Direct Research Journal of Biology and Biotechnology
Vol. 6(6), Pp. 90-100, October 2020
ISSN 2734-2158
DOI: https://doi.org/10.26765/DRJBB917352046
Article Number: DRJBB917352046

Full-Length Research Paper

Comparative Study on the Coagulating Potentials of Alum and *Moringa Oleifera* in Raw Water Treatment

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Received 5 August 2020; Accepted 9 September 2020; Published 24 October 2020

ABSTRACT: Comparative analysis was carried out on Alum and *Moringa oleifera* seed powder in respect of their coagulating effects in water purification which was conducted for a period of six months from January to June 2017. Jar test was conducted to determine the optimum dosages of the coagulant needed in the treatment of raw water. The concentration of the dose selected for the jar test were; 0.02g/L, 0.04g/L, 0.06g/L and 0.08g/L for all the two coagulants. Physicochemical parameters of raw water samples from Suma River showed that turbidity ranged between 30.6 to 89.9 NTU, pH from 6.84 to 7.40, temperature from 29.5°C to 31.8°C, TDS from 198 to 260mg/l, total hardness from 74 to 140mg/l, DO from 4.0 to 6.3mg/l, Colour from 360 to 542 PtCo, Alkalinity from 120 to 136mg/l, Conductivity from 289 to 344µS/cm, Iron from 0.89 to 1.5mg/l and Manganese from 1.83 to 2.10mg/l. The turbidity of the sample treated with alum significantly reduced (29.45 ± 5.79 NTU) at $p<0.05$ compared to that of untreated water (59.17 ± 8.44 NTU). Furthermore, turbidity of alum treated water was significantly lower than *M. oleifera* (37.53 ± 6.35 NTU). Total hardness for alum reduced from 136 to 70mg/L, *M. oleifera* from 136 to 74mg/L. DO for alum reduced from 6.3 to 3.3mg/L, *M. oleifera* from 6.8 to 3.2mg/L. There was a significant reduction in the colour of water treated with Alum (264.2 ± 16.9 PtCo), *Moringa oleifera* (353.8 ± 17.8 PtCo) compared to the control (Untreated water). However, alum treated water exhibited better clarity ($p<0.05$). The iron content of alum water (0.80 ± 0.08mg/l) was significant lower than that of the untreated water, *M. oleifera* treated water. The water treated with *M. oleifera* achieved neutral pH whereas treatment with alum made water slightly acidic.

Keywords: Alum, *Moringa oleifera* seed, coagulating potentials, water treatment

INTRODUCTION

Water treatment is a process whereby naturally occurring water (raw water) from various sources is put through a series of steps designed to purify it and make it portable for human consumption and industrial purposes. It played a crucial part in the origin of life according to scientist and still has an essential role in maintaining plants and animals' life (Lawal *et al*., 2013).

Coagulation is the first unit process in water treatment and it is very crucial for the removal of suspended and dissolved particles. Coagulation has been defined as the addition of positively charged ion of metal salt or catalytic polyelectrolyte that results in particle destabilization and charge neutralization (Sahu *and* Chaudhari, 2013).

Coagulation is affected by the type of coagulant used and its doses; pH and initial turbidity of water that is being treated; and properties of pollutants present (Jiang, 2015 and Ramavandi, 2014). The effectiveness of the coagulation process is also affected by pretreatments like oxidation (Jiang, 2015; Ayekoe *et al*., 2017).

Several chemical coagulants have been used in conventional water treatment processes for portable water production that include inorganic, synthetic organic polymer and naturally occurring coagulants (Lawal *et al.*, 2013).

Alum (Aluminium Sulphate) has been the most popular coagulant for treatment of water and is widely used in treatment plants. It has been found to pose some health, economic and environmental problems upon usage, among which are neurological diseases such as percentile dementia and induction of Alzheimers disease (Ugwu, 2017). Sludge production is also voluminous and non-biodegradable after treatment, leading to increase in cost of treatment. The high cost of chemical importation results in loss of foreign exchange to nations. The effect of most coagulants like alum on the pH of the treated water attracts extra cost on lime which should be added to buffer its effect (Bachir *et al*., 2016).

There is therefore the need to investigate the use of non-chemicals which would be available locally in most developing countries; the use of natural materials of plant origin to clear turbid water is not a new idea (Vijayaraghavan *et al*., 2011). The cost of this natural coagulant would be less expensive compared to the conventional coagulant (alum) for water purification since it is available in most rural communities where treated water is a scarce resource. In addition, natural coagulants produce readily biodegradable and less voluminous sludge that amounts 20-30% that of alum treated counterpart (Chun-Yang, 2010).

However, the production of water fit for human consumption is not as easy as it sounds. The desired end-product comes into existence because coagulation is a commonly used treatment method apart from flocculation, sedimentation, filtration and disinfection. In fact, in case of rapid-sand filtration plants, it is impossible to achieve crystal-clear water in absence of the coagulation unit in which coagulants are added to incoming water and intense mixing is done for few minutes. The purpose of adding coagulants to water is to agglomerate colloidal particles to flocs so that they settle readily (Lawal *et al*., 2013).

