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Synthesis, Characterization, and Application for the removal of Mno2/Bc Composite

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Abstract: This study focuses on the synthesis, characterization, and application of a manganese dioxide (MnO_2)/biochar (BC) composite for the removal of contaminants from water. The MnO_2/BC composite was synthesized through a co-precipitation method, where biochar derived from [insert biomass source] was used as a supporting matrix for MnO_2 nanoparticles. The composite was characterized using techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and Fourier transform infrared spectroscopy (FTIR) to confirm the successful synthesis and to analyze its structural and surface properties. The removal efficiency of the composite was evaluated for various water contaminants, including heavy metals and organic pollutants. The results demonstrated that the MnO_2/BC composite exhibits high adsorption capacity, rapid kinetics, and good reusability, making it a promising material for water purification applications. The underlying mechanisms of adsorption and the influence of operational parameters such as pH, contact time, and initial concentration were also investigated to optimize the removal process. This study provides a comprehensive understanding of the potential of MnO_2/BC composites in environmental remediation, particularly in the treatment of contaminated water.

Keywords: MnO_2/BC, Synthesis, Characterization, Application

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INTRODUCTION

Since water is essential for human existence on our planet, it must always be accessible. Because you can't drink anything without it, you can't exist without it. As the human population continues to expand at an exponential pace, providing everyone with access to clean drinking water is becoming more and more difficult. Water use has substantially grown, adding to the problem as new industries are added to the mix every day. To make things worse, when more water is used by these businesses, more wastewater is produced, and when this wastewater is dumped into rivers and ponds without adequate treatment, it contaminates the clean water. Governments all around the world have started efforts to raise awareness about the need to provide access to clean drinking water for their citizens, despite the fact that water covers 72% of the earth's surface [1]. Some people think that the third world war would be fought over water since nature has conserved 97% of all water as saltwater and humans are destroying the remaining water, which is why this isn't happening [2].

Water contamination by heavy metals and organic pollutants poses a significant threat to environmental sustainability and human health [3]. Traditional water treatment methods often fall short in effectively removing these contaminants, especially at low concentrations. In recent years, the development of advanced materials for environmental remediation has gained considerable attention. Among these, composites combining metal oxides with carbon-based materials have shown promise due to their synergistic properties, which enhance their adsorption capabilities [4].

Businesses including those in the chemical, oil and gas, pharmaceutical, food, energy, textile, and metal sectors need a lot of water. Water is also the most typical solvent. It may be used for a variety of tasks, including cooling, heating, cleaning, washing, and conveying both completed items and raw materials. It may be used as steam or as a solid. The quantity of water necessary for a product's synthesis may also be related to the product's quality [5-7], thus a better product would need more water to be consumed. As a consequence, greater industrial activity for human development may lead to an increase in water consumption in certain countries. In terms of ground water, which is mostly utilized for agriculture and residential water supply, India has a relatively tiny proportion. However, given that ground water is being drained at an alarming pace, India has begun to look at other supplies, such as the rivers that span about 90% of the nation's surface. Despite all attempts, India's water situation is still becoming worse [8]. This is mostly because of river droughts, excessive demand brought on by a rapidly expanding population, and a lack of technical knowledge. India and the rest of the world have a responsibility to address water quantity and quality issues since the world is suffering from a scarcity of fresh water resources and a rise in pollution in existing water sources. Indian ranks 120th worldwide in terms of water quality. Numerous water sources in India are contaminated with hazardous waste materials from industrial operations or pathogenic microorganisms, which include both organic and inorganic toxic components. [9-12].

Manganese dioxide (MnO_2) is a widely recognized material for its oxidative and adsorptive properties, making it effective in removing various pollutants from water. However, its practical application is limited by issues such as agglomeration and difficulty in recovery [13]. To address these challenges, biochar (BC) derived from biomass has been explored as a supportive matrix. Biochar not only provides a large surface area and porosity but also facilitates the dispersion and stabilization of MnO_2 nanoparticles, thereby enhancing their functional properties [14, 15].

This study aims to synthesize a MnO_2/BC composite and investigate its potential for water purification. The research objectives include the synthesis of the composite, its detailed characterization to understand its structural and functional properties, and the evaluation of its effectiveness in removing contaminants from water. By exploring the operational parameters and adsorption mechanisms, this study seeks to contribute to the development of more efficient and sustainable water treatment solutions.

