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Comparative Study of Alum and Moringa Oleifera Seed Powder in Turbidity Removal from River Water and Synthetic Solution (Kaolin)

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Abstract

As the global demand for clean water rises, turbidity remains a significant issue in developing countries. Conventional coagulants like Alum can reduce turbidity but they also pose environmental and health risks. This study compares the effectiveness of Moringa Oleifera seed powder, which is a natural coagulant, with Alum for removing turbidity from river water and synthetic solution (kaolin). The Moringa Oleifera seeds were harvested and then dried at 40°C for two days, cracked, blended to approximately 100 microns, and sieved to 150 micron size before storing the powder. Alum solution was prepared by dissolving 3 grams in 100 mL of distilled water. Jar tests were conducted using both Moringa oleifera seed powder and Alum with synthetic kaolin suspension and Panchor river water. The experiments evaluated turbidity reduction at dosages of 200 mg/L for synthetic solution and 150 mg/L for river water, at neutral pH (7.52 and 7.38), and 120 minutes settling time. Fourier Transform Infrared Spectroscopy (FTIR) and Field Emission Scanning Electron Microscopy (FESEM) were also used to analyze the chemical structure and physical properties of Moringa Oleifera seed powder. The results showed that Moringa Oleifera achieved 94.2% turbidity reduction in synthetic kaolin solution and 93.95% in river water. Additionally, it produced minimal sludge compared to Alum. Based on these findings, Moringa Oleifera can be considered a low-cost and environmentally friendly coagulant that could provide a potential solution for regions with limited access to chemical coagulants.

1. Introduction

Water pollution represented one of the most critical global challenges, particularly affecting developing countries with limited access to safe drinking water. Approximately 1.1 billion people lacked access to clean and safe drinking water worldwide, with the majority residing in less developed nations [1]. Turbidity refers to the cloudiness or haziness of water caused by small particles such as clay, silt, organic matter, and plankton, which are usually not visible to the naked eye. It is a critical parameter in water treatment, indicating the effectiveness of filtration and the overall water quality. High turbidity levels signify increased concentrations of suspended particles, which can hinder water treatment processes like coagulation, filtration, and disinfection. Additionally, turbidity can lead to higher levels of nutrients and pathogens in water [2]. The increasing concern about environmental degradation and water-related health issues highlighted the urgent need for effective water treatment solutions to achieve Sustainable Development Goals focused on clean water and sanitation.

Conventional water treatment methods relied heavily on coagulation processes that used chemical coagulants to destabilize suspended particles and form larger clusters called flocs for easy removal. Alum (aluminum sulfate) served as the most widely used synthetic coagulant due to its effectiveness in turbidity reduction [3]. However, research revealed significant health concerns associated with aluminum exposure, including neurological disorders and potential links to Alzheimer's disease from residual aluminum remaining in treated water [3]. Additionally, alum-based treatment generated toxic sludge that posed environmental risks when discharged into water bodies.

Natural coagulants derived from plant sources emerged as promising alternatives to synthetic chemicals for water treatment applications. Moringa Oleifera, a tropical plant with natural coagulation properties, demonstrated effectiveness in reducing water turbidity and eliminating bacteria through proteins present in its seeds [4]. Unlike chemical coagulants, Moringa-based treatment produced biodegradable residues without harmful environmental impacts. Previous studies indicated that Moringa Oleifera achieved comparable or superior performance to conventional coagulants in removing turbidity and other contaminants from surface water [5]. However, questions remained regarding optimal operating conditions and comparative effectiveness under different water quality scenarios.

This research aimed to evaluate the effectiveness of Moringa Oleifera seed powder as a natural coagulant compared to alum for turbidity removal in river water and synthetic kaolin solutions. The study sought to determine optimal operating parameters including coagulant dosage, pH levels, and settling time through systematic jar test experiments. Additionally, the research investigated the physical and chemical properties of Moringa Oleifera using FTIR (Fourier Transform Infrared) spectroscopy and FESEM (Field Emission Scanning Electron Microscopy) to understand the coagulation mechanisms. The findings would provide essential data for implementing sustainable, cost-effective water treatment solutions, particularly in developing regions where chemical coagulants remained expensive and environmentally problematic.

