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Original Research Article

Evaluation of Mango Leaves Powder-Sudfloc Dosage Ratios for Enhanced Coagulation-Flocculation in Surface Water Treatment

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ABSTRACT

This study investigated the use of mango leaf powder (MLP) as a natural coagulant in surface water treatment, both alone and in combination with Sudfloc, a chemical coagulant. Microstructural analysis of MLP was done through Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy (SEM-EDS) analyses as well as X-ray diffraction (XRD). Surface water samples with varying ratios of MLP and Sudfloc treatment were tested for pH, colour, turbidity, total dissolved solids (TDS), and electrical conductivity. The SEM-EDS results showed that the potential of MLP, which promote effective particle adsorption and flocculation, stems from its porous structure and mineral-rich organic matrix. The XRD analysis further revealed an amorphous structure with crystalline phases which supports MLP's coagulation capabilities. Water quality results showed that a combination of 25% MLP and 75% Sudfloc achieved significant colour and turbidity reductions, nearly matching the performance of full chemical treatment. Using 100% MLP resulted in optimal TDS and conductivity levels while maintaining pH stability at approximately 7.2 across all samples. These findings indicate that MLP can serve as an alternative or supplement to chemical coagulants in order to reduce chemical usage while maintaining effective water treatment performance.

1. INTRODUCTION

Water treatment is a global concern, with the primary focus on reducing contaminants such as colour, turbidity, total dissolved solids (TDS), and conductivity (Adjovu *et al.,* 2023; Shah *et al.,* 2023). Coagulation-flocculation is a widely employed method for treating surface water, particularly for removing turbidity, colour, and other particulate matter (Iwuozor, 2019; Getahun *et al.,* 2024). Traditionally, chemical coagulants such as aluminum sulfate (alum) and synthetic polymers like Sudfloc are used to aggregate suspended particles, making them easier to remove through sedimentation or filtration (Tahraoui *et al.,* 2024). Conventional chemical coagulants, such as Sudfloc, are widely used in coagulation-flocculation processes, but their environmental impact and cost are often a source of concern (Manda *et al.,* 2016). The environmental impact and health concerns associated with chemical coagulants have led to growing interest in natural alternatives (Koul *et al.,* 2022; Badawi *et al.,* 2023).

In recent years, research has focused on natural coagulants derived from plants, seeds, and other bio-based sources (Olabanji *et al.,* 2021a, Olabanji *et al.,* 2021b, Ojo, 2024). These coagulants offer several advantages as they are biodegradable, sustainable, and pose fewer health risks compared to chemicals like alum. Moringa oleifera, cactus, and various fruit extracts have been studied for their coagulation potential (Yin, 2010; Alam *et al.,* 2020; Olabanji *et al.,* 2021b; Deswal *et al.,* 2023). Mango leaves (*Mangifera indica*) are one such natural source with coagulant properties. Rich in bioactive compounds such as tannins, flavonoids, and polyphenols, mango leaves have shown potential for removing impurities from water by promoting the coagulation of suspended particles (Kumar *et al.,* 2021; Sferrazzo *et al.,* 2022). Mango Leaves Powder (MLP) acts as a coagulant primarily through charge neutralization and adsorption. The organic compounds in the leaves, particularly tannins, can neutralize the negative charge on colloidal particles, causing them to aggregate and settle out of the water. Additionally, the high surface area of the powder aids in adsorption, further reducing turbidity and colour (Azman *et al.,* 2019; Benalia, *et al.,* 2024). This study investigated the potential of MLP, a natural coagulant, to partially replace Sudfloc in treating wastewater. The goal is to determine an optimal mango-to-Sudfloc ratio that provides efficient water treatment while minimizing chemical use.

