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MODIFICATION OF TAP WATER TREATMENT RESIDUE BY ZERO-VALENT IRON FOR ARSENIC IONS ADSORPTION

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Abstract

Sludge of tap water production from the Metropolitan Waterworks Authority (Bangkhen, Thailand) was modified by zero-valent iron (ZVI) with the purpose to be an adsorbent for the removal of arsenite and arsenate ions from water. The dispersion of zero-valent iron on the surface of modified sludge (ZVI-S) was characterized by scanning electron microscope with energy dispersive spectroscopy (SEM-EDS). The factors affecting the removal of arsenite and arsenate ions in batch system were studied. Our study revealed that the optimal pH for the adsorption was 3. The equilibrium contact time of both arsenite and arsenate was 1 hour. The maximum adsorption capacity was found to be 15.1 and 41.0 mg/g for arsenite and arsenate respectively. All results showed that the modified tap water production by zero-valent iron was effective for arsenite and arsenate removal from water.

Methodology

The tap water production sludge modified by zero-valent iron (ZVI-S) was prepared via sodium borohydride reduction of ferric chloride. Briefly, 12.8 g of sludge was added into 30 mL of 0.67 mol/L ferric chloride solution which prepared by dissolving $FeCl_3$ into 4 %(v/v) ethanol in water. The mixture was held on a magnetic stirrer to be mixed. Then, 100 mL, 0.8 mol/L $NaBH_4$ was added dropwise into the mixture. The black solid produced in the solution. After the addition of the sodium borohydride solution was completed, the mixture was stood for 10 minutes. After that, the ZVI-S was filtered and washed with deionized water and ethanol, respectively. Last step, the ZVI-S was dried in an oven at 50°C overnight and kept in a desiccator to prevent the moisture from the air. Parameters affecting arsenic adsorption were studied in batch system.

Results and discussion

Characterization of zero-valent iron-sludge

The zero-valent iron in the modification of tap water production sludge was prepared via sodium borohydride reduction of ferric chloride. The reaction mechanism is shown in Equation 1,

$$4Fe^{3+} + 3BH_4^- + 9H_2O \longrightarrow 4Fe^0(s) + 3H_2BO_3^- + 12H^+ + 6H_2(g) \qquad \text{(Eq. 1)}$$

Theoretically (Eq.1), when ZVI-S is prepared using the procedure above, the ratio of zero-valent iron to sludge is supposed to be 92:8 (w/w). The photographs of sludge before and after modified by zero-valent iron are shown in Fig. 1a and Fig.1b, respectively.

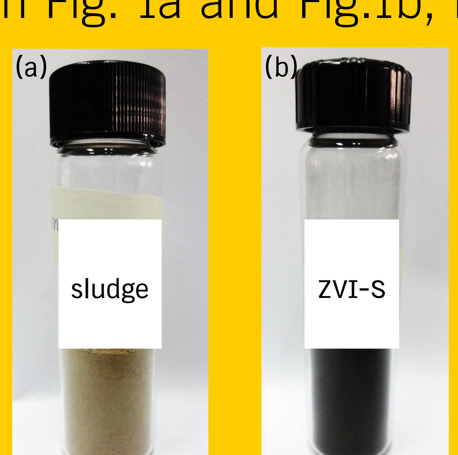

Figure 1. (a) Tap water production sludge and (b) zero-valent iron modified tap water production sludge.

An EDX spectrum (shown in Fig. 2a) of ZVI-S shows characteristic peaks of zero-valent iron, indicating that ZVI-S contained zero-valent iron on its surface. The mapping EDX image of ZVI-S in Fig. 2b shows that zero-valent iron (red spots) was dispersed well on the surface of ZVI-S and thus confirms that the modification of tap water production sludge by zero-valent iron was successful.