2. Materials and Methods

2.1 Preparation of Moringa Oleifera Seed Powder

Matured Moringa oleifera fruits were purchased from a market in Nilai, Negeri Sembilan. Subsequently, the seeds were extracted by cracking the fruits and kept on the tray, then oven-dried at 40°C for two days. Once dried, the kernels were removed, ground into powder and sieved to below 150 microns. size to ensure that there are no pieces or clumps and that it is uniform. The final powder was stored in an airtight container for testing. Figure 1 below shows the Moringa Oleifera Seed Powder from the fruit, then the seeds before and after the drying process at 40°C for two days, together with the blending process

(a) **(b)** **(c)** **(d)**

Figure 1: Moringa Oleifera Seed Powder (a) Matured Moringa Oleifera Fruit (b) Seeds before drying (c) Seeds after drying process (d) Blending process

2.2 Preparation of Aluminum Sulfate

A 3% aluminum sulfate (alum) solution was prepared by dissolving 3 grams of alum in 100 mL of distilled water, sourced from the Water Treatment Lab at UTHM Pagoh. The solution was mixed thoroughly to ensure full dissolution. For the jar test, 5 mL, 10 mL, and 15 mL of the solution were measured using a measuring cylinder and pipette, then added to beakers containing either Panchor River water or kaolin solution to initiate coagulation. Four dosage combinations were used in each experiment series

2.3 Water Sampling in Panchor

Grab sampling was conducted at Panchor River (217.684'N, 10272.0530'E) using sterilised polyethylene bottles. Bottles were rinsed, filled with 10 L of water without surface contact, sealed, and stored at 4°C in a cooler to preserve sample integrity. Samples were labelled and transported to the UTHM Pagoh lab for pH, COD, BOD, and turbidity analysis, ensuring reliable data for further testing.

2.4 Characterization of Moringa Oleifera Seed Powder

Fourier Transform Infrared Spectroscopy (FTIR) and Field Emission Scanning Electron Microscopy (FESEM) were used to analyze the chemical composition and physical properties of Moringa Oleifera seed powder.

2.4.1Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was conducted to identify functional groups in Moringa oleifera seed powder. The powder was mixed with KBr, pressed into a pellet, and analyzed using a Cary 630 FTIR spectrometer (4000–400 cm^{-1} range). Functional groups such as hydroxyl (-OH), carbonyl (C=O), and ether (C-O) were identified, which are known to aid in coagulation and contaminant adsorption, consistent with previous studies. [6]

2.4.2 Field Emission Scanning Electron Microscopy (FESEM)

FESEM was used to examine the surface morphology and particle structure of the Moringa seed powder. The sample was gold-coated (~8 nm) using a sputter coater and scanned at magnifications from 100× to 50,000× using an FEI Quanta 250 FEG SEM. The analysis provided insights into particle size, texture, and surface uniformity, key factors in coagulant performance. [7]

2.5 Jar Test- Experimental Procedure

The jar test was conducted to determine the optimum dosage, settling time, and pH for Moringa Oleifera seed powder and Alum. The apparatus used for the coagulation process is shown in Figure 2. Initially, the pH and turbidity of the river water were recorded. A multiple stirrer held six beakers, each containing one liter of river water. The first beaker, which contained no coagulant, was used as the control setup. The setup was mixed thoroughly at 100 rpm for two minutes to ensure complete dispersion of the coagulant. Afterward, the device was reprogrammed to run at a slower speed (30 rpm) for 20 minutes to facilitate flocculation. The beakers were then set aside on a workbench for one hour to allow the flocs to settle. After settling, samples for turbidity and pH measurements were carefully collected from the top of each beaker. The turbidity of each sample was measured using a turbidity meter. The same procedure was repeated for the synthetic kaolin solution, with varying dosages and pH levels, to identify the optimum coagulation parameters, which include optimum dosage, settling time, and pH. Next, equation 1 was used to compute turbidity removal in this study, analyzing the effectiveness of Moringa Oleifera Seed Powder in river water and in a synthetic solution (kaolin).

