# Supplementary: Evaluating Carbon/Hydroxyapatite's Efficacy in Removing Heavy Metals from Groundwater

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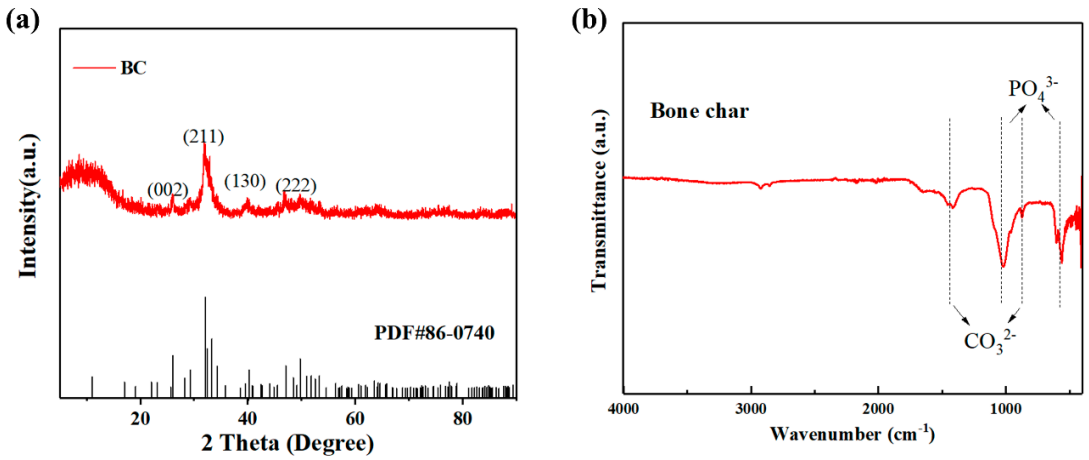
**Text S1**. Composition and related characterization of bone char.

In this study, commercial bone char (BC) was selected for the comparative experiment. The bone charcoal was purchased from Zhangjiakou, Hebei province. The XRD pattern of bone charcoal is shown in Figure A. The main phase of bone charcoal is hydroxyapatite with poor crystallinity and few miscellaneous phases. Figure b shows the infrared spectrum of bone charcoal, which contains carbon functional groups and phosphoric acid.




(a) XRD pattern of bone charcoal; (b) FT-IR of bone char.

XRF tests were performed on bone char, and the results are shown in the table below. The results show that the bone charcoal mainly contains calcium, oxygen, phosphorus and carbon elements but also contains other impurities such as sodium, chlorine, silicon, etc. The total impurity content is about 6.8%, and the carbon content in the sample is 10.3 %.

Table of elements content in bone charcoal

| Element | Content (%) | Element | Content (%) |
|---|---|---|---|
| C | 10.300 | Si | 0.436 |
| N | 2.620 | Mg | 0.398 |
| O | 36.600 | K | 0.328 |
| Ca | 34.300 | Fe | 0.302 |
| P | 12.000 | Al | 0.215 |
| Na | 1.300 | S | 0.144 |
| Cl | 0.934 | Zn、Cd | 0.123 |

**Table S1**. Fitting parameters of Langmuir and Freundlich models for copper adsorption by CHAP.

| Temperature | Langmuir adsorption isothermal model | | | Freundlich adsorption isothermal model | | |
|---|---|---|---|---|---|---|
| | Qm（mg/g） | KL | R2 | Kf | 1/n | R2 |
| 298K | 78.53 | 105.88 | 0.501 | 31.56 | 0.1101 | 0.936 |

**Table S2**. Quasi-first-order and quasi-second-order kinetic fitting parameters of copper adsorption by CHAP.

| Sample | Quasi-first-order kinetic parameters | | | Quasi-second-order kinetic parameters | | |
|---|---|---|---|---|---|---|
| | k1 | Qe (mg/g) | R2 | k2×103 | Qe (mg/g) | R2 |
| CHAP | 0.19 | 197.16 | 0.819 | 2.102 | 130.38 | 0.985 |

**Table S3**. Concentration settings of three heavy metal mixtures.

| Serial number | Cu2+（mg/L） | Zn2+（mg/L） | Mn2+（mg/L） |
|---|---|---|---|
| 1 | 50 | 50 | 20 |
| 2 | 100 | 100 | 40 |
| 3 | 150 | 150 | 60 |
| 4 | 200 | 200 | 80 |
| 5 | 250 | 250 | 100 |
| 6 | 300 | 300 | 120 |
| 7 | 400 | 400 | 160 |
| 8 | 500 | 500 | 200 |

