Green synthesis, characterization and application of calcium carbonate nanoparticles in the effective treatment of grey water for sustainable water management.

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Keywords

Calcium carbonate, Nanoparticles , Chemical oxygen demand, Grey water, Organics.

Introduction

The Sultanate of Oman relies heavily on water treatment plants to address the severe scarcity of fresh water, with approximately 86% of the country's potable water being supplied through desalination plants. The discharge of significant volumes of grey water resulting from daily household activities poses long-term environmental pollution concerns and contributes to an increased consumption of freshwater. Nanoparticle-mediated treatment technologies are viewed as a promising alternative to conventional water treatment methods. Regular release of large quantities of grey water from domestic activities can lead to environmental issues, including contamination through reduced dissolved oxygen levels and accelerated bacterial growth in water bodies. This study aimed to develop calcium carbonate nanoparticles using a homogenization and precipitation process for batch treatment of domestic grey water. The synthesized calcium carbonate nanoparticles were utilized in the batch treatment of grey water, with variations in contact time, solution pH, agitation speed, and nanoparticle dosage. The effectiveness of the nanoparticles in removing contaminants was evaluated by measuring parameters such as Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), and turbidity. This research aligns with the United Nations Sustainable Development Goal 6 (clean water and sanitation). Through this community engagement project, significant amounts of fresh water will be conserved daily by reusing treated grey water, thereby contributing to a cleaner environment and benefiting society at large.

Objectives

The objective of the research was to adapt a highly advanced nanotechnology in the grey water treatment by employing nanoparticles in the effective removal of pollutants. The fabrication of calcium carbonate nano particles are performed by homogenization and precipitation process for the treatment of domestic grey water. The batch experimental study focused on the effect of variation of processing conditions like pH, stirring time, stirring speed and dosage of nanoparticles and the effectiveness of treatment process was optimized.

Methodology

The methodology employed in the preparation of calcium carbonate nanoparticles was precipitation and homogenization process using sodium carbonate and calcium chloride. The synthesized nanoparticles were characterized by Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Analysis (EDX), X-Ray Diffractometer (XRD), Fourier Transform Infrared Spectroscopy (FTIR)) and zeta potential measurement. The batch treatment of grey water with $CaCO_3$ nanoparticles was carried out by varying the processing conditions (grey water pH, stirring time, stirring speed, and dosage of $CaCO_3$). The efficiency of the treatment process was measured by analyzing the Chemical Oxygen Demand (COD), Dissolved oxygen (DO), Total dissolved solids (TDS), Total suspended solids (TSS), and Turbidity.

Results

The nanoparticles were successfully synthesized and characterized using (SEM), (EDX), (FTIR), (XRD) and zeta potential measurement. Batch experimental studies were performed using the synthesized nanoparticles by varying the grey water solution pH, stirring time, stirring speed, and dosage. The effectiveness of nanoparticles in the removal of the pollutants was assessed by analyzing COD, TDS, TSS, DO, and Turbidity before and after treatment. The results show that the optimum pollutants removal efficiency was obtained at pH 8.0, stirring speed of 100 rpm, mixing time of 60 minutes and 0.7 g dosage of $CaCO_3$.

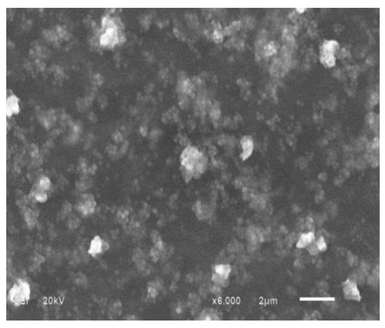

Fig. 1 SEM micrograph of $CaCO_3$ nanoparticles

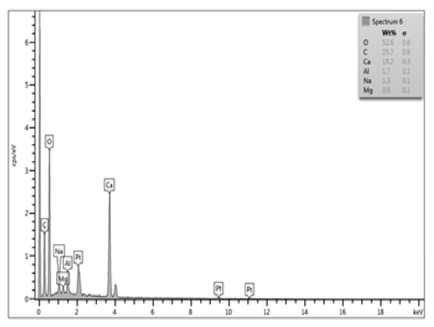

Fig. 2 EDS spectra of $CaCO_3$ nanoparticles

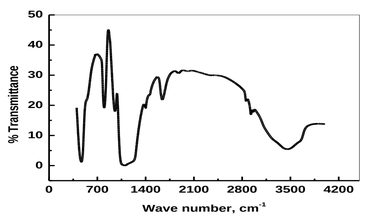

Fig. 3 FTIR analysis of $CaCO_3$ nanoparticles

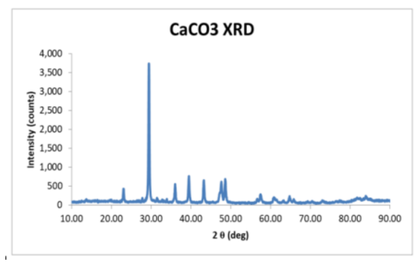

Fig. 4 XRD patterns of $CaCO_3$ nanoparticles

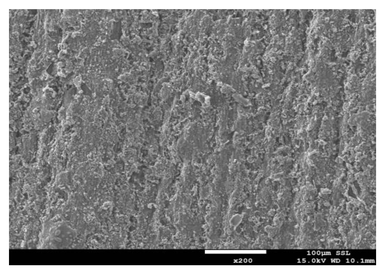

Fig.10 SEM micrograph of nanoparticles after grey water treatment

Analysis

Batch treatment of grey water using $CaCO_3$ nanoparticles:

Effect of pH variation:

The experiment was carried out by varying the pH from 2 to 10, and the analysis revealed that the pH at which maximum percentage reduction in parameters was achieved is 8.0, which is considered to be the optimal pH for the treatment

Effect of stirring time variation:

The contact time was varied from 15 minutes to 120 minutes. The highest reduction in COD was obtained at 60 min of stirring time.

Effect of stirring speed variation:

The stirring speed was varied from 25 rpm to 150 rpm. The maximum reduction in COD was obtained at 100 rpm.

Effect of variation of nanoparticle dosage:

The dosage of nanoparticle was varied from 0.1 g to 0.8 g. At a dosage of 0.7 g, the largest reduction in values was observed.

Conclusion

Through the utilization of a cost-effective and straightforward treatment method, calcium carbonate nanoparticles were successfully synthesized and characterized using SEM, EDX, FTIR, XRD, and zeta potential measurement. A series of batch experiments were conducted employing the synthesized nanoparticles, wherein the grey water solution's pH, stirring time, stirring speed, and nanoparticle dosage were systematically varied. The efficacy of the nanoparticles in eliminating pollutants was assessed by analyzing parameters such as COD, TDS, TSS, DO, and Turbidity. The findings of this study indicate that $CaCO_3$ nanoparticles exhibit significant potential in efficiently purifying grey water by removing pollutants. This research initiative, based on corporate social responsibility (CSR), aligns with Oman Vision 2040 and is in accordance with the United Nations' Sustainable Development Goal 6 (clean water and sanitation). By conserving water resources and promoting a hygienic environment, this project contributes to the betterment of society as a whole.

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