$$\%\ \text{turbidity removal} = \frac{\text{initial turbidity} - \text{final turbidity}}{\textit{initial turbidity}} \times 100 \quad (1)$$

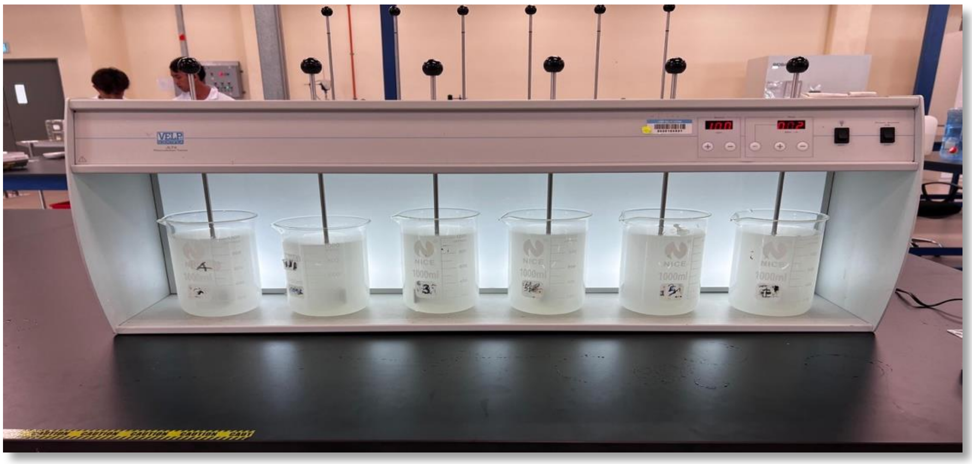
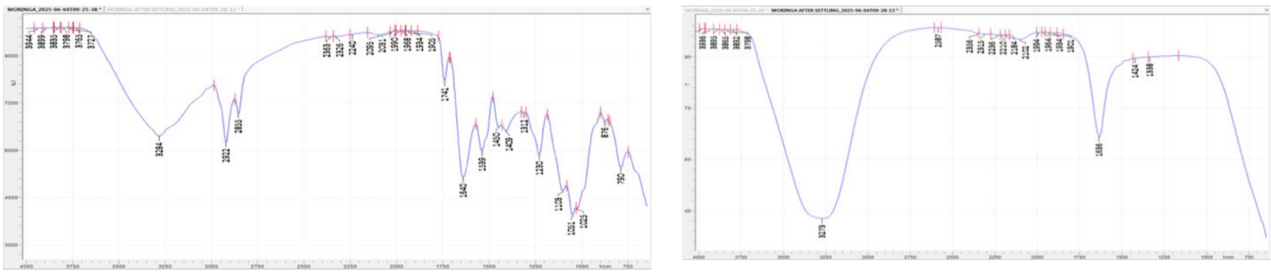


Figure 2 Jar Test Experiment

3. Results and Discussion

3.1 FTIR Analysis of Moringa Oleifera Seed Powder

Figure 3 below shows the FTIR Analysis of Moringa Oleifera Seed Powder. Moringa Oleifera seed powder was characterized using FTIR (Fourier Transform Infrared) spectroscopy to identify functional groups and observe chemical changes during coagulation treatment. The FTIR spectrum of untreated Moringa powder showed key absorption peaks at 3284 cm^{-1} (O-H stretching from hydroxyl groups), 2922-2855 cm^{-1} (C-H stretching from aliphatic chains), 1640 cm^{-1} (C=O stretching from proteins), 1384 cm^{-1} (C-N bending), and 1051 cm^{-1} (C-O stretching from alcohols or polysaccharides). After settling, spectral shifts and intensity changes indicated interaction with impurities, with diminished peaks around 1057 cm^{-1} suggesting C-O groups actively participated in contaminant binding. FTIR analysis confirmed that hydroxyl (O-H), carbonyl (C=O), amine (N-H), and ether (C-O) functional groups participated in coagulation, validating Moringa Oleifera is considered a better eco-friendly coagulant because its natural biopolymers, such as proteins and polysaccharides, are biodegradable and non-toxic, making it a sustainable alternative to chemical coagulants like Alum. These functional groups, predominantly found in the proteins and fatty acids of Moringa seeds, enabled effective destabilization of suspended particles, forming flocs and improving water clarity[8]. Figure 3 shows the FTIR analysis of Untreated Moringa Oleifera Seed Powder and after used of Moringa Oleifera Seed Powder.

