Electronic Supplementary Material (ESI) for RSC Advances.

Supplementary Materials

Tables

Table 1. Company and molecular weight for materials used

No	Materials	Company
1	industrial wastewater	Rocket fertilizer factory in new salhia, sharqia, Egypt
2	Chitosan	Local market, Ismailia, Egypt
3	hydrochloric acid	Alpha chemika, Egypt
4	sodium hydroxide	Alpha chemika, Egypt
5	Graphite powder	Alpha chemika, Egypt
6	Silver nitrate	Alpha chemika, Egypt
7	Sodium borohydride	Oxford lab fine chem LLP, Egypt
8	Trisodium Citrate Dihydrate	Oxford lab fine chem LLP, Egypt
9	potassium dichromate	Oxford lab fine chem LLP, Egypt
10	ferric chloride	Oxford lab fine chem LLP, Egypt
11	Manganese chloride	Oxford lab fine chem LLP, Egypt

Table 2. The characteristics of the industrials wastewater

Colour	PH	TSS (ppm)	COD (ppm)	TDS (ppm)	Fe (ppm)	Mn (ppm)	Alk
Light grey	3.22	542	5500	9160	68.15	49.29	0

Table 3. Langmuir isotherm models

Heavy metals	**Langmuir model**	**Plotting**	**$q_{o(mg \cdot g^{-1})}$**	**($K_{L(L\ mg^{-1})}$**	**R_L**	**R^2**
Cr (VI)	Nonlinear: $q_e = q_o \frac{K_L C_e}{1 + K_L C_e}$ (1)	$q_e\ vs.\ C_e$	60443.73	0.0007	0.972	0.996
	Linear : $= 1/q_o K_L + Ce/q_o$ (2)	$Ce/q_e\ vs.\ C_e$	-159.39	-0.052	0.791	0.791
	Nonlinear:		[illegible]	[illegible]	[illegible]	[illegible]

	$q_e = q_o \frac{K_L C_e}{1 + K_L C_e}$ (1)					
	Linear : $= 1/q_o K_L + Ce/q_o$ (2)	$Ce/q_e\ vs.\ C_e$	254.771	0.004	0.977	0.430

Table 4. Freundlich isotherm models

Heavy metals	**Freundlich model**	**Plotting**	**($K_{f((mg/g)/(mg/L)n)}$**	**n**	**R^2**
Cr (VI)	Nonlinear: $q_e = K_f C_e^{1/n}$ (3)	$q_e\ vs\ C_e$	20.053	0.787	0.957
	Linear : $\ln K_F + \frac{1}{n} \ln C_e$ (4)	$\ln q_e\ vs \ln C_e$	5.803127	0.557848	0.921
Fe (III)	Nonlinear: $q_e = K_f C_e^{1/n}$ (3)	$q_e\ vs.\ C_e$	0.826977	1.040647	0.997
	Linear : $\ln K_F + \frac{1}{n} \ln C_e$ (4)	$\ln q_e\ vs \ln C_e$	2.803122	1.461737	0.988

Table 5. Dubinin-Radushkevich isotherm models

Heavy metals	**Dubinin-Radushkevich**	**Plotting**	**q_m**	**β**	**(E(kJ·mol−1**	**R^2**

	model					
Cr (VI)	Non-linear: ${}_e = q_m\, exp^{-\beta\varepsilon^2}$ (5)	$q_e\ vs.\ \varepsilon^2$	301.042	2.09	-488.589	0.972
	Linear : ${}_e = \ln q_m - \beta\varepsilon^2$ (6)	$\ln q_e\ vs.\ \varepsilon^2$	1023.484	1.288	-196.963	0.924
Fe (III)	Non-linear: ${}_e = q_m\, exp^{-\beta\varepsilon^2}$ (5)	$q_e\ vs.\ \varepsilon^2$	234.158	0.002	-14.458	0.934
	Linear : ${}_e = \ln q_m - \beta\varepsilon^2$ (6)	$\ln q_e\ vs\ \varepsilon^2$	45.388	0.001	-159.231	0.754

Table 6.Tempkin models

Heavy metals	Tempkin model	Plotting	b	K_T	B	R^2
Cr (VI)	Nonlinear: $q_e = \frac{RT}{b}\ln(K_T C_e)$ (7)	$q_e\ vs.\ C_e$	7.849	0.502	315.647	0.725
	Linear : $q_e = \frac{RT}{b}\ln K_T + \frac{RT}{b}\ln C_e$ (8)	$q_e\ vs \ln C_e$	7.849	0.502	315.647	0.858
Fe (III)	Nonlinear: $q_e = \frac{RT}{b}\ln(K_T C_e)$ (7)	$q_e\ vs.\ C_e$	106.797	0.293	23.599	0.650
	Linear : $q_e = \frac{RT}{b}\ln K_T + \frac{RT}{b}\ln C_e$ (8)	$q_e\ vs \ln C_e$	106.797	0.293	23.599	0.650