On the other hand, there is evidence that the use of extracts from plant species possessing both coagulating and antimicrobial properties is safe for human health (Iloamuzor *et al*., 2017). Of the large number of plant materials, it has been shown that *Moringa oleifera* seed is one of the most effective primary coagulants for water treatment especially in rural communities (Noor *et al*., 2013 and Ali *et al*., 2010). *M. oleifera* is one of the vegetables of the Brassica order and belongs to the family *Moringaceae*. The *Moringaceae* is a single genus family with 13 known species (Khawaja *et al*., 2010). *M. oleifera* is a small native tree of the sub-Himalayan regions of North West India, which is now found worldwide in the tropics and sub-tropics. *M. oleifera* seed kernels are biological coagulants having significant quantities of low molecular weight water soluble proteins (6-16kDa with isoelectric point above pI 10), which in solution carry an overall positive charge. *M. oleifera* is safe and very effective in removing impurities. Apart from its turbidity removal properties (Sotheeswaran *et al*., 2011) it has been reported to have antimicrobial properties in water (Ali *et al*., 2010). It also has been reported as having the ability to remove metals from water (Nand *et al*., 2012). Earlier studies have found *Moringa* to be non-toxic and recommended its use as a coagulant in developing countries. The use of *M. oleifera* has an added advantage over the chemical treatment of water because it is biological and has been reported as edible (Adeniran *et al*., 2017). The seeds of *M. oleifera* have been shown to be one of the most effective primary coagulants for water treatment especially in rural communities in comparison with other plant materials used over the years (Adeniran *et al*., 2017).

The conventional methods for treating waste water are expensive. Consequently, the search for contrarily but effective, efficient and economic methods has been on the increase in recent times. Thus, the use of biomaterials, such as agricultural waste as adsorbents for organic and metal ions is being exploited due to their availability and low cost.

Coagulation Performance between Alum and *Moringa oleifera*

Comparative analysis carried out on Alum and *M. oleifera* seeds powder in respect of their coagulating effects in water purification. A research carried out by Sarpong et al. (2010) compared *M. oleifera* seed's effectiveness at removing turbidity from water against those of Alum. The researchers found that the reduction of turbidity achieved by *M. oleifera* seed was very similar to that of alum. The use of *M. oleifera* did not affect the pH and conductivity of the treated water at the dosage used.

Lilian *et al.* (2017) carried out a parallel study between alum coagulant and the seed extract of *M. oleifera*. The efficiency of both coagulants was evaluated through measurement of turbidity and colour of water samples. *M. oleifera* proved to be more efficient, with removals of 94.9%of turbidity and 92.5% of colour, when using a dose of 20mgL^{-1}. The water obtained results close to drinking water required by Brazilian regulation, indicating that *M. oleifera* seed could be an alternative for water treatment providing water for small communities.

Hendrawati *et al*. (2016) carried out a research to observe the effect of *M. oleifera* seed as natural coagulant to replace synthetic coagulant. *M. oleifera* reduced 98.6% turbidity of wastewater, 10.8% of its conductivity. When applied to ground water, *M. oleifera* removed the turbidity as much as 97.5%, while reduced the conductivity to 53.4%.

Another practical investigation by Miraji (2014), on a study to compare effectiveness of *M. oleifera* seeds powder as a natural coagulant with alum as a chemical coagulant and found out that by using concentrations of *M. oleifera* and alum ranging between 50-200mg/L, a significant reduction of pH, EC, TDS, turbidity, total hardness and total alkalinity were observed. *M. oleifera* treated samples showed promising quality than alum solution that significantly lowered the pH of the water. The established optimal *M. oleifera* seed powder dose for turbidity was 200mg/L.

Lawal *et al*. (2013) also found out that the sample treated with alum gave clearer water (turbidity) ranged from 10.37-27.60 NTU with lower pH values of 4.18-6.71 compared to samples treated *with M. oleifera* seed powder with turbidity values of 22.97-30.4 NTU and pH ranged from 6.28-6.86. Samples treated with *M. oleifera* produced less number of flocs and TDS in the samples than those treated with alum. Alum sample gave 56mg/l of total hardness, while samples treated with *M. oleifera* showed lower values of hardness (48mg/l). Higher DO were observed in sample of *M. oleifera* (16.23mg/l), compared to that of alum with 13.33mg/l.

A study by Jodi *et al*. (2017) on the optimum dosages concentration and turbidity (NTU) values at different concentration showed that the dosage of alum at 100ppm gave 7NTU turbidity values while *M. oleifera* at the same dosage 100ppm gave a higher turbidity value of 40 NTU. The result obtained when *M. oleifera* and alum were mixed was found to be 5 NTU.