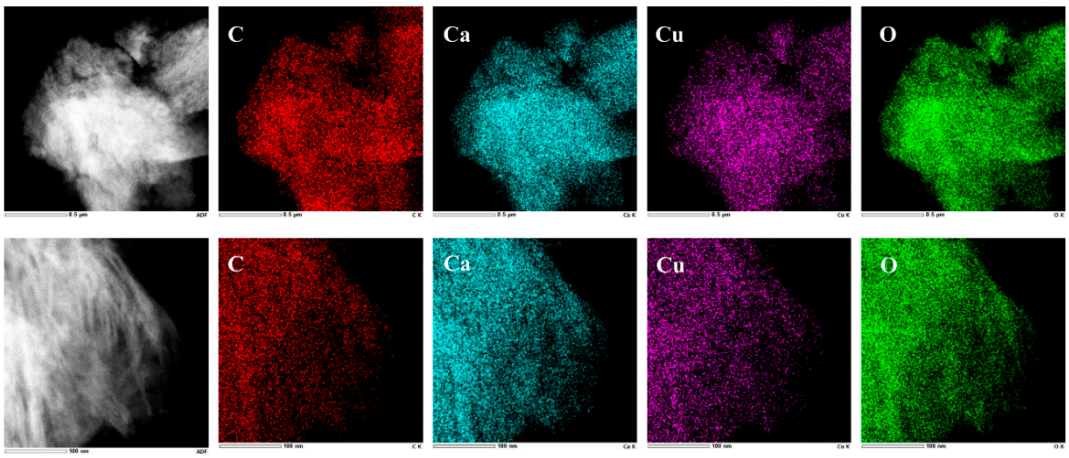



**Figure S1**. Element mapping of the reaction products of CHAP and copper solution.

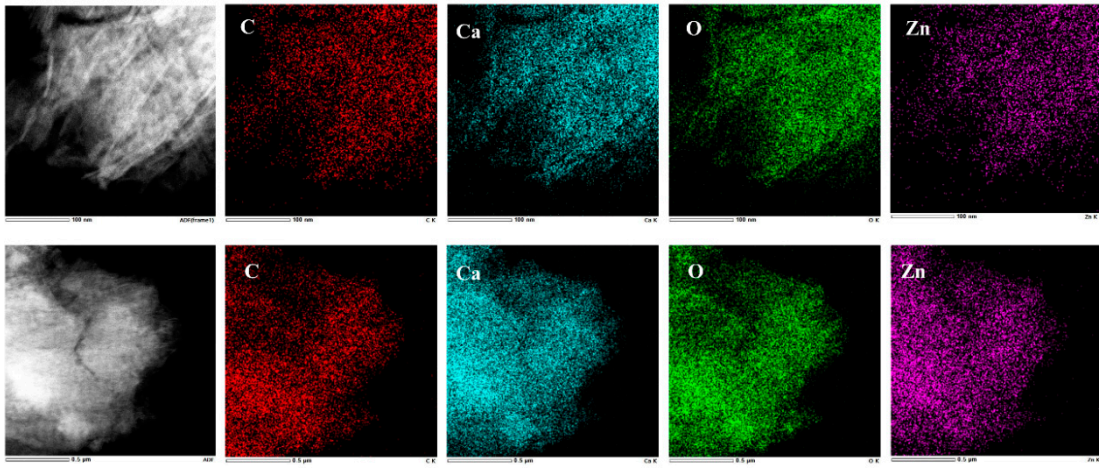



**Figure S2**. Element mapping of the reaction products of CHAP and zinc solution.

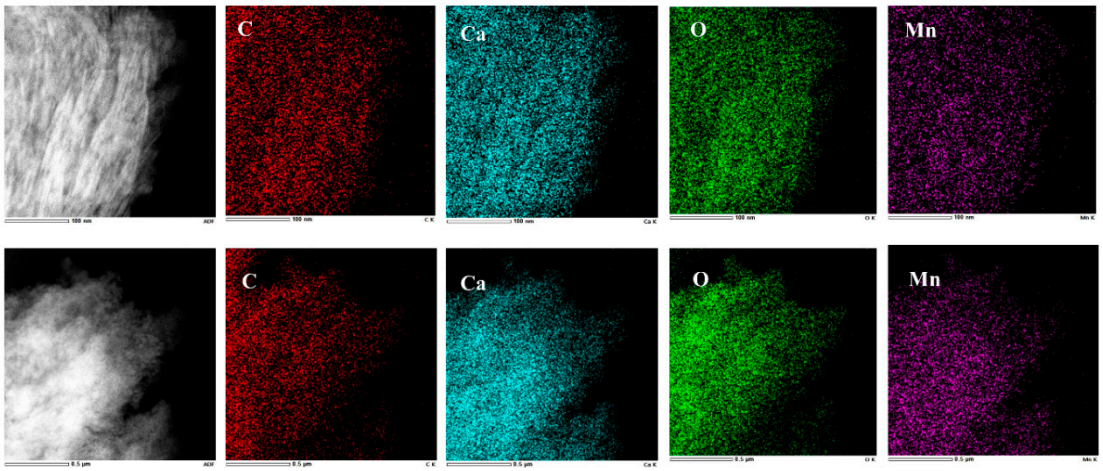



**Figure S3**. Mapping of the reaction products of CHAP and manganese solution.