J. Bangladesh Acad. Sci. 47(1); 119-125: June 2023 DOI: https://doi.org/10.3329/jbas.v47i1.61838

Journal of Bangladesh Academy of Sciences

Journal homepage: http://www.bas.org.bd/publications/jbas.html

Research Article

Comparative assessment of *moringa oleifera* seed extract and aluminum sulfate solution efficiency as coagulants for storm water treatment

Garba Barde Bate, Adeniyi Olarewaju Adeleye*, Afeez Oladeji Amoo, Emmanuel Madu Ijanu, Catherine Iyabo Asaju and Haruna Sale Mohammed

Department of Environmental Sciences, Federal University Dutse, Nigeria

ARTICLE INFO

Article History

Received: 12 October 2022
Revised: 05 March 2023
Accepted: 02 April 2023

Keywords: Storm water, *Moringa oleifera*, Alum, Coagulants, Water treatment

ABSTRACT

Chemical coagulants used in water treatment are detrimental to human health. This research assessed the viability of *Moringa oleifera* (MO) seed extract compared with Aluminium Sulphate (Alum) as coagulants for treating stormwater. Five hundred mL of each of the eight storm water samples were analyzed through the Jar test method and zone settling rate experiment. Temperature, pH, conductivity, turbidity, and total suspended solids were assessed before and after adding the coagulants. Results obtained on the percentage reduction in interface height show lesser percentages (0.47, 0.76, 1.14, and 0.19%) when varying concentrations (50, 60, 70, and 80 mg/L) of MO seed extract were employed compared to the superior reduction percentages (87.07, 90.09, 95.27 and 94.57%.) when the same varying concentrations of Alum solution were added. Nonetheless, the percentage reduction in interface heights of the coagulants are significantly ($p<0.05$) different from each other.

Introduction

The literature has overwhelmingly established that to avert public health crisis, water from surface sources must be purified before it can be considered potable for human consumption (Guchi, 2015). According to USEPA (2014), storm water emanates from the sky in the form of rain, hail, or snow and flows over streets, parking space, and roofs of buildings into a water body or storm drain. If properly harnessed and treated, the all-year availability of storm water in Dutse can serve as a panacea to water scarcity, especially in the dry season.

Various methods are used to make water safe and attractive to consumers. However, the method that can be employed depends largely on the character of the raw water involved (Dinka, 2018). One of the difficulties with the treatment of surface water is the large seasonal variations in turbidity (McConnachie et al.,1999). According to Pillai (2004), the use of natural coagulants had been documented for over 100 years and had been used in the past before chemical coagulants were discovered (Bratby, 2016).

It has been reported that *Moringa oleifera* (MO) can eliminate river water's turbidity and dissolved organic matter (Damayanti et al., 2011). Aluminium sulphate [$Al_2(SO_4)_3$], generally known as Alum, has been in existence for over 100 years and has been comprehensively adopted as a flocculating agent in the treatment of wastewater (Harper et al., 1998). Further, adding Alum to water produces chemical precipitates that aid the removal of pollutants in suspended solids,

*Corresponding author:<adeniyadeleye@fud.edu.ng>

algae, phosphorus, heavy metals, and bacteria. The use of Alum, however, leaves behind both dissolved and residual aluminum compounds in the drinking water, which is associated with several human health problems, including Alzheimer's disease, osteomalacia, osteodystrophy, Parkinson's disease, etc. (Krupinska, 2020). Based on this scientific background, this study assessed the suitability of MO seed extract compared to Alum solution in treating water samples collected from a storm water reservoir in Dutse North West, Nigeria.

Materials and Methods

Sampling Technique and Preparation of Coagulants

A grab sampling technique was employed to collect the storm water samples along the mechanic village in Dutse urban, Jigawa State. MO seeds were collected, sun-dried, de-shelled, and subsequently crushed to a fine powder using a mortar to make it an effective coagulant, as Ndabigengesere et al. (1995) recommended.

Experimental Design

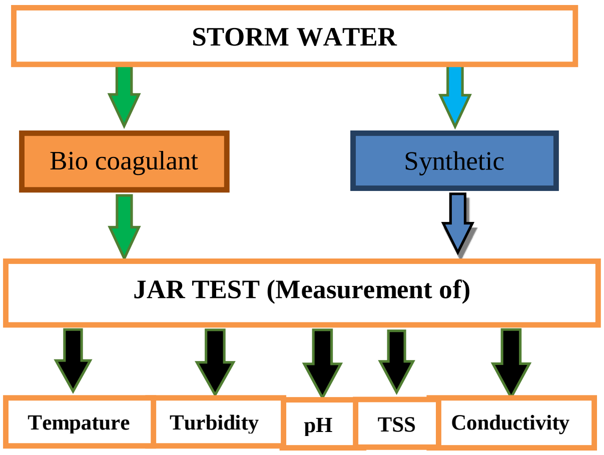

Fig. 1. A flow chart of the experimental design

The powder was then sieved, weighed, and dissolved in distilled water to make a 50 g/L solution, stirred for 30 minutes using a centrifuge, and filtrated through a Whatman filter paper (No. 40).

