Journal of Agriculture and Agricultural Technology
(JAAT)
Journal of Agriculture and Agricultural Technology 14 (2), 2025

MODELLING THE TURBIDITY REMOVAL EFFICIENCY OF *MORINGA OLEIFERA* AND *TAMARINDUS INDICA* IN HOSPITAL WASTEWATER

***ADESIJI, A. R.[1], ANJORIN, S. O. [1], SAIDU, M.[1], ADEOYE, P. A.[2], ODEKUNLE, M. O.[3] AND OLOTU, J.[1]**

1 Department of Civil Engineering Federal University of Technology, Minna

2 Department of Agriculture and Bio-Resources Engineering, Federal University of Technology, Minna

3 Department of Geography, Federal University of Technology, Minna

***Corresponding author email: ade.richard@futminna.edu.ng**

ABSTRACT

This study investigated the turbidity removal efficiency of Moringa oleifera and Tamarindus indica as natural coagulants in hospital wastewater. Batch experiments were conducted using different dosages of the seeds. The results showed that both coagulants significantly reduced turbidity, with Tamarindus indica achieving 63.87% removal at 1.25 g/L dosage and Moringa oleifera achieving 67.09% removal at the same dosage. A mathematical model was developed to predict turbidity removal efficiency, revealing a strong correlation between coagulant dosage and turbidity removal (R^2=0.981). Moringa oleifera demonstrated higher turbidity removal efficiency than Tamarindus indica. The study concludes that both natural coagulants are effective for hospital wastewater treatment, offering a sustainable alternative to conventional chemical coagulants. The developed model can be used to optimize coagulant dosage for efficient turbidity removal in hospital wastewater treatment plants. Both coagulants show promise for improving water quality and reducing environmental impact.

Keywords: *Moringa oleifera, Tamarindus indica*, *Turbidity Removal, Hospital Wastewater, Natural Coagulants, Statistical Modelling.*

INTRODUCTION

Water is essential for all life on Earth, as water is required for several domestic, commercial, and agricultural activities. Approximately 1400 million cubic kilometres of water exist on Earth, with freshwater bodies accounting for 2.5 % and marine waters accounting for 97.5 % (Koul *et al*., 2022). The community's water requirement has significantly increased due to the recent surge in urban population. Hence, there is significant demand for existing water resources. Water contamination can be caused by various non-anthropogenic reasons, such as hydrogeologic processes, variations in climate, natural disasters such as floods, droughts, earthquakes, and atmospheric deposition, which can occur fast or gradually.

Water is essential to hospital hygiene and operations. All over the world, water is necessary for the effective operation of hospitals and other healthcare facilities. Together with all other medical waste, hospital wastewater (HWW) can contaminate surface and groundwater and reach watersheds when handled and disposed of incorrectly in the hydrosphere, posing a major risk to public health and the environment (Biswal, 2013). According to Majumder *et al*. (2021), the hospitals' water use produces large volumes of wastewater. This is because hospital care is specialised, and the effluent from these facilities contains a wide range of pollutants. These include chemicals, metals, bacteria, disinfectants, and prescription drugs. Certain pollutants have the potential to be harmful or contagious, which means they can affect living organisms as well as the environment. The extreme susceptibility of hospital wastewater to the spread of various infections makes it a serious threat to human health security. Prichard and Granek (2016) illustrated that the risks to human health and the environment are associated with the types and quantities of chemicals discovered in hospital wastewater.

The application of traditional chemical coagulants in wastewater treatment continues to attract considerable attention due to their effectiveness in removing a broad spectrum of contaminants. However, increasing concerns have emerged regarding the potential long-term environmental and health impacts associated with their use, particularly due to the generation of non-biodegradable sludge as a residual by-product (Yin, 2010; Ahmad *et al*., 2016). These concerns have prompted a growing interest in the development and adoption of natural, biodegradable coagulants derived from plant-based or microbial sources, which offer a more sustainable and eco-friendlier alternative (Saranya and Sundar, 2020; Nandini *et al*., 2022).

