Towards Sustainability: Use of Local Palm Tree Waste in the Fabrication of Zinc Oxide Nanoparticles and Nanocomposite Beads for Biomedical and Environmental Applications

Osama Zeidan*,Ali Zayer*,G. Roshan Deen

Materials for Medicine Research Group, School of Medicine, Royal College of Surgeons in Ireland, Medical University of Bahrain, Kingdom of Bahrain

Introduction and Aims

Introduction:
The growing emphasis on sustainability and waste management has led to innovative approaches in utilizing agricultural waste. This study explores the use of local palm tree waste for the synthesis of zinc oxide nanoparticles (ZnO NPs) and nanocomposite beads, aiming to create value-added materials for biomedical and environmental applications.

Aims:
1- To develop a sustainable synthesis method for zinc oxide nanoparticles (ZnO NPs) and nanocomposite beads using local palm tree waste as a renewable resource, emphasizing green chemistry principles.
2- To evaluate the biomedical and environmental applications of the synthesized ZnO NPs and nanocomposite beads, specifically their antibacterial properties and heavy metal adsorption capabilities for water purification.

Methods:
Palm tree waste was collected, cleaned, and processed to extract cellulose fibers. These fibers were purified using chemical treatments and dried to create a substrate for zinc oxide nanoparticle (ZnO NP) synthesis. Zinc acetate was used as the zinc precursor, and a green synthesis approach was employed, leveraging the natural reducing and stabilizing properties of the cellulose. The mixture was heated and dried to form ZnO NPs, which were further calcined for purity.

The synthesized ZnO NPs were characterized using UV-Vis spectroscopy to confirm their optical properties and transmission electron microscopy (TEM) to determine their size and shape.
To create nanocomposite beads, ZnO NPs were mixed with sodium alginate solution and dropped into a calcium chloride bath to form gel beads. The resulting beads were rinsed, dried, and tested for mechanical stability.

The antibacterial activity of the nanocomposite beads was evaluated against *Escherichia coli* and *Staphylococcus aureus.* Their ability to adsorb heavy metals from water was tested to assess their environmental application potential.

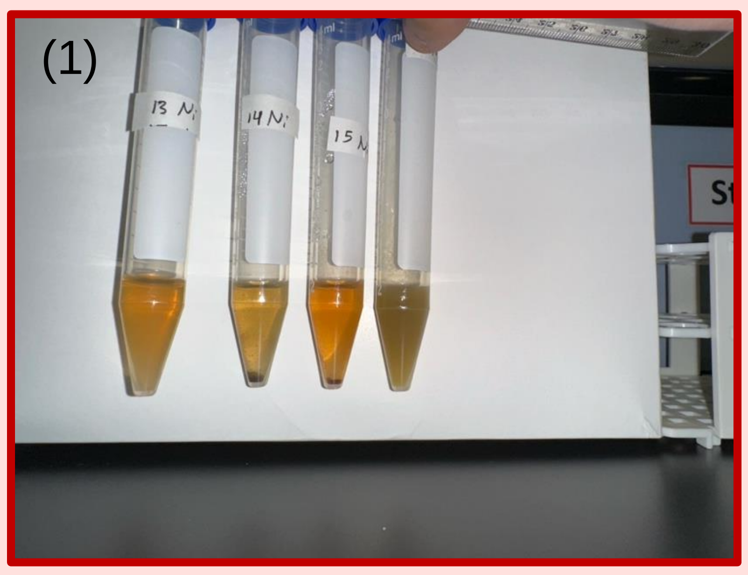


Figure 1: Initial Batches of ZnO Nanoparticles (Samples 1–4)

Figure 2: Intermediate Batches of ZnO Nanoparticles (Samples 5–8)