Finally, Egbuikwem *et al*. (2013), used optimum dosages of 2.5, 4.5 and 6.0 ml of *M. oleifera* seeds extract, the turbidity removal efficiencies were 90.4%, 95.6% and 96.7% for the well, stream and pond water samples respectively. The respective values for alum at optimum dosages of 2.0, 3.5 and 4.0ml were 100%, 99.9% and 99.9%. The result showed that *M. oleifera* seed is a good coagulating substance that is comparable to commercial alum in turbidity removal.

Alum (Aluminium Sulphate) as chemical coagulant

Aluminium sulphate is a chemical compound with the formula $Al_2(SO_4)_3$. It is soluble in water and is mainly used as a coagulating agent in the purification of drinking water (Sahu *et al*., 2013) and waste water treatment plants, and also in paper manufacturing.

Properties of alum

Aluminium sulphate based alum has a number of common physico-chemical properties such as: soluble in water, have a sweetish taste, react with acid to litmus, and crystallize in regular octahedral.

Coagulation with alum

Alum is a chemical compound used in industrialized communities for water purification. The following study verified the coagulation performance of alum. Kalavathy *et al*. (2016) tested the coagulation performance of alum on synthetic high turbid water (90-140NTU). In this study, the effectiveness of alum was evaluated at room temperature with initial pH (6 -7.4) for two coagulant doses 10mg/l and 20mg/l in 250ml synthetic high turbid water by adopting manual agitation at very slow settling time conditions rather than traditional jar test. Results showed that coagulation process could remove turbidity effectively using relatively low levels of alum. Studies revealed that turbidity removal is dependent on pH, coagulant dose, as well as initial turbidity of the water. The highest turbidity removal efficiency was 46.15% over the applied range of turbidity.

Non chemical coagulant

The use of non- chemical coagulant such as *M. oleifera* for treatment of drinking water in some parts of the world has been recorded in human history. However, these natural materials have not been recognized or duly supported due to lack of knowledge on their exact nature and the mechanism by which they function. As a consequence, non- chemical coagulant has been unable to compete effectively with the commonly used water chemicals (Adeniran *et al*., 2017).

Moringa oleifera

Moringa is a plant known as *M. oleifera.* It belongs to Moringaceae family Genus *Moringa*. This is native to Arabian, Sub-Himalayan areas of India, Pakistan, Bangladesh, and Afghanistan. It is also grown in the tropics. The leaves, bark, flowers, fruit, seeds, and root are used to make medicine, food, and presently used for water treatment (Noor *et al*., 2013).

Properties of *Moringa oleifera* seed

The seeds are eaten green, roasted, powdered and steeped for tea or used in curries. It has found applications in medicinal uses, as cosmetics, in food supplements, and in water treatment. One of the active ingredients in the *M. oleifera* seed has been identified as a polyelectrolyte. Its use for coagulation, co-coagulation, or coagulant aid has been a subject of investigation in many parts of the world (Mustapha, 2013). Softening of water with *M. oleifera* has also been identified to have potential advantage since it is accompanied by very low reduction in alkalinity (Noor *et al*., 2013 and Tat *et al*., 2010), which is required to provide the necessary buffering capacity to achieve required treatment objectives. Many researchers have also identified the presence of an active antimicrobial agent in *M. oleifera* seeds (Ali *et al*., 2010).

Coagulation with *Moringa oleifera*

M. oleifera seed is effective as a water purifier. The following studies verified this by measuring the seeds' effectiveness at removing turbidity of water. Each study differs in its preparation of the seed for water purification.

An investigation on the effectiveness of *M. oleifera* seed for the treatment of domestic sewage was carried out by Adeniran *et al*. (2017) found out that the turbidity value was reduced drastically for the treatments. The water hardness was reduced from 64.2mg/l to 36mg/l for the treatments, Alkalinity reduced from 148mg/l to 114mg/l, TDS reduced from 896mg/l to 820.3mg/l, DO reduced 124.8mg/l to 112.7mg/l and finally pH reduced from 9.6 to 7.5. The results showed that the higher the quantity of *M. oleifera* seed applied to sewage, the better the purification of the sewage.

Keogh *et al*. (2017) carried out a study to access the efficacy of *M. oleifera* to clear turbid water as pretreatment for Solar Disinfection (SODIS). *M. oleifera* seeds reduced turbidity best and that SODIS treatment of highly turbid water was effective regardless of reduced turbidity.

According to a study conducted by Magaji *et al*. (2015) on the Bio-coagulation activity of *Moringa* seeds for water treatment, they found out that lowest turbidity values were obtained at dose levels of 0.1g/L and 1.0g/L for raw water and waste water respectively. The pH, conductivity and total dissolved solids of the *M. oleifera* treated water were not significantly increased ($p>0.05$) at the test dose levels (0.1-5.0 g/L). These findings suggest that *M. oleifera* seed powder can be used as a source of oil, while the cake is being employed as bio-coagulant for point of use water treatment in developing countries.

