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# Wastewater Treatment Using Adsorbents: Combining Rice Husk and Zeolite

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***Abstract:*** In response to the growing global concern over water pollution, this study investigates the potential of rice husk and zeolite as low-cost, sustainable adsorbents for wastewater treatment. Rice husk, an abundant agricultural waste product, and zeolite, a naturally occurring aluminosilicate mineral, were evaluated for their effectiveness in removing a variety of contaminants from wastewater, including heavy metals, organic compounds, and excess nutrients. The research focused on optimizing several critical parameters such as pH, temperature, contact time, and adsorbent dose through batch adsorption experiments. The results revealed that rice husk demonstrated significant potential for removing organic pollutants, while zeolite exhibited excellent efficiency in adsorbing metal ions through ion-exchange mechanisms. Comparative studies showed that the combined use of these two materials led to enhanced adsorption capacities, outperforming individual materials in terms of contaminant removal. Additionally, the materials were found to be environmentally friendly, cost-effective, and capable of being sourced locally, thus offering a sustainable solution for wastewater treatment in developing regions. The findings highlight the importance of utilizing agricultural waste and naturally available minerals as viable alternatives to traditional treatment methods, contributing to both environmental conservation and the reduction of industrial treatment costs. This study underscores the potential of rice husk and zeolite as a practical solution to address the growing challenges of wastewater management.

***Index Terms* - Zeolite, Rice Husk, Adsorption, Wastewater Treatment, Sustainable Remediation**

## 1. INTRODUCTION

Water pollution is one of the most pressing environmental challenges today, driven by industrial, agricultural, and domestic activities that release contaminants into natural water bodies. The increasing demand for clean water, coupled with the depletion of freshwater resources, has made efficient wastewater treatment a necessity. Conventional treatment methods, while effective, often involve high operational costs, complex chemical processes, and energy-intensive technologies that may not be sustainable for widespread use, especially in resource-limited areas. This has led to a growing interest in low-cost and eco-friendly alternatives for wastewater remediation.

Adsorption has emerged as a promising technique due to its simplicity, efficiency, and cost-effectiveness. Among various natural adsorbents, agricultural byproducts and mineral-based materials have gained attention for their ability to remove a wide range of pollutants. Rice husk, a readily available agricultural waste, contains high amounts of silica and lignocellulosic compounds, making it a potential adsorbent for organic and inorganic contaminants. Similarly, zeolite, a naturally occurring aluminosilicate mineral, possesses a high ion-exchange capacity and microporous structure, enabling the removal of heavy metals and dissolved impurities.

This study explores the combined use of rice husk and zeolite as adsorbents for municipal wastewater treatment. By optimizing key parameters such as adsorbent dosage, pH, and contact time, the research aims to evaluate their efficiency in removing turbidity, total dissolved solids (TDS), chlorides, sulphates, and other pollutants. The results of this study will provide insights into the feasibility of using these locally available and sustainable materials as an alternative to conventional wastewater treatment methods, contributing to environmental conservation and cost-effective water management solutions.

## 2. NEED OF THE STUDY.

### 2.1 Environmental Concerns and Water Pollution

Industrialization and population growth have led to increased discharge of pollutants (heavy metals, dyes, organic contaminants) into water bodies. Conventional treatment methods are often expensive and may not completely remove all contaminants. Adsorption is a promising alternative due to its simplicity, efficiency, and low cost.

### 2.2 Advantages of Rice Husk as an Adsorbent

Abundant agricultural waste: Rice husk is readily available in rice-producing countries. Low-cost and biodegradable: It's a cheap, renewable resource that also addresses the problem of agro-waste disposal. Rich in silica and lignin: This provides good adsorption properties for heavy metals, dyes, and other contaminants. Surface area and functional groups can be enhanced through treatments (carbonization, activation).

### 2.3 Benefits of Zeolite as an Adsorbent

Naturally occurring mineral with a porous structure, high surface area, and ion-exchange capacity. Selective adsorption: Effective for removing heavy metals ($Pb^{2+}$, $Zn^{2+}$, $Cu^{2+}$, etc.), ammonia, and certain organic compounds. Reusability and stability: Zeolites can be regenerated and reused with minimal performance loss.

### 2.4 Synergistic Use of Rice Husk and Zeolite

Combining bio-based (rice husk) and mineral-based (zeolite) adsorbents could enhance overall performance. Potential for hybrid materials with improved efficiency, selectivity, and capacity.

