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Research paper

A simple water treatment procedure using a moringa activated two-tier filtration and Nano-silver impregnated ceramic pot system

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Abstract

This study was aimed at investigating the effectiveness of a customized ceramic pot treated with moringa oleifera and coated with silver sulphate solution for domestic water treatment. The customized pots were made by combining clay with sawdust at different ratios of 10:90, 20:80, 30:70, 40:60 and 50:50 respectively then coated with colloidal silver. The results obtained from all filtration pots indicated a 100% removal of coliform bacteria and Escherichia coli and were thus suitable for deployment in drinking water treatment. All ratios of the filtration pots were found to be effective, however, the 60:40 was found to be more practicable because of its higher filtration rate. Additionally, it was noted that the various filtration pots were very effective in lowering the higher values of the physicochemical parameters of pH, TS, TDS, TSS and turbidity as compared to the values of the world health organization (WHO) standard. This filtration method was however, not very effective in the reduction of the elemental concentration of the respective raw water samples. Overall, the results obtained encouraged the use of the two-tier filtration system especially in rural and developing areas where sophisticated dosing equipment or appropriate dose of the moringa oleifera is not required as different dosages were all effective and did not pose any undesirable effect on the physicochemical and elemental composition of the treated water samples.

Keywords: *Ceramic Pots; Moringa oleifera; Nano-silver; Natural coagulants; Two-tier filtration.*

1. Introduction

Water is one of the most basic necessities of mankind and the absence of drinkable or portable water is the major cause for many diseases and deaths in the world. Portable water is essential for human life because it is free from contaminants. Children carry the greatest health problems associated with untreated water supplies through preventable diseases like diarrhea and cholera. In developing countries, about 2 million people die every year due to diarrhea disease; most are children of less than 5 years of age (WHO, 2006). Other water related diseases reported are, but not limited to; trachoma, schistosomiasis, ascariasis, trichuriasis, ancylostomiasis (hookworm), malaria and encephalitis (Sridhar and Oloruntoba, 2008). The World Health Organization recognized clean, drinkable water as one of the universal human rights. However, not all governments have the resources to provide potable water for all of their people. This is especially true in countries with large rural populations (WHO; 2011). In recognition of the failure of many countries to provide for its citizens their water needs, the UN had stated that improving access to clean water is one of its top eight Millennium Development Goals. By 2015 the goal was to half the number of people on the planet without sustainable access to potable water as compared to 2007 (WHO; 2011). Till date, this has not been met. Meeting this goal would require efforts and interventions of many different types including water provision, household water treatment, hand washing promotion, and sanitation (Lemons & Maji, 2008). The focus of community water treatment is one of the most viable forms of interventions and will be the spotlight of this research.

In Nigeria for instance, water in many dugouts have very high turbidity. The use of coagulants greatly reduces the turbidity and microbes in the water, but does not disinfect pathogens, and therefore needs to be used in conjunction with other technologies. Cloth filtration have been used to remove the microorganism responsible for guinea worm, but not turbidity or smaller microorganisms. Candle filters are effective, but the filter element have very small pore sizes, resulting in very low flowrates when filtering turbid surface waters (Vanessa Green 2008). The use of Moringa oleifera seed powder with the ceramic pot filter will be advantageous since the water will undergo a two tier filtration process.

Moringa oleifera seeds when applied in water treatment, act both as a coagulant and as an antimicrobial agent. It is generally accepted that Moringa oleifera works as a coagulant due to the positively charged water-soluble proteins, which bind to the negatively charged particles (silt, clay, bacteria, toxins, etc) allowing the resulting “flocs” to settle to the bottom or be removed by filtration. Several studies have been carried out to determine the potential risks associated with the use of the seeds in water treatment. Till date, none have shown any evidence suggesting any acute or chronic effects on humans, particularly at the low doses required for water treatment.

Silver acts as a bactericide, therefore, has been incorporated into filters in different quantities, different forms, and using different application methods in water purifications in the past. The mechanisms by which silver act as an antimicrobial agent are: (1) reaction with thiol groups in bacterial cells, (2) production of structural changes in bacterial cell membranes, and (3) interaction with nucleic acids (Russell & Hugo 1994). Silver has been used in many different health applications ranging from eradicating Legionella pneumophila (Liu et al., 1994) in hospital water supplies to healing wounds in burn patients (Burnell, 2003). It does not pose a human health risk when consumed below the recommended levels that the United States Environmental Protection Agency (EPA) has set (0.1 mg/L) for drinking water, (EPA 1992). The colloidal silver solution is made by diluting 3.2% of colloidal silver by approximately 125 times (Estrada, 2004; Bielefeld et al., 2009).

