Development of Zeolite-Based Nanocomposite Materials for Removal of Toxic Metals and Escherichia Coli from Water.

Files

Wangi-CEDAT-PhD -Thesis.pdf (5.64 MB)

Date

2026

Authors

Wangi Godfrey Mario

Publisher

Makerere University

Abstract

Access to safe water remains a persistent challenge in low-resource settings, where conventional treatment systems are often ineffective or unaffordable. Natural zeolites offer a low-cost, abundant, and eco-friendly alternative for water purification. Still, their native properties usually require modification to achieve effective performance in removing chemical and microbial contaminants. Advances in nanotechnology have created promising opportunities for point-of-use water treatment. When processed at the nanoscale, natural zeolite exhibits enhanced treatment properties but tends to agglomerate. To overcome this limitation, forming a composite becomes necessary. This study aimed to develop a Silver-Zeolite-Polyethylene – Glycol (PEG) nanocomposite for simultaneous adsorption of toxic metals and disinfection of Escherichia coli in contaminated water. The research addressed four critical specific objectives namely; the beneficiation of natural zeolites, the optimization of powder production, the synthesis of nanocomposite materials, and the performance evaluation of the developed composite. Natural zeolite was characterized using XRD, SEM-EDX, and BET analyses to assess its mineralogical and morphological properties. Ball milling parameters namely; milling speed, milling time and ratio of milling balls to zeolite powder were optimized using Response Surface Methodology (RSM) to enhance the surface area and uniformity coefficient. Subsequently, a silver-zeolite-PEG nanocomposite optimized using Central Composite Design of RSM was synthesized via wet impregnation of silver nanoparticles and PEG onto zeolites, considering PEG content (10–90 %), reaction temperature (25–65 °C), and reaction time (10–300 minutes) as independent variables. Minimum inhibitory concentration (MIC) and methylene blue number (MBN) were selected as performance metrics for disinfection of Escherichia coli (E. coli) and adsorption of methylene blue (MB) respectively. Natural zeolites were found rich in laumontite and with good adsorption properties such as high ion exchange and a porous structure. The average surface area and uniformity coefficient for zeolite powder were 147.4 m^2/g and 5.2 respectively at milling speed of 332 rpm, milling time 25 min, and a 50% ball-to-powder ratio. The nanocomposite exhibited strong antibacterial efficacy on culture medium prepared using Mueller-Hinton broth with an MIC as low as 0.031 mg/mL against E. coli and adsorption capacity for MB as high as 150 mg/g. The zeolite-based nanocomposite demonstrated dual functionality, achieving a high Pb^{2+} adsorption capacity (176.7 mg/g, R^2 = 0.999) and complete E. coli disinfection of water from a protected spring in less than 60 minutes, highlighting its potential for decentralized water treatment. This study contributes a novel, optimized formulation of a multifunctional silver-zeolite-PEG material, linking material processing parameters with water treatment performance and its reusability. Future research should optimize, scale, and integrate AgNPs-Zeolite-PEG for broad, cost-effective water treatment.

Description

A thesis submitted to the Directorate of Research and Graduate Training for the award of the Degree of Doctor of Philosophy of Makerere University.

Citation

Wangi Godfrey Mario. (2026). Development of Zeolite-Based Nanocomposite Materials for Removal of Toxic Metals and Escherichia Coli from Water. (Unpublished PhD Thesis) Makerere University; Kampala, Uganda.

URI

https://makir.mak.ac.ug/handle/10570/16519

Collections

School of Engineering (SEng.) Collections