Graphene and Ceria Nanotube-Supported ZIF-8 Nanocomposites: High-Performance Adsorbents for CO_2 Capture, H_2S Scavenging, and Wastewater Treatment.

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Priority Topic Area: **Environmental Protection and Improvement**

1 – Objective

Industrial sustainability is currently hindered by toxic dye-contaminated wastewater, hazardous H_2S emissions, and the need for efficient CO_2 capture. While ZIF-8 is an exceptional adsorbent, its performance is often limited by particle agglomeration. This project aimed to engineer a modular hybrid platform by growing ZIF-8 onto two high-performance structural scaffolds: Ceria Nano Tubes (CeNT) and Pristine Graphene. The primary objective was to deliver a suite of multifunctional nanocomposites capable of high-capacity liquid-phase remediation and high-selectivity gas-phase separation to protect aquatic and atmospheric environments.

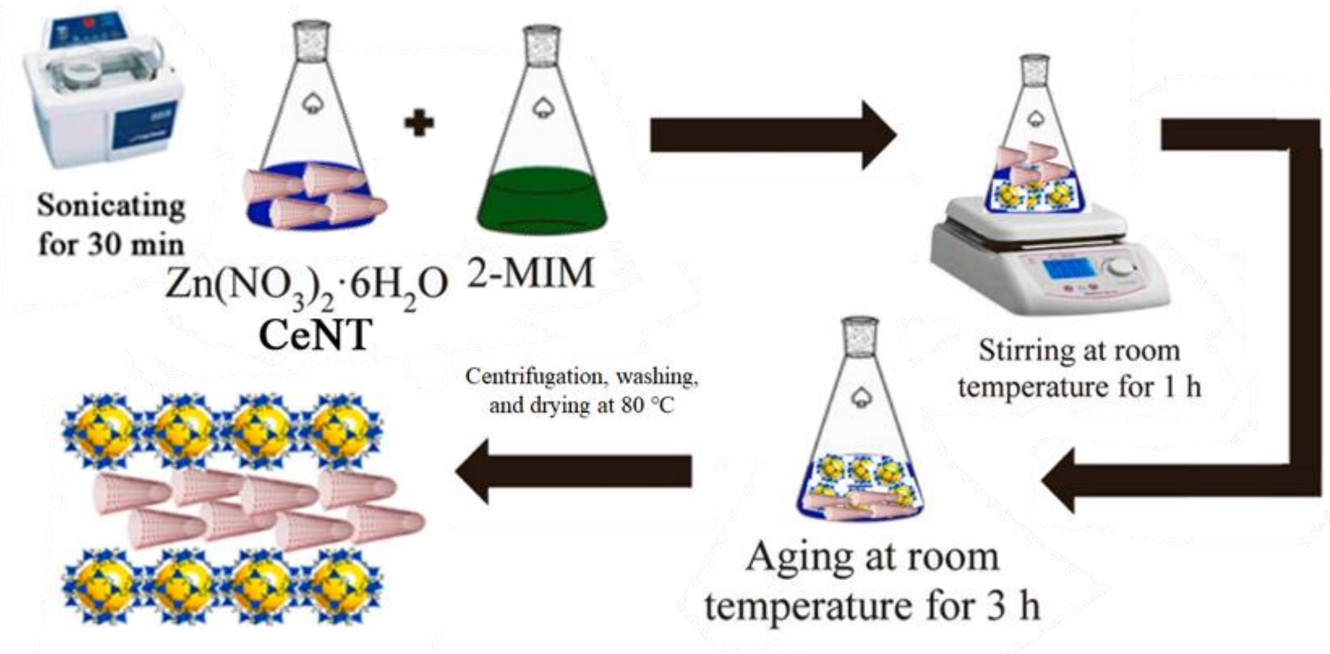

Figure 1: Synthesis of CeNT@ZIF-8 Nanocomposite.

