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APPENDIX

Table 1 A. Langmuir isotherm parameters determined by different error functions for removal of chromium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	6.820000	6.115234	6.022722	6.112055	6.112071	6.112059
b	0.291300	0.904197	0.980543	1.136825	1.136817	1.136837
R^2_{adj}	-0.516427	0.312591	0.302098	0.270482	0.270477	0.270476
ERRSQ	3.421719	1.551095	1.574772	1.646110	1.646121	1.646123
HYBRID	19.181305	7.949681	7.847716	8.518162	8.518253	8.518245
MPSD	30.393142	22.906364	23.169870	20.411491	20.411495	20.411606
ARE	10.131047	7.635455	7.723290	6.803830	6.803832	6.803869
EABS	2.818269	2.353298	2.427402	2.119473	2.119468	2.119480
SUM	5.000000	3.210111	3.255349	3.020376	3.607977	3.020394
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	7.230000	6.501885	6.392386	6.657742	6.668750	6.671580
b	0.312100	0.914413	0.997212	1.060039	1.054577	1.042776
R^2_{adj}	-0.295064	0.361665	0.350427	0.265820	0.259745	0.262992
ERRSQ	3.827729	1.886682	1.919897	2.169965	2.187919	2.178323
HYBRID	20.998827	9.379984	9.244262	11.156509	11.259377	11.211073
MPSD	30.441846	24.755093	24.969921	21.093320	21.027032	21.133547
ARE	10.147282	8.251698	8.323307	7.031107	7.009011	7.044516
EABS	2.858702	2.651746	2.736418	2.208820	2.195980	2.204502
SUM	5.000000	3.493580	3.539527	3.256675	3.257417	3.262589
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	7.800000	7.040311	6.938564	7.304378	7.302857	7.304514
b	0.381100	1.135885	1.238132	1.251942	1.252659	1.251593
R^2_{adj}	-0.154884	0.506317	0.498146	0.372574	0.373542	0.372603
ERRSQ	4.337774	1.854287	1.884976	2.356627	2.352992	2.356521
HYBRID	22.825596	8.107479	7.986746	10.693689	10.676598	10.693237
MPSD	31.165683	24.272849	24.213141	20.061941	20.070554	20.064361
ARE	10.388561	8.090950	8.071047	6.687314	6.690185	6.688120
EABS	3.139052	2.892377	2.952223	2.319142	2.320948	2.319285
SUM	5.000000	3.261749	3.278768	3.038017	4.024316	3.038174

Table 1 A (continued). Langmuir isotherm parameters determined by different error functions for removal of chromium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	8.370000	7.478105	7.364118	7.671222	7.670258	7.671366
b	0.418400	1.456300	1.596474	1.648861	1.649405	1.648779
R^2_{adj}	-0.212036	0.525135	0.516482	0.452554	0.452935	0.452497
ERRSQ	5.933817	2.324816	2.367181	2.680155	2.678291	2.680436
HYBRID	30.547837	9.452519	9.293090	11.261862	11.252836	11.263221
MPSD	34.988882	24.471190	24.289735	20.646326	20.651328	20.647132
ARE	11.662961	8.157063	8.096578	6.882109	6.883776	6.882377
EABS	3.677001	3.099294	3.160666	2.601849	2.602991	2.601910
SUM	5.000000	2.942909	2.951148	2.708104	2.708091	2.708258
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	9.010000	7.916734	7.776751	8.044463	8.044316	8.044469
b	0.452000	1.979855	2.190706	2.287742	2.288571	2.286756
R^2_{adj}	-0.293594	0.497237	0.486534	0.459708	0.459661	0.459814
ERRSQ	8.465273	3.290078	3.360117	3.535671	3.535977	3.534974
HYBRID	42.832916	12.641592	12.393597	13.915451	13.916484	13.912487
MPSD	40.521918	26.739503	26.436541	23.197861	23.200112	23.203911
ARE	13.507306	8.913168	8.812180	7.732620	7.733371	7.734637
EABS	4.381795	3.581695	3.656618	3.149241	3.149517	3.149757
SUM	5.000000	2.820952	2.825581	2.606209	2.606444	2.606474
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	9.680000	8.492286	8.322282	8.653810	8.653861	8.584393
b	0.477400	2.730704	3.066008	3.167320	3.167092	3.226756
R^2_{adj}	-0.260747	0.502088	0.489828	0.464894	0.464896	0.476466
ERRSQ	11.378729	4.493845	4.604501	4.829540	4.829516	4.725093
HYBRID	57.310609	15.840023	15.465655	17.490279	17.490299	16.901872
MPSD	41.839612	30.290985	29.694638	26.312478	26.310804	26.569576
ARE	13.946537	10.096995	9.898213	8.770826	8.770268	8.856525
EABS	4.535233	4.374508	4.455353	3.865710	3.865502	3.946217
SUM	5.000000	3.083841	3.076353	2.839771	2.839643	2.850366