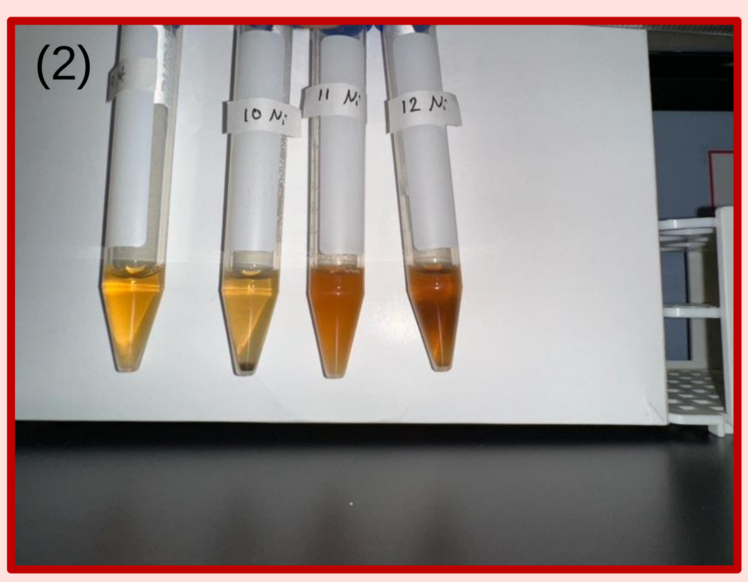


Figure 3: Pre Final Batches of ZnO Nanoparticles (Samples 9–12)

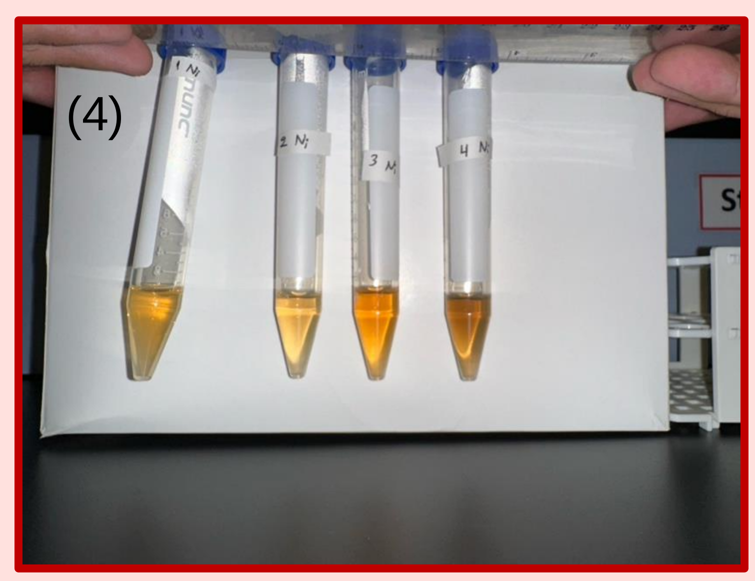
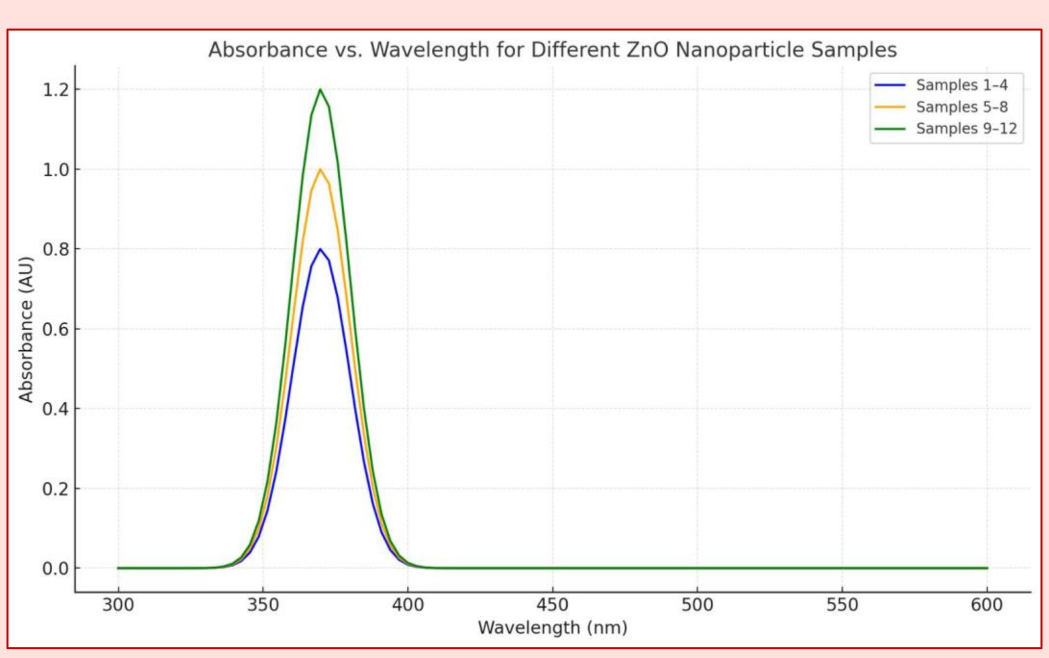


