Sodium-Copper Hexacyanoferrate-Modified Magnetic Nanoadsorbents for Removal of ^{137}Cs from Contaminated Water

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1. Introduction

The hazards of radioactive cesium contamination have attracted significant attention following the crisis at the Fukushima Daiichi Nuclear Power Plant in Japan in 2011. Although three years have passed, concerns regarding radioactive ^{137}Cs have come to the forefront as the most significant concern because of the harmful health effects of this isotope and its potential to persist for decades. ^{137}Cs enters the food chain through uptake by plants, it can be readily ingested by both animals and human beings. For these reasons, the capture of ^{137}Cs from waste waters is currently an urgent priority[1].

A variety of ^{137}Cs adsorbents, including zeolites, crystalline silicotitanate, aluminum molybdophosphate and metal-ferrocyanide. However, these adsorbents cannot be used in an open environment because there is no easy way to collect them after their application. Thus, an ideal ^{137}Cs adsorbent must be readily separable and provide excellent and selective ^{137}Cs binding[2].

In the present study, magnetic nanoparticles functionalized with sodium-copper hexacyanoferrate for the effective decontamination of ^{137}Cs. The fabricated NaCuHCF-modified magnetic nanoparticles (NaCuHCF-MNPs) were characterized by XRD, TGA and VSM. The adsorption capability of NaCuHCF-MNPs in removing cesium ions from water was also investigated.

2. Experimental

2.1 Synthesis and Adsorption Experiments

1,6-Hexanediamine (HMD) - coated magnetic nanoparticles (HMD-MNPs) were synthesized using a hydrothermal method. Next, polyethyleneimine (PEI) was coated onto the magnetic nanoparticles (HMD-MNPs) surfaces via a simple adsorption process as a foundation material to incorporate the sodium-copper hexacyanoferrate (NaCuHCF) on the surface of nanoparticles via the formation of coordination bonds between the amine groups in the PEI and Cu ions. After immobilizing the NaCuHCFs onto the PEI-coated magnetic nanoparticle surfaces, we conducted adsorption tests using inactive cesium to evaluate the and radioactive cesium removal performance.

2.2 Results & Discussion

The procedure used to synthesize the NaCuHCF-MNPs for the removal of ^{137}Cs. The crystalline structure of the HMD-MNPs was determined by X-ray diffraction (XRD), as shown in Fig. 1. The XRD analysis revealed six characteristic peaks at (2 2 0), (3 1 1), (4 0 0), (4 2 2), (5 1 1), and (4 4 0) phases of Fe_3O_4, respectively, indicating that the magnetic nanoparticles consisted of a Fe_3O_4 phase. The magnetic properties of the NaCuHCF-MNPs were next examined using a VSM. Plots of the magnetization versus the magnetic field for the HMD-MNPs and NaCuHCF-MNPs at room temperature are illustrated in Fig. 2. Both samples showed superparamagnetic behaviors. The saturation magnetizations (*M*s value) of the HMD-MNPs and NaCuHCF-MNPs were 68.6 emu/g and 45.2 emu/g, respectively. The Cs removal performance of the NaCuHCF-MNPs was evaluated by measuring the adsorption isotherms using inactive Cs. Fig. 3 shows a plot of the equilibrium amounts of inactive Cs adsorbed onto the NaCuHCF-MNPs prepared with different initial concentrations versus the concentration of cesium after equilibrium, while maintaining the NaCuHCF-MNPs : liquid ratio at

0.1 g/L. Batch experiments revealed that cesium adsorption equilibrium was rapidly achieved within 10 min, and the maximum adsorption capacity of the adsorbent was 125 mg/g.

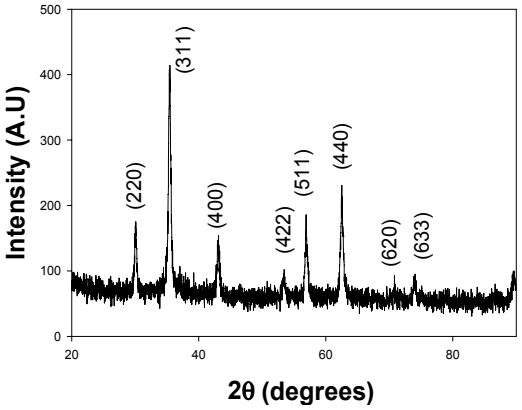

Fig. 1. XRD analysis of HMD-MNPs.

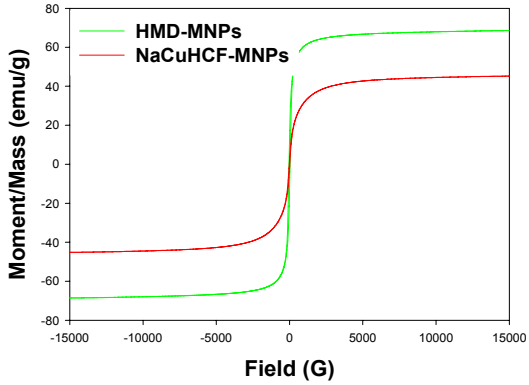

Fig. 2. Magnetization curves obtained from the HMD-MNPs and NaCuHCF-MNPs.

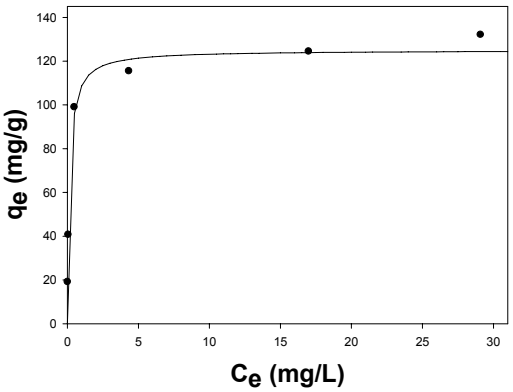

Fig. 3. Adsorption isotherm data obtained from the NaCuHCF-MNPs. The curve fits were obtained from the Langmuir adsorption isotherm models.

3. Conclusions

We successfully fabricated sodium-copper hexacyanoferrate-modified magnetic nanoparticles (NaCuHCF-MNPs) for the highly efficient removal of radioactive cesium from water with the ability to separate the absorbent magnetically. The NaCuHCF-MNPs exhibited high removal efficiency of cesium in water and showed rapid magnetic separation of the adsorbent from the water after treatment. NaCuHCF-MNPs can be easily recovered once spread into an open environment.

4. Acknowledgements

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5. REFERENCES

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