Supporting Information (SI)

Sustainable Remediation: Advances in Red Mud-Based Synergistic Fabrication Techniques and Mechanistic Insights for Enhanced Heavy Metal(loid)s Sorption in Wastewater

Feng Li [1], Renjian Deng [1,2,*], Baolin Hou [1,2], Lingyu Peng [1], Bozhi Ren [1], Xiangxing Kong [3], Bo Zhang [3], Andrew Hursthouse [1,4]

[1] School of Civil Engineering, Hunan University of Science and Technology, Xiangtan 411201, China; 17673977117@163.com (F.L.); h3i3t0@126.com (B.H.); peng01327@163.com (L.P.); bozhiren@126.com (B.R.); andrew.hursthouse@uws.ac.uk (A.H.)
[2] Hunan Province Key Laboratory of Coal Resources Clean Utilization and Mine Environment Protection, Xiangtan 411201, China
[3] CCCC First Highway Consultants Co., Ltd., Xi'an 710075, China; xiangxingkong8129@163.com (X.K.); 15191865157@163.com (B.Z.)
[4] School of Computing, Engineering and Physical Sciences, University of the West of Scotland, Paisley PA1 2BE, UK
* Correspondence: deng800912@163.com

The number of pages: 15

The number of tables: 4

Tables

Table S1. Performance characteristics and adsorption mechanisms of red mud-based adsorbents for heavy metal removal from water: conditions and efficacy.

Table S2. Red mud-based adsorbent for pH_{PZC}.

Table S3. Thermodynamic parameters of red mud-based adsorbents.

Table S4. Isothermal and kinetic modeling of red mud-based adsorbents.

Table S1. Performance characteristics and adsorption mechanisms of red mud-based adsorbents for heavy metal removal from water: conditions and efficacy.

	Absorbents	Method	Heavy metal (loid)	Material Characteristics				Adsorption Conditions			Adsorption efficiency and mechanism			References
				SBET m^2/g	Particle size (nm)	Average pore size(nm)	Pore volume (m^3/g)	Time (min)	pH	Initial concentration (mg/L)	Adsorption capacity (mg/g)	Adsorption mechanism	Reuse	
1	RMPC	Physical mixing	Cd(II) Mn(II) Cu(II) Zn(II)	-	-	-	-	-	4	-	-	Chemical precipitation	-	[1]
2	L-PR	Physical mixing	Cd(II) As(V)	8.033	13.031	-	0.026	0–1440	3-9	1-100	-	Electrostatic attraction, Ion exchange, Complexation, and Precipitation	-	[2]
3	RM/CS	Physical mixing	Ni(II)	105.7	-	-	-	5-240	2-6	20-120	31.66	Electrostatic force	-	[3]
4	C1R4	Alkali fusion	Pb(II) Cu(II) Cd(II)	63.825	11.338	-	0.1821	90	6	100	49.9 49.7 49.6	Ion exchange, Complexation, Surface hydroxyl, Electrostatic attraction	-	[4]
5	4A- Zeolite	Alkali fusion	Pb(II) Cd(II) Zn(II) Ni(II) Cu(II)	-	-	-	-	5-300	4	50-800	Pb(100) Cd(56.5) Zn(45.4) Ni(41.1) Cu(35.5)	-	-	[5]

