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Preparation Of Activated Carbon For Treatment Of Waste Water From Various Sources

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Abstract - Freshwater resources are limited and increasingly threatened by contamination from industrial, agricultural, and domestic activities. Among various pollutants, heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) are of major concern due to their toxic, non-biodegradable nature and their tendency to accumulate in living organisms. In this study, activated carbon was prepared from low-cost and locally available biomass materials such as neem bark, mango bark, coconut shell, and rudraksha. A screening study was conducted under identical experimental conditions to evaluate and compare the adsorption efficiency of these adsorbents for the removal of heavy metals and other water quality parameters. The results indicated that neem-based activated carbon exhibited superior performance due to its higher surface area and adsorption capacity.

Based on the screening results, neem activated carbon was selected for further optimization studies. Key parameters such as pH, adsorbent dosage, contact time, agitation speed, and temperature were optimized to achieve maximum removal efficiency. The optimized conditions were then applied to real water samples collected from Gudlavalleru, Gudivada, Machilipatnam, and Vijayawada, including both groundwater and surface water. Significant reductions in heavy metals and parameters such as total hardness, chlorides, sulphates, TDS, and TSS were observed after treatment. Kinetic studies revealed that the adsorption process follows pseudo-second-order kinetics, indicating chemisorption as the dominant mechanism. The study concludes that neem-based activated carbon is an efficient, cost-effective, and sustainable solution for wastewater treatment.

KEY WORDS

Activated Carbon, Heavy Metals, Adsorption, Wastewater Treatment, Neem Biomass, Low-Cost Adsorbents, Optimization, Kinetics Study, Water Qualit

1. INTRODUCTION

Water is one of the most essential natural resources, yet its quality is increasingly threatened by rapid industrialization, urbanization, and agricultural activities. Among various pollutants, heavy metals such as lead, cadmium, chromium, and mercury are of particular concern due to their toxic, non-biodegradable nature and their ability to accumulate in living organisms. Even at low concentrations, these metals can cause severe health issues including neurological disorders, kidney damage, and carcinogenic effects. Conventional methods for removing heavy metals, such as chemical precipitation, ion exchange, and membrane filtration, often involve high operational costs, generation of secondary pollutants, and complex operational requirements. Therefore, the development of efficient, economical, and sustainable treatment methods is essential for ensuring safe water quality.

In recent years, adsorption using activated carbon has emerged as one of the most effective techniques for water purification due to its high surface area, porous structure, and strong affinity towards a wide range of contaminants. Moreover, the use of low-cost biomass materials for the preparation of activated carbon has gained significant attention, as it offers a sustainable and eco-friendly alternative to commercial adsorbents. Agricultural and natural wastes such as neem bark, mango bark, coconut shell, and rudraksha have shown promising adsorption capabilities, making them suitable candidates for wastewater treatment applications. However, limited studies are available that compare the performance of different biomass-derived activated carbons under identical experimental conditions and evaluate their effectiveness for real water samples.

The objective of the present study is to prepare and evaluate activated carbon derived from various locally available biomass materials for the removal of heavy metals and other water quality parameters. A comparative screening study is conducted to identify the most efficient adsorbent, followed by optimization of key parameters such as pH, adsorbent dosage, contact time, agitation speed, and temperature. Furthermore, the optimized adsorbent is applied to real water samples collected from different locations to assess its practical applicability. The study also includes kinetic analysis to understand the adsorption mechanism. The main contributions of this work are: (i) development of low-cost activated carbon from biomass sources, (ii) systematic comparison of multiple adsorbents under uniform conditions, and (iii) evaluation of optimized adsorption performance for real-world water treatment applications.

2. LITERATURE REVIEW

The removal of heavy metals from water has been widely studied due to their toxic and non-biodegradable nature. Conventional treatment methods such as chemical precipitation, ion exchange, and membrane filtration are effective but often involve high cost and operational complexity. As a result, adsorption has emerged as a preferred method due to its simplicity, efficiency, and cost-effectiveness.