2. Materials and methods

2.1. Pot molding and kiln construction

Locally available clay was collected from a dug well in Akunza Ubangeri (behind the University). The clay was dried, pounded, and sieved using a 150mm sieve. A mixture of clay and kaolin was obtained in the ratio 70:30 by volume, this became the working clay. Sawdust was locally collected and sorted. A moistened suspension containing clay – sawdust was allowed to mature for 1 hour before molding into pots in volume by volume ratio 50:50, 60:40, 70:30, 80:20, 90: 10, and 100. Due to the plasticity of the moistened composed (clay-sawdust blend) a potter's wheel was used in throwing the pots. The filters were molded in the shape of a frustum (Donachy, 2004). The experimental filtration pots had a lower circumference of 54-60 cm and a height of 20-25 cm. The filter wall had a thickness of 2.0 cm. The molded pots were dried in open air for several days until the pots turned light brown.

They were then kilned at a temperature range of 900 0C to 10000 C, burning off the combustible organic material. The heating was done in three stages; Preheating for 1hour 30minutes; Advance heating for 1 hour and Blasting for 1 hour 30 minutes. This created very tiny pores in the pot capable of excluding fungi, protozoa and bacteria from passing through as was done by (Bielefeld et al., 2009). After burning, an upward gas kiln was allowed to cool overnight and the pots removed and soaked in water for 24 hours to remove the ashed sawdust particles present in the pores of the pots.

2.2. Preparation of moringa oleifera

Matured Moringa oleifera seed pods were collected and the seeds were removed from the pods. The seed husks were removed, leaving a whitish kernel. Colored seeds were discarded and the quantity of kernels needed was determined based on the amount and turbidity of water. In general, one seed of kernel will treat 1 liter of water. The seed kernels were blended to obtain a fine powder which was sieved using a small mesh.

2.3. Stock solutions and suspensions

Test solution was done as reported by (Ghebremichael et al., 2015). Exactly 1.0 g Moringa oleifera was weighed and dissolved in 100 mL distilled water. The mixture was stirred vigorously and allowed to stand for 20 min. The mixture was then sieved using a fine mesh sieve. This was kept aside for subsequent usage.

2.4 Preparation of working solution

The treatment of water was carried out in ratios. Jar testing was carried out using a volume by volume mixture of the stock solution and raw water, this was then agitated for 5 min and allowed to stand for 20 min. The ratios used were 5:5, 4:6, 3:7 and 2:8. This became the working ratios, the water samples were treated in the same ratio and filtered through each pot.

2.5 Impregnation of Silver unto Pots

A solution of colloidal silver was made. A brush was used to paint the inside and outside of the Ceramic pots. This was allowed to stand for 24 hours before usage.

2.6 Water samples

Water samples were collected from two different sources; a well in Akunza Ubangeri near Federal University Lafia (takeoff site) labeled 'A' and at the Asharah stream, also a major source of water supply to dwellers in Akunza Ubangeri, and labelled 'B'.

2.7 Analysis

The following were evaluated to determine the physio-chemical properties of the water samples from the pots: pH values were estimated by the electrometric method; the conductivity of the samples using a conductivity meter. The turbidity, was determined by Nephelometric Turbidity Meter expressed in terms of NTU: Alkalinity and Total Dissolved Solutes (TDS) were determined using a conductivity meter.

2.8 Coagulant dosage

The required dosage of coagulant stock solution, for all tests samples in this study, was added into the jars by a syringe. The jar testing equipment had a maximum capacity of six vessels of 1L. Geometrical dosage series of M. oleifera coagulant solutions between 0.1 to 0.6 ml in 12 incremental steps were selected to provide a range for determining optimal dosage for turbidity removal. For the aluminum sulfate, dosages between 0.2 and 1.2 ml were evaluated. The stock solutions were prepared considering different transformation strategies seeds based on the methodologies proposed by Ledo et al., (2009), Pritchard et al., (2010a, b), and Poumaye et al., (2012).

