare to biosand filter.

F. Metals in the Final Purified Water

The ceramic water filter showed variation in either reducing metals in the raw water into the final purified water and or in some cases increased the metal content in the purified water (Table 2).

TABLE 2: THE COMPARISON OF METAL CONCENTRATIONS IN RAW AND PURIFIED (FILTERED) WATER

Metals/	sample 1 river water BF (ppb)	sample 1 river water AF (ppb)	sample 2 dam water BF (ppb)	sample 2 dam water AF (ppb)
11 B	<0.01	13.19	10.37	16.02
52 Cr	2.82	2.3	3.41	2.49
55 Mn	5.37	92.96	24.64	12.9
60 Ni	<0.01	<0.01	<0.01	<0.01
65 Cu	3.32	6.78	0.66	3.57
66 Zn	12.11	47.77	<0.01	9.29
75 As	**<0.01**	**<0.01**	**<0.01**	**<0.01**
82 Se	<0.01	<0.01	<0.01	<0.01
85 Rb	2.97	11.45	7.41	9.08
88 Sr	91.87	36.13	194.8	68.52
111 Cd	<0.01	<0.01	0.31	0.1
121 Sb	<0.01	0.01	0.3	<0.01
125 Te	0.2	<0.01	0.16	0.15
137 Ba	44.71	9.48	180.1	17.93
202 Hg	**0.49**	**0.31**	**0.76**	**0.22**
208 Pb	<0.01	<0.01	<0.01	<0.01
238 U	<0.01	<0.01	<0.01	<0.01

BF before filtration and AF after filtration

G. Chromium

The WHO guideline for total Cr in drinking water was set at 0.05 ppm. The chromium (iv) if inhaled may cause the lungs cancer [14].The raw water after being filtered using ceramic filter shows that there was significant removal in both river and dam water where river decreased by 18% while dam decreased by 27% (Table 2).

H. Manganese

This one of the abundant metal in the earth crust and is found in the rock and ore and is likely to turn up in the groundwater due to reduction in condition in soil and rock bring in soluble form. The level of Mn in the purified water was lower than the WHO guideline value of 400 ppb (Table 2). The concentration of Mn in drinking water may cause taste, discoloration and staining problem. The increase in Mn concentration in river water that was purified may be due to leaching of clay material and or the contribution from the raw river water. However at this stage, the reasons are unknown and require further investigation. For the dam water sample, there was a 48% reduction in the Mn levels in the final purified water. Thus it may be tentatively concluded that the Mn levels in the purified water are coming from the raw water sources instead of the clay materials but further research is required.

I. Nickel

The WHO guideline values for nickel in drinking water was set at0.07ppm. There was no change in the Ni level in the purified water for both river and dam water samples.

J. Copper

The WHO guideline values for copper was set at 2 ppm. Copper is an essential element the human body, it bound in the in protein, but it can be toxic in human in the high concentration. This resulted from corrosion of plumbing connection. The upper limits of acceptable range from the intake in adult in the range of 2-3 ppm, This affect the gastrointestinal due to water contaminated by copper [14]. There was an increase in Cu levels in the purified water for both dam and river water samples but the Cu levels were within the WHO guideline value of 2000 ppb.

K. The Microbiological Analysis of Water

The microbiological water quality data for Mambedi dam and Luvuvhu raw water and purified water are shown in Tables 3 and 4. The results of purified Mambedi dam show that the total coliforms range between 1 cfu/100 mL to 5 cfu/100 mL and maybe suitable for domestic water uses (Table 4). DWAF [12]states that the total coliform target of 5 cfu/100 ml that there is a negligible risk of microbial infection. As according to South African Guidelines the number of total coliforms in drinking water should be less than 10 colonies per 100ml [15]. The ceramic water filter was able to remove total coliforms by achieving 1.3 log removal efficiency. The high total coliform counts in the water sources and especially in dams increases the health risk associated with waterborne diseases such as, cholera, typhoid fever and diarrhoea which are caused by pathogenic organisms [12]. On the other hand the feacal coliforms, the range in purified water was from 21 to 103 cfu per 100 mL and this corresponded to 0.3 to 0.7 log removal efficiency. DWAF [12] guideline states that the faecal coliform target of > 20 cfu/100 ml that there is a significant and increase risk of microbial infection. The faecal coliforms values from the purified water were higher than the South African recommended guideline value of 0 per 100 ml [15]. The water is unfit for drinking by human being.

