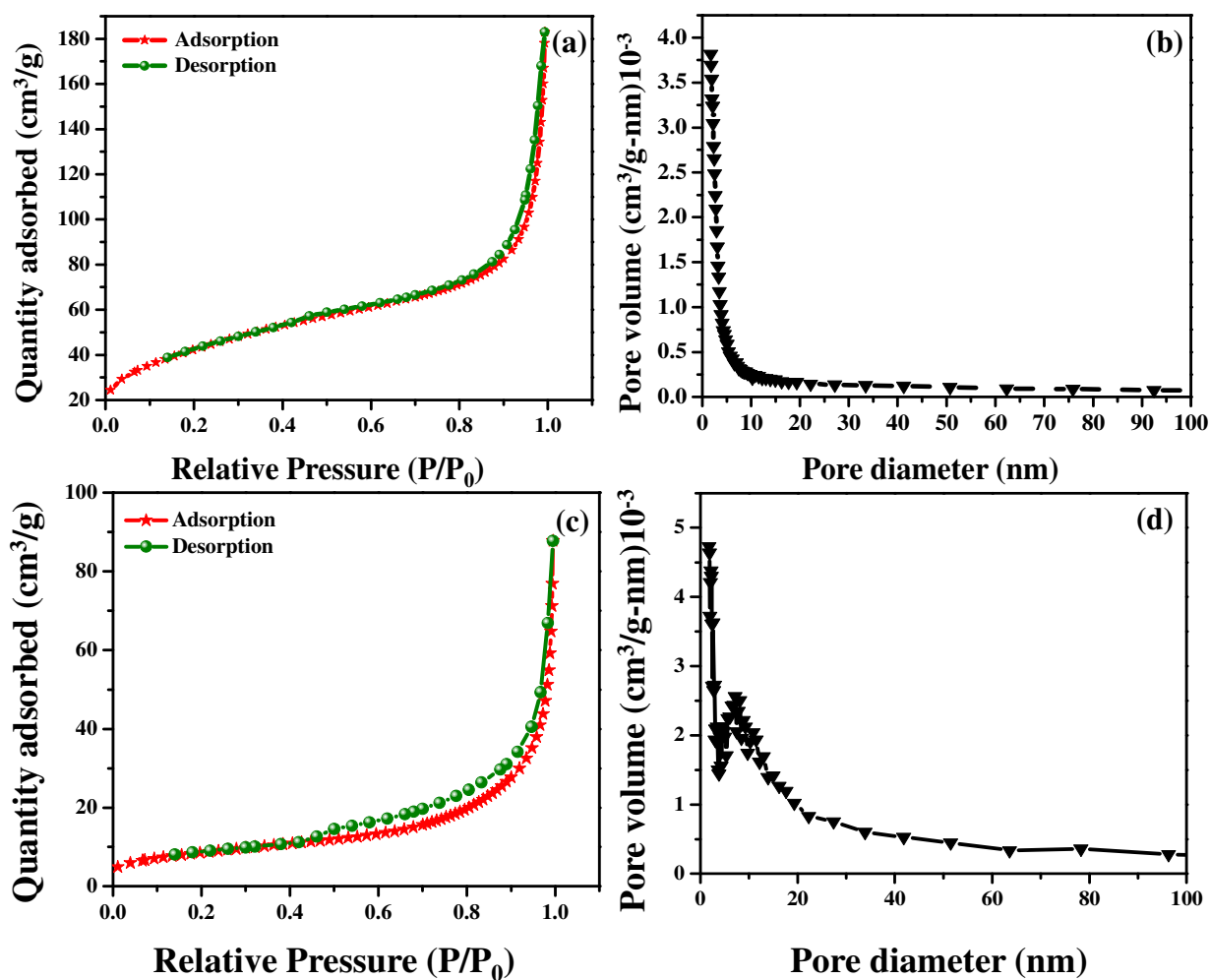


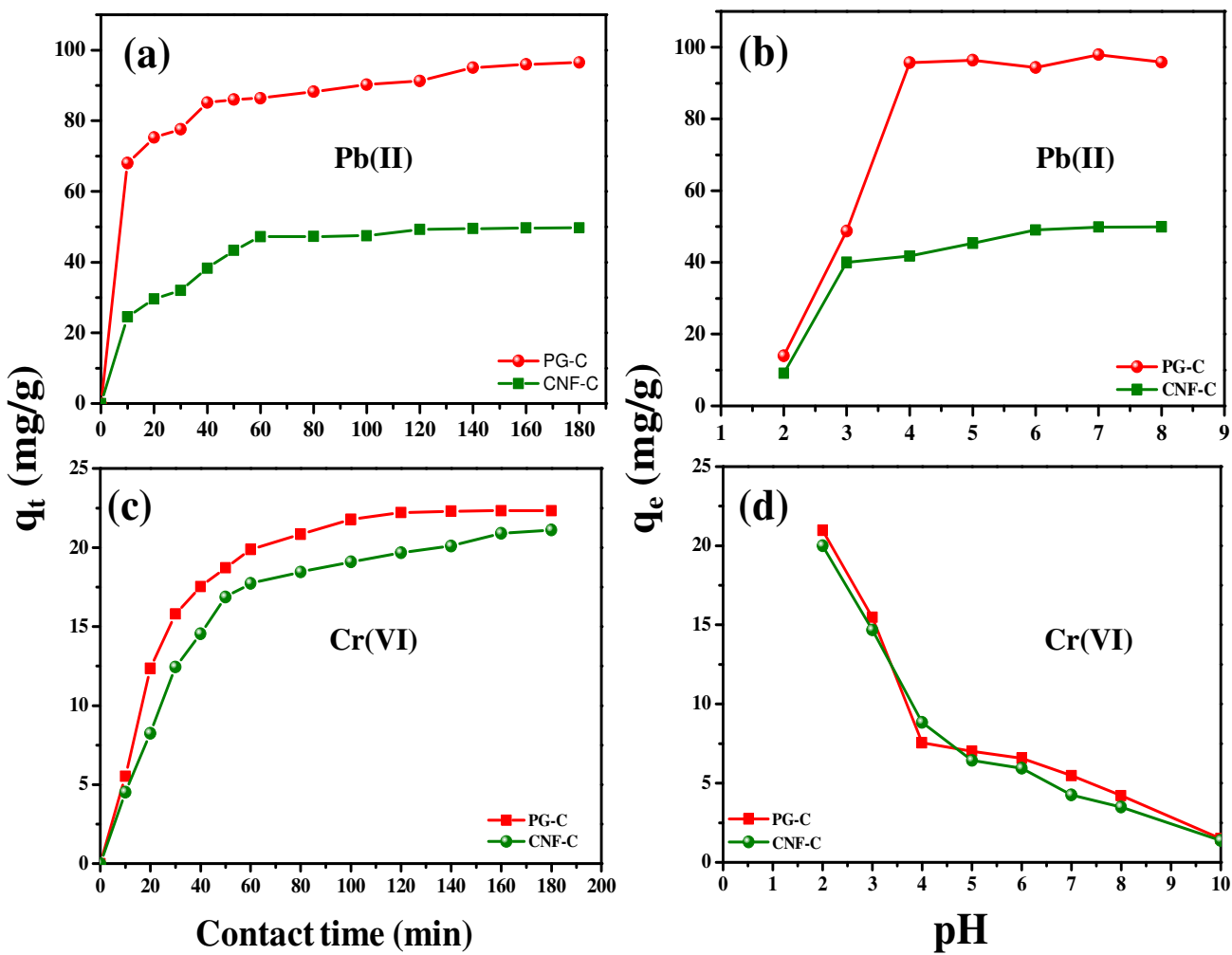
# Removal of cationic and anionic heavy metals from water by 1D and 2D-carbon structures decorated with magnetic nanoparticles

Chella Santhosh <sup>a,\*</sup>, Ravi Nivetha <sup>b</sup>, Pratap Kollu <sup>c,d</sup>, Varsha Srivastava <sup>e</sup>, Mika Sillanpää <sup>e</sup>,

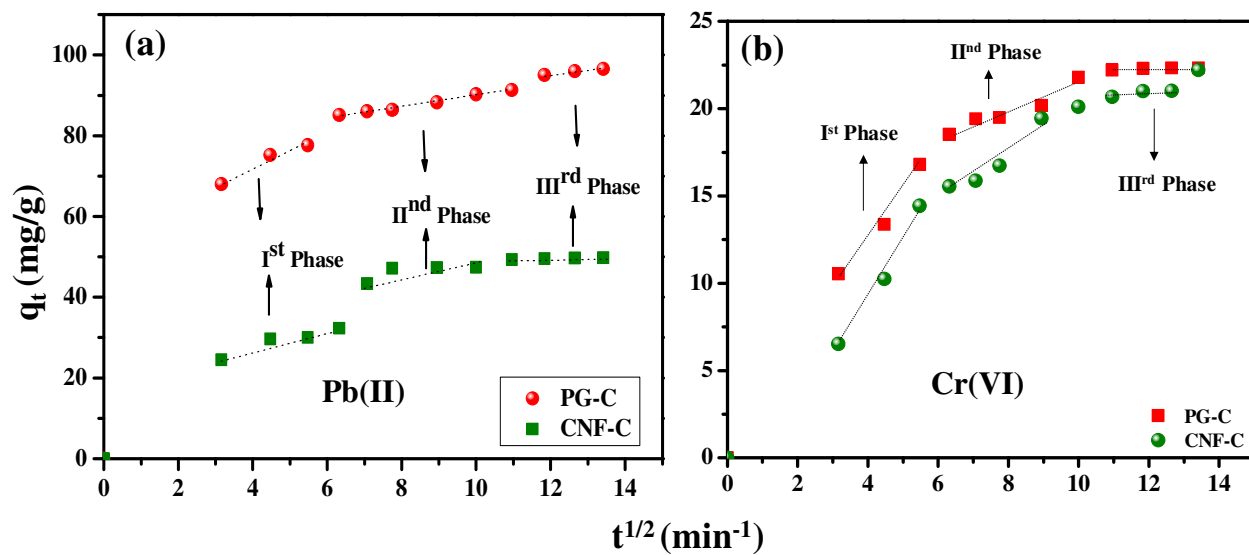
Andrews Nirmala Grace <sup>b,\*</sup>, Amit Bhatnagar <sup>a,\*</sup>



