## Supporting Information

Appendix A1: The equations of $Q_e$ and $AE$

The adsorption capacity ($Q_e$) and adsorption efficiency ($AE$) of Re(VII) were calculated by the following equations:

$$Q_e = (C_i - C_e) \times V/m \tag{1}$$

$$AE = (C_\mathrm{i} - C_\mathrm{e})/C_i \times 100\% \tag{2}$$

where $C_i$ and $C_e$ are the initial and equilibrium concentrations (mg/L) of Re(VII) in the solution, respectively; $V$ is the solution volume (L) and $m$ is the mass of the adsorbent (g).

Appendix A2: Dissolution test

The hydrolytic stability of the ZnO nanoparticles on the surface of biochar was examined via dissolution tests with solution pH range of 1–6. After that, the $Zn^{2+}$ concentrations in the leaching solution were detected using inductively coupled plasma emission spectrometer (ICP-OES, iCAP7400; Thermo FisherScientific, USA). The total zinc load on the surface of biochar was measured by the following method: The sample was first heated in a muffle furnace at 750℃ for 6 h, and the obtained ash was dissolved in 3 mol/L HCl solution; finally, the $Zn^{2+}$ concentrations in the acidic solution were determined using ICP-OES. As shown in Table 1, negligible amounts of $Zn^{2+}$ in the solution indicated strong stability of ZnO nanoparticles fixation on the biochar surface.

Appendix A3: Water contact angle measurement

Water contact angle measurements were performed on water droplets (drop volume 4 μL) with an optical contact angle meter (OCA25; Dataphysics, Germany) at room temperature. Deionized water was used as a probe liquid and when deionized water droplet of 4 μL was put on the carbonaceous adsorbent surface, the water contact angle was averaged at five points of each sample.

Appendix A4: Point of zero charge determination

The point of zero charge ($pH_{pzc}$) of the biochar were determined as described by the previous study (Zhu et al., 2014): 1) 10 mL NaCl solution (0.01 mol/L) was placed in a 20 mL glass bottle to maintain the ion strength of the solution, 2) the pH of solution was adjusted ranged from 2.0 to 10.0 at pH intervals of 1 by using 0.1 mol/L of HCl or NaOH solution, 3) 0.02 g biochar was added into the solution and the mixtures were then vigorously shaken at 130 r/min and 25℃ for 48 h, 4) the supernatant was decanted and the final pH of solution was measured by using a calibrated pH meter (PHS-3C, Shengbang, China). The $pH_{pzc}$ from each set were calculated based on the ΔpH (final-initial pH) = 0.

Appendix A5: pH of biochar measurement

The pH value of biochar was measured according to previous literature using 1 g of biochar in 20 mL of deionized water, which was shaken at 140 r/min for 24 h on a temperature controlled shaker (Wang et al., 2015). The solution was measured by a calibrated pH meter (PHS-3C; Shengbang, China).

**Table S1** The element ratio of ZBC

| Element | Wt % |
|---|---|
| C | 40.787 |
| O | 5.304 |
| Si | 21.035 |
| Zn | 32.873 |

**Table S2** Adsorption isotherm and kinetic models used in the study

| Models | Names | Equations |
|---|---|---|
| Isotherm models | Langmuir | $Q_e = \frac{Q_m K_L C_e}{1+K_L C_e}$, $R_L = \frac{1}{1+K_L C_m}$ |
| | Freundlich | $Q_e = K_F C_e^{1/n}$ |
| | Temkin | $Q_e = \frac{RT}{B_T}\ln\left(K_T C_\mathrm{e}\right)$ |
| Kinetic models | pseudo-first-order | $Q_t = Q_e\left(1-\exp\left(-K_1 t\right)\right)$ |
| | pseudo-second-order | $Q_t = \frac{K_2 Q_e^2 t}{1+K_2 Q_e t}$ |
| | Elovich | $Q_t = \frac{1}{\beta}\ln\left(1+\alpha\beta t\right)$ |
| | intra-particle diffusion | $Q_t = K_{id} t^{0.5} + C$ |
| | liquid film diffusion | $\ln\left(1-F\right) = -K_{\mathrm{lf}} t$, $F = \frac{Q_t}{Q_e}$ |