METHODOLOGY

Synthesis of composites

Metal oxides, and binary metal oxides, Precursor salts were precipitated under continuous stirring at an alkaline pH and acceptable temperature using a simple co-precipitation process.

Preparation of MnO2/BC

For the synthesis of MnO_2/BC, 100 mL of solution of manganese salt (0.1M of manganese chloride, $MnCl_2$) was mixed with 100 mL of solution of 1.0 gram of dispersed Black cumin seed grains (prepared as above) followed by the drop wised addition of 100 mL of 0.1M of potassium permanganate, $KMnO_4$ solution.

Characterization and instrumentation analysis

- Functional group analysis
- Crystal phase and size analysis
- Morphology analysis
- Elemental analysis
- Thermal analysis
- Magnetic properties
- Zero point charge

Adsorption studies

- Preparation of adsorbate solutions
- Determination of arsenic
- Batch adsorption experiments
- Thermodynamic studies
- Isotherm models
- Kinetic of adsorption and mechanism
- Determination of adsorption parameters and regression coefficients
- Recyclability of exhausted adsorbents

Photocatalytic activity

The photocatalytic degradation of methylene blue using MnO2/BC was carried out by stirring (10 mL of Methylene blue solution, 10 mgL-1 concentrations, with 1.0 gL-1 quantity of MnO2/BC for 15 minutes at pH 7 under sunshine irradiation.

Antibacterial activity

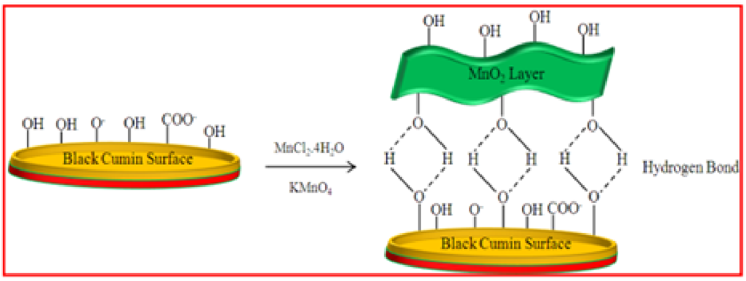
The antibacterial activity of the composite for bacterial cells was investigated using the disc diffusion technique. This approach is used to determine the sensitivity of antibiotic medicines, as well as their efficiency against bacterial cells and their application in clinical practice. As a result, the procedure was utilized to get data on the prevention of microbe growth on the created composite surface.

RESULTS

The composite MnO2/BC was orchestrated by integrating MnO2 into the cellulosic system of Dark cumin seed through straightforward preparative response and was portrayed. The composite was examined as an adsorbent for the evacuation of MB color, tried for hostile to bacterial, and photocatalytic exercises. A few group adsorption tests were done under different circumstances to investigate the capacity of recently pre-arranged composite for the expulsion of MB color. Results got from these examinations has been shown thus and talked about in succeeding areas.

Characterization of MnO_2/BC

The carbon structure given by the natural part goes about as a layout for the scattering and development of nanoparticles. BC seed grains have number of - Gracious, - COOH, and - NH2 bunches at the surface that gave asylum to Mn^{4+} particles to the development of manganese oxide nanoparticles. By along these lines, MnO2 octahedral network get scattered in the carbon system however hydroxyl bunches on carbon structure and hydrous MnO2 through hydrogen holding and in this way MnO2 firmly stuck in BC structure. The FT-IR range set forward the proof for the joining of MnO_2 in the BC system for the development of MnO2/BC through following response:



Scheme 1: Chemical route for the synthesis of MnO_2/BC

SEM imaging of MnO2/BC showed the deeply grounded δ-MnO2 developed into the BC carbon system. The amplified SEM picture demonstrated that the composite has graineous MnO_2 particles become on the BC structure. Also, a portion of the MnO_2 nanoparticles could have agglomerated together and framed enormous permeable construction.