Treating wastewater from industrial and agricultural activities often involves physicochemical and biological processes, including coagulation, flocculation, sedimentation, and microbial degradation (Rizzo *et al*., 2019). Agricultural wastewater, particularly from livestock operations, typically exhibits elevated levels of chemical oxygen demand (COD), biological oxygen demand (BOD), turbidity, and a complex mixture of organic and inorganic pollutants (Zhao *et al*., 2021). These characteristics necessitate efficient treatment strategies that are both cost-effective and environmentally benign.

Several comparative studies have been conducted to evaluate the performance of organic versus inorganic coagulants, with attention to optimising operational parameters such as pH, dosage, and mixing speed to maximise pollutant removal efficiencies (Kurniawan *et al*., 2020; Akinnawo *et al*., 2023a). Although chemical coagulation, electrocoagulation, and biological treatment methods demonstrate comparable pollutant removal capabilities, biological treatments tend to produce significantly lower sludge volumes. They are more effective in long-term ecological sustainability. Nonetheless, they generally require extended retention times to achieve desired removal efficiencies (Aboulhassan *et al*., 2014; Akinnawo *et al*., 2023b).

Turbidity removal from hospital wastewater prevents environmental pollution and protects public health. Natural coagulants offer a sustainable and eco-friendly solution. Hospital wastewater contains high levels of turbidity, caused by suspended particles, bacteria, and viruses. Conventional chemical coagulants have limitations, such as toxicity and residual sludge generation. Natural coagulants, derived from plants and biodegradable materials, provide an alternative. Various natural coagulants have been studied to remove the turbidity in the HWW. *Moringa oleifera* seeds have been used effectively to remove turbidity and heavy metals from HWW with reasonable outcomes. *Moringa oleifera* has historically been used to treat inflammation, cancer, heart disease, liver illness, wounds, and discomfort (Pareek *et al*., 2023). It is a member of the following groups: Order: *Capparales*; Family: *Moringaceae*; Genus: *Moringa*; Species: *oleifera*; Superdivision: *Spermatophyta*; Division: *Magnoliophyta*; Class: *Magnoliopsida*; Subclass: *Dilleniidae*; Order: Plantae (Mallenakuppe *et al*., 2019).

As a natural coagulant, Cactus has demonstrated remarkable potential as a bio-coagulant/flocculent in wastewater treatment and a role in environmental sustainability due to its abundance and non-toxicity to human health. This prompted Ayat *et al*. (2021), based on experimental design, to optimise the two operating factors: bio-coagulant dosage and initial pH. The response surface methodology (RSM) based on a central composite faced design (CCFD) was used to study the effect of these factors on turbidity and chemical oxygen demand (COD) reduction performance when treating sewage wastewater from plants through the coagulation/flocculation process. The impact of pH on supernatant turbidity removal and COD reduction was quite considerable, although coagulant dosage did not affect COD removal efficiency. The most effective reduction of turbidity and COD was achieved with a coagulant dosage of 28 mg/L and a pH of 12. Under these ideal conditions, turbidity and COD were removed with 98.33% and 96.55% efficiency, respectively.

This study aimed to model the performance *of Moringa oleifera* and *Tamarindus indica in* turbidity removal from hospital wastewater, considering the influence of key operating parameters. The specific objectives of the study were; to analyse the physicochemical characteristics of hospital wastewater, to investigate the coagulation and flocculation properties of *Moringa Oleifera* extract through laboratory experiments, assessing its efficacy in turbidity removal and identifying optimal dosage and treatment conditions, and to develop a statistical model or empirical equations to predict the turbidity removal efficiency of *Tamarindus indica* and *Moringa Oleifera* extracts.

METHODOLOGY

The study area for this research was the city of Minna, Niger state of Nigeria, located in the north-central region of the country. It is the state capital and the second largest city in Niger state, after Suleja. Minna is a major economic centre in the region, known for its agriculture, manufacturing, and commerce. The geographical coordinates of the study area are 9° 15'N and 6° 10'E

.

