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Evaluation Of Banana Peel As A Natural Coagulant For Wastewater Treatment

[1]Bhagyalaxmi Bilgundi, [2]Dr.Doddappa Appa Patil, [3]Dr Srinivas Kustagi, [4]S K Inganakal

[1]Student, [2]Assistant Professor, [3]Assistant Professor, [4]Assistant Professor

[1,2,3,4] Department of Civil Engineering,

[1,2,3,4] PDA College of Engineering, Kalaburagi, India

Abstract: Wastewater treatment is essential for protecting environmental quality and ensuring public health safety. Conventional chemical coagulants used in wastewater treatment are often associated with high operational costs, sludge generation, and environmental concerns. In recent years, natural coagulants derived from agricultural waste materials have gained significant attention due to their eco-friendly, biodegradable, and cost-effective nature. This study evaluates the effectiveness of banana peel as a natural coagulant for wastewater treatment applications. Banana peel powder was prepared and utilized in laboratory-scale jar test experiments to analyze its ability to reduce turbidity, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD) from wastewater samples. The effects of pH, coagulant dosage, and settling time on treatment efficiency were also investigated. Experimental observations revealed that banana peel powder effectively improved wastewater quality by removing suspended particles and organic pollutants. The study demonstrates that banana peel can serve as a sustainable and environmentally friendly alternative to conventional chemical coagulants. The utilization of banana peel not only enhances wastewater treatment efficiency but also promotes agricultural waste management and sustainable environmental practices.

Index Terms - Wastewater Treatment, Banana Peel, Natural Coagulant, Turbidity Removal, COD Reduction, Eco-Friendly Treatment.

I. INTRODUCTION

Water is one of the most essential natural resources required for the survival of human beings, animals, plants, and industrial activities. Rapid industrialization, urbanization, and population growth have significantly increased the demand for freshwater resources and simultaneously generated large quantities of wastewater. Wastewater generated from domestic, industrial, agricultural, hospital, and commercial activities contains suspended solids, organic pollutants, heavy metals, toxic chemicals, oils, grease, and pathogenic microorganisms. The discharge of untreated wastewater into rivers, lakes, ponds, and other natural water bodies causes serious environmental pollution and public health hazards.

Conventional wastewater treatment methods commonly involve physical, chemical, and biological treatment processes. Among these methods, coagulation and flocculation are widely used for removing turbidity and suspended particles from wastewater. Chemical coagulants such as alum and ferric chloride are highly effective; however, they are associated with several disadvantages including high operational cost, excessive sludge generation, environmental pollution, and possible health risks due to residual chemicals in treated water. These limitations have encouraged researchers to investigate sustainable and eco-friendly alternatives for wastewater treatment.

Natural coagulants derived from plant materials and agricultural wastes have gained considerable attention because of their biodegradable nature, low cost, and environmental compatibility. Various natural materials such as Moringa oleifera seeds, rice husk, tamarind seeds, cactus, and banana peel have demonstrated promising coagulation and adsorption properties for pollutant removal. Among these materials, banana peel has emerged as an effective natural coagulant due to its high cellulose, hemicellulose, lignin, and pectin content. Banana peel also contains hydroxyl and carboxyl functional groups that enhance adsorption and coagulation efficiency.

Banana peel is an agricultural waste material that is easily available and biodegradable. The utilization of banana peel for wastewater treatment not only improves water quality but also supports sustainable waste management practices. Banana peel powder has shown excellent capability in reducing turbidity, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and other pollutants from wastewater through adsorption and coagulation mechanisms.

The present study focuses on evaluating banana peel as a natural coagulant for wastewater treatment applications. Laboratory-scale jar test experiments are conducted to analyze the treatment efficiency of banana peel powder under different operating conditions such as dosage, pH, and settling time. The study aims to provide a sustainable, eco-friendly, and cost-effective alternative to conventional chemical coagulants for wastewater treatment.

II. LITERATURE REVIEW

S. Nimesha et al. (2022) reviewed the effectiveness of natural coagulants in wastewater treatment and reported that plant-based coagulants are sustainable alternatives to chemical coagulants because they produce less sludge and are environmentally friendly [1].

