



Green Synthesis and Optimization of ZnO-Loaded Adsorbent for Malachite Green Removal



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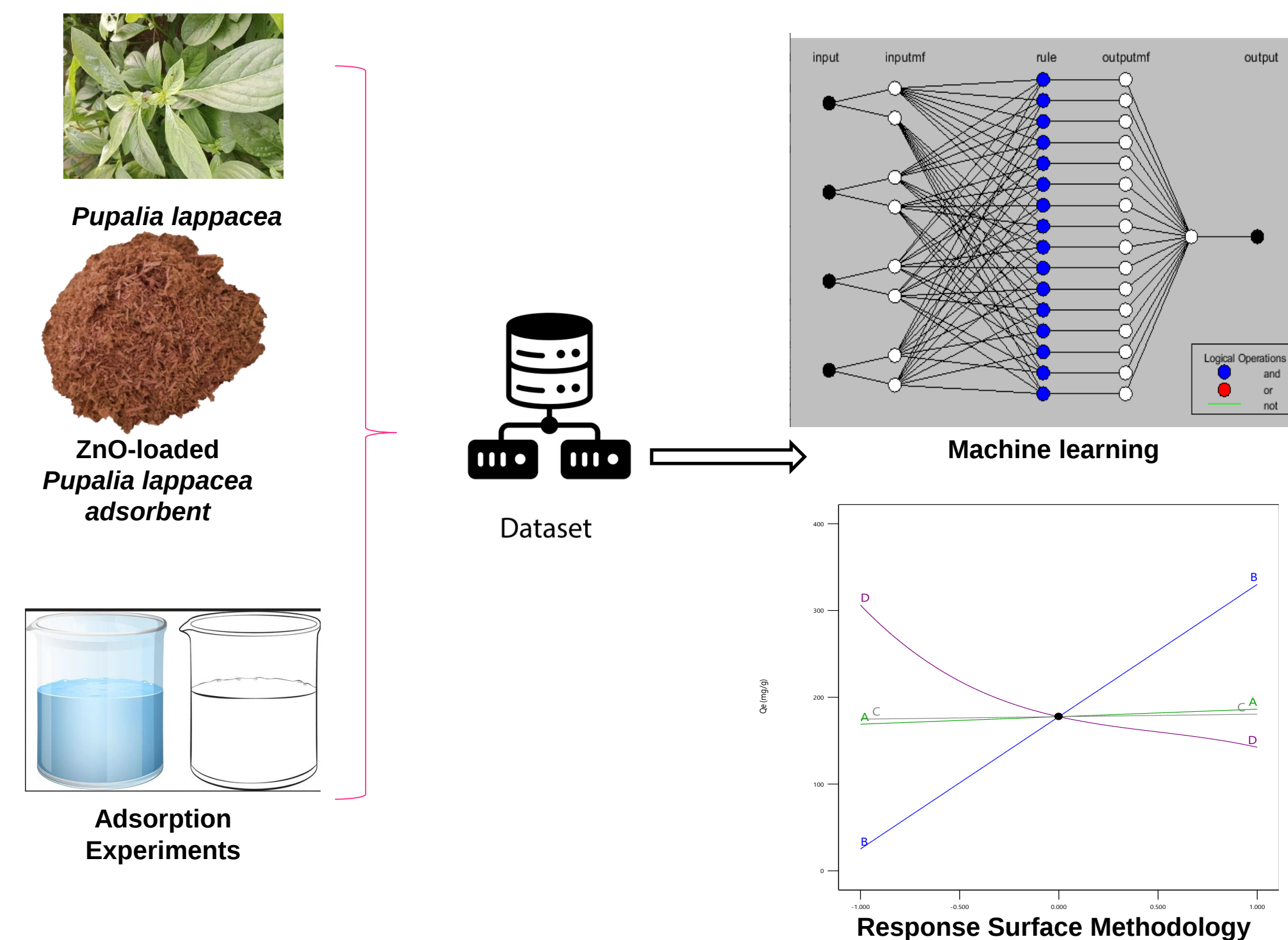
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Introduction

Malachite green (MG) is a persistent dye pollutant in textile wastewater. Traditional methods of removal are often costly or unsustainable. This study introduces a green synthesized ZnO-nanoparticles raw *Pupalia lappacea* adsorbent composite (Z-RPL) for MG removal.

