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Sustainable Water Treatment: Utilizing Banana Peel Extract as a Natural Coagulant

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ABSTRACT: The need for sustainable water treatment solutions has become increasingly urgent due to the rising concerns about environmental pollution and resource depletion. Conventional methods, while effective, often rely on synthetic chemicals that may have adverse environmental impacts. This research explores the potential of banana peel extract as a natural coagulant for water treatment, offering a sustainable and cost-effective alternative. Banana peels, a commonly discarded agricultural by-product, are rich in polysaccharides and other active compounds that can enhance coagulation and flocculation processes. This paper presents a comprehensive analysis of banana peel extract's effectiveness in removing turbidity and contaminants from water, compares its performance with conventional coagulants, and discusses its environmental and economic benefits.

I. INTRODUCTION

Background

Water scarcity and pollution are pressing global issues that necessitate innovative and sustainable solutions. Traditional water treatment methods, such as chemical coagulation, often involve synthetic coagulants like alum or ferric chloride. While effective, these chemicals can lead to secondary pollution and increased operational costs. As a result, there is a growing interest in natural coagulants derived from agricultural by-products. Banana peels, often discarded as waste, have been identified as a promising candidate due to their natural coagulation properties.

Objectives

This research aims to:

1. **Evaluate the Coagulation Performance:** Assess the effectiveness of banana peel extract in removing turbidity and contaminants from water.
2. **Optimize Extraction and Dosage:** Determine the optimal extraction method and concentration of banana peel extract for maximum coagulation efficiency.
3. **Compare with Conventional Coagulants:** Compare the performance of banana peel extract with traditional chemical coagulants in terms of turbidity reduction and overall treatment efficiency.
4. **Assess Environmental and Economic Impact:** Analyse the environmental benefits and cost-effectiveness of using banana peel extract as a natural coagulant.

II. LITERATURE REVIEW

Water Treatment Challenges

Contaminants in Water

Water sources often contain a range of contaminants, including suspended solids, organic matter, microorganisms, and heavy metals. Effective treatment is crucial to ensure safe and clean water. Conventional methods like coagulation-flocculation, filtration, and disinfection are commonly employed but may have limitations in terms of environmental impact and cost.

Conventional Coagulants

1. **Alum:** Aluminium sulphate is a widely used coagulant that effectively reduces turbidity and suspended solids. However, it generates aluminium sludge and can lead to residual aluminium in treated water, which may have health implications.

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2. **Ferric Chloride:** Ferric chloride is another common coagulant, effective in turbidity reduction and heavy metal removal. Its use, however, is associated with higher operational costs and potential environmental issues.

Natural Coagulants

Natural coagulants are derived from plant materials and offer several advantages, including biodegradability, cost-effectiveness, and reduced environmental impact. Notable examples include:

1. **Moringa Oleifera:** Extracts from moringa seeds are known for their coagulation properties and effectiveness in turbidity reduction.
2. **Okra:** Okra mucilage has been explored for its coagulating and flocculating abilities.
3. **Cactus Opuntia:** Cactus mucilage is used for water purification due to its natural coagulation and flocculation properties.

Banana Peel Extract

Composition

Banana peels are rich in polysaccharides, including pectin, hemicellulose, and cellulose, which contribute to their coagulation properties. They also contain natural antioxidants and other bioactive compounds that can enhance their effectiveness as coagulants.

Previous Studies

1. **Ghosh et al. (2016)** investigated the use of banana peel extract for turbidity removal and reported promising results.
2. **Kumar et al. (2018)** explored the coagulation potential of banana peel in comparison with synthetic coagulants and highlighted its efficiency and sustainability.

III. METHODOLOGY

Materials

Banana Peel Preparation

1. **Collection:** Banana peels were collected from local markets and thoroughly washed to remove contaminants.
2. **Drying and Grinding:** Peels were dried in a shaded area and ground into a fine powder. The powder was used for extracting the coagulant.

Extraction Process

1. **Extraction Method:** The coagulant was extracted using different solvents, including distilled water and ethanol, to determine the most effective extraction method.
2. **Preparation of Extracts:** Extracts were prepared at various concentrations (0.5%, 1%, 1.5%) for use in coagulation experiments.

Water Samples

1. **Source:** Raw water samples were obtained from a local river and characterized for turbidity, pH, and other parameters.
2. **Contaminants:** Water samples were spiked with synthetic contaminants to simulate industrial wastewater conditions.

Experimental Procedure

Coagulation-Flocculation Tests

1. **Jar Test Apparatus:** Coagulation experiments were conducted using a jar test apparatus to simulate real-world conditions.
2. **Procedure:** Water samples were treated with banana peel extract at different concentrations. The process included rapid mixing, flocculation, and sedimentation.

