Evaluation of plant-based natural coagulants for surface water treatment of Pratapgarh District Uttar Pradesh, India

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Abstract

The efficacy of three plant-based natural coagulants, namely papaya seed powder, banana peel powder, and lemon peel powder, was evaluated in this study for their ability to remove high electric conductivity turbidity, hardness, fluoride, and nitrate from surface water. The experiments were conducted at room temperature without any adjustment to the initial pH. The results indicated that banana peel powder exhibited the highest turbidity removal rate, achieving 87.5% removal when used at a dosage of 0.4 g/L. Furthermore, banana peel powder demonstrated excellent removal efficiency for fluoride and nitrate, with 85% removal observed at the same dosage. Lemon peel powder also exhibited significant effectiveness, achieving 60% removal. Papaya seed powder proved to be the most efficient coagulant for removing hardness, demonstrating a removal rate of 69.6%. The study further revealed a noteworthy linear relationship between the removal of turbidity and hardness, as evidenced by correlation coefficients (R2) ranging from 0.67 to 0.88. Similar linear relationships were observed for turbidity removals, with R2 values ranging from 0.68 to 0.8. An additional advantage of using these natural coagulants was that they did not cause any pH alteration in the treated surface water. Moreover, Fourier-transform infrared (FTIR) analysis of banana peel powder, papaya seed powder, and lemon leaf powder indicated the presence of functional groups such as carboxylic acid, hydroxyl, and aliphatic amines, which likely play a crucial role in facilitating coagulation and flocculation by neutralizing the charges of impurities in the water. This study suggests that inexpensive natural coagulants, including papaya seed powder and lemon peel powder, hold promise for surface water treatment, offering a viable alternative to conventional methods.

Keywords: *Coagulation. Natural coagulants · Turbidity. Banana peel Powder. Papaya seed powder. Lemon peel powder. Surface water treatment*

1. Introduction

Access to safe and clean drinking water is a critical global concern that demands effective treatment methods to eliminate contaminants (Maurya & Saxena, 2022). The removal of turbidity and other impurities, especially when utilizing surface water sources, stands as a pivotal step in the water treatment process. To ensure clean water is accessible to a larger population, it is imperative to employ methods that are not only cost-effective but also simple, reliable, and efficient (Daverey et al., 2019).

In recent years, there has been growing interest in plant-based natural coagulants derived from various parts of plants, such as seeds, roots, and leaves. These natural substances exhibit coagulation properties owing to their chemical composition, primarily characterized by the presence of cationic substances and bioactive compounds.

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This environmentally friendly option not only reduces the ecological footprint of water treatment but also minimizes health risks associated with the use of synthetic chemicals. The complexity of suspended particles in water, which can vary significantly in composition, charge, size, shape, and density, underscores the importance of comprehending their interactions for successful coagulation and flocculation processes. Developing countries, in particular, face numerous challenges in providing safe drinking water, including limited financial resources, escalating water treatment costs, and high levels of suspended and colloidal particles resulting from land development, agriculture, and industrial effluents (Jadhav & Mahajan, 2014). Insufficient access to safe drinking water remains a major contributor to millions of child deaths from diseases like diarrhea each year. In many African and Latin American countries, native plants have traditionally been used to enhance water quality. For instance, Guatemala utilizes Moringa seeds (Camacho et al., 2017), Bolivia employs Peach and Bean seeds, and Bolivia and Peru rely on Schoenoplectus tatora. Natural coagulants derived from plant-based materials or renewable sources offer a more environmentally friendly and sustainable approach to turbidity removal, gaining popularity due to their numerous advantages over chemical alternatives. Coagulation and flocculation are pivotal in the production of drinking water as they effectively eliminate suspended particles, colloidal materials, and turbidity. While conventional treatment processes typically rely on chemical coagulants and flocculants, natural alternatives, such as plant waste, have demonstrated promise (Sakarya et al., 2023). In regions where waterborne diseases are prevalent, especially in developing countries, the use of natural coagulants holds particular advantages due to their cost-effectiveness and practicality. Furthermore, the utilization of agricultural waste from rural areas for water purification can help mitigate water pollution and the spread of diseases. Natural coagulants are cost-effective due to their lower cost compared to chemical coagulants and their production of sludge with high nutritional value, which reduces treatment expenses. Despite their numerous benefits, natural coagulants have not been widely commercialized, except for Moringa oleifera seeds. Conversely, chemical coagulants, while effective, pose sustainability challenges due to the generation of excessive non-biodegradable sludge and potential adverse health effects from chemicals like lime and alum (Prabhakaran et al., 2020). In contrast, natural coagulants are safe for human health, biodegradable, cost-effective, and produce less voluminous sludge, making them promising alternatives for sustainable environmental technology (Kalibbala et al., 2023; Owodunni et al., 2023).

