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Treatment of River Water Using Activated Bio-Char Derived from Eucalyptus Tree Wood

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Abstract: *Access to safe drinking water remains a major challenge in many rural and semi-urban regions due to increasing contamination of surface water sources. Rivers are often affected by domestic sewage, agricultural runoff, and industrial discharges, leading to deterioration in water quality. This study investigates the effectiveness of activated biochar derived from eucalyptus tree wood as a low-cost and sustainable adsorbent for river water treatment. Biochar was prepared through slow pyrolysis of eucalyptus wood under limited oxygen conditions and chemically activated using zinc chloride ($ZnCl_2$) to enhance its adsorption capacity. River water samples collected from the Tungabhadra River were treated using both normal biochar and $ZnCl_2$-activated biochar in a bed filtration system. The treated water was analysed for physicochemical parameters such as pH, alkalinity, hardness, chlorides, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and heavy metals. The results indicate that activated biochar shows superior performance in reducing organic pollutants and heavy metals compared to normal biochar. The study demonstrates that eucalyptus-based activated biochar can serve as an effective, eco-friendly, and affordable material for improving river water quality, especially in areas lacking advanced water treatment facilities.*

Keywords: Activated biochar, Eucalyptus wood, River water treatment, Adsorption, $ZnCl_2$

I. INTRODUCTION

Water is one of the most essential natural resources for sustaining life, agriculture, and economic development. Rivers play a vital role in supplying water for domestic, agricultural, and industrial purposes, particularly in developing countries. However, rapid urbanization, population growth, discharge of untreated sewage, and agricultural runoff has significantly degraded river water quality in recent years. Consumption of contaminated river water without adequate treatment poses serious health risks, including water-borne diseases and heavy metal toxicity.

Conventional water treatment methods such as chemical coagulation, membrane filtration, and advanced oxidation processes are often expensive and require skilled operation, making them unsuitable for rural and semi-urban communities. As a result, there is a growing need for low-cost, simple, and sustainable water treatment technologies. Adsorption is considered one of the most effective and economical techniques for water purification due to its simplicity and efficiency.

Biochar, a carbon-rich material produced from biomass under oxygen-limited conditions, has gained significant attention as an alternative adsorbent for water treatment. Its porous structure, large surface area, and presence of functional groups make it effective in removing organic pollutants, suspended solids, and heavy metals from water. Among various biomass sources, eucalyptus wood is abundantly available and possesses good carbon content, making it a suitable feedstock for biochar production.

In this study, eucalyptus wood-derived biochar activated using zinc chloride ($ZnCl_2$) is employed for treating river water collected from the Tungabhadra River. The objective is to evaluate the performance of activated biochar in improving water quality parameters and to assess its suitability as a low-cost water treatment material for practical applications.

II. LITERATURE SURVEY

1. **ZnCl2-modified eucalyptus bark biochar as adsorbent: preparation, characterization and its application in adsorption of Chromium (VI) from aqueous solutions: A review by Adeyinka S. Yusuf (6 August 2022).**

Biochar is a by product of biomass pyrolysis that has been identified as an effective and novel bio-adsorbent for contaminant removal from wastewater. A pyrolysis-chemical activation process was used to convert eucalyptus tree bark to activated biochar; the effects of adsorption process conditions (adsorbate concentration, contact time, adsorbent amount and pH) on Cr (VI) removal efficiency were investigated. The best experimental conditions for the maximum equilibrium uptake of Cr (VI) by activated eucalyptus bark biochar (AEBB) were 10 mg/L, 140 min, 6.0 and 0.3 g/L for initial Cr (VI) concentration, contact time, pH and adsorbent amount, respectively. The AEBB's outstanding performance was aided by its high surface area, well-developed porous structure and dominance of active surface functional groups, as validated by BET, SEM and FTIR.
The Freundlich model fitted the equilibrium data the best. The pseudo-second-order model appeared to better predict the kinetics of Cr (VI) adsorption onto AEBB, indicating the dominance of chemisorptions.

