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Effect of *Moringa Oleifera* Seed Cake on Drinking Water Quality in Some Displaces Peoples Camp´s in Darfur Sudan

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Abstract

Moringa oleifera Seed Cake (MOSC) is one of the alternatives to replace chemical coagulants. The water quality of the Displaced Peoples Camps in Darfurs was examined before and after the treatment. Various parameters with (MOSC) were examined. Preliminary laboratory results showed the great potential of the (MOSC) for use in water treatment. MOSC shows an excellent turbidity reduction highest turbidity reductions were achieved by treatment with 10 or 12 g / L Moringa seed cake in the hand pump water from Otash Camp, with 6 and 8 g / L Moringa seed cake in the well water from Mossai Camp and with 8 and 10 g / L Alum in the borehole water from Otash Camp. The electrical conductivity values of the water samples from the camps were 753.9, 722.2, 819.7 s / cm in the hand pump water of the Mossai camp, the borehole water (Mossai camp) and the borehole water (Otash camp). The pH values of the raw water from the three water sources showed only slight fluctuations.

Keywords: *Moringa oleifera*, drinking water, physicochemical properties, displaced camps, Sudan

1. Introduction

Many African, Asian and South American populations use Moringa oleifera seeds to treat water pollution problems. The Sudanese community largely ignored water pollution problems for many years; however, its membe rs are becoming more aware of the need for clean water. (Lea, 2010).

An efficient reduction of high cloudiness (80.0% to 99.5%) leads to an aesthetically clear supernatant, followed by a bacteria reduction of 90.00% to 99.99% (1 to 4 log). This inexpensive Moringa oleifera process is recommended for simple, low-risk water treatment on site in rural and urban areas where people who live in great poverty currently consume excessively cloudy and microbiologically contaminated water. The resettlement of people is one of the tragic consequences of the civil war in the Darfur region.

Aluminum salts have been used in drinking water treatment in the past to protect it from pollution, but the overuse of such chemical coagulants increases treatment costs and can cause health and environmental problems (Joshua and Vasu 2013). More recently, natural alternative water treatment methods, especially in rural areas (Folkard et al. 1993; Doerr 2005; Onwuliri and Dawang 2006), have been used to remove pollutants from drinking water by using natural compounds from plants such as okra (Agarwal et al. 2001), rice. (Yarahmadi et al. 2009), fenugreek (Rajani and Mishra 2008). The tree Moringa oleifera is one of the most frequently used plants (leaves and seeds) in water treatment as a natural coagulant because of its low cost, high biodegradability and short shelf life Life and its harmlessness for human health and the environment in comparison to synthetic organic or inorganic coagulants (Muyibi et al. 2002; Katayon et al. 2005; Katayon et al. 2006).

In Sudan, Moringa was originally an ornamental tree planted by foreigners in avenues, parks and gardens along the Nile during British rule. It is likely that Arab women in Sudan discovered this remarkable mud tree. Preliminary laboratory tests by Samia Jahn (German scientist) confirmed the presence of a very effective coagulant in Moringa oleifera seeds (Gidde and Bhalerao 2006). Later, another Moringa seed from Kenya was found to have similar flocculation properties.

2. Materials and Methods

2.1. Study Location

The purpose of this work was to study the effects of seed and leaf extracts of the horseradish tree (drumstick) Moringa oleifera Lam. (Household Moringa) for water purification. Two camps were selected for the study, Camp Mosai, east of the town of Nyala, and Camp Ortas, northwest of Nyala. Nyala city is the capital of South Darfur state in western Sudan. It is located at longitude 240 53 degrees east and is divided in half by latitude 120 04 degrees. It is located approximately 900 kilometers southwest of Khartoum and 251 kilometers east of the border with the Republic of Chad. Mosai and Ottash camps obtain drinking water from three sources: 1. Borehole with submersible pump (Table 1), 2. Hand pump (Table 2) and 3. Water intake point (bladder and tank) (Table 3)

2.2. Collection of water samples

In order to study the chemical and microbiological parameters of drinking water in Mosai and Ottash camps and propose corrective measures, from boreholes equipped with submersible pumps, hand pumps, water intake points (water tanks), household containers (cerium, plastic containers) and donkey carts. Water samples were collected from displaced person camps in Darfur as follows: Otash camp: Water samples were collected from earthen domestic containers (zers), donkey carts and boreholes. Mossai Camp: Water samples were taken from boreholes, Zersen and hand pumps. Samples were collected according to APHA13 Standard Method for the Examination of Water and Wastewater (2000). Samples were collected over an 18-month period from January 2019 to July 2021. A total of 132 drinking water samples were collected weekly. Water samples for physicochemical analysis were collected in clean plastic containers (1 L capacity).All samples were processed in the laboratory of the Water and Environment Sanitary Unit (WES), Water Corporation, Nyala City, South Darfur State.

