Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 22 | No. 2 | pp. 699-707 | 2023
Original Research Paper
https://doi.org/10.46488/NEPT.2023.v22i02.013
Open Access Journal

Moringa Oleifera Coagulation Characteristics in Wastewater Treatment in a University Dormitory

M. S. Ogunshina*, O. M. Abioye†, K. A. Adeniran* and D. A. Olasehinde*****
*Department of Agricultural Engineering, University of Ilorin, PMB 1515, Ilorin, Kwara State, Nigeria
**Department of Agricultural and Biosystems Engineering, Landmark University, PMB 1001, Omu-Aran, Kwara State, Nigeria
***Landmark University SDG 6 (Clean Water and Sanitation Research Group), Nigeria
†Corresponding authors: O. M. Abioye; abioye.oluwaseyi@lmu.edu.ng

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 07-06-2022
Revised: 27-07-2022
Accepted: 30-07-2022

Key Words:
Cake residue
Coagulation
Jar test experiment
Moringa oliefera seed
Turbidity
Wastewater

ABSTRACT

Wastewater treatment necessitates the use of an appropriate method to achieve satisfactory results. The conventional method of Alum addition has been widely used for years, but it is prohibitively expensive. This study uses *Moringa oleifera*, an inexpensive and readily available plant, as a natural coagulant to treat wastewater collected from university dormitories. Physicochemical parameters such as pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) were examined based on appropriate standards. Wastewater treatment with varied coagulant dosages of 50, 100, and 150 mg.L^{-1}) was monitored using a standard jar test device with an initial wastewater perturbation at 100 rpm for 5 min was reduced to 50 rpm in 10 minutes with a rest time of 30 min. The results showed that the quality of the physicochemical properties of the water improved. The percentage increase in the water quality is; BOD (92%), COD (92%), and TDS (52-64%), with an increase in Moringa coagulant achieving a reduction of 96% of Turbidity. While the DO improved (79%), the pH remained below acceptable limits (6.73-7.56) for effluent disposal. The treated water showed clarity (colorless) and no odor compared to the wastewater. Hence, *Moringa oleifera* seeds cake residue can be an effective coagulant for wastewater treatment.

INTRODUCTION

The quality of surface and groundwater bodies in the immediate area is jeopardized by improper wastewater discharge (Kharake & Raut 2012). Untreated wastewater can have long-term negative consequences on the environment. Water bodies in developing countries, such as Nigeria, where wastewater treatment infrastructure is limited, are the most vulnerable to its detrimental effects. This has numerous negative effects on human health since it contains diseases that contribute to the emergence of bacteria and chemicals damaging the ecology (Iheukwumere et al. 2018). Traditionally, wastewater is classified as either black water or greywater. Blackwater is considered more hazardous, especially when in contact with human waste.

On the other hand, greywater is non-hazardous water without contact with human waste, discharged from various water facilities on a property. Wastewater considered in this study tends to be greywater. In reality, the composition of wastewater generated in many Nigerian Universities is a hybrid of greywater and blackwater that requires proper treatment. Most learning institutions cannot treat their wastewater before discharging it due to the high cost of chemicals and improper infrastructure. In water treatment processes, coagulants are classified according to their chemical characteristics (Vijayaraghavan et al. 2011). Chemical coagulants such as aluminum sulfate and iron salts have been traditionally used in wastewater treatment. For many developing countries, the cost of chemical coagulants, the side effects of high sludge volumes, and a decrease in pH value make this treatment process difficult and endanger aquatic life (Egbuikwem & Sangodoyin 2013). Polyaluminium chloride and alum are currently used for wastewater treatment with numerous disadvantages, such as epichlodine. This is a poisonous impurity and can cause Alzheimer's disease. Coagulation is one of the stages of water treatment. It is an essential physicochemical process for reducing suspended and colloidal materials causing turbidity in wastewater.

ORCID details of the authors:

O. M. Abioye: https://orcid.org/0000-0002-1108-4970

In contrast, as described by Doerr (2005), the typical household water treatment method recommends settling the particles and contaminants for one to two hours at the tank's base. Lilliehöök (2005) uses sand filtration with *Moringa oleifera* and a settling time of 30 minutes to two hours for low, medium, and high turbidity water. For clean water, Hsu et al. (2006) specified that *Moringa oleifera* seed powder mixed with water should be kept for hours without specifying the amount of time. In developing countries, natural coagulants are preferred due to their efficiency, availability, low price, and biodegradability (Betatache et al. 2014, Antov et al. 2012). Subramanium et al. (2011) explored using *C. Obtusifolia* seed gum in undiluted pulp and paper mill effluents. In textile wastewater, *Ocimum basilicum* has been used as a coagulant (Shamsnejati et al. 2015). The defatted cake is the seed waste remaining after oil extraction, which can be utilized as fertilizer and animal feed ingredients (Ganatra et al. 2012). It is also cost-effective and commonly employed in water treatment and purification (Marquetotti et al. 2010, Beltran et al. 2011, Pandey et al. 2011). Processed *Moringa oleifera* seed is a good example of these coagulants. *Moringa oleifera* seed has excellent antimicrobial qualities and decent coagulating capabilities and is also less expensive than artificial coagulants such as aluminum sulfate (Alo et al. 2012, Egbuikwem et al. 2013). *Moringa oleifera* powder can reduce high and low surface water turbidity levels (Bina et al. 2010). Various settling times for *Moringa oleifera* water treatment have been used, and a one-hour settling time has been advocated for softening hard water with *Moringa oleifera* seed powder (Thakur & Choubey 2014). By the literature review, for the past 30 years, researchers have reported many uses of *Moringa oleifera*, especially in developing countries. Muyibi & Evison (1995) use *Moringa oleifera* seed powder in treating low and high-turbid surface water. Hsu et al. (2006) used the powdery form of *Moringa oleifera*. Thakur & Choubey (2014) used the seeds of *Moringa oleifera* ground into powder to treat turbid water. Also, López-Ramírez et al. (2022) use *Moringa oleifera* seeds powder for treating urban wastewater. This research used the defatted seed of *Moringa oleifera* to treat turbid water due to its inexpensive and environmental benefits in wastewater treatment. The current study aims to purify low-turbid wastewater by using *Moringa oleifera* seed cake residue to replace existing chemical-based coagulants with natural coagulants.

