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Comparative study between Aluminium sulphate and Moringa Oleifera seeds as coagulants in drinking water treatment

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Abstract: This study is a laboratory based study comparing the efficiency of Alum with Moringa seeds as coagulants in order to treat the water samples from Blue Nile River in Blue Nile State. The samples turbidities were 8580 NTU, 3000 NTU and 29.4 NTU from different sites. Six different doses for each coagulant and for each sample were used in Jar test apparatus with six-paddle gang stirrer. The initial turbidity 8580 NTU was reduced by 99.5% when used 150 ppm Alum. Meanwhile, Moringa coagulant gave 99.8% removal when using 130 ppm. The pH was decreased from 7.9 to 7.36 corresponding to Alum dose with increasing in EC and TDS but was in acceptable levels. With Moringa the pH, EC and TDS were insignificantly changed. The taste and color in both coagulants were unsuitable while the odor was acceptable. In the sample 3000 NTU, the best activity at 100 ppm Alum. Achieved 90% reduction in turbidity load and 99.4% reduction at 100 ppm Moringa. The pH in Alum. Also started to fall down from 7.61 to 6.8, in Moringa no significant change was occurred. The EC, TDS, odor and taste were not affected with used doses. The color still unsuitable for consumer in both coagulants. In sample 29.4 NTU the Alum coagulant enhanced the turbidity removal till to 95.4% when 50 ppm was used, while in 10 ppm Moringa, reduced the turbidity by 87.9%. The other characteristics color, odor and taste were acceptable at both coagulants with no significant change in EC and TDS.

Keywords: *Aluminum, Moringa, pH, EC, TDS, color, odor, taste, Blue Nile.*

1. INTRODUCTION

Safe drinking water should generally be free from heavy metals, turbidity, organic compounds and pathogens. Turbidity may be increased by these compounds. It is also important to remove turbidity for the aesthetic values of the drinking water (Blix, 2011).

Coagulation and flocculation step which is essential process in the treatment of surface water includes the removal of dissolved organic species and turbidity from water most commonly via the addition of conventional chemicalbased coagulants.

The most wildly used are Aluminium sulphate andFerrous sulphate (Muyibi andAlfugara, 2003). Alumimium sulphate is known as the filter alum or alum only. Its chemical composition is $Al_2 (SO_4)_3$, $18H_2O$. The alum has proved to be an effective coagulant and its use as a coagulant is more or less universal at present in water treatment projects. The alum, in water treatment practice, is commonly supplied and used in the form of flakes or solid lumps and then applied in a solution form. The advantages of using alum as a coagulant are that, it reduces taste and odor in addition to turbidity in water and it is the cheapest one of the chemical coagulants. Also it is simple in working and does not require skilled supervision compared with others. In addition it produces crystal clear water and the floc formed by this coagulant is better than that formed by any other coagulant and it is not broken easily.

This coagulant is found to be effective between pH range of 6.5 to 8.5, the dosage of coagulant will depend on various factors such as turbidity of water, pH value, temperature of water, etc.

The disadvantages of using alum as a coagulant may be it is difficult to dewater the sludge formed and further, it is not easy to dispose it off. Also, as it is found unsuitable for filling of low lying lands. This may increase the cost of treatment. Also some studies indicated to be a causative agent in neurological diseases such as pre-senile dementia and Alzheimer’s disease.The significant factor that, the costs of these chemicals have beenincreasing at an alarming rate in developingcountries (Rangwala, 2005; Muyibi, 2005).

Among the techniques for water treatment is the use of natural coagulants, aiming at a better quality of treated water by reducing the use of chemicals. It is therefore desirable to replace these chemical coagulants with plant-based coagulants to counteract the aforementioned drawbacks. Thus, in water treatment, the use of natural coagulants could be an option with many advantages over chemical agents, particularly the biodegradability, low toxicity and low residual sludge production. Biopolymers may be of great. interest since they are natural low-cost products, characterized by their environmental friendly behavior and usually have a large number of surface charges that increase the efficiency of the coagulation process. These advantages are especially augmented if the plant from which the coagulant is extracted is indigenous to local community.