Plate 1: Boreholes equipped with submersible pumps.

Plate 2: Hand pump

Plate 3: Water point (water tank)

2.3. Preparation of the Moringa oliefera seed cake

The fruit of the M. oliefera tree growing in the southern region of the Blue Nile was picked during the 2016-2017 season. The fruit was divided along the sutures and seeds were picked (Table 4), then the seed coat and wings were removed from the white/yellow pit as described by Jahn (1988) (Table 4). When roasting the grains, mash them thoroughly with a mortar and pestle. Boil the seed cake in boiling water for 5 minutes, then filter the liquid through a cotton filter cloth into a clean container, leaving the seed cake next to the cotton cloth. Finally, seed cakes (press cakes) were dried in direct sunlight for 2 days using the procedure described in Current Protocols in Microbiology (2010).

2.4. Preparation of the Moringa Oleifera Methanol Seed Extract

Moringa seeds were hulled and dried for five days and then processed as described by Atieno Walter et al. Process as described. Aluminum (2010). Grind the white granules to a fine powder using a Christy laboratory grinder at 8000 rpm. The resulting fine powder was then sieved through a No. 26 sieve. In a 5L Ehlenmeyer flask, soak 1000 g of olive powder in 2000 mL of n-hexane, seal and place on a laboratory shaker for 4 hours, then overnight. Pour into 1 L flask and pass #1 Whattman filter paper into Buchner flask. The filtrate was concentrated on a rotary evaporator in a 40 °C water bath until condensation of the solvent stopped dripping. The extract was then transferred to a sterilized beaker.

2.5. Preparation of Moringa oleifera Methanol Leaf Extract

Maringa leaves were dried for 5 days before grinding as described by Atieno Walter et al. aluminum. (2010). Grind the leaves to a fine powder using a Christy laboratory grinder at 8000 rpm. The resulting fine powder was then sieved through a No. 26 sieve. In a 5 L Ehlenmeyer flask, soak 1000 g of olive powder in 2000 ml of n-hexane, stopper and place on a laboratory shaker for 4 hours, then overnight. Pour it into a 1 L flask and pass it through Whattman filter paper into a Buchner flask. The filtrate was concentrated on a rotary evaporator in a 40°C water bath until condensation of the solvent stopped dripping. The extract was then transferred to a sterilized beaker.

Plate 4: Left side *Moringa Oliefera* seeds with seed coating and right side seeds without seed coating

The solid residue obtained from the powder sieving was placed in two 5 liter Erlenmeyer flasks with 2000 ml of methanol and placed in a laboratory shaker (UAR orbital shaker SO1) for 4 h and left to stand overnight in order to decant in a 1 liter flask. The extract was filtered through Whattman No. 1 filter paper using a water suction pump and placed in a Buchner flask. The filtrate was concentrated on a rotary evaporator at a 40 ° C. water bath until the condensation of the solvent stopped dripping. The extract was then transferred to a sterilized beaker.
Determination of the physico-chemical parameters before and after treatment with Moringa seed cake and aluminum sulfate (alum)

2.6. Turbidity

Turbidity measurements were carried out by the nephelometric method (APHA, 2000) using a 2100 N opacimeter (HACH Instruments, USA). The results were reported in nephelometric turbidity units (NTU).

2.7. Electrical Conductivity (EC)

Electrical conductivity was measured using a 4510 conductivity meter (JENWAY Instruments, UK). The results were expressed in micro-seeds per centimeter (s / cm).

2.8. pH

The pH of the water was measured in the laboratory by the glass electrode method with an electrode-type pH microprocessor pH meter (Hanna Instruments, Portugal).

