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Original Research Article

Adoption of a Natural Coagulant (*Moringa oleifera*) in Domestic Water Treatment

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ABSTRACT

Provision of clean water is a major challenge in developing countries due to increasing cost of chemicals used in water treatment. The search for sustainable and affordable natural plant material has been a subject of research for decades. This study aims to investigate the efficiency of Moringa oleifera as natural coagulant in domestic water treatment. Raw water sample was collected and analysed before and after treatment with the seeds powder at varying coagulant dosages. Maximum removal of turbidity and colour was observed at an optimum coagulant dose of 750 mg/l corresponding to removal efficiencies of 93% and 98% respectively. The quality of water improved as coagulant dose increased. The addition of Moringa oleifera to water did not cause any undesirable change in the water quality. This research recommends that Moringa oleifera should be grown locally and adopted as a natural coagulant for domestic water treatment in developing countries.

1. INTRODUCTION

Water is essential for the survival of human beings (Rao and Prasad, 2013; Pandey *et al.*, 2020) but this natural resource is under threat due to poor management, over population and increasing urbanization (Valverde *et al.*, 2018; Ali *et al.* 2019).

Purification of water continues to become a major challenge in many parts of the world due to increasing pressure to provide safe water supplies (Nouhi *et al.*, 2019). A range of water treatment technologies have been developed and improved in the past decades, yet coagulation still remains one of the oldest and simplest methods employed to remove suspended particles and colloids during water treatment processes (Ang and Mohammad, 2020). Chemicals such as aluminium sulphate, ferric chloride and pre-hydrolized coagulants have been used and shown great performance in water treatment but limitations such as high cost of coagulants and increased sludge volume have been identified (Thakur and Choubey, 2014; Bobor and Aghedo, 2020). Hoa and Hue, (2018) have also linked excessive intake of residual aluminium in drinking water to Alzheimer's disease. In view of this, a number of natural coagulants have been suggested.

Natural coagulants from plant origin have been in use for the past decades in India, China and Africa (Megersa *et al*., 2016; Hans, 2017). A study by Megersa *et al.* (2014) showed that natural plants such as *Moringa oleifera, Solanum incunum, Ocimum sanctum, Azadirachta indica, Triticum aestivum, Phyllanthus emblica* and *Strychnos potatorum* have been used for water treatment. *Moringa oleifera* seeds have been proven by many researchers as a good coagulant and widely recommended for use in developing countries due to its non-toxic nature and availability (Hoa and Hoe, 2018; Sulaiman *et al*., 2019; Bobor and Aghedo, 2020).

A review by Popoola and Obembe (2013), on the availability and use pattern of *Moringa oleifera* in Nigeria revealed that it is readily available, well distributed and known in all ecological zones in Nigeria. They also reported that its use for medicine was more prominent amongst all the ethnic groups while its use as a coagulant for water treatment was more frequent in the North compared to the Southern part of Nigeria.

The provision of clean water in Lagos state is solely the responsible of the state water corporation. Only 35% of the water demands of the residents are met by the corporation despite investment by previous administration while 65% of the populace depend on private boreholes, hand-dug wells and water vendors (Shiru *et al*., 2020). The state's public water supply is faced with problems such as lack of maintenance and damage of water infrastructure, water loss due to leakage from pipes, illegal connections and erratic power supply (Ayeni *et al*., 2015 and Shiru *et al*., 2020). Increasing population, urbanization, industrialization and water pollution have also been identified as major challenges facing the state in ensuring adequate and sustainable provision of water supply to the residents of the State (Kunnuji, 2014; Balogun *et al*., 2017 and Shiru *et al*., 2020).

In order to reduce the difficulties and cost associated with the provision of potable water in the State, sustainable and affordable water treatment system should be adopted through the use of locally available materials with low cost and no side effects. This study therefore aims to investigate the efficiency or the use of *Moringa oleifera* seeds in domestic water treatment.

2. MATERIALS AND METHODS

2.1. Collection and Identification of Plant Materials

Matured seeds of *Moringa oleifera* seeds were collected from a local farm in Odogunyan, Ikorodu, Lagos State, Nigeria (latitude 6039'28" N and longitude 30 30'01" E). Thereafter, the seeds were washed with water and dried in the sun for ten days. The dried seeds (10 g) were taken for identification at the Herbarium, Department of Botany, University of Lagos, Nigeria.