MATERIALS AND METHODS

Description of the Study Area

The study area in the present work is an educational institution in the ancient city of Ilorin (University of Ilorin),

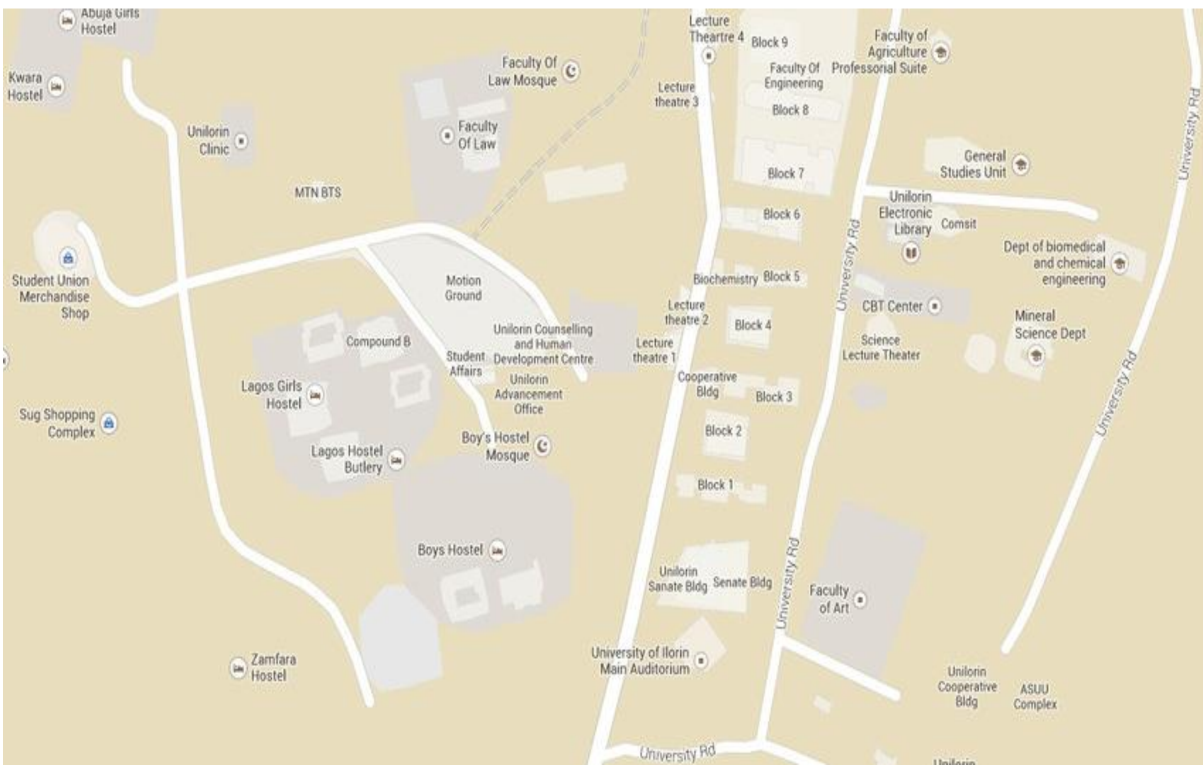

Fig. 1: University of Ilorin hostel map showing the study area.

with available bed spaces in the hostel on campus of about 5000 with the private hostels contributing about 2150-bed spaces for accommodation. Approximately 30 % of these students are residents on campus (Agava et al. 2018). The university has a land area of about 5000 hectares; the part covered by this work is approximately located between longitude 4°39′36″ E to 4°41′19″ E and latitude 8°27′54″ N to 8°28′09″ N (Alade et al. 2020). Fig. 1 shows the location of the study.

Sample Collection for Wastewater

Grab sampling was used to collect samples from the study area in a sterilized 25 L gallon container. The wastewater sample from the dormitory, including the toilet, was transported to the laboratory at 25°C and analyzed for physicochemical parameters such as pH, turbidity, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Bacteriological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) following the American Public Health Association's Standard (APHA 2008). Dried *Moringa oleifera* pods (2 kg) were obtained from the Kwara State Ministry of Agriculture, Ilorin, Nigeria (Fig. 2a). To maintain a steady seed weight, the shells were removed (Fig. 2b) and air-dried at 40°C for two days. The seeds were crushed into a powdery form (Fig. 2c) using an electric grinder (Eurosonic Model ES-242) and screened with a 0.5 mm mesh sieve size to obtain a dried cake.