2.9. Hardness

The water hardness was determined by titration, a water sample of 50 ml being transferred to a 250 ml Erlenmeyer flask, Erochrome black T indicator and 2 ml buffer solution being added. Then it was titrated against ethylene diamine tetra acetic acid (EDTA 0.1 N) until the end point (blue color) was reached (APHA, 2000[13]). The total hardness (as CaCO3) in mg / L was then calculated as follows:

Total hardness (mg/L) = $\frac{\mathrm{Mw} \times \mathrm{N} \times \mathrm{V} \times 1000}{\text{Sample volume (mL)}}$

Where: Mw=Molecular weight of $CaCO_3$

N= Normality of EDTA

V= Volume of EDTA

2.10. Alkalinity

The water alkalinity was determined by titration, placing a water sample (50 ml) in an Erlenmeyer flask, adding a drop of phenolphthalein indicator and adding 0.02 N sulfuric acid with constant swirling until the pink color turned colorless. The milliliter of sulfuric acid was multiplied by 20 to get the alkalinity of mg / l phenolphthalein (as CaCO3). A drop of methyl orange indicator was added and the addition of sulfuric acid was continued until a light green blue-gray color developed (APHA, 2000[13]). The alkalinity was then calculated as follows:

Alkalinity (as $CaCO_3$) mg/L = $\frac{\mathrm{Ms} \times \mathrm{N} \times 50000}{\text{Sample volume (mL)}}$

Where:

Ms= mL standard acid used

N= Normality or titer of standard acid

2.11. Total dissolved solids (TDS)

The TDS were measured directly with a HQ14d Conductivity Meter (Hach Instrument, USA). The results were expressed in mg / L

2.12. Study of microbiological parameters before and after treatment with Moringa seed cake and alum Sterilization of glassware

All glassware was washed thoroughly and allowed to dry, followed by sterilization in a hot air oven (PTL Limited, England) at 160 ° C for at least 3 hours (Harrigan and McCance, 1976). Instruments such as loops and spatulas were flame-sterilized after being immersed in alcohol.

2.13. Total Viable Bacteria Counts (TVBC)

Total Viable Bacteria Counts (TVBCs) was performed using the pour plate technique as described by Harrigan (1998).

2.14. Most probable number (MPN) technique

The Most Probable Number (MPN) technique was used for the counting of coliforms, fecal coliforms of all samples according to APHA (2000).

2.15. Statistical analysis

The data were statistically analyzed using the M-STAT statistical analysis software. The means were separated by Duncan's Multiple Range Test (Steel and Torrie, 1980).

3. Results and Discussion

3.1. Physicochemical parameters

3.1.1. Turbidity

Untreated water samples in the camps of displaced in Darfur showed very high turbidity values, the 1193, 1374 and 743.30 nephelometric turbidity units (NTUs) in hand pump water (Mossai camp), borehole water (Mossai camp) and hand pump water (Otash camp), respectively. However, these values were significantly reduced by treatment with increasing concentrations of either aluminum sulfate (alum) or with seed cake of Moringa oleifera. In most cases, treatment with the moringa seed cake at the same concentration was more effective than treatment with alum. The highest turbidity reductions, however, were achieved by treatment with 10 and 12 g / L Moringa seed cake in the hand pump water of the Otash camp, with 6 and 8 g / L Moringa seed cake in the borehole water of the Mossai camp, and with 8 and 10 g / L Alum in the borehole water from the Otash camp (Table 1).

3.1.2. Water electrical conductivity (EC)

The electrical conductivity values of the water samples from the camps were 753.9, 722.2, 819.7 s / cm in the hand pump water of the Mossai camp, the borehole water (Mossai camp) and the borehole water (Otash camp). These levels were significantly reduced by treatment with either alum or moringa seed cake. In general, the reduction was greater with the higher concentrations of clearing agents. In all three water samples, the greatest reduction in electrical conductivity was achieved by adding 12 g / l of either alum or moringa seed cake. The reduction achieved was between four and five times the original electrical conductivity values (Table 2).

Table 1. Turbidity (NTU units) of three water samples from the camps of the displaced in Darfur before and after treatment with Moringa oleifera seed cake and aluminum sulfate