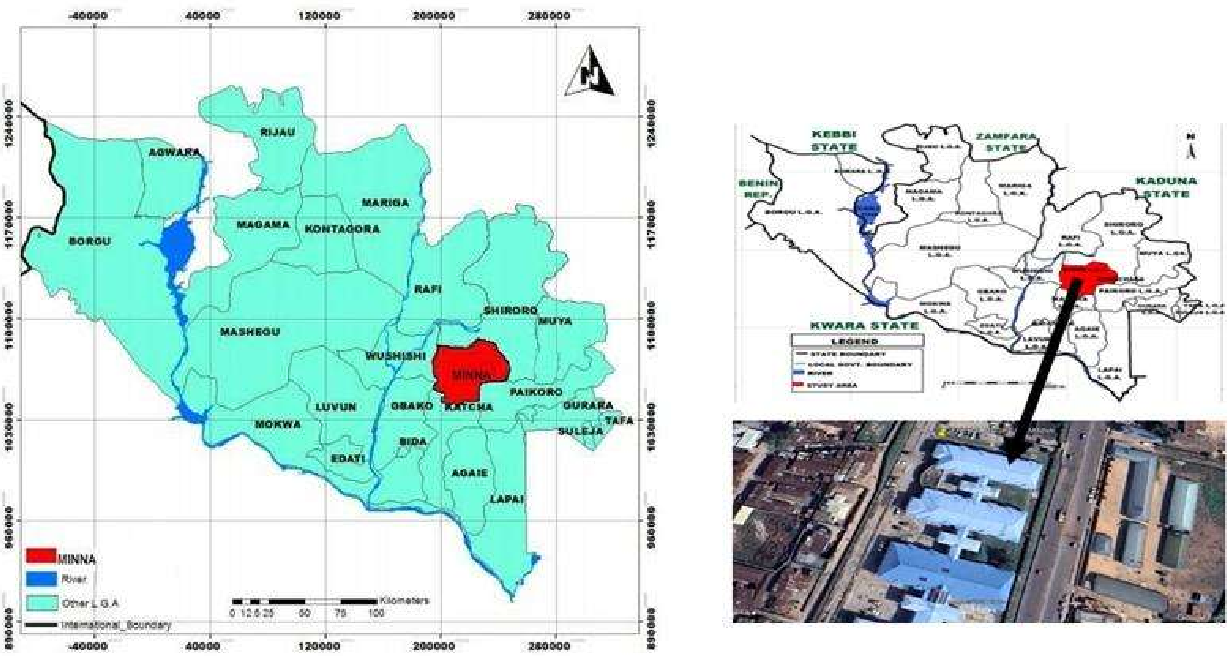

Figure 1: Map of Niger State Showing the Location of the study area

Wastewater Sampling and Characterisation

Hospital effluent was collected from a government-owned hospital. The wastewater generated from this hospital is expected to vary in quantity and loading concentrations. General Hospital, Minna, located at Latitude 9.611677 North and 6.543834 East, was used as a case study. In this hospital, the wastewater from each service was drained by PVC pipes and sent to a storage tank for easy sampling. Three wastewater sampling points, TH1, TH2, and TH3, were sampled at the visited hospital. This was done to ensure a detailed characterisation of the hospital wastewater for the study period.

Experimental Method and Materials Preparation

Moringa oleifera seeds used in this study were sourced and harvested in Minna. Mature *Moringa Oleifera* pods from dried, cracked fruit were selected. The seeds were extracted from the fruits by breaking them and air-dried for two days. The outer shells of the seed kernels were removed using a knife, and the kernels were then crushed in a mortar and pestle before being sieved through a 600 mm stainless steel sieve to create a fine powder. The fine powder was maintained in a refrigerator in a sterilised plastic rubber container. 2 g of residues were dispersed in 100 mL of NaCl 1 M solution, stirred for 30 min, then left to settle for 15 min; afterwards, the supernatant was filtered on Whatman1 filter paper.