The focus of this study is to assess the coagulation potential of banana peel powder, papaya seed powder (Amran et al., 2021), and lemon peel powder (Dolan et al., 2021) for treating highly turbid surface water resulting from sediment loss and suspended solids (Khee et al., 2023). The standard practices in the water treatment industry involve coagulation-flocculation, followed by sedimentation, filtration, and disinfection before water distribution to consumers. By investigating the effectiveness of these natural coagulants, this research aims to make a significant contribution to the development of sustainable and accessible water treatment methods for regions grappling with water scarcity and pollution challenges (Koul et al., 2022). Additionally, it aims to provide evidence-based insights for policymaking and sustainable water resource management in these areas.

The research will involve the collection of water samples from various surface water sources, including rivers, lakes, and ponds, commonly used for drinking water supply in many communities. These samples will be treated with different plant-based coagulants, and the resulting changes in water quality parameters will be carefully analyzed and compared against conventional coagulation methods. Parameters such as turbidity reduction, hardness removal, nitrate EC, fluoride, and turbidity will be closely monitored to assess the effectiveness of the plant-based coagulants.

The exploration of plant-based natural coagulants for surface water treatment offers a promising avenue for sustainable and eco-friendly water purification. By investigating their performance, cost-effectiveness, and compatibility with existing infrastructure, this research seeks to provide valuable insights into harnessing the potential of nature's coagulation agents to enhance the quality and accessibility of drinking water. Ultimately, the findings of this study may contribute to the development of innovative and environmentally responsible solutions for safe water provision, benefiting both current and future generations.

In this paper, firstly we have discussed the potential applications of plant-based coagulants, there is a need for further research to explore their effectiveness in different water sources and under varying conditions. This would help us determine the range of situations in which these coagulants can be most beneficial. Secondly, the characterization of plant-based coagulants is an area that requires more in-depth investigation. Understanding the chemical composition and properties of these coagulants is essential for optimizing their use in water and wastewater treatment processes. Additionally, research into the long-term stability and shelf life of these coagulants would be valuable information for practical implementation.

Our paper aims to provide a clear rationale for the novelty of our study and its distinctive contributions, there are still significant gaps in the research on plant-based coagulants in water and wastewater treatment. Addressing these gaps will not only advance our understanding but also contribute to more effective and sustainable water treatment solutions.

2. Materials and methods

2.1 Study Area

Poor water quality can have direct health implications for the population of Pratapgarh, including the risk of waterborne diseases, exposure to harmful contaminants, and overall reduced quality of life. This study aims to address these potential health risks through a comprehensive assessment of raw water quality.

The district is situated between the parallels of 25^{o}34’ and 26^{o}11’ North latitude and between the meridians of 81^{o}18’ and 82^{o}27’ East longitude. Total 40 samples were taken for water analysis. The district has a total groundwater availability of 126,236.34 ha-m, with Sadar block accounting for 4,759.23 ha-m. The major sources of water for drinking and irrigation purposes are deep wells, tube wells, hand pumps, and river water. However, the total groundwater draft in the district is 90,193, with Sadar block alone marked under the overexploitation category with 5,185 (CGWB,2012-13). The district receives an average yearly precipitation of approximately 1000 millimetres, with approximately 90% of this rainfall occurring between the months of June and September (Tiwari et al.,2018). The primary economic activity in this region revolves around agriculture. The Sai River holds a significant position as it flows from the western to the eastern direction, traversing the heartland of Pratapgarh district. It plays a crucial role in irrigating both the northern and southern regions of the district before eventually merging with the Gomti River downstream in the Jaunpur district. During the monsoon season, the Sai River is prone to flooding, while in the summer, a slender stream of water navigates its way through vast stretches of sand. The district's average elevation stands at 137 meters above mean sea level, with the terrain sloping gently from northwest to southeast. Notably, Pratapgarh district lacks economically exploitable minerals, with the exception of sand extraction along the banks of the Ganga and Sai rivers.

