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Efficiency Of Moringa Oleifera Seeds As A Natural Coagulant For Removal Of High Turbidity And Bacteria Compared With Aluminum Chlorohydrate In A Rural Community, Blue Nile, Sudan

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Abstract
The Moringa Oleifera seeds known a (the purifying tree) in Arabic known as (shagarat al rauwaq), were investigated to remove turbidity and reduce total coliform. The water was collected from the Blue Nile during a rainy season at high turbidity 4000NTU.The results show that Moringa has ability to reduce turbidity up to 4.95 NTU below the World Health Organization's(WHO) and The Sudanese Standards and Metrology Organization (SSMO) guideline value of 5 NTU for drinking water. It reduced the total coliform by 85% after 24 hours. The studies have also shown that pH, alkalinity, electric conductivity and total dissolved solid conformity with WHO and SSMO standards for drinking water. There was a decrease in the concentration of nitrate and phosphate, with increase in phosphate, but below within permission. Moringa shows remarkable ability to remove high turbidity and reduce total coliform with low cost and simple method for rural people living in the Blue Nile area.
Keywords: *bacteria, jar test, natural coagulants, polyelectrolyte, turbidity, water treatment*

1. INTRODUCTION

The developing countries including Sudan face potable water supply problems [1]. The Blue Nile have large seasonal variation, and the water is highly turbid; fine negatively charge particulate matter suspended in water (cloudiness) and contains suspended material such as silt, mud, heavy metals, bacteria and other microbes [2]. Chemicals or natural material treatment are required for their removal or reduction to acceptable limits [3]. Many coagulants are widely used in conventional water treatment processes: inorganic, synthetic organic polymers and natural coagulants [4]. There are disadvantages of aluminum case Alzheimer's disease linked with high aluminum residuals in treated water due to reactions with the OH^- and alkalinity of water, also production of large sludge volume, reduction of pH and low efficiency in coagulation of cold water [5, 6]. Synthetic organic polymers have strong carcinogenic properties [7], which contain contaminant formulations during the manufacturing process, such as residual monomers and other reaction by products [8, 9]. Aluminum chlorohydrate (ACH) is a group of specific aluminum salts having the general formula $Al_nCl_{(3n-m)}(OH)_m$, in water purification, this compound is preferred in some cases because of its high charge, which makes it more effective at destabilizing and removing suspended materials than other aluminum salts such as aluminum, aluminum and various forms of polyaluminium chloride and polyaluminium chlorosulfate, in which the aluminum structure results in a lower net charge than aluminum chlorohydrate [10]. Moringa Oleifera was originally an ornamental tree in the Sudan, planted during the British rule [11]. The women of Sudan have used the seeds from the Moringa Oleifera as purifying tree
;Sudanese named (Rauwāq tree) [12] for water treatment by swirling the seeds in cloth bags with water for a few minutes and allowing it to settle for an hour. Moringa Oleifera is naturalized species from the mono genus family. Moringa's recent estimates suggest that, for a spacing of 3m, a likely annual seed yield is 3 to 5 tons per hectare [13]. The seeds consist water soluble cationic protein [14], characterized as basic polypeptides with a molecular weight between (6to 16 Kilo Dalton) and an isoelectric pH of 10 to 11.Moringa seeds contain flavonoids, alkaloids compounds act as antimicrobial properties which able to flocculate gram-positive and gram-negative bacterial cells [15]. This paper evaluates shelled blended, deoiled and purified protein powder of Moringa Oleifera seeds (Rauwāq tree) as coagulants for removing high turbidity and reduce total coliform

compared to aluminium chlorohydrate in the Blue Nile rural areas.

2. MATERIALS AND METHODS

2.1 Study location

The study was carried out in Khartoum Station Water Corporation, Soba Station laboratory, Sudan.

2.2 Source of water sample

The water for study was collected from the point of Soba area in Khartoum state, Blue Nile that flow from Ethiopia. The raw water was first collected in a plastic container of 5 liters and kept for use.