2. **Recent advancements in biochar preparation, feedstock's, modification, characterization and future applications: A review by K. Vijayaraghavan (9 June 2019).**

Biochar is a stable carbon-rich product synthesized from biological materials through different heating techniques. The main aim of this review is to evaluate various biochar production methods, parameters affecting the production of biochar, facilities to investigate the composition and structure of biochar, mechanism associated with production of biochar as well as various modification procedures to suit biochar for different applications. Various methods used to synthesize biochar include pyrolysis, torrefaction, and gasification, hydrothermal and flash carbonization.
Several factors such as feedstock composition and type, pyrolysis conditions such as temperature and time strongly influence the property of synthesized biochar. The physicochemical properties of biochar strongly influence the role of biochar in several applications such as fuel cells, biosorption, agriculture, supercapacitors, catalyst/support and environmental remediation. It was identified through research efforts that the properties of biochar can be altered using various chemical or physical agents to suit various applications. Thus, the present review consolidates recent advancements in biochar research with special attention towards contaminant remediation and agricultural applications.

III. MATERIALS AND METHOD

3.1 Materials Used

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The primary raw material used for the preparation of biochar was eucalyptus tree wood, which was selected due to its high carbon content, local availability, and suitability for biochar production. Zinc chloride ($ZnCl_2$) was used as a chemical activating agent to enhance the adsorption characteristics of the biochar. River water samples were collected from the Tungabhadra River for experimental analysis. Other materials used in the study included fine sand, coarse sand, aggregates, steel mesh, plastic and water cans, and laboratory-grade reagents for water quality analysis.

3.2 Collection of River Water Sample

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River water samples were collected from an accessible location along the Tungabhadra River using clean, pre-washed plastic containers to avoid contamination. Prior to sample collection, the containers were rinsed with river water. Care was taken to avoid the inclusion of floating debris and sediments. The collected samples were properly labeled with date and location and transported immediately to the laboratory for filtration and analysis.

3.3 Preparation of Biochar

Eucalyptus wood pieces were cut into uniform sizes and subjected to slow pyrolysis under limited oxygen conditions. A pre-existing concrete cylindrical pit was used as the pyrolysis chamber. The wood was ignited and allowed to burn slowly for approximately 2–3 hours per day over a period of three days. To restrict oxygen supply and promote carbonization rather than complete combustion, the pit was covered with a mild steel plate and sealed at the edges. After completion of the pyrolysis process, the pit was allowed to cool naturally. The resulting biochar was collected,

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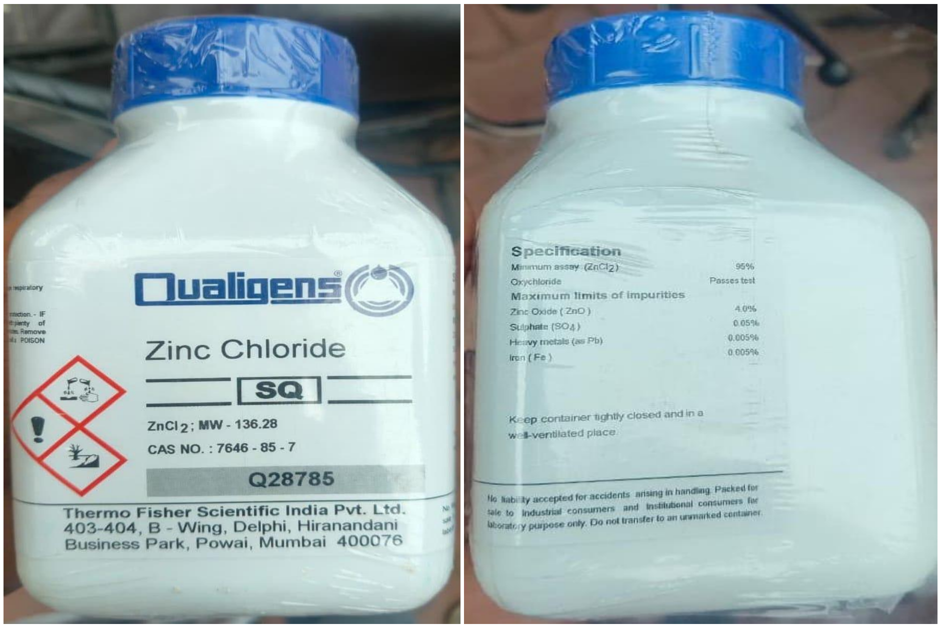
crushed manually, and sieved to obtain uniform particle size. The prepared biochar was stored in airtight containers to prevent moisture absorption.