Also, Lorena *et al*. (2015) carried out a study which focuses on the behavior of colour and turbidity removal of different extraction methodologies of *M. oleifera*. Results showed that turbidity removal efficiency was not affected by oil extraction. However, oil extraction increased the complexity of the process. Salt addition during the coagulant solution preparation increased turbidity and colour efficiency removal. No significant difference ($p<0.05$) on turbidity and colour removal was found between coagulant solution storage at 24^{o}C (room temperature) and 4^{o}C. Coagulant solution of *M. oleifera* was found to be very efficient on polluted waters with high concentration of colour.

Vasavi *et al*. (2015) carried out a study using water samples from three different rivers and treated with various doses of *Moringa* seed viz, 50, 100, 150 and 200mg/L. It was observed that in post treatment water samples, most of the parameters like turbidity, TDS, total alkalinity and total hardness were significantly reduced with increased doses of seed powder compared to untreated samples.

Kawo *et al*. (2011) result of *M. oleifera* treated water samples had values for turbidity fluctuating between 14 NTU and 25NTU, alkalinity 30 mg/L and 43 mg/L, pH 7.0 and 7.2, temperature 20^{o}C and 27^{o}C.

A study conducted by Sanchez-Martin *et al*., (2012) focused on the optimization of certain parameters affecting the use of *M. oleifera* in the clarification of real surface water. The acidic pH levels enhanced the coagulation performance and the turbidity removal increased as the stirring period became longer (up to 95% with 40 min). The optimum stirring rate was identified as 80 rpm. Water clarified with this optimum coagulation and flocculation process is turbidity competitive with other well-known coagulants and flocculants and its quality is inside standard ranges for clarified water.

Aim of the study

This research work is aimed at determining and comparing the coagulating properties of the chemical coagulant (alum) and non-chemical coagulant (*M. oleifera*) using raw water.

Objectives of the study

Determine the physico-chemical parameters of the raw water (Usuma River).
Determine the coagulating properties of the different coagulants under study.
Determine the best coagulant dosage for the coagulation process.

MATERIALS AND METHODS

Study area

Kuje is a local government area in the Federal Capital Territory in Nigeria. It has an area of 1,644 km² and a population of 97,367 at the 2006 census. The postal code of the area is 905. The study area is Usuma River in

Kugibi village, Kuje Area Council in the Federal Capital Territory with GPS Coordinates recorded as 8º 60'0" N 7º 15'0" E. The activities carried on and around the river water are: fishing, irrigation, bathing, washing of clothes and cars and block making. Also, the villagers use the water for cooking and drinking. The sampling site was selected based on preliminary information and feasibility study of the area. Other variables considered include access road to sampling site and availability of hydrological data, instrument and expertise for analysis.

Collection of water sample

The water sample used for this study was collected from Usuma River in Kugibi village along Kuje road, Abuja, Nigeria from January to June 2017 on a monthly basis. The river water was collected by dipping the plastic gallon into the water body. The water was collected in a 25L jerry can which was used for the various analysis (Alo *et al*., 2012).

Collection, identification and treatment of *Moringa oleifera* Seed

Seeds of *M. oleifera* were purchased from Monday Market, Garki-Abuja, Nigeria. The identification was established at Herbarium of Biological Sciences university of Abuja. The seeds were peeled to obtain the nuts and sun dried for 3 days. Thereafter, the dried seeds were ground into a powdered form using laboratory mortar and pestle and then sieved to a fine powder. The powdered *Moringa* was stored in an air tight container (Gideon *et al*., 2010).

Collection of Alum

The alum was collected from Lower Usuma Dam Water Treatment Plant, Bwari, FCT Abuja Nigeria. The Alum was also ground to a fine powder form with laboratory mortar and pestle (Gideon *et al*., 2010).

Preparation of 1% stock solution

1g each of alum and *M. oleifera* seed powder were dissolved in 100mls of deionized water resulting in the stock solution with an approximate concentration of 10,000 mg/l (1%). The solutions were stirred using magnetic stirrers for 10minutes. Fresh stock solutions were prepared each day for the analysis (Gideon *et al*., 2010).

Experimental design

A completely randomized design was used for this experiment. The treatments were performed with varying concentrations (0.02g/l, 0.04g/l, 0.06g/l and 0.08g/l) of alum, *M. oleifera* seed powder and control (no alum and *M. oleifera*). Each treatment effects on the response (Turbidity, pH, Temperature, TDS, Total Hardness, DO, Colour, Alkalinity, Conductivity, Iron and Manganese) were repeated 3 times (Omodamiro *et al*., 2014).