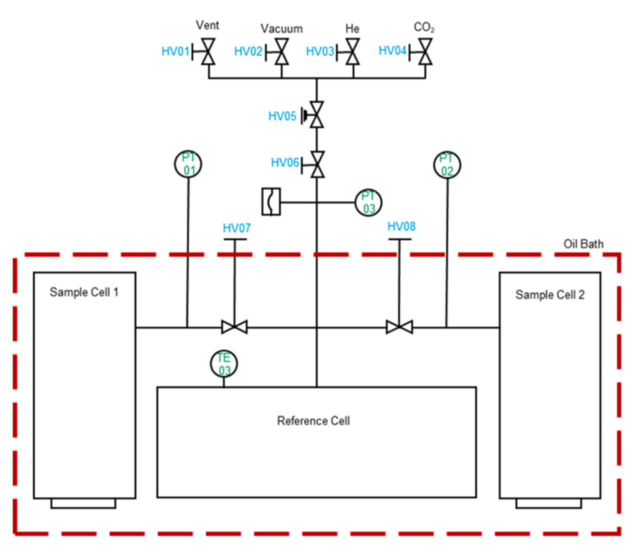

Figure 2: Schematic of the Low-pressure gas adsorption isotherm system.

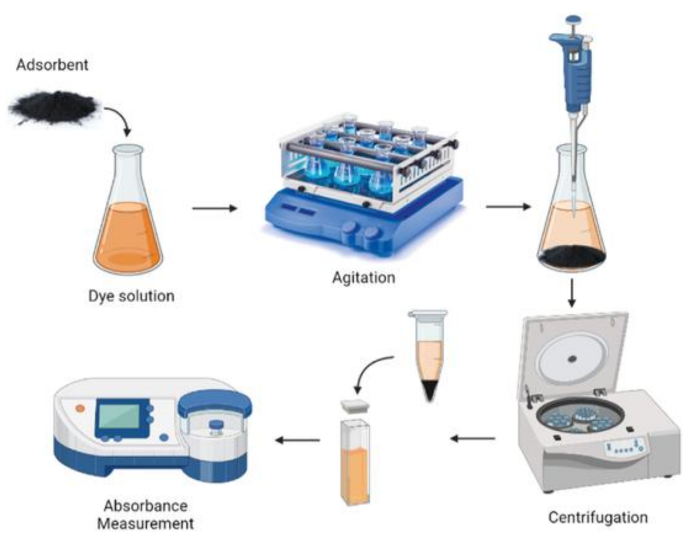

Figure 2: Dye Adsorption and Analysis Procedure.

2 – Methodology

Nanocomposites were synthesized by sonicating scaffolds with ZIF-8 precursors for 30 min, followed by 1 h stirring and 3 h aging. Wastewater treatment was assessed via batch adsorption (100 ppm dye, 50 mg/L adsorbent, 250 rpm, 24 h). H_2S scavenging performance was evaluated by bubbling gas through mud-dispersed composites in a sealed cell with real-time outlet monitoring. CO_2/H_2 separation capacities were measured using the static volumetric method in a GADIS-LP system. Structural integrity was verified using FESEM and XRD.

3 – Results

Wastewater Treatment (CeNT@ZIF-8): Hybridization with ceria nanotubes yielded a performance leap, with Methyl Orange removal capacity increasing 7-fold over pristine ZIF-8 and 18-fold over CeNT. The predicted maximum capacity q_{max} reached 425.5 mg/g.

H_2S Scavenging (Graphene@ZIF-8): In the energy sector, the composite captured 5 times more H_2S than standard water-based drilling fluids. It maintained a zero-gas breakthrough time for 7.5 hours without compromising the mud's rheological properties.

CO_2 Separation: High-pressure adsorption showed a 2x increase in CO_2 uptake compared to pristine ZIFs, reaching 75 cm^3/g. A maximum CO_2/H_2 selectivity of approximately 11 was achieved at 200 psi.

Characterization: Included XRD (crystallinity), FTIR (chemical groups), SEM (morphology), BET (surface area), and TGA (thermal stability).