Experimental Work

The coagulation properties of wastewater were tested using sedimentation jars in the laboratory. Coagulation was performed as described by Ndabigengesere et al. (1995). Control bottles were used, as well as bottles with various coagulant doses. Raw wastewater samples collected in jars from the dormitory were tested. In the 1-liter capacity container, the addition of the coagulant doses of 0, 50, 100, and 150 $mg.L^{-1}$ of the *Moringa oleifera* seeds cake was done. The doses were chosen based on the safety threshold of less than 200 $mg.L^{-1}$. The samples were subjected to a rapid mixing at 100 rpm for 5 minutes and a slow mixing step at 50 rpm for 10 min. The stirrer was switched off, and the floc was allowed to settle for 30 minutes. The evaluation was in triplicate. The ability of the *Moringa oleifera* as a coagulant was assessed by the physicochemical analysis of untreated and treated wastewater samples in terms of color, pH, turbidity, TDS, BOD, and COD. After treatment, the color and odor of the wastewater were observed. The pH of the untreated and treated wastewater was measured using an Inolab pH meter (Model: pH 7310), while turbidity was measured using a 2100 Q turbidity meter (HACH Instrument). A benchtop EC meter (EC 214) was used for conductivity measurement, while a TDS meter was used to measure total dissolved solids (TDS). $BOD_n = DF. OC - (DF - 1). OC_{DW}$, where DF= Dilution Factor ($V_{\text{diluted sample}} / V_{\text{sample before dilution}}$), OC = the difference in oxygen concentration ($mgO_2.L^{-1}$), OC_{DW} = oxygen consumption of the blank, and n = several days for organic biochemical degradation at 20°C. The COD analyses were performed using the dichromate open reflux method using the COD apparatus (5101 Instrument). Biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) were determined by conventional methods according to the Association of Official Analytical Chemists (AOAC 2002). The physicochemical parameters were calculated as % removal = $C_i - C_r / C_i \times 100$, where C_i and C_r are the initial and residual concentration of examined parameters, respectively. Fig. 3 shows the process involved in the use of *Moringa oleifera* in the treatment of wastewater.

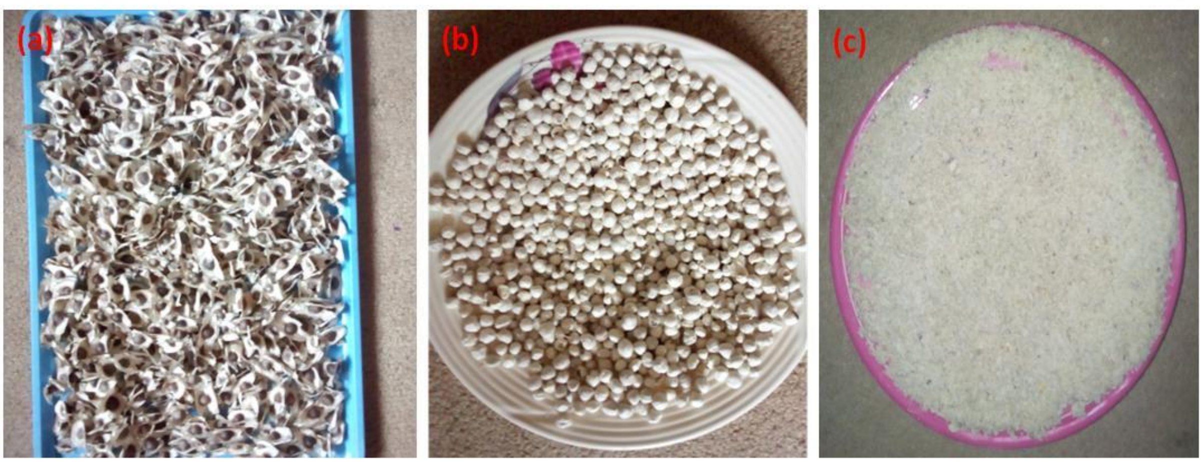

Fig. 2: (a) Matured *Moringa oleifera* pods (b) *Moringa oleifera* removed from the pod (c) *Moringa oleifera* cake.

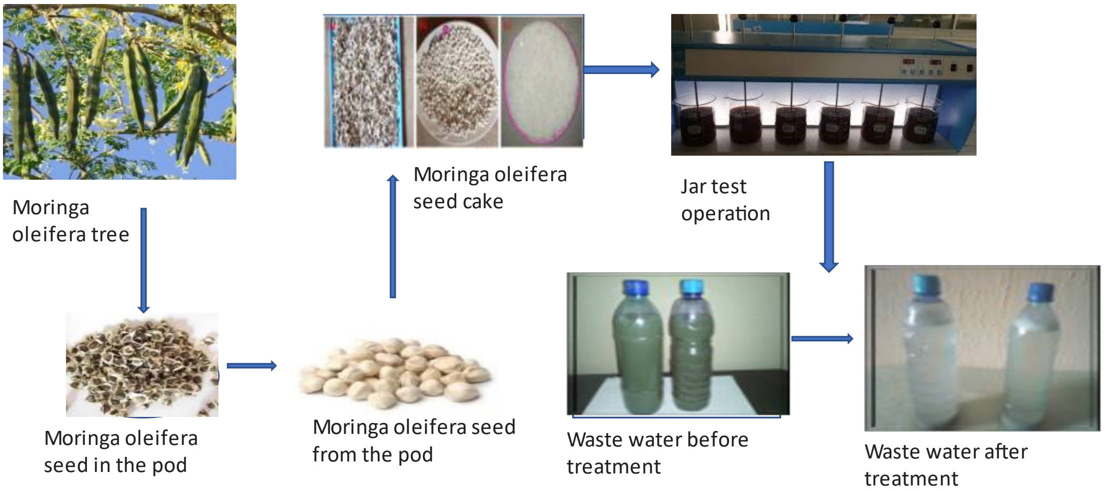

Fig. 3: The general overview of the procedure utilized.