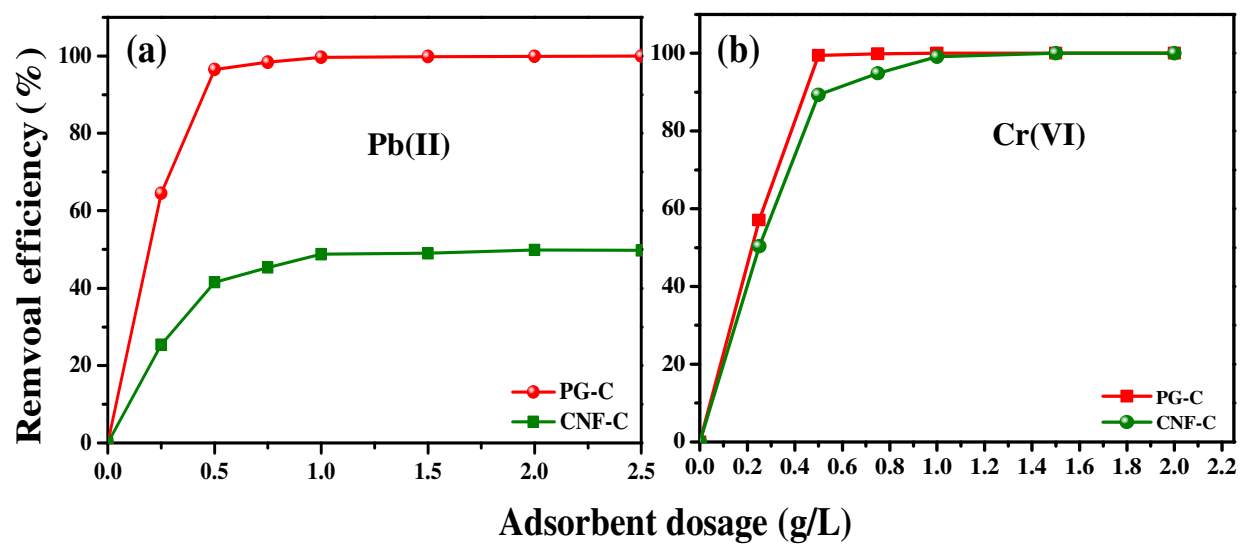
**Supplementary Fig. S1.** (a, c) N<sub>2</sub> adsorption – desorption isotherm and (b, d) Pore size distribution of PG-C and CNF-C nanocomposites.



**Supplementary Fig. S2.** Effect of (a, c) contact time and (b, d) pH of Pb(II) and Cr(VI) ions adsorption by PG-C and CNF-C nanocomposites.



**Supplementary Fig. S3.** Intra-particle diffusion model for (a) Pb(II) and (b) Cr(VI) ions adsorption by PG-C and CNF-C nanocomposites.



**Supplementary Fig. S4.** Effect of adsorbent dosage on (a) Pb(II) and (b) Cr(VI) ions adsorption by PG-C and CNF-C nanocomposites.