Table 1B. Freundlich isotherm parameters determined by different error functions for removal of chromium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	3.74524300	0.37843011	0.39107148	0.38281576	0.38264809	0.38177617
1/n	0.13641000	0.50320390	0.49968741	0.48027573	0.48048652	0.48158454
R^2_{adj}	-209.43042373	-13.02070259	-13.06824863	-13.10326737	-13.10326409	-13.10325772
ERRSQ	474.82268428	31.63681145	31.74409602	31.82311356	31.82310616	31.82309178
HYBRID	1906.25650215	162.83069105	162.39509507	164.73514526	164.73509242	164.73498972
MPSD	362.80861897	116.40283699	116.83231437	115.83689642	115.83689507	115.83691692
ARE	120.93620632	38.80094566	38.94410479	38.61229881	38.61229836	38.61230564
EABS	43.20437004	11.78856834	11.89372224	11.65000111	11.65000226	11.65000761
SUM	5.00000000	1.06657995	1.07137877	1.06164434	1.06164431	1.06164447
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	3.88347000	0.41519439	0.42108123	0.36103137	0.36043728	0.39862163
1/n	0.14569000	0.50683242	0.51290702	0.55988609	0.56080891	0.50708833
R^2_{adj}	-179.01313822	-11.21640987	-11.25721689	-11.30789948	-11.30789958	-11.30790096
ERRSQ	532.05233276	36.10719436	36.22780483	36.37760386	36.37760415	36.37760822
HYBRID	2013.62283758	177.27854290	176.81757920	179.69245822	179.69246005	179.69248602
MPSD	357.55244660	121.45109536	122.01598573	120.60526641	120.60526596	120.60525959
ARE	119.18414887	40.48369845	40.67199524	40.20175547	40.20175532	40.20175320
EABS	45.06661576	12.92677524	13.05226642	12.73887317	12.73887307	12.73887165
SUM	5.00000000	1.12208766	1.12802976	1.11489405	1.11489405	1.11489400
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	4.26235900	0.44141711	0.44371177	0.34912438	0.34921096	0.35674208
1/n	0.14762000	0.55220404	0.56423881	0.65743468	0.65727127	0.64339560
R^2_{adj}	-144.63871250	-10.97614538	-11.01541689	-11.15820484	-11.15820846	-11.15820964
ERRSQ	547.02282002	44.98271583	45.13022066	45.66653592	45.66654954	45.66655396
HYBRID	1903.31203148	207.28498729	206.76898664	211.89914314	211.89921290	211.89923555
MPSD	321.76657319	129.31002506	130.10449499	127.59943778	127.59942075	127.59942752
ARE	107.25552440	43.10334169	43.36816500	42.53314593	42.53314025	42.53314251
EABS	44.11426141	14.77471171	14.93896428	14.42105659	14.42105307	14.42105370
SUM	5.00000000	1.32980909	1.33846915	1.31483417	1.31483404	1.31483412

Table 1B (continued). Freundlich isotherm parameters determined by different error functions for removal of chromium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	4.60076400	0.45750964	0.47119371	0.37984209	0.37996352	0.38889271
1/n	0.14887000	0.60730407	0.60649417	0.67440331	0.67418778	0.65870780
R^2_{adj}	-108.88577737	-9.73700991	-9.77462518	-10.01826454	-10.01826454	-10.01826721
ERRSQ	537.97246953	52.56563566	52.74979035	53.94258592	53.94258590	53.94259895
HYBRID	1746.53464342	230.26059590	229.66203079	238.00962166	238.00962158	238.00967953
MPSD	299.52774001	133.73331262	134.69594018	131.10106968	131.10106970	131.10106041
ARE	99.84258000	44.57777087	44.89864673	43.70035656	43.70035657	43.70035347
EABS	43.54333980	16.11853417	16.32309745	15.55916910	15.55916911	15.55916694
SUM	5.00000000	1.49268252	1.50380767	1.46925671	1.46925671	1.46925666
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	4.96386500	0.52949598	0.54577695	0.43468845	0.43479909	0.44689560
1/n	0.15019000	0.60416479	0.60386503	0.69133101	0.69115508	0.67244700
R^2_{adj}	-77.13840757	-8.25649885	-8.29207539	-8.39944809	-8.39944823	-8.39944807
ERRSQ	511.33745966	60.57449538	60.80730813	61.50995470	61.50995563	61.50995456
HYBRID	1552.20571039	252.62282760	251.91964989	258.26730728	258.26731148	258.26730665
MPSD	274.18339860	136.28097997	137.37799431	134.08199966	134.08199857	134.08199982
ARE	91.39446620	45.42699332	45.79266477	44.69399989	44.69399952	44.69399994
EABS	42.10469425	17.20262976	17.45217287	16.70241717	16.70241692	16.70241721
SUM	5.00000000	1.68386800	1.69779906	1.66141344	1.66141343	1.66141344
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	5.41477000	0.49760794	0.52299233	0.52833403	0.52841390	0.54736384
1/n	0.15377000	0.76870255	0.75484498	0.69595160	0.69584641	0.67175584
R^2_{adj}	-51.66906201	-6.94771162	-6.98091984	-6.99617563	-6.99617560	-6.99617600
ERRSQ	475.35852674	71.73115189	72.03086887	72.16855819	72.16855790	72.