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Removal of nitrobenzene from aqueous solution by a novel clay-supported nanoscale zero-valent iron material

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ABSTRACT. Hangjin 2# clay (HJ) was used as the supporter for nanoscale zero-valent iron (nZVI) to fullfil an affordable and efficient decontamination material HJ-nZVI. In comparison with the kaolinite (K) and montmorillonite (M) supported nZVI materials (K-nZVI and M-nZVI), HJ-nZVI exhibited the best performance. The NB removal efficiency achieved by HJ-nZVI (93.2%) was not only much higher than that achieved by HJ (38.2%) and nZVI (52.3%) alone, but also better than the combined use of nZVI and HJ (70.2%).

Introduction

Nanoscale zero-valent iron (nZVI) has been extensively used for reduction of NB in contaminated water [1]. Nevertheless, there are still some technical challenges associated with its application. To stabilize the synthesized iron nanoparticles, immobilization of nZVIs on supports provides an alternative solution[2-3]. “Hangjin 2# clay” (HJ) is a kind of natural non-metallic clay minerals which was discovered in Inner Mongolia Hangjinqi China in the 1990s. In this paper, it was used as supports to inhibit the aggregation of iron nanoparticles and hence increase the reaction performance. The morphologies of the as-prepared HJ-nZVI were analyzed. The reactivity of the HJ-nZVI was compared with nZVI, K-nZVI and M-nZVI.

Materials and methods

The natural HJ was obtained from the region of hangjinqi of Ordos area in Inner Mongolia. K and M were obtained from Sinopharm Chemical Reagent Co. Ltd. (China). And its chemical composition was in Table 1. nZVI, HJ-nZVI, K-nZVI and M-nZVI particles were prepared under N_2 atmosphere using conventional liquid-phase method by the reduction of ferric iron by borohydrid. Weight ratio of appropriate clay and nZVI was 5:1. The surface morphology images of HJ-nZVI were taken by scanning electron microscope (SEM) (SU8010, Hitachi, Japan). Transmission electron microscopy (TEM) images were obtained on a HJ7700 (HITACHI) electron microscope. Batch reduction experiments of NB were performed in 250 mL sealed conical flasks, and the conical flasks with solution were shaked at 250 rpm.

Table 1 Chemical composition and cation exchange capacity of clay materials.

	Cation exchange capacity (CEC cmol kg^{-1})	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	K_2O	Na_2O	TiO_2
		wt %							
HJ	32.2	50.9	15.2	6.4	5.9	3.6	3.6	0.9	0.6
K	3.6	45.9	35.3	0.3	3.3	1.5	0.2	0.1	--
M	80.2	58.5	18.5	1.0	1.8	3.3	0.8	2.8	--

Results and discussion

Morphology analysis

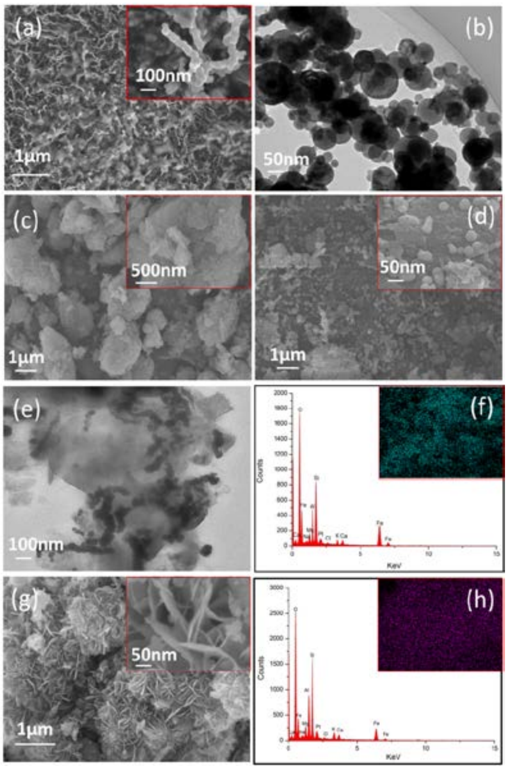

Fig.1 (a-b): SEM and TEM images of nZVI; (c) SEM images of HJ; (d-f) SEM, TEM images and EDX spectrum, elemental iron map (insert) of HJ-nZVI before reaction; (g-h) SEM images, EDX spectrum and elemental iron map (insert) of HJ-nZVI after reaction.

In Fig. 1d and Fig. 1e, it can be observed that the nZVI nanoparticles were loaded evenly on the surface of HJ. Less chain-like and spherical aggregation indicated their preferable dispersion on HJ. The EDX also clearly demonstrated that nZVIs were evenly distributed onto HJ (Fig. 1f, the inserted mapping image).