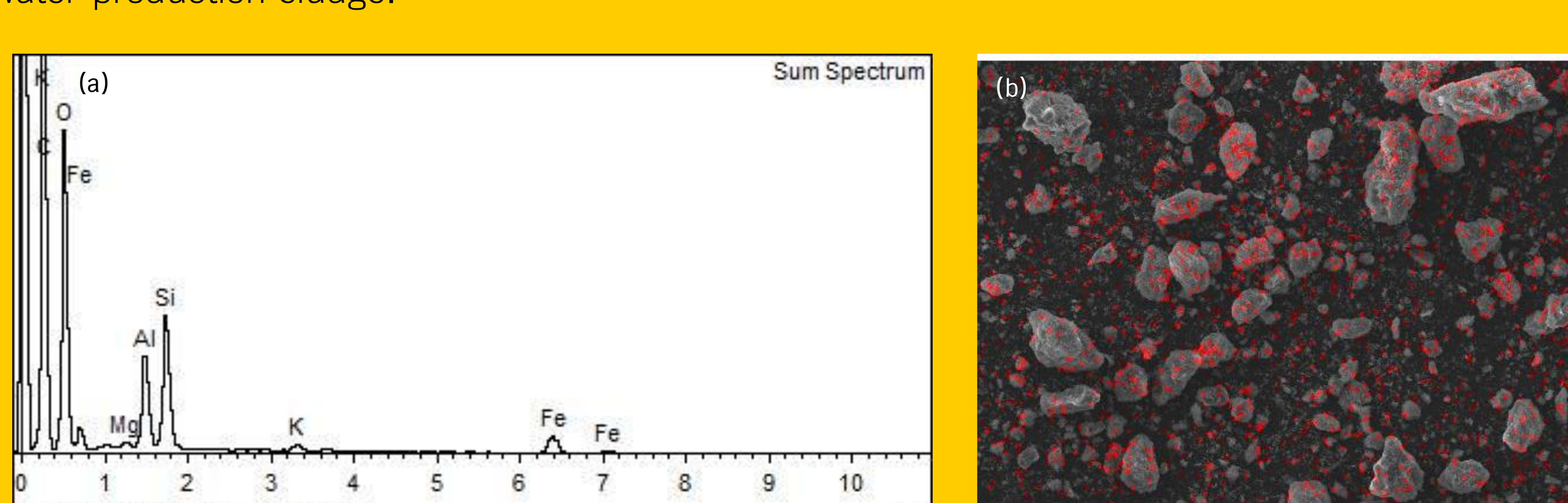

Figure 2. (a) EDX spectrum of ZVI-S and (b) Elemental EDX mapping image (Fe) of ZVI-S.

Effect of pH

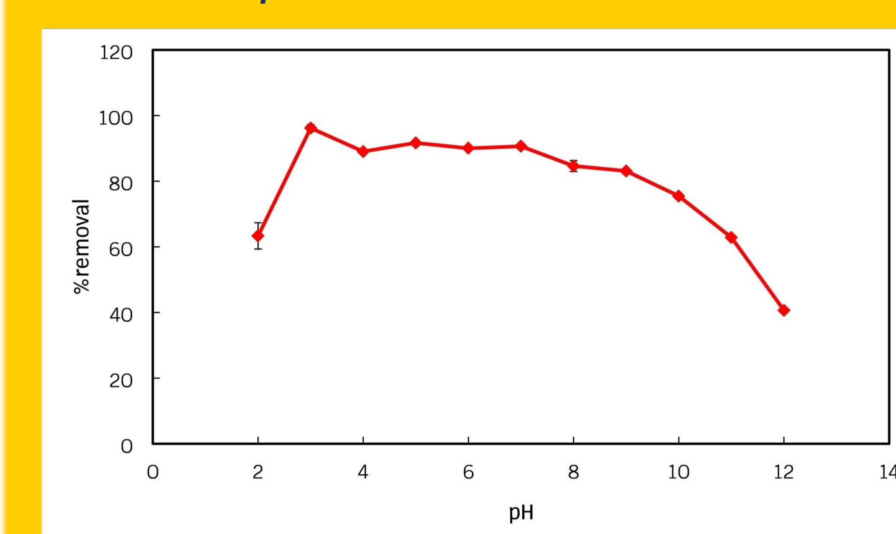

Figure 3. Effect of pH on arsenite adsorption. [As] = 100 mg/L, V = 10 mL, t = 24 h and ZVI-S = 0.05 g.

The highest adsorption amount of arsenite is at pH 3 and then the adsorption amount of arsenite on ZVI-S decreased when the pH of solution increased due to less electrostatic forces between the adsorbent. Therefore, in this study the pH of sample solution used in all following experiments was 3.

