

Supporting information

BSA-Modified g-C₃N₄ Nanosheets as a Sustainable Dual-Purpose Adsorbent for Efficient Pb²⁺ Removal and CO₂ Capture

Bitupan Mohan,^{a,b} Rahul Sonkar,^{a,b} Sakyabmani Bharali,^a Devasish Chowdhury^{a,b*}

^aMaterial Nanochemistry Laboratory, Physical Sciences Division, Institute of Advanced Study in Science and Technology, Paschim Boragan, Garchuk, Guwahati-781035, Assam, India

^bAcademy of Scientific and Innovative Research (AcSIR), Ghaziabad- 201002, India

*Email- devasish@iasst.gov.in (Email of the corresponding author)

Table of Contents:

Fig. S1- ZETA potential of g-C₃N₄, Ox-CN, Ep-CN and BSA-CN.

Fig. S2- AFM image and corresponding height profile of Ox-CN.

Fig. S3- TEM images of as synthesised g-C₃N₄ and SAED pattern

Fig S4- Pb²⁺ ion adsorption comparison of CN and BSA-CN

Fig. S5- Arrhenius plot of log k₂ vs 1/T for determining adsorption activation energy.

Fig. S6- SEM micrographs of BSA-functionalized CN (BSA-CN) after Pb²⁺ adsorption along with corresponding EDX spectra

Fig. S7- FTIR spectra of BSA-CN after Pb²⁺ and CO₂ adsorption respectively

Fig. S8- (a) FTIR spectra of fresh BSA-CN and after the 1st and 3rd adsorption-desorption cycles; (b, c) corresponding zeta potential distributions after Cycle 1 and Cycle 3

Fig. S9- Recyclability of CO₂ Adsorption isotherm of BSA-CN at 276 K (a) First cycle, (b) Second cycle, respectively

Table S1- Equilibrium Pb²⁺ adsorption comparison of CN and BSA-CN (T = 25 °C, C_o = 30 mg L⁻¹, m = 10 mg, V = 50 mL)

Table S2- Pb²⁺ adsorption performance in real water samples (T = 25 °C, C_o = 30 mg L⁻¹, m = 10 mg, V = 50 mL)

Table S3-Comparative analysis of Pb²⁺ adsorption capacity of BSA-CN with other materials

Table S4- Comparison of CO₂ adsorption capacity.

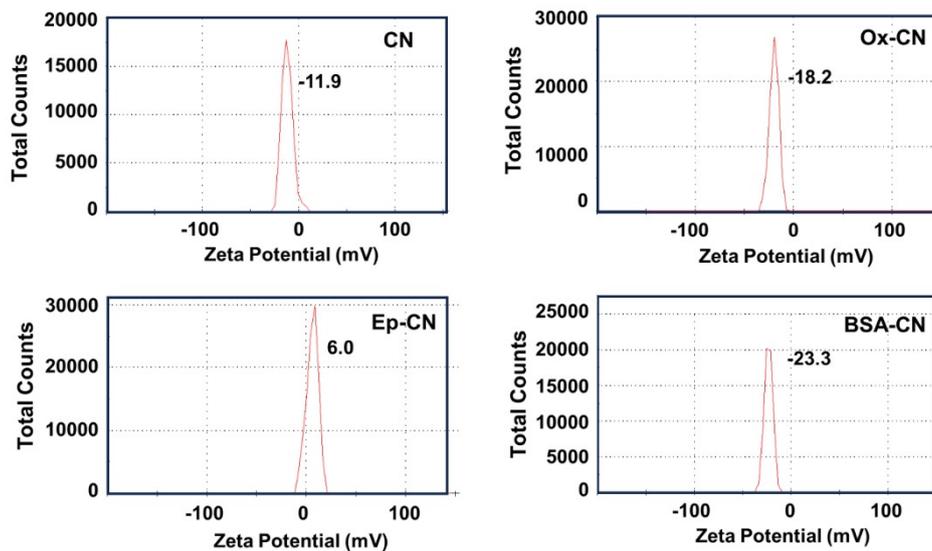


Fig. S1 ZETA potential of g-C₃N₄, Ox-CN, Ep-CN and BSA-CN.

