**Supplementary material**

**Preparation of three kinds of efficient adsorbents from sludge for metal ions and organic wastewater removal**

Hui Guoa , Song Cheng b, c,d\*, Baolin Xingb, c, d, Mingliang Mengb, Yanhe Nieb, Chuanxiang Zhangb

 (a. School of Materials Science and Engineering, Henan Polytechnic University, Jiaozuo 454003, China

b. College of Chemistry and Chemical Engineering, Henan Polytechnic University, Jiaozuo 454003, China；

c. Collaborative Innovation Center of Coal Work Safety and Clean High Efficiency Utilization, Jiaozuo, 454003, China;

d. Henan International Joint Laboratory of Clean Coal Utilizatio, Jiaozuo, 454003, China)

# Materials

The sludge and pine sawdust was collected by sewage treatment plant of the Guangdong province, China and Fujian province, China, respectively. MgCl2.6H2O was purchased from the Tanjin Kemiou Chemical Reagent Co., LTD. MO and Pb(NO3)2 were purchased from the Tianjin Kemi Ou Chemical Reagent Co., LTD. ZnCl2 was obtained from the Tianjin Hedong District Hongyan Reagent Co., LTD. CIP was purchased from the Shanghai Aladdin Biochemical Technology Co., LTD.

# Adsorption experiment

CIP, MO and Pb2+ adsorption experiments are carried out in a series of 250 mL conical flasks. A certain of the adsorbent is mixed with 100 mL CIP (200-400 mg/L), MO (200-400 mg/L) and Pb2+ (200-400 mg/L) solution to investigate adsorption performance of adsorbent. The above mixture solution is stirred with the rotating speed of 180 r/min until adsorption equilibrium. In adsorption kinetics study, A certain of adsorbent is mixed with CIP (200-400 mg/L), MO (200-400 mg/L) and Pb2+ (200-400 mg/L)solution to analyze the adsorption kinetics process. A small amount of suspension that is taken from solution is used to detect CIP, MO and Pb2+ concentrations at specific time intervals. An atomic absorption spectrophotometer and UV–Vis spectrophotometer are used to determine the adsorbent amount of CIP (276 nm), MO (463 nm) and Pb2+, respectively.

CIP, MO and Pb2+ adsorption amount of adsorbents are calculated by Equation (1):

$$ q=\frac{V\left(C\_{o}-C\_{i}\right)}{M} (1)$$

where Co and Ci are the initial and residual concentrations (mg/L), respectively. M represents the weight of adsorbent (g) and V represents the adsorption solution volume (L). The adsorption isotherm and adsorption kinetics models are listed in the Table S1 and Table S2.

**Table S1** Adsorption isotherm models adopted in this work and their parameters.

|  |  |  |
| --- | --- | --- |
| Isotherms | Equations | Parameters |
| Langmuir | $$q\_{e}=\frac{k\_{L}q\_{m}C\_{e}}{1+k\_{L}C\_{e}}$$ | qm means the adsorption amount (mg/g).kL (L/mg) is coefficient. |
| Freundlich | $$q\_{e}=k\_{F}C\_{e}^{1/n}$$ | kF is adsorption constant (mg/g). (L/mg)1/n, 1/n is adsorption intensity |

**Table S2**Adsorption kinetic model and corresponding parameters

|  |  |  |
| --- | --- | --- |
| Kinetic models | Equation | Parameters |
| Pseudo-first order | $$q\_{t}=q\_{t}(1-e^{-tk\_{1}})$$ | qt is uptake at time (mg/g).k1 means adsorption rate constant(1/min). |
| Pseudo-second order |  | K2 means rate constant (g/mg min). |

**Table S3** The adsorption capacity of similar adsorbents for MO and CIP removal from wastewater.

|  |  |  |
| --- | --- | --- |
| Adsorbents | Adsorption capacity (mg/g) | References |
| MO | CIP |
| **Sludge activated carbon** | 754.05 | **-** | **This study** |
| AC from sugarcane mills boiler residue | 161.80 | - | (Martini et al., 2018) |
| Zinc-doped lithium manganese oxides | 312.50 | - | (Popat et al., 2024) |
| Cd-zeolite imidazolate framework | 145.50 | - | (Ba Mohammed et al., 2021) |
| Carbon/Fe3O4 composites | 102.04 | - | (Zhang et al., 2020) |
| Magnetic lignin-based carbon nanoparticle | 142.90 | - | (Guo et al., 2023) |
| **Sludge activated carbon** | **-** | 635.6 | **This work** |
| Activated banana stalk | - | 23.30  | (Patel et al., 2021)) |
| Magnetic herbal biochar | - | 47.62 | (Kong et al., 2017) |
| Chitosan/biochar hydrogel beads | - | 36.72 | (Afzal et al., 2018) |
| CoFe-LDH modifed sludge biochar | - | 14.00 | (Zheng et al., 2022) |
| Sewage sludge-coconut fiber biochar | - | 66.67 | (Yang et al., 2022) |

**Table S4** The adsorption capacity of similar adsorbents for Pb2+ removal from wastewater.

|  |  |  |
| --- | --- | --- |
| Adsorbents | Adsorption capacity (mg/g) | References |
| Pb2+  |
| MgAl-layered double hydroxides | 147.89 | **This work** |
| Chitosan coated MgO-biochar | 59.66 | (Jxa et al., 2021) |
| MgCl2 pretreated sawdust biochar | 202 | (Jellali et al., 2016) |
| Mg/Al LDH-SHMP  | 45.66 | (Hossain et al., 2022) |
| Mg2Al-LDH | 66.16 |  Zhao et al. (2011) |
| LDH–Cl | 43.46 | (Liang et al., 2010) |
| CoMo-LDH | 73.40 | Mostafa et al. (2016) |
| MgAl-LDHs/MnO2 | 49.87 | Bo et al. (2015) |
| MgAl-LDH | 131.16 | González et al. (2015) |

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