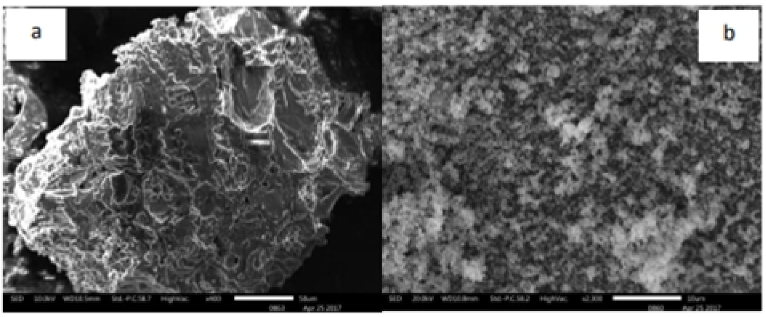


Figure 1: SEM image of BC (a) and MnO_2/BC (b)

Synthetic organization of the MnO2/BC was assessed from EDX range investigation. The EDX range showed prevalent pinnacles relating to the C (41.00%), O (38.60%), and Mn (19.80%), one minor pinnacle relating to N (0.50%) which proposed the rate nuclear constituents C, O, N, and Mn in the MnO_2/BC lattice. This investigation proposed that the components C, O, and N were because of BC structure while Mn come because of the joining of MnO_2 in the structure.

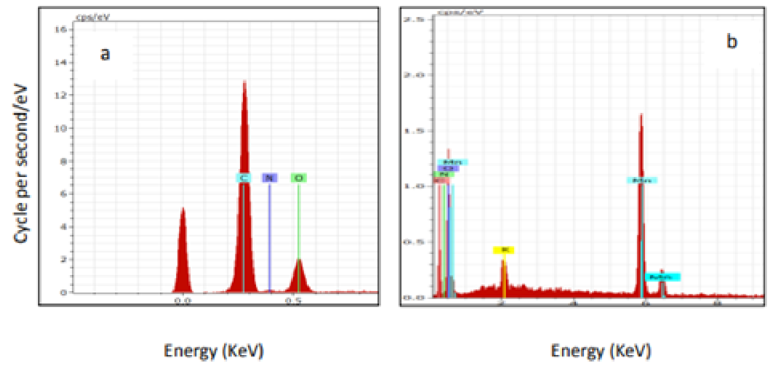


Figure 2: EDX graph of BC (a) and MnO2/BC (b)

Adsorption studies

The adsorption conduct of MnO_2/BC towards Methylene blue, MB was examined in single framework affected by different boundaries like MB focus, MnO2/BC measurements, contact time, temperature and pH of the arrangement. The sorption of MB onto 1.0 gL−1 measurement of MnO_2/BC diminished somewhat from 98.28 to 96.52% when the fixation was expanded from 10 to 45 mgL−1, and no further change in adsorption rate was seen on expanding the centralization of MB arrangement, which may be because of the total filling of the surface locales at the given focus and extra added color remained unadsorbed causing decline in adsorption. The adsorption adequacy was additionally impacted by how much MnO2/BC which expanded with the measurement from 0.5 to 3.0 g L−1. This was the aftereffect of addition of surface locales, on expanding how much MnO_2/BC. Additionally, the similar sorption investigations of MnO_2/BC to BC proposed that the consolidation of MnO_2 into the BC carbon structure improved the adsorption limit of the composite in contrast with BC. 1.0 gL^{-1} portion of MnO_2/BC could eliminate 97.30% of MB from the 10 mgL−1 focus, which was a lot higher than the adsorption by virgin BC under the comparable circumstances which could eliminate just 63% MB. Hence, 1.0 gL^{-1} of MnO2/BC was chosen as ideal portion for 10 mgL^{-1} centralization of MB arrangement.

