

Research Group for Sustainable Functional Materials Science

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Research Group for Sustainable Functional Materials Science started up from FY2022. This group was launched to conduct basic and applied research to aim at creating materials that combine high resistance (or resistivity) to harsh and/or extreme conditions (such as irradiation, heat, and corrosion) and specific functions (such as magnetism, optical-, mechanical-, and electrochemical properties). Also, this group covers fundamental researches on water treatment for removal of radionuclides and toxic elements.

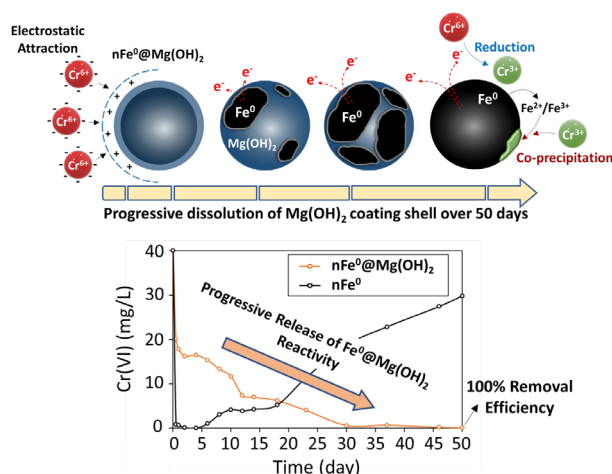
Prolonging Reactivity of Iron Nanoparticles for Cr(VI) Removal from Aqueous Solutions via Magnesium Hydroxide Coating

Chromium (Cr) is one of the highly toxic heavy metals with the potential to cause severe effects on human health, through exposure to elevated concentrations in aqueous environments. In this regard, zero-valent iron nanoparticles ($n\text{Fe}^0$) can reduce Cr(VI) to Cr(III) and integrate adsorption and/or co-precipitation in Cr(VI)/Cr(III) immobilization. Nevertheless, $n\text{Fe}^0$ nanoparticles suffer from some drawbacks, such as particle aggregation, poor mobility, and rapid core consumption, affecting their reactive performance [1]. Hence, in this work, a non-magnetic magnesium hydroxide ($\text{Mg}(\text{OH})_2$) coating was used to prolong the reactivity of $n\text{Fe}^0$ nanoparticles towards Cr(VI) removal from contaminated water. The short- and long-term progressive release of $n\text{Fe}^0$ reactivity was evaluated through several batch tests. As shown in Fig. 1, the results revealed a multifunctional effect of $\text{Mg}(\text{OH})_2$ coating in protecting $n\text{Fe}^0$ -core from rapid consumption (moderately soluble coating resulted in the progressive release of electrons) and Cr(VI) removal added-value (involvement of the coating shell in Cr(VI) adsorption and Cr(III) co-precipitation) [1]. Additionally, $n\text{Fe}^0$ showed good performance in preserving $n\text{Fe}^0$ long-term reactivity within a wide range of pH (3.0 – 9.0) and temperature (15 – 55 °C). The long-term investigation exhibited 100% removal efficiency of 40 mg/L initial Cr(VI) concentration, progressively achieved over 50 days reaction time (prolonged reactivity of 1.0 g/L material dose without desorption). Furthermore, $n\text{Fe}^0$ showed high regeneration abilities (> 5 cycles) with 1.36 times the average enhancement in Cr(VI) removal efficiency compared to that of $n\text{Fe}^0$. In conclusion, $\text{Mg}(\text{OH})_2$ showed promising performance in preserving the reactivity of $n\text{Fe}^0$ -core, confirming the high potential of $n\text{Fe}^0$ as a nanomaterial candidate for groundwater treatment applications.

The Effect of Reaction Conditions on As(V) Sorption onto $n\text{Fe}^0$ @ $\text{Mg}(\text{OH})_2$

For several decades, arsenic (As) contamination in water has been considered an issue of great concern. In this study, the effect of different reaction conditions (e.g., Mg/Fe coating ratio, material dose, initial pH, etc.) on As(V) removal by $n\text{Fe}^0$ @ $\text{Mg}(\text{OH})_2$ was investigated. The results indicated the superiority of the highest Mg/Fe coating ratio (100%) over the other lower ratios (25, and 50%) in As(V) removal, corresponding to the adsorption contribution of $\text{Mg}(\text{OH})_2$

coating shell. Furthermore, low pH conditions were favorable for As(V) removal by $n\text{Fe}^0$ @ $\text{Mg}(\text{OH})_2$, owing to the induced dissolution of $\text{Mg}(\text{OH})_2$ coating shell, exposing $n\text{Fe}^0$ -core to aqueous corrosion [2]. As K-edge X-ray absorption near edge structure (XANES) spectra of the reacted samples confirmed As(V) adsorption and the absence of As(III), implying the comparable role of As(V) sorption to the reduction of As(V) to As(III) (involvement of electrostatic sorption, and As(V) uptake by the formed FeOOH) [2]. Moreover, $n\text{Fe}^0$ @ $\text{Mg}(\text{OH})_2$ -100% showed high preservation ability towards air oxidation, showing just 19% decrease in removal efficiency after 1.0 day shelf-time, compared with that of the freshly synthesized material storage. However, the observed visual deformation in the total size of the material as well as the material hardness, affected the dispersion of the material in the reaction solution, thus influencing As(V) removal (especially at the early stages of the reaction).



Cr(VI) removal by $n\text{Fe}^0$ and $n\text{Fe}^0$ @ $\text{Mg}(\text{OH})_2$ over 50 days reaction time

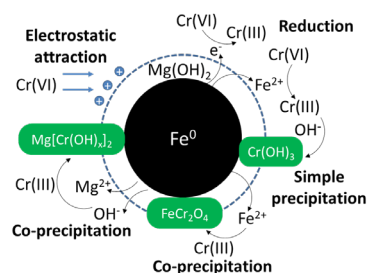


Fig. 1 Multifunctional magnesium hydroxide coating for iron nanoparticles towards prolonged reactivity in Cr(VI) removal from aqueous solutions.

References

- [1] I. Maamoun *et al.*, J. Env. Chem. Eng. **10**, 107431 (2022).
- [2] I. Maamoun *et al.*, Adv. Mater. Lett. **14**(2), 23021721 (2023).