Preparation of *Moringa oleifera* and *Tamarindus indica* coagulants

Tamarindus indica and *Moringa oleifera* seeds were sourced from Minna, Niger State, Nigeria. The seeds were processed for use as coagulants. *Tamarindus indica* seeds were soaked, washed, dried (5 days at 105 °C/30 min), crushed, and pulverised into 600-micron powder. *Moringa*

Oleifera seeds were extracted from dried pods, air-dried (2 days), shelled, ground, and sieved into 600 mm powder. The powders were stored in sterile containers (*Tamarindus indica*) and refrigerated (*Moringa oleifera*). For residue analysis, 2g of sample was dispersed in 100 mL NaCl solution, stirred (30 min), settled (15 min), and filtered through Whatman 1 paper. The processed powders were used for coagulation studies.

Stock solutions of *Moringa oleifera* and *Tamarindus indica* seed powders were prepared for coagulation studies. *Moringa oleifera* solutions were made by dissolving 500-1250 mg of powder in 250 ml of distilled water, yielding 2-5 mg/ml concentrations. *Tamarindus indica* solutions were prepared similarly, but in 0.5 M NaCl solution. The mixtures were formed into pastes, dissolved, and filtered through Whatman filter paper. Concentrations of 1 g/L (250 mg/250 ml) were achieved. Four concentrations (500, 750, 1000, 1250 mg/250 ml) were prepared for each seed powder. The filtered solutions were ready for coagulation activity testing.

TURBIDITY REMOVAL EFFICIENCY

Turbidity Removal Efficiency R (%) was calculated according to the following equation:

$$R(\%) = \frac{N_1 N_2}{N_1} * 100 \quad (1)$$

Where;

N_1 and N_2 represent the initial hospital wastewater turbidity (NTU) and residual turbidity after coagulation-flocculation (NTU), respectively.

Turbidity removal was carried out under four different conditions as previously mentioned. The first scenario is using only *Moringa oleifera* as a coagulant. The stock solution prepared for the purpose was added to the tested wastewater. This was after the initial turbidity must have been recorded. The turbidity level will also be recorded after the treatment. The turbidity removal efficiency (TRE) was obtained. This was followed by the second scenario, where *Tamarindus indica* seed stock solution was added to the wastewater and the turbidity level before and after treatment was recorded to calculate the TRE.

DATA ANALYSIS

Statistical Modelling

Residual Turbidity

To manipulate the results, statistical models were built using multiple regression analysis using the SPSS 20 package, which was adopted to perform the stepwise multiple regression analysis. The general multiple regression equation adapted was:

$$Y = a_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + e \quad (2)$$

Where;

Y = Dependent variable,

$a0$ = Intercept,

$b1$, $b2$, $b3$, $b4$ = Partial regression coefficients,

$X1$, $X2$, $X3$, $X4$ = Independent variables, and

e = Error term (residuals).

Notably, e must be normally and independently distributed with mean $\mu = 0$ and standard deviation $\sigma = 1$ (it is written as NID (0,1). In this study, the dependent variable is the residual turbidity ($N2$), which was predicted for the optimum dosage using *Moringa oleifera* seeds.

The investigation of the *Moringa oleifera* as a coagulant will lead to nine (9) models, each having three coagulants. The dependent variable for all the models was Y = $N2$, so the analysis was performed for modelling $N2$ (residual turbidity) for optimum dosage using *Moringa oleifera* seeds. The independent variables for the coagulants are:
$X1$ = pH,
$X2$ =$N1$ (Initial turbidity)
$X3$ = TEMP and
$X4$ = COD

When the data were subjected to correlation analyses, the choice of which independent variables to use was observed. The results of correlation analyses enabled the choice of which parameters to serve as independent variables. The same modelling was applied for *Tamarindus indica*, and the modelling followed the same patterns as *Moringa Oleifera*.