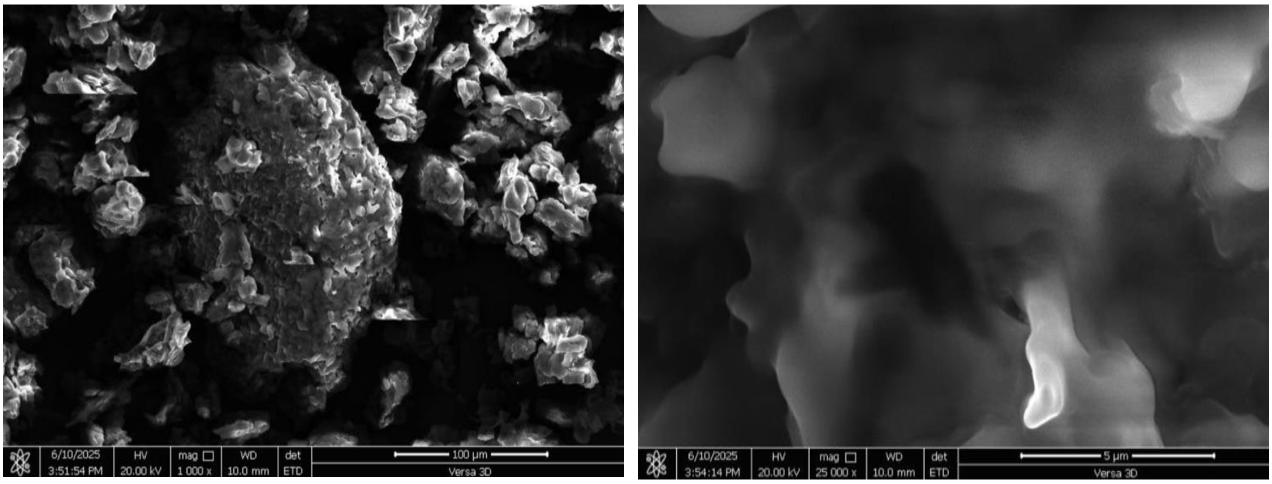


(a) **(b)**

Figure 3: FTIR Analysis of Moringa Oleifera Seed Powder (a) FTIR spectrum of Untreated Moringa Oleifera Seed Powder b) FTIR spectrum of Moringa Oleifera Seed Powder after used

3.2 FESEM Analysis of Moringa Oleifera Seed Powder

Figure 4 is shown the FESEM Analysis of Moringa Oleifera Seed Powder. Moringa oleifera seed powder was characterized using FESEM (Field Emission Scanning Electron Microscopy) to evaluate surface properties and particle interaction during coagulation. FESEM images revealed non-uniform and rough particles that enhanced agglomeration particle clustering during coagulation by improving interaction with suspended particles and promoting flocculation formation of particle clusters. (1000x magnification) showed clustered, rough Moringa particles with increased interaction sites, while (25,000x magnification) revealed smaller particles providing additional aggregation surfaces. The irregular surface morphology physical structure significantly contributed to turbidity removal effectiveness, with rough particle surfaces promoting floc formation and improved coagulation performance, validating Moringa oleifera's potential as an effective eco-friendly coagulant. In conclusion, the FESEM analysis highlighted the critical role of Moringa Oleifera seed powder's surface morphology in improving turbidity removal. The rough, irregular surfaces of the particles contributed significantly to the coagulant's effectiveness by promoting floc formation, leading to a more substantial reduction in turbidity during water treatment. These findings are consistent with earlier studies, such as Poonam Jaglan [7], which also observed that the coarse surface morphology of Moringa particles enhances interaction with contaminants during coagulation. Additionally, the results align with Deepika Kaushik [7], who found that coagulants with smaller particles in irregular shapes can increase their surface area, improving flocculation and coagulation performance. This further validates the potential of Moringa Oleifera as an effective, eco-friendly coagulant.