2.2. Proximate Analysis

The dried seeds were pulverised using a blender and sieved with 600 microns IS sieve and analysed for the proximate analyses (moisture content, crude protein, fat, ash and carbohydrate contents) using standard methods (Association of Official Analytical Chemists (AOAC), 2005) at the Department of Chemistry, University of Lagos, Nigeria.

2.3. Water Collection and Analysis

Water sample (25 l) were collected from a borehole in Bariga, Somolu Local Government Area, Lagos State with GPS of latitude 6031'26.44" N and longitude 30 23'53.20" E. The water sample was stored in clean and sterile plastic container. Water quality parameters (such as pH, turbidity, conductivity, total dissolved solids and colour) were analysed using standard methods at quality control laboratory, Works and Physical Planning Department, University of Lagos, before and after treatment with *Moringa oleifera*. Turbidity was measured with turbidimeter (HACH DR 900 Colorimeter), colour with HANNA HI 83200 Multiparameter photometer and pH with bench top pH meter. TDS was measured with ADWA AD 201 TDS meter while conductivity was measured with ADWA AD 204 conductivity meter.

2.4. Jar Test

The powdered *Moringa seed* (5 g) was mixed with 100 ml of distilled water to prepare stock solution of the coagulant. This was mixed for 5 minutes using a magnetic stirrer and thereafter filtered through a filter paper (Whatman, 125 mm diameter). The filtered mixture was used during the coagulation process. Beakers of 500 ml capacity were filled with raw water sample and coagulant dose at varying concentrations between 50 and 1250 mg/l were measured into the beakers respectively. The jar test mixer was operated at an initial speed of 180 rpm for 3 minutes, then the speed was reduced to 40 rpm and this continued for 20 minutes. Thereafter, it was allowed to settle for 60 minutes and an aliquot of the supernatant was taken using a pipette and analyzed for physico-chemical parameters (Figures 1a and b).

Figure 1a: Raw water sample

Figure 1b: Treated water sample after settling

The removal efficiency (RE%) for turbidity and colour were calculated from Equation (1).

$$RE = \frac{C_i - C_f}{C_i} \times 100\% \quad (1)$$

Where C_i is the initial concentration of turbidity and colour of untreated water sample and C_f is the final concentration of turbidity and colour of treated water sample

3. RESULTS AND DISCUSSION

3.1. *Moringa* Identification and Proximate Analysis

The seed was identified as *Moringa oleifera Lam.* of the Moringaceae family. The results of proximate analysis of *Moringa oleifera* seed in (%) are presented in Table 1. The moisture content, crude protein, fat content, ash content and carbohydrate content were 9.14, 29.03, 37.22, 5.04 and 23.07% respectively. The moisture content obtained in this study (9.14 %) is lower than the 9.56% recorded by Mgbemena and Obodo (2016), but higher than the 4.0% recorded by Abdulkadir *et al.* (2016) and the 7.2% recorded by Hoa and Hue, (2018). Moisture content is an indicator used to evaluate the amount of water present in the plant material and is used to evaluate the shelf life of the seed. High moisture content contributes to increased biochemical activities by microorganisms (Mgbemena and Obodo, 2016). Low moisture content observed in the present study suggested longer shelf life of the seeds as a result of reduced microbial activity. This was also corroborated by Oluwole *et al.* (2013). The protein content of *M. oleifera* seed in this study was lower than the 35.97% reported by Olagbemide and Alikwe (2014), the 43.26% reported by Manju *et al.* (2018), and the 34.51 to 36.5% reported by Barakat and Ghazal (2016) but greater than the 17.94% reported by Mgbemena and Obodo (2016) and the 26.5% reported by Abdulkadir *et al.* (2016). Proteins have been identified by Yin, (2010), Bichi (2013) and Megersa *et al.* (2014) as the active ingredient required by *M. Oleifera* to act as a coagulant in water treatment. The differences and variation in values reported in this study with other researchers could be due to the origin and sources of the *M. Oleifera* seed as reported by Manju et al. (2018). The fat content of 37.22% recorded in this study was lower than the 38.67% reported by Olagbemide and Alikwe (2014) but higher than the 34.5% reported by Hoa and Hue (2018) and the 20.1% reported by Abdulkadir *et al.* (2016). Although the oil content could be extracted for domestic and industrial use but it could lead to increase in organic pollutants during water treatment (Hoa and Hue, 2018). The ash content of 5.04% obtained in this study was higher than the 3.87% reported by Olagbemide and Alikwe (2014) but lower than the 8.24% obtained by Mgbemena and Obodo (2016). Ash content is an indication of the amount of minerals present in the plant material. The carbohydrate content of 23.07% recorded in the present study was higher than the 8.67% reported by Olagbemide and Alikwe (2014) but lower than the (48.26% recorded by Mgbemena and Obodo (2016) and the 27.5% reported by Abdulkadir *et al.* (2016). Even though its high carbohydrate content of the seed is essential for use in humans, as it serves as a source of energy supply to the body (Mgbemena and Obodo, 2016) but it could increase the concentration of organic matter when used as a coagulant in water treatment (Ang and Mohammad, 2020).