Fig. 4: (a) Untreated wastewater sample (b) Treated wastewater

RESULTS AND DISCUSSION

Color and Odor of the Water Sample

The color of the untreated and treated wastewater is shown in Fig. 4a and 4b. Using *Moringa oleifera* seeds cake residue, the wastewater sample's dark greyish color was removed entirely. It can be observed that the more the *Moringa oleifera* seeds cake residue dosage in the wastewater, the cleaner the treated water sample was. According to Wilson and Andrews (2011), *Moringa oleifera* seeds reduced discoloration in effluent and improved clarity. Mangale et al. (2012) demonstrated that *Moringa oleifera* seeds could absorb liquids. *Moringa oleifera* seeds have been reported to contain between 37 and 27 percent protein. This property is attributed to cellulose bonded to lignin in proteins, fatty acids, and carbohydrates (Ndibewu et al. 2011). As a coagulant, *Moringa oleifera* seed powder binds contaminants and improves the color purity of wastewater (Madrona et al. 2012).

The pH of the Wastewater Sample

Fig. 5 compares the pH of wastewater with different coagulant dosages and several benchmarks. With an increased dose, wastewater treated with *Moringa oleifera* seed cake residues has a higher pH. SON (2007) suggested a pH limit of 6.5 to 8.5 for surface water. The pH range of the wastewater (6.73 - 7.56) in this study was within the WHO (2006), and the National Environmental Standards and Regulations Enforcement Agency (2009) suggested an acceptable effluent limit. However, Ubuoh et al. (2013) reported no difference in pH values before and after treatments at different mixture ratios when the leaves of *Moringa oleifera* were used. According to Garcia-Fayos et al. (2010), the result observed could be attributed to the existence of a small amount of oil content remaining after extraction, as well as the release of CO_2 during aerobic degradation of organic matter, which could produce a slight increase in pH value (Hagman & Lansen 2007). The results, however, are consistent with Arnoldsson et al. (2008), Amagloh & Benang (2009), Suhartini et al. (2013), and Eman et al. (2014), who found a modest change in the pH of treated water after adding *Moringa oleifera* seed. According to Suhartini et al. (2013), natural coagulant does not require pH modification, and there is no need to modify the pH value of wastewater following treatment.

Turbidity of the Wastewater

The turbidity of the wastewater was 76.75 NTU, which is higher than the 5 NTU recommended for effluent limitation standards by the Nigerian Standards Organization and National Environmental Standards and Regulations Enforcement Agency and the World Health Organization (NESREA 2009, SON 2007, WHO 2006). Wastewater having a turbidity of more than 5 NTU is deemed detrimental to the environment and should not be let into receiving water bodies or utilized for irrigation. The WHO and NESREA standards and SON requirements of 5 NTU for residual

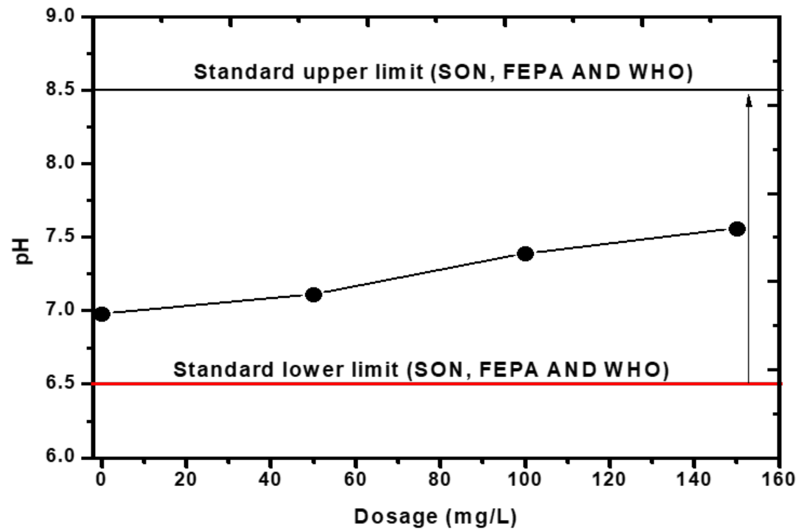

Fig. 5: The effect of coagulant dosage on the pH of the wastewater compared with some standards.

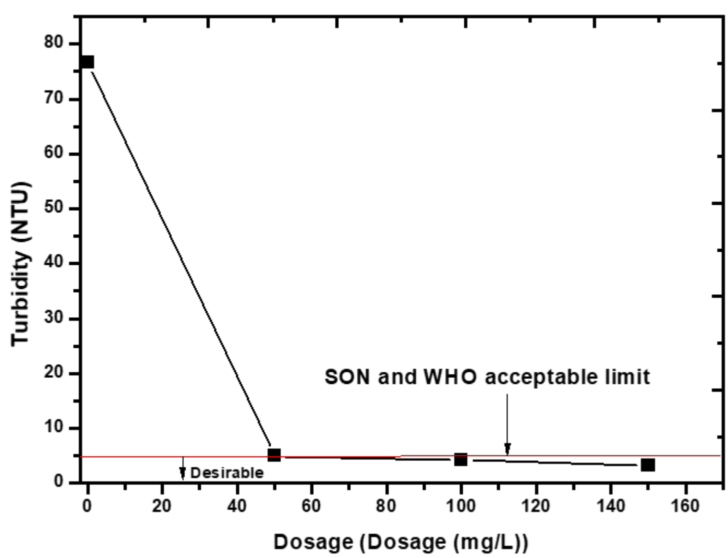

Fig. 6: The effect of coagulant dosage on the turbidity of the wastewater compared with some standards.