Treatment	Hand pump (OC)	Borehole (MC)	Borehole (OC)
Untreated	1193.00^{a}	1374.00^{ab}	743.30^{a}
M_1((4 g/L)	20.00^{d}	10.39^{b}	32.16^{ef}
M_2(6 g/L)	17.90^{e}	5.59^{d}	32.93^{ef}
M_3(8 g/L)	16.50^{ef}	7.39^{c}	33.59^{e}
M_4(10 g/L)	11.41^{h}	7.69^{c}	37.07^{d}
M_5(12 g/L)	14.02^{g}	10.19^{b}	39.50^{c}
A_1(4 g/L)	1191.00^{a}	1376.00^{a}	714.80^{b}
A_2(6 g/L)	1190.00^{a}	1376.00^{a}	713.70^{bc}
A_3(8 g/L)	94.67^{c}	7.15^{c}	4.74^{i}
A_4 (10 g/L)	99.07^{bc}	11.10^{b}	6.11^{h}
A_5 (12 g/L)	10.70^{b}	10.85^{b}	8.13^{g}
SE±	0.6184	0.7313	0.3673

Values are mean±SD.
Any two means sharing same superscript are not significantly different (P≤0.05).
MC= Mossai Camp; OC= Otash Camp
M_1....M_5= *Moringa oleifera* seed cake concentrations
A_1, A_2, A_3, A_4, A_5= Alum (Aluminium sulfate) concentrations

Table 2. Electrical conductivity (s / cm) of three water samples

Treatment	Hand pump (MC)	Borehole (MC)	Borehole (OC)
Untreated	753.90^{a}	722.20^{a}	819.70^{a}
M_1(4 g/L)	749.30^{ab}	721.80^{a}	818.70^{a}
M_2(6 g/L)	721.10^{b}	671.30^{b}	704.20^{b}
M_3(8 g/L)	192.20^{e}	127.70^{d}	233.70^{e}
M_4(10 g/L)	190.00^{e}	121.50^{de}	186.40^{f}
M_5(12 g/L)	117.20^{g}	105.70^{f}	127.40^{g}
A_1(4 g/L)	606.10^{c}	503.00^{c}	568.20^{c}
A_2(6 g/L)	567.40^{d}	503.60^{c}	522.20^{d}
A_3(8 g/L)	566.50^{d}	504.50^{c}	520.80^{de}
A_4(10 g/L)	170.80^{f}	117.20^{e}	128.20^{g}
A_5(12 g/L)	120.30^{h}	111.40^{g}	126.90^{g}
SE±	3.332	3.59	3.401

Abbreviations as in Table 1

3.1.3. Total dissolved solids (TDS)

The total dissolved solids were 8020.9, 951.24 and 1115.1 mg / L in the hand pump water sample from the Mossai camp, the borehole water sample (Mossai camp) and that from the borehole at the Otash camp, respectively. Solids load was significantly reduced due to the addition of increasing amounts of either alum or moringa seed cake to the water. The highest reduction in the water sample from the hand pump of the Mossai camp was achieved by adding 12 g / L Moringa seed cake, while it was achieved in the sample from the borehole in the same camp by adding 10 or 12 g / l. L alum. In the sample from the borehole in the Otash camp, this was achieved by adding 10 or 12 g / L Moringa seed cake. Although the reductions were significant, they were no more than 50% of the original values (Table 3).

3.1.4. pH

The pH values of the raw water from the three water sources showed only slight fluctuations. They were between 6.57 and 6.63. In general, slight and insignificant reductions in these values were made due to the addition of moringa seed cake or alum (Table 4).

3.1.5. Total alkalinity

The total alkalinity values of the untreated drinking water were 252.0, 48.33 and 68.0 mg / L in the water samples from the hand pump (Mossai storage facility), the borehole in the Mossai storage facility and the borehole in the Otash storage facility. However, a significant reduction in these values could be achieved by adding moringa seed cake or alum, especially when high amounts (12 g / l) were added (Table 5).

Table 3. Total dissolved solids (TDS, mg / L) of three water samples

Treatment	Hand pump	Borehole (MC)	Borehole (OC)
Untreated	8020.90^{a}	951.24^{a}	1115.10^{a}
M_1(4 g/L)	651.46^{f}	681.44	664.87^{f}
M_2(6 g/L)	650.72^{f}	574.79^{f}	631.53^{g}
M_3(8 g/L)	599.84^{h}	505.93^{g}	590.10^{h}
M_4(10 g/L)	547.82^{i}	505.39^{g}	573.10^{i}
M_5(12 g/L)	527.52^{j}	469.34^{h}	573.03^{i}
A_1(4 g/L)	1174.50^{b}	672.88^{c}	1020.00^{b}
A_2(6 g/L)	1147.53^{c}	590.75^{d}	986.90^{c}
A_3(8 g/L)	817.20^{d}	586.33^{de}	959.57^{d}
A_4(10 g/L)	722.97^{g}	353.25^{i}	684.47^{e}
A_5(12 g/L)	685.84^{e}	351.84^{i}	683.44^{e}
SE±	22.42	4.371	4.583