2. MATERIALS AND METHODS

2.1. Materials and Preparation

The natural coagulant was prepared by collecting mango leaves from trees within the Federal University of Technology, Akure. The leaves were washed thoroughly and sundried for 72 hours. Thereafter, the leaves were oven dried at 60°C for 24 hours, and then ground into a fine powder, which was subsequently sieved to achieve a uniform particle size. This MLP was used as the natural coagulant in the study. For comparison, Sudfloc, a commercial chemical coagulant, was used.

2.2. Characterization of MLP

The MLP was analyzed for microstructural properties using Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy (SEM-EDS) to determine surface morphology and elemental composition. X-ray diffraction (XRD) analysis was performed to assess the crystallinity and amorphous nature of the MLP, with particular attention to peaks indicating cellulosic material. The scan range was set from 10° to 50° at a scanning rate of 2° per minute to identify crystalline and amorphous phases.

2.3. Preparation of Water Samples

2.3.1. Raw water collection

Surface water samples were collected from a natural Ala river source. Initial pH, colour, turbidity, total dissolved solids (TDS), and conductivity were measured. The experiment was conducted using raw water with initial levels of colour (225 TCU), turbidity (45 NTU), pH (7), TDS (122 mg/L), and conductivity (182 μS/cm).

2.3.2. Dosage preparation

Different ratios of MLP and Sudfloc were prepared to analyze their combined effects on water quality. Dosage ratios were as follows: A (100% MLP - 0% Sudfloc), B (75% MLP - 25% Sudfloc), C (50% MLP - 50% Sudfloc), D (25% MLP - 75% Sudfloc), and E (0% MLP - 100% Sudfloc).

2.4. Coagulation and Flocculation Process

Each prepared dosage was added to 1-liter beakers containing 500 mL of raw water, and jar testing was performed to simulate coagulation and flocculation. The samples were initially stirred rapidly at 100 rpm for 1 minute, followed by slow stirring at 30 rpm for 15 minutes to facilitate floc formation. After stirring, the samples were allowed to settle for 30 minutes, and then the supernatant was carefully collected for analysis.

2.5. Water Quality Analysis

The treated water samples were analyzed immediately after coagulation to observe any changes across different dosages. The pH was measured using a calibrated pH meter, and colour was assessed in True Colour Units (TCU) with a colourimeter. Turbidity was measured in Nephelometric Turbidity Units (NTU) using a calibrated turbidity meter. Total Dissolved Solids (TDS) were recorded with a TDS meter to evaluate the influence of coagulant dosage on dissolved solid content, and electrical conductivity (EC), reflecting ion concentration in water, was measured in µS/cm using a conductivity meter.

2.6. Data Analysis

Results were averaged and analyzed to determine the effectiveness of each dosage combination on water quality parameters.

3. RESULTS AND DISCUSSION

3.1. Microstructural Analysis of MLP

The SEM and EDS analyses of MLP, as shown in Figure 1, reveal a porous structure and an organic matrix enriched with minerals such as potassium, calcium, and magnesium. This morphology and composition make MLP effective natural coagulants, as the high surface area allows for the adsorption and aggregation of suspended particles, while mineral elements contribute to charge neutralization, promoting flocculation (Ali *et al.,* 2023; Badawi *et al.,* 2023). Such natural coagulants, with bioactive components and microstructures that support particle entrapment, have shown potential in sustainable water treatment applications by enhancing coagulation and floc formation (Koul *et al.,* 2022).