Aluminum sulfate was bought from a vendor in Dutse ultra-modern market. It was completely crushed to a finely sieved powder using a mortar to attain the desired effect. The powder was weighed and dissolved in distilled water to make a 50 g/L solution. The solution was stirred for 30 minutes and filtrated through a Whatman filter paper (No. 40). As Ukanwa and Verstraete (2010) prescribed, the fresh solution was prepared daily to avoid the aging effects of the MO and aluminum sulfate powder solution.

Jar Test

To assess the coagulation and flocculation effect of the coagulants (MO seeds extract and aluminium sulphate solution) on their coagulating capacity due to the continuous stirring mechanism, the standard Jar test method was performed as recommended by Ndabigengesere and Narasiah (1998) and Khader et al. (2018). The Jar test in this study involved a combination of rapid and slow mixing processes before sedimentation was achieved. The rotational speed of the mixers was changed accordingly to simulate different mixing intensities such that flocculation would occur, as Katayon et al. (2007) and Vieira et al. (2010) reported.

The procedure involved using 500 mL glass beakers filled with storm water which was agitated using the Jar test apparatus. The measured amounts (5, 60, 70, and 80 mg/L) of MO and Alum coagulants were added to each storm water sample (500 mL) while agitating the suspension. The suspension was initially mixed at a higher speed (120 rpm), followed by a slow mixing at 80 rpm, and finally set at 20 rpm for 30 minutes to enable sedimentation. The solid/liquid interface in the beakers was recorded during the settling period.

Zone Settling Rate

The effectiveness of the coagulants assessed in this study was determined by measuring the amount of settleable sludge attained and the rate at which it settled.

The methodology adopted in this current study can be connected with previous and similar studies conducted on conditioning sludge with different chemicals. The effectiveness of the coagulants found in terms of the reduction of suspension of solids particles in the supernatant fluid can then be calculated based on the percentage reduction of the solid/liquid interface height (Amirtharajah and O'Melia, 1990).

The standard methods recommended a column of one meter in height and ten cm in diameter (Amirtharajah and O'Melia, 1990), corresponding to a large volume of sludge. In contrast, this experiment used one L measuring cylinders approximately forty-one cm in height and six cm in diameter with a one L volume of sludge, similar to the method used by Muyibi et al. (2001).

Assessment of Coagulation Efficiency of Coagulants

A storm water sample weighing 0.5 L was measured and put in each beaker in which varying concentrations of coagulants were added. The extract of MO seeds and solution of Alum, which were introduced into each beaker containing the storm water in different concentrations, were mixed for 5 minutes. The samples were then allowed to settle for 30 minutes until all the settleable flocs had fully settled. Before and after treatment, samples were measured for turbidity, temperature, pH, conductivity, and total suspended solids (TSS). This was done to identify the dose of the MO seed extract and Alum solution required to achieve turbidity below International standards. The tests were performed at doses of 0 (control, before), 5, 6, 7, 8, and 50, 60, 70, and 80 mg/L of Alum solution and MO seed extract, respectively.

Data Analysis

Data were analyzed using SPSS version 20.0. Results were summarized using descriptive statistics. Student's T-test was used to determine the significant difference in the effectiveness of MO seed extracts and Alum solution in effecting coagulation of the sampled stormwater.

Results and Discussion

The initial temperature of the stormwater was 33 ˚C before the addition of MO (Table 1). After adding varying concentrations (50, 60, 70, and 80 mg/L) of MO, the temperature dropped to 29 ˚C across all the varying concentrations added (Table 2). This indicates that MO facilitated a reduction in the temperature of the storm water, thereby enhancing the slight conformity with the temperature range (27-28.8 ˚C) recommended by Mata-Alvarez et al. (2000).