Coagulation test

Flocculation/coagulation experiments were conducted using a range of coagulant dosing from the respective stock solutions and a control without coagulant addition. For repeatability, each experimental set-up was repeated 3 times. A laboratory jar test apparatus (SW6 Stuart flocculator) was used with 1000 ml beakers as the flocculation/coagulation reactor volume. The dosing was set at 2, 4, 6 and 8mls for alum and *M. oleifera* stock solution.1liter of raw water were measured and introduced into 12 beakers (4 beakers for each coagulant). With a calibrated pipette, each stock solution dosages of alum and *M. oleifera* solutions (2ml, 4ml, 6ml and 8mls) were added into the water samples in the beakers. Note: 1ml stock solution contains 0.01g solute ≡ 10mg. The stirring paddles were lowered into the beakers, and the jar tests mixer turned on. Flash fast mixing was done for 3mins at a speed of 250rpm, followed by slow mixing for 17mins at 25 rpm to aid in floc formation. This is the standard procedure used in Lower Usuma Dam Water Treatment Plant. The beakers were observed and evaluated for specific dosages and floc quality (i.e. the floc appearance time in minutes and the floc size). The jar test mixer was turned off and the flocs were allowed to settle in the beakers for 30mins and flocs settling characteristics were observed (i.e. the time the flocs started settling in minutes and the clarity of the water after the flocs have settled (Hussein, 2016).

Physicochemical analysis

The supernatants thus formed were used for determination of the following physicochemical parameters.

Determination of temperature

Temperature was measured with a mercury thermometer. This was done on collection of water sample on site and after treatment (Omodamiro *et al*., 2014).

Determination of pH

The pH was measured with the 3150 Jenway pH meter. The pH meter was standardized with buffer of pH 7 prior to usage. The pH meter probe was dipped into water sample to take the pH reading. This was done in triplicates and results were recorded (Omodamiro *et al*., 2014).

Determination of turbidity

The turbidities of the water samples were measured with Turbidirect (Lovibond Product) turbidimeter. The cuvette was filled with the sample to the mark and inserted in the meter and reading was taken (Omodamiro *et al*., 2014).

Determination of total dissolved solids (TDS)

Total Dissolved Solids (TDS) was measured with the Extech-Exstik meter (EC500 model). The TDS meter was switched on, the reading zeroed and then the electrode dipped into the water samples, ensuring that the sample covers the membrane. Readings were taken appropriately and recorded (Omodamiro *et al*., 2014).

Determination of colour

The colour of the water samples were measured with Hach DR5000 spectrophotometer. 10mls of deionized water was used to zero the meter and 10mls of sample was filled in the cuvette and read off at 455nm wavelength. Results were recorded (Adeniran *et al*., 2017)

Determination of alkalinity

100mls each of the water samples were measured into a conical flask. The burette was filled to zero mark with alkalimetric reagent (0.04N acid solution of 1.12 mls H_2SO_4 and 3.32 mls of HCl in 1000mls of distilled water). 2 drops of methyl orange indicator were added to the water samples which turned yellow. Samples were titrated with the alkalimetric reagent. The end point was indicated by a change in coloration from yellow to orange. Alkalinity was calculated as: titre value multiplied by 20 (Oria-Usifo *et al*., 2014).

Determination of total hardness

100mls of each of the water samples was measured into a conical flask. The burette was filled with Ethylene Di-amine Tetra Acetate (EDTA) solution up to zero mark. 20 drops of K10 Buffer (it adjusts the pH to ensure that the reaction goes to completion) and 5 drops of NET indicator were added to each of the water samples. The solution turned purple. The samples were titrated against EDTA solution. The end point was indicated by a change in coloration from purple to blue. The titre value was taken and multiplied by 20 (Oria-Usifo *et al*., 2014).

Determination of conductivity

Conductivity was measured with the DDS-307 meter (Searchtech Instruments). The conductivity probe was inserted into the Erlenmeyer flask containing 250 mls water sample. Half of the probe was inserted while the solution was stirred using a magnetic stirrer. The read button was pressed too and records taken (Adeniran *et al*., 2017)

Determination of dissolved oxygen (DO)

The JPB-607A Portable Dissolved Oxygen Analyzer was used. This was switched on and allowed to equilibrate according to the manual instruction. When stable, the probe was dipped into the water samples and readings taken and recorded accordingly (Adeniran *et al*., 2017).

Statistical analysis

One Way Analysis of variance (ANOVA) was used to compare the effect of alum, and *M. oleifera* on Turbidity, pH and other water parameters like Temperature, Alkalinity, Total Hardness, Dissolved Oxygen, the analyzed data is represented in Tables and Bar Charts.

RESULTS

Physicochemical analysis of raw water (control)

The result for the Physiochemical parameters of the raw water (control) from January to June 2017 is shown in (Table 1). The physicochemical parameters determined were Turbidity which ranged between 30.6-89.0 NTU (59.17 ± 8.44),pH ranged between 6.84-7.40 (7.15 ± 0.08), Temperature ranged between 29.5-31.7ºC (30.75 ± 0.29), TDS ranged between 198-262mg/l (242.0 ± 10.1), Total Hardness ranged between 74-140mg/l (110.3 ± 12.4), DO ranged between 4.0-6.3mg/l (5.45 ± 0.43), Colour ranged between 350-542PtCo (444.8 ± 33.2), Alkalinity ranged between120-136mg/l (128.3 ± 2.80), Conductivity ranged between 289-344 µS/cm (325.7 ± 9.98), Iron ranged between 0.89-1.5mg/l (1.13 ± 0.09), and Manganese ranged between 1.83-2.10mg/l (1.97 ± 0.05).