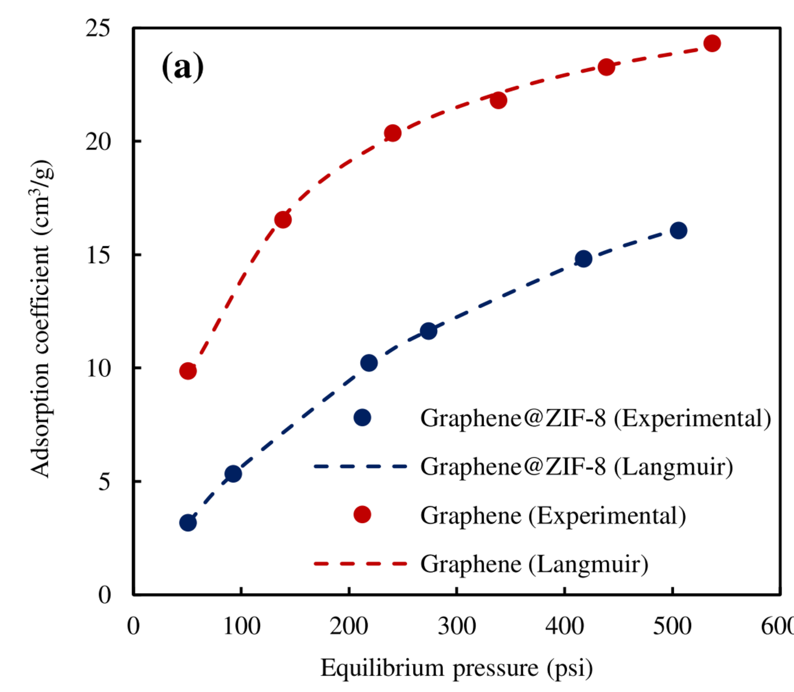

Figure 3: CO_2 adsorption isotherms.

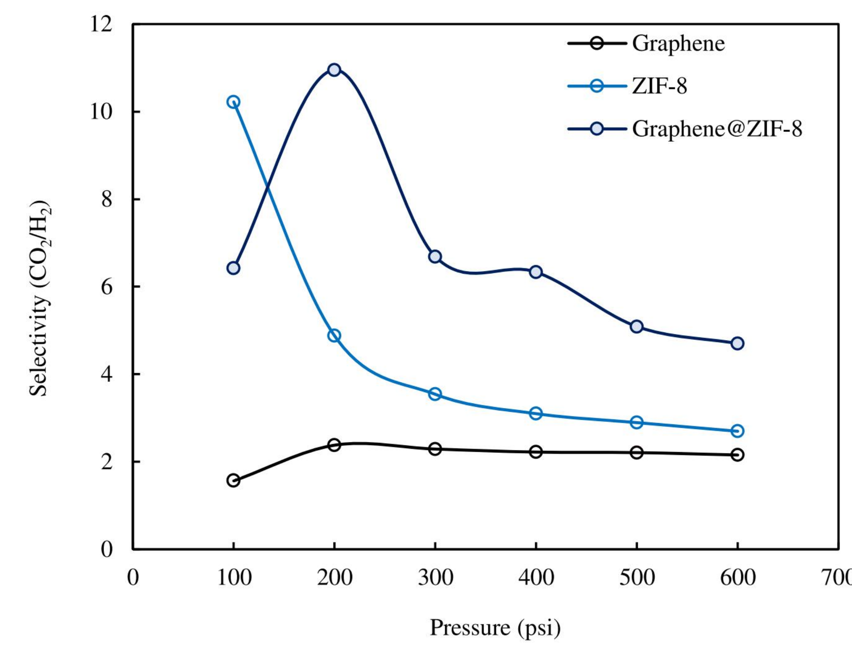

Figure 4: Ideal selectivity of CO_2/H_2.