3.4 Chemical Activation of Biochar



The prepared biochar was chemically activated using zinc chloride ($ZnCl_2$) to improve its adsorption capacity. A $ZnCl_2$ solution was prepared by dissolving the required quantity of $ZnCl_2$ powder in water. The biochar was soaked in this solution for 24 hours to allow sufficient impregnation and interaction between the activating agent and the biochar surface. After soaking, the biochar was removed, thoroughly dried, and stored for further use. Chemical activation increased the porosity and surface area of the biochar, thereby enhancing its ability to adsorb contaminants from water.

3.5 Preparation of Bed Filter

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A cylindrical or column bed filter was constructed for the treatment of river water. The filter consisted of layered media arranged from bottom to top as activated biochar coarse sand and fine sand. The sand layers facilitated physical filtration by removing suspended particles, while the activated biochar layer acted as the primary adsorbent for removing organic matter, color, odor, and dissolved contaminants.

3.6 Filtration Procedure

Raw river water was gently poured into the top of the bed filter and allowed to pass through the filter media under gravity flow conditions. The water sequentially passed through the biochar and sand layers, enabling both adsorption and physical filtration mechanisms. A controlled flow rate was maintained to ensure effective contact between water and filter media. The filtered water was collected at the outlet in clean containers for further analysis.

3.7 Water Quality Analysis

Both raw and treated water samples were analyzed in the laboratory to evaluate the effectiveness of the biochar treatment process. Physicochemical parameters such as pH, alkalinity, acidity, total hardness, chlorides, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total dissolved solids (TDS) were determined using standard testing procedures. Heavy metals including copper and nickel were also analyzed to assess the removal efficiency of biochar filtration.

IV. RESULTS AND DISCUSSION

Table 1: Raw River Water Quality Parameters

Parameter	Unit	Raw Water
Alkalinity	mg/L	142
Total Hardness	mg/L	230
Chlorides	mg/L	88
DO	mg/L	5.34
BOD	mg/L	12
COD	mg/L	26.8

Table 2: Comparison of Biochar Treatment

Parameter	Unit	Raw Water	Normal Biochar	Activated Biochar
Alkalinity	mg/L	142	152	160
Total Hardness	mg/L	230	242	252