6	MZA	Alkali fusion-reduction	Pb(II) Cu(II)	35.17	5.76	-	0.0411	-	-	-	330.72 142.72	-	85% after 5 cycles	[6]
7	MRM	Hydrothermal	Ni(II)	-	-	-	-	-	-	-	-	Cation exchange, Inner Sphere complex	-	[7]
8	Modified RM	Hydrothermal	Pb(II)	37.32	-	-	0.138	5-60	5	-	564.97	Ion exchange and Precipitation	-	[8]
9	Mn-RM	Hydrothermal	Pb(II)	38.91	-	-	0.02	-	5	301.04	721.35	Electrostatic attraction, Ion exchange, and Chemical precipitation	75% after 5 cycles	[9]
10	RM@HC	Hydrothermal	Cd(II)	86.47	57.956	-	0.125	-	7	-	598.26	Co-precipitation, Adsorption, and Reduction	72.75% after 5 cycles	[10]
11	RM/BL-850	Hydrothermal-Pyrolysis	Cr(VI)	106.03	11.32	-	0.15	-	2-7	10-1000	349.5	Chemical reduction, Physical adsorption	-	[11]
12	IMC	Hydrothermal-Pyrolysis	Cr(VI)	-	-	-	-	-	6	10-1000	-	Chemical reduction, Physical adhesion, Complexation, Co-precipitation	-	[12]
13	MZ	Calcination - Hydrothermal	Cu(II) Cd(II) Pb(II)	45.78	16.51	-	0.112	-	-	50-300	Cu(76.2) Cd(92.2) Pb(178.4)	-	Cu(52.89) Cd(63.91) Pb(82.87) after 5 cycles	[13]
14	RM-BC	Pyrolysis	Pb(II)	75.3792		9.0185	0.06371	0-3000	5	3-1000	426.84	Electrostatic interactions, Surface complexation, and Ion exchange	82% after 5 cycles	[14]

15	Fe-biochar	Pyrolysis	As(V) Ni(II)	-	-	-	-	-	-	-	-	Ion exchange	Ni(100%) As(37.3%) after 5 cycles	[15]
16	MMBC	Pyrolysis	Pb(II)	-	-	-	-	-	-	-	-	Chemical precipitation	-	[16]
17	SRMBC-750	Pyrolysis	Cu(II)	62.43	-	4.923	0.0768	1440	5	-	242.62	Electrostatic attraction, Complexation, Cation exchange	75% after 5 cycles	[17]
18	Fe-BC	Pyrolysis	Pb(II)	55.72	-	6.63	0.092	420	-	100-800	232.1	Surface Precipitation and Complexation	-	[18]
19	RMLL	Pyrolysis	Pb(II)	19.714	-	17.871	0.088	-	7	500	188.1	Ion exchange, Chemical precipitation	90% after 5 cycles	[19]
20	PRMLL	Pyrolysis	Pb(II)	23.675	-	15.492	0.086	-	7	500	213.4	Ion exchange, Chemical precipitation	90% after 5 cycles	[19]
21	RM/fly ash	Cured Foam Method	AMD	-	-	-	-	-	-	-	-	Adsorption, Precipitation	-	[20]
22	MK/RM	Cured Foam Method	Pb(II)	28.8	-	-	-	360	5	100	30.96	-	Cycle 5 times	[21]
23	RSG	Cured Foam Method	Ni(II)	31.36	-	8.84	0.069	30-600	2-5	60-180	12.39	Physical and Chemical adsorption, Electrostatic attraction, and Ion exchange		[22]
24	ZVI@GRM	Carbothermal reduction	Cr(VI) Pb(II)	44.575	-	3.413	-	-	1-13 1-7	20-100 100-400	51.55 188.67	Adsorption, Reduction, and Precipitation	-	[23]
25	RM/carbon	Carbothermal reduction	Cr(VI)	147	-	3.6	0.09	-	3-7	-	-	Reduction, Precipitation	Still largely removed after 5 cycles	[24]

26	RM/CNT	CDV Method	Pb(II)	78	-	-	-	20-70	5	-	-	-	-	[25]
27	AAM-CNT	CDV Method	Pb(II)	117.8	-	-	-	-	-	-	-	-	-	[26]
28	FexOy-BC(RM)	In situ reduction and Oxidation	Cd(II)	18.02	57.01	0.04	23.64	-	6	10	-	Chemisorption	74.33% after 5 cycles	[27]
29	HRM@ nFe_3O_4	Coprecipitation	Sb(III)	171.63	-	7.62	0.31	240	-	5-80-	-	Complex	60% after 5 cycles	[28]
30	RM/PAA	In situ graft polymerization	Cd(II)	-	2-4	13.972	0.0148	300	6	100	96.15	Physical adsorption, Ion exchange, and Chelation	-	[29]
31	RM-nZVI	Reductionism	Hg(II)	111.59	3.82	-	0.49	-	2-10	1-70	94.58	Physical adsorption and Reduction	50% after 5 cycles	[30]

Table S2. Red mud-based adsorbent for pH_{PZC}.