Activated carbon is one of the most widely used adsorbents because of its high surface area and porous structure. Previous studies have shown that activated carbon prepared from low-cost biomass materials can effectively remove heavy metals such as lead, cadmium, and chromium. Researchers have also reported that adsorption efficiency depends on parameters such as pH, contact time, dosage, and temperature, and the process often follows pseudo-second-order kinetics.

However, most studies focus on a single adsorbent or controlled laboratory conditions. Limited research is available on the comparative performance of different biomass-based activated carbons under identical conditions and their application to real water samples. Therefore, this study aims to evaluate and compare multiple low-cost activated carbons and assess their practical applicability in water treatment.

3. MATERIALS AND METHODS

3.1 Experimental Setup and Materials The experimental study was carried out using contaminated water samples prepared with heavy metals and other water quality parameters. Activated carbon was developed from locally available biomass materials including neem bark, mango bark, rudraksha bark, and coconut shell. Commercial activated carbon was also used for comparison.The experiments were conducted in batch mode using conical flasks with a fixed volume of 200 ml water sample. The adsorbent dosage, contact time, pH, agitation speed, and temperature were controlled to study their effect on adsorption performance. Standard analytical methods were used to measure parameters such as lead, cadmium, chromium, mercury, total hardness, calcium hardness, magnesium hardness, chlorides, sulphates, total dissolved solids (TDS), and total suspended solids (TSS).

3.2 Preparation of Activated Carbon The raw biomass materials were washed thoroughly with distilled water to remove impurities and dried under sunlight. The dried materials were subjected to carbonization at high temperatures in the absence of oxygen. Further activation was carried out using chemical/thermal methods to enhance the surface area and porosity. The prepared activated carbon was crushed, sieved, and stored in airtight containers for further use.

3.3 Screening of AdsorbentsA comparative screening study was conducted using five different adsorbents: neem, mango, rudraksha, coconut shell, and commercial activated carbon. Equal experimental conditions were maintained for all samples. A fixed dosage of 1 g adsorbent was added to 200 ml contaminated water in conical flasks.The samples were placed on a mechanical shaker at 200 rpm for 60 minutes to ensure proper mixing. After adsorption, the samples were filtered and analyzed for different parameters. The removal efficiency of each adsorbent was calculated based on initial and final concentrations. The adsorbent showing the highest efficiency was selected for further optimization studies.

3.4 Optimization of Process Parameters The best-performing adsorbent (neem activated carbon) was further analyzed by optimizing key parameters. Experiments were conducted by varying one parameter at a time while keeping others constant.

- pH: 6, 6.5, 7, 7.5, 8, 8.5, 9
- Dosage: Different concentrations (0.5–2 g/L)
- Contact Time: 30, 60, 90, 120 minutes
- Agitation Speed: 60–150 rpm
- Temperature: 25°C, 30°C, 35°C, 40°C

The optimum conditions were determined based on maximum removal efficiency.

3.5 Treatment of Real Water Samples Water samples were collected from different locations including Gudlavalleru, Gudivada, Machilipatnam, and Vijayawada. Both groundwater and surface water samples were analyzed.The collected samples were treated using neem activated carbon under optimized conditions. After treatment, the samples were filtered and analyzed to determine the improvement in water quality parameters.

3.6 Kinetic Study The adsorption kinetics were studied to understand the rate and mechanism of adsorption. Experimental data obtained at different contact times were analyzed using kinetic models such as pseudo-first order and pseudo-second order. The results indicated that the adsorption process follows pseudo-second order kinetics, suggesting chemisorption as the dominant mechanism.

3.7 Evaluation Parameters

The performance of adsorption was evaluated using removal efficiency calculated as:

$$\text{Removal Efficiency (\%)} = \frac{C_i - C_f}{C_i} \times 100$$

where C_i is the initial concentration and C_f is the final concentration of contaminants

4. RESULTS AND DISCUSSION

The experimental results obtained from the adsorption studies are presented through graphs and tables and analyzed to evaluate the performance of different activated carbons. The study primarily focused on the removal of heavy metals and water quality parameters using biomass-derived activated carbon.