Table 1. Physicochemical parameters of storm water (before treatment)

	Temperature (˚C)	Conductivity (µs/cm)	pH	Turbidity (NTU)	TSS (mg/L)
Values	33	634	8.09	1050	9672
APHA recommended Limits	27-28.1	8.50-14.14	6.50-8.50	5-25	-----

NTU= NephelometricTurbidity Units, TSS= Total Suspended Solids

Table 2. Efficiency of *Moringaoleifera* seed extracts and Aluminium Sulphate solution for the purification of stormwater

VSW (L)	Dose (g)	Concentration (mg/L)	Temperature (˚C)	Turbidity (NTU)	pH	Conductivity (μs/cm)	TSS (mg/L)
***Moringa oleifera* seed extracts**							
0.5	5	50	29.0	1045	8.9	627	962.6
0.5	6	60	29.0	1042	8.9	621	959.8
0.5	7	70	29.0	1038	8.9	602	956.1
0.5	8	80	29.0	1048	8.9	620	966.2
Alumnium Sulphate solution							
0.5	5	50	27.7	216	8.9	627	99.448
0.5	6	60	26.4	206	8.9	628	59.88
0.5	7	70	25.6	99.2	8.9	618	45.68
0.5	8	80	25.5	114	8.9	620	52.62

VSW═ Volume of Storm Water, MO═ *Moringa oleifera*, NTU= NephelometricTurbidity Units, TSS═ Total Suspended Solids

However, the addition of Alum concentrations (50, 60, 70, and 80 mg/L) brought the temperature about 27.7, 26.4, 25.6, and 25.5 ˚C, respectively (Table 2). These results show a better effect of Alum on the temperature of sampled storm water. In this case, the results are all within the normal range (27 ˚C) recommended by Mata-Alvarez et al. (2000).

Percentage (%) reduction in *Moringa oleifera* seeds extracts was calculated using the formula:

$$\% \text{ Reduction}=\frac{\mathrm{Ti-Tf}}{Ti}\times 100$$

where T_i= Initial Turbidity and T_f =Final Turbidity

The conductivity of storm water was initially measured before (634 μs/cm) (Table 1) and after the addition of MO seed extracts at varying concentrations (50, 60, 70, and 80 mg/L). The conductivity of the storm water dropped to 627, 621, 602, and 620 μs/cm, respectively (Table 2). Unfortunately, the addition of MO did not facilitate the conformity of the storm water samples with the recommended standard range (8.50-14.14 μs/cm) of GE (2012). Likewise, the same effect was recorded after the addition of Alum concentrations (50, 60, 70, and 80 mg/L) as the conductivity (627, 628, 618, and 620 μs/cm) were recorded, respectively (Table 2). This indicates that both coagulants did not aid the conformity of the storm water with the conductivity standard recommended by GE (2012). The results recorded in this study regarding the effect of Alum on the conductivity of the stormwater are contrary to the report of Harper and Herr (2000) on storm water as the conductivity before (587 μs/cm) the addition of Alum solution increased to 600, 609, 619 and 627 μs/cm after the addition of 5, 10, 15 and 20 mg/L of Alum solution, respectively.

When measured before treatment, the storm water's pH was recorded at 8.09 but increased to 8.9 with the addition of MO seed extracts (50, 60, 70, and 80 mg/L) and Alum solution (Table 2). These results show that both coagulants did not change the pH of the storm water appreciably during this study. Apart from the fact that the pH results obtained in this study are slightly above the normal range recommended by Appels et al. (2008), it also contradicts the pH results reported by Harper and Herr (2000) and Adeniran et al. (2017).

The initial turbidity of the storm water was 1050 (NTU) before adding varying concentrations (50, 60, 70, and 80 mg/L) of MO seed extracts. However, after the addition and subsequent retention time, it recorded 1045, 1042, 1038, and 1048 NTU, respectively (Figure 2). These results are, however, high above the standard range (5-25 NTU) recommended and reported by Raghuwanshi et al. (2002). Again, applying the same Alum solution concentrations facilitated massive and better reduction (216, 208, 99.2, and 114 NTU) in turbidity compared to the results obtained when varying concentrations of MO were employed (Fig. 2).

The percentage reduction in interface height had lesser percentages (0.47, 0.76, 1.14, and 0.19%) when varying concentrations of MO seed extract were employed compared to the superior reduction percentages (87.07, 90.09, 95.27, and 94.57%.) when Alum solution was used (Tables 3).