turbidity were substantially exceeded (WHO 2006, NESREA 2009, SON 2007). The lower the turbidity of the wastewater, the higher the dosage of *Moringa oleifera* seed cake residue, implying better coagulation characteristics (Jadhav & Mahajan 2014). As indicated in Fig. 6, *Moringa oleifera* seed cake residue successfully eliminated 93 percent to 96 percent turbidity from wastewater. According to Muyibi & Evison (1995) and Katayon et al. (2006), *Moringa oleifera* is ineffective in treating low turbid water, but the current investigation proves otherwise. This could be because the oil from the *Moringa oleifera* seed was removed, and the *Moringa oleifera* seed cake was used instead of the powdered form in this study. Nwaiwu & Bello (2011) also found that by employing *Moringa oleifera* seed powder and a 24-h settling time, excellent efficiency (up to 96.3 percent) may be achieved while treating low turbid wastewater.

Conductivity and Total Dissolved Solids (TDS)

Fig. 7 compares the effect of coagulant dosage on wastewater conductivity to specific industry norms. Before treatment, the effluent had a conductivity of 401.07 mS/cm. After treatment, the conductivity value was found to have increased to 1000 mS/cm. This could be due to dissolved ions in the water, which allows it to conduct electricity, which is essential for living organisms. It can indicate other water quality issues due to its ease of measurement. As demonstrated in Fig. 8, the initial TDS (630 $mg.L^{-1}$) was over WHO-acceptable limits. After treatment with *Moringa oleifera* seed cake residue, the total dissolved solids were reduced. The residual total dissolved solids range between 225 and 309 $mg.L^{-1}$, which are still below safe limits (NESREA 2009, SON 2007, WHO 2006). This is well-supported by Chonde & Raut (2017), as TDS decreases with increased dosage concentration.

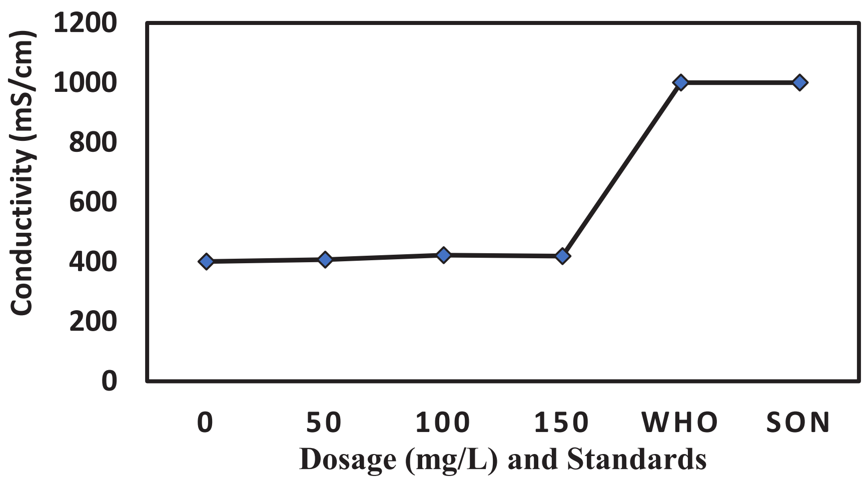

Fig. 7: The effect of coagulant dosage on the conductivity of the wastewater compared with some standards.

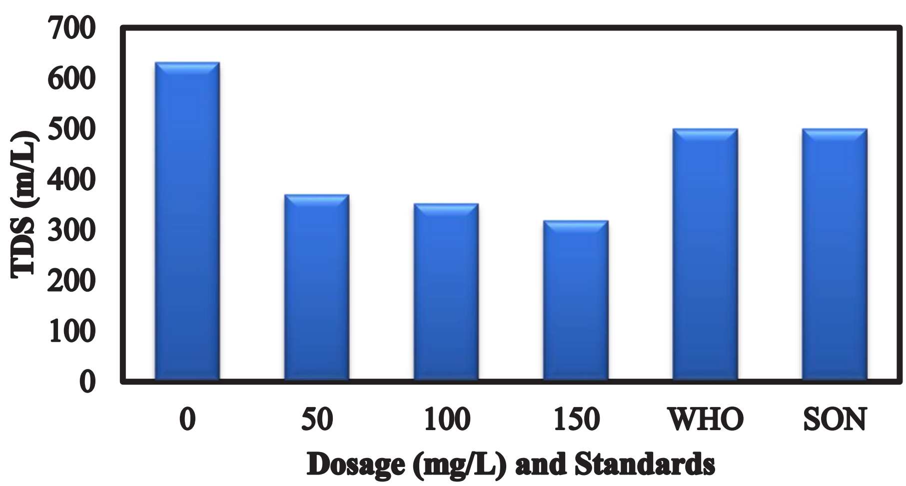

Fig. 8: The TDS of the wastewater compared with some standards.

Moringa oleifera has a natural cationic polyelectrolyte and flocculant chemical composition comprising essential polypeptides with molecular weights ranging between 6000 and 1600 dalton and six amino acids, the majority of which are glutamic acid, arginine, and methionine (Muyibi & Evison 1995).