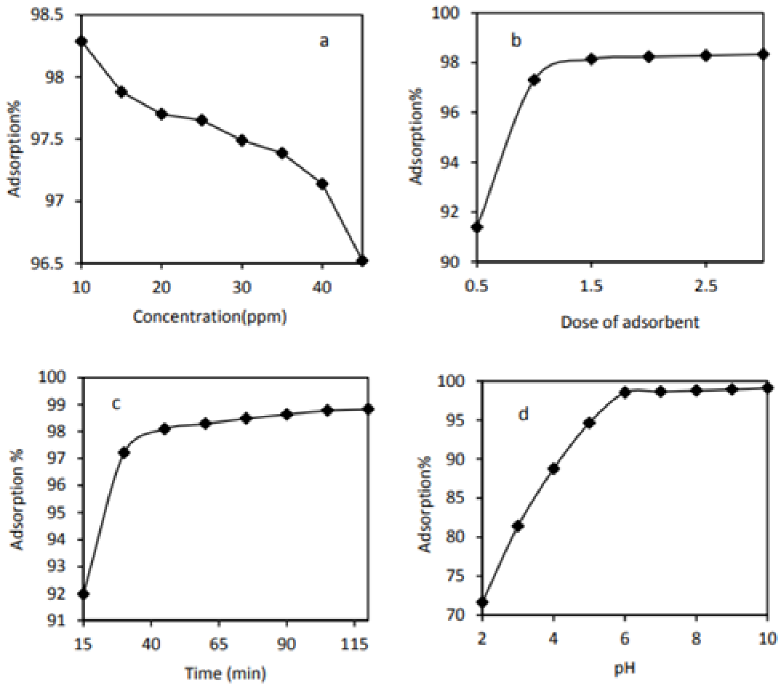


Figure 3: Effect of MB concentraion (a), adsorbent dose (b), contant time (c) and solution pH (d) onto the MB adsorption capacity

Temperature effect, thermodynamics, and isotherms

The impact of temperature on the adsorption (10-45 mgL^{-1} fixation scope of MB, and 1.0 gL^{-1} MnO_2/BC portion) was explored at 27, 35, and 45 °C. The adsorption of MB was seen to diminish with the climb in temperature. The pattern may be because of the presence of frail hydrogen holding among MB and MnO2/BC, which on getting energy at higher temperature (35 and 45 °C) separated and MB particles could have gotten away from the limiting destinations.

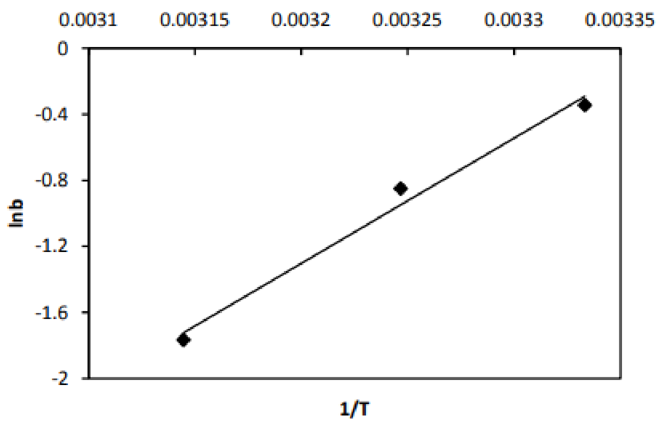


Figure 4: Thermodynamic plot of MB adsorption

Adsorption kinetics

Mechanism, efficacy, and kinetic parameters depend on chemical properties of the adsorbent and the adsorbate, and the experimental conditions. Adsorbate transfers from aqueous phase to the solid surface by following different steps which control the whole process.

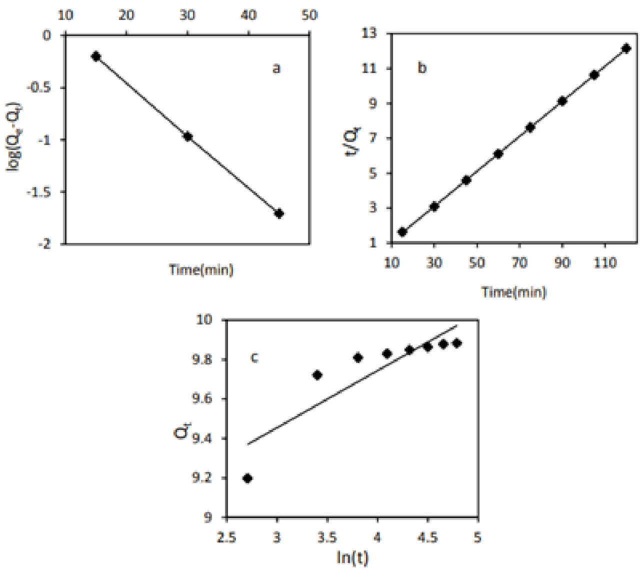


Figure 5: Pseudo-first order (a), pseudo second order (b), and Elovich (c) kinetic plots for MB adsorption