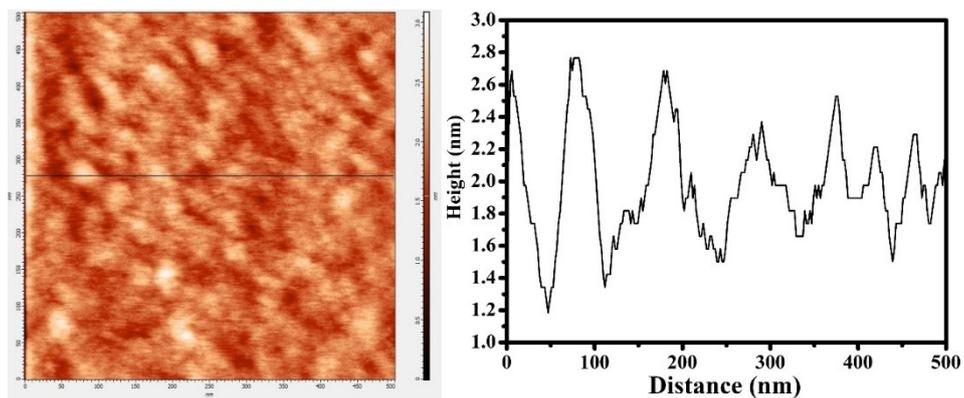


Fig. S2 AFM image and corresponding height profile of Ox-CN

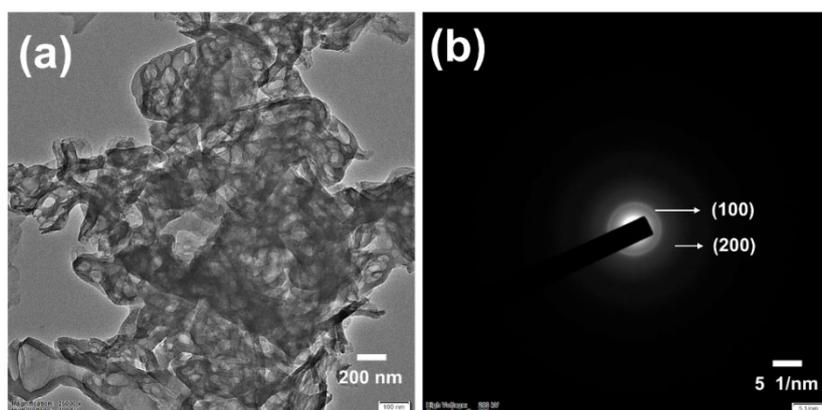


Fig. S3 TEM images of as synthesised g-C₃N₄ and SAED pattern

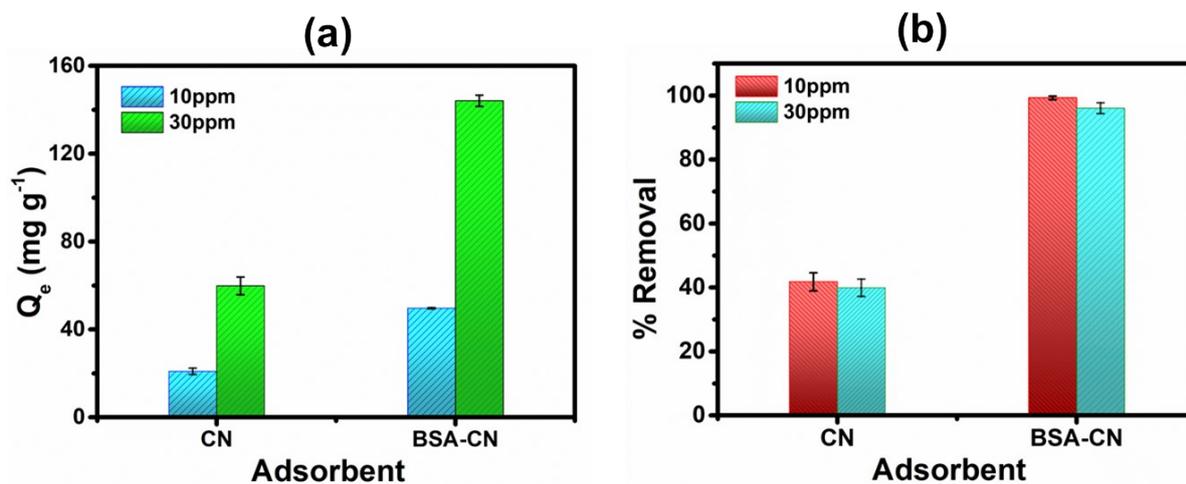


Fig. S4 Pb²⁺ ions adsorption comparison of CN and BSA-CN (a) equilibrium adsorption capacity and (b) percentage removal.