3. Results and discussions

Table 1: Physiochemical and Elemental Parameters of Raw Water Samples (A and B)

S/No	Parameters	Raw Water A	Raw Water B	WHO guidelines
1.	pH	6.64	6.44	6.5 -8.5
2.	Odour and Taste	Objectionable	Objectionable	Not objectionable
3.	Turbidity	0.77	0.65	<5 NTU
4.	Electrical Conductivity (mS)	270	300	
5.	Total Alkalinity (mg/L)	292.8	280.6	<500 mg/L
6.	Total hardness (mg/L)	75	23.2	<500 mg/L
7.	Total solids (TS)	5.41	4.31	0.1 mg/L
8.	Total dissolved (TD)	>1800	>2000	<1500 mg/L
9.	Total suspended solids (TSS)	>2.0	>2.0	0.1 mg/L
10.	Fluoride	>2.05	>2.03	<1.5 mg/L
11.	Calcium	>200	>200	<200 mg/L
12.	Copper	>1.5	>1.5	<1.5 mg/L
13.	Magnesium	>150	>150	<150 mg/L
14.	Iron	>1.0	>1.0	<1.0 mg/L
15.	Zinc	>10	>10	<10 mg/L
16.	Lead	>0.1	>0.1	<0.1 mg/L
17.	Manganese	>0.5	>0.5	<0.5 mg/L
18.	Chlorine	23.6	0.00	<250 mg/L
19.	Nitrate	5678.19	462.08	<10 mgN/L
20.	Total coliforms (EMB)	32	18	0 MPN/100 Ml
21.	E.coli (MAC)	24	48	0 MPN/100 mL

Table 1 gives the results obtained from the physiochemical and elemental analysis of the sampled raw water A and B. It was observed that all the parameters with the exception of pH (6.64 & 6.44), total alkalinity (292.8 & 280.6mg/l) and total hardness (193.33 & 38.08 mg/l) for both samples were much higher than the World Health Organization (WHO, 2010) safety limit for drinking water. This is a clear indication of the un-portability of both sampled raw water for drinking purposes.

Table 2: Total Feacal and Coliform of Raw Water Samples, Pot + Raw Water Samples and Treated Pot + Treated Water Samples

S/NO	SAMPLE	TOTAL COLIFORM	FEACAL COLIFORM
1.	Raw Water A	24	24
2.	Raw Water B	32	18
3.	Pot + Raw water A	2	2
4.	Pot + Raw water B	2	2
5.	Pot +Treated water A	-	-
6.	Pot + Treated water B	-	-
7.	Treated Pot + Treated water A	-	-
8.	Treated Pot + Treated water B	-	-

In table 2, the total and feacal coliform count were observed to be high in both raw water samples. On treatment with the filtration pot alone, the coliform count reduced tremendously to only 2 units. However, upon sampled water treatment in addition to filtration using the pot, all coliform units were totally eliminated. Further treatment of the pot and filtering the treated water also showed no coliform count. The initially high coliform counts further attest to the un-portability of the raw water A and B while giving credence to the effectiveness of the two tier water treatment procedure. Similar observation was noted by (Akpomie et al. 2020).

Table 3: Physiochemical and Elemental Parameters of Pot and Raw Water Samples A & B

S/no	Parameters	WHO guidelines	P+RA 50/50	P+RA 60/40	P+RA 70/30	P+RA 80/20	P+RB 50/50	P+RB 60/40	P+RB 70/30	P+RB 80/20
1.	pH	6.5 -8.5	7.33	7.33	7.22	7.0	7.20	7.35	7.30	7.30
2.	Turbidity	<5 NTU	0.77	0.77	0.76	0.77	0.65	0.65	0.65	0.65
3.	Electrical Conductivity.		450	390	390	410	309	310	300	250
4.	Total Alkaline	<500 $MgCaCO_3$/L	231.8	280.6	280.6	248	250.1	260.2	280.0	250
5.	Total hardness	<500 MgCaCO3/L	73	70	70	66.13	22	21	21	19
6.	Total solids	mg/L	5.39	4.9	5.39	4.39	4.22	3.41	4.38	4.34
7.	Total dissolved	<1500 mg/L	300	260	270	270	200	210	200	300
8.	Total Suspended dissolved (TSS) mg/L		2.1	1.6	2.1	1.8	0.7	2.0	0.8	0.7
9.	Fluoride	<1.5 mg/L	0.000	0.001	0.01	0.002	0.003	0.002	0.002	
10.	Calcium	<200 mg/L	>200	>200	>200	>200	>200	>200	>200	<200
11.	Copper	<1.5 mg/L	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5
12.	Magnesium	<150 mg/L	>150	>150	>150	>150	>150	>150	>150	>150
13.	Iron	<1.0 mg/L	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
14.	Zinc	<10 mg/L	>10	>10	>10	>10	>10	>10	>10	>10
15.	Lead	<0.1 mg/L	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
16.	Manganese	<0.5 mg/L	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5
17.	Chlorine	<250 mg/L	23.6	23.6	23.6	23.6	0	0	0	0
18.	Nitrate	<10 mgN/L	8	8	8	8	8	8	8	8
19.	Total coliforms	0 MPN/100 mL	2	2	2	2	2	2	2	2