Sandly Maurya and Achlesh Daveray (2018) conducted experiments using plant-based natural coagulants and found that banana peel powder showed higher coagulation efficiency compared to other natural materials [2].

Fatombi et al. (2013) investigated natural coagulants for surface water treatment and concluded that plant-based materials effectively reduce turbidity and organic pollutants while minimizing chemical contamination [3].

Yin (2010) reviewed natural polymer-based coagulants and observed that biodegradable coagulants offer sustainable and low-cost wastewater treatment solutions suitable for developing countries [4].

Beltran-Heredia and Sanchez-Martin (2009) studied natural products as coagulants and reported that natural coagulants produce less toxic sludge and reduce environmental risks compared to alum-based treatment methods [5].

Sonal Choubey et al. (2014) investigated the removal of turbidity from wastewater using banana peel powder through adsorption technology and achieved approximately 95% turbidity removal under optimized conditions [6].

Thuraiya Mahir Al Khusaibi et al. (2017) evaluated banana peel as a natural adsorbent for dairy wastewater treatment and observed effective pollutant removal within a pH range of 6–8 [7].

Nikhitha T. (2024) evaluated banana peel powder as a natural coagulant for pond wastewater treatment and reported effective absorption of suspended pollutants and heavy metals from wastewater samples [8].

Ali et al. (2018) investigated agricultural waste adsorbents and identified banana peel as a promising material because of its porous structure and adsorption characteristics [9].

Pathak et al. (2015) reported that banana peel and other agricultural wastes are economical alternatives for pollutant removal from wastewater [10].

Abdassalam A. Azamzam et al. (2022) investigated modified banana peel bio-coagulant for wastewater treatment and achieved turbidity removal efficiency up to 90% [11].

Bhatnagar et al. (2010) reviewed agricultural waste-based adsorbents and highlighted banana peel as an effective adsorbent for dyes and heavy metals [12].

Memon et al. (2008) studied the adsorption of heavy metals using banana peel and reported effective removal of chromium and lead ions from wastewater [13].

Foo and Hameed (2012) reviewed adsorption processes using agricultural wastes and concluded that banana peel exhibits excellent adsorption efficiency because of its fibrous structure and surface area [14].

Annadurai et al. (2002) investigated dye adsorption using banana peel and demonstrated significant color removal from contaminated water samples [15].

The reviewed literature indicates that banana peel is an effective, low-cost, biodegradable, and eco-friendly natural coagulant suitable for wastewater treatment applications. Previous studies demonstrated significant removal of turbidity, suspended solids, COD, BOD, dyes, and heavy metals using banana peel powder. However, further studies are required for dosage optimization, large-scale implementation, and treatment efficiency analysis under different wastewater conditions.

III. OBJECTIVES OF THE STUDY

The main objective of this study is to evaluate the effectiveness of banana peel as a natural coagulant for wastewater treatment applications.
The specific objectives of the study are as follows:

- To evaluate the efficiency of banana peel powder in removing pollutants from wastewater.
- To determine the optimum dosage of banana peel powder required for effective treatment.
- To analyze the reduction of turbidity, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD).
- To study the effect of pH and settling time on coagulation efficiency.
- To compare the performance of banana peel coagulant with conventional chemical coagulants.
- To promote sustainable and eco-friendly wastewater treatment methods using agricultural waste materials.

IV. MATERIALS AND METHODOLOGY

A. Materials Used

The materials and equipment used in this study include wastewater samples, banana peels, distilled water, beakers, measuring cylinders, jar test apparatus, turbidity meter, pH meter, COD analysis kit, BOD bottles, weighing balance, filter paper, hot air oven, and grinder.

B. Collection of Wastewater Samples

Wastewater samples were collected from selected wastewater discharge locations and stored in clean containers for laboratory analysis. Proper precautions were taken during sample collection and preservation to avoid contamination before experimentation.

C. Preparation of Banana Peel Powder

Fresh banana peels were collected and washed thoroughly using distilled water to remove dust and impurities. The peels were cut into small pieces and dried under sunlight for several days. Further drying was carried out in a hot air oven to remove moisture content completely. The dried banana peels were ground into fine powder using a grinder and stored in airtight containers for further use.