**Supplementary Table S1:** Kinetic parameters for Pb(II) and Cr(VI) ions adsorption onto synthesized nanocomposites.

Adsorbate	Adsorbent	<i>Pseudo-second-order model</i>					
		$q_{e(\text{exp})}$ (mg g <sup>-1</sup> )	$k_2$ (min <sup>-1</sup> )	$q_{e(\text{cal})}$ (mg g <sup>-1</sup> )	RMSE	R <sup>2</sup>	
Pb(II)	PG-C	96.54	0.002	95.85	2.25	0.998	
	CNF-C	49.76	0.001	55.78	2.71	0.992	
Cr(VI)	PG-C	22.33	0.004	23.97	6.03	0.990	
	CNF-C	21.11	0.002	22.34	5.62	0.991	
Adsorbate	Adsorbent	<i>Avrami model</i>					
		$q_{e(\text{exp})}$ (mg g <sup>-1</sup> )	$K_{\text{av}}$	$n_{\text{av}}$	$q_{e(\text{cal})}$ (mg g <sup>-1</sup> )	RMSE	R <sup>2</sup>
Pb(II)	PG-C	96.54	0.017	6.78	89.70	4.57	0.994
	CNF-C	49.76	0.006	6.79	49.13	3.16	0.989
Cr(VI)	PG-C	22.33	0.038	1.33	22.21	5.99	0.986
	CNF-C	21.11	0.031	1.53	19.78	5.26	0.832
Adsorbate	Adsorbent	<i>Intra-particle diffusion model</i>					
		$C_i$ (mg L <sup>-1</sup> )	I	$K_p$	RMSE	R <sup>2</sup>	
Pb(II)	PG-C	50	5.24	0.25	70.98	0.906	
	CNF-C	50	5.24	0.25	31.72	0.956	
Cr(VI)	PG-C	10	11.32	1.00	8.86	0.936	
	CNF-C	10	11.32	1.00	9.13	0.959	

**Supplementary Table S2:** Isotherm studies for Pb(II) and Cr(VI) ions onto the PG-C and CNF-C nanocomposites.

Adsorbate	Adsorbent	<i>Langmuir isotherm model</i>				
		$q_m$ (mg g <sup>-1</sup> )	$K_L$	$R_L$	RMSE	$R^2$
Pb(II)	PG-C	131.40	2.05	0.009	14.75	0.987
	CNF-C	42.90	7.10	0.002	5.19	0.985
Cr(VI)	PG-C	68.85	2.70	0.004	7.84	0.990
	CNF-C	51.07	3.20	0.002	5.87	0.989

Adsorbate	Adsorbent	<i>Freundlich isotherm model</i>				
		$K_F$ (mg g <sup>-1</sup> ) (L mg <sup>-1</sup> ) <sup>1/n</sup>	n	-	RMSE	$R^2$
Pb(II)	PG-C	73.91	5.53	-	19.15	0.786
	CNF-C	29.48	9.86	-	9.80	0.510
Cr(VI)	PG-C	33.62	5.55	-	9.64	0.847
	CNF-C	29.73	7.43	-	7.58	0.897

Adsorbate	Adsorbent	<i>Sips isotherm model</i>				
		$q_m$ (mg g <sup>-1</sup> )	$K_s$ (L mg <sup>-1</sup> )	n	RMSE	$R^2$
Pb(II)	PG-C	130.51	2.32	1.07	15.20	0.965
	CNF-C	44.34	5.43	0.85	6.42	0.976
Cr(VI)	PG-C	136.54	0.34	0.27	9.42	0.942
	CNF-C	72.22	0.76	0.29	5.62	0.914

Adsorbate	Adsorbent	<i>Redlich-Peterson isotherm model</i>				
		$K_{RP}$ (L mg <sup>-1</sup> )	a	n	RMSE	$R^2$
Pb(II)	PG-C	238.6	1.77	0.85	15.61	0.858
	CNF-C	30.99	1.58	1.12	6.13	0.803
Cr(VI)	PG-C	207.90	33.00	0.81	9.35	0.887
	CNF-C	107.82	29.85	0.86	7.58	0.897

**Supplementary Table S3:** Thermodynamic parameters for Pb(II) and Cr(VI) ions onto synthesized nanocomposites.

		<b>Pb(II)</b>			<b>Cr(VI)</b>		
Adsorbent	Temp. (K)	$\Delta G^\circ$ (kJmol <sup>-1</sup> )	$\Delta H^\circ$ (kJmol <sup>-1</sup> )	$\Delta S^\circ$ (Jmol <sup>-1</sup> K <sup>-1</sup> )	$\Delta G^\circ$ (kJmol <sup>-1</sup> )	$\Delta H^\circ$ (kJmol <sup>-1</sup> )	$\Delta S^\circ$ (Jmol <sup>-1</sup> K <sup>-1</sup> )
PG-C	298	-9.96			-17.94		
	308	-9.05	6.07	1.19	-16.16	15.42	0.45
	318	-3.02			-14.73		
CNF-C	298	-13.21			-14.01		
	308	-10.97	12.45	3.65	-12.31	27.87	0.55
	318	-5.76			-8.04		