Table 1: Proximate analysis of *M. Oleifera* seed

Properties	Value (%)
Moisture content	9.14
Crude protein	29.03
Fat	37.22
Ash	5.04
Carbohydrate	23.07

3.2. Characteristics of Raw Water Sample

The analysis of concentrations of turbidity, pH, colour, conductivity and TDS of the water sample is shown in Table 2. The results revealed that the pH and conductivity were within the limits of WHO (2006) and NSDWQ (2015). A TDS value of 396 mg/L was recorded in the water sample. Although this value was within the set guidelines but the presence of dissolved solids could be due to dissolved organic and inorganic substances in the groundwater sample (Iroye and Okunola, 2019). Turbidity and colour levels were above the permissible limits. High concentration of suspended particles in water affects its colour and turbidity levels. Colour of water could also change due to the presence of colloidal particles such as iron and manganese (Isa *et al.*, 2015). Hence, the water sample needs to be treated to enhance its suitability for domestic use.

Table 2: Characteristics of raw water sample

Parameters	Concentration	WHO (2006)	NSDWQ (2015)
Turbidity (NTU)	100	5	5
pH	7.15	6.5-8.5	6.5-8.5
Colour (TCU)	495	15	15
Conductivity (mS/cm)	0.98	1000	1000
TDS (ppm)	396	600	500

3.3. Characteristics of Treated Water Sample

It can be seen that the percentage turbidity removal increased from 29% to 93% as the amount of *Moringa* seed powder increased (Figure 2). The optimum dose for maximum removal of turbidity in the water sample occurred at 750 mg/L at a removal efficiency of 93%. Turbidity level reduced from 100 NTU to 7 NTU at the optimum dose. High optimum dose discovered in this study have also been recorded by Pritchard *et al.* (2010) where 1000 mg/L was reported as the optimum dose for *Moringa oleifera* in the treatment of water sample with high turbidity values ranging between 159-161 NTU. However, lower optimum dosages have also been reported for water with high turbidity.