RESULTS AND DISCUSSION

The laboratory results of the raw water samples are presented in Table 1.
Laboratory Analyses of Hospital Wastewater

Table 1: Result for Raw Water Analysis

Parameter	Values	WHO	NSDQW
PHYSICAL PARAMETERS			
pH	8.26	6.5 – 8.5	6.5 – 8.5
Turbidity (NTU)	184	<5	5
Total Dissolved Solid (mg/L)	731	300	500
Temperature (°C)	25	NIL	Ambient
Electrical Conductivity (uS/cm)	1220	400	1000
CHEMICAL PARAMETERS			
Hexavalent Chromium (mg/L)	*BDL	0.05	0.05
Calcium (mg/L)	480	100-300	100
Magnesium (mg/L)	288	50	20
Total Hardness (mg/L)	2500	NIL	100
Chloride (mg/L)	799	250	250
Phosphates (mg/L)	12.3	1	10
Chemical Oxygen Demand (COD) (mg/L)	600	250-500	250-500
Iron (mg/L)	1.14	0.3	0.3

*BDL: Below Detection Limit

Table 2 presents laboratory analysis of hospital wastewater treated with *Tamarindus indica*. Initial turbidity was 184 NTU. After treatment with 1.25g *Tamarindus indica*, residual turbidity ranged from 56-87 NTU, significantly reducing. The table displays various parameters' initial and final values, demonstrating *Tamarindus indica*'s effectiveness in wastewater treatment.

Table 2: Physical Properties of Hospital Wastewater Treated with *Tamarindus indica*

S/N	pH.	N_1	TDS (mg/L)	Temp (°C)	COD (mg/L)	N_2
1	8.26	184	731	26	600	87
2	6.3	178	12747	28	400	73
3	6.3	169	11390	25	266	68
4	6.3	174	11710	27	351	72
5	6.1	162	11550	31	309	65
6	7.2	155	11390	29	310	56
7	7.3	165	11230	31	320	67
8	6.8	176	11070	25	289	72
9	6.8	183	10910	26	321	82
10	7.8	184	10750	27	276	83

N_1= Intial Turbidity
TDS= Total Dissolved Solids
COD= Chemical Oxygen Demand
N_2 = Residual Turbidity

Turbidity Removal Efficiency for *Tamarindus indica*

Turbidity Removal Efficiency R (%) was calculated for each sampling period from Day 1 to Day 10. Equation 1 was used in the removal efficiency calculation.

$$R(\%) = \frac{N_1 - N_2}{N_1} * 100$$

For trial 1, where initial turbidity, N_1 is 184 NTU and residual turbidity, N_2 is 87NTU, removal efficiency is calculated as;

$$R(\%) = \frac{184 - 87}{184} * 100 = 52.72\ \%$$

Table 3 presents laboratory analysis of hospital wastewater treated with *Moringa oleifera*. Initial turbidity was 184 NTU. After treatment with 1.25g *Moringa Oleifera*, residual turbidity removal efficiency ranged from 51-85 NTU, showing effective removal. The table displays various parameters' initial and final values, demonstrating *Moringa oleifera*'s efficacy in reducing wastewater turbidity.

Table 3: Physical Properties of Hospital Wastewater Treated with *Moringa oleifera*

S/N	pH.	N_1	TDS (mg/L)	Temp (°C)	COD (mg/L)	N_2
1	8.26	184	731	25	600	85
2	6.3	178	542	27	450	73
3	6.3	169	633	26	370	68
4	6.3	174	675	28	348	72
5	6.1	162	776	25	520	65
6	7.2	155	682	31	450	51
7	7.3	165	721	30	487	62
8	6.8	176	692	29	462	70
9	6.8	183	598	27	365	85
10	7.8	184	701	26	453	81

N_1= Intial Turbidity
TDS= Total Dissolved Solids
COD= Chemical Oxygen Demand
N_2 = Residual Turbidity

The results for the rest of the Days are as shown in Table 4
Table 4 shows that *Tamarindus indica* has good turbidity removal efficiency, which is far above average in all the samples. The removal efficiency from all 10 trials ranged from 52.7 % in trial 1 to 63.9 % in trial 6, which is found to be consistent with Reddy *et al*. (2024) and Bhattacharya & Khan (2023). This efficiency has been linked to polyphenols and tannins, which act as natural polyelectrolytes facilitating bridging flocculation (Adeniyi *et al*., 2024).