### 2.5 Sustainability and Circular Economy

Promotes **waste valorization** (using waste to treat waste). Supports **green chemistry** and **sustainable development goals** (especially SDG 6: Clean Water and Sanitation). Reduces dependence on expensive synthetic adsorbents or chemicals.

## 3. RESEARCH METHODOLOGY

### 3.1 Selection of Adsorbents

Rice husk and zeolite were selected as adsorbents for wastewater treatment due to their natural abundance, cost-effectiveness, and proven adsorption capabilities.

Rice husk, an agricultural by-product, is widely available and often underutilized, making it an eco-friendly and economical choice for adsorption applications. It has a high silica content, which enhances its ability to remove contaminants from wastewater. Additionally, its porous structure and surface functional groups contribute to efficient adsorption of heavy metals and organic pollutants. Utilizing rice husk for wastewater treatment also promotes waste recycling, reducing environmental pollution.

Zeolite, a naturally occurring aluminosilicate mineral, is well known for its high ion-exchange capacity, microporous structure, and strong affinity for a variety of pollutants, including heavy metals and ammonium ions. Its stability, reusability, and effectiveness in removing contaminants make it a valuable material for wastewater treatment.

The combination of rice husk and zeolite leverages their complementary properties to enhance the overall adsorption efficiency. Their availability, low cost, and environmental benefits make them suitable for large-scale and sustainable wastewater treatment applications.

### 3.2 Collection of Wastewater Sample

The wastewater sample for the experimental study was collected from the Sewage Treatment Plant (STP) located in Manjapalam, Kannur, Kerala. This location was selected for its relevance to the study, as it provides wastewater that reflects typical conditions found in such treatment facilities. To ensure the quality and integrity of the sample, a total volume of 15 liters of wastewater was collected. The wastewater was carefully gathered in sterilized plastic containers to prevent any contamination that could affect the results of the analysis. After collection, the samples were immediately stored at a temperature of 4°C. This low temperature was maintained to preserve the chemical and biological characteristics of the wastewater, preventing any alterations or degradation before the experiments were conducted.

### 3.3 Characterization of Wastewater

Table 1 Characterization of Wastewater

| Parameter | Value | Permissible limit |
|---|---|---|
| Turbidity | 570 NTU | 5 – 10 NTU |
| TDS | 924 mg/L | 500 mg/L |
| pH | 5.2 | 6.5 – 8.5 |
| Chlorides | 413.95 mg/L | 250 mg/L |
| Sulphates | 387 mg/L | 250 mg/L |

### 3.4 Preparation of Adsorbents

The preparation of adsorbents begins with the rice husk. The rice husk is collected from local mills, ensuring that the material is sourced fresh and free from contaminants. After collection, the husks are thoroughly washed using distilled water to eliminate any dust, dirt, or foreign impurities that may interfere with the adsorption process. Once cleaned, the rice husk is dried at a controlled temperature of 60–80°C for a full 24 hours. This drying process ensures that any residual moisture is removed, preparing the material for further processing. To maximize the surface area of the rice husk for efficient adsorption, the dried husk is then ground into a fine powder. The fine particle size enhances the surface area, which is crucial for improving its effectiveness as an adsorbent.

Similarly, the preparation of zeolite starts with sourcing the material from natural deposits, where it is typically found in volcanic rocks. Like the rice husk, the zeolite is washed thoroughly to remove any impurities, ensuring that only the pure form of the material is used. After washing, the zeolite is dried at a higher temperature of 105°C for 24 hours to ensure that all moisture is eliminated. This step is critical as moisture can hinder the adsorption capabilities of the zeolite. In some cases, depending on the initial particle size, the zeolite is ground further to improve its adsorption efficiency. By reducing the particle size, the surface area of the zeolite is increased, which enhances its capacity to adsorb substances effectively.

**3.5 Experimental Studies**

Experimental studies were carried out to investigate the adsorption efficiency by varying key parameters. One of the parameters examined was the adsorbent dosage. Different amounts of adsorbent were tested, ranging from 2g, 4g, 6g, 8g, and 10g per Litre of wastewater, to assess how the quantity of adsorbent influences the removal of contaminants. The aim was to identify the optimal dosage at which the highest adsorption capacity is achieved.

Another critical factor in the experiments was the contact time, which was varied in intervals of 10 minutes until the system reached equilibrium. The purpose of this variation was to observe the time-dependent adsorption process and determine how long the adsorbents need to effectively remove contaminants from the wastewater. The equilibrium point was identified as the time at which no significant increase in adsorption occurred.