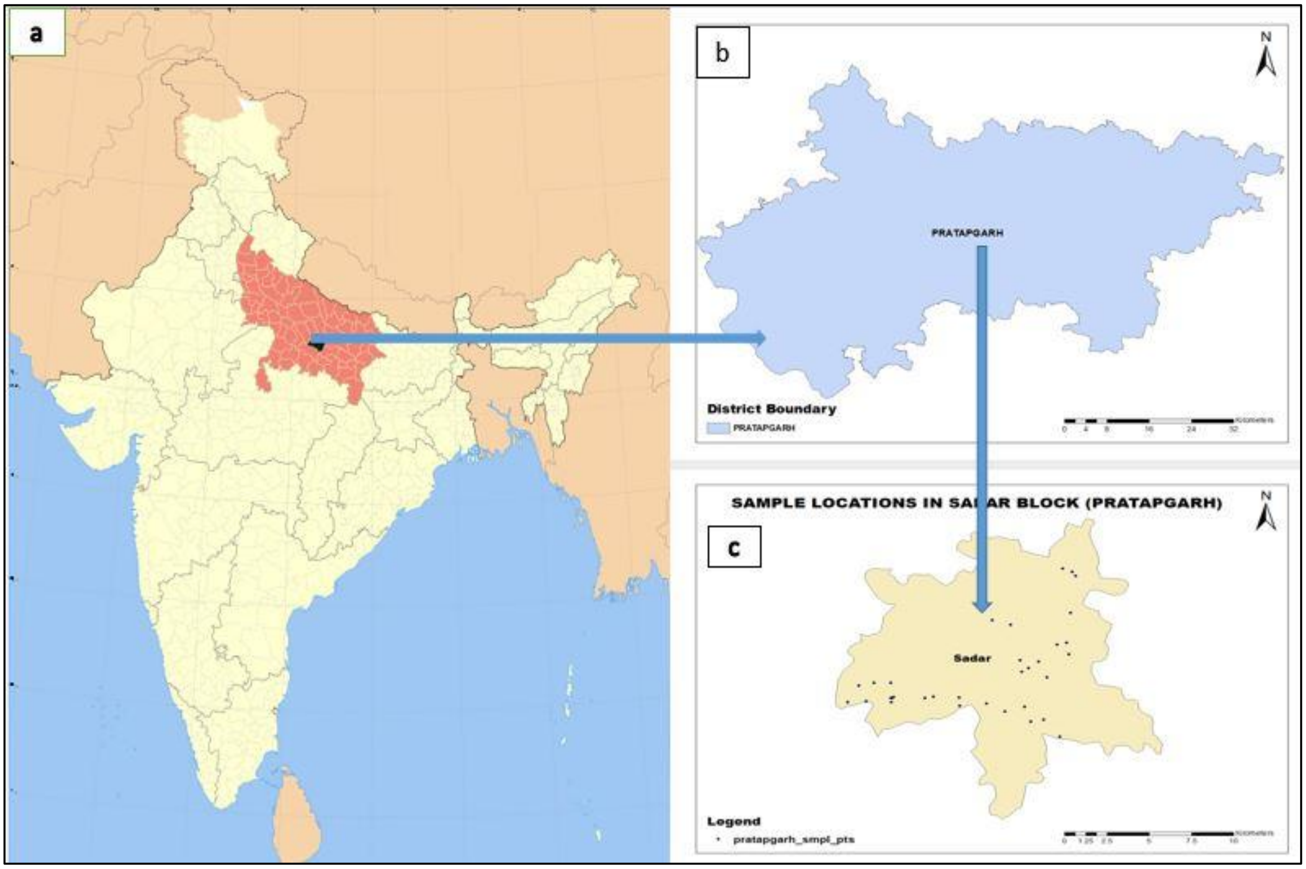


Figure 1: (a) Showing Uttar Pradesh in map of India (b) Showing Pratapgarh in Uttar Pradesh (c) sampling points in Sadar block of Pratapgarh

2.2 Materials and methods

The peels of fresh bananas (Musa acuminate) and papaya seeds (Carica papaya) were obtained from the Gargi Girls Hostel Kitchen at Shri Ramswaroop Memorial University, located on Deva Road in Lucknow. To ensure cleanliness, the collected peels were washed with distilled water to eliminate any dirt and suspended impurities (Khalid Salem et al., 2023). Subsequently, they were left to dry under sunlight for a period of 7 days. Once thoroughly dried, the peels were crushed into a fine powder using a mortar and pestle (Appiah-Brempong et al., 2023). For the study, raw water samples were gathered from various sources within Pratapgarh district, Sadar, Uttar Pradesh, India. These sources included rivers, ponds, lakes, and canals. The prominent surface water sources in the area are the Sai and Gomti rivers. Sterilized plastic containers were utilized to collect the water samples. These containers underwent a thorough cleaning process involving washing with nitric acid until completely full, after which they were tightly sealed. The surface water was analysed based on several parameters. These included pH, hardness, turbidity, fluoride content, and nitrate levels.

2.3 Preparation of natural coagulants

The lemon peels and banana peels were collected and cut into small pieces. They were thoroughly washed with distilled water to eliminate any dirt and suspended impurities. Subsequently, the peels were left to dry under sunlight for a period of 7 days. After the initial drying process, they were further dried in an oven for 4 hours at 105 °C. Once completely dried, the peels were crushed into a fine powder using a mortar and pestle (Dhrubo et al., 2023). The resulting powder was sieved to achieve a particle size of 0.5 mm, which was suitable for use as a coagulant.

As for the Carica papaya fruits, they were sliced open using a clean knife. The seeds were washed with distilled water and similarly dried under sunlight for 7 days. Once fully dried, the seeds were crushed into a fine powder using a home grinder. The resulting powder was also sieved to a particle size of 0.5 mm, making it suitable for use as a coagulant. Coagulant materials are given in Figure 2.

