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Coffee Waste-Based Nanostructures: A Cost-Effective Fluorescent Probe for Ni^{2+} Detection in Water

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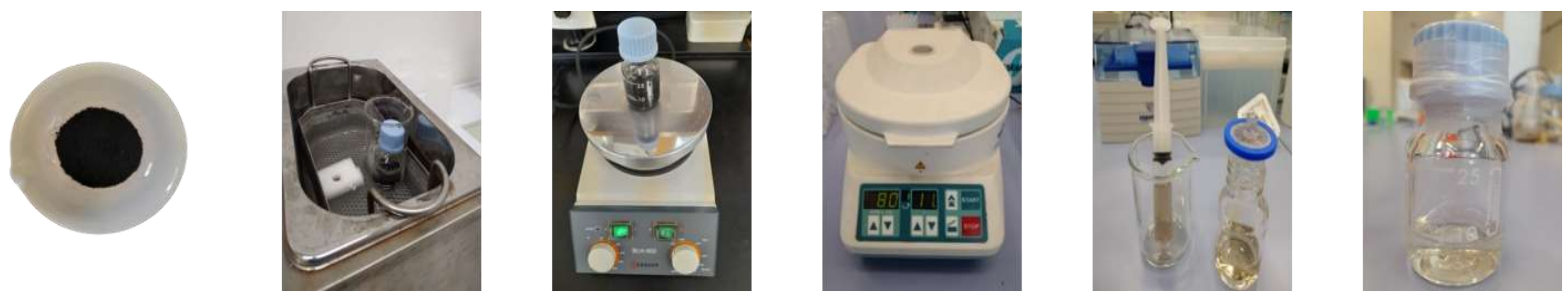
INTRODUCTION & AIM

Heavy metal pollution in aquatic systems is a pressing global issue, with nickel (Ni^{2+}) being particularly hazardous even at trace concentrations [1]. To safeguard public health, the WHO has set a strict limit of 0.07 mg/L for Ni^{2+} in drinking water [2], driving the demand for rapid, inexpensive, and selective detection methods. Among available approaches, fluorescence-based sensors stand out due to their simplicity, high sensitivity, and fast response [3].

To overcome limitations of conventional nanomaterials, sustainable and cost-effective strategies are increasingly sought. Waste valorization offers both environmental and economic advantages, with spent coffee grounds emerging as an abundant, carbon-rich feedstock. Previous studies have demonstrated their potential for nanocomposite synthesis and water remediation [4]–[6]. Building on this, we report the synthesis of carbon nanostructures from coffee waste and their application as a selective, eco-friendly, and low-cost fluorescent probe for Ni^{2+} detection in aqueous environments.

METHOD



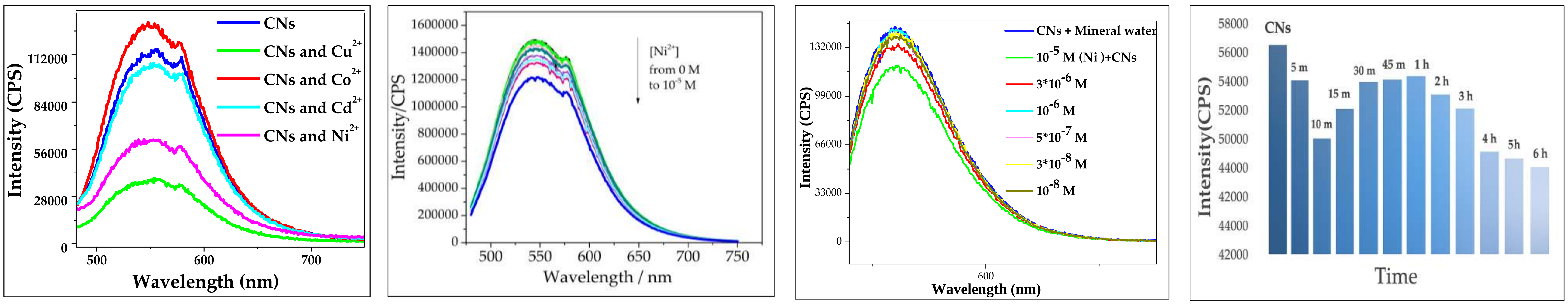
(a) (b) (c) (d) (e) (f)

Fluorescence measurements: Performed on a spectrometer (excitation 470 nm, emission 480–750 nm) to evaluate CNs for metal ion detection (Co^{2+}, Cu^{2+}, Cd^{2+}, Ni^{2+}).

Figure 1: Preparation of CNs: a) Carbonization of coffee waste at 600 °C for 1 h, b) Sonication for 10 min, c) Sonication after H_2O_2 addition, d) Centrifugation (8000 rpm, 20 min), e) Filtration (0.2 μm), f) CNs

Figure 2: Performed on a HORIBA Fluorolog spectrometer

RESULTS & DISCUSSION



(a) (b) (c) (d)

Figure 2: (a) Comparison Fluorescence of spectra CNs and metal ions, (b) Fluorescence spectra of CNs at varying Ni^{2+} ion concentrations (0 to 10^{-5} M), (c) Emission spectra of CNs at varying Ni^{2+} concentrations (10^{-5}–10^{-8} M) in mineral water, (d) Graph bars of mixture 10^{-4} M (Ni^{2+}) CNs in 5 min-6 hours.

CONCLUSION

Carbon nanostructures (CNs) derived from coffee waste were demonstrated as sustainable, low-cost fluorescent probes for Ni^{2+} detection. The CNs showed high selectivity, stable fluorescence, and reproducible performance in ultrapure and mineral water. While variability in tap water and a current detection limit of 10^{-4} M remain challenges, this study establishes a proof of concept for Ni^{2+} sensing in industrial wastewater. With further optimization of surface functionalization and sensor design, coffee-derived CNs hold potential as eco-friendly materials for water quality monitoring.

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