Fig. 1. Preparation Process of Banana Peel Powder for Wastewater Treatment

D. Experimental Procedure

Jar test experiments were conducted to evaluate the coagulation efficiency of banana peel powder for wastewater treatment. Different dosages of banana peel powder were added to wastewater samples placed in beakers.

The treatment process involved the following steps:

• Rapid mixing for 2–3 minutes to ensure uniform distribution of the coagulant.

• Slow mixing for 15–20 minutes to promote floc formation.

• Settling of wastewater samples for approximately 30 minutes.

After settling, the supernatant water was collected carefully for further analysis.

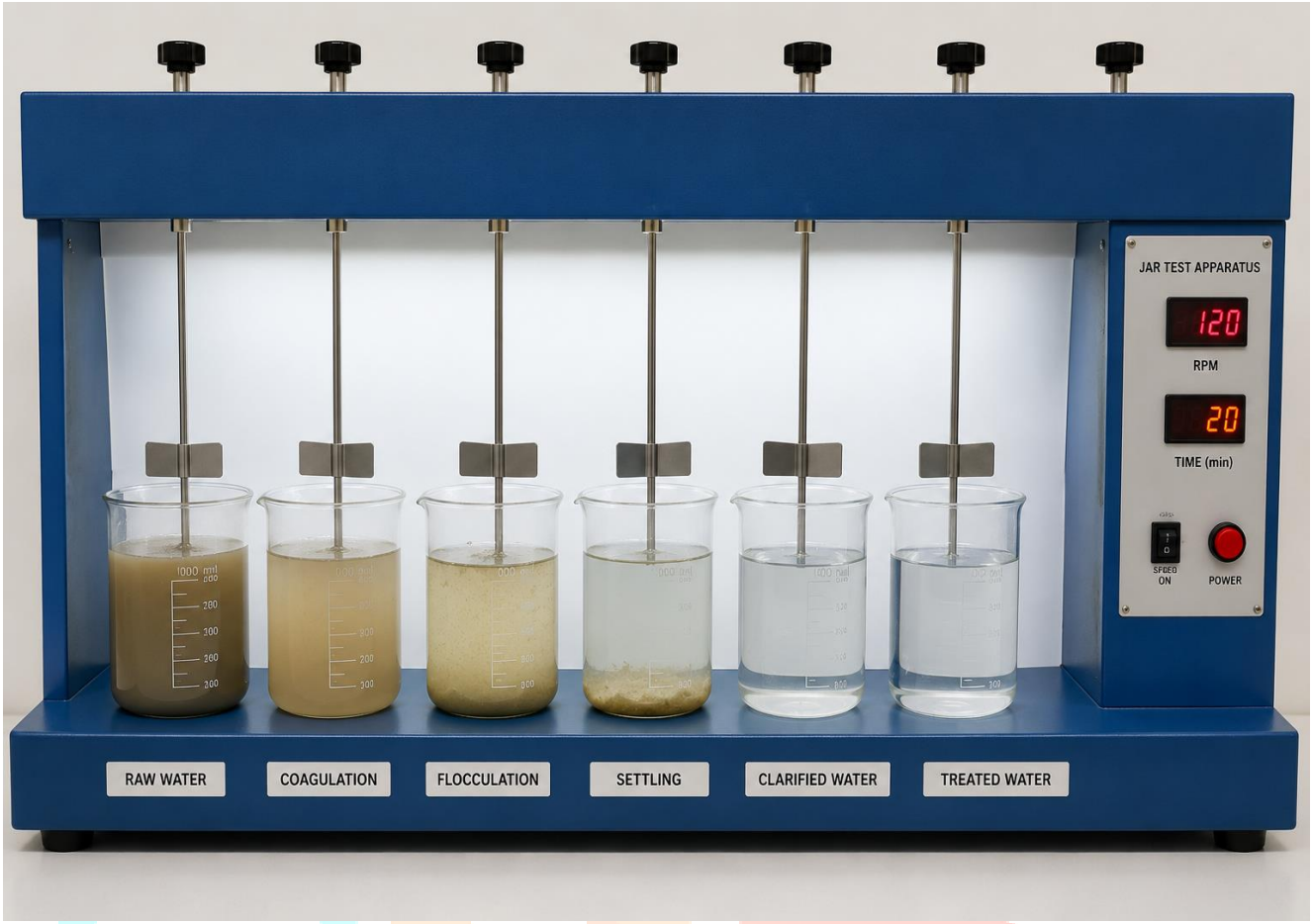

Fig. 2. Laboratory Jar Test Experimental Setup for Wastewater Treatment Analysis

E. Parameters Analyzed

The wastewater quality parameters analyzed before and after treatment include:

- Turbidity
- pH
- Total Suspended Solids (TSS)
- Chemical Oxygen Demand (COD)
- Biochemical Oxygen Demand (BOD)

F. Data Analysis

The treatment efficiency was evaluated by comparing the initial and final values of wastewater quality parameters. Percentage removal efficiency was calculated using standard analytical methods and graphical analysis was performed to study the effectiveness of banana peel as a natural coagulant.

