Enhanced reduction of doxycycline from aqueous solution by Sucrose modified Nanoscale Zero Valent Iron

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Abstract

Pharmaceutical pollution of environment is closely related to the growth of drug consumption. It is proved that these pharmacologically active substances, even in trace amounts are expected to have a negative impact on human health. Doxycycline (DOX) is one of the widely used antibiotics for the treatment of human and animal diseases. The high concentration of DOX in drinking – water can cause health issues such as drug-resistant microorganisms. One of the main drawback is that NZVI agglomerates rapidly, this research work investigated the metal loading and modified NZVI for doxycycline removal. And the degradation of doxycycline was analyzed by Uv-vis spectrophotometer and HPLC chromatography.

Introduction

Figure 1. Doxycycline structure

>Doxycycline (DOX) is one of the bacteriostatic agent against for gram-positive and gram-negative bacteria. It has been extensively used for the treatment of diseases emerged by chlamydiae, rickettsiae and mycoplasmas². It has been verified that exposure to low-level and accumulative DC may lead to a variety of dangerous effects, including destruction of aquatic photosynthetic organisms and indigenous microbial populations and dissemination into antibiotic-resistant genes among microorganisms.

>In recent years, nanoscale zero-valent iron (NZVI) has been widely used in in-situ remediation of inorganic and organic contaminants¹. However, some limitations had been reported, such as passivation of the reactive sites and limited efficiency to remove some contaminants. To overcome this disadvantage and enhance the reactivity, modifying NZVI with stabilizer and support with monometal (e/g/ sucrose or metal) has been a favorable solution.

> The objectives of this study were to

-Compare the removal of doxycycline by bimetallic and S-NZVI;

-- characterization of synthesized of S-NZVI

Experimental conditions

Condition	
Catalyst Loading (mg/L)	10
Initial Doxycycline conc.(mM)	0.225
pH	6.5
Temperature (°C)	25

- ✓ The concentration of doxycycline was analyzed by HPLC.
- ✓ Removal capacity was calculated as followed:

$$q_t = \frac{V(C_0 - C_t)}{M}$$

Analytical Procedures

HPLC measurements were carried out using a Agilent HPLC -1026 with DAD. The mobile phase was a mixture of acetonitrile-methanol (25:75, V/V) in isocratic system at flow rate of 0.2mL/min. Fig.2.

Figure 3. UV-Vis spectrophotometer (wavelength from 220nm to 450nm)

Surface modified Nanoscale Zero Valent Iron (S-NZVI)

The modification of NZVI with sucrose conducted for reducing its aggregation, improving its transfer performance in environmental media, and increasing its degradation ability to contaminants. This kind of stabilizer can not only prevent agglomeration of the NZVI, but also control the particle size.

Figure 4. a) SEM images and EDX image of S-NZVI. The scale bar is 100 nm. b)XRD-analysis S-NZVI

The FTIR spectrum of the S-NZVI is shown in Fig.3. Broad bands at 3029-3455 cm⁻¹ and 1624 cm⁻¹ resulted from O-H stretching. Bands at 2495cm⁻¹, at 1929cm⁻¹ and 1467cm⁻¹ related to C-H, C=C and COO- respectively, resulted from aliphatic, aromatic and carboxylic group from sucrose.

Figure 5. FTIR – spectra of Sucrose modified NZVI

Results and discussion

Figure 6. Reaction kinetics of different NZVI

Table 1. Comparison of doxycycline removal

Catalyst	Removal efficiency	Kinetic rate constant
Sucrose-NZVI	100% (30 min)	0.7min ⁻¹
Cu-NZVI	100% (120 min)	0.309min ⁻¹
Sn/NZVI	100% (<180 min)	0.292min ⁻¹

>As shown in Fig.6. no photolysis and adsorption by PTFE were occurred.

>Sucrose modified shows higher reactivity for the removal of doxycycline from aqueous solution by compare with Sn/NZVI and Cu/NZVI bimetallic catalysts.

Conclusions

>The present work demonstrated that the sucrose can be used as cost-effective and environmentally friendly material for NZVI stabilization enhancing the reactivity by compare with Sn/NZVI and Cu/NZVI bimetallic catalysts.

> SEM/EDX morphology and FTIR spectrum of S-NZVI were characterized.

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Reference

- Nova 'k-Pe'kli M, El-Hadi Mesbah M, Petho G (1996) Equilibrium studies on tetracycline-metal ion systems. J Pharm Biomed Anal 14:1025–1029
- Roberts MC (1996). Tetracycline resistance determinants: mechanism of action, regulation of expression, genetic mobility, and distribution. FEMS Microbiol Rev 19:1–24