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Hydrogel Composites of Agro-Waste-Derived Graphene Oxide and Silica for Removing Methylene Blue Dye from Aqueous Solution

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Extended Abstract

The increasing environmental impact of industrial wastewater, particularly in developing nations like Bangladesh, has led to growing interest in sustainable solutions for water purification. This research introduces novel hydrogel composites synthesized by incorporating agricultural-waste-derived graphene oxide (GO-A) from sugarcane bagasse (SCB) and silica (SiO_2) from rice husk into a polyacrylamide (PAAm) polymer network for the removal of methylene blue (MB) dye from aqueous solutions. These materials were systematically characterized using X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and Fourier Transform Infrared Spectroscopy (FT-IR), demonstrating the successful formation of GO-A and SiO_2 and their integration into the PAAm matrix.

The GO-A/PAAm and GO-A/SiO_2/PAAm composites exhibited remarkable dye adsorption efficiency, achieving over 99% removal of MB under optimized conditions. The hydrogel composites followed the Freundlich isotherm model, with the GO-A/PAAm composite showing an adsorption capacity of 344.83 mg/g. Notably, the inclusion of SiO_2 enhanced adsorption kinetics, providing faster dye removal (Fig. 1). The use of SCB-derived GO-A and rice husk-derived SiO_2 highlights a sustainable and cost-effective approach to wastewater treatment, addressing both environmental and economic concerns. Adsorption studies also revealed that while GO-A powder and PAAm hydrogel alone exhibited 83% and 16% dye removal efficiencies, respectively, the GO-A/PAAm and GO-A/SiO_2/PAAm hydrogel composites demonstrated nearly 99% removal efficiency (Fig. 2). The superior performance of the hydrogel composites is attributed to the well-dispersed GO-A and SiO_2 within the PAAm network, creating more accessible adsorbent sites, which enhances the binding of MB dye. This highlights the significant advantage of using hydrogels over powder adsorbents, as the three-dimensional polymeric network provides greater surface area and stability, facilitating more effective and rapid dye removal.

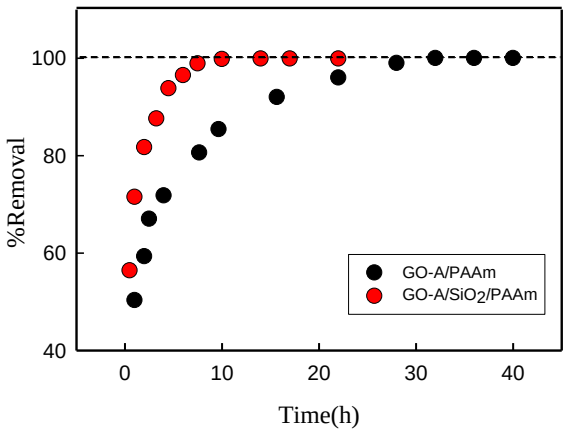

Figure 1: Kinetic study for MB adsorption on the hydrogels.

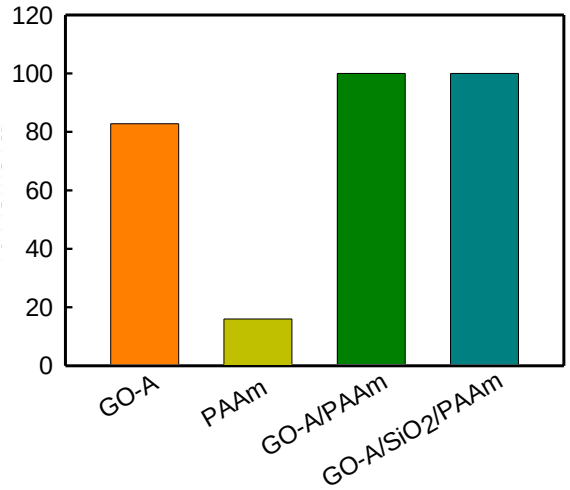

Figure 2: Relative adsorption capacities for MB adsorption on the adsorbents.

This study reflects the potential of agricultural-waste-derived materials in addressing key environmental challenges, particularly for Bangladesh, where industrial textile effluents contribute significantly to water pollution [1]. Moreover, this research aligns with the goals of Japan-Bangladesh research collaborations, emphasizing the importance of developing low-cost, high-efficiency solutions for wastewater management [2]. By leveraging Japan's advanced material science and Bangladesh's abundant agricultural resources, this partnership can help create scalable technologies to combat environmental degradation. The use of agro-waste materials not only reduces waste but also provides a viable solution for the industrial sectors in both nations, particularly in the textile industry.

In conclusion, the development of GO-A/PAAm and GO-A/SiO_2/PAAm hydrogel composites represents a significant step forward in sustainable wastewater treatment, with promising applications for domestic and industrial sectors in Bangladesh and beyond.

References

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