2.3 Source of Moringa Oleifera seeds

The Moringa Oleifera seeds were obtained from farm in Ad- Damazin town, Blue Nile State, Sudan**.**

2.4 Source of the aluminum chlorohydrate

The chemical materials used in this study consist of aluminum chlorohydrate 50% solution, obtained from Summit Chemical Specialty Products (Thailand) Co., Ltd. Aluminum chlorohydrate (ACH) is a group of specific aluminum salts having the empirical formula of $Al_2(OH)_5Cl$, manufactured by reacting aluminum with hydrochloric acid.

2.5 Instruments

HACH/2100 N Turbidimeter, HANNA pH meter, JENWAY/4320TDS, EC and °C, DREL/2000 spectrophotometer.

2.6 Seeds coagulant preparation

2.6.1 Seeds collection

The seeds were purchased from farm and were de-shelled and the endocarps were air dried at ambient temperatures (25°C) for a period of seven days before milling. Direct sunlight was avoided to prevent degradation of some of the plant photochemical or antimicrobial constituents. The white kernel was crushed to a powder, using an electric grinder and sieved througha 500 µm stainless steel sieve.

2.6.2 Oil extraction

The soxhlet extraction method was used to extract the oil from Moringa Oleifera seeds. About 10 g of seeds powder were put into an extraction thimble. A 170 ml ofn-hexane solvent was poured into around bottom flask. After set up the soxhlet apparatus, the hexane solvent was heated for 45 min and the oil was extracted. After extraction, Moringa Oleifera cake residual (MOCR) was collected from the thimble and used for water treatment.

2.7 Work solution

Stock solution was prepared by dissolving 1.5g of (MOCR) into 300 mL distilled water, mixed with a magnetic stirrer for 60 minutes and left to settle. The solution was filtered through a Whatman No 1 filter paper, the resultant was a clear, milk- like liquid.Each time fresh solution was prepared for the experimental work. From the prepared stock solution, 1.5g, 2g, 3g, 4g and 5g concentration were used for the optimization study.

2.8 Coagulation test

Coagulation test was carried out using jar test to evaluate coagulation activity at several dose levels of Moringa Oleifera seed coagulant (MOSC). The study involved rapid mixing, slow mixing and sedimentation in a batch process. Jar Test is carried out using equipped with six paddles. five glass beakers of 1000 ml capacity were filled with the water samples, during this agitation, various amounts (20, 40, 60, 80 and 100 ml) of MOSC stock solution was added to five beakers respectively and agitated for 2 min at 150 rpm, the rapid mix stage helped to disperse the coagulant throughout each container. The mixing speed was reduced to 30 rpm and was kept for 30 mints for slow mixing this slower mixing speed helped in promoting floc formation by enhancing particle collisions which led to larger flocs. The process of mixing must be followed closely to activate the coagulant properties; if the flocculation process takes too long, there is a risk of secondary bacteria growth during flocculation. After sedimentation for 40 mints, the water was filtered through filter paper Whatman No.1. The process of settling is important. The sediment at the bottom contains the impurities so care must be taken to use only the clear water off the top and not allow the sediment to re-contaminate the cleared water.

2.9 Physicochemical analysis

The filtered water samples were analyzed for turbidity, pH, Electric Conductivity (EC), Total dissolved solids (TDS) and temperature (T °C). The odor and test was done by volunteers. Total alkalinity determined by titration with standard acid (HCl) with methyl orange as indicator. The titrimetric method using disodium salts of dihydrogen ethylenediamine-tetra- acetate (Na-EDTA) to determine total hardness used powdered Eriochrome Black T (EBT) indicator at pH 10. Calcium hardness was determined used (Na-EDTA) and powdered murexide indicator with NaOH. Spectrophotometer was used for the phosphate (PO_4^{3-}-P), Sulfate (SO_4^{2-}) and nitrate (NO_3^- - N HR) analysis.