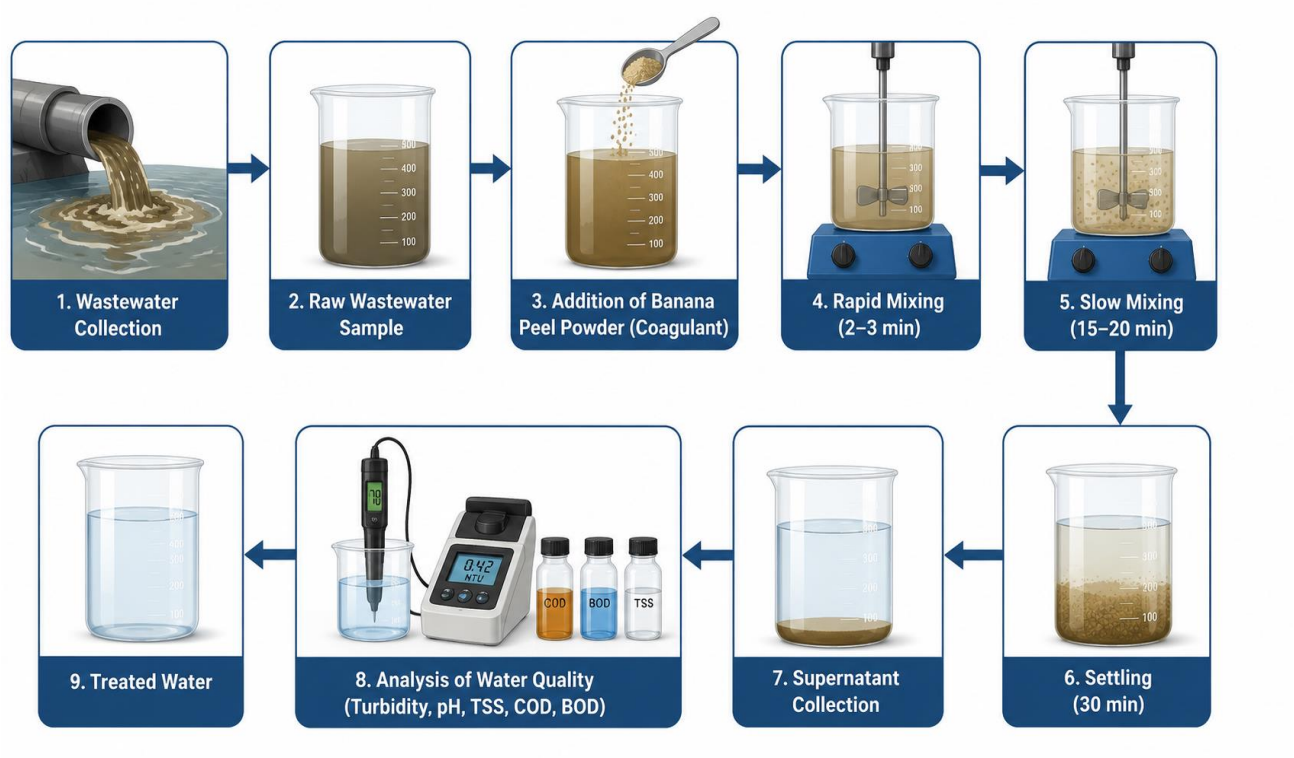

Fig. 3. Wastewater Treatment Process Flow Diagram Using Banana Peel Coagulant

V. RESULTS & DISCUSSION

The experimental analysis was carried out to evaluate the effectiveness of banana peel powder as a natural coagulant for wastewater treatment. The wastewater samples were analyzed before and after treatment to determine the reduction efficiency of various parameters such as turbidity, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD).

The results indicated that banana peel powder effectively removed suspended particles and organic pollutants from wastewater. The coagulation efficiency increased gradually with increase in banana peel dosage up to the optimum level. Beyond the optimum dosage, the treatment efficiency slightly decreased due to particle restabilization.

A significant reduction in turbidity was observed after treatment. The treated wastewater became visibly clearer due to the formation and settling of flocs during the coagulation and flocculation process. The removal of suspended solids demonstrated the excellent adsorption capability of banana peel powder.