4.1 Screening of Adsorbents

The screening results indicate that different activated carbons exhibit varying adsorption efficiencies under identical experimental conditions. Among the tested adsorbents, neem activated carbon showed the highest removal efficiency for heavy metals such as lead, cadmium, chromium, and mercury. Coconut shell and commercial activated carbon also demonstrated good performance, while mango and rudraksha showed comparatively lower efficiencies. The superior performance of neem activated carbon can be attributed to its higher surface area, well-developed pore structure, and availability of active adsorption sites. Based on these results, neem activated carbon was selected for further optimization studies.

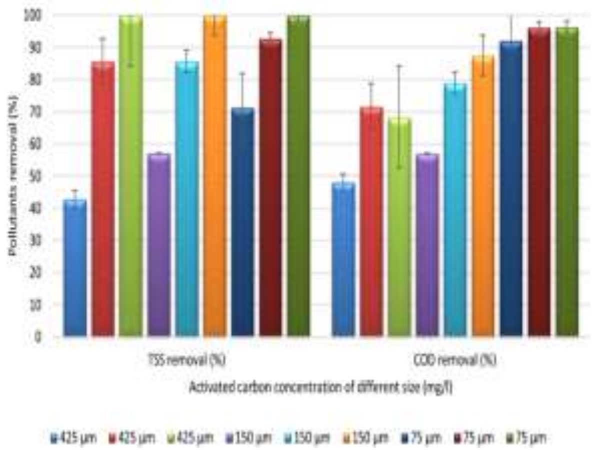

Fig:4.2.1: Removal Efficiency of Lead using Different Adsorbents

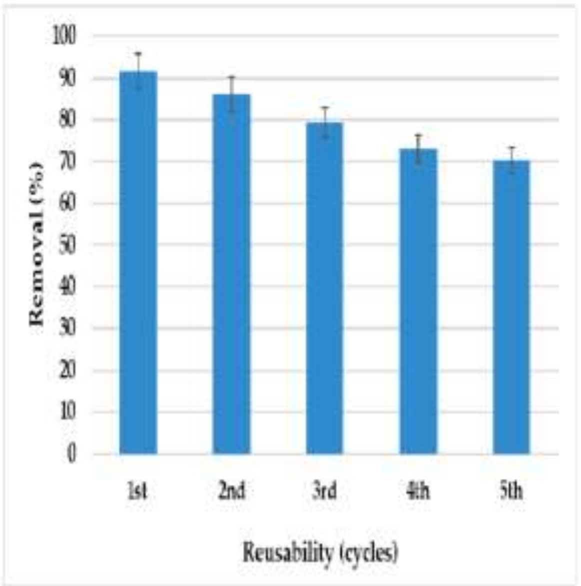

Fig:4.2.2: Removal Efficiency of Cadmium using Different Adsorbents

5. CONCLUSION

This study investigated the effectiveness of activated carbon prepared from different biomass materials for the removal of heavy metals and water quality parameters. A comparative screening study was conducted using neem, mango, rudraksha, coconut shell, and commercial activated carbon under identical experimental conditions. Among all the adsorbents, neem activated carbon exhibited the highest removal efficiency for contaminants such as lead, cadmium, chromium, mercury, hardness, chlorides, sulphates, TDS, and TSS, due to its higher surface area and porous structure.

Further optimization studies revealed that the adsorption process is significantly influenced by parameters such as pH, dosage, contact time, agitation speed, and temperature. The optimum conditions were found to be around pH 7–7.5, appropriate dosage, contact time of about 120 minutes, moderate agitation speed, and temperature around 30–35°C. Under these optimized conditions, maximum removal efficiency was achieved.

The performance of neem activated carbon was further validated using real water samples collected from different locations. The results showed significant reduction in all tested contaminants, confirming its practical applicability. Kinetic analysis indicated that the adsorption process follows pseudo-second order kinetics, suggesting chemisorption as the dominant mechanism. Overall, this study demonstrates that biomass-derived activated carbon, especially neem-based carbon, is an efficient, low-cost, and sustainable solution for water purification.

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