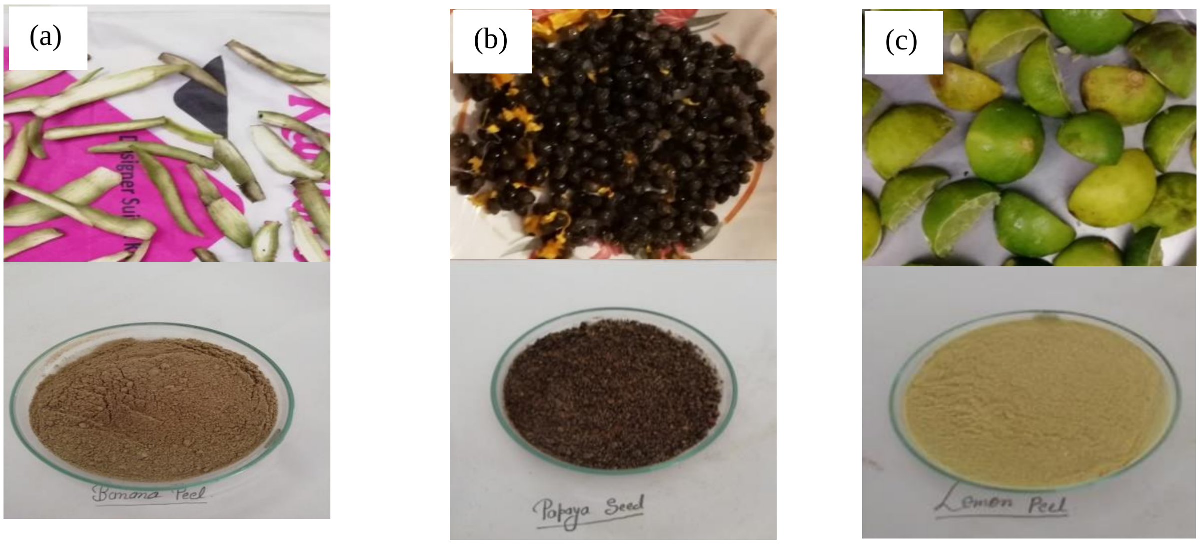


Figure 2: Coagulant materials (a) banana peel (b) papaya seed powder (c) lemon peel powder used for water purification.

2.4 Coagulation tests to study surface water treatment using natural coagulants

To perform coagulation tests, we utilized a laboratory jar testing apparatus (Model Microteknik, India) (Gatew & Worku, 2023) equipped with two paddle rotors suitable for 500-1000 ml beakers. In each beaker, 500 ml of surface water was combined with the appropriate dosage of natural coagulants. The surface water in the beakers, both with and without coagulant, underwent vigorous stirring at approximately 170 rpm for a duration of 5 minutes. Subsequently, the mixer speed was lowered to approximately 25 rpm, and the contents of the beakers were mixed for an additional 20 minutes.

Maurya and Daverey, 2018, employed a high-speed mixing technique to ensure even distribution of the coagulant throughout the water sample. Additionally, they utilized slow speed mixing to keep the suspended flock particles uniformly dispersed. Subsequently, the mixture was allowed to settle for one hour, facilitating the settling of flock particles. The supernatant, containing the settled particles, was carefully collected without causing any disturbance and subjected to analysis for turbidity, hardness nitrate, and fluoride. The experiments were conducted at room temperature, and the pH of the surface water was not adjusted before or during the experiment. Furthermore, all experiments were replicated.

2.5 Analytical methods

Analytical techniques were employed to assess the characteristics of the surface water both before and after conducting jar tests. These techniques included the use of specialized equipment to measure turbidity and pH. Furthermore, the fluoride and nitrate content in the water samples were assessed using fluoride and nitrate electrodes, following standardized methods for water and wastewater treatment (APHA, 2005). The hardness of the water was determined using the Trimetric method.

The efficiency of the coagulation-flocculation process in removing various water quality parameters (pH, Turbidity, Alkalinity, Electric Conductivity, Hardness, F^- and, NO_3^-) was determined using equation (1).

$$R\% = \frac{(C_i - C_f)}{C_i} X100 \quad (1)$$

where C_i and C_f are the initial and final values of each contaminant, respectively, and R is the response parameter (Okolo et al., 2021; Precious Sibiya et al., 2021)

3. Results

The sample was subjected to treatment using varying doses of Lemon peel powder, Banana peel powder, and Papaya seed powder. In the subsequent Results and Discussion section, we present the outcomes of our analysis of water quality parameters, which encompass pH, turbidity, electrical conductivity, alkalinity, hardness, nitrate, and fluoride levels in the surface water. The treatment efficiencies of these natural coagulants, as documented by Gandiwa et al. (2020). Notably, the highest coagulation activities were observed for banana peel powder at a dosage of 0.4 g/L, while both lemon peel powder and papaya seed powder also exhibited effective coagulation at the same dosage of 0.4 g/L.