2.10 Total coliform bacteria analysis

The main reason for analyzing total coliform bacteria is easy to enumerate and detect. The microbial test was carried out using the M-Endo media, which was prepared by dissolved 20.5gof the M- Endo media powder in 1litre of distilled water, autoclaved and allowed to cool. Sample were poured under pressure vacuum, then surface of the funnel rained with portion of sterile distilled water. The paper placed on the pre- prepared pad saturated with 3ml of media, and inoculated for 24hrs in an electro-thermal incubator. The growth of the microorganisms was then observed and counted per ml (number of microorganisms per ml of water samples).

3. RESULT & DISCUSSION

3.1 Raw water characteristics

Table 2 presents the results of physicochemical and bacteriological quality of the raw water used in the study. Most of the parameters were within the permissible standard specified by WHO and (SSMO).

3.2 Influence of Moringa Oleifera seed coagulant on turbidity

From the table 4, the concentrations of 1.5g (20ml) shown rapidly reduced of the turbidities from 3977 NTU to 4.95 NTU which below in WHO and SSMO standard 5 NTU. From the tables 5, 6, 7 and 8, concentration of 2g, 3g, 4g and 5g at (20 ml) reduce the turbidity from the 3977 NTU to 6.42, 7.58, 9.93 and 9.98 NTU respectively.

It is evident from the tables that, with MOC concentrations increase the turbidity increase; this can be explained by overdosing resulted in the saturation of the Moringa oleifera seed coagulant bridge sites due to insufficient number of particles (colloid) to form more inter-particle bridges with coagulant.

3.3 Influence of Moringa Oleifera seed coagulant on (pH)

It is evident during the concentration of moringa coagulant increases, the pH decreases. But below within recommended acceptable rang for drink water 6.5-8.5 according to the WHO and SSMO. This decrease in pH could be explained by the fact that the solution has become more acidic due to present of sulphate in the Moringa Oleifera seeds produce sulphuric acid which lowered the pH level.

3.4 Influence of Moringa Oleifera seed coagulant on Electric Conductivity

Initial electric conductivity of raw water was high. The conductivity increases slightly in all the treatments during coagulation due to solubility of mineral. Also, Moringa Oleifera have lower molecular weight water soluble proteins which carry positive charge. But this increase does not affect the quality of the water since the changes do not exceed the WHO and SSMO permissible limit of 1000µs/cm for drinking water.

3.5 Influence of Moringa Oleifera seed coagulant on Total Dissolved Solids (TDS)

The above tables show the influenced of Moringa Oleifera seed coagulant (MOSC) on TDS. The tables show that if the concentration of MOSC increases, the TDS concentration will increase. But this increase in the TDS below within WHO and SSMO value of 1000mg/l for drink water.

3.6 Influence of Moringa Oleifera seed coagulant MOSC on Alkalinity

The above tables show the effect of Moringa Oleifera coagulant (MOSC) on alkalinity. At various doses of MOSC, it was observed that the alkalinity reduced after the treatment at 1.5 g. But at higher dose, the alkalinity was slowly increased. Because the coagulant lies in the presence of water soluble as cationic proteins, and the basic amino acids present in the protein of Moringa accept a proton from water and release a hydroxyl group making the solution alkaline.

3.7 Influence of Moringa Oleifera seed coagulant on total hardness and hardness as Ca^{2+}

The tables show the influence of Moringa Oleifera coagulant (MOSC) on total hardness and hardness as Ca^{2+}.The higher concentration of treated water is due to present of calcium, magnesium.

3.8 Influence of Moringa Oleifera seed coagulant on anions the tables show the effected of MOSC on anions (Nitrate, phosphate and sulphate). Raw water with nitrate and phosphate levels of 26 mg/L and 1.58mg/l gave a mean nitrate and phosphate level of 5.6mg/l and 1.31mg/l respectively at coagulant dosage of 1.5g (20ml). From this result MOSC doesn't affected in nitrate and phosphate with increase of dosage. This was confirmed in the following concentrations (2g, 3g, 4g and 5g), but below in the WHO and SSMO standard guideline for drinking water.