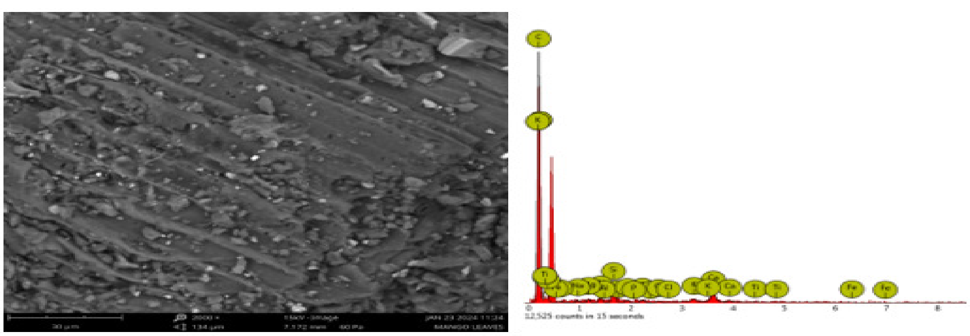

Figure 1: SEM-EDS image of MLP

The X-ray diffraction analysis of MLP, shown in Figure 2, reveals a distinctive amorphous nature, primarily attributed to the existence of lignin and hemicelluloses. The presence of a few crystalline phases at 14.84°, 24.30°, 29.98°, and 38.08° suggests the presence of cellulosic material exhibiting regular lattice characteristics. Peaks in the graph indicate stages where the effectiveness of the MLP coagulants and flocculants is high, achieving maximum particle aggregation and removal (Ali *et al.,* 2022).

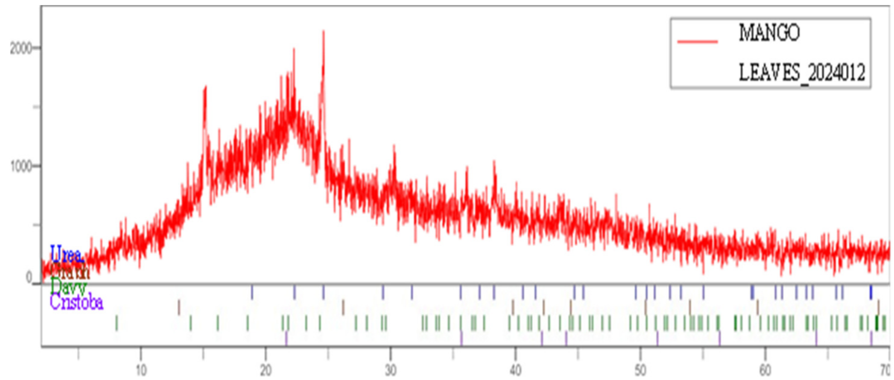

Figure 2: XRD image of MLP

3.2. Physiochemical characteristics of Natural and Chemical coagulant treated surface water

The results, presented in Table 1, show a clear trend in the performance of different MLP-Sudfloc dosage ratios on the five water parameters. The table shows that, while the pH remained stable across all dosage combinations at approximately 7.2, significant reductions were achieved in colour and turbidity. The most efficient colour and turbidity reductions occurred with dosage D (25% natural, 75% chemical) and dosage E (100% chemical). TDS and conductivity exhibited minor variations, with the lowest TDS and conductivity values at 100% natural dosage.

Table 1: Performance of natural coagulants (MLP) versus chemical coagulant (Sudfloc) treatment

Parameters	Dosages (%Natural - %Chemical)					
	Raw Water (0-0%)	A (100-0%)	B (75-25%)	C (50-50%)	D (25-75%)	E (0-100%)
pH	7	7.2	7.2	7.2	7.2	7.2
Color	225	220	110	45	10	5
Turbidity	45	43.84	30.57	8.1	0.45	0.14
TDS	122	121	123	123	123	124
Conductivity	182	180	184	184	184	185

The results reveal that the pH of the treated water remains stable at approximately 7.2 across all dosage variations of MLP and Sudfloc combinations, indicating no significant alteration in the pH from the raw water's initial value of 7. This stability is important, as drastic pH changes during water treatment can adversely impact water quality and may require additional neutralization steps to meet drinking water standards. The observed stability aligns with findings in existing literature on natural coagulants, which often have minimal impact on pH levels compared to chemical coagulants, allowing for safer and more environmentally friendly water treatment processes (Kuhiyop *et al.,* 2020). Using natural coagulants can help avoid the challenges of pH fluctuations and provide a sustainable alternative to conventional coagulants, making them advantageous in water treatment applications, especially in regions where pH-sensitive water ecosystems are a concern (Koul *et al.,* 2022).