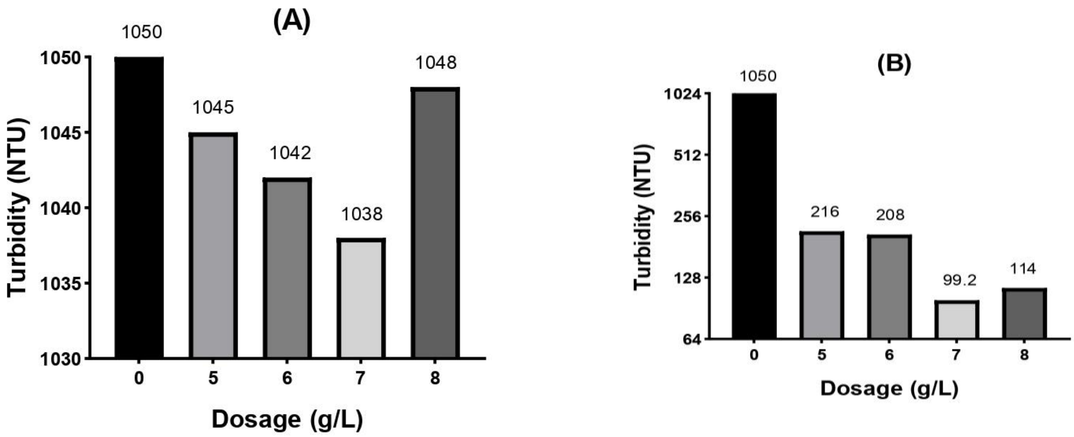

Fig. 2. Turbidity of storm water after adding (A) *Moringa oleifera* seed extract and (B) Alum solution.

Table 3. Interface height reduction (%) of the coagulants (*Moringa oleifera* seed extract and Alum solution).

Concentration of Coagulant (mg/L)	Total height reduction of the interface (%)	
	***MO* seed extract**	**Alum solution**
50	0.47[a]	87.07[b]
60	0.76[a]	90.09[b]
70	1.14[a]	95.27[b]
80	0.19[a]	94.57[b]

Means in the same row having different superscripts are significantly different from each other (p<0.05).

The superiority of chemical coagulants against natural polymers have been documented by International Water Association (2022). Nonetheless, in Table 3, it can be seen that the percentage reduction in interface heights of the coagulants are significantly ($p<0.05$) different from each other. The results obtained in this study agree with the reports of Muyibi and Alfugara (2010), and Adeniran et al. (2017), who reported that the higher the quantity of MO extract added for water purification, the better result was obtained.

Despite the efficiency of chemical coagulants in water purification, they certainly have disadvantages, as Vieira et al. (2010) reported in their study that there is an association between residual Aluminium in treated water and Alzheimer's disease. Additionally, Kaggwa et al. (2001) reported that sludge that has been thickened with chemical coagulants and polymers poses a threat to the environment by contributing to ground water pollution. MO seed extract, on the contrary, is non-toxic and was reported to be efficient in removing and preventing bacterial growth and heavy metals from the water, along side many advantages (Shan et al., 2017).

Conclusion

Varying concentrations of Alum solution had the best reduction percentages across all the measured parameters in this current study. However, MO-treated samples had lower reduction percentages than treated sludge samples suggesting that MO coagulant is not as effective in settling the suspended particles in the storm water samples. Due to the human health effects associated with using Alum, it is strongly suggested that further research be carried out on using MO seed extract as a coagulant in water treatment because of its natural availability, non-toxicity, and other immense benefits.

Author Contributions

G.B. Bate and A.O. Adeleye designed the experiment and wrote the manuscript, H.S. Mohammed carried out the laboratory work, and A.O. Amoo and E.M. Ijanu did the statistical analyses. C.I. Asaju helped with the manuscript arrangement. The final manuscript was reviewed and approved by all authors.

Conflict of interest

The authors declare that there is no conflict of interest as regards this study.

References

Adeniran KA, Akpenpuun TD., Akinyemi BA and Wasiu RA. Effectiveness of *Moringa oleifera* seed as a coagulant in domestic waste water treatment. *Afr. J. Sci., Technol. Innov. Dev.* 2017; 9(3): 323-328.

Amirtharajah A and O'Melia CR. Coagulation processes: destabilization, mixing, and flocculation. In: *Water Quality and Treatment*. Pontius FW (ed.), 4th Edition, Mcgraw-Hill, New York, 1990, pp.269-365.

Appels L, Baeyens J, Degrève J and Dewil R. Principles and potential of the anaerobic digestion of waste-activated sludge. *Prog. Energy Combust. Sci.* 2008; 34(6): 755-781.

Bratby J. Coagulation and flocculation in water and wastewater treatment. 3rd Edition, International Water Association. 2016.

Damayanti A, Ujang Z and Salim MR.The Influence of PAC, Zeolite, and *Moringa oleifera* as biofouling reducer (BFR) on hybrid membrane bioreactor of palm oil mill effluent (POME). *Bioresour. Technol.* 2011; 102(6): 4341-4346.