Additionally, the study investigated the impact of different adsorbent combinations. The experiments tested rice husk alone, zeolite alone, and a 1:1 blend of both adsorbents to determine how each material, as well as the combination, performed in terms of adsorption efficiency. This allowed for a comparison of the individual and combined effects of rice husk and zeolite on the removal of pollutants from wastewater.

## 4. RESULTS AND DISCUSSION

### 4.1 Effect of Adsorbent Dosage

The effect of adsorbent dosage was evaluated by conducting experiments with varying dosages of 2g/L, 4g/L, 6g/L, 8g/L, and 10g/L using rice husk, zeolite, and a combined adsorbent. The results indicated that 8g/L was the optimum dosage for all three adsorbents, as further increases did not significantly improve removal efficiency. This suggests saturation of adsorption sites, where additional adsorbent remained underutilized. Maintaining the optimum dosage ensures effective adsorption while minimizing material wastage.

For rice husk and zeolite, removal efficiency initially increased with dosage but plateaued beyond 8g/L, indicating saturation. The combined adsorbent, integrating the properties of both materials, also exhibited an optimum dosage at 8g/L, balancing adsorption capacity and material efficiency.

### 4.2 Effect of pH

To analyse the effect of pH on removal efficiency, the pH was maintained at 6 by adding NaOH tablets into the wastewater sample. At this optimum dosage of 8g/L, the removal efficiency for rice husk was 97.54%, indicating that it performed well under slightly acidic conditions. Zeolite achieved 99.47% efficiency at this pH, demonstrating its superior adsorption capability in neutral conditions. The combined adsorbent reached 100% efficiency, suggesting a synergistic effect that maximized contaminant removal. The pH value played a crucial role in determining adsorption efficiency, as deviations from this optimal level could lead to either reduced adsorption or desorption effects.

### 4.3 Effect of Contact Time

The adsorption process was studied over a range of contact times while maintaining a dosage of 8g/L and pH 6. For rice husk, the removal efficiency increased with contact time, reaching maximum efficiency at 130 minutes. Beyond this duration, desorption effects were observed, causing a decline in efficiency. Zeolite required a slightly longer contact time of 140 minutes for optimal removal, after which desorption set in. The combined adsorbent achieved its highest removal efficiency at 120 minutes, showing a quicker adsorption equilibrium compared to the individual adsorbents. These results indicate that contact time is a critical parameter, as insufficient time leads to incomplete adsorption, while excessive contact results in desorption and reduced efficiency.

**4.4 Removal Efficiency**

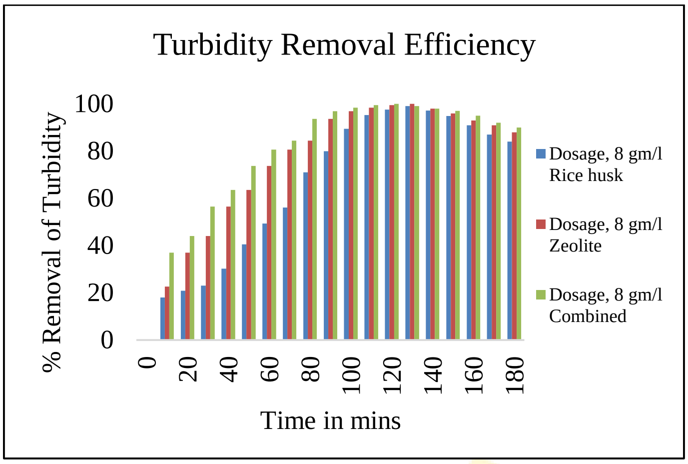


Fig 1 Turbidity Removal Efficiency.

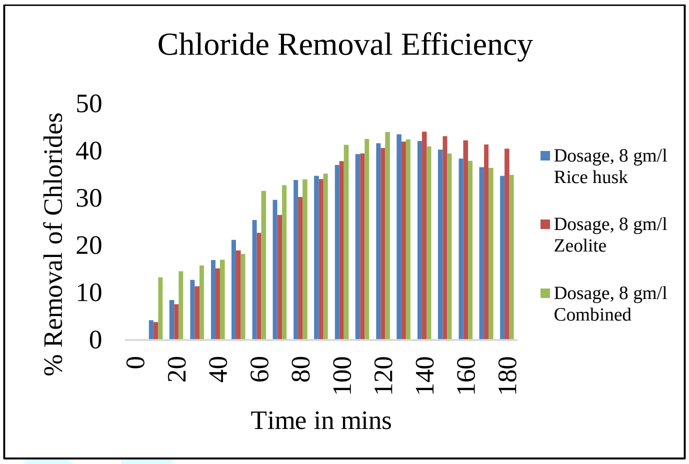


Fig 2 Chlorides Removal Efficiency.

