Magnetic Nanocomposites for Water Treatment Adsorption Technologies – the Case of Toxic Metal Removal and the Critical Metals Recovery

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INTRODUCTION

Adsorption continues to be a highly effective water treatment technology, appealing for its high efficiency and selectivity in contaminant removal, simple design, cost-effectiveness, and broad applicability. Unlike other methods, it generates no undesirable by-products and accommodates a diverse range of adsorbents, notably environmentally friendly nanomaterials. The integration of nanotechnologies has spurred significant advancements, enhancing adsorbent properties and creating new possibilities for efficient molecular separation at the adsorbent interface. Magnetic carbon-based nanocomposites exemplify this progress, incorporating inverse spinel ferrites (MFe_2O_4, M=Fe, Co or Mn) nanoparticles and exfoliated graphite. These adsorbents effectively combine the high surface area and magnetism of MFe_2O_4 NPs with the surface chemistry provided by the oxygen functional groups of exfoliated graphite. The application of these adsorbents extends beyond the removal of toxic metals like mercury (Hg), arsenic (As), and lead (Pb). They are equally effective in recovering high-value elements, such as rare earth elements (REEs). In this keynote, I'll highlight recent developments in MFe_2O_4 nanoadsorbents, covering their synthesis, properties, and application in both toxic metal removal and REE recovery from water and wastewater.

EXPERIMENTAL STUDY

Synthesis of the magnetic carbon-based nanocomposites involves a two-step process. Initially, commercial graphite undergoes exfoliation in DMF via 5 hours of sonication. Subsequently, MFe_2O_4 is synthesized through oxidative hydrolysis, performed in the presence of the previously exfoliated graphite. The resulting adsorbents were fully characterized using TEM, XRD, FTIR, and Raman spectroscopy. Adsorption studies were then conducted in batch mode, optimizing key parameters such as equilibrium time, pH, and adsorbent dosage.

RESULTS AND DISCUSSION

Successful synthesis of the magnetic carbon-based nanocomposite (Fig. 1) was achieved through an oxidative hydrolysis approach. Comprehensive characterization techniques confirmed the effective attachment of MFe_2O_4 NPs to exfoliated graphite sheets, validating the successful merging of the precursor materials' distinct properties, including saturation magnetization, crystallinity, and characteristic C-C, M-O, and O-H functional groups.

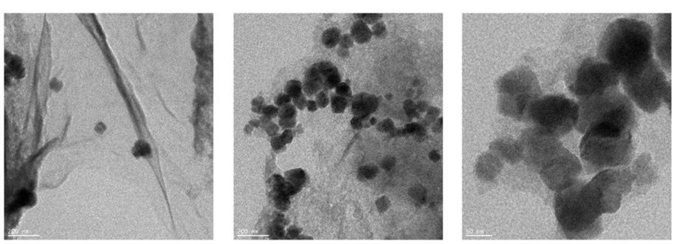

Fig. 1 Magnetic carbon-based nanocomposites ($CoFe_2O_4$@EG) synthesized by oxidative hydrolysis.

CONCLUSION

In conclusion, these newly developed magnetic carbon-based nanocomposites proved effective in removing mercury (Hg) and arsenic (As), and in recovering rare earth elements (La, Eu, Nd, Dy, Tb) from aqueous solutions. Sorption efficiency was significantly impacted by experimental parameters like adsorbent dosage, ionic strength, and especially pH, with electrostatic interactions identified as the primary adsorption mechanism.

ACKNOWLEDGMENTS

This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), financed by national funds through the FCT/MCTES (PIDDAC). C.B.L. thanks FCT for her researcher contract DOI 10.54499/2021.03739.CEECIND/ CP1659/CT0025.