In recent numerous studies a variety of plant materials has been reported as a source of natural coagulants. But the most studied is Moringa Oleifera whose efficiency has been approved for turbidity removal as well as antimicrobial properties (Antovet al.,2012). Moringa Oleifera Lam. (*Moringaceae*) is a well-known tree in folk medicine in its native land, with nutritional and traditional medicinal claims, but scientific awareness has only recently been acknowledged. It is used traditionally to purify water in Asia and Africa, due to its effective coagulation properties (Flora and Vidhu, 2011; Ndabigengesere and Narasiah, 1998).

The seeds may be powdered and added to the water directly or after preparing crude extract. The seed kernels contain significant quantities of series of low molecular weight and water soluble protein, which carries positive charge to the solution. The seeds contain about 43% fat, 41% protein, 9% carbohydrates and other minerals. These percentages may be varying from seeds to seeds according to plant original. The protein is considered to act similar to a synthetic and positively charged polymer coagulant. When this protein is added to raw water, it binds with the predominantly negatively charged particulate making the raw water turbid. Under proper agitation these bound particulates then grow in size to form the flocks, which may be left to settle by gravity or removed by sedimentation (Gidde et al, 2012).

An earlier study has found that the Moringa Oleifera seeds do not significantly affect the pH and conductivity of the water after the treatment (Ndabigengesere et al, 1995).

The main objective of this paper is to investigate and compare the efficiency of Alum. and Moringa seeds as coagulants in the treatment of surface water from Blue Nile river, at Blue Nile State.

2. MATERIALS AND METHODS

The experiments were done in environmental laboratory of Blue Nile University, to investigate the coagulation and flocculation activities. The experiments were performed on turbidity, pH, EC, TDS, color, taste, odor and temperature before and after treatment, using Alum and Moringa Oleifera, as coagulants.

2.1. Samples collection

Water samples were collected from different sites of Blue Nile River in Blue Nile State. Approximately thirty (30) litres of each sample were collected in plastic containers from the main stream of the River, and transported to laboratory for analysis. The samples were collected in different times on rainy and dry seasons to coincide with high, medium and low turbidity loads.

2.2. Equipments and materials

A Jar test apparatus (RI India) with a six-paddle gang stirrer was used for coagulation for optimum coagulants dosage for each experimental run. A pH meter (JEWAY model 370 England) was used for measuring the pH of the water samples. A portable turbidimeter (HANNA instruments, Romania) was used to measure the turbidity; a portable conductmeter (JEWAY model 470, England) was used for measuring the EC, TDS and laboratory temperature.

2.3. Preparation of Coagulants

2.3.1. Aluminium sulphate

The aluminium sulphate used in the study was obtained from Um Dormman market in the Sudan. It was ground to fine particles manually in the laboratory to ease the solubility and weighing.

2.3.2. Moringa Oleifera

Moringa Oleifera seeds used in the study were obtained from trees in ER Roseires area. The seeds were harvested when they were fully matured. This is determined by observing if there are any cracked pods on the plants. The pods that were plucked were cracked to obtain the seeds which were air-dried at room temperature for several days. The shells and wings surrounding the seed kernels were removed using a knife, then the seed kernels were dried in the oven at 50 C° for 24 hours, and ground using a domestic food blender (Model Moulinex, France) into powder. The powder stocked in container out of reach of humidity.

2.4. Laboratory Analyses+

2.4.1. Coagulation tests

Jar tests were used for evaluating the coagulation-flocculation experiments. Different dosages of Aluminium sulphate were added separately into six glass beaker each one containing one liter of water sample,and placed on the base illuminator of the Jar apparatus. The intensity and duration of rapid and slow mixing were (120) revolution per minute (RPM) for four minutes (min) and (30) RPM for 20 min, respectively. After slow mixing, the beakers were carefully removed from the floc illuminator and were placed in a safe place for the sedimentation phase to take place. The duration of sedimentation of coagulated water was one hour, then, supernatant was collected from each beaker to measure the turbidity, pH, conductivity, TDS, color, taste and odor. The method applied was according to (Eman et al. 2010).