Notes: $Q_e$ is adsorption capacity (mg/g) at equilibrium time; $Q_m$ is maximum adsorption capacity (mg/g); $K_L$ is Langmuir constant; $C_m$ is highest initial Re concentration (mg/L); $K_F$ and $n$ are Freundlich constants; $R$ is universal gas constant (8.314 J/(mol·K)); $T$ is absolute temperature (K); $B_T$ is Temkin constant (kJ/mol); $K_T$ is equilibrium bond constant related to the maximum energy of bond; $Q_t$ is adsorption capacity (mg/g) at time $t$; $K_1$ and $K_2$ are rate constants of the pseudo-first-order and pseudo-first-order models, respectively; $\alpha$ and $\beta$ are Elovich constants; $C$ and $K_{id}$ are intraparticle diffusion constans (mg/g, (mg·h$^{0.5}$)/g); $K_{lf}$ is adsorption rate constant

**Table S3** Kinetic parameters for the adsorption of Re(VII) onto BC and ZBC

| Kinetic models | Parameters | BC | ZBC |
|---|---|---|---|
| Experimental | $Q_{e,exp}$ | 3.58 | 5.86 |
| Pseudo-first-order | $Q_{e,cal}$ | 3.37 | 5.25 |
| | $K_1$ | 0.2684 | 1.2797 |
| | $R^2$ | 0.8972 | 0.8550 |
| | $RSS$ | 0.1310 | 0.2830 |
| Pseudo-second-order | $Q_{e,cal}$ | 3.84 | 5.61 |
| | $K_2$ | 0.0987 | 0.3308 |
| | $R^2$ | 0.9456 | 0.9606 |
| | $RSS$ | 0.0693 | 0.1062 |
| Elovich | $Q_{e,cal}$ | 3.56 | 5.86 |
| | $\alpha$ | 4.7396 | 113.8923 |
| | $\beta$ | 1.4314 | 1.4031 |
| | $R^2$ | 0.9734 | 0.9979 |
| | $RSS$ | 0.0338 | 0.0057 |
| Intraparticle diffusion | $K_{id}$ | 0.7911 | 3.1120 |
| | $C$ | 0.6343 | 0.6277 |
| | $R^2$ | 0.9674 | 0.9409 |
| | $RSS$ | 0.2374 | 0.4319 |

**Table S4** Isotherm parameters for the adsorption of Re(VII) onto BC and ZBC

| Isotherm models | Parameters | BC | ZBC |
|---|---|---|---|
| Langmuir | $Q_m$ | 13.72 | 29.41 |
| | $K_L$ | 0.0330 | 0.0959 |
| | $R^2$ | 0.9775 | 0.9608 |
| | $RSS$ | 0.1723 | 2.2733 |
| Freundlich | $K_F$ | 1.8414 | 6.7245 |
| | $n$ | 2.6586 | 3.1403 |
| | $R^2$ | 0.9572 | 0.9866 |
| | $RSS$ | 0.3273 | 0.7791 |
| Temkin | $K_T$ | 0.3590 | 1.9153 |
| | $B_T$ | 0.3430 | 0.1926 |
| | $R^2$ | 0.9767 | 0.9812 |
| | $RSS$ | 0.1783 | 1.0888 |

**Table S5** Thermodynamics model used in the study

| Model | Equations |
|---|---|
| Themodynamics models | $\Delta G° = -RT \ln K$ <br> $\ln K = -\frac{\Delta H°}{RT} + \frac{\Delta S°}{R}$ |

Notes: $R$ is universal gas constant (8.314 J/(mol·K)); $T$ is absolute temperature (K); $K$ is the thermodynamic equilibrium constant

**Table S6** Thermodynamic parameters for the adsorption of Re(VII) onto ZBC

| Thermodynamic parameters | Values |
|---|---|
| ΔG° (kJ/mol) | −0.19 (298.15 K) |
| | −1.13 (303.15 K) |
| | −2.07 (308.15 K) |
| | −3.01 (313.15 K) |
| ΔH° (kJ/mol) | 55.90 |
| ΔS° (J/(mol·K)) | 188.12 |

**References**


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