Abbreviations as in Table 1

Table 4. pH of three water samples

Treatment	Hand pump (MC)	Borehole (MC)	Borehole (OC)
Untreated	6.58^{a}	6.63^{a}	6.57^{a}
M_1(4 g/L)	5.32^{a}	5.66^{a}	5.10^{a}
M_2(6 g/L)	6.30^{a}	6.53	6.50^{a}
M_3(8 g/L)	6.33^{a}	6.53^{a}	6.53^{a}
M_4(10 g/L)	6.47^{a}	6.53^{a}	6.47^{a}
M_5(12 g/L)	6.40^{a}	6.80^{a}	6.67^{a}
A_1(4 g/L)	6.35^{a}	6.53^{a}	6.67^{a}
A_2(6 g/L)	6.15^{a}	6.63^{a}	6.37^{a}
A_3(8 g/L)	5.17^{a}	5.30^{a}	5.13^{a}
A_4(10 g/L)	5.26^{a}	5.33^{a}	5.23^{a}
A_5(12 g/L)	5.32^{a}	5.30^{a}	5.03^{a}
SE±	1.133	1.449	1.397

Abbreviations as in Table 1

Table 5. Total alkalinity (mg / l) of three water samples

Treatment	Hand pump (MC)	Borehole(MC)	Borehole (OC)
Untreated	259.67^{a}	61.67^{a}	68.33^{a}
M_1(4 g/L)	113.67^{c}	49.33^{d}	68.00^{a}
M_2(6 g/L)	94.33^{d}	48.33^{f}	63.67^{d}
M_3(8 g/L)	94.00^{d}	37.00^{h}	35.33^{e}
M_4(10 g/L)	54.67^{e}	36.33^{i}	34.67^{ef}
M_5(12 g/L)	38.00^{g}	28.33^{j}	26.67^{g}
A_1(4 g/L)	252.00^{b}	56.33^{b}	67.33^{a}
A_2(6 g/L)	251.67^{b}	50.00^{c}	65.33^{c}
A_3(8 g/L)	43.67^{f}	49.67^{e}	64.67^{cd}
A_4(10 g/L)	43.00^{f}	45.67^{g}	64.67^{cd}
A_5(12 g/L)	32.33^{h}	25.67^{k}	37.33^{g}
SE±	1.5817	2.1898	2.6317

Abbreviations as in Table 1

Table 6. Total bacterial count (CFU / ml) in three water

Treatment	Source of water sample		
	Zeer water	Hand pump	Borehole
Untreated	29.160^{a}	21.000^{a}	15.500^{a}
M_1(4 g/L)	28.333^{de}	13.000^{cd}	12.000^{e}
M_2(6 g/L)	24.333^{f}	12.333^{cde}	11.850^{e}
M_3(8 g/L)	14.667^{g}	12.067^{de}	11.667^{e}
M_4(10 g/L)	14.00^{g}	11.733^{de}	11.100^{f}
M_5(12 g/L)	0.633^{h}	0.500^{e}	0.767^{f}
A_1(4 g/L)	15.600^{b}	13.600^{b}	6.000^{b}
A_2(6 g/L)	13.000^{d}	4.333^{c}	2.467^{d}
A_3(8 g/L)	14.333^{c}	3.000	3.867^{c}
A_4(10 g/L)	12.667^{def}	3.000^{cd}	2.000^{e}
A_5(12 g/L)	12.533^{ef}	2.533^{cde}	1.800^{e}
SE±	1.411	1.159	0.912

Abbreviations as in Table 1

Table 7. Total coliforms (MPN / ml) in water samples

Treatment	Source of water sample		
	Zeer water	Hand pump	Boreholes
Untreated	42.00[a]	93.00 [a]	23.00 [a]
M_1(4 g/L)	9.10 [b]	13.30 [b]	13.30[c]
M_2(6 g/L)	7.30 [c]	11.70 [b]	16.70 [b]
M_3(8 g/L)	3.60 [d]	8.70 [c]	18.30 [b]
M_4(10 g/L)	0.40 [e]	0.60 [d]	0.00[d]
M_5(12 g/L)	0.30[e]	0.33[d]	0.00[d]
A_1(4 g/L)	0.00[e]	0.00[d]	0.00[d]
A_2(6 g/L)	0.00[e]	0.00[d]	0.00[d]
A_3(8 g/L)	0.00[e]	0.00[d]	0.00[d]
A_4(10 g/L)	0.00[e]	0.00[d]	0.00[d]
A_5(12 g/L)	0.00[e]	0.00[d]	0.00[d]
SE±	0.4274	0.7979	1.059