2.4.2. PH measurement

Supernatant was placed in small beaker (50 m/L), and connected the pH electrode to the measuring instrument, then removed the cap from the electrode and rinsed with distilled water; then immersed the electrode in the beaker, and pressed enter to start the measurement unit. The electrode was shook for several seconds and let it to stabilize and a reading was recorded.

2.4.3. EC and TDS measurement

The samples used for the pH measurements were used for the conductivity and TDS tests. Starting by connecting the electrode of conductivity to the measuring unit, and the cap of the electrode was removed, then, the electrode was rinsed with distilled water quite enough and immersed immediately in the test beaker with shaking for several seconds (about 5 sec) after starting up the measurement unit. Then, the reading was allowed to stabilize and recorded in μS cm^{-1} units. The function of the measurement device was changed to measure the TDS and noted also.

2.4.4. Turbidity measurement

Turbidity measurements were done, pre and post treatment. About 10 mL volume of sample was poured to etched sign on the tube of the turibidimeter and closed the sample tube to prevent spillage of the sample into the instrument, then, cleaned before inserting into the sample compartment avoiding finger press. The instrument was then started up and after few seconds the reading appeared on the screen of the unit and noted in formazin turbidity units (FTUs). If the turbidity reading were over the range of reading of the instrument, the sample was diluted. The coagulation activity may be calculated as follows:

Coagulation activity (%) = $(RT_B - RT_S)/ RT_B * 100$

Whereas:

RT_B = Residual turbidity of blank

RT_S = Residual turbidity of sample

2.4.5. Color, Taste and Odor measurements

These were based on aesthetic reasons and personal opinions. They were carried out by asking at least four persons about the samples "whether objectionable or not?"

3. RESULTS AND DISCUSSION

3.1. Coagulation activities on turbidity of 8580 NTU

Several initial trials were run in order to investigate and compare the physical and chemical phenomena in coagulation activity between Alum and Moringa Oleifera seeds as coagulants. So, different concentrations were used. It can be seen from Table 1, 2 and 3 the initial turbidity falls down from 8580 NTU by 97.1% (beaker No.1) and 99.5% (beaker No.2) when using 100 ppm and 150 ppm Alum respectively, meanwhile, Moringa coagulant gave 99.6% reduction (beaker No.1) and 99.8% (beaker No.6) when using 80 ppm and 130 ppm respectively.

Table 1: The characteristics of water sample (blank) from Abu Ramad village location without adding coagulant

Characteristics	Reading
Temperature/°C	27.1
Ph	7.9
Turbidity/*NTU*	8580
EC µS/cm	139.8
TDS mg/L	83.8
Color	Objectionable
Odor	Un
Taste	Un

Table 2: The characteristics of water sample Abu Ramad village location after one hour settling (treated with Alum).

beaker No.	1	2	3	4	5	6
Dose/*ppm*	100	110	120	130	140	150
Temperature/°C	26.9	26.9	26.9	26.9	26.7	26.8
pH	7.62	7.61	7.60	7.59	7.52	7.36
Turbidity/*NTU*	252	193	140	152	103	41.58
ECµS/cm	224	234	243	241	255	260
TDS mg/L	134.4	140.1	145.6	144.8	158.7	156.0
Color	Objec	Objec	Objec	Objec	Objec	Objec
Odor	Un	Un	Un	Un	Un	Un
Taste	Un	Objec	Objec	Objec	Objec	Objec

Table 3: The characteristics of water sample from Abu Ramad village location after one hour settling (treated with Moringa).