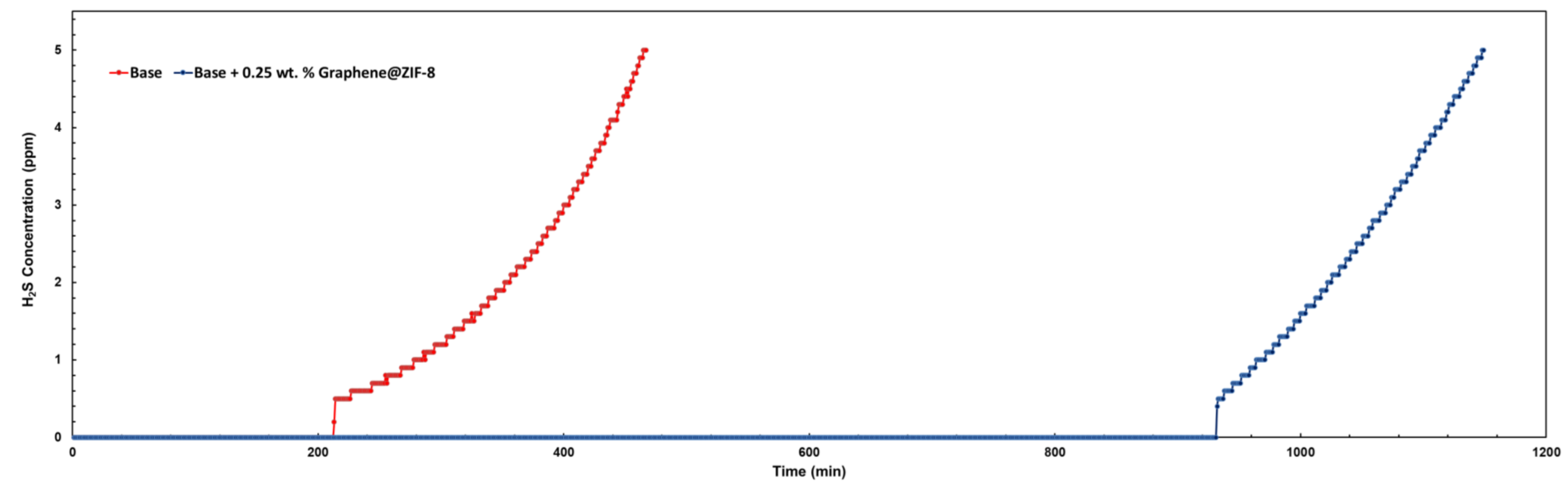

Figure 5: H_2S Scavenging Tests.

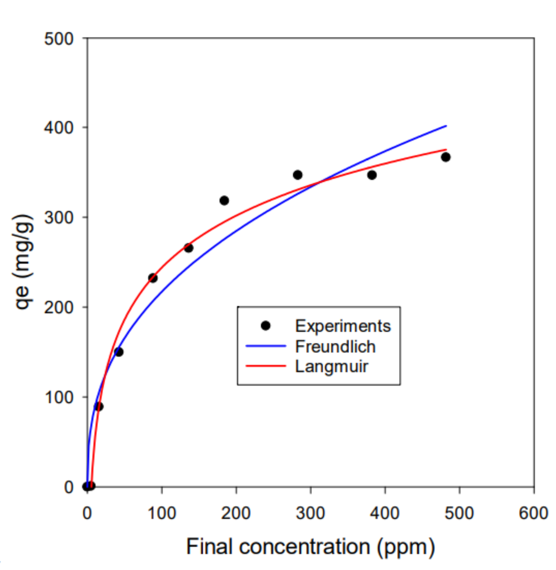

Figure 6: Adsorption Isotherms of CeNT@ZIF-8.

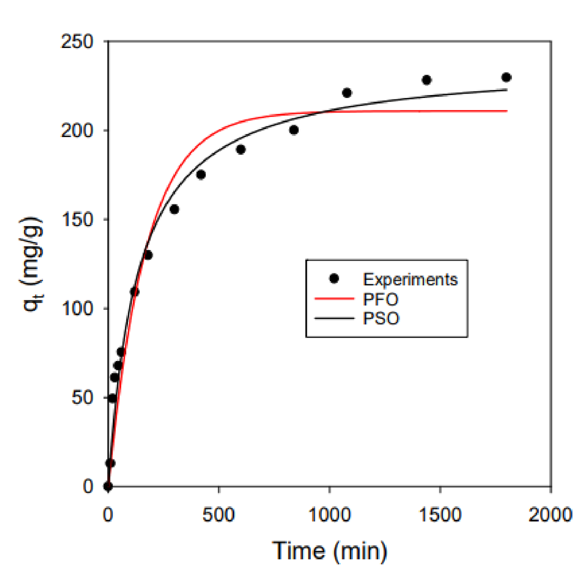

Figure 7: Adsorption Kinetics of CeNT@ZIF-8.

