Supplementary information

Immobilization of hydrous iron oxides into porous alginate beads for arsenic removal from water

Abinashi Sigdel, Joowan Lim, Jeongwon Park, Hyoeun Kwak, Sojin Min, Keehong Kim, Hosung Lee, Chang Hyun Nahm, Pyung-Kyu Park*

Department of Environmental Engineering, Yonsei University, 1 Yonseidae-gil, Wonju, Gangwon, 26493, Republic of Korea.

*Corresponding author: Pyung-Kyu Park

Tel.: +82-33-760-2890; Fax: +82-33-760-2571; E-mail: pkpark@yonsei.ac.kr
Table S1. Langmuir and Freundlich isotherm parameters for As(III) and As(V) adsorption onto HIO-P-alginate beads

<table>
<thead>
<tr>
<th></th>
<th>As(III)</th>
<th>As(V)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Langmuir Isotherm</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$q_m$ [mg/g]</td>
<td>47.3</td>
<td>30.0</td>
</tr>
<tr>
<td>$b$ [L/mg]</td>
<td>0.023</td>
<td>0.038</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.985</td>
<td>0.995</td>
</tr>
<tr>
<td><strong>Freundlich Isotherm</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$K_f$ [(mg/g)·(L/mg)$^{1/n}$]</td>
<td>5.02</td>
<td>4.80</td>
</tr>
<tr>
<td>$n$</td>
<td>2.84</td>
<td>3.45</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.997</td>
<td>0.990</td>
</tr>
</tbody>
</table>

Langmuir and Freundlich isotherm equations are expressed as follows: $^{S1}$

\[
q_e = \frac{q_m b C_e}{(1 + b C_e)} \quad (S1)
\]

\[
q_e = K_f C_e^{1/n} \quad (S2)
\]

where $C_e$ and $q_e$ are the equilibrium concentrations of an adsorbate in liquid (water) and solid phases, respectively; $q_m$ and $b$ are Langmuir isotherm constants related to the maximum monolayer adsorption capacity of the adsorbent and the strength of adsorption, respectively; $K_f$ and $n$ are Freundlich constants related to adsorption capacity and heterogeneity respectively. Equation (S1) and (S2) can be linearized as follows:
\[
\frac{C_e}{q_e} = \frac{1}{b q_{e,\text{max}}} + \frac{C_e}{q_{e,\text{max}}} \quad \text{(S3)}
\]

\[
\frac{C_e}{q_e} = \frac{1}{b q_{e,\text{max}}} + \frac{C_e}{q_{e,\text{max}}} \quad \text{(S4)}
\]

As shown in Table S1, the \(q_m\) and \(K_f\) values obtained from Langmuir and Freundlich isotherm equations were higher for As(III) than As(V). This indicates that the adsorption capacity for As(III) of the HIO-P-alginate beads prepared in this study was higher than that for As(V). The \(b\) value of the Langmuir isotherm was greater for As(V), meaning the adsorption of As(V) toward the HIO-P-alginate beads was stronger than that of As(III). The Freundlich parameter \(n\) was greater than 1, indicating favorable nature of adsorption by the HIO-P-alginate beads under the investigated conditions.\textsuperscript{S2, S3}
Fig. S1. FTIR spectra of (a) HIO-P- and (b) HIO-alginate beads.
FTIR (Fourier transform infrared) analysis for HIO-P- and HIO-alginate beads was conducted to investigate whether unreacted carbonate and bicarbonate ions existed in the beads using a FTIR spectrometer (Spectrum One™, Perkin Elmer, USA). Samples for the analysis were prepared using KBr pellet method. As shown in Fig. S1, the peaks at 1650-1780 cm\(^{-1}\) (small shoulder in the blue circles) and 1000-1300 cm\(^{-1}\) (red circles) correspond to C=O and C-O bonds, respectively. In these regions, the peaks of HIO-P- and HIO-alginate beads were similar, proposing that unreacted carbonate and bicarbonate ions hardly remained in HIO-P-alginate beads and thus did not exert any significantly negative effect on arsenic adsorption by the HIO-P-alginate beads in this study.
Fig. S2. N$_2$ adsorption-desorption isotherms and pore size distributions of (a) HIO-P- and (b) HIO-alginate beads.
Fig. S2 shows that the N$_2$ adsorption-desorption isotherms of HIO-P- and HIO-alginate beads are similar to type IV, according to IUPAC classification, which means they were mesoporous adsorbents.$^{S4}$ Also, HIO-P- and HIO-alginate beads had broad H$_2$ hysteresis loops, which is the characteristics of mesoporous materials with complex pore structure.$^{S4, S5}$ In the pore size distribution results of Fig. S2, the average pore size of HIO-P- and HIO-alginate beads were 4.5 and 4.2 nm, respectively. These results also indicate that both of the HIO-P- and HIO-alginate beads had mesoporous structures.
References

S1. X. L. Li, Y. X. Qi, Y. F. Li, Y. Zhang, X. H. He and Y. H. Wang, Novel magnetic beads based on sodium alginate gel crosslinked by zirconium(IV) and their effective removal for Pb\textsuperscript{2+} in aqueous solutions by using a batch and continuous systems, *Bioresource Technol.*, 2013, **142**, 611-619.