Table 1: Parameters studied before and after treatment of surface water

Parameters		pH	Turbidity (NTU)	Electrical Conductivity µS/cm	Alkalinity (mg/l)	Hardness (mg/l as $CaCO_3$)	Fluoride (mg/l)	Nitrate (mg/l)
Before treatment		7.67	36	1400	219	264	1.4	48.2
After Treatment	Dosage	Percentage (%) Removal efficiency after treatment on different dosages						
	0.4gm/500ml	6.9	87.5	67.5	31.5	54.54	85.2	85
Banana Peel Powder	0.8gm/500ml	7.2	87.2	65	24.6	50.1	44.2	34
	1.2gm/500ml	7.2	86.1	58	7.7	24.8	36.4	22.4
	0.4gm/500ml	7.0	83.3	48	26.2	69.6	77.8	42
Papaya Seed Powder	0.8gm/500ml	7.2	82.7	46	21.5	52	56.4	40
	1.2gm/500ml	7.2	80.2	26	14	8.5	45.7	18
	0.4gm/500ml	7.0	84.7	50.4	36	62	60.1	60
Lemon Peel Powder	0.8gm/500ml	7.3	83.3	45.5	25	56.5	37.1	28
	1.2gm/500ml	7.4	81.3	42	18	34.2	37.8	24.2

3.1 pH

The initial pH of the water was within the acceptable range (6.8-8.4) for drinking water quality. However, when a coagulant was added at a dosage of 0.4 grams in 500 ml water, the pH was reduced by 6.9, indicating that this dosage had an acidic effect on the water.

3.2 Turbidity

In this research study, the focus was on reducing turbidity in water, typically measured in Nephelometric Turbidity Units (NTU), to meet drinking water quality standards. The initial turbidity of the raw water sample was found to be high at 36 NTU, exceeding the permissible limit (7 NTU). Various coagulant dosages were tested in triplet form along with natural substances like lemon peel powder, banana peel powder, and papaya seeds. Lemon peel powder effectively reduced turbidity to 84.7% NTU (Table 1), Banana peel powder 87.5% NTU, and payaya seed powder 83.3 % NTU at a dosage of 0.4 gm/500ml, but showed increasing turbidity at higher dosages.

3.3 Electrical Conductivity:

This study employed a digital conductivity meter (model no. 161E) to assess the water's electrical conductivity. The acceptable range for electrical conductivity in drinking water, as per the Bureau of Indian Standards (BIS) in 2012, is 750 µS/cm. Prior to conducting jar tests, the water's electrical conductivity was 1400 µS/cm, surpassing the permissible limit. This high conductivity indicated a significant presence of dissolved solids in the water. The study achieved a maximum reduction in electrical conductivity of 67.5% with a coagulant dosage of 0.4 gm/500ml.

3.4 Alkalinity

During the research project, alkalinity levels were assessed, revealing that the untreated raw water sample had an alkalinity of 219 mg/L. The acceptable range for alkalinity in drinking water, as per the Bureau of Indian Standards (BIS) in 2012, is 250 mg/l. However, when subjected to treatment with lemon peel powder, banana peel powder and papaya seed powder, the alkalinity exhibited a decline when treated with doses of 1.2 gm/l, 0.8 gm/l, and 0.4 gm/l, respectively. Various coagulant dosages were tested in triplet form. Lemon peel powder effectively reduced alkalinity to 36 %, Banana peel powder 31.5 %, and payaya seed powder 26.2% at a dosage of 0.4 gm/500ml.

3.5 Hardness

Water hardness is primarily caused by the presence of calcium and magnesium ions in water. The initial hardness level of the untreated water was measured at 264 mg/l, exceeding the permissible limit (250mg/l). Various coagulant dosages were tested in triplet form along with natural substances like lemon peel powder, banana peel powder, and papaya seeds. Lemon peel powder effectively reduced hardness to 62%, Banana peel powder 54.5%, and payaya seed powder at a dosage of 69.6% gm/500ml, but showed increasing hardness at higher dosages.