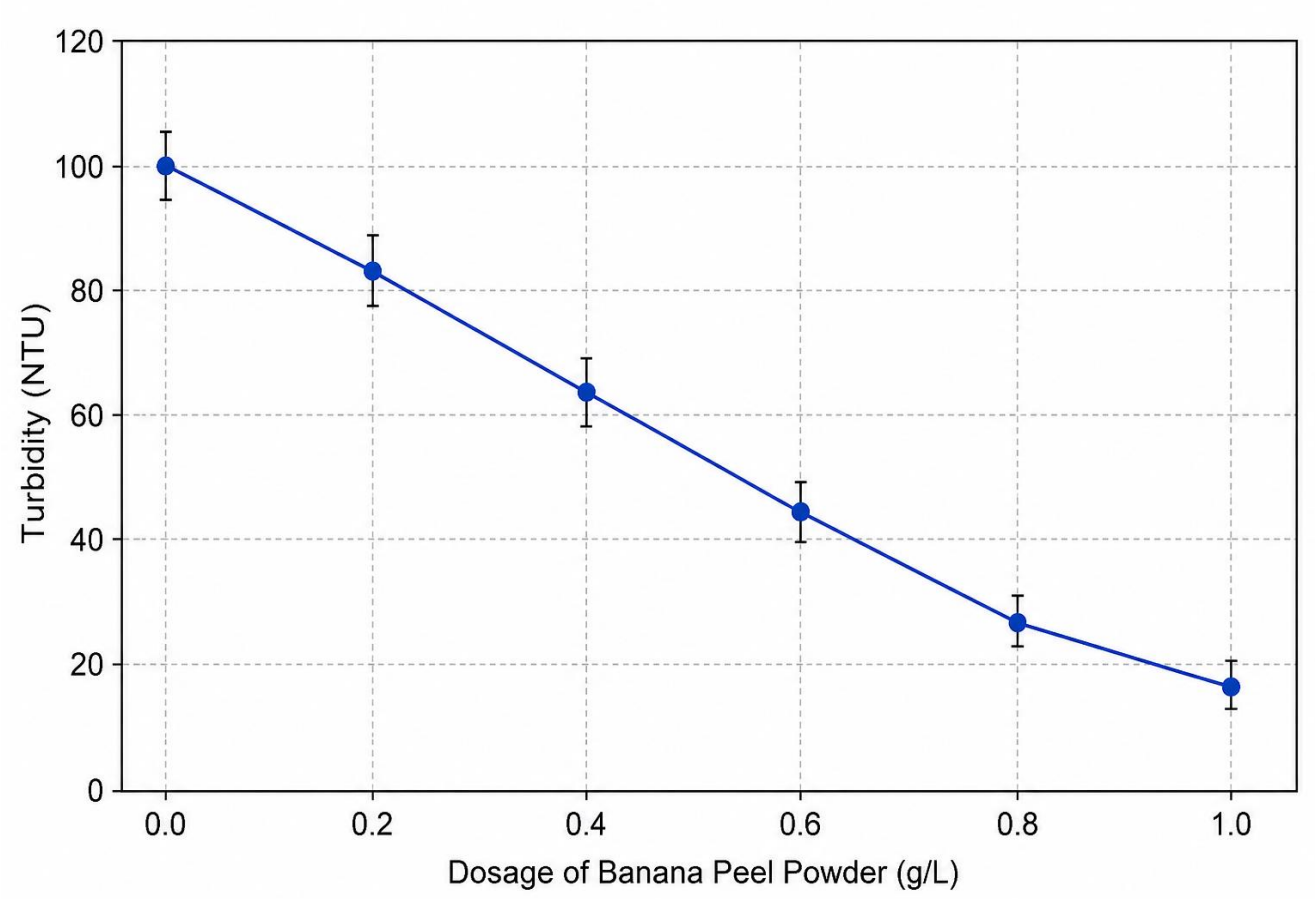

Fig. 4. Turbidity Reduction in Wastewater Using Banana Peel Powder at Different Dosages

The study also showed effective reduction in TSS, COD, and BOD values. The decrease in COD and BOD indicates the removal of biodegradable and organic pollutants from wastewater samples. The presence of cellulose, lignin, hemicellulose, and active functional groups such as hydroxyl and carboxyl groups in banana peel contributed to enhanced adsorption and coagulation performance.