Turbidity Removal Efficiency for *Moringa Oleifera*
For *Moringa Oleifera* analysis, the initial turbidity, *N1*, was 184 NTU and the residual turbidity, *N2*, was 85 NTU; removal efficiency was calculated as

$$R(\%) = \frac{184 - 85}{184} * 100 = 53.80\ \%$$

Table 4: Turbidity Removal Efficiency for *Tamarindus indica*

Trial	Initial Turbidity (N_1)	Residual Turbidity (N_2)	Removal Efficiency (R%)

1	184	87	52.7174
2	178	73	58.9888
3	169	68	59.7633
4	174	72	58.6207
5	162	65	59.8765
6	155	56	63.871
7	165	67	59.3939
8	176	72	59.0909
9	183	82	55.1913
10	184	83	54.8913

Table 5 shows that *Moringa Oleifera* has good turbidity removal efficiency, which is far above the average in all the trials. The removal efficiency from all 10 trials ranged from 53.6 % in trial 9 to 67.1 % in trial 6. From the two treatments, *Moringa Oleifera* was adjudged to be more effective in treating HWW as it possesses higher removal efficiency (67.1 %) compared to *Tamarindus indica* (63.9 %). This has been attributed to its high content of cationic, dimeric proteins, which effectively neutralise negatively charged colloidal particles and promote flocculation (Getachew & Cherie, 2024; Adejumo *et al*., 2024).

Table 5: Turbidity Removal Efficiency for *Moringa Oleifera*

S/N	Initial Turbidity (N_1)	Residual Turbidity (N_2)	Removal Efficiency (R%)
1	184	85	53.8043
2	178	70	60.6742
3	169	68	59.7633
4	174	72	58.6207
5	162	65	59.8765
6	155	51	67.0968
7	165	62	62.4242
8	176	70	60.2273
9	183	85	53.5519
10	184	81	55.9783

Correlation Analyses Among the Parameters for *Tamarindus indica* Treatment

From the correlation analyses results in Table 6, the residual turbidity, $N2$, was observed to be very strongly correlated with initial turbidity, $N1$, moderately correlated with pH (0.492), and having a negative but strong correlation with temperature (-0.525). A positive correlation was also observed between *N2* and COD (0.502). This shows that all these parameters could accurately predict N2.

Table 6: **Correlation Analyses Among the Parameters for *Tamarindus indica* Treatment**

	pH	N_1	***TDS***	***Temp***	***COD***	N_2
pH	1					
N_1	0.348456	1				
TDS	-0.72372	-0.40012	1			
Temp	-0.10709	-0.62891	0.267781	1		
COD	0.493594	0.393099	-0.85621	-0.11045	1	
N_2	0.492004	0.961616	-0.57304	-0.52518	0.502045	1

Modelling Residual Turbidity (*N*2) in HWW *Tamarindus indica* treatment

The modelling of residual turbidity is now easy to analyse since the parameters that influence it have been observed. Applying the data from the multiple regression model represented by equation 5, using SPSS version 20, the appropriate stepwise multiple regression model for *Tamarindus indica* residual turbidity, *N2* treatment was

:

$$N_2 = 0.881\, N_1 + 1.79\, \text{pH} + 0.38\, \text{Temp} - 105.06 \qquad (3)$$

This means that the independent variable of COD was statistically insignificant based on the outcome of the statistics. The regression was highly negligible, though the obtained *R2* value of 0.981 indicates that the regression contribution ratio was very acceptable (Pallant 2005). In other words, equation 3 precisely predicts the residual turbidity of HWW treated with *Tamarindus indica*

Correlation Analyses Among the Parameters for *Moringa Oleifera* Treatment

From Table 7, the residual turbidity, *N2*, was observed to be very strongly correlated with Initial turbidity, *N1* (0.96), slightly correlated with pH (0.318) and having a negative, but strong correlation with temperature (-0.665). No correlation was observed between the N2 and COD (0.042) and TDS (-0.206). This shows that N1, Temperature and pH are the only parameters that could predict the N2 accurately with *moringa oleifera* treatment. The linear regression used these correlated parameters to model residual turbidity estimation.