Table 1: Mean values for the physicochemical parameters of raw water

Parameters	Jan	Feb	Mar	Apr	May	Jun	Mean
Turbidity (NTU)	30.60	51.60	49.6	58.20	76.00	89.00	59.17 ± 8.44
pH	6.84	7.21	7.00	7.32	7.40	7.10	5.00 ± 0.08
Temp(ºC)	30.60	30.70	31.70	30.80	29.50	31.20	30.75 ± 0.29
TDS (mg/l)	228.00	198.00	256.00	248.00	262.00	260.00	242.00 ± 10.10
T.H (mg/l)	82.00	74.00	134.00	94.00	140.00	138.00	110.30 ± 12.40
DO (mg/l)	4.00	6.10	6.30	4.20	6.00	6.10	5.45 ± 0.43
Colour (PtCo)	350.00	539.00	378.00	542.00	410.00	450.00	44.80 ± 33.2
Alk (mg/l)	120.00	120.00	136.00	130.00	134.00	130.00	128.3 ± 2.80
Conduc.(µS/cm)	300.00	289.00	344.00	340.00	342.00	339.00	325.70 ± 9.98
Fe (mg/l)	1.20	1.50	1.00	0.99	1.20	0.89	1.13 ± 0.09
Mn (mg/l)	1.99	1.94	2.10	1.83	2.01	1.94	1.97 ± 0.05

Mean values of physicochemical parameters of raw water (control) ±standard deviation

Table 2: Coagulation performance test for Alum.

MONTHS	PARAMETERS															
	FLOC APPEARANCE TIME				FLOC MARK				FLOC SETTLING TIME				CLEARITY			
	0.02g/l	0.04g/l	0.06g/l	0.08g/l	0.02g/l	0.04g/l	0.06g/l	0.08g/l	0.02g/l	0.04g/l	0.06g/l	0.08g/l	0.02g/l	0.04g/l	0.06g/l	0.08g/l
JANUARY	<1	<1	<1	<1	5	6	7	8	<1	<1	<1	<1	SC	SC	CL	CL
FEBRUARY	<1	<1	<1	<1	5	6	7	8	<1	<1	<1	<1	SC	SC	CL	CL
MARCH	<1	<1	<1	<1	5	6	7	8	<1	<1	<1	<1	SC	SC	CL	CL
APRIL	<1	<1	<1	<1	5	6	6	7	<1	<1	<1	<1	SC	SC	CL	CL
MAY	<1	<1	<1	<1	6	6	7	8	<1	<1	<1	<1	SC	SC	CL	CL
JUNE	<1	<1	<1	<1	6	6	7	8	<1	<1	<1	<1	SC	SC	CL	CL

Coagulation performance test (jar test trials) for coagulants

Physical assessment was carried out on the water treated with coagulants to check their coagulation performance in terms of floc appearance, size, shape, number of flocs, clarity of water between and above settled flocs.

Coagulation performance test for alum

The result showed in (Table 2) is the physical assessment of the coagulation performance test for raw water treated with alum from January to June 2017. The floc appearance and settling time were recorded to be less than one minute for all concentrations from January to June. The floc mark (size) and number for all the varying concentrations of alum produced clusters of many flocs. The clarity of water increases with the increase in concentration of alum, it was slightly clear when the concentrations were 0.02 and 0.04g/l and clearer as concentration increases from 0.6 to 0.08g/l.

Coagulation performance test for *Moringa oleifera*

The physical assessment of the coagulation performance test for raw water treated with *M. oleifera* seed powder from January to June 2017 is indicated in (Table 3). The floc appearance and settling time was less than one minute for all concentrations except for 0.02g/l which was greater than one minute in May and June while in April it was greater than one minute for all concentrations. For the floc mark and numbers, the particles conglomerated into smaller cluster of few flocs for all the concentrations.