Photocatalytic degradation

The photocatalytic debasement was done at three tried temperature, 27, 35 and 45°C, by lighting daylight for 5-120 min on MB arrangement having MnO_2/BC photocatalyst. It was seen that almost 80% of MB could be debased in somewhere around 45 minutes utilizing MnO_2/BC nanocomposite under the daylight light at 27°C. After the hour and a half, just 5% improvement in MB corruption was noticed and afterward no further debasement was noticed. In this manner, debasement process got immersed at an hour and a half, and eventual outcome showed that 85% of MB could be corrupted following 120 minutes of daylight light at 27°C. At the point when the arrangement temperature was raised from 27 to 45°C, the corruption of MB likewise expanded from 85 to 97%.

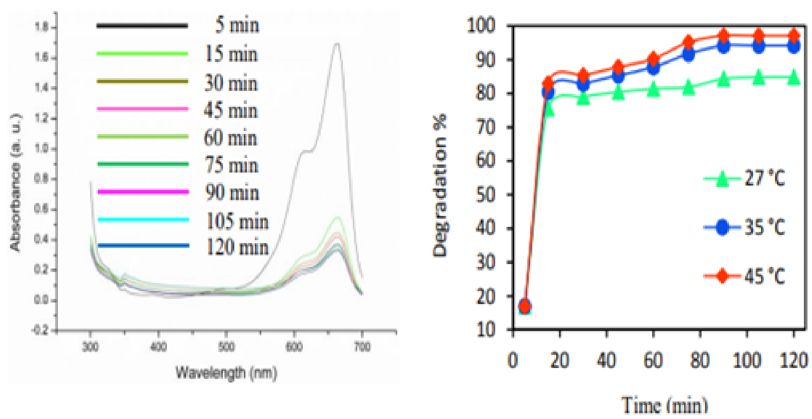


Figure 6: UV-vis spectral changes of MB during degradation process as a function of reaction time using MnO_2/BC (a) and percentage degradation of MB by MnO_2/BC at 27, 35 and 45°C (b).

Anti bacterial activity

The antibacterial exercises of the MnO_2/BC towards *Staphylococcus aureus, S. aureus* and *Escherichia coli, E.coli,* the two bacterial species which are related with the clinical diseases, were tried. The outcomes demonstrated that MnO_2/BC showed great inhibitory zone. The distances across of the zones of hindrance were determined as 19 and 25mm for *S. aureus,* and *E. coli,* individually.

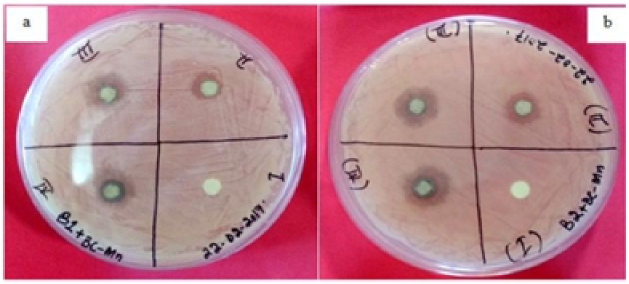


Figure 7: Antibacterial activity of MnO_2/BC for (a) gram negative Escherichia coli bacterial cell, B1 and (b) gram positive Staphylococcus aureus, B2, where (I) Control, (II) 10 µL loaded disk, (III) 20 µL loaded disk and (IV) 30 µL loaded drug against *Escherichia coli* and *Staphylococcus aureus*

CONCLUSION

A multifunctional hybrid composite MnO_2/BC was prepared by one step co-precipitation method. The MnO_2/BC showed excellent antibiotic0 activity against *E. coli* and *S. aureus,* photocatalytic degradation, and adsorption activity for Methylene blue. The antibacterial activity results indicated that MnO_2/BC showed 19 and 25 mm diameter of inhibitory zone for *S. aureus* and *E. coli*, respectively. The adsorption results showed that

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