Chemical Oxygen Demand, Biochemical Oxygen Demand, and Dissolved Oxygen

After directly applying *Moringa oleifera* seeds cake residue into wastewater, the initial chemical oxygen demand (COD) decreased. The COD was reduced by 92 percent when the *Moringa oleifera* seeds cake residue dosage was 150 $mg.L^{-1}$. The reduction was wide-ranging from 953.45 mg/l before treatment to 79.5 mg/l after treatment with 150 $mg.L^{-1}$ *Moringa oleifera* seeds cake residue. This implies that *Moringa oleifera* is a suitable coagulant for COD reduction because it reduces solids, organics, and nutrients, especially when de-oiled. *Moringa oleifera*, according to Suhartini et al. (2013) and Patel & Vashi (2013), lowered the chemical oxygen demand (COD) of wastewater. Fig. 9 demonstrates that as the dosage of *Moringa oleifera* was increased, the BOD values decreased. Studies have demonstrated that dumping wastewater with high BOD levels into a stream or river accelerates bacterial growth and depletes oxygen levels in the river (Kumar & Chopra 2012). Folhard & Sutherland (2001) and Suhartini et al. (2013) found a similar pattern in the reduction of BOD after varied therapy doses. This is also in line with the findings of Adeniran et al. (2017), who found that a greater concentration of *Moringa oleifera* is needed to eliminate BOD. However, this finding contrasted with that of Eman et al. (2014), who found that BOD increased as *Moringa oleifera* seed dose was raised following treatment, probably due to the presence of natural and organic compounds in *Moringa oleifera* seed cake as reported by (Tan et al. 2017). BOD value decreased with an increase in the *Moringa oleifera* seed cake residue dose from 550-50 $mg.L^{-1}$. This could result from the use of *Moringa oleifera* alone without the mixture of Alum and the solvent used to extract the oil from *Moringa oleifera* seeds. The dissolved oxygen (DO) value significantly increased after the treatment (1.98 to 7.39 $mg.L^{-1}$), as shown in Fig. 9. The DO obtained for the 150 $mg.L^{-1}$ doses was better than 50 and 100 $mg.L^{-1}$. This implied that a higher *Moringa oleifera* seed cake residue dosage resulted in better coagulation properties. An increase in DO can lead to aerobic conditions, which pose no danger to higher aquatic life forms. Eman et al. (2014) reported a similar finding of DO in wastewater of 5- 7 $mg.L^{-1}$. Besides this, the *Moringa oleifera* seed cake residue dosage is directly proportional to the DO value. Hence, using *Moringa oleifera* seed cake residue to improve the DO value is strongly recommended. The improvement of DO in the water sample after treatment is traceable to extracted oil from *Moringa oleifera* seeds.

CONCLUSION

The coagulation potentials of *Moringa oleifera* in wastewater treatment were evaluated in this study. *Moringa oleifera*

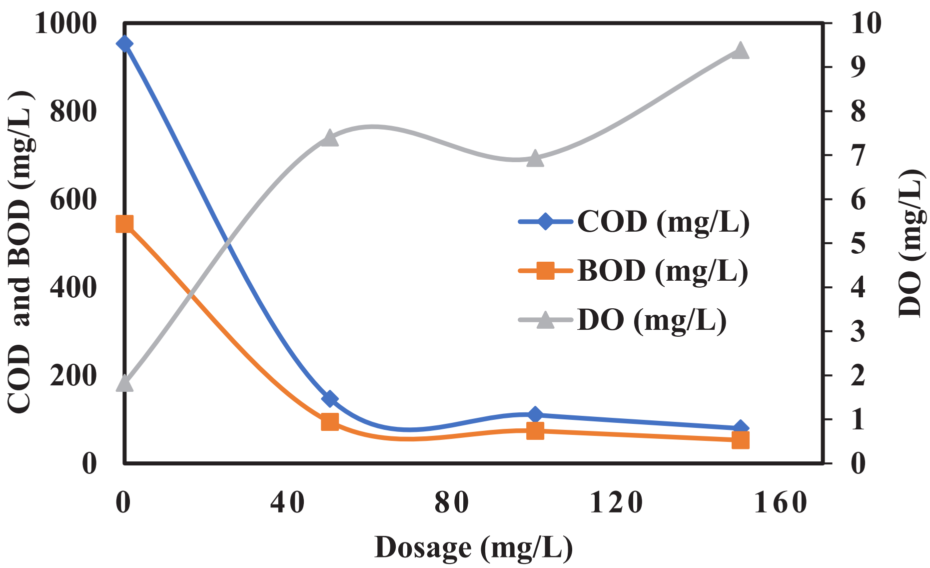

Fig. 9: The variations in chemical oxygen demand, biochemical oxygen demand, and dissolved oxygen with the dosage of *Moringa oleifera* cake residue

seeds cake residue successfully removed turbidity up to 96% after treatment. The turbidity of the wastewater sample after treatment with all three doses from the *Moringa oleifera* seed cake residue reduced the turbidity of the water sample below the acceptable limit. Treated wastewater became aesthetically cleared and odorless. *Moringa oleifera* cake is easy to use as an alternative to conventional treatment. The wastewater treated can be used for other activities within the dormitory and the institution. The results obtained from this work compare favorably well with WHO, SON, and NESREA standards.

ACKNOWLEDGEMENT

The authors would like to acknowledge Engineer Ezekiel Ariyo and Mrs. Umu Zeinat of the State Ministry of Agriculture for supplying *Moringa oleifera* seeds. Department of Chemistry Laboratory Technology, University of Ilorin, Ilorin, Nigeria support in water quality assessment is also acknowledged for this study.

REFERENCES

Adeniran, K.A., Akpenpuun, T.D., Akinyemi, B.A. and Wasiu, R.A. 2017. Effectiveness of *Moringa oleifera* Seed as a Coagulant in domestic wastewater treatment. Afr. J. Sci. Technol. Innov. Dev., 16: 1-6.

Agava, Y.H., Bello, N.A., Abdulraheem, M.O. and Gombwer, N.W. 2018. Implications of mass off-campus student housing at the University of Ilorin, Nigeria. Ife Res. Publ. Geogr., 16(1): 75-86.