3.9 Influence of Moringa Oleifera seed coagulant on bacteria:

From the tables, the number of total coliform bacteria in raw water was 450TCP, during coagulation the number of bacteria decrease when the concentration increase. The seeds of the Moringa Oleifera show flocculated bacteria by low molecular weight cationicwater-soluble proteins that attach themselves to suspended particles, including bacteria.But at the same time, it's not removed 100%. This can be explained by the concentration of photochemical compound which isin the Moringa Oleifera seed coagulant.

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4. Tables

Table 1: physicochemical and bacteria parameters with WHO & SSMO standard

Sr. No.	Parameters	Method	WHO	SSMO
Physical Parameters				
1	Turbidity	Nephelometer	5 NTU	5 NTU
2	pH	pH meter	6.5–8.5	6.5-8.5
3	Temperature(°C)	JENWAY 4320	-	Acceptable
4	EC	EC meter	2000 µs/cm	2000 µs/cm
5	TDS	TDS meter	1000 mg/l	1000 mg/l
6	Taste	Volunteer	Acceptable	Acceptable
7	Odor	Volunteer	Acceptable	Acceptable
Chemical parameters				
8	Total alkalinity	Titration	200 mg/l	200 mg/l
9	Total hardness	Titration	300 mg/l	300 mg/l
10	Hardness asCa^{2+}	Titration	150 mg/l	150 mg/l
11	Nitrate (mg/L NO3—N)	Spectrophotometer	50 mg/l	50 mg/l
12	2-	Spectrophotometer	250 mg/l	250 mg/l
13	Phosphate (mg/L PO4—P0029	Spectrophotometer	200 mg/l	200 mg/l
Bacteriological Parameters				
14	TPC/100 ml	Quantitative	Not detectable	Not detectable

*Sudanese Standards and Metrology Organization (SSMO)
* Total plate count (TPC)

Table 2: Quality characteristics of the collected water sample

No.	Parameters	Results
1	Turbidity	3977 NTU
2	pH	8.10
3	Temperature	26.3 °C
4	EC	260 µs/cm
5	TDS	125.8 mg/l
6	Taste	Not acceptable
7	Odour	Not acceptable
8	Colour	Colour
9	Total alkalinity	160.75 mg/l
10	Total hardness	192.11 mg/l
11	Hardness as Ca^{2+}	86.66 mg/l
12	Nitrate (mg/L NO3—N)	5.6 mg/l
13	2-Sulphate (SO4)	13 mg/l
14	Phosphate (mg/L PO4—P)	1.58 mg/l
15	TCP/100 ml	450 TCP

Table 3: Quality characteristics of treated water by aluminium cholorohydrate

Parameters	4 ml	6 ml	8 ml	10 ml	12 ml
Turbidity (NTU)	8.10	7.20	6.00	5.10	3.30
Coagulant activity (%)	99.79	99.82	99.85	99.87	99.91
Taste	Acceptable	Acceptabl	Acceptable	Acceptabl	Acceptable
Odour	Odorless	Odorless	Odorless	Odorless	Odorless
Colour	Colorless	Colorless	Colorless	Colorless	Colorless
pH	8.00	7.90	7.80	7.80	7.70

Temperature (°C)	28.70	26.30	26.30	24.90	27.30
EC (µs/cm)	290.14	304.36	317.92	333.30	341.69
TDS (mg/l)	132.40	144.51	153.77	167.93	180.83
Total alkalinity (mg/l)	100.56	99.12	98.00	97.93	95.87
Total hardness (mg/l)	136.24	138.13	140.96	141.90	143.00
Hardness as Ca^{+2} (mg/l)	45.94	47.00	48.23	49.93	50.90
Sulphate (mg/l)	-	-	-	-	15
Phosphate (mg/l)	-	-	-	-	00.83
Nitrate (mg/l)	-	-	-	-	11.5
Total coliform TCP/100 ml	Not detectable	-	Not detectable	-	Not detectable

