**Supplementary material**

**Preparation of high-efficient KMnO4 modified biochar for**

**heavy metal removal from municipal wastewater**

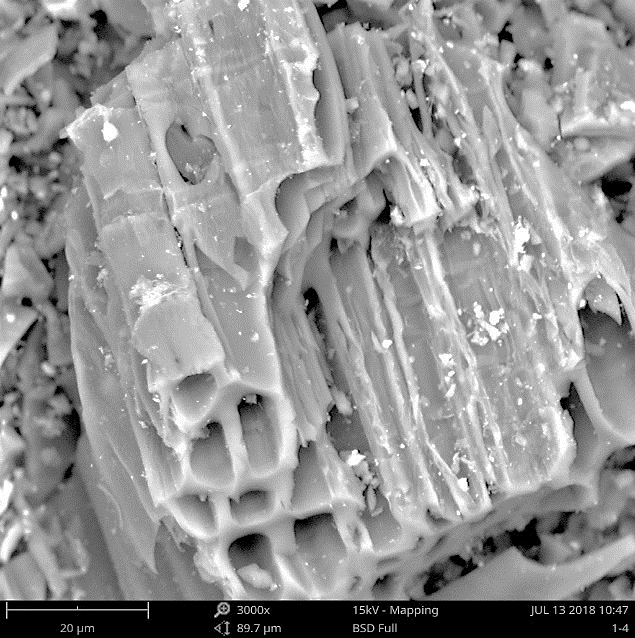
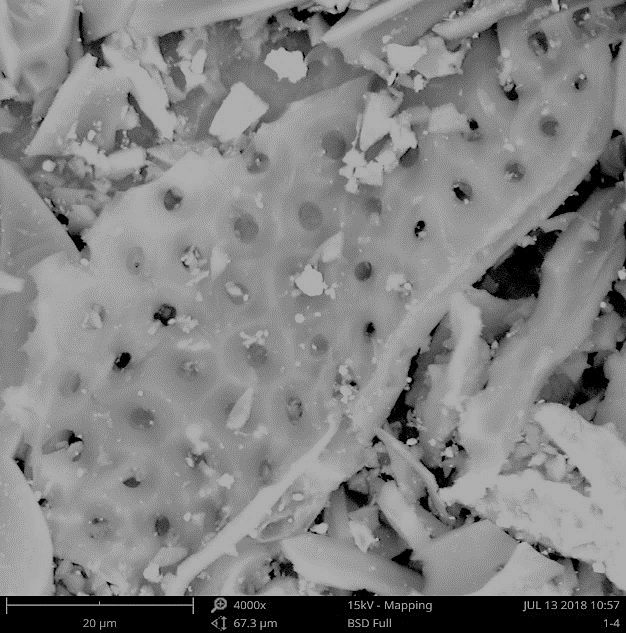
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## Characterization analysis

X-ray diffraction (XRD) is employed to identify the crystallographic structure of the KM/biochar. Scanning electron microscopy (SEM) equipped with dispersive X-ray spectroscopy (EDS) is used to observe and assess the surface microstructures and element distribution of sample. Nitrogen adsorption apparatus is employed to measure the specific surface area and pore structure parameters of the sample. Fourier transform infrared spectroscopy (FT-IR) is employed to investigate chemical function groups of the biochar. X-ray photoelectron spectroscopy (XPS) is used to determine the surface properties of the samples. The atomic absorption spectrophotometer is employed to measure the concentrations of Pb(II).



**b**

**a**

**Fig.S1** The surface morphology and micro composition of KM/biochar-1:9(a) and KM/biochar-1:39 (b).

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**Fig.S2** Comparison of Pb(II)adsorption capability of KM/biochars and original biochar

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**Fig.S3** Slope and intercept of ln (Kd) vs. 1/T plot for the Pb(II).

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Fig.S4 The influence of the coexisting ions on Pb(II) removal.

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Fig.S5 Pb(II)removal of the KM/biochar-1:1 after regeneration.

**Table S1** Adsorption kinetic model and corresponding parameters

|  |  |  |
| --- | --- | --- |
| Kinetic models | Equation | Parameters |
| Pseudo-first order |  | qt is uptake at time (mg/g).  k1 means adsorption rate constant(1/min). |
| Pseudo-second order |  | K2 means rate constant (g/mg min). |
| Intraparticle diffusion |  | K3 (mg/g min1/2) is rate constant  C is a constant. |
| Boyd |  | B is the constant of Boyd model. |

**Table S 2** Adsorption isotherm models and corresponding parameters.

|  |  |  |
| --- | --- | --- |
| Isotherms | Equations | Parameters |
| Langmuir |  | qm means the adsorption amount (mg/g).  kL (L/mg) is coefficient. |
| Freundlich |  | kF is adsorption constant (mg/g). (L/mg)1/n, 1/n is adsorption intensity |
| Temkin |  | is adsorption heat, J/mol  is binding equilibrium, L/g |
| Hill |  | Qm is the maximum  adsorption capacity (mg/g) , n and C are the number of ions per site  and semi saturated concentration, respectively. |

**Table S3** The maximum adsorption capacity of similar adsorbents for Pb(II) adsorption capacity.

|  |  |  |
| --- | --- | --- |
| Adsorbents | Adsorption  capacity (mg/g) | References |
| KM/biochar | 88.15-144.49 | This study |
| H3PO4 pretreated chicken feather biochar | 78.4 | ([Chen et al., 2019](#_ENREF_2)) |
| Biochar - manganese oxide nanoparticles | 110.00 | ([Wan et al., 2018](#_ENREF_6)) |
| MgCl2 modified crayfsh shell biochar | 93.90 | ([Zhang et al., 2020](#_ENREF_10)) |
| PHF-modified activated carbon | 50.25 | ([Yin et al., 2019](#_ENREF_9)) |
| MgAl-layered double hydroxides | 147.89 | ([Guo et al., 2024](#_ENREF_3)) |
| Magnetic DTPA-modified chitosan | 214.63 | ([Liu et al., 2024](#_ENREF_5)) |
| Biomass-derived porous carbon | 126.4 | ([Wang et al., 2019](#_ENREF_7)) |
| Bacteria TJ6 immobilized on biochar | 250.10 | ([Wang et al., 2024](#_ENREF_8)) |
| UV-aged microplastics | 93.49 | ([Chang et al., 2024](#_ENREF_1)) |
| MnO2-composted mixture biochar | 127.75 | ([Liang et al., 2017](#_ENREF_4)) |
| MnSO4-peanut shell biochar | 68.00 | ([Wan et al., 2018](#_ENREF_6)) |

**Referene**

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