Absorbent	Heavy metal(loid)s	pH_{PZC}	References
L-PR	Cd、As	7.55	[2]
Modified Red Mud Synthesized Zeolite	Pb	7.59	[8]
IMC	Cr	6.86	[12]
RSG Sphere	Ni	2.4	[22]
ZVI@GRM	Cr、Pb	5.2	[23]
RM/CS	Ni	6.1	[3]
RM-nZVI	Hg	4.6	[30]
MZA	Pb、Cu	5.16	[6]
RM@HC	Cd	5.4	[10]

The influence of temperature on adsorption is often associated with the thermodynamic characteristics of the adsorption process, with metrics such as enthalpy change (ΔH°), free energy change (ΔG°), and entropy change (ΔS°) being obtained from thermodynamic equations[31].

$$\ln k_c = -\frac{\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R} \quad (1)$$

$$\Delta G^\circ = -RT \ln k_c \quad (2)$$

R is the universal gas constant (8.314 J/mol), whereas T (K) represents the absolute temperature; ΔG° and ΔH° may facilitate the comprehension of adsorption behavior using isotherm data[32]; Negative ΔG° values indicate that the adsorption process is spontaneous; The ΔG° value often decreases with rising temperature, suggesting that the adsorption process becomes more vigorous at elevated temperatures; Enthalpy change (ΔH°) values over 0 imply that adsorption is an endothermic process[33,34]; Given that ΔH° exceeds 80 kJ/mol (ΔH° = 119.23 kJ/mol)[35], the process is classified as chemisorption; Negative ΔS° values indicate the spontaneity of adsorption and the decrease in disorder and unpredictability at the solid-liquid interface throughout the adsorption process [7].

Table S3. Thermodynamic parameters of red mud-based adsorbents.

Absorbent	Heavy metal(loid)s	Temperature (K)	Parameters	References
MRM	Ni	298	ΔG°<0,ΔH°<0	[7]
Mn-RM	Pb	298	ΔG°<0,ΔH°>0,ΔS°>0	[9]
IMC	Cr	298	ΔG°<0,ΔH°>0,ΔS°>0	[12]
ZVI@GRM	Cr、Pb	298	ΔG°<0,ΔH°>0,ΔS°>0	[23]
RM/PAA	Cd	313	ΔG°<0,ΔH°>0,ΔS°>0	[29]
RM/CS	Ni	323	ΔG°<0,ΔH°<0,ΔS°>0	[3]
RM@HC	Cd	298	ΔG°<0,ΔH°>0,ΔS°>0	[10]

Described by the adsorption isotherm model as follows:

Langmuir adsorption isotherm ： $$\frac{C_e}{Q_e}=\frac{C_e}{Q_m}+\frac{1}{k_L Q_m} \quad (3)$$

Freundlich adsorption isotherm ： $$Q_e = K_F \cdot C_e^{1/n} \quad (4)$$

Extended Langmuir isotherm : $$Q_{e,i}=\frac{Q_{m,i}K_{L,i}C_{e,i}}{1+\sum K_{L,i}\cdot C_{e,i}} \quad (5)$$

Temkin isotherm： $$Q_e=B \ln K_T+B \ln C_e Q_e \quad (6)$$

D-R model： $$q=q_m \exp(-\beta\varepsilon^2),\ \varepsilon=RT \ln\left(1+\frac{1}{C}\right) \quad (7)$$