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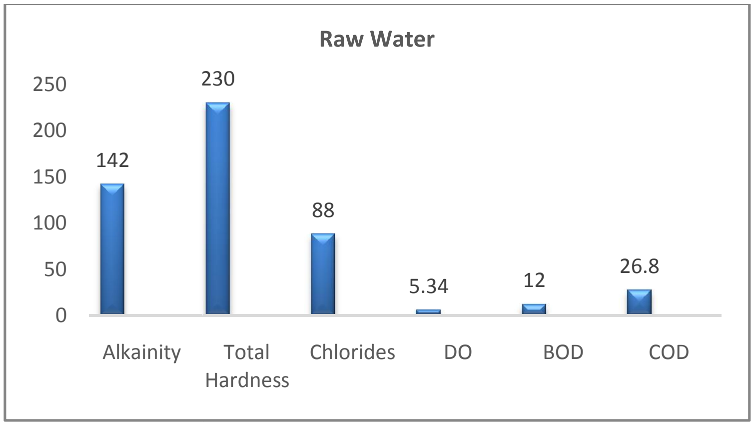
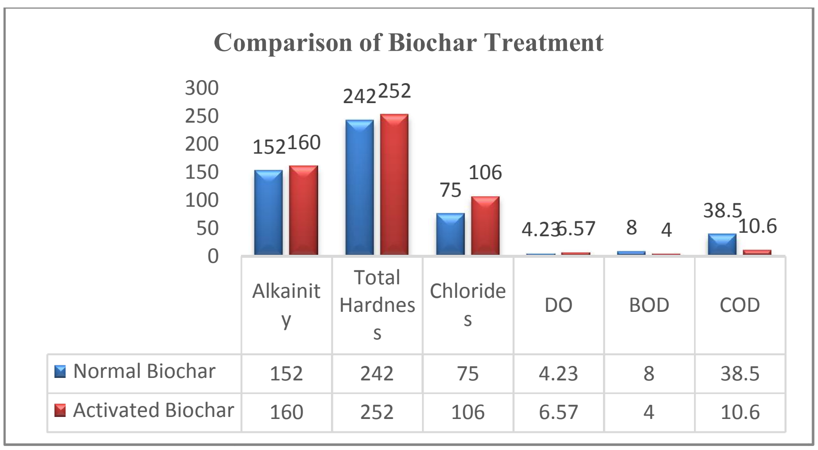
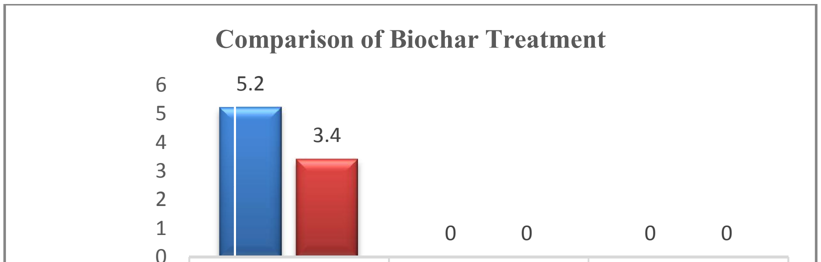
Chlorides	mg/L	88	75	106
DO	mg/L	5.34	4.23	6.57
BOD	mg/L	12	8	4
COD	mg/L	26.8	38.5	10.6

Table 3: Heavy Metal Concentration after Treatment

Metal	**Unit**	**Raw Water**	**Normal Biochar**	**Activated Biochar**
Copper (Cu)	mg/L	5.2	<0.2	<0.2
Nickel (Ni)	mg/L	3.4	<0.2	<0.2







	Raw Water	Normal Biochar	Activated Biochar
Copper (Cu)	5.2	0	0
Nickel (Ni)	3.4	0	0

V. CONCLUSION

The present study demonstrates the effectiveness of activated biochar derived from eucalyptus tree wood as a low-cost and sustainable material for river water treatment. Biochar produced through slow pyrolysis and chemically activated using zinc chloride ($ZnCl_2$) exhibited enhanced adsorption properties, leading to significant improvement in water quality parameters. Experimental results showed noticeable reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and heavy metal concentrations, indicating effective removal of organic and inorganic contaminants from river water.

Comparison between normal biochar and activated biochar revealed that $ZnCl_2$-activated biochar performed more efficiently due to increased porosity and availability of active adsorption sites. Heavy metals such as copper and nickel were reduced to below detectable limits after treatment, confirming the suitability of activated biochar for contaminant removal. Improvements in dissolved oxygen levels further indicate enhanced water quality after filtration.

Overall, the study confirms that eucalyptus-based activated biochar can serve as an eco-friendly, economical, and practical alternative to conventional water treatment methods, particularly in rural and semi-urban areas where advanced treatment facilities are limited. The simple bed filtration system employed in this work highlights the potential for decentralized water purification applications. Further research is recommended to optimize operating conditions and evaluate long-term performance for large-scale implementation.

VI. ACKNOWLEDGEMENT

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