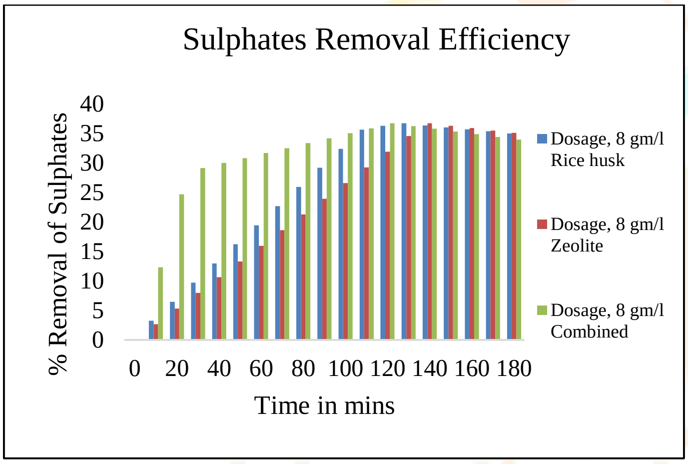


Fig 3 Sulphates Removal Efficiency.

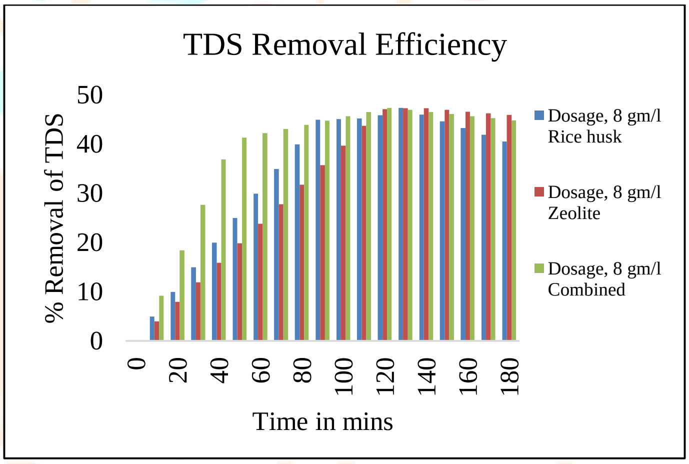


Fig 4 TDS Removal Efficiency.

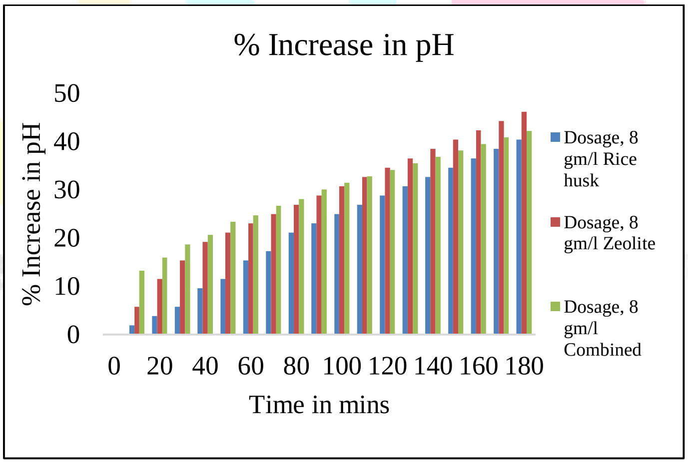


Fig 5 Percentage Increase in pH

**5. CONCLUSION**

This study investigated the use of rice husk and zeolite as low-cost and sustainable adsorbents for wastewater treatment. The experimental findings highlighted their efficiency in removing pollutants under optimized conditions. Rice husk was effective in removing organic contaminants, while zeolite exhibited strong adsorption for metal ions. Their combination in a 1:1 ratio further enhanced pollutant removal efficiency.

The study determined the optimal conditions for adsorption, with an adsorbent dosage of 8g/L, pH 6, and an equilibrium contact time of 120–140 minutes, depending on the adsorbent used. Under these conditions, rice husk achieved 97.54% removal efficiency, zeolite 99.47%, and the combined adsorbent 100%, confirming the effectiveness of their combined application.

These results demonstrate that rice husk and zeolite can serve as efficient and environmentally friendly alternatives to conventional treatment methods. Their availability and cost-effectiveness make them viable options for wastewater remediation, particularly in resource-limited settings. Future research should focus on large-scale applications, adsorbent regeneration, and long-term environmental impacts to enhance their practical feasibility in wastewater treatment systems.

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