Where Q_e is the equilibrium adsorption capacity, $mg\cdot g^{-1}$; Q_m is the maximum adsorption capacity, $mg\cdot g^{-1}$; C_e is the equilibrium concentration of the remaining heavy metal ions in solution, $mg\cdot L^{-1}$; k_L is the Langmuir constant for the affinity of the solute to the adsorbent, $L\cdot mg^{-1}$; k_F is the adsorption capacity-related Freundlich constant related to adsorption capacity, $(mg\cdot g^{-1})(L\cdot mg^{-1})$; 1/n is the Freundlich constant related to adsorption strength; B is the constant related to heat of adsorption; K_T is the equilibrium binding constant corresponding to the maximum binding energy, $L\cdot mg^{-1}$; q is the amount of metal ions adsorbed per weight unit of adsorbent after equilibrium, mol/g; q_m is the maximum adsorption when the monolayer is completely covered, mol/g; β is the activity coefficient related to the average adsorption energy, mol^2/kJ^2; ε is the Polanyi potential; R is the ideal gas constant, 8.3145 J $mol^{-1}\cdot K^{-1}$; T is the absolute temperature, K.

A frequently used kinetic model is represented by the equation below.

$$\text{The pseudo-first-order model:}\quad \log\left(Q_t-Q_t\right)=\log Q_e-\frac{k_1 t}{2.303} \tag{8}$$

$$\text{The pseudo-second-order model:}\quad \frac{t}{Q_t}=\frac{1}{k_2 Q_e^2}+\frac{t}{Q_e} \tag{9}$$

$$\text{The Weber-Morris equation :}\quad Q_t=k_{WM}\sqrt{t}+c \tag{10}$$

$$\text{Elovich kinetic model :}\quad Q_t=\left(\frac{1}{\beta}\right)\ln(\alpha\beta)+\left(\frac{1}{\beta}\right)\ln t \tag{11}$$

$$\text{Intra-particle diffusion :}\quad q_t=k_i\times t^{1/2}+C \tag{12}$$

$$B_t=-\ln(1-F)-0.4799 \tag{13}$$

Q_t represents the adsorption quantity at time t, measured in $mg\cdot g^{-1}$; Q_e denotes the equilibrium adsorption quantity, also in $mg\cdot g^{-1}$; k_1 signifies the quasi-first-order adsorption rate constant, expressed in min^{-1}; t indicates time, in min; k_2 refers to the quasi-second-order adsorption rate constant, in $g\cdot(mg\cdot min^{-1})$; k_{WM} is the intra-particle diffusion rate constant, measured in $mg\cdot(g\cdot min^{1/2})^{-1}$; c is a constant associated with thickness and boundary layer; α represents the initial adsorption rate, in $mg\cdot(g\cdot min^{-1})$; β is the desorption constant, in $g\cdot mg^{-1}$; qt represents the equilibrium adsorption, measured in $mg\cdot g^{-1}$; k_i is the equilibrium rate constant of the internal diffusion model of the particles, expressed in $mg\cdot(min^{1/2}\cdot g)^{-1}$. F represents the adsorbed mass fraction at time t; B_t denotes the vertical coordinate, with t as the horizontal coordinate.

Table S4. Isothermal and kinetic modeling of red mud-based adsorbents.

Absorbent	Heavy metal(loid)s	Isotherm model	Kinetic model	References
L-PR	As	Freundlich	The pseudo-second-order model	[2]
C1R4	Pb;Cd;Cu	Langmuir	The pseudo-second-order model	[36]
MRM	Ni	Langmuir	The pseudo-second-order model	[7]
4A-Zeolite	Zn;Cu;Ni;Pb;Cd	Langmuir	The pseudo-second-order model	[37]
Mn-RM	Pb	Langmuir	The pseudo-second-order model	[9]
Modified Red Mud Synthesized	Pb	Langmuir	The pseudo-second-order model	[8]
ICM	Cr	Langmuir	The pseudo-first-order model	[12]
RM/BL-850	Cr	Langmuir	The pseudo-second-order model	[11]
MZ	Cu	Freundlich	The pseudo-first-order model	[13]
MZ	Cd;Pb	Langmuir	The pseudo-second-order model	[13]
Fe-Biochar	Ni;As	Freundlich	The pseudo-second-order model	[15]
SRMBC-750	Cu	Freundlich	The pseudo-second-order model	[17]
RSG Sphere	Ni	Langmuir	The pseudo-second-order model	[22]
ZVI@GRM	Pb;Cd	Langmuir	The pseudo-second-order model	[23]
RM/PAA	Cd	Langmuir	The pseudo-second-order model	[29]
HRM@nFe_3O_4	Sb	Langmuir	The pseudo-second-order model	[28]
Fe(III)/Al (hydr)oxide	As	Langmuir	The pseudo-second-order model	[38]
RM/CS	Ni	Sips model	Intra-diffusion kinetic model	[3]
RM-nZVI	Hg	Langmuir	The pseudo-first-order model	[30]

