

*Supporting Information*

Efficient removal of Pb(II) and Co(II) ions from aqueous solution with a chromium-based metal-organic framework/activated carbon composites

*Hossein Shahriyari Far<sup>1</sup>, Mahdi Hasanzadeh<sup>2\*</sup>, Mina Najafi<sup>1</sup>, Targol Rahimi Masale Nezhad<sup>1</sup>, Mahboubeh Rabbani<sup>1</sup>*

<sup>1</sup> Department of Chemistry, Iran University of Science and Technology, Narmak, P.O. Box 16846-13114, Tehran, Iran

<sup>2</sup> Department of Textile Engineering, Yazd University, P.O. Box 89195-741, Yazd, Iran

*[h\\_shahriyarifar@alumni.iust.ac.ir](mailto:h_shahriyarifar@alumni.iust.ac.ir) (H. Shahriyari Far)*

*[m\\_najafi96@chem.iust.ac.ir](mailto:m_najafi96@chem.iust.ac.ir) (M. Najafi)*

*[targol.rahimi@yahoo.com](mailto:targol.rahimi@yahoo.com) (T. R. Masale Nezhad)*

*[m\\_rabani@iust.ac.ir](mailto:m_rabani@iust.ac.ir) (M. Rabbani)*

\* Corresponding author. E-mail: [m.hasanzadeh@yazd.ac.ir](mailto:m.hasanzadeh@yazd.ac.ir); Tel: +98-353-1232569; Fax: +98-353-8209817