Table 3: Coagulation performance test for *moringa oleifera* seed powder

MONTHS	PARAMETERS															
	FLOC APPEARANCE TIME				FLOC MARK				FLOC SETTLING TIME				CLEARITY			
	0.02g/l	0.04g/l	0.06g/l	0.08g/l	0.02g/l	0.04g/l	0.06g/l	0.08g/l	0.02g/l	0.04g/l	0.06g/l	0.08g/l	0.02g/l	0.04g/l	0.06g/l	0.08g/l
JANUARY	<1	<1	<1	<1	4	4	4	5	<1	<1	<1	<1	CD	CD	CD	SC
FEBRUARY	<1	<1	<1	<1	4	4	4	5	<1	<1	<1	<1	CD	CD	CD	SC
MARCH	<1	<1	<1	<1	4	4	4	5	<1	<1	<1	<1	CD	CD	CD	SC
APRIL	>1	>1	>1	>1	3	3	3	3	>1	>1	>1	>1	CD	CD	CD	CD
MAY	>1	<1	<1	<1	3	4	4	5	>1	<1	<1	<1	CD	CD	CD	SC
JUNE	>1	<1	<1	<1	3	4	5	5	>1	<1	<1	<1	CD	CD	CD	SC

However, the floc mark and number increases with the increase in concentration. For clarity, the water was cloudy (CD) for the concentrations of 0.02g/l, 0.04g/l and 0.06g/l in January, February, March, May and June, while in April the water was cloudy for all concentrations. The treated water was slightly clear for 0.08g/l concentration of *M. oleifera* in January to June with the exception of April.

Effect of Season on coagulation potential of Alum and *Moringa oleifera*

The effect of season on the coagulation potential of alum, and *M. oleifera* is shown in (Figures 1 and 2) respectively. It is pertinent to note that the concentrations of alum and *M. oleifera* remains constant for this research work while the effect on water parameters during the different months may be affected by season. Alum and *M. oleifera* reduced water turbidity significantly in the months of January, February, March and April ($p<0.05$). The Total hardness of alum and *M. oleifera* treated water in the months of January, February, and April were significantly lower than Total hardness in the months of March, May and June.

DISCUSSION

The present study compared the coagulation potential of Alum (a hydrated double Sulphate salt of Aluminium.) and *Moringa oleifera.* In the present study, it was observed that the turbidity values of Alum decreased with increasing concentration. This agrees with the work of Egbuikem *et al*. (2013) for alum.

The reverse was observed for *M. oleifera* as the turbidity increased with increasing dosage from 0.02g/l to 0.04g/l then decreased as the concentration increased from 0.06g/l to 0.08g/l. Lilian *et al*. (2017), Hendrawati *et al*. (2016) and Magaji *et al.* (2015) all concluded that since the bioactive constituents of *M. oleifera* extract is low molecular weight short chain polyelectrolyte, it would be inefficient in the removal of turbidity from water with low initial turbidity. But disagrees with Oria-Usifo *et al.* (2014) who observed decreased turbidity with increased dose from 0.03g/l to 0.05g/l and increased turbidity with increased dose from 0.05g/l to 0.07g/l and decreased turbidity from 0.07g/l to 0.09g/l. Also disagrees with the findings of Adeniran *et al*. (2017), Jodi *et al*. 2017, Vasavi *et al*. (2015) and Egbuikem *et al*. (2013) all observed reduced turbidity with increased dosage.

The degree of acidity (pH) is one of the most important factors affecting the coagulation process. When the coagulation is not carried out at the optimum pH range, it could lead to failure of the floc formation and poor quality of water produced.

pH of the water samples was not significantly affected following coagulation with alum and *M. oleifera* in the present study. There was slight reduction in the pH of water treated with alum with increase in dosage due to series of hydrolytic reactions which produced hydrogen ions and hence the pH of the water reduced. However, most research findings observe significant reduction in pH following coagulation with alum which is in contrast with this research work, like the findings of Kalavathy*et al*. (2017), Miraji *et al*. (2014), Lawal *et al*. (2013) and Egbuikem *et al*. (2013) all observed drastic reduction in pH in response to increasing concentration of alum. Work done by Hendrawati *et al.* (2016), Magaji *et al.* (2014), Miraji *et al.* (2014), Lawal *et al.* (2013), Kawo *et al.*