Abbreviations as in Table 1

3.1.6. Total hardness

Table (6) shows that treatment with Moringa seed cake resulted in a significant reduction in the total hardness of the water, especially at the higher dosages (10 and 12 g / L). On the other hand, the treatment with alum increased the hardness significantly, which was seen with the application of 4, 6 or 8 g / L. With 10 or 12 g / L this effect was less, but the hardness was still higher than with the untreated sample. Moringa oleifera Lam. and Moringa stenopetala (Baker f.) Cufod. are the most commonly grown species of the monogenic Moringaceae family (Fahey 2005). Moringa oleifera is grown in Africa, Central and South America, the Indian subcontinent and Southeast Asia. In these poor countries across Africa, Asia and Latin America, around 1.4 billion rural and suburban people live in extreme poverty and struggle to survive on a daily basis (Chen and Ravallion, 2008). The majority of this population is almost exclusively dependent on traditional sources of extremely cloudy and untreated surface water for their domestic water requirements.

3.2. Total viable bacterial counts (CFU/ml)

Table 6 shows the Total Viable Bacteria Counts (TVBC) in the three drinking water sources in Camp Otash. In the untreated water samples, the total viable bacterial load was highest in donkey cart water, followed by sea water and then borehole water. However, when treated with the lowest applied dose of moringa seed cake or alum (4 mg / L), the exposure was significantly reduced. In both cases, the reduction increased linearly with the level of the dose applied, but was more pronounced with the application of moringa seed cake than with alum.

3.3. Total coliforms (MPN/mL)

The most likely total coliform count in the untreated water samples was highest in donkey cart water (37.67 MPN / ml), followed by sea water (22.3 MPN / ml), then borehole water (8.77 MPN / ml). When treated with the dose (12 g / L) of either moringa seed cake or alum, no coliforms were reported in any of the three water samples (Table 7).

In the present study, the measured parameters of the drinking water in the camps of the displaced in Darfur (turbidity, total dissolved solids, hardness ... etc ..) make it exceptionally unsuitable for drinking. The water turbidity was significantly very high, but was reduced from values of 1193 NTU (hand pump, Mossai bearing), 1374 NTU (borehole, Mossai bearing) and 743 NTU (borehole, Otash bearing) to only 11.4, 5, 59 or 32.16 NTU reduced due to the use of Moringa seed cake. The resulting haze compares favorably to that obtained using similar alum loadings. This corresponded to a haze removal of 95.4% - 99%, which is consistent with the results of other workers such as

Madsen et al. (1987) who reported 90-99% haze removal, Futi et al. (2011) 26 who reported a removal of 85% and with Amagloh and Benang (2009). The declared WHO guideline for safe drinking water is 5NTU (WHO 2006). With a dosage of 12g / L, the excess water obtained in this way is still higher than prescribed by the WHO, but represents a significant reduction in turbidity. This is certainly due to the unusually high turbidity values in the untreated spring water.

One of the advantages of using moringa seeds over synthetic water clarifiers like alum is that, unlike alum, moringa does not lower the pH of the treated water (Katayon et al. 2004, Muyibi and Evison 1995, Nwaiwu and Bello 2011) . The acceptable pH range for drinking water recommended by the WHO (2006) is between 6.0 and 8.0. In the present study, the pH of the raw water samples was between 6.57 and 6.63. Treatment with Moringa seed cake, however, resulted in a drop in these values, but the drop in pH values was always comparatively greater when similar doses of alum were used. The resulting pH values are below the WHO recommended pH value. Such acidic water can be harmful to human health as it can lead to stomach ulcers or even accelerate their development. Futiet al. (2011) reported that the addition of 0.25 g / l aluminum sulfate led to a sharp decrease in the pH of the water from 7.1 to 4.4, while the addition of 0.25 g / l M. oleifera - Seed cake did not result in any pH change.