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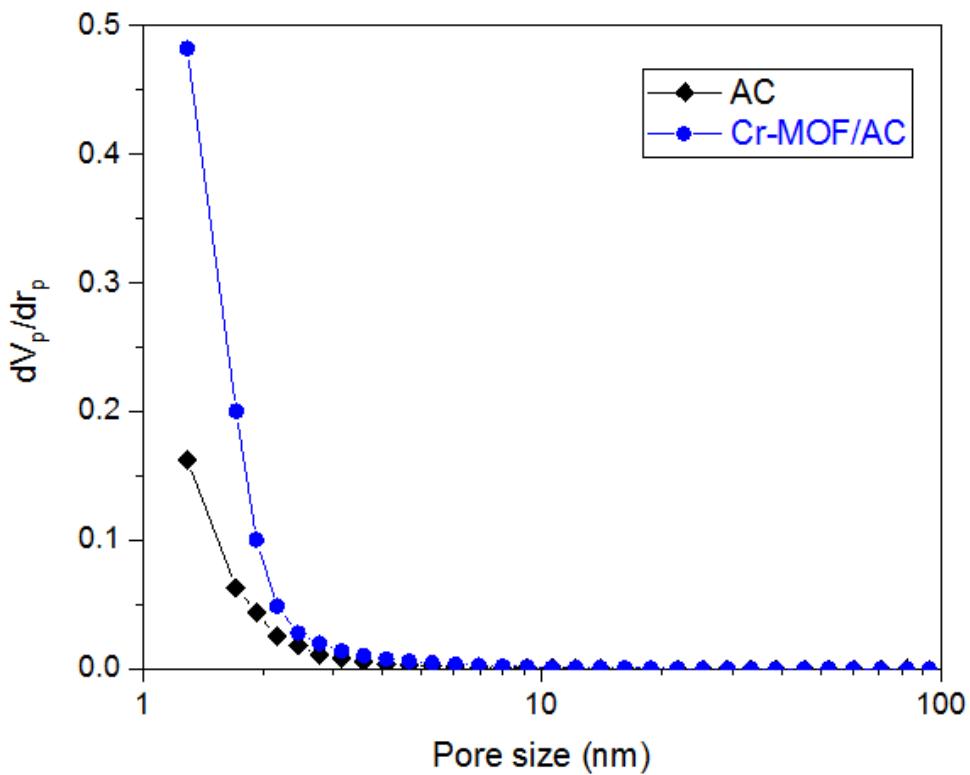
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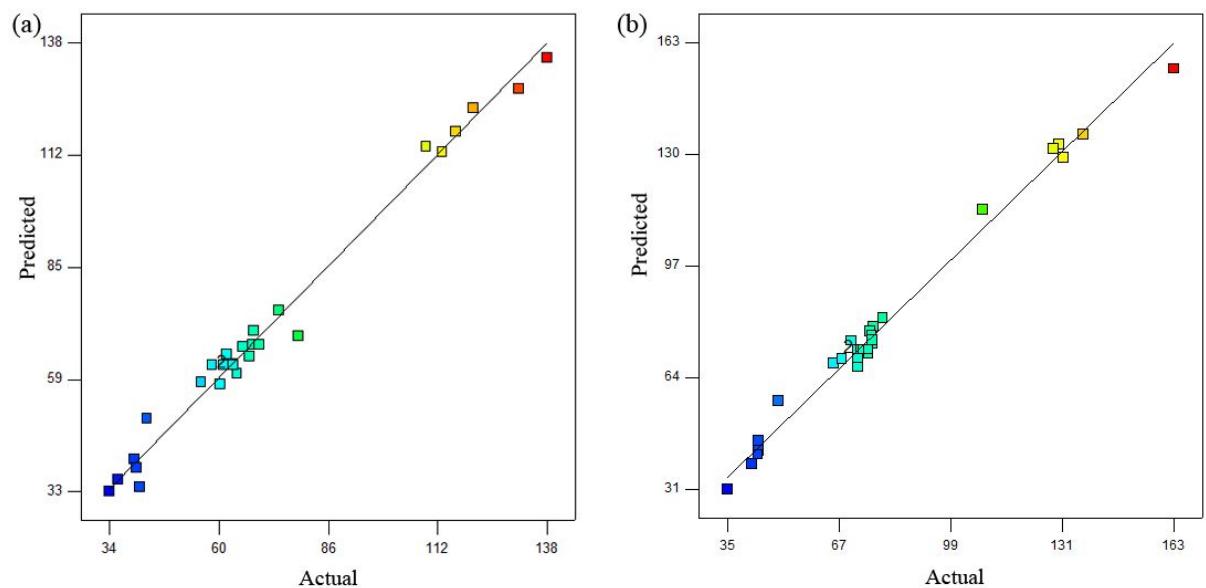
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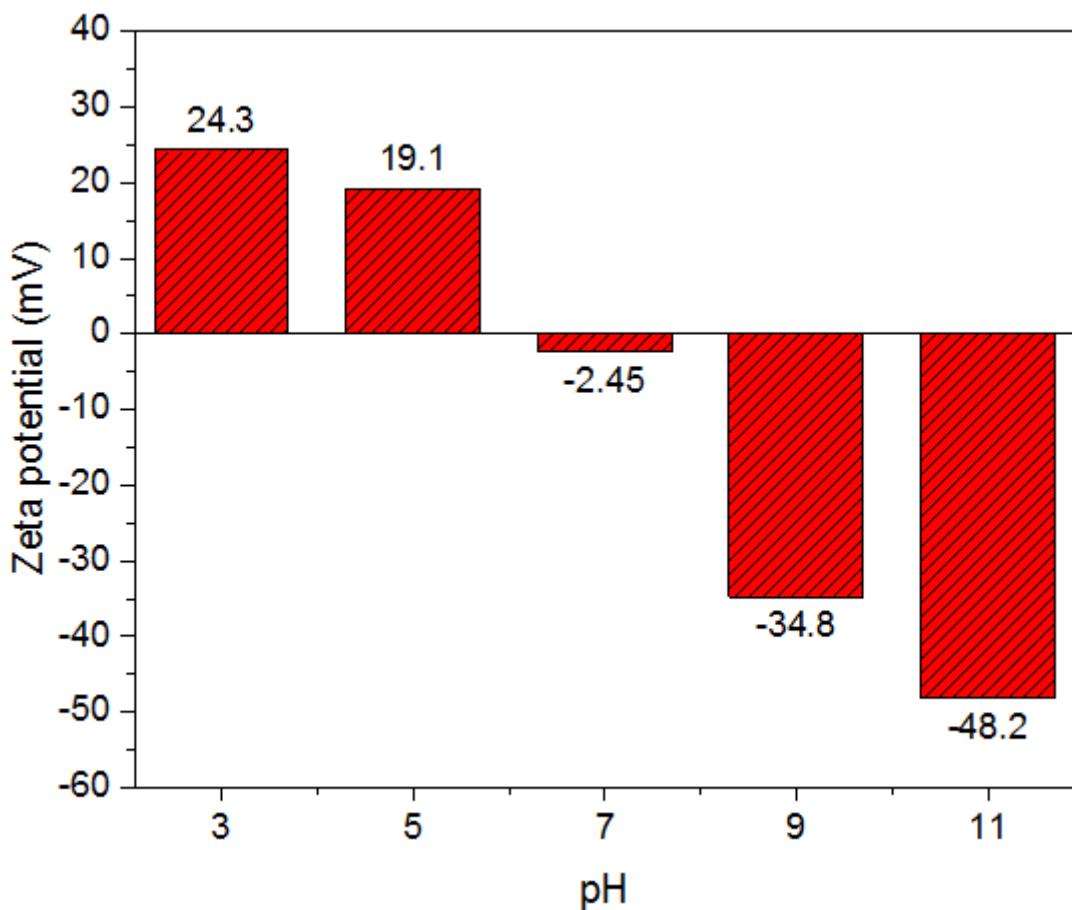
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**Figure S1.** The BJH pore size distribution AC and Cr-MOF/AC composite.