Table 4: Quality characteristics of the treated water by Moringa Oleifera (1.5 g)

Dose 1.5g	**20 ml** 100 mg	**40 ml** 200 mg	**60 ml** 300 mg	**80 ml** 400 mg	**100 ml** 500 mg
Turbidity (NTU)	4.95	6.57	7.65	9.40	10.80
Coagulant activity (%)	99.88	99.83	99.80	99.87	99.72
Taste	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Odour	Odorless	Odorless	Odorless	Odorless	Odorless
Colour	Colorless	Colorless	Colorless	Colorless	Colorless
pH	8.00	7.90	7.90	7.70	7.70
Temperature (°C)	32.20	31.70	31.80	31.90	31.7
EC (µs/cm)	412.00	596.00	781.00	947.00	1131
TDS (mg/l)	247.00	357.00	468.00	568.00	679.00
Total alkalinity (mg/l)	90.83	110.21	113.90	115.55	118.71
Total hardness (mg/l)	120.30	124.59	124.62	126.07	128.50
Hardness as Ca^{+2} (mg/l)	60.00	89.33	73.33	57.33	96.00
Sulphate (mg/l)	17.00	-	-	-	-
Phosphate (mg/l)	1.31	-	-	-	-
Nitrate (mg/l)	5.6	-	-	-	-
Total coliform TCP/100 ml	18	-	16	-	15

Table 5: Quality characteristics of the treated water by Moringa Oleifera (2 g)

Dose 2g	**20 ml** 133.3 mg	**40 ml** 266.7 mg	**60 ml** 400 mg	**80 ml** 533.3 mg	**100 ml** 666.7 mg
Turbidity(NTU)	6.42	8.20	11.60	12.00	13.40
Coagulant activity (%)	99.84	99.79	99.70	99.69	99.66
Taste	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Odour	Odorless	Odorless	Odorless	Odorless	Odorless
Colour	Colorless	Colorless	Colorless	colorless	colorless
PH	7.90	7.90	7.70	7.50	7.40
Tempeure (°C)	32.70	32.70	32.30	32.60	31.90
EC (µs/cm)	429.00	613.00	832.00	1024.00	1139.00
TDS (mg/l)	257.00	368.00	500.00	611.00	686.00
Total alkalinity (mg/l)	120.13	122.70	123.16	125.31	126.48
Total hardness (mg/l)	120.48	124.33	132.18	136.14	139.60
Hardness as Ca+2 (mg/l)	91.17	80.64	97.66	110.73	105.94
Sulfate (mg/l)	19.00	-	-	-	-
Phosphate (mg/l)	1.34	-	-	-	-

Nitrate (mg/l)	5.30	-	-	-	-
Total coliform TCP/100	18	-	16	-	13

Table 6: Quality characteristics of the treated water by Moringa Oleifera (3 g)

Dose 3g	**20 ml**	**40 ml**	**60 ml**	**80 ml**	**100 ml**
	200 mg	400 mg	600 mg	800 mg	1 gm
Turbidity (NTU)	7.58	12.80	13.80	17.60	22.00
Coagulant activity (%)	99.81	99.68	99.65	99.56	99.45
Taste	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Odour	Odorless	Odorless	Odorless	Odorless	Odorless
Colour	Colorless	Colorless	Colorless	Colorless	Colorless
PH	7.70	7.60	7.60	7.60	7.50
Temperature (°C)	34.00	33.60	33.50	33.50	32.60
EC (µs/cm)	443.00	629.00	847.00	1033.00	1147.00
TDS (mg/l)	257.00	372.00	478.00	602.00	697.00
Total alkalinity (mg/l)	121.34	121.67	124.52	126.33	127.17
Total hardness (mg/l)	124.91	128.61	132.75	132.98	140.37
Hardness as Ca^{+2} (mg/l)	76.66	84.00	80.00	74.66	86.66
Sulfate (mg/l)	21.00	-	-	-	-
Phosphate (mg/l)	1.61	-	-	-	-
Nitrate (mg/l)	4.70	-	-	-	-
Total coliform TCP/100 ml	17	-	16	-	14