(a) **(b)**

Figure 4: FESEM Analysis of Moringa Oleifera Seed Powder (a) The FESEM image at 1000x magnification (b) The FESEM image at 25000x magnification

3.3 Analysis of Optimum Coagulant Dosage

The final turbidity levels for various dosages of Moringa Oleifera Seed Powder were measured after coagulation treatment of both the kaolin solution and river water. These levels were compared with initial turbidity to determine the optimum dosage for turbidity reduction. Figure 5 shows these results, displaying the turbidity reduction percentage at various dosage levels.

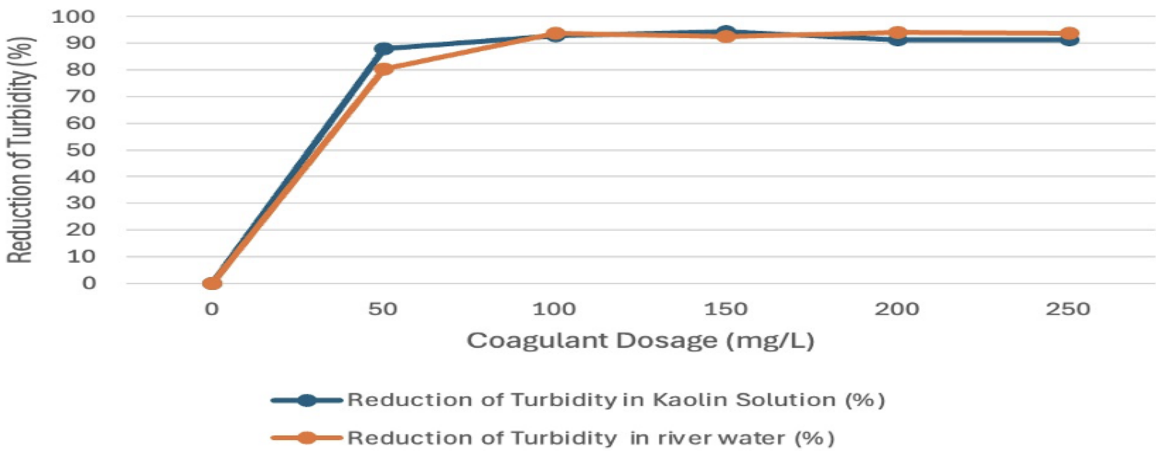


Figure 5: The graph of reduction of Turbidity against coagulant dosage

Based on Figure 5, the turbidity of the kaolin solution decreased from 112 NTU to 6.5 NTU at 150 mg/L of Moringa Oleifera Seed Powder, achieving a 94.2% reduction. Beyond this dosage, turbidity increased slightly due to coagulation site saturation and over-coagulation. Excess coagulant caused flocs to become too large, hindering efficient settling. Similar results were observed in previous studies [7], where excessive dosages failed to improve coagulation.

For river water, the initial turbidity of 83.0 NTU decreased to 5.02 NTU at 200 mg/L, with a 93.95% reduction. After 200 mg/L, further turbidity reduction plateaued as coagulation sites became saturated. The complexity of river water, containing organic particles, microorganisms, and other contaminants, required a higher dosage to reach optimal coagulation. As dosage increased beyond this point, over-coagulation occurred, disrupting floc formation and reducing settling efficiency, as seen in studies by [9] and [7].