Dinka MO. Safe drinking water: concepts, benefits, principles and standards. In: *Water Challenges of an Urbanizing World*. Matjaž G. (Eds.), Chapter 10. Intechopen, London, 2018. pp.163-181.

GE. WATER AND PROCESS TECHNOLOGIES 2012. Handbook of Industrial Water Treatment. Clarification. United States: G.E. Water and Process Technologies.

Guchi E. Review on slow sand filtration in removing microbial contamination and particles from drinking water. *Am. J. Food Nutr.* 2015; 3(2): 47-55.

Harper HH, Herr JL and Livingston EH. Alum treatment of stormwater: The first ten years**.** New Applications in Modeling Urban Water Systems – Monograph 7. Proceedings of the Conference on *Stormwater and Urban Water Systems Modeling Conference*, Toronto, Canada, February 19-20, 1998.

Harper HH and Herr JL. Chemical coagulation of storm water runoff: An economical alternative for reducing nonpoint source impacts.Proceedings of the Delaware Urban Erosion, Sediment & Stormwater Conference. Newark, Delaware, October 24-26, 2000**.**

Kaggwa RC, Mulalelo CI, Denny P and Okurut TO. The impact of Alum discharges on a natural tropical wetland in Uganda. *Water Resour.* 2001; 35(3)**:** 795-807.

Katayon S, Noor MJMM, Wai KT, Ghazali AH, Thamer AM and Badronisa Y. Effect of natural coagulant application on microfiltration performance in treatment of secondary oxidation pond effluent. *Desalination*,2007; 204(1-3)**:** 204-212.

Khader EH, Mohammed THJ and Mirghaffari N. Use of natural coagulants for removal of COD, Oil and turbidity from produced waters in the petroleum industry. *J. Pet. Environ. Biotechnol.* 2018; 9(3): 1-7.

Krupinska I. Aluminium drinking water treatment residuals and their toxic impact on human health. *Molecules* 2020; *25*(3): 641.

Mata-Alvarez J, Mace S and Llabres P. Anaerobic digestion of organic solid wastes: An overview of research achievements and perspectives. *Bioresour.Technol.*.2000; 74(1): 3-16.

McConnachie GL, Folkard GK, Mtawali MA and Sutherland JP. Field trials of appropriate hydraulic flocculation processes. *Water Resour.* 1999; 33(6): 1425-1434.

Muyibi S and Alfugara A. Treatment of surface water with *Moringa oleifera* seed extract and Alum: A comparative study using a pilot scale water treatment plant. *Int. J. Environ. Sci.* 2010; 60(6): 617-626.

Muyibi SA, Noor MJMM, Ong DT and Kai KW. *Moringa oleifera* seeds as a flocculants in waste sludge treatment. *Int. J. Environ. Sci.* 2001; 58(2)**:** 185-195.

Ndabigengesere A, NarasiahK. S and Talbot BG. Active agents and mechanism of coagulation of turbid waters using *Moringa oleifera*. *Water Res*our. 1995; 29**:** 703-710.

Ndabigengesere A and Narasiah KS. Quality of water treated by coagulation using *Moringa oleifera s*eeds. *Water Res*our. 1998; 32**:** 781-791.

Pillai J. Flocculants and coagulants: The keys to water and waste management in aggregate production. *Illinois: Nalco Company, USA* 2004; pp. 308.

Raghuwanshi PK, Mandloi M, Sharma AJ, Malviya HS and Chaudhari S. Improving filtrate quality using agro-based materials as coagulant aid. *Water Qual. Res. J. Canada* 2002; 37(4): 745-756.

Shan TC, Matar MA, Makky EA and Eman NA. The use of *Moringa oleifera* seed as a natural coagulant for wastewater treatment and heavy metals removal. *Appl. Water Sci.* 2017; 7: 1369-1376.

Ukanwa W and Verstraete W. Anaerobic digestion of primary sludge from chemical pre-precipitation. *Water Sci. Technol.* 2010; 36**:** 357-365.

United States Environmental Protection Agency (USEPA) Coastal Stormwater Management through Green Infrastructure: A Handbook for Municipalities 2014; USEPA Publication.

Vieira AMS, Vieira MF, Silva GF, Araújo AA, Fagundes-Klen MR., Veit MT and Bergamasco R. Use of *Moringa oleifera* seed as a natural adsorbent for wastewater treatment. *Water Air Soil Pollut.* 2010; 206**:** 273-281.