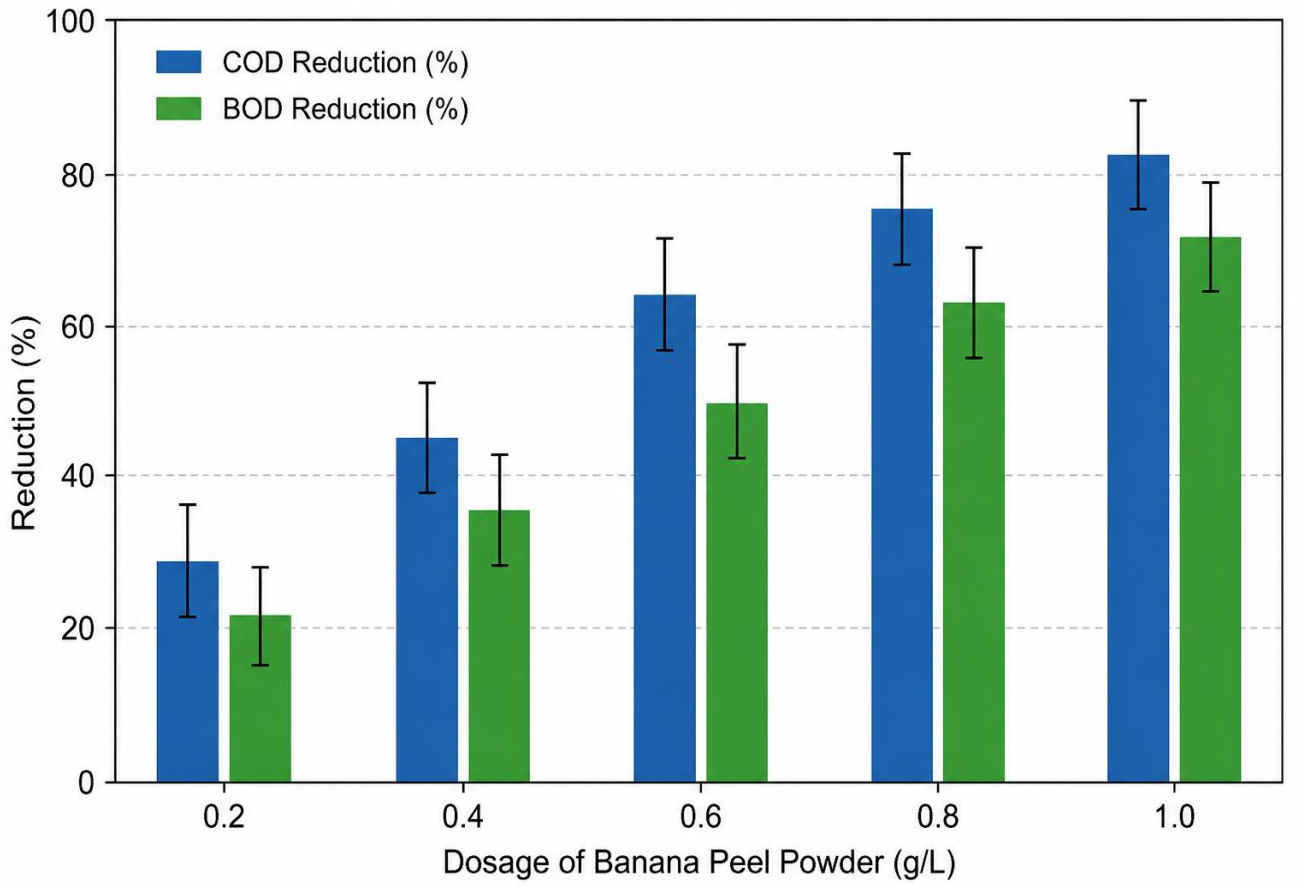

Fig. 5. Comparison of COD and BOD Reduction Efficiency Using Banana Peel Powder at Different Dosages

The pH of treated wastewater remained within acceptable limits, indicating that banana peel powder does not significantly alter water chemistry compared to conventional chemical coagulants. This makes banana peel an environmentally friendly treatment material suitable for sustainable wastewater management applications.

The experimental observations confirmed that banana peel powder can serve as an effective, low-cost, biodegradable, and eco-friendly natural coagulant for wastewater treatment.

Table 5.1: Typical Wastewater Parameters Before and After Treatment

Parameter	Before Treatment	After Treatment	Removal Efficiency
Turbidity	**220 NTU**	**45 NTU**	**79.5%**
TSS	**310 mg/L**	**95 mg/L**	**69.3%**
COD	**480 mg/L**	**180 mg/L**	**62.5%**
BOD	**260 mg/L**	**90 mg/L**	**65.4%**
PH	**7.8**	**7.1**	**Stable**

The obtained results are consistent with previous research studies that reported effective pollutant removal using banana peel-based natural coagulants. The treatment process also supports agricultural waste utilization and promotes sustainable environmental management practices.

VI. ADVANTAGES OF BANANA PEEL AS A NATURAL COAGULANT

- Banana peel is biodegradable and environmentally friendly.
- It is a low-cost and easily available agricultural waste material.
- Banana peel produces less sludge compared to chemical coagulants.
- It effectively reduces turbidity, TSS, COD, and BOD from wastewater.
- It does not significantly alter the pH of treated water.
- It supports sustainable waste management and resource utilization.
- It is suitable for rural and decentralized wastewater treatment applications.