Alade, A.K., Abdulyekeen, A.O., Ahmadu, H.A., Yusuf, A. and Amoo, A.K. 2020. 3D Reconstruction of the University of Ilorin Campus using High-Resolution Satellite Imagery and Conventional Survey, FIG Working Week 2020. Smart Surveyors for Land and Water Management, Amsterdam, the Netherlands.

Alo, M.N., Anyim, C. and Elom, M. 2012. Coagulation and Antimicrobial Activities of *Moringa oleifera* Seed Storage at 3˚C Temperature in Turbid Water. Adv. Appl. Sci. Res., 3: 887-894.

Amagloh, F.K. and Benang, A. 2009. Effectiveness of *Moringa oleifera* Seed as Coagulant for Water Purification. African Journal of Agricultural Research 4: 119-123.

Antov, M., Sciban, M. and Prodanovic, J. 2012. Evaluation of the efficiency of natural coagulant obtained by ultrafiltration of common bean seed extract in water turbidity removal. Ecol. Eng., 49: 48-52.

AOAC. 2002 Official Method of Analysis. Sixteenth Edition, Association of Official Analytical, Washington DC.

APHA. 2008. Standard Methods for the Examination of Water and Wastewater. Twentieth edition. American Public Health and American Water Works Association and Water Environment Association.

Arnoldsson, E., Bergman, M., Matsinhe, N. and Persson, M.K. 2008. Assessment of drinking water treatment by using *Moringa oleifera* natural coagulant. Vattern, 64: 137-150.

Aswathy, V G., Arun, O S., Gobinath R., Arun, P. C., Vijayakumar, S., Shanmugam, T. and Nagaraj, C. 2013. Studies on the Efficiency of Polyelectrolyte as Coagulant Aid. Universal J. Environ. Res. Technol., 3(4): 458-464.

Ayotunde, E.O., Fagbenro, O.A. and Adebayo O.T. 2011. Toxicity of aqueous extract of *Moringa oleifera* seed powder to Nile tilapia Oreochromis niloticus (LINNE I779) fingerlings. Int. Res. J. Agric. Sci. Soil Sci., 1(4): 142-150.

Beltran-Heredia, J., Sanchez-Martin, J. and Barrado-Moreno, M. 2011. Removal of anionic surfactants in aqueous solutions with *Moringa oleifera* seed extract coagulant. Sustainability, 5: 1 -20.

Betatache, H., Aouabed, A., Drouiche, N. and Lounici, H. 2014. Conditioning of sewage sludge by prickly pear cactus (Opuntia ficus Indica) Juice. Ecol. Eng., 70: 465-469.

Bina, M.H. Mehdinejad, G., Dalhammer, G., Rajarao, M., Nikaee, H. and Movahedi, A. 2010. Effectiveness of *Moringa oleifera* coagulant protein as a natural coagulant aid in the removal of turbidity and bacteria from turbid waters. World Acad. Sci. Eng. Technol., 67: 617-620.

Chonde, S. and Raut, P.D. 2017. Treatment of dairy wastewater by *Moringa oleifera* seeds. World J. Pharm. Res., 6(8): 1484-1493.

Doerr, B. 2005. Moringa Water Treatment: An ECHO technical note, ECHO, USA.

Egbuikwem, P.N. and Sangodoyin, A.Y. 203. Coagulation Efficacy of *Moringa oleifera* Seed Extract Compared to Alum for Removal of Turbidity and E. coli in Three Different Water Sources. Europ. Int. J. Sci. Technol., 2: 13-20.

Eman, N.A., Tan, C.S. and Makky, E.A. 2014. Impact of *Moringa oleifera* cake residue application on wastewater treatment: A case study. J. Water Resour. Prot., 6: 677-687.

Folhard, G. and Sutherland, T. 2001. The Use of *Moringa oleifera* Seed as a natural coagulant for water and wastewater treatment. Department of Engineering, University of Leicester, The UK.

Ganatra, T.H., Joshi, U.H., Bhalodia, P.N., Desai, T.R. and Tirgar, P.R. 2012. Review article therapeutic and prophylactic values of *Moringa oleifera*. Int. Res. J. Pharm., 3: 1-7.

Garcia–Fayos, B., Arnal, J.M., Verdu, G. and Sauri, A. 2010. Study of *Moringa oleifera* Oil extraction and its influence in primary coagulant activity for drinking water treatment. Int. Conf. Food. Innov., 16: 4561.

Hagman, M.F. and Lansen, J.C. 2007. Oxygen uptake rate measurements for application at wastewater treatment plants. Vatten, 63: 131-138.

Iheukwumere, S.O., Nwabudike, P.C., Nkwocha, K.F. and Phil-Eze, O.P. 2018. Domestic Wastewater Treatment and Reuse in Awka Urban, Anambra State, Nigeria. IIARD. Int. J. Geogr. Environ. Manag., 4(2): 16-24.

Jadhav, M.V. and Mahajan, Y.S. 2014. Assessment of the feasibility of natural coagulants in turbidity removal and modeling of the coagulation process. Desal. Water Treat., 52(31-33): 5812 -5821.

Kharake, A.C. and Raut, V.S. 2021. An assessment of water quality index of Godavari River water in Nashik city, Maharashtra. Appl. Water Sci., 11: 101.

Kumar, V. and Chopra, A. K. 2012. Monitoring of Physicochemical and Microbiological Characteristics of Municipal Wastewater at Treatment Plant, Haridwar City (Uttarakhand) India. J. Environ. Sci. Technol., 5(2): 109-118.