Removal of NB using different supported nZVI materials. As shown in Fig. 2a, the NB adsorption capacity of different clays was in the order of HJ (40.7%)> M (31.0%)> K (32.9%). The NB removal efficiencies were 94.3%, 50.2% and 42.8% for HJ-nZVI, M-nZVI and K-nZVI, respectively (Fig. 2c). HJ-nZVI exhibited the best removal performance for NB removal. The removal efficiency of NB using HJ, nZVI, HJ-nZVI and HJ+nZVI was investigated. As shown in Fig. 2d, the efficiency of NB by HJ-nZVI was much higher than that of HJ (38.2%) and nZVI (52.3%) alone and was also superior to the combined use of nZVI and HJ (70.2%). This result confirmed that HJ was an ideal support material that could maximize the reactivity of nZVI.

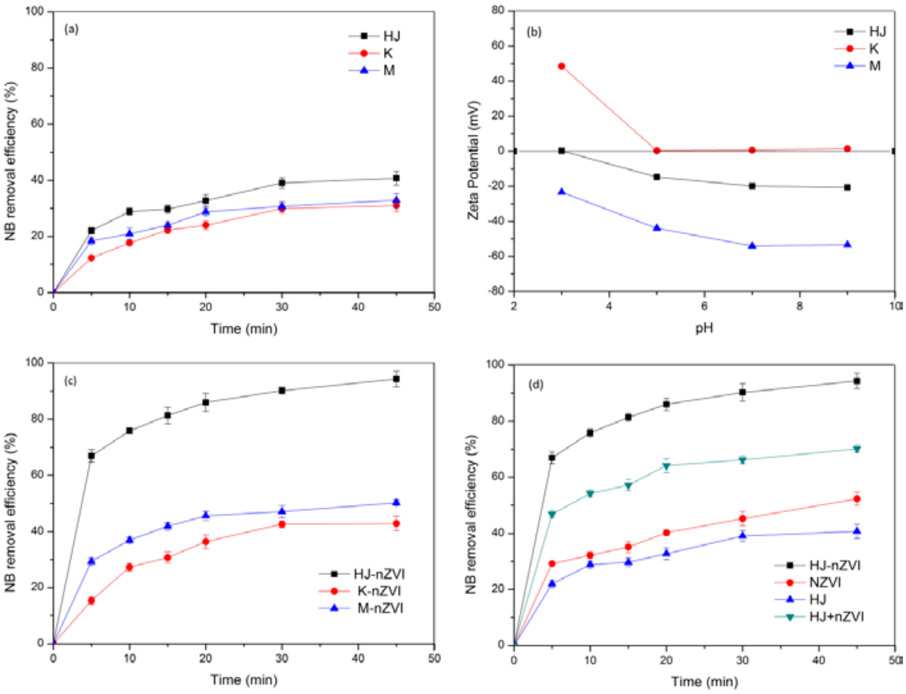

Fig. 2 (a-b) NB removal efficiency and zeta potential of three different clays alone (1.67g L^{-1}); (c) different clays supported nZVI materials: (2.0g L^{-1}); (d) different HJ supported nZVI materials: HJ-nZVI (2.0g L^{-1}), HJ (1.67g L^{-1}), nZVI (0.33g L^{-1}), HJ+nZVI (1.67g L^{-1}+0.33g L^{-1})); 50 mg L^{-1}; 200 mL; 25 ^{o}C; $pH_{(ini)}$ =7.0; 250 rmp.

Conclusion

A novel composite material (HJ-nZVI) was successfully synthesized for decontamination for the first time. Spherical nZVI nanoparticles evenly distributed onto the surface of HJ. Relative to K-nZVI and HJ-nZVI samples, HJ-nZVI showed higher NB removal capability.

References

[1] O.S. Kuscu, D.T. Sponza, Effects of nitrobenzene concentration and hydraulic retention time on the treatment of nitrobenzene in sequential anaerobic baffled reactor (ABR)/continuously stirred tank reactor (CSTR) system, Bioresour. Technol. 100 (2009) 2162-2170.

[2] T.Y. Liu, Z.L. Wang, X.X. Yan, B. Zhang, Removal of mercury (II) and chromium (VI) from wastewater using a new and effective composite: Pumice-supported nanoscale zero-valent iron, Chem. Eng. J. 245 (2014) 34-40.

[3] X. S, X.S. Wang, J.S. Li, L.J. Wang, Degradation of nitrobenzene in groundwater by nanoscale zero-valent iron particles incorporated inside the channels of SBA-15 rods, J. Taiwan. Inst. Chem. E. 45 (2014) 996-1000.