beaker No.	1	2	3	4	5	6
Dose/*ppm*	80	90	100	110	120	130
Temperature/°C	26.0	25.94	25.9	25.9	25.8	25.9
pH	7.93	7.95	7.94	7.94	7.93	7.95
Turbidity/*NTU*	31.26	30.33	27.87	20.79	24.81	15.53
EC µS/cm	151.8	149.9	150.7	152.2	150.7	152.9
TDS mg/L	91.1	89.9	90.4	91.3	90.4	91.7
Color	Un	Un	Un	Un	Un	Un
Odor	Un	Un	Un	Un	Un	Un
Taste	Un	Un	Un	Objec	Objec	Objec

In contrast, the pH values, were decreased gradually with Alum. doses. According to (Ndabigengesere and Narasiah, 1998; Amagloh and Bnang, 2009) this could be explained by the fact that the solutions were becoming more acidic. This was attributed to the fact that the Alum in the treatment procedure produced sulphuric acid which lowered the pH levels. The increase in acidity could be due to the trivalent cation aluminum which serves a Lewis acid. Thus it can accept alone pair of electrons.

On the other hand, the pH also slightly increases with increasing concentrations of the Moringa coagulant. Amagloh and Bnang, 2009, reported that the action of Moringa as a coagulant lies in the presence of water soluble cationic proteins in the seeds. This suggests that in water, the basic amino acids present in the protein of Moringa would accept a proton from water resulting in the release of a hydroxyl group making the solution basic.

Apart from that, the EC and TDS increased considerably with the increasing dosage of alum. but not greater than acceptable levels. The increase in EC is caused by sulphate ions remaining in the treated water. The EC and TDS using Moringa increased also but slightly. The taste was acceptable only in 100 ppm Alum. coagulant based on aesthetically and displeasing reasons. The odor did not change as in initial turbidity for both coagulants.

The color was objectionable for consumer for the same above reasons. It may be noted, especially after 24 hours from adding the coagulant, the odor was observed to be very bad and was similar to fecal odor. According to Eman et al.,

(2010) and Vijay Kumar .K et al., 2012, they claim that the main concern in using Moringa Oleifera for water treatment is the significant increase in organic load, as organic matters originating from the seeds can be released into the water during treatment. This presence of organic matter in treated water can cause problems of color, taste and odor, and also facilitates the development of microorganisms upon storage. Therefore it should not be stored for more than 24 hours.

3.2 Coagulation activities at turbidity of 3000 NTU:

Based on Table 4 and 5 (beaker No.1) and Table 6 (beaker No.3) the doses were reduced to 100 ppm as maximum and 50 ppm as minimum, to prevent the unsuitable taste in treating, also to suit 3000 NTU turbidity load.

The best activity in Alum. Achieved was 90% reduction in turbidity (Table 4 and 5) and 99.4% reduction in Moringa (Table 6) versus doses 100 ppm for both coagulants. The pH in Alum. also started to fall down gradually till near acceptable levels, in Moringa no change occurred. Ec, TDS, odor and taste were not affect by used doses. The color still unsuitable for consumer.

While the jar tests were running and at settlement phase, it was observed that there was a formation of an emulsion or film coating the water at top layers of the beakers, when using Moringa as coagulant in jar test operations. This phenomena may be explained by looking at the oil content in the seeds and the result of chemical composition analysis of seeds which has about 40.4% oil. This result seemed to reaffirm the findings of a study conducted by Eman et al., 2010 and Ndabigengesere et al, 1995et al., (1995).

Table 4: The characteristics of water sample (blank) from Abu Ramad village location without adding coagulant.

Characteristics	Reading
Temperature/°C	27.9
pH	7.61
Turbidity/*NTU*	3000
EC µS/cm	97.9
TDS mg/L	58.8
Color	Objec
Odor	Un
Taste	Un

Table 5: The characteristics of water sample Abu Ramad village location after one hour settling (treated with Alum).

beaker No.	1	2	3	4	5	6
Dose/*ppm*	50	60	70	80	90	100
Temperature /°C	27.6	27.6	27.6	27.5	27.5	27.5
pH	7.28	7.16	7.00	6.99	6.91	6.8
Turbidity/*NTU*	1122	1050	997	816	520	301
EC µS/cm	115.1	110.9	116.3	118.3	130.0	122.4
TDS mg/L	69.1	66.6	69.8	71.0	78.0	73.7
Color	Objec	Objec	Objec	Objec	Objec	Objec
Odor	Un	Un	Un	Un	Un	Un
Taste	Un	Un	Un	Un	Un	Objec