The hardness of the untreated water samples ranged from 116.67 to 2658.0 mg / L. The sample from the hand pump in the Mossai camp had an acceptable hardness and was therefore not reduced much by the treatment with Moringa seed cake, but the borehole water in the Otash camp had the exceptionally high value of 2658 mg / L and was clearly at 500.33 mg / L of moringa seed cake and 66.67 of alum. The reduction by moringa extract was more than 80%. A reduction in water hardness from 188 mg / L to 156 mg / L has been reported by Mangale et al. (2012) with M. oleifera seed powder, while Muyibi and Evison (1995) achieved a reduction from 1017 mg / L to almost zero with 1800 mg / L Moringa seed cake. The WHO hardness standard is 500 mg / L (WHO 2006), which shows that some of the results of this study are acceptable. The total dissolved solids content in the untreated samples was exceptionally high, particularly in the sample from the hand pump in the Mossai camp (8020.9 mg / L) and that from the borehole at the Otash camp (1115.1 mg / L). However, these values were reduced to 527.5 and 573 mg / L (a reduction of 50-90%) through the use of 12 g / L Moringa seed cake. These values approach the TDS limit value set by the WHO for drinking water (500 mg / L). Mangale et al. (2012) reported a reduction in TDS from 652 to 235 mg / L in turbid river water (a reduction of 64%). Similar reductions in alkalinity and electrical conductivity were achieved in the present study.

References:

Agarwal M, Srinivasan R. and Mishra A. (2001). A study on flocculation efficiency of okra gum in sewage wastewater. Macromol. *Mat. Eng. 9, 560-563.* https://doi.org/10.1002/1439-2054(20010901)286:9<560::AID-MAME560>3.0.CO;2-B

Amagloh F K. and Benang, A. (2009) Effectiveness of Moringa oleifera Seed as Coagulant for Water Purification. *African Journal of Agricultural Research*, 4, 119-123. https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1186559

APHA (2000*).* Standard Methods for the Examination of Water and Wastewater. 2 ed., American Public Health Association, Washington, DC, 2000.

Atieno Walter,Wagai S, Arama P and Ogur J. (2010). Antibacterial activity of Moringa oleifera and Moringa bacteria implicated in water borne diseases. Department of Botany and Horticulture, Maseno University, Kenya. *African Journal of Microbiology Research* Vol. 5(2) pp. 153-157, 18 January, 2011. DOI: 10.5897/AJMR10.457

Chen S and Ravallion M. (2008). The Developing World is Poorer than We Thought, But No Less Successful in the Fight Against Poverty. The World Bank Development Research Group. Washington, D.C . Coagulants for water purification. Tech. Rep. No. R4254. University of Leicester. http://hdl.handle.net/10986/6322

Dishna Schwarz (2000) 'Water clarification using M.O.' Gate information service, pp 1-5. file:///C:/Users/Dell/Downloads/Documents/SCHWARTZ%202000%20Water%20Clarification%20Using%20Moringa%20Oleifera.pdf

Doerr B. (2005). Field Guides for Emergency Water Treatment with *Moringa oleifera* . https://www.jumpjet.info/Emergency-Preparedness/Emergency-Supplies/Field_Guide_for_Emergency_Water_Treatment_with_Moringa_oleifera.pdf

Fahey J. (2005). *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. J. Trees for Life 1: 5. DOI: 10.1201/9781420039078.ch12

Folkard G K, Sutherland J P and Shaw R (1993). Water clarification using *Moringa oleifera* seed coagulant. www.iboroac.uk/well.downloadedAccessed 13th Dec.2008

Futi A P, Otieno W S., Acholla O J, Otieno W A, Ochieng O S, and Clerkson M. (2011). Harvesting surface rainwater – purification using *Moringa oleifera* seed extracts and aluminium sulfate. Journal of Agricultural Extension and Rural Development 3(6) : 102-112.https://doi.org/10.5897/JAERD.9000045

Gidde M R, and Bhalerao A R. (2006). Review Article *Moringa oleifera* - a Multipurpose Tree and a Natural Coagulant. Department of Civil Engineering B.V.U. College of Engineering, Pune

Jahn S.A.A. (1988). Using *Moringa oleifera* seeds as coagulant in developing countries. *Journal of American Water Works Association* 80: 43–50. https://scirp.org/reference/referencespapers.aspx?referenceid=1422616

Joshua R and Vasu V. (2013). Characteristics of Stored rain water and its treatment technology using Moringa Seeds. Int. J. LifeSc. Bt & Pharm. Res. 2(1) : 174- 155

Katayon S N C, Megat Mohd Noor S. M J. and Abdullah A G L. (2006). the effectiveness of *Moringa oleifera* as primary coagulant in high –rate settling pilot scale water treatment plant , Faculty of Engineering, University Putra Malaysia, International Journal of Engineering and Technology 3 (2), 2006.