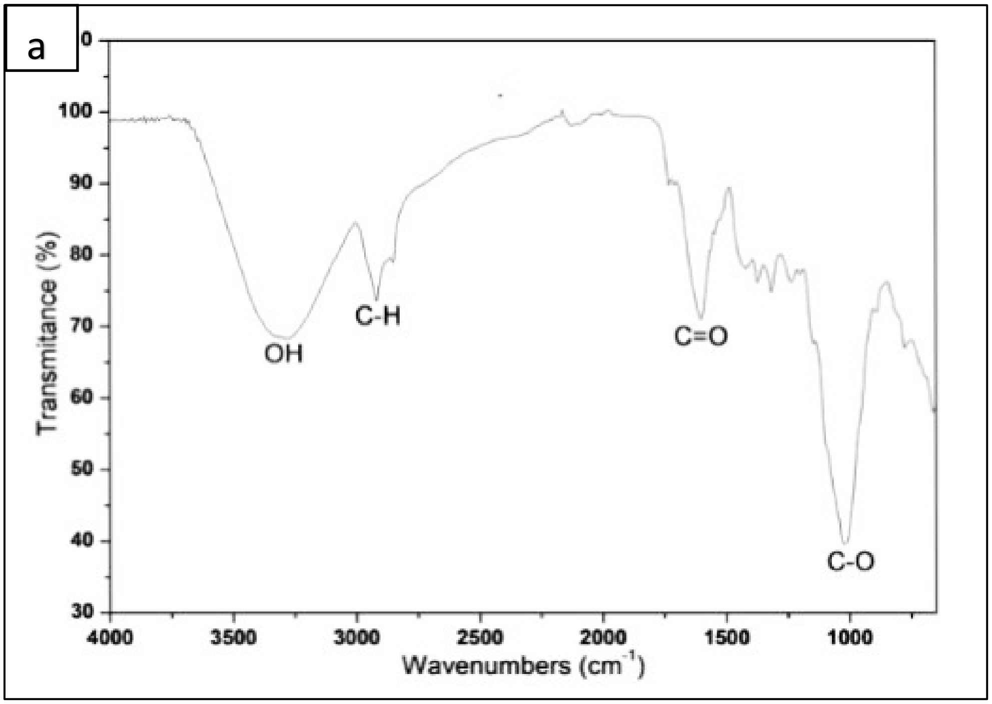
3.6 Nitrate

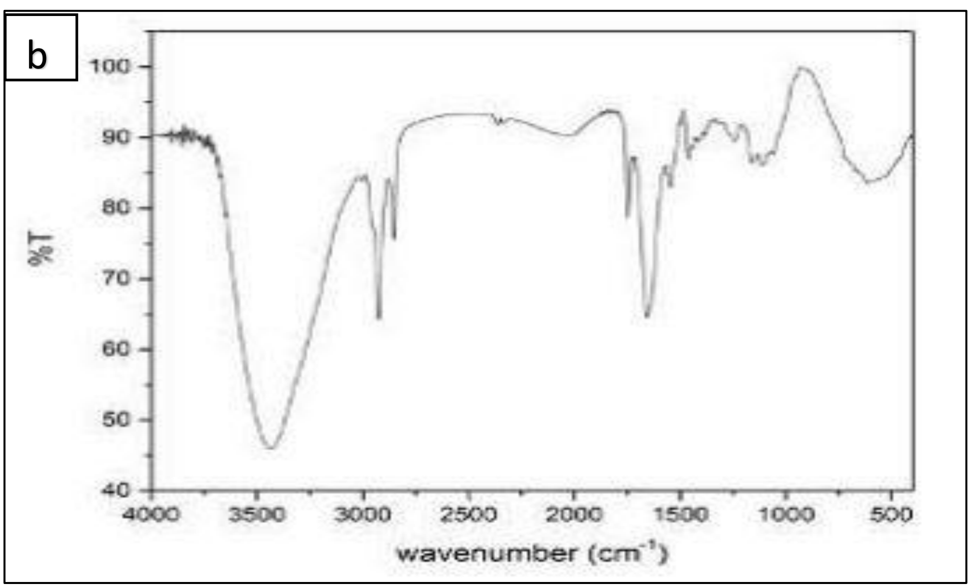
This paragraph discusses an experiment involving the reduction of nitrate levels in a water sample. Initially, the nitrate concentration in the raw water sample was measured at 48.2 milligrams per liter (mg/L), which was higher than the limit (45 mg/l) recommended by the World Health Organization (WHO). The experiment tested three different natural substances: lemon peel powder, banana peel, and papaya seed, to see how they could reduce the nitrate levels in the water. Various coagulant dosages were tested in triplet form. Lemon peel powder effectively reduced nitrate to 60%, Banana peel powder 85 %, and payaya seed powder 42% at a dosage of 0.4 gm/500m.l

3.7 Fluoride

The initial fluoride of the raw water sample was found to be high at 1.4 mg/l, exceeding the permissible limit (1 mg/l) as per BIS limit. Various coagulant dosages were tested in triplet form along with natural substances like lemon peel powder, banana peel powder, and papaya seeds. Lemon peel powder effectively reduced fluoride 60.1% (Table 1), Banana peel powder 85.2%, and payaya seed powder 77.8 at a dosage of 0.4 gm/500ml but showed increasing fluoride at higher dosages.