- It reduces dependency on conventional chemical coagulants.

VII. APPLICATIONS OF BANANA PEEL COAGULANT

- Domestic wastewater treatment
- Industrial wastewater treatment
- Pond and lake water purification
- Rural water treatment systems
- Agricultural wastewater treatment
- Eco-friendly water purification systems
- Sustainable environmental management applications

VIII. CONCLUSION

The present study evaluated banana peel as a natural coagulant for wastewater treatment applications. Experimental analysis demonstrated that banana peel powder effectively reduced turbidity, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD) from wastewater samples. The coagulation efficiency increased with dosage and showed significant pollutant removal capability under optimized conditions.

The study confirmed that banana peel is an eco-friendly, biodegradable, low-cost, and sustainable alternative to conventional chemical coagulants. The utilization of agricultural waste materials such as banana peel not only improves wastewater treatment efficiency but also promotes sustainable waste management and environmental protection.

Therefore, banana peel powder can be considered a promising natural coagulant for small-scale and decentralized wastewater treatment systems.

IX. FUTURE SCOPE

- Large-scale implementation of banana peel coagulant in wastewater treatment plants.

- Development of modified banana peel bio-adsorbents for enhanced pollutant removal.

- Combination of banana peel with activated carbon and nanomaterials for improved treatment efficiency.

- Investigation of heavy metal and dye removal efficiency using banana peel powder.

- Application of banana peel coagulant in industrial wastewater treatment systems.

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