Katayon S, Megat M N, Asma M, Ghani L A A, Thamer A M, Azni I, Ahmad J, Khor. B C, and Suleyman A M. (2005). Effects of storage conditions of *Moringa oleifera* seeds on its performance in coagulation. Bioresource Technology. Ref Type: In Press. DOI: 10.1016/j.biortech.2005.07.031

Katayon S, Mohammed Nor M.J. Megat, Asma A, Thamer A N, Liew Abdullar A.G. , Idris A., Suleyman A.M., Aminuddin M.B. and Khor B.C. (2004). Effects of storage duration and temperature of MO stock solution on its performance in coagulation. Int. J. Eng. Technol. 1(2): 146-151.

Madsen M, Schlundt J and Omer E F E. (1987). Effect of water coagulation by seeds of *Moringa oleifera* on bacterial concentrations***.*** *The Journal of tropical medicine and hygiene 90(3):101-9.* DOI: 10.1016/0378-8741(88)90285-1

Mangale S.M., Chonde S.G., Jadhav A.S., and Raut P.D. (2012). Study of *Moringa oleifera* (Drumstick) seed as natural absorbent and antimicrobial agent for river water treatment. J. Nat. Prod. Plant Resour. 2 (1):89-100. www.scholarsresearchlibrary.com

Muyibi S A, and Lilian M. Evison , (2002). Effects of oil extraction from *Moringa oleifera* seeds on coagulation of turbid water. International Journal of Environmental Studies 59: 243-25. DOI: 10.1080/00207230210924

Muyibi S.A. and Evison L.M. (1995). *Moringa oleifera* seeds for softening hard water. Water Resour., 29(4): 1099-1105.file:///C:/Users/Dell/Downloads/Documents/waterabstract.pdf

Ndabigengesere A. (1995) 'Active agents and mechanism of coagulation of turbid waters using M.O.' Water Research, 29 (2): 703-710.

Ndabigengesere A. (1998) 'Quality of water treated by coagulation using M.O.' Water Research, 32 (3): 781-791. http://dx.doi.org/10.1016/S0043-1354(97)00295-9

Nwaiwu N.E. and Bello A.A. (2011). Effect of *Moringa oleifera*-alum ratios on surface water treatment in North East Nigeria. Research Journal of Applied Sciences, Engineering and Technology 3(6): 505-512. https://www.cabdirect.org/cabdirect/abstract/20113280958

Onwuliri F C and Dawang N D. (2006). Antimicrobial activity of aqueous and ethanolic leaf extract of drumstick plant (*Moringa oleifera* Lam.) on some bacteria species associated with gastro intestinal diseases, Nigerian Journal of Botany9(2):272-279 .

Rajani S, and Mishra A. (2008). Okra (*Hibiscus esculentus*) and Fenugreek (*Trigonella foenum graceum*) mucilage: Characterisation and application as flocculants for textile effluent treatment. *Chinese Journal of Polymer Science, 26 (6): 679-687.* DOI: 10.1142/S0256767908003424

Rajani, S, Agarwal, M and Mishra A. (2002*) Plantago psyllium* grafted polyacrylonitrile-synsthesis characterization and its use in suspended and dissolved solid removal from textile effluent. Water Qual. Res J. Canana 37 (2): 371-378. DOI: 10.2166/wqrj.2002.023

Walter A, Samuel W, Peter A and Joseph O. (2011). Antibacterial activity of *Moringa oleifera* and *Moringa stenopetala* methanol and n-hexane seed extracts on bacteria implicated in water borne diseases. *African Journal of Microbiology Research* 5(2): 153-157. https://doi.org/10.5897/AJMR10.457

WHO (2006). Guideline for drinking-water quality (electronic resources): incorporating first addendum. Vol. 1, Recommendations, 3rd edition. Internet: http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf.

Yarahmadi M, Hossieni M, Bina B, Mahmoudian M H, Naimabadie A and Shahsavani A. (2009). Application of *Moringa oleifera* seed extract and polyaluminium chloride in water treatment. *World Appl. Sci. J. 8(7): 962-967*. file:///C:/Users/Dell/Downloads/Documents/4_8.pdf