Table 7: **Correlation Analysis Among the Parameters for *Moringa oleifera* Treatment**

	pH	N_1	*TDS*	*Temp*	*COD*	N_2
pH	1					
N_1	0.548456	1				
TDS	-0.72372	-0.40012	1			
Temp	-0.10709	-0.62891	0.267781	1		
COD	0.343594	0.393099	-0.45621	-0.23045	1	
N_2	0.318004	0.961616	-0.20604	-0.66502	0.042045	1

Modelling Residual Turbidity (*N*2) in HWW *Moringa oleifera* treatment

The appropriate parameters and correlation analysis influenced the modelling of residual turbidity for *Moringa oleifera* treatment of HWW. Applying the data from the multiple regression model represented by equation 5, using SPSS version 20, the proper stepwise multiple regression model for *Tamarindus indica* residual turbidity, *N2* treatment was

:

$$N_2 = 0.878\ N_1 + 0.481\ \text{pH} - 1.238\ \text{Temp} - 50.18 \quad (4)$$

This means that the independent variables, COD and TDS, were statistically insignificant based on the statistical outcome. The regression was highly insignificant, though the obtained *R2* value, 0.980, indicates that the regression contribution ratio was very acceptable according to Pallant (2005). In other words, equation 4 can precisely predict the residual turbidity of HWW being treated with *Moringa oleifera*.

CONCLUSION

The study results concluded that *Moringa oleifera* and *Tamarindus indica* treated the hospital wastewater efficiently, which means they have good and similar coagulation/flocculation properties. They were both competent for turbidity removal. This indicates the possibility of using these coagulants in large-scale field applications, as evident in their coagulating tendencies. It was also concluded that, with the knowledge of the initial turbidity of the hospital wastewater, the residual turbidity using these coagulants could be estimated with good precision. Another fact from this study was that the most statistically significant parameters in the flocculation process were the initial turbidity, pH, and temperature, as shown by equations (3) and (4).

ACKNOWLEDGEMENTS

Deepest gratitude must be given to the Tertiary Education Trustfund (TETFund), which sponsored this research work through Institution-Based Research (IBRI) 2023 under the grant number **TETFUND/FUTMINNA/2024/023** and the Civil Engineering Department of Federal University of Technology, where the laboratory analyses were carried out

REFERENCES

Aboulhassan, M.A., Souabi, S., and Yaacoubi, A. (2014). Coagulation–flocculation process for dye removal using coagulants mixture. *Journal of Hazardous Materials, 168*(2–3), 1035–1039.

Adejumo, I.A., Ojo, E.O., and Yusuf, T.T. (2024). Evaluation of Moringa oleifera seed extract for coagulation-flocculation treatment of domestic wastewater. *African Applied Research Journal*, 10(1), 45–54.

Adeniyi, O.A., Okonkwo, J.O., and Ojo, O.T. (2024). Performance evaluation of Tamarindus indica seed extract as a natural coagulant for surface water treatment. *International Journal of Research and Analytical Reviews*, 11(2), 112–120.

Ahmad, A.L., Sumathi, S., and Hameed, B.H. (2016). Coagulation of residue oil and suspended solid in palm oil mill effluent by chitosan, alum and PAC. *Chemical Engineering Journal, 118*(1–2), 99–105.

Akinnawo, O., Adewuyi, G.O., and Alabi, A. B. (2023a). Comparative analysis of chemical, electrochemical, and biological methods for industrial wastewater treatment. *Journal of Environmental Management, 326*, 116588.

Akinnawo, S., Ayadi, P.O., and Oluwalope, M.T. (2023b). Chemical coagulation and biological techniques for wastewater treatment. *Ovidius University Annals of Chemistry*, 34(1), 14-21.