RMLL PRMLL	Pb	Langmuir	The pseudo-second-order model	[19]
RM@HC	Cd	Langmuir	The pseudo-second-order model	[10]
Fe-BC-700	Pb	Langmuir	Elovich kinetic model	[18]

References

1. Xu, W.; Yang, H.; Mao, Q.; Luo, L.; Deng, Y. Removal of Heavy Metals from Acid Mine Drainage by Red Mud-Based Geopolymer Pervious Concrete: Batch and Long-Term Column Studies. *Polymers* **2022**, *14*, 5355, doi:10.3390/polym14245355.
2. Shang, C.; Geng, Z.; Sun, Y.; Che, D.; Zhao, Q.; Chen, T.; Tang, M.; Huo, L. Lanthanum-Modified Phosphogypsum Red Mud Composite for the Co-Adsorption of Cadmium and Arsenic: Mechanism Study and Soil Remediation. *Agriculture* **2024**, *14*, 464, doi:10.3390/agriculture14030464.
3. Luu, T.-T.; Nguyen, D.-K.; Nguyen, T.T.P.; Ho, T.-H.; Dinh, V.-P.; Kiet, H.A.T. The Effective Ni(II) Removal of Red Mud Modified Chitosan from Aqueous Solution. *Environ Monit Assess* **2023**, *195*, 254, doi:10.1007/s10661-022-10877-0.
4. Zhao, Y.; Luan, H.; Yang, B.; Li, Z.; Song, M.; Li, B.; Tang, X. Adsorption of Pb, Cu and Cd from Water on Coal Fly Ash-Red Mud Modified Composite Material: Characterization and Mechanism. *Water* **2023**, *15*, 767, doi:10.3390/w15040767.
5. Liu, Y. dong; Cuiping, Y.E.; Liyuan, H. a. N.; Meisheng, L. Synthesis of 4A Zeolite from Red Mud and Mechanism of Adsorption Removal of Cu^{2+} and Mn^{2+} from Water. *Environmental Protection of Chemical Industry* **2023**, *43*, 813–820, doi:10.3969/j.issn.1006-1878.2023.06.014.
6. Cui, K.; Lyu, J.; Liu, H.; Yang, J.; Yan, Z.; Yang, W.; Liu, X.; Qiu, J. Eco-Friendly Synthesis of Magnetic Zeolite A from Red Mud and Coal Gasification Slag for the Removal of Pb2+ and Cu2+. *Journal of Environmental Chemical Engineering* **2024**, *12*, 113739, doi:10.1016/j.jece.2024.113739.