Table 6: The characteristics of water sample from Abu Ramad village location after one hour settling (treated with Moringa).

beaker No.	1	2	3	4	5	6
Dose/*ppm*	50	60	70	80	90	100
Temperature/°C	26.9	26.9	27.0	27.0	26.9	26.9
pH	7.62	7.62	7.68	7.62	7.67	7.61
Turbidity/*NTU*	49.49	30.03	25.0	23.56	20.00	18.65
EC µS/cm	105.5	101.9	104.7	102.1	99.20	102.2
TDS mg/L	63.3	61.2	62.8	61.3	59.5	61.4
Color	Objec	Objec	Objec	Objec	Un	Un
Odor	Un	Un	Un	Un	Un	Un
Taste	Un	Un	Un	Un	Un	Un

3.3. Coagulation activities at turbidity of 29.4 NTU:

In this faze, Alum. coagulant enhanced the turbidity removal gradually at beaker No. 1,2,3,4 and 5, as soon started to slight increasing and raised up in turbidity load (tables 7 and 8). The best reduction was 95.4% (beaker No.5), meanwhile, Moringa gave 87.9% reduction in turbidity load (Table 9 beaker No.1), noted that, the Moringa coagulant was decreased gradually in its efficiency of removal turbidity. The other characteristics color, odor and taste were lies in acceptable levels at both coagulants with no significant change in EC and TDS.

Table 7: The characteristics of water sample (blank) from Sereiw village location without adding coagulant.

Characteristics	Reading
Temperature/°C	29.1
pH	8.26
Turbidity/*NTU*	29.41
EC µS/cm	164.3
TDS mg/L	98.6
Color	Objec
Odor	Un
Taste	Un

Table 8: The characteristics of water sample from Sereiw village location after one hour settling(Treated with Moringa).

beaker No.	1	2	3	4	5	6
Dose/*ppm*	10	20	30	40	50	60
Temperature/°C	29.4	29.1	28.9	28.7	28.7	28.5
pH	7.96	7.95	7.95	7.96	7.95	7.94
Turbidity/*NTU*	14.85	8.57	4.57	2.31	1.34	1.59
ECµS/cm	168.9	170.8	176.4	181.0	185.1	191.7
TDSmg/L	101.2	102.5	105.8	108.6	111.1	115.0
Color	Un	Un	Un	Un	Un	Un
Odor	Un	Un	Un	Un	Un	Un
Taste	Un	Un	Un	Un	Un	Un

Table 9: The characteristics of water sample from Sereiw village location after one hour settling (treated with Moringa).

Beaker No.	1	2	3	4	5	6
Dose/*ppm*	10	20	30	40	50	60
Temperature/°C	28.4	28.4	28.4	28.4	28.4	28.4
pH	8.20	8.20	8.22	8.21	8.21	8.23
Turbidity/*NTU*	3.57	7.48	7.70	8.79	9.16	8.89
EC μS/cm	165.5	165.6	163.9	166.0	163.3	164.0
TDS mg/L	99.2	99.3	98.4	99.7	98.0	98.9
Color	Un	Un	Un	Un	Un	Un
Odor	Un	Un	Un	Un	Un	Un
Taste	Un	Un	Un	Un	Un	Un

4. CONCLUSIONS

1. In the present study a seed of Moringa Oleifera was found to be most effective compared to Alum. However, taste or colors are unacceptable for consumers.
2. Moringa Oleifera seeds have excellent potential as a coagulant for the removal of water turbidity especially at very high turbidity.
3. Alum. has a good efficiency in low turbidity removal compared with Moringa Oleifera seeds.
4. The water treated with Moringa Oleifera should not be stored more than 24 hours. The presence of organic substances in the Moringa seeds can enhance developing of microorganisms in the treated water.

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