The adsorption of MG onto Z-RPL was optimized using Response Surface Methodology (RSM) and Adaptive Neuro-fuzzy Inference System (ANFIS), combining experimental design with machine

Methodology



Results

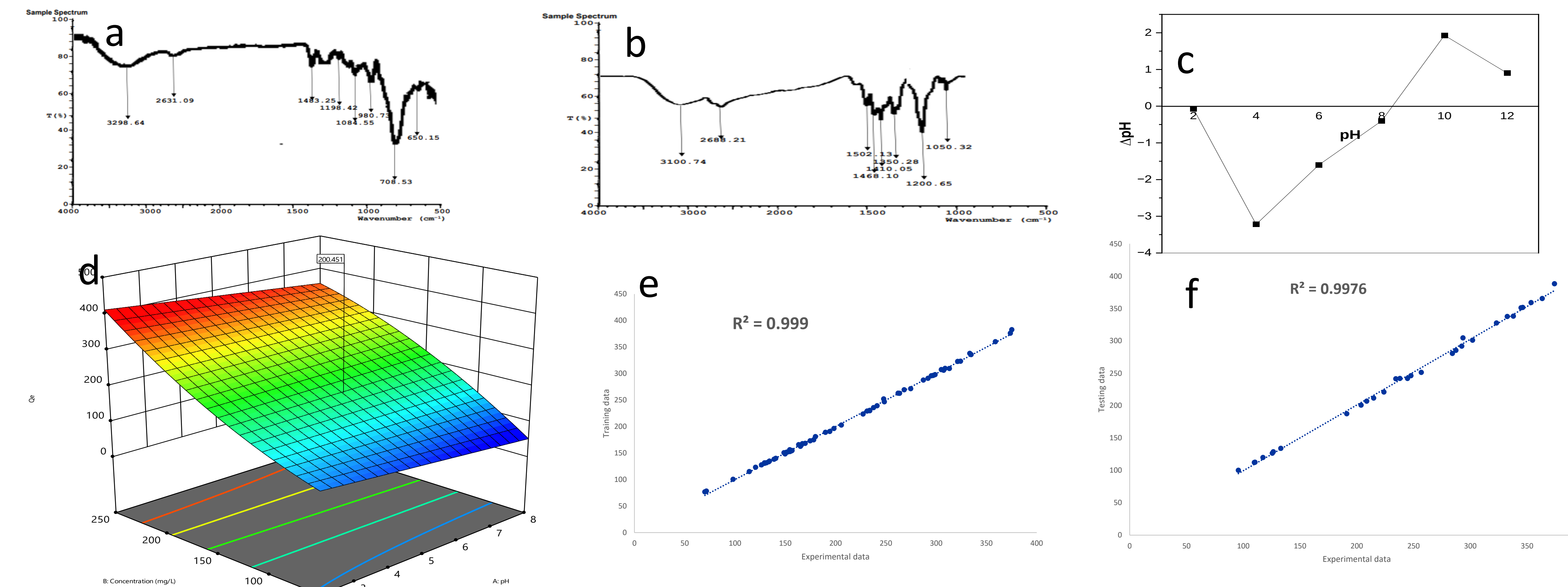


Figure 1: (a, b, c) FTIR and pH_{pzc} plots for ZnO-loaded *Pupalia lappacea*; (d, e, f) 3D response surface plot and Adaptive Neuro-fuzzy Inference System modelling cross plot analysis for MG removal onto Z-RPL.