3.8 FTIR analysis of natural coagulants





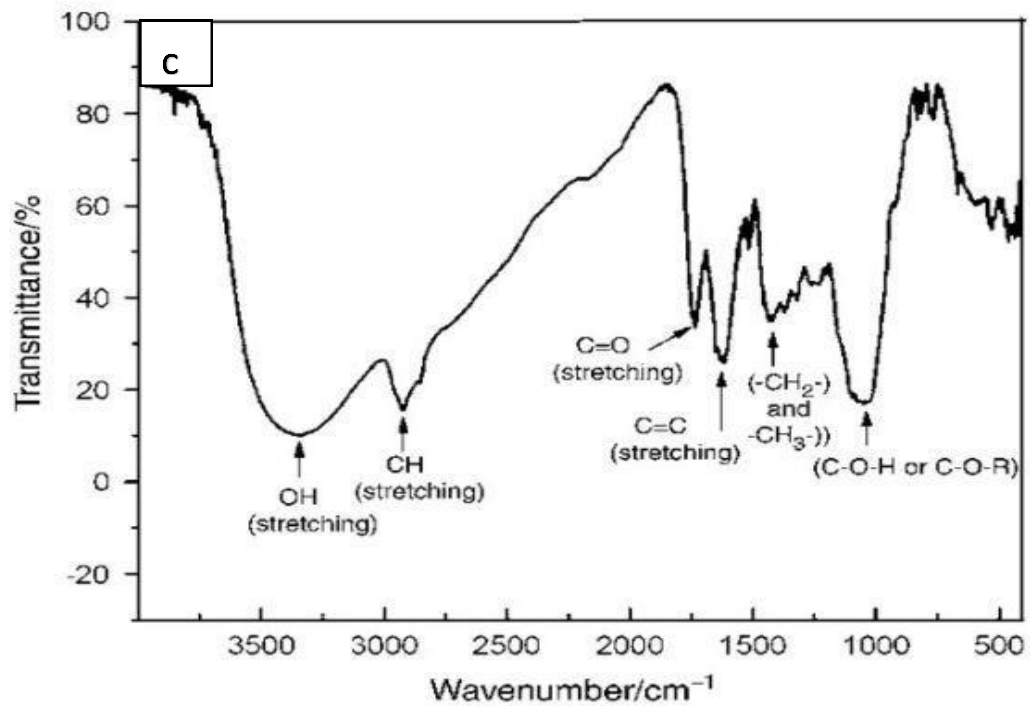


Figure 3: (a) FTIR analysis of Banana peel powder (b) Papaya seed powder and (c) Lemon peel powder

4. Discussion

4.1 Efficacy of natural coagulation based on different parameters

pH impact

This study provides valuable insights into the impact of coagulant dosage on the acidity of water. The research began with the water's initial pH falling within the acceptable range for drinking water quality. However, when a coagulant was introduced at a dosage of 0.4 grams in 500 ml of water, the pH dropped by 6.9 units, indicating the coagulant's acidic effect on the water. This finding is significant as it highlights the dosage-dependent influence of coagulants on pH. Moreover, it's observed that higher coagulant dosages had a detrimental effect on the coagulation process, potentially reducing its efficiency in water treatment.

Turbidity reduction

The study examined the impact of various coagulants and natural substances on reducing turbidity. The results indicate that lemon peel powder, banana peel powder, and papaya seeds have the potential to effectively reduce turbidity at a dosage of 0.4 gm/500ml, with substantial reductions observed. However, a noteworthy finding is that overdosing of coagulants can lead to the formation of smaller, more stable flocs, which are less likely to settle and be removed from the water.

Electrical conductivity

The initial high electrical conductivity of the untreated water sample highlights a significant level of dissolved solids. The research demonstrates that the addition of coagulants and natural substances can effectively reduce electrical conductivity. The dosage-dependent reduction in electrical conductivity indicates that the coagulants play a key role in neutralizing ions, specifically dissolved salts (Alawane and Jadhav, 2015).

Alkalinity control with coagulants

Alkalinity provides insights into how coagulants and natural substances can impact the buffering capacity of water. The study began with an assessment of the alkalinity of the untreated water sample, which initially exceeded permissible limits. However, the introduction of coagulants and natural substances, particularly at a dosage of 0.4 gm/500ml, effectively reduced alkalinity to within the acceptable range.

Water hardness

Water hardness, associated with calcium and magnesium ions, was a focus of this study. The initial water hardness levels were found to exceed permissible limits. Coagulants and natural substances, particularly at a dosage of 0.4 gm/500ml, effectively reduced water hardness. The research consistently demonstrated that higher coagulant dosages are necessary for treating elevated water hardness levels.

Nitrate Reduction

Nitrate reduction in the study reveals that the untreated water sample initially had nitrate levels exceeding recommended limits. The study tested the effectiveness of different natural substances in reducing nitrate levels, with promising results. The findings emphasize that, at a dosage of 0.4 gm/500ml, lemon peel powder, banana peel powder, and papaya seeds effectively reduced nitrate levels.