3.4 Analysis of Optimum pH Level

Following to establishing the ideal coagulant dosage, the following phase was examining the influence of pH levels on the coagulation process. The pH of the kaolin solution and river water was modified to evaluate its effect on turbidity reduction. The three pH levels examined were pH 3 (acidic), pH 7.38 (neutral), and pH 9 (alkaline), with the objective of determining the ideal pH for the coagulation of Moringa Oleifera Seed Powder in each water type. The turbidity reduction percentage for both synthetic solution (kaolin) and river water is presented in Figure 6. This graph shows the results at various pH levels, testing the treatment effectiveness across a pH range of 3 to 9.

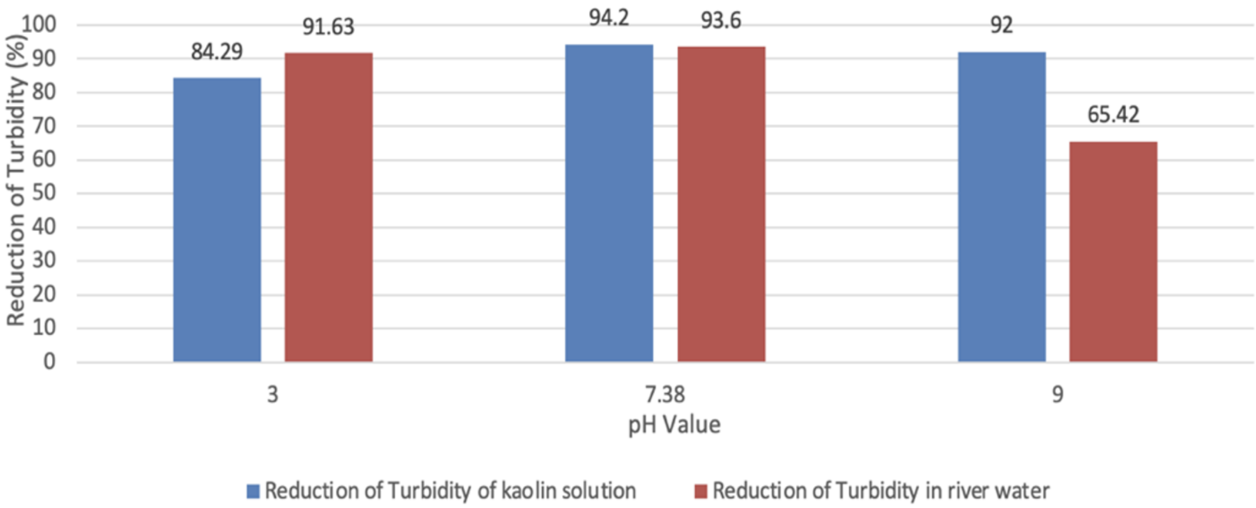


Figure 6: The graph of reduction of Turbidity against pH level

Figure 6 demonstrates the impact of pH on turbidity reduction using Moringa Oleifera Seed Powder. For the kaolin solution, turbidity decreased by 94.2% at neutral pH (7.52), suggesting it as the optimal pH for coagulation. At pH 3 (acidic) and pH 9 (alkaline), turbidity reduction was slightly lower because the charge interactions between the coagulant proteins and suspended particles were less optimal compared to neutral pH, reducing coagulation efficiency, but still effective. This indicates that neutral pH (7.52) is the optimal pH of the Moringa Oleifera Seed Powder in synthetic solution (kaolin). Similar results were observed in previous studies [9], where neutral pH is the best optimum pH for Moringa Oleifera Seed Powder. For river water, turbidity reduced by 93.6% at pH 7.38, with a sharp decrease at pH 3 but a significant drop to 65.42% at pH 9. This decline at alkaline pH suggests that coagulation was less effective. As noted by [9], alkaline conditions diminish the protein adsorption capacity of Moringa, reducing its ability to flocculate particles effectively. The superior performance at neutral pH is attributed to favorable charge interactions between the coagulant and particles, making it the most efficient condition for coagulation [4].