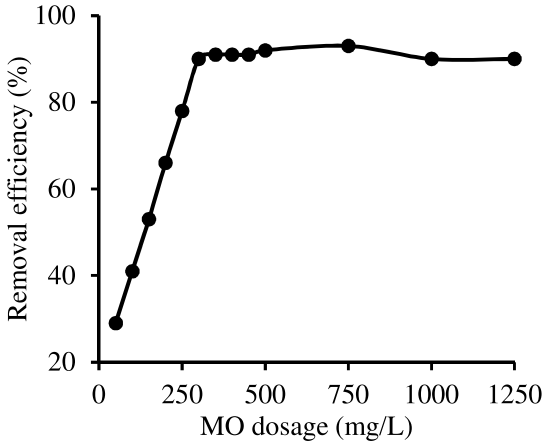

Figure 2: Effect of coagulant dosage on turbidity removal

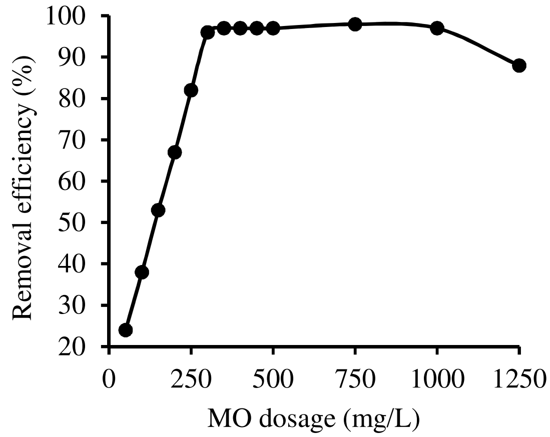

Figure 3: Effect of coagulant dosage on colour removal

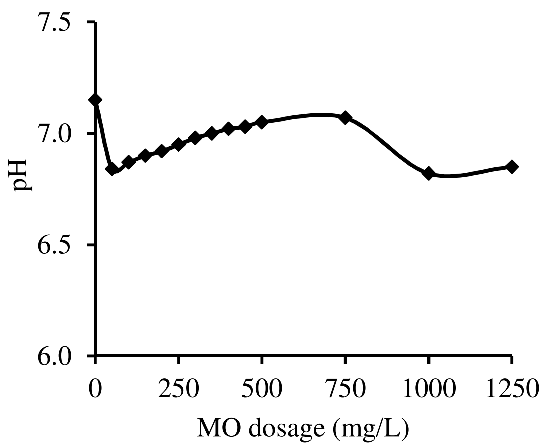

Figure 4: Effect of coagulant dosage on pH

For instance, Yusuf *et al.* (2015) recorded 90 mg/L as optimum dosage for high turbid water of 339 NTU collected from river Kaduna, Nigeria. Synthetic turbid water with turbidity of 150 NTU was also treated by Thakur and Choubey (2014) with *M. oleifera*, 80.7% reductions was recorded at optimum dosage of 200 mg/L. The differences in results could be due to the species of *M. oleifera* used, experimental conditions such as settling time, mixing velocity gradient and durations (Katayon, 2006). Megersa *et al.* (2016) have also indicated that the use of natural or synthetic source of water could also affect experimental results. Both water sources have different characteristics and contaminants which could influence the performance of coagulants. This study also observed that increasing *Moringa* dose above the optimum dosage (1000 mg/L and 1250 mg/L respectively), did not enhance turbidity removal. Pritchard *et al.* (2010), Thakur and Choubey (2014) have similarly reported that addition of *M. oleifera* after the optimum dosage has been reached, made the coagulation effect inefficient. Overdosing usually results in the saturation of the polymer bridge sites and this causes restabilization of the destabilized particles (Katayon *et al.*, 2006). Even though, the turbidity level achieved in this study (7 NTU) is slightly above the recommended guidelines, *Moringa oleifera* has proven to be effective in the treatment of highly turbid groundwater.

There was reduction in the colour as the turbidity level reduced. Maximum colour removal was 98% at the optimum dosage of 750 mg/L (Figure 3). The colour of the water sample changed from reddish brown to colourless. This shows that *Moringa oleifera* had good absorbent properties. This is supported by Mangale *et al.* (2012) and Patil *et al.* (2017). As the coagulant dosage increased, the colour of the water sample changed signifying increase in dissolved *M. oleifera* in the water sample. Nkurunziza *et al.* (2009) also confirmed reduction in colour as turbidity reduced on application of *M. oleifera*.

There was no significant change in the pH of the water sample (6.85 -7.07) at varying concentrations of *M. oleifera* (Figure 4). pH at the optimum dose was 7.07 and this is within the permissible range of 6.5-8.5 (WHO, 2008; NSDWQ, 2015). In the study carried out by Delelegn *et al.* (2018), they discovered that the application of *M. oleifera* seed extract on Angereb and Shinta rivers, Gondar, Ethiopia did not affect the pH of the river samples. This was also confirmed by Hoa and Hue (2018); Ang and Mohammad (2020). Hoa and Hue (2018) reported that lack of chemical reactions between the cationic proteins of *M. oleifera* and alkalinity in water could be responsible for reduced variations in pH during water treatment with *M. oleifera*. This could save the need and cost for pH adjustment after water treatment process compared to other chemical coagulants.

4. CONCLUSION

The results obtained from this study confirmed the use of locally available natural materials in the removal of turbidity and colour in groundwater. *M. Oleifera* seeds was efficient in the treatment of highly turbid groundwater. An optimum dose of 750 mg/l was efficient in the removal of turbidity and colour at removal efficiencies of 93% and 98% respectively at no significant change in pH. The production and use of the seeds should be encouraged in rural areas where no water treatment facilities are available as this would reduce the cost of water treatment. This study has also shown that the efficiency of *M. Oleifera* is also dependent on its composition. Further investigation should therefore be carried out on elemental composition and optimum dosage of different species of *M. Oleifera* grown locally.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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