**Figure S2.** Comparison between experimental data and predicted values of Pb(II) and Co(II) adsorption capacity.



**Figure S2.** Zeta potential of Cr-MOF/AC composite at different pH.

**Table S1.** Independent variables of adsorption process and their corresponding levels

Symbol coded	Independent variables	Levels of factors				
		-alpha	-1	0	+1	+alpha
$X_1$	Ion concentration (ppm)	25	40	55	70	85
$X_2$	Contact time (min)	10	20	30	40	50
$X_3$	Adsorbent content (mg)	15	25	35	45	55
$X_4$	pH	2	3	4	5	6

**Table S2.** RSM design and the experimental results of Pb (II) and Co (II) adsorption capacity

No.	Actual values of independent variables				Response	
	Ion concentration (ppm)	Contact time (min)	Adsorbent content (mg)	pH	Pb uptakes (mg/g)	Co uptakes (mg/g)
1	25	30	35	4	33.6	34.96
2	40	20	25	3	64	70.4
3	40	40	25	3	68	76.8
4	40	20	45	3	35.6	41.8
5	40	40	45	3	40.92	43.78
6	40	20	25	5	61.6	76
7	40	40	25	5	74	79.52
8	40	20	45	5	39.6	43.6
9	40	40	45	5	40	43.82
10	55	10	35	4	55.44	65.45
11	55	50	35	4	65.45	76.38
12	55	30	15	4	138	163.35
13	55	30	55	4	42.5	49.4
14	55	30	35	2	60	67.76
15	55	30	35	6	69.3	76.62
16	55	30	35	4	58.1	72.38
17	55	30	35	4	63.14	73.15
18	55	30	35	4	62.44	73.92
19	55	30	35	4	61.6	73.15
20	55	30	35	4	60.83	73.9
21	55	30	35	4	63.14	75.46
22	70	20	25	3	113	131.6
23	70	40	25	3	120.4	130.2
24	70	20	45	3	67	72.38

25	70	40	45	3	63.1	75.46
26	70	20	25	5	116.2	128.8
27	70	40	25	5	131.2	137.2
28	70	20	45	5	78.7	72.38
29	70	40	45	5	67.7	76.46
30	85	30	35	4	109.06	108.29