7. Zhong, W.; Li, X.; Ma, X.; Cao, Z.; Zhong, H.; Yang, J.; Wang, S. Transferring Red Mud to Efficient Adsorbent for the Adsorption and Immobilization of Ni(Ⅱ) from Aqueous Solution. *Colloids and Surfaces C: Environmental Aspects* **2024**, *2*, 100045, doi:10.1016/j.colsuc.2024.100045.
8. Lyu, F.; Niu, S.; Wang, L.; Liu, R.; Sun, W.; He, D. Efficient Removal of Pb(II) Ions from Aqueous Solution by Modified Red Mud. *J Hazard Mater* **2021**, *406*, 124678, doi:10.1016/j.jhazmat.2020.124678.
9. Bai, Y.; Pang, Y.; Wu, Z.; Li, X.; Jing, J.; Wang, H.; Zhou, Z. Adsorption of Lead from Water Using MnO2-Modified Red Mud: Performance, Mechanism, and Environmental Risk. *Water* **2023**, *15*, 4314, doi:10.3390/w15244314.
10. Cui, T.; Chen, D.; Duan, R.; Yang, F.; Li, D.; Tian, L.; Zhang, Y.; Wang, H.; Xu, R. Taloring Sawdust Derived Hydrochar via Red Mud for Cadmium Removal: Electron Transfer Insight and Recyclability Assessment. *Chemosphere* **2025**, *370*, 143924, doi:10.1016/j.chemosphere.2024.143924.
11. Wang, H.; Cai, J.; Liao, Z.; Jawad, A.; Ifthikar, J.; Chen, Z.; Chen, Z. Black Liquor as Biomass Feedstock to Prepare Zero-Valent Iron Embedded Biochar with Red Mud for Cr(VI) Removal: Mechanisms Insights and Engineering Practicality. *Bioresource Technology* **2020**, *311*, 123553, doi:10.1016/j.biortech.2020.123553.
12. Wang, H.; Cui, T.; Chen, D.; Luo, Q.; Xu, J.; Sun, R.; Zi, W.; Xu, R.; Liu, Y.; Zhang, Y. Hexavalent Chromium Elimination from Wastewater by Integrated Micro-Electrolysis Composites Synthesized from Red Mud and Rice Straw via a Facile One-Pot Method. *Sci Rep* **2022**, *12*, 14242, doi:10.1038/s41598-022-18598-7.
13. Yan, K.; Zhang, J.; Liu, D.; Meng, X.; Guo, Y.; Cheng, F. Feasible Synthesis of Magnetic Zeolite from Red Mud and Coal Gangue: Preparation, Transformation and Application. *Powder Technology* **2023**, *423*, 118495, doi:10.1016/j.powtec.2023.118495.
14. Ahmed, W.; Mehmood, S.; Mahmood, M.; Ali, S.; Shakoor, A.; Núñez-Delgado, A.; Asghar, R.M.A.;