Fluoride Reduction

The study's exploration of fluoride reduction is particularly important, given the health implications of elevated fluoride levels in drinking water. The initial fluoride concentration in the untreated water sample exceeded permissible limits. The study tested different coagulant dosages and natural substances, with notable reductions in fluoride levels observed at a dosage of 0.4 gm/500ml. The mechanism behind fluoride reduction, involving the neutralization of negative fluoride ions by positively charged coagulants, leading to the formation of larger flocs that can be easily removed. This information is significant for regions dealing with excess fluoride in their water sources and underscores the potential of natural substances in fluoride remediation.

4.2 Characterization of natural coagulants

Banana peels, known for their biodegradability, offer a sustainable approach to water treatment. They contain polysaccharides such as pectin, which possess coagulation properties. Pectin aids in the aggregation of suspended particles and impurities, promoting clearer water (Fig 3a). Additionally, banana peels contain natural reducing agents like polyphenols, which play a crucial role in removing heavy metals from water by forming metal complexes (Amran et al., 2021). Additionally, Fourier-transform infrared spectra were obtained for banana peel powder, using KBr pallet with Thermo, Nikolet (U.S.A 2009).

Papaya seeds, on the other hand, contain proteolytic enzymes like papain that effectively break down proteins and organic matter in water. This enzymatic action aids in coagulation and flocculation processes, with the added advantage of requiring lower dosages, thus making it a cost-effective choice (Unnisa & Bi, 2018). Furthermore, papaya seeds exhibit antimicrobial properties, inhibiting the growth of harmful microorganisms and contributing to safer water treatment practices. They have proven effective in enhancing water clarification by efficiently removing suspended particles. The FTIR analysis of papaya seeds powder revealed several key findings (Fig 3b). According to Kristianto et al. (2018) indicated the presence of O-H and N-H stretching and C-H stretching, respectively. Additionally, a distinct peak suggested the existence of C=O ester groups. These observations align with the known composition of papaya seeds, which are rich in carbohydrates, proteins, and fats. The abundance of these functional groups in papaya seeds suggests their potential for effectively removing contaminants from water (Prasetya et al., 2018).

Lemon peels, rich in natural polysaccharide pectin, also offer valuable coagulation properties in water treatment (Mhgub et al., 2018). Pectin helps in the flocculation of suspended particles and impurities by attracting and binding with negatively charged particles. Additionally, lemon peels contain antioxidants such as flavonoids and limonene, which form complexes with certain contaminants, including heavy metals e.g. selenium (Se) (Dev et al., 2020). This unique attribute makes lemon peels a valuable asset in the removal of toxic substances from water, aligning with environmentally friendly and sustainable water treatment practices (Fig 3c).

4.3 Factors Affecting Coagulant Efficiency:

The efficiency of a coagulant can change with increased dosage due to various factors, including saturation, optimal dosage ranges, chemical interactions, floc formation, and agglomeration,

i. **Saturation**: Saturation point beyond which adding more coagulant doesn't significantly enhance the removal efficiency. This means that at a certain dosage, the coagulant has already bonded with most of the impurities, and adding more doesn't have a noticeable effect.
ii. **Optimal dosage**: Coagulants often have an optimal dosage range where they work most effectively. Going beyond or below this range can lead to reduced efficiency.
iii. **Flock formation**: Coagulants work by causing particles to clump together (agglomerate). Beyond a certain dosage, excessive coagulant can lead to over-agglomeration or instability, negatively impacting removal efficiency.
iv. **Chemistry and Water Quality:** The chemistry of the water and the type of impurities present can influence the coagulant's performance. Different water conditions may require different dosages for optimal results.
v. **Agglomeration**: Coagulants work by causing particles to clump together (agglomerate). Beyond a certain dosage, excessive coagulant can lead to over-agglomeration or instability, negatively impacting removal efficiency.

It's important to carefully control and monitor the dosage to achieve the desired removal efficiency.

Conclusion

The assessment of various water quality parameters has unveiled significant improvements resulting from the application of coagulants and natural substances. While the initial pH of the water remained within an acceptable range, it was adversely affected by the addition of coagulants. Turbidity, electrical conductivity, alkalinity, hardness, nitrate, and fluoride levels initially exceeded permissible limits, reflecting poor water quality. However, the introduction of coagulants and natural substances, particularly at a dosage of 0.4 gm/500ml, displayed promising outcomes in reducing these parameters, with notable percentage reductions observed. The utilization of banana peels, papaya seeds, and lemon peels in water treatment has demonstrated their remarkable potential as sustainable and cost-effective approaches. Banana peels, enriched with coagulating polysaccharides and metal-complex forming polyphenols, enhance water clarity and heavy metal removal. Papaya seeds, with their proteolytic enzymes and antimicrobial properties, efficiently coagulate and remove organic matter and suspended particles. Their distinct functional groups, as revealed by FTIR analysis, further support their suitability for water treatment. These natural materials offer environmentally friendly and efficient solutions for water treatment, promoting cleaner and safer water sources. This research underscores the promising potential of utilizing bio-based resources for sustainable water purification and highlights the significance of exploring innovative and eco-friendly approaches in the field of water treatment.

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