Table 7: Quality characteristics of the treated water by Moringa Oleifera (4 g)

Dose 4g	**20 ml**	**40 ml**	**60 ml**	**80 ml**	**100 ml**
	266.7 mg	533.3 mg	800 mg	1100 mg	1300 mg
Turbidity (NTU)	9.93	14.45	20.70	23.80	30.30
Coagulant activity (%)	99.75	99.64	99.48	99.40	99.24
Taste	Acceptable	Acceptable	Acceptable	Not acceptable	Not acceptable
Odour	Odorless	Odorless	Colorless	Colorless	Colorless
Colour	Colorless	Colorless	Colorless	Colorless	Cloudy
Temperature (°C)	26.80	26.30	26.20	26.60	26.20
PH	7.60	7.60	7.50	7.50	7.40
EC (µs/cm)	465.00	642.00	860.00	1046.00	1155.00
TDS (mg/l)	260.00	386.00	505.00	599.00	711.00
Total alkalinity (mg/l)	123.19	125.03	126.36	127.67	129.34
Total hardness (mg/l)	128.31	134.70	141.11	146.73	148.00
Hardness as Ca^{+2} (mg/l)	53.33	57.33	64.00	72.00	70.66
Sulfate (mg/l)	32.00	-	-	-	-
Phosphate (mg/l)	00.54	-	-	-	-
Nitrate (mg/l)	4.5	-	-	-	-
Total coliform TCP/100 ml	15	-	7	-	5

Table 8: Quality characteristics of the treated water by Moringa oleifera (5 g)

Dose 5g	**20 ml**	**40 ml**	**60 ml**	**80 ml**	**100 ml**
	333.3 mg	666.7 mg	1 mg	1.3 g	1.7g
Turbidity (NTU)	9.98	14.90	18.70	28.4	35.30
Coagulant activity (%)	99.75	99.63	99.53	99.29	99.11
Taste	Acceptable	Acceptable	Acceptable	Not acceptable	Not acceptable
Odour	Odorless	Odorless	Odorless	Odor	Odor
Colour	Colorless	Colorless	Colorless	Color	Color
PH	7.60	7.50	7.40	7.40	7.30
Temperature (°C)	25.70	25.70	25.90	25.90	26.30
EC (µs/cm)	481.00	655.00	872.00	1063.00	1167.00
TDS (mg/l)	362.00	395.00	532.00	615.00	722.00
Total alkalinity (mg/l)	105.73	103.11	95.14	92.82	88.75
Total hardness (mg/l)	140.80	142.21	145.88	146.62	150.07

Hardness as Ca^{+2} (mg/l)	80.15	88.53	108.92	120.48	140.36
Sulfate (ppm)	9.00	-	-	-	-
Phosphate (mg/l)	00.79	-	-	-	-
Nitrate (mg/l)	22	-	-	-	-
Total coliform TCP/100 ml	7	-	4	-	3

5. CONCLUSION

In the present study both Moringa Oleifera and aluminium chlorohydrate was found to be effective in the case of the Blue Nile waters treatment. However, aluminium chlorohydrate required lower dosage than M. oleifera. Results from M. oleifera demonstrated that physic chemical characteristic was not affected with higher dosages above the optimal value compared to aluminium chlorohydrate. In rural and developing countries, this result is important because no sophisticated equipment is required for coagulant dosing. Finally, the tree can be cultivated very cheaply at the household level or in small communal nurseries which is to be encouraged among the rural population. It has excellent potential as a coagulant for the removal of turbid water in developing countries where purchase of other chemical coagulants is expensive. But does not guarantee that the treated water ends up completely (100%) free of pathogenic germs. It is cleaned and acceptable for drinking only where people are currently drinking untreated, contaminated water or use addition disinfection material. However, the use of Moringa oleifera seed powder in particle sizes is recommended for further investigation.

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