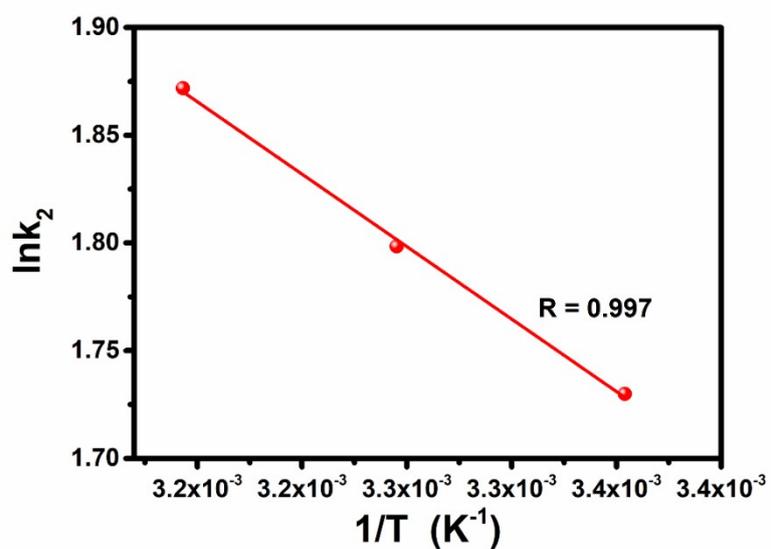


Fig. S5 Arrhenius plot of $\log k_2$ vs $1/T$ for determining adsorption activation energy.

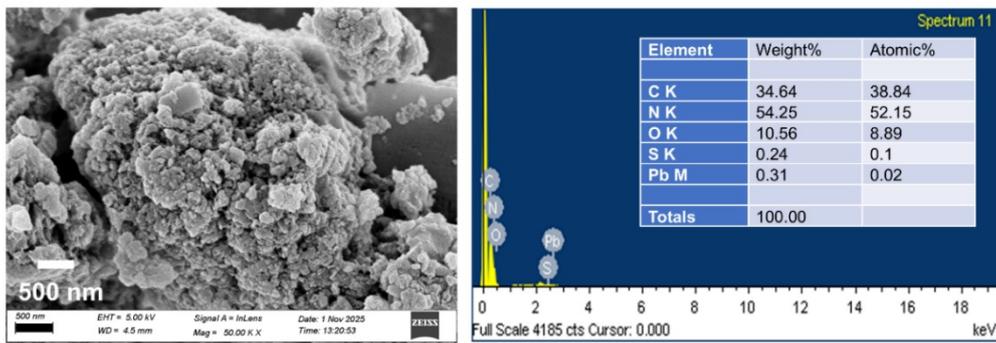


Fig. S6 SEM micrographs of BSA-functionalized CN (BSA-CN) after Pb^{2+} adsorption along with corresponding EDX spectra