Zhao, H.; Liu, W.; Li, W. Adsorption of Pb(II) from Wastewater Using a Red Mud Modified Rice-Straw Biochar: Influencing Factors and Reusability. *Environmental Pollution* **2023**, *326*, 121405, doi:10.1016/j.envpol.2023.121405.

15. Yoon, K.; Cho, D.-W.; Bhatnagar, A.; Song, H. Adsorption of As(V) and Ni(II) by Fe-Biochar Composite Fabricated by Co-Pyrolysis of Orange Peel and Red Mud. *Environmental Research* **2020**, *188*, 109809, doi:10.1016/j.envres.2020.109809.
16. Cho, D.-W.; Yoon, K.; Ahn, Y.; Sun, Y.; Tsang, D.C.W.; Hou, D.; Ok, Y.S.; Song, H. Fabrication and Environmental Applications of Multifunctional Mixed Metal-Biochar Composites (MMBC) from Red Mud and Lignin Wastes. *Journal of Hazardous Materials* **2019**, *374*, 412–419, doi:10.1016/j.jhazmat.2019.04.071.
17. Jiang, G.; Li, H.; Cheng, T.; Tian, Y.; Liu, P.; Guo, J.; Cui, K.; Ma, R.; Ma, X.; Cui, F.; et al. Novel Preparation of Sludge-Based Spontaneous Magnetic Biochar Combination with Red Mud for the Removal of Cu2+ from Wastewater. *Chemical Physics Letters* **2022**, *806*, 139993, doi:10.1016/j.cplett.2022.139993.
18. Lee, J.-I.; Choi, D.; Kim, S.; Park, S.-J.; Kwon, E.E. Fabrication of Fe-Doped Biochar for Pb Adsorption through Pyrolysis of Agricultural Waste with Red Mud. *Chemosphere* **2025**, *370*, 143930, doi:10.1016/j.chemosphere.2024.143930.
19. Jin, W.; Yang, Y.; Jin, J.; Xu, M.; Zhang, Z.; Dong, F.; Shao, M.; Wan, Y. Characterization of Phosphate Modified Red Mud–Based Composite Materials and Study on Heavy Metal Adsorption. *Environ Sci Pollut Res* **2024**, *31*, 43687–43703, doi:10.1007/s11356-024-33969-5.
20. Gonçalves, N.P.F.; Almeida, M.M.; Labrincha, J.A.; Novais, R.M. Effective Acid Mine Drainage Remediation in Fixed Bed Column Using Porous Red Mud/Fly Ash-Containing Geopolymer Spheres. *Science of The Total Environment* **2024**, *940*, 173633, doi:10.1016/j.scitotenv.2024.173633.
21. Carvalheiras, J.; Novais, R.M.; Labrincha, J.A. Metakaolin/Red Mud-Derived Geopolymer Monoliths: Novel Bulk-Type Sorbents for Lead Removal from Wastewaters. *Applied Clay Science* **2023**, *232*, 106770, doi:10.1016/j.clay.2022.106770.
22. Yan, S.; Zhang, M.; He, C.; Zhai, X.; Wang, S. Synthesis of Porous Red Mud/Slag-Based Spherical Geopolymers for Efficient Methylene Blue and Ni2+ Removal from Water. *Langmuir* **2024**, *40*, 23882–23894, doi:10.1021/acs.langmuir.4c02930.
23. Du, Y.; Dai, M.; Cao, J.; Peng, C. Fabrication of a Low-Cost Adsorbent Supported Zero-Valent Iron by Using Red Mud for Removing Pb(II) and Cr(VI) from Aqueous Solutions. *RSC Adv.* **2019**, *9*, 33486–33496, doi:10.1039/C9RA06978J.
24. Li, C.; Yu, J.; Li, W.; He, Y.; Qiu, Y.; Li, P.; Wang, C.; Huang, F.; Wang, D.; Gao, S. Immobilization, Enrichment and Recycling of Cr(VI) from Wastewater Using a Red Mud/Carbon Material to Produce the Valuable Chromite (FeCr2O4). *Chemical Engineering Journal* **2018**, *350*, 1103–1113, doi:10.1016/j.cej.2018.06.072.
25. Mesgari Abbasi, S.; Rashidi, A.; Ghorbani, A.; Khalaj, G. Synthesis, Processing, Characterization, and Applications of Red Mud/Carbon Nanotube Composites. *Ceramics International* **2016**, *42*, 16738–16743, doi:10.1016/j.ceramint.2016.07.146.
26. Carvalheiras, J.; Oliveira, I.E.; Silva, R.M.; Silva, R.F.; Novais, R.M.; Labrincha, J.A. Catalyst-Free CNTs Growth on Red Mud-Based Alkali Activated Adsorbents: Innovative Route to Boost Heavy Metals Adsorption from Wastewaters. *Materials Letters* **2023**, *353*, 135246, doi:10.1016/j.matlet.2023.135246.
27. Qi, J.; Zhu, H.; Yang, T.; Wang, X.; Wang, Z.; Lei, X.; Li, B.; Qian, W. Biomass-Derived Carbon/Iron

Composite (FexOy-BC (RM)) with Excellent Cd(II) Adsorption from Wastewater – Red Mud Resource Utilization. *Arabian Journal of Chemistry* **2024**, *17*, 105411, doi:10.1016/j.arabjc.2023.105411.