Figure 4: Final Batches of ZnO Nanoparticles (Samples 13–16)

The images showcase successful synthesis of ZnO nanoparticles using palm tree waste, with variations in color intensity indicating different nanoparticle concentrations or synthesis conditions. The consistent yellowish hues in most samples confirm the reproducibility and stability of the green synthesis method. Darker shades in some tubes suggest higher yields or aggregation, reflecting the influence of reaction parameters. These results highlight the method's scalability and potential for optimizing nanoparticle properties.

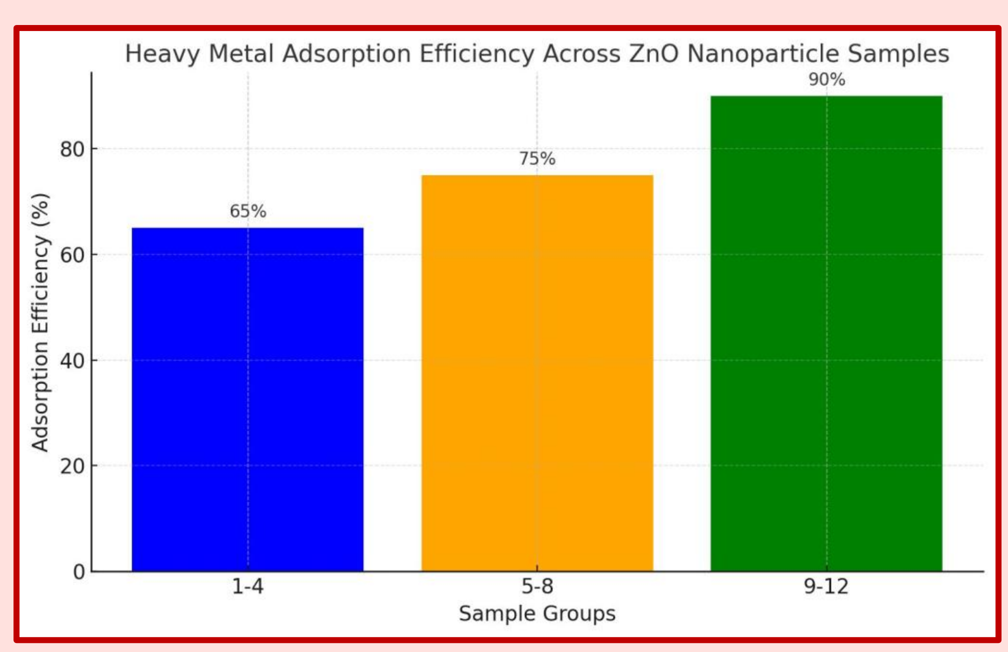
Preliminary Results

Results:
The green synthesis method successfully produced ZnO NPs with a mean diameter of 20-30 nm, as confirmed by TEM analysis. XRD patterns indicated the crystalline nature of the ZnO NPs. The nanocomposite beads exhibited enhanced mechanical stability and were effective in various applications. In biomedical assays, the beads demonstrated significant antibacterial activity against Escherichia coli and Staphylococcus aureus. For environmental applications, the beads showed promising results in the adsorption of heavy metals from aqueous solutions, indicating their potential for water purification.



Conclusions & Work in progress

Conclusion:
This study highlights the dual benefits of waste valorization and sustainable material production. The successful incorporation of palm tree waste into ZnO NPs and nanocomposite beads underscores the potential of these materials in addressing biomedical and environmental challenges. Future research will focus on optimizing the synthesis process and expanding the application scope of these eco-friendly nanomaterials.



Acknowledgement

Financial support from RCSI-Summer School is gratefully acknowledged.