TABLE 3: MICROBIOLOGICAL WATER QUALITY DATA FOR MAMBEDI DAM RAW AND FILTERED WATER

Day	Raw water		Filtered water		Log removal	
	Total coliforms	Feacal coliforms	Total coliforms	Feacal coliforms	Total coliforms	Feacal coliforms
1	115±2	200±0	1±1	103±3	2.2	0.3
2	109±2	228±0	3±1	103±1	1.6	0.3
3	106±4	307±0	4±2	101±1	1.5	0.2
4	91±9	465±0	5±1	21±3	1.3	0.7

Data in mean of triplicate. In colony forming units (cfu) per 100 mL

The results of purified Luvuvhu river show that the total coliforms range between 0 cfu/100 mL to 3 cfu/100 mL and maybe suitable for domestic water uses (Table 5). As according to South African Guidelines the number of total coliforms in drinking water should be less than 10 colonies per 100ml (DWAF, 1998)[15]. The ceramic water filter was able to remove total coliforms by achieving 0.8 log removal efficiency. The high total coliform counts in the water sources and especially in rivers increases the health risk associated with waterborne diseases such as, cholera, typhoid fever and diarrhoea which are caused by pathogenic organisms [12].

On the other hand the feacal coliforms, the range in purified water was from 16 to 36 cfu per 100 mL and this corresponded to 0.5 to 1.1 log removal efficiency. The faecal coliforms values from the purified water were higher than the South African recommended guideline value of 0 per 100 ml (DWAF, 1998)[15]. The water is unfit for drinking by human being. The high faecal coliform counts in the river water samples indicated that the river has been contaminated due to direct faecal contamination from warm-blooded animals and humans during rainy periods [14].

TABLE 4: MICROBIOLOGICAL WATER QUALITY DATA FOR LUVUVHU RIVER RAW AND PURIFIED WATER

Day	Raw water		Filtered water		Log removal	
	Total coliforms	Feacal coliforms	Total coliforms	Feacal coliforms	Total coliforms	Feacal coliforms
1	63±31	169±3	2±1	36±7	1.5	0.7
2	0±1	200±0	2±1	28±7	1.7	0.9
3	103±2	200±0	3±2	16±4	1.5	1.1
4	1±1	103±47	0	29±9	0.8	0.5

Data in mean of triplicate. In colony forming units (cfu) per 100 mL

IV. Conclusion

The traditionally manufactured ceramic water filter was able to reduce the chemical and microbial load of the surface water sources considerable. However more research is required to improve the flow rate and the microbial load.

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Professor Jabulani Ray Gumbo graduated with a PhD in Water Resources Management from University of Pretoria in 2007. He was awarded the second best student poster price at the 12th International Conference on Harmful Algae in 2006 and the study was then published in the prestigious conference proceedings after a rigorous peer review process. This author became a Member (M) of International Society for the Study of Harmful Algae; International Mine Water Association; Water Institute of Southern Africa; Microscopy Society of Southern Africa and South African Council for Natural Scientific Professions. In 2008, he was appointed as a senior lecturer at University of Venda and in 2016 he was appointed as Associate Professor. He is the first or second author of more than 47 peer reviewed papers, conference proceedings and co-authored a chapter in a book. He acts as a reviewer for NRF in the fields of cyanobacteria and has been invited to be a reviewer for Ohio Sea Grant Proposal (USA); Journal of Applied Phycology (Australia); Bioresource Technology Journal (BITE) (USA); Journal of Freshwater Ecology (Britain); South African Journal of Science (SAJS) (South Africa) and African Journal of Biotechnology (AJB) (Nigeria). He lectures students at undergraduate and postgraduate levels in the fields of water treatment; water quality management; water law and institutions; rural water supply and sanitation; data information systems and water quality principles and he supervises several Honours, Masters and PhD students in the fields of water quality management; aquatic ecotoxicology and limnology and water treatment. In 2016 he and two other colleagues registered a patent on Defloridation of ground water rich in fluoride.