3.5 Analysis of Optimum Settling Time

After determining the optimal coagulant dosage and pH level, the next step was to analyze the effect of settling time on turbidity reduction. Settling times ranged from 30 minutes to 120 minutes to find the optimal duration for maximum turbidity reduction in both kaolin solution and river water. The same coagulant dosages of 150 mg/L for kaolin and 200 mg/L for river water were used. T Figure 7 shows how the turbidity reduction changes for both the kaolin solution and river water at different settling times from 30 to 120 minutes. The graph compares the initial and final turbidity levels after the coagulation treatment.

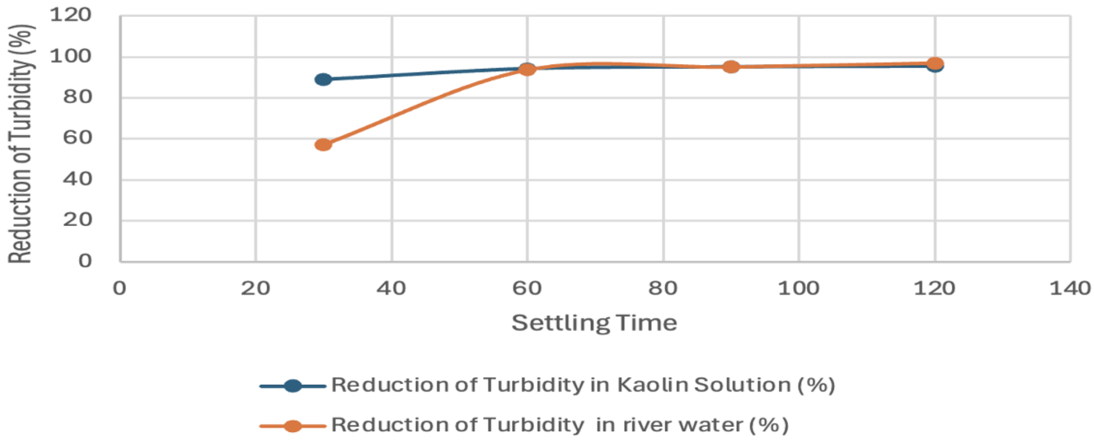


Figure 7: The graph of reduction of Turbidity against Settling Time

Figure 7 shows the turbidity reduction in both kaolin solution and river water over different settling times. For kaolin solution, the optimum turbidity reduction of 95.36% occurs at 120 minutes, with the final turbidity at 5.2 NTU. This increase in reduction is due to the flocculation process, where particles aggregate and settle more effectively over time. Similarly, for river water, the highest turbidity reduction of 96.94% is achieved at 120 minutes, with a final turbidity of 2.54 NTU. The gradual increase in turbidity reduction reflects the time needed for larger flocs to form and settle, improving particle removal. Both solutions show that longer settling times which is 120 minutes lead to more efficient turbidity removal. which aligns with finding from [10], who demonstrated that increasing settling time improves coagulation. Longer settling times, such as 120 minutes, improve turbidity reduction by allowing more time for the flocculation process [9]. As coagulant particles destabilize suspended particles, they aggregate into larger, heavier flocs that settle more easily. Longer settling times allow these larger flocs to form, increasing their ability to capture and remove finer suspended particles, resulting in more efficient turbidity removal.

4.0 Conclusion

This research shows that Moringa Oleifera seed powder works really well as a natural coagulant for removing turbidity from water. The results demonstrated that it can achieve high turbidity reduction of 94.2% in synthetic kaolin solution and 93.95% in river water when used at the right dosages (150 mg/L and 200 mg/L respectively) under neutral pH conditions. The FTIR and FESEM analyses helped identify the important functional groups and surface characteristics that make Moringa effective for coagulation. What's particularly good about Moringa is that it performs almost as well as conventional Alum but is much more environmentally friendly and doesn't produce toxic sludge. The findings suggest that Moringa Oleifera could be a practical and sustainable alternative to chemical coagulants, especially for areas that don't have easy access to expensive treatment chemicals. Future studies should look at using Moringa in larger scale applications and testing it for other water treatment processes like heavy metal removal.

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