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Performance Measurement

1. **Turbidity Measurement:** Turbidity was measured using a turbidity meter to assess the clarity of treated water.
2. **pH Analysis:** The pH of water samples was monitored to ensure optimal coagulation conditions.
3. **Chemical Oxygen Demand (COD):** COD was analyzed to evaluate the reduction of organic matter.
4. **Suspended Solids:** The concentration of suspended solids was quantified to determine the effectiveness of coagulation.

Comparison with Conventional Coagulants

1. **Control Coagulants:** Alum and ferric chloride were used as control coagulants for comparison.
2. **Performance Metrics:** The effectiveness of banana peel extract was compared with conventional coagulants in terms of turbidity reduction, COD, and suspended solids removal.

IV. RESULTS

Coagulation Performance of Banana Peel Extract

Turbidity Reduction

1. **Effectiveness:** Banana peel extract demonstrated significant turbidity reduction, with a maximum of 65% reduction observed at a concentration of 1 g/L. This performance was comparable to conventional coagulants, which achieved up to 70% turbidity reduction.
2. **Dosage Optimization:** The optimal concentration for maximum turbidity removal was found to be 1 g/L. Higher concentrations did not significantly improve performance and may lead to increased sludge production.

Chemical Oxygen Demand (COD) Reduction

1. **Reduction Efficiency:** The COD reduction using banana peel extract was around 50% at 1 g/L concentration. This reduction was slightly lower compared to conventional coagulants, which achieved up to 60% COD reduction.
2. **Impact of Dosage:** The COD reduction improved with increasing concentration up to the optimal level, beyond which the benefits plateaued.

Suspended Solids Removal

1. **Effectiveness:** The removal of suspended solids using banana peel extract was effective, with a reduction of approximately 55% at 1 g/L concentration. Conventional coagulants showed slightly higher removal efficiencies, reaching up to 60%.
2. **Optimal Dosage:** Similar to turbidity removal, the optimal dosage for suspended solids removal was 1 g/L.

Comparison with Conventional Coagulants

Alum

1. **Performance:** Alum achieved higher removal efficiencies for turbidity, COD, and suspended solids compared to banana peel extract.
2. **Environmental Impact:** While alum is effective, its use results in the production of aluminium sludge and potential environmental concerns related to residual aluminium.

Ferric Chloride

1. **Performance:** Ferric chloride demonstrated comparable performance to alum, with high removal efficiencies for turbidity, COD, and suspended solids.
2. **Cost and Environmental Impact:** Ferric chloride is more expensive and can pose environmental risks due to its chemical composition.

V. DISCUSSION

Effectiveness of Banana Peel Extract

Banana peel extract proved to be an effective natural coagulant, demonstrating substantial reductions in turbidity, COD, and suspended solids. The results suggest that banana peels can serve as a sustainable and cost-effective alternative to

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synthetic coagulants. The coagulation efficiency of banana peel extract is influenced by factors such as concentration, pH, and water characteristics. Optimizing these parameters is crucial for maximizing the effectiveness of the coagulant.

Environmental and Economic Benefits

Environmental Sustainability

1. **Biodegradability:** Banana peel extract is biodegradable and does not contribute to secondary pollution, unlike synthetic coagulants.
2. **Resource Utilization:** Utilizing banana peels, an agricultural by-product, promotes waste reduction and resource efficiency.

Economic Considerations

1. **Cost-Effectiveness:** Banana peel extract is cost-effective, especially when sourced locally. Its use can lower treatment costs and provide an economically viable alternative to expensive chemical coagulants.
2. **Operational Efficiency:** While banana peel extract may not match the performance of conventional coagulants in all aspects, its benefits in terms of sustainability and cost make it an attractive option.

Comparison with Conventional Coagulants

1. **Performance Trade-Offs:** Although banana peel extract may not achieve the same level of performance as conventional coagulants, its environmental and economic advantages make it a viable alternative.
2. **Application Potential:** Banana peel extract can be used in conjunction with other treatment methods or coagulants to enhance overall treatment efficiency.

Future Research Directions

1. **Optimization Studies:** Further research should focus on optimizing the extraction process and dosage of banana peel extract to improve its performance in various water treatment scenarios.
2. **Scalability:** Investigating the scalability of banana peel extract for large-scale water treatment systems is essential for practical applications.
3. **Long-Term Performance:** Long-term studies are needed to assess the durability and effectiveness of banana peel extract in diverse environmental conditions.

VI. CONCLUSION

The study demonstrates that banana peel extract is an effective and sustainable natural coagulant for water treatment. Its ability to reduce turbidity, COD, and suspended solids highlights its potential as a cost-effective alternative to conventional chemical coagulants. The environmental and economic benefits of using banana peel extract underscore its value in promoting sustainable water treatment practices. Future research and development efforts should focus on optimizing its use and exploring its application in various water treatment contexts.

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