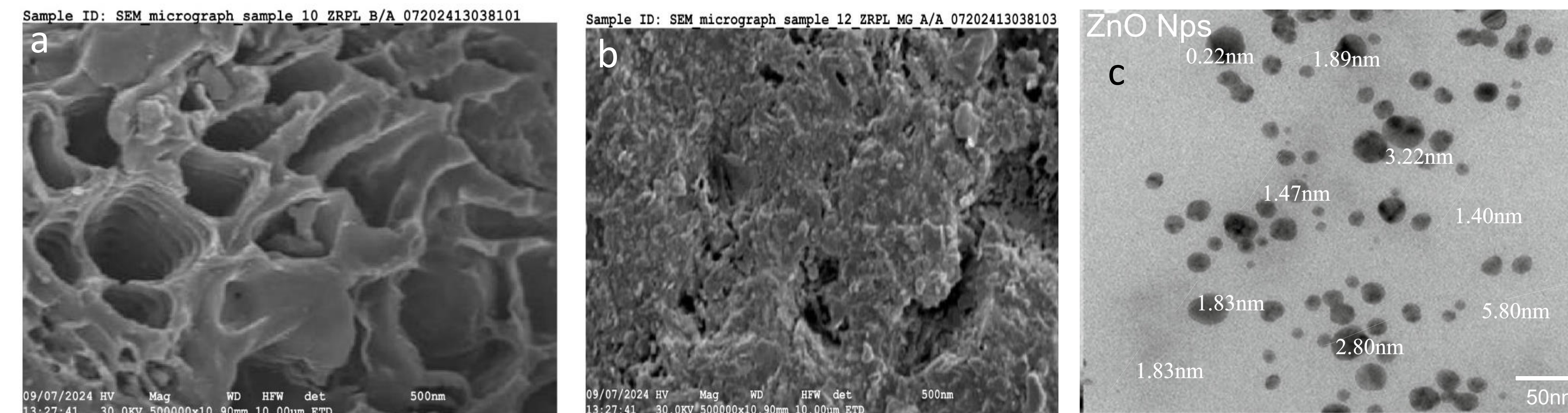


Figure 2: (a, b) SEM micrographs of ZnO-loaded *Pupalia lappacea* adsorbent before and after adsorption; (c) TEM image of ZnO nanoparticles synthesized using *Pupalia lappacea*

Discussion

- The FTIR spectra of Z-RPL shows different peaks corresponding to various functional groups (Figure 1a), while the pH_{pzc} of Z-RPL was 8.4 (Figure 1c). The 3D Response Surface plots in Figure 1d shows the interaction between pH and contact time. Figures 1e and 1f are the cross plot analysis of the Adaptive Neuro-fuzzy Inference System modelling.
- The surface of Z-RPL before the adsorption process shows several craters which could as a result of ZnO nanoparticles incorporation, however, after the adsorption process, the visible hollow were covered (Figure 2a and 2b). The TEM images shows ZnO-nanoparticles between 0.22 nm and 5.80 nm (Figure 2c).

Conclusion and Future Perspective

- The ZnO-loaded *Pupalia lappacea* (Z-RPL) adsorbent synthesized via green route demonstrated excellent performance for Malachite green removal, with high adsorption efficiency and strong model predictability. The integration of sustainable material development and intelligent modelling highlights the potential for scalable, and eco-friendly wastewater treatment solutions.
- Future works should explore the application of the adsorbent in real industrial wastewater, and scaling up the process using continuous flow systems to assess feasibility in large scale operations.

References

I. A. Olowonyo, K. K. Salam, M. O. Aremu, and A. Lateef, "Synthesis, characterization, and adsorptive performance of titanium dioxide nanoparticles modified groundnut shell activated carbon on ibuprofen removal from pharmaceutical wastewater," *Waste Management Bulletin*, vol. 1, no. 4, pp. 217–233, Mar. 2024, doi: [10.1016/j.wmb.2023.11.003](https://doi.org/10.1016/j.wmb.2023.11.003).