Ayat, A., Arris, S., Abbaz, A., Bencheikh-Lehocine, M., and Meniai, A.H. (2021). Application of response surface methodology for modeling and optimization of a bio-coagulation process (sewage wastewater treatment plant). *Environmental Management*, 67(3), 489-497.

Bhattacharya, S., and Khan, N. (2023). Comparative analysis of plant-based natural coagulants for wastewater treatment. *Current World Environment*, 20(1), 45–54.

Biswal, S. (2013). Liquid biomedical waste management: An emerging concern for physicians. Muller Journal of Medical Sciences and Researchwll be, 4, 99.

Getachew, T., and Cherie, M. (2024). Moringa oleifera seed extract for water treatment: Optimization and antimicrobial efficacy. *Environmental Science and Pollution Research*, 31, 17125–17136.

Koul, B., Bhat, N., Abubakar, M., Mishra, M., Arukha, A.P., and Yadav, D. (2022). Application of natural coagulants in water treatment: a sustainable alternative to chemicals. *Water*, *14*(22), 3751.

Kurniawan, T.A., Chan, G.Y.S., Lo, W.H., and Babel, S. (2020). Comparison of alum and Moringa oleifera seeds as coagulants for water treatment. *Environmental Technology and Innovation, 17*, 100576.

Nandini, R., Kumar, R., and Mehta, R. (2022). Sustainable wastewater treatment using bio-coagulants derived from plant and microbial sources: A review. *Journal of Environmental Chemical Engineering, 10*(1), 106884.

Majumder, A., Gupta, A.K., Ghosal, P.S., & Varma, M. (2021). A review on hospital wastewater treatment: A special emphasis on occurrence and removal of pharmaceutically active compounds, resistant microorganisms, and SARS-CoV-2. *Journal of environmental chemical engineering*, *9*(2), 104812.

Mallenakuppe, R., Homabalegowda, H., Gouri, M.D., Basavaraju, P.S., and Chandrashekharaiah, U.B. (2019). History, taxonomy, and propagation of Moringa oleifera - A review. *International Journal of Life Sciences*, 5, 2322–2327.

Pallant, J (2005). SPSS survival manual, McGraw-Hill Inc., Sydney.

Pareek, A., Pant, M., Gupta, M.M., Kashani, P., Ratan, Y., Jain, V., Pareek, A., and Chuturgoon, A.A. (2023). Moringa oleifera: An updated comprehensive review of its pharmacological activities, ethnomedicinal, phytopharmaceutical formulation, clinical, phytochemical, and toxicological aspects. *International Journal of Molecular Sciences*, 24(3), 2098.

Prichard, E. and Granek, E.F. (2016) Effects of Pharmaceuticals and Personal Care Products on Marine Organisms: From Single-Species Studies to an Ecosystem-Based *Approach. Environmental Science and Pollution Research*, 23, 22365-22384.

Reddy, S. R., Raju, V., & Kumar, A. (2024). Treatment of hospital wastewater using Tamarindus indica as a natural coagulant: Performance evaluation and mechanism analysis. *Journal of Environmental Chemical Engineering*, 12(3), 110847.

Rizzo, L., Manaia, C., Merlin, C., Schwartz, T., Dagot, C., Ploy, M.C., and Fatta-Kassinos, D. (2019). Urban wastewater treatment plants as hotspots for antibiotic resistant bacteria and genes spread into the environment: A review. *Science of the Total Environment,* 447: 345–360.

Saranya, V., and Sundar, S. (2020). A review on plant-based natural coagulants for water and wastewater treatment. *Environmental Nanotechnology, Monitoring and Management,* 14: 100333.

Yin, C.Y. (2010). Emerging usage of plant-based coagulants for water and wastewater treatment. *Process Biochemistry,* 45(9), 1437–1444.

Zhao, R., Su, H., Fang, Y., Wang, Y., and Chen, Y. (2021). Characteristics and treatment technologies of livestock and poultry wastewater: A review. *Science of the Total Environment,* 755: 142538.