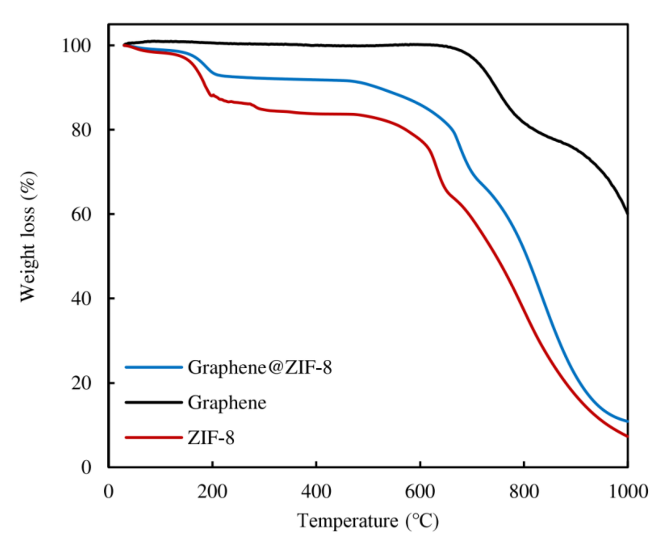

Figure 8: TGA of Graphene@ZIF-8 at 500 nm.

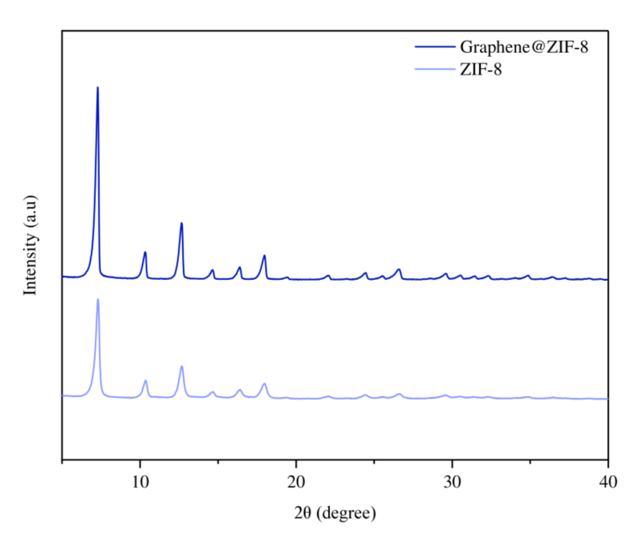

Figure 9: XRD ZIF-8 and Graphene@ZIF-8.

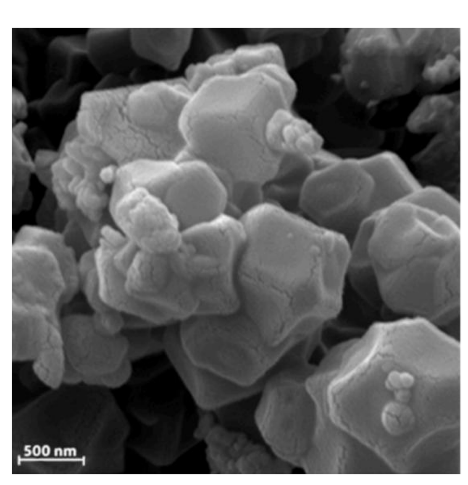

Figure 10: SEM image of Graphene@ZIF-8 at 500 nm.

4 – Benefit to society

This innovation directly supports SDG 6 (Clean Water) and SDG 13 (Climate Action) . The CeNT@ZIF-8 composite removes carcinogenic dyes, protecting public health and aquatic ecosystems. Simultaneously, the Graphene@ZIF-8 platform enhances industrial safety by scavenging toxic H_2S and enables a low-carbon transition through efficient CO_2 separation for clean hydrogen production . These regenerable materials offer sustainable pollution control with a minimal environmental footprint.

5 – Next steps

Future work will focus on testing the platform's stability in multicomponent real-world industrial effluents and complex, humid gas mixtures. We aim to integrate these hybrid powders into thin-film nanocomposite membranes for continuous-flow water and gas purification at pilot scale.

References

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