28. Peng, Y.; Luo, L.; Luo, S.; Peng, K.; Zhou, Y.; Mao, Q.; Yang, J.; Yang, Y. Efficient Removal of Antimony(III) in Aqueous Phase by Nano-Fe3O4 Modified High-Iron Red Mud: Study on Its Performance and Mechanism. *Water* **2021**, *13*, 809, doi:10.3390/w13060809.
29. Liu, J.; Xie, Y.; Li, C.; Fang, G.; Chen, Q.; Ao, X. Novel Red Mud/Polyacrylic Composites Synthesized from Red Mud and Its Performance on Cadmium Removal from Aqueous Solution. *Journal of Chemical Technology & Biotechnology* **2020**, *95*, 213–222, doi:10.1002/jctb.6223.
30. Sahu, M.K.; Patel, R.K.; Kurwadkar, S. Mechanistic Insight into the Adsorption of Mercury (II) on the Surface of Red Mud Supported Nanoscale Zero-Valent Iron Composite. *Journal of Contaminant Hydrology* **2022**, *246*, 103959, doi:10.1016/j.jconhyd.2022.103959.
31. Mohan, S.; Kumar, V.; Singh, D.K.; Hasan, S.H. Effective Removal of Lead Ions Using Graphene Oxide-MgO Nanohybrid from Aqueous Solution: Isotherm, Kinetic and Thermodynamic Modeling of Adsorption. *Journal of Environmental Chemical Engineering* **2017**, *5*, 2259–2273, doi:10.1016/j.jece.2017.03.031.
32. Jun, B.-M.; Kim, S.; Kim, Y.; Her, N.; Heo, J.; Han, J.; Jang, M.; Park, C.M.; Yoon, Y. Comprehensive Evaluation on Removal of Lead by Graphene Oxide and Metal Organic Framework. *Chemosphere* **2019**, *231*, 82–92, doi:10.1016/j.chemosphere.2019.05.076.
33. Eltaweil, A.S.; Ali Mohamed, H.; Abd El-Monaem, E.M.; El-Subruiti, G.M. Mesoporous Magnetic Biochar Composite for Enhanced Adsorption of Malachite Green Dye: Characterization, Adsorption Kinetics, Thermodynamics and Isotherms. *Advanced Powder Technology* **2020**, *31*, 1253–1263, doi:10.1016/j.apt.2020.01.005.
34. Cheng, Y.; Xu, L.; Jiang, Z.; Liu, C.; Zhang, Q.; Zou, Y.; Chen, Y.; Li, J.; Liu, X. Feasible Low-Cost Conversion of Red Mud into Magnetically Separated and Recycled Hybrid SrFe12O19@NaP1 Zeolite as a Novel Wastewater Adsorbent. *Chemical Engineering Journal* **2021**, *417*, 128090, doi:10.1016/j.cej.2020.128090.
35. Li, T.; He, Y.; Peng, X. Efficient Removal of Tetrabromobisphenol A (TBBPA) Using Sewage Sludge-Derived Biochar: Adsorptive Effect and Mechanism. *Chemosphere* **2020**, *251*, 126370, doi:10.1016/j.chemosphere.2020.126370.
36. Zhao, Y.; Luan, H.; Yang, B.; Li, Z.; Song, M.; Li, B.; Tang, X. Adsorption of Pb, Cu and Cd from Water on Coal Fly Ash-Red Mud Modified Composite Material: Characterization and Mechanism. *Water* **2023**, *15*, 767, doi:10.3390/w15040767.
37. Xie, W.-M.; Zhou, F.-P.; Bi, X.-L.; Chen, D.-D.; Li, J.; Sun, S.-Y.; Liu, J.-Y.; Chen, X.-Q. Accelerated Crystallization of Magnetic 4A-Zeolite Synthesized from Red Mud for Application in Removal of Mixed Heavy Metal Ions. *Journal of Hazardous Materials* **2018**, *358*, 441–449, doi:10.1016/j.jhazmat.2018.07.007.
38. Zhang, D.-R.; Chen, H.-R.; Zhao, X.-J.; Xia, J.-L.; Nie, Z.; Zhang, R.; Shu, W.-S.; Pakostova, E. Fe(II) Bio-Oxidation Mediates Red Mud Transformations to Form Fe(III)/Al (Hydr)Oxide Adsorbent for Efficient As(V) Removal under Acidic Conditions. *Chemical Engineering Journal* **2022**, *439*, 135753, doi:10.1016/j.cej.2022.135753.