Lilliehöök, H. 2005. Use Of Sand Filtration On River Water Flocculated With *Moringa oleifera*, Division Of Sanitary Engineering, Department Of Civil And Environmental Engineering, Luleå University of Technology, Sweden.

López-Ramírez, M.A., Argüelles-López, C., Aguilar-Rodríguez, M.R., Barragán-Díaz, J., Castellanos-Onorio, O.P. and Lango-Reynoso, F. 2022. The effect of *Moringa oleifera* as a primary treatment in urban wastewater in Martínez De La Torre, Veracruz. Nature Environment & Pollution Technology, 21(1): 241-246.

Madrona, G.S., Branco, I.G., Seolin, V.J., Bdaa, F., Fagundes-Klen, M.R. and Bergamasco, R. 2012. Valuation of extracts of *Moringa oleifera* Lam Seeds obtained with NaCl and their effects on water treatment. Acta Sci.Technol., 34: 289-293.

Mangale S.M., Chonde S.G., Jadhav A.S. and Raut, P.D. 2012. Study of Moringa oleifer (Drumstick) Seed as Natural Absorbent and Antimicrobial Agent for River Water Treatment. J. Nat. Prod. Plant Resour., 2: 89-100.

Marquetotti, A., Vieira, S., Vieira, M.F., Silva, G.F., Araujo, A.A., Fagundes-Klen, M.R. and Veit, M.T. 2010. Use of *Moringa oleifera* Seed as a Natural Adsorbent for Wastewater Treatment. Water Air Soil Pollution 206: 273-281.

Mataka, L.M., Henry, E.M.T., Masamba, W.R.L and Sajidu S.M. 2006. Lead remediation of contaminated water using *Moringa stenopetala* and *Moringa oleifera* seed powder. Int. J. Environ. Sci. Tech., 3(2): 131-139.

Muyibi, S.A. and Evison, L.M. 1995. *Moringa oleifera* seeds for softening hard water. Water Resources, 29(4):1099-1105.

Ndabigengesere, A., Narasiah, K.S. and Talbot, B.G. 1995. Active agents and mechanism of coagulant of turbid waters using *Moringa oleifera*. Water Res., 29(2): 703-710.

Ndibewu, P.P., Mnisi, R.L., Mokgalaka, S.N. and Mccrindle, R.I. 2011. Heavy metal removal in aqueous systems using *Moringa oleifera*: A review. J. Mater. Sci. Eng., 1: 843-853.

NESREA 2009. National Environmental Standards and Regulations Enforcement Agency. Effluents Limitations Standards for Food, Beverages and Tobacco Sector Regulations, 96(65): B1211-1248.

Nwaiwu, N.E. and Bello, A.A. 2011. Effect of *Moringa oleifera*- alum ratios on surface water treatment in North-East Nigeria. Res. J. Appl. Sci. Eng. Technol., 3(6): 505-512.

Pandey, A., Pradheep, K., Gupta, R., Nayar, E.R. and Bhandari, D. 2011. Drumstick tree (*Moringa oleifera* Lam): A potential multipurpose species in India. Gene. Resour. Crop Evol., 58: 453- 460.

Pardede, A., Budihardjo, M.A. and Purwono, S. 2018. The removal of turbidity and TSS of the domestic wastewater by coagulation: Flocculation process involving oyster mushroom as bio coagulant. E3S Web Conf., 31: 05007-05011.

Patel, H. and Vashi, R.T. 2013. Comparison of naturally prepared coagulants for removal of COD and colour from textile wastewater global. NEST J., 15(4): 522-528.

Shamsnejati, S., Chaibakhsh, N., Pendashteh, A.R. and Hayeripour, S. 2015. Mucilaginous Seed of Ocimum basilicum as a natural coagulant for textile wastewater treatment. Ind. Crop. Prod., 69: 40-47.

SON 2007. Standards Organisation of Nigeria. Nigeria Standards for Drinking Water Quality: Nigerian Industrial Standard (NIS 554): 15-20.

Subramanium, S., Vikashini, N., Matakite, M. and Kanayathu, K. 2011. *Moringa oleifera* and other local seeds in water purification in developing countries. Res. J. Chem. Environ., 15: 135-138.

Suhartini, S., Hidayat, N. and Rosaliana, E. 2013. Influence of powdered *Moringa oleifera* seeds and natural filter media on the characteristics of tapioca starch wastewater. Int. J. Recycl. Org. Waste Agric., 2: 1-11.

Tan, C.S., Manaf, A.M., Essam, A.M. and Eman, N.A. 2017. The use of *Moringa oleifera* seed as a natural coagulant for wastewater treatment and heavy metals removal. Appl. Water Sci., 7: 1369 -1376.

Tat, W.K., Idris, A., Noor, M.J.M.M., Mohamed, T.A., Ghazali, A.H. and Muyibi, S.A. 2010. Optimization Study on Sewage Sludge Conditioning Using *Moringa oleifera* Seeds. Desal. Water Treat., 16: 402-410.

Ubuoh, E. A. Akhionbare, S. M. O. and Onifade A. O. 2013. Potential of *Moringa oleifera* seed powder as a coagulation agent for Refinery wastewater treatment in Warri, Delta State, Nigeria. Int. J. Adv. Biol. Res., 3(1): 17-20.

WHO. 2006. Guidelines for Drinking-Water Quality. Third Edition, World Health Organization, Geneva, Switzerland.

Wilson, S.A. and Andrews, S.A. 2011. Impact of a natural coagulant pretreatment for colour removal on solar water disinfection (SODIS). J. Wash. Dev., 1: 57-67.