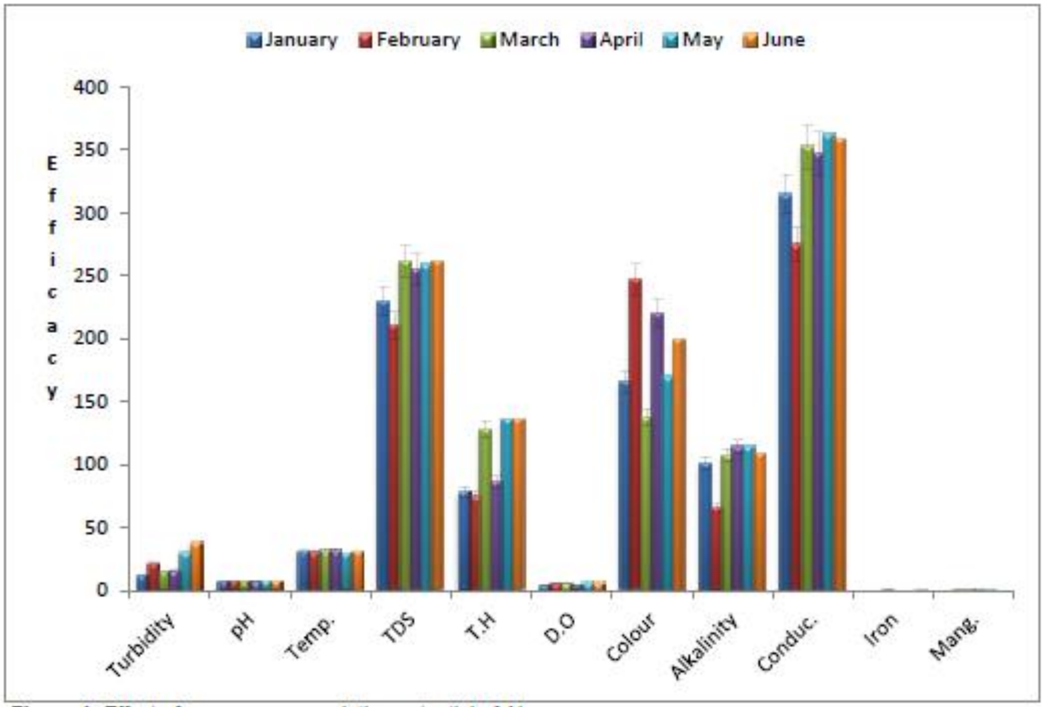

Figure 1: Effect of season on coagulation potential of Alum

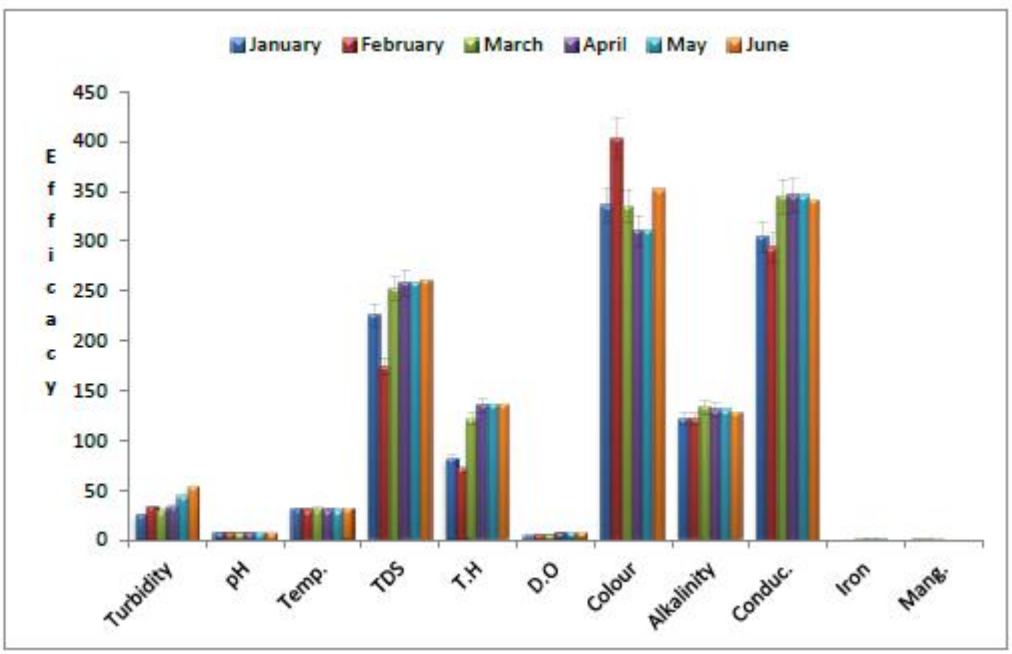

Figure 2: Effect of season on coagulation potential of *Moringa oleifera*

(2013) and Alo *et al.* (2012) showed that *M. oleifera* did not modify water pH and conductivity which agrees with this research work. But this disagrees with the findings of Oria-Usifo *et al.* (2014) and Omodamiro *et al.* (2014) both observed increased pH with increased dose; Adeniran *et al.* (2017) and Jodi *et al.* (2017) observed decrease in pH with increased dose. At low concentration of *M. oleifera*, cationic proteins bound alkaline ions leaving free hydrogen ions that resulted in low pH. At high concentration, basic amino acids dominated by binding with acidic ions from water resulting in the release of hydroxyl group making the solution basic. This accounted for the basic pH values observed for *M. oleifera* treatments compared with alum treatments.

Conclusion

Alum and *M. oleifera* are the principal coagulants used in this study's water purification. They were excellent at lowering water turbidity and color. The level of clarity varies amongst coagulants and was found to increase with increasing coagulant dosage. Alum, on the other hand, is more effective than *M. oleifera* in terms of turbidity and color, but also lowers the pH of the water, making it somewhat acidic. During the course of this investigation, it was observed that *M. oleifera* had an advantage over alum in terms of achieving neutral pH following water treatment*. M. oleifera* has been demonstrated to be a suitable substitute for alum in water treatment since they are natural coagulants that are toxic-free, eco-friendly, sustainable, and less expensive.

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