Table 7.The pseudo-first-order models

Heav y	The pseudo-first-order model	Plotting	k_1 min$^-$	q_e mg	R^2

metal s			1	g^{-1}	
Cr (VI)	$q_t = q_e(1 - e^{-k_1 t})$ Nonlinear : (1)	$q_t\ vs.\ t$	0.189	41.698	0.325
	Linear : (2) $\log(q_e - q_t) = \log(q_e) - k_1 t/\ln 10$	$_e - q_t)\ vs\ t$	0.040	15.062	0.786
Fe (III)	$q_t = q_e(1 - e^{-k_1 t})$ Nonlinear : (1)	$q_t\ vs\ t$	0.029	38.401	0.764
	Linear : (2) $\log(q_e - q_t) = \log(q_e) - k_1 t/\ln 10$	$_e - q_t)\ vs\ t$	0.001	40.139	0.442

Table 8. The pseudo-second-order model

Heavy metals	**The pseudo-second-order model**	**Plotting**	**K_2 g mg^{-1} min^{-1}**	**q_e mg g^{-1}**	**R^2**
Cr (VI)	Nonlinear: $q_t = k_2 q_e^2 t/(1 + k_2 q_e t)$ (3)	$q_t\ vs\ t$	0.002	45.469	0.686
	Linear : $t/q_t = 1/(k_2 q_e^2) + t/q_e$ (4)	$t/q_t\ vs\ t$	-0.001	51.120	0.996
Fe (III)	Nonlinear: $q_t = k_2 q_e^2 t/(1 + k_2 q_e t)$ (3)	$q_t\ vs\ t$	0.0008	44.933	0.681
	Linear : $t/q_t = 1/(k_2 q_e^2) + t/q_e$ (4)	$t/q_t\ vs\ t$	0.023	37.993	0.999

Table 9. Intraparticle diffusion models

Heavy metals	**Intraparticle diffusion model**	**Plotting**	**k_1 mg g^{-1} $min^{-0.5}$**	**C mg g^{-1}**	**R^2**
Cr (VI)	Non-linear:	$q\ vs.\ t$	1.187	31.923	0.891

	$q = k_i t^{0.5} + C$ (5)				
	$q = k_i t^{0.5} + C$ Linear: (5)	$q\ vs\ t^{0.5}$	1.187	31.923	0.891
Fe (III)	Non-linear: $q = k_i t^{0.5} + C$ (5)	$q\ vs.\ t$	0.872	31.339	0.561
	$q = k_i t^{0.5} + C$ Linear: (5)	$q\ vs\ t^{0.5}$	0.872	31.339	0.561

Table 10. Pore diffusion models

Heavy metals	Pore diffusion model	Plotting	k_p $min^{-0.5}$	D_{ii} cm^2min^{-1}	R2
Cr (VI)	$\frac{6}{r_o}(-\frac{D_{ii}.t}{\pi})^{1/2} = k_p * t^{1/2}$ (6)	$\frac{q_t}{q_e}\ vs\ t^{0.5}$	0.112	6.243	0.891
Fe (III)	$\frac{6}{r_o}(-\frac{D_{ii}.t}{\pi})^{1/2} = k_p * t^{1/2}$ (6)	$\frac{q_t}{q_e}\ vs\ t^{0.5}$	0.170	0.00001	0.561

Table 11. Film diffusion models

Heavy metals	film diffusion model	Plotting	k_{fd} min^{-1}	D_{ii} cm^2min^{-1}	R2
Cr (VI)	$=-\left(\frac{D_i}{r_o^2}\right).\pi^2.t =- k_{fd}.t$ (7)	$\ln\left(1-\frac{q_t}{q_e}\right)\ vs.\ t$	0.055	2.81.07	0.817
Fe (III)	$=-\left(\frac{D_i}{r_o^2}\right).\pi^2.t =- k_{fd}.t$ (7)	$\ln\left(1-\frac{q_t}{q_e}\right)\ vs\ t$	0.160	0.0001	0.860

List of abbreviation

Abbreviation	Terminology
FTIR	Fourier transform infra-red
SEM	Scanning electron microscopic
TEM	Transpiration electro microscopic
BET	Brunauer, Emmett, Teller
TGA	Thermogravimetric analysis
COD	Chemical Oxygen Demand
TDS	Total Dissolved Solids
XRD	X-ray diffraction
TSS	Total suspended solids
AlK	Alkalinity

List of materials

Materials	Index
industrial wastewater	WW
Chitosan	Cs
Chitin	Ct
hydrochloric acid	HCl
sodium hydroxide	NaOH
Graphite oxide	GO
Graphite powder	G
Silver nitrate	$AgNO_3$
Sodium borohydride	$NaBH_4$
Trisodium Citrate Dihydrate	$C_6H_5Na_3O_7.2H_2O$
potassium dichromate	$K_2Cr_2O_7$
ferric chloride $FeCl_3.6H_2O$	$FeCl_3.6H_2O$
silver nanoparticles	AgNPs
calcium carbonate	$CaCO_3$
calcium chloride	$CaCL_2$
carbon dioxide	CO
Distilled water	Dw