**Table S3.** Analysis of variance (ANOVA) for the RSM model of Pb (II) adsorption capacity

Source	Sum of	Degree of	Mean	F-value	p-value
	Squares	Freedom	Squares		Prob > F
Model	23042.53	8	2880.32	179.57	< 0.0001
X1- Pb ion concentration	9780.84	1	9780.84	609.77	< 0.0001
X2- Contact time	102.67	1	102.67	6.40	0.0195
X3- Adsorbent content	10701.08	1	10701.08	667.14	< 0.0001
X4- pH	128.71	1	128.71	8.02	0.0001
X1X3	538.47	1	538.47	33.57	< 0.0001
X2X3	143.88	1	143.88	8.97	0.0069
$X_1^2$	200.10	1	200.10	12.48	0.0020
$X_3^2$	1550.19	1	1550.19	96.64	< 0.0001
Residual	336.85	21	16.04	--	--
Lack of Fit	318.57	16	19.91	5.45	0.0353
Pure error	18.27	5	3.65	--	--
Total	23379.37	29	--		

Note:  $R^2=0.986$  ;  $R^2$  (Adj)= 0.980.

**Table S4.** Analysis of variance (ANOVA) for the RSM model of Co (II) adsorption capacity

Source	Sum of	Degree of	Mean	F-value	p-value
	Squares	Freedom	Squares		Prob > F
Model	27515.98	6	4586.00	319.63	< 0.0001
X1- Co ion concentration	10226.71	1	10226.71	712.78	< 0.0001
X2- Contact time	96.56	1	96.56	6.73	0.0162
X3- Adsorbent content	14442.28	1	14442.28	1006.60	< 0.0001
X4- pH	45.60	1	45.60	3.18	0.0878
X1X3	642.62	1	642.62	44.79	< 0.0001
$\chi^2_3$	2062.21	1	2062.21	143.73	< 0.0001
Residual	330.00	23	14.35	--	--
Lack of Fit	324.47	18	18.03	16.32	0.0029
Pure error	5.52	5	1.10	--	--
Total	27845.97	29	--		

Note:  $R^2=0.988$  ;  $R^2(\text{Adj})= 0.985$ .

**Table S5.** Comparison of Pd(II) and Co(II) ions adsorption on different adsorbents

Heavy metals	Adsorbent	Experimental conditions				Adsorption capacity (mg/g)	Ref.
		pH	Time (min)	Metal concentration (ppm)	Adsorbent content (mg)		
Pb(II)	MOF-Chitosan	6	180	200	500	407.5	<sup>1</sup>
	EDTA-graphene oxide	6.8	15	100	20	479	<sup>2</sup>
	Fe <sub>3</sub> O <sub>4</sub> @Activated carbon	6	60	50	2 *	71.42	<sup>3</sup>
	Activated alumina	5	60	10	7.5 *	83.33	<sup>4</sup>
	Zn-MOF/Calcium alginate	5	120	300	12.5	1321.21	<sup>5</sup>
	Amine-functionalized Zr-MOF	6	120	10	--	166.74	<sup>6</sup>
	DHAQ-modified Zr-MOF	4	30	450	--	213.3	<sup>7</sup>
	Chitosan-Methacrylic acid	5	120	50	5 *	11.30	<sup>8</sup>
	β-cyclodextrin polymer	8.4	5	200	1 *	196.42	<sup>9</sup>
	Magnetic silica gel	6	60	210	100	115	<sup>10</sup>
Co(II)	Fe-MOF/graphene oxide	6	15	300	20	128.6	<sup>11</sup>
	Resorcyal aldehyde-modified MOF	4	360	800	--	189.8	<sup>8</sup>
	Activated carbon	5	40	70	25	92.4	This study
	Cr-MOF/Activated carbon	5	40	70	25	127	This study
	Fe <sub>3</sub> O <sub>4</sub> /Bentonite	9	10	800	100	18.76	<sup>12</sup>
	Amine-modified graphene oxide	6	5	60	300 *	116.35	<sup>13</sup>
	Manganese Oxide	8	120	2	100 *	25.5	<sup>14</sup>
	Magnetic GO/Chitosan	5	160	20	20	15.24	<sup>15</sup>

Ion-exchange Resin	6	40	400	100	69.4	20
SDS-modified activated carbon	7	90	20	1200 *	51	21
Activated carbon	5	40	70	25	86.8	This study
Cr-MOF/Activated carbon	5	40	70	25	138	This study

\* The concentration of adsorbent (mg/L).

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