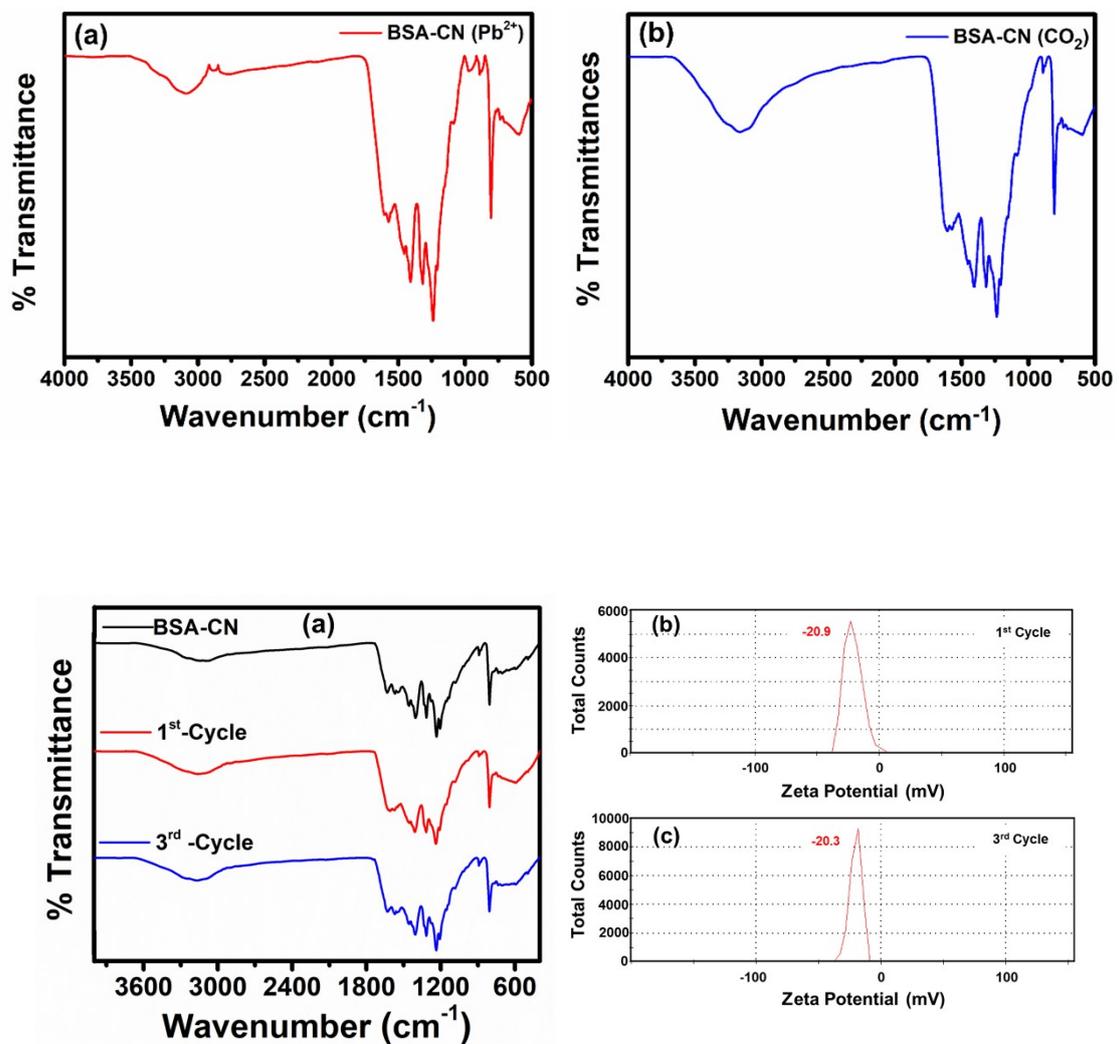


Fig. S7 FTIR spectra of BSA-CN after Pb^{2+} and CO_2 adsorption respectively

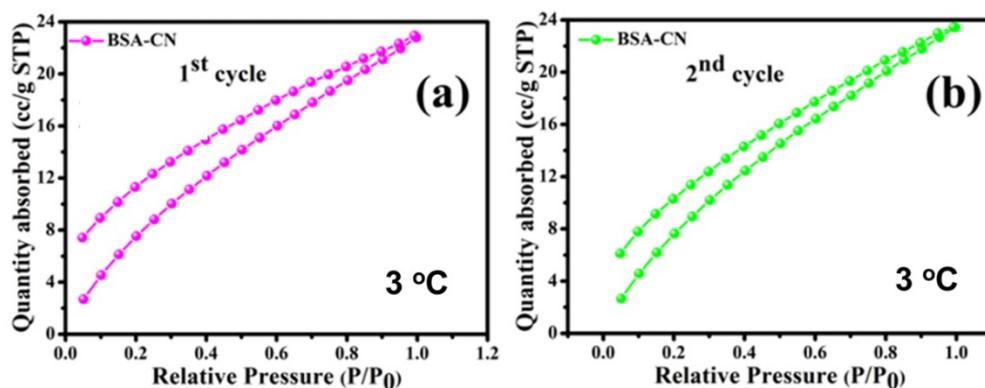


Fig. S8 (a) FTIR spectra of fresh BSA-CN and after the 1st and 3rd adsorption–desorption cycles; (b, c) corresponding zeta potential distributions after Cycle 1 and Cycle 3

Fig. S9 Recyclability of CO₂ Adsorption isotherm of BSA-CN at 276 K (a) First cycle, (b) Second cycle, respectively

Table S1. Equilibrium Pb²⁺ adsorption comparison of CN and BSA-CN (T = 25 °C, C₀ = 30 mg L⁻¹, m = 10 mg, V = 50 mL)

Absorbent	Q _e (mg g ⁻¹)	Removal (%)	Relative Improvement (%)
CN	59.8	39.8	-
BSA-CN	144.6	96.1	+141.8%

Table S2. Pb²⁺ adsorption performance in real water samples (T = 25 °C, C₀ = 30 mg L⁻¹, m = 10 mg, V = 50 mL)

Water Type	Pb ²⁺ spike (mg L ⁻¹)	% Removal	Q _e (mg g ⁻¹)	Retention (%)
DI Water	10	99.3	49.6	-
	30	96.1	144.6	-
Surface water	10	93.8	46.9	94.5
	30	89.9	134.9	93.2