The results illustrate that dosages D (25% MLP, 75% Sudfloc) and E (100% Sudfloc) achieved the highest colour removal efficiency, reducing the colour from an initial 225 TCU in raw water to 10 TCU and 5 TCU, respectively. This significant reduction indicates that even a mixture with 25% MLP can effectively reduce colour, performing almost as well as a full chemical coagulant dose. This outcome affirms the potential of mango powder as a natural coagulant to partially replace chemical coagulants in water treatment, offering a cost-effective and sustainable alternative. Studies on natural coagulants by Abujazar *et al.* (2022) and Nimesha *et al.* (2022) have similarly shown that plant-based coagulants can achieve high levels of colour and turbidity reduction. This further supports the viability of natural coagulants in water treatment processes (Malakootian & Fatehizadeh, 2010).

The turbidity reduction results reveal that Dosages D (25% MLP, 75% Sudfloc) and E (100% Sudfloc) achieved nearly complete turbidity removal, lowering turbidity levels from 45 NTU in raw water to 0.45 NTU and 0.14 NTU, respectively. This substantial reduction underscores the effectiveness of combining mango powder with Sudfloc, as the coagulant blend enhances particle aggregation and facilitates effective sedimentation. Such synergy between natural and chemical coagulants aligns with findings from studies by Al-Wasify *et al.* (2023) and Kurniawan *et al.* (2023), which have shown that natural coagulants can effectively reduce turbidity when used alone or in combination with chemical coagulants. The use of natural coagulants like mango powder can lower costs and environmental impacts while maintaining treatment efficiency, making it an attractive option for sustainable water treatment (Koul *et al.* ,2022).

The best TDS reduction occurred with dosage A (100% MLP, 0% Sudfloc). The result demonstrates that the use of 100% MLP as a natural coagulant achieves the best reduction in Total Dissolved Solids (TDS) in surface water, lowering it from 122 ppm (raw water) to 121 ppm. In contrast, increasing the proportion of Sudfloc causes a slight rise in TDS, with the highest level at 124 ppm when using 100% Sudfloc. Singh and Kishor (2022) and Nimesha *et al.* (2022) showed that natural coagulants like mango powder effectively reduce turbidity and TDS due to their adsorption properties, while chemical coagulants may contribute to elevated TDS due to residual chemicals.

Electrical Conductivity measurements also indicated slight variations, with the lowest value (180 µS/cm) observed at dosage A. The results show that 100% MLP (Dosage A) achieves the lowest conductivity in treated water, reducing it to 180 µS/cm, while increasing the proportion of Sudfloc raises conductivity to 185 µS/cm (Dosage E). This trend suggests that the natural coagulant introduces fewer dissolved ions compared to the chemical coagulant, which contributes to higher conductivity levels. Electrical conductivity (EC) measures how well water can conduct electricity, which is largely influenced by the presence of various anions (such as Chloride, nitrite, sulphate and phosphate) and cations (like sodium, magnesium, calcium, Iron and Aluminium). This makes EC closely related to the total dissolved solids (TDS) in the water, reflecting its overall mineral content. Additionally, turbidity can also impact EC measurements. Research by Koul *et al.* (2022) and El Bouaidi *et al.,* 2022 support these findings, highlighting that natural coagulants like MLP help minimize ion concentrations, unlike chemical coagulants that can leave residuals. The results align with Muhamad *et al.* (2020), who found that natural coagulants reduce conductivity more effectively, offering a more environmentally friendly option for water treatment.

4. CONCLUSION

The results indicate that a mixture of 25% MLP and 75% Sudfloc provides a highly efficient solution for water treatment, especially in reducing colour and turbidity. The use of natural coagulants like MLP can enhance the sustainability and cost-effectiveness of water treatment processes without compromising performance. Additionally, complete reliance on natural coagulants could provide improved results in TDS reduction, making it a promising area for future research.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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