Effect of contact time

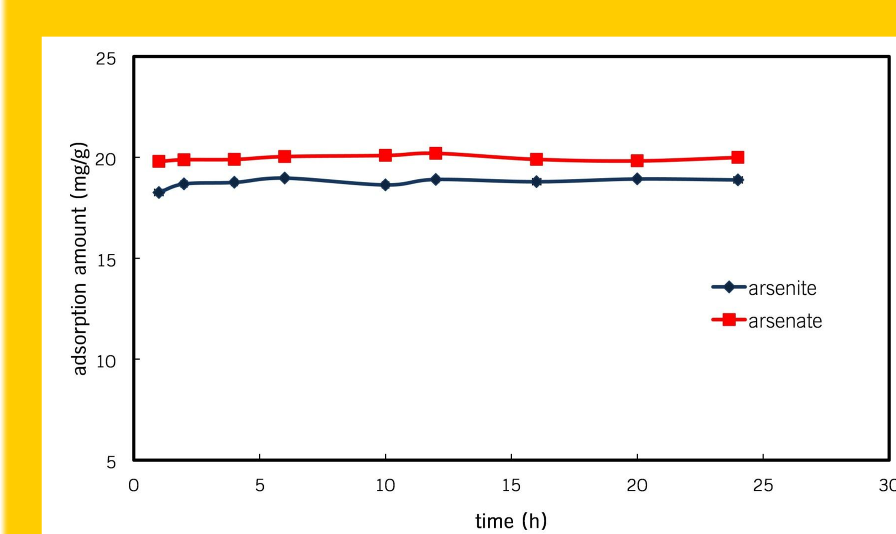

Figure 4. Adsorption amounts of arsenite and arsenate as a function of time. [As] = 100 mg/L, V = 10 mL and ZVI-S = 0.05 g.

The adsorption amount of arsenite and arsenate against time are shown in Fig.4. The results show that the adsorption kinetics of arsenite and arsenate were rapid. They took about 1 hour to reach equilibrium.

Adsorption isotherms

Both arsenite and arsenate adsorption on ZVI-S was fitted to the Langmuir and the Freundlich models. The maximum adsorption capacity of arsenite and arsenate calculated by the Langmuir adsorption isotherms were 15.1 and 41.0 mg/g, respectively

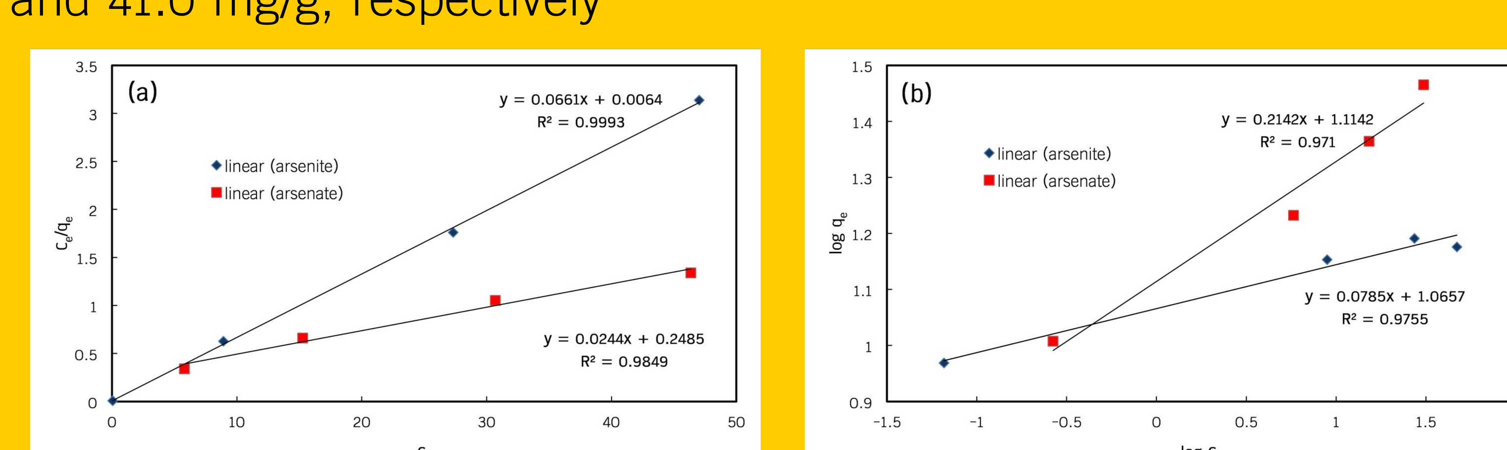

Figure 5. (a) Langmuir (b) Freundlich isotherms plots of arsenite and arsenate.

Conclusion

ZVI-S was successfully prepared via in-situ sodium borohydride reduction of ferric chloride. Batch adsorption studies showed that ZVI-S is effective in the removal of both arsenite and arsenate with rapid time under controlled conditions. The maximum adsorption capacity was found to be 15.1 and 41.0 mg/g for arsenite and arsenate respectively.

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