Lake water	10	93.6	46.8	94.3
	30	90.9	136.4	94.3

Performance retention (%) was calculated by using the following equation

$$\text{Performance (\%)} = \frac{Q_{e, \text{ref}}}{Q_{e, \text{II}}} \times 100$$

Table S3. Comparative analysis of Pb²⁺ adsorption capacity of BSA-CN with other materials

Sl. No	Adsorbent	Q _{max} (mg g ⁻¹)	Adsorption Model	Reference
1	BSA-CN	292.94	Langmuir	this work
2	Magnetic biochar from modified AMD sludge	329.65	Langmuir	1
3	Magnetic graphene oxide-calcium alginate composite	270.27	Langmuir	2
4	Activated hydrochar (activated via KHCO ₃)	289	Langmuir	3
5	Modified KMnO ₄ biochar (KFBC)	170.67	Langmuir	4
6	MnO ₂ -loaded resin	80.64	Langmuir	5
7	Biochar from corn straw	113.70	Langmuir	6
8	Kappaphycus striatum	176.83	Extended Freundlich	7
9	Costariacostata	160.990	Freundlich	8

Table S4. Comparison of CO₂ adsorption capacity of BSA-CN with other materials

Sl. No	Materials	Temperature	CO ₂ Adsorption Capacity (cm ³ /g)	References
1	BSA-CN	276K	23.40	This work
2	Biochar of orange peel	273K	22.83	9
3	Biochar of bamboo	273K	14.12	9
4	Ph@SnO ₂	280K	9.948	10
5	ZTS nanocomposite	293K	11.32	11
6	BSA-CN	298K	8.35	This work
7	ZIF-8	298K	18.82 (0.84 mmol/g)	12
8	Enteromorpha	298K	11.65 (0.52 mmol/g)	13
9	Pine sawdust biochars	298K	16.35 (0.73 mmol/g)	14
10	Ph@SnO ₂	300K	5.7908	10

References

1. X. Long, R. Zhang, R. Rong, P. Wu, S. Chen, J. Ao, L. An, Y. Fu and H. Xie, *Toxics*, 2023, **11**, 590.
2. S. B. Malitha, D. Md. Mahmudunnabi, S. Mazumder, K. S. Hossain, M. Nurnabi and Md. Z. Alam, *Environ. Sci. Adv.*, 2024, **4**, 595–605.

3. B. Chen, H. Guan, Y. Zhang, S. Liu, B. Zhao, C. Zhong, H. Zhang, W. Ding, A. Song, D. Zhu, L. Liu, B. Wulan, H. Li, G. Liu and X. Feng, *Heliyon*, 2023, **9**, e14930.
4. Y. Xu, Y. Qu, Y. Yang, B. Qu, R. Shan, H. Yuan and Y. Sun, *Int. J. Mol. Sci.*, 2022, **23**, 14053.
5. L. Dong, Z. Zhu, H. Ma, Y. Qiu and J. Zhao, *J. Environ. Sci.*, 2010, **22**, 225–229.
6. J. Peng, Z. Zhang, Z. Wang, F. Zhou, J. Yu, R. Chi and C. Xiao, *J. Taiwan Inst. Chem. Eng.*, 2024, **156**, 105363.
7. A. Verma, M. Agarwal, S. Sharma and N. Singh, *Environ. Nanotechnol. Monit. Manag.*, 2021, **15**, 100449.
8. J. -k. Kang, B. N. Pham, C. -g. Lee and S. -j. Park, *Int. J. Environ. Sci. Technol.*, 2022, **20**, 10113–10122.
9. C. W. Kwon, S. Tae and S. Mandal, *Molecules*, 2025, **30**, 1607.
10. N. Sultana, N. Barman, P. J. Medhi and N. S. Sarma, *Langmuir*, 2023, **39**, 18946–18957.
11. S. Kumar, P. Puzari and S. Kundu, *ACS Appl. Nano Mater.*, 2025, **8**, 19283–19300.
12. J. McEwen, J.-D. Hayman and A. O. Yazaydin, *Chemical Physics*, 2012, **412**, 72–76.
13. S. Ding and Y. Liu, *Fuel*, 2019, **260**, 116382.
14. A. D. Igalavithana, S. W. Choi, J. Shang, A. Hanif, P. D. Dissanayake, D. C. W. Tsang, J.-H. Kwon, K. B. Lee and Y. S. Ok, *Sci. Total Env.*, 2020, **739**, 139845.