20.	E.coli	0 MPN/100 mL	2	2	2	2	2	2	2	2
21.	Flow rate		0.424	0.305	0.257	0.212	0.424	0.305	0.257	0.212

Key: P = Pot, RA & RB = Raw water A & Raw water B

Table 3 showed the results obtained after treatment of the raw water samples A and B using the different clay pots made from the 50:50, 60:40, 70:30 and 80:20 blends or mixtures of clay to sawdust respectively. It was observed that the water quality was improved particularly with reference to the physiochemical parameters such as the total alkalinity which reduced from 290 and 280 in raw water A and B, to 280 and 260 mgCaCO3/L respectively, using the 60:40 clay-sawdust blends. The elemental parameters (fluoride, calcium, magnesium, iron, lead etc.) and the microbial loads remain largely unchanged. Other clay-sawdust mixtures of 70:30 and 80:20 also showed similar and in some cases, better treatment but the flow rate of 0.305 of the 60:40 was higher than the 0.257 and 0.212 ml/s of the 70:30 and 80:20 respectively as it was found to be more practicable in terms of filtration.

Table 4: Physiochemical and Elemental Parameters of Treated Pot and Raw Water Samples (A/B)

S/N	Parameters	WHO guidelines	TP+RA 50/50	TP+RA 60/40	TP+RA 70/30	TP+RA 80/20	TP+RB 50/50	TP+RB 60/40	TP+RB 70/30	TP+RB 80/20
1.	pH	6.5 -8.5	7.22	7.10	7.30	7.26	7.26	7.12	7.04	7.30
2.	Turbidity	<5 NTU	0.77	0.77	0.76	0.77	0.65	0.65	0.65	0.65
3.	Electrical Conductivity		280	387	540	420	430	306	300	320
4.	Total Alkalinity	<500 MgCaCO3/L	288.4	278	268.4	266	163	262	244	244
5.	Total hardness	<500 MgCaCO3/L	71	60	72	70	15	10	14	10
6.	Total solids	mg/L	5.38	5.38	5.41	5.40	5.40	4.40	4.40	4.40
7.	Total dissolved	<1500 mg/L	190	400	360	280	290	250	200	210
8.	Total Suspended solids (TSS)	mg/L	2.0	2.1	1.9	1.7	1.9	2.0	1.9	1.1
9.	Fluoride	<1.5 mg/L	0.001	0.001	0.002	0.001	0.000	0.000	0.02	0.003
10.	Calcium	<200 mg/L	>200	>200	>200	<200	>200	>200	>200	>200
11.	Copper	<1.5 mg/L	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5
12.	Magnesium	<150 mg/L	>150	>150	>150	>150	>150	>150	>150	>150
13.	Iron	<1.0 mg/L	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
14.	Zinc	<10 mg/L	>10	>10	>10	>10	>10	>10	>10	>10
15.	Lead	<0.1 mg/L	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1	>0.1
16.	Manganese	<0.5 mg/L	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5
17.	Chlorine	<250 mg/L	23.6	23.6	23.6	23.6	0	0	0	0
18.	Nitrate	<10 mgN/L	8	8	8	8	8	8	8	8
19.	Total coliforms	0 MPN/100 mL	0	0	0	0	0	0	0	0
20.	E.coli	0 MPN/100 mL	0	0	0	0	0	0	0	0
21.	Flow rate		0.435	0.345	0.267	0.214	0.435	0.345	0.267	0.214

Key: TP = Treated pot
RA & RB = Raw Water A & Raw water B

In table 4, the raw water samples A, B was filtered using the different blends of the treated clay pots (pots impregnated with colloidal silver solution). Expectedly, the results did not show major significant changes in the physico-chemical and elemental parameters. There was however, a complete reduction of the bacterial load (total coliform and E. coli) of the water samples to zero. This undoubtedly may be as a result of the colloidal silver solution which acted as a bactericide (Silvestry-Rodriguez et al., 2007).

Table 5: Physiochemical and Elemental Parameters of Treated Pot and Treated Raw Water Samples (A/B)

S/No	Parameters	WHO Guidelines	TP+TWA 50/50	TP+TWA 60/40	TP+TWA 70/30	TP+TWA 80/20	TP+TWB 50/50	TP+TWB 60/40	TP+TWB 70/30	TP+TWB 80/20
1.	pH	6.5 -8.5	7.19	7.26	7.20	7.25	7.27	7.30	7.32	7.25
2.	Turbidity	<5 NTU	0.68	0.57	0.57	0.56	0.55	0.51	0.55	0.50
3.	Electrical conductivity (mS)		390	388	260	250	310	315	-	316
4.	Total Alkalinity	<500 MgCaCO3/L	268.6	268.6	283	283	267.4	263.0	267.80	170.8
5.	Total Hardness	<500 MgCaCO3/L	62.24	63.3	62	56.67	60.0	16.67	13.33	16.67
6.	Total solids (TS)	mg/L 5.39	5.38	5.38	5.38	5.39	4.19	5.38	4.20	
7.	Total dissolved Solids (TDS)	<1500 mg/L	270	240	170	170	210	290	200	230
8.	Total suspended solids (TSS)	mg/L	1.6	0.6	0.7	0.6	2.0	1.1	0.8	0.7
9.	Fluoride	<1.5 mg/L	0.003	0.010	0.001	0.006	0.002	0.003	0.000	0.001
10.	Calcium	<200 mg/L	<200	<200	<200	<200	<200	<200	<200	<200
11.	Copper	<1.5 mg/L	>1.5	>1.5	>1.5	<1.5	>1.5	>1.5	<1.5	<1.5
12.	Mg	<150 mg/L	>150	>150	>150	<150	>150	>150	>150	<150
13.	Iron	<1.0 mg/L	>0.7	>0.7	>1.0	>0.7	>0.7	>0.7	>0.7	>0.7
14.	Zinc	<10 mg/L	>10	>10	>10	>10	>10	>10	>10	<10
15.	Lead	<0.1 mg/L	>0.1	>0.1	>0.1	<0.1	>0.1	>0.1	<0.1	<0.1
16.	Mn	<0.5 mg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
17.	Chlorine	<250 mg/L	23.6	23.6	23.6	23.6	0	0	0	0
18.	Nitrate	<10 mgN/L	8	8	8	8	8	8	8	8
19.	Total coliforms	0 MPN/100 mL	0	0	0	0	0	0	0	0
20.	E. coli	0 MPN/100 mL	0	0	0	0	0	0	0	0

Key: TP = Treated Pot
TWA & TWB = Treated Water A & Treated Water B

Table 5 shows the results obtained when water samples from both sources were first treated with a specific dose (4:6) of the moringa olivera solution and the test water samples before being filtered with the pots impregnated with the colloidal silver solution. The observations were a further reduction in most of the physiochemical parameters of the water samples (turbidity, total alkalinity, total solids, total dissolved solids, and total suspended solids). The concentrations of calcium and manganese (> 200 and > 0.5 mg/L respectively) in both water samples, were reduced to <200 and < 0.5mg/L respectively after treatment which falls within the safety limit of < 200 and < 0.5mg/L respectively by the World Health Organization (WHO, 2010). The other elements (Cu, Mg, Fe, Zn, Pb and Cl) still had their concentrations above the WHO threshold.
Additionally, the use of the treated pots and treated water samples also showed a 100 % removal of the bacterial load in the treated water (total coliform and E. coli count was zero) an indication of the effectiveness of the treatment procedure. In general, the treatment of the water samples using a combination of the moringa olivera and treated pots as seen in table 5, showed all the physiochemical and bacteriological parameters to be within the WHO safety limit.

4. Conclusion

A simple water treatment system using a moringa activated two-tier filtration, nano-silver impregnated ceramic pot was developed and used to treat underground water from two sources. The results showed that the system was effective for the treatment of the water samples. Some physiochemical parameters of the raw water samples (TS, TDS, TSS, odor and taste), elemental parameters (fluoride, calcium, magnesium, iron, copper, zinc, lead, manganese) and bacterial count (total coliform and E. coli) all had their initial concentrations higher than the WHO safety limit for drinking water. On treatment with the ceramic pots, there was a general reduction in the concentration of these parameters especially the bacterial load which was 100 % reduced. With the exception of fluoride, calcium and manganese, all other elemental parameters were higher than the WHO safety limit.
Several local methods developed have only been capable of removing the physical water contaminants but are ineffective in the removal of microbial contaminants. This method investigated was effective not only in the reduction of physiochemical but also some elemental and bacteriological parameters and should be encouraged. Additionally, it was cost-effective, simple and could be utilized in all homes both in rural and urban areas especially in developing countries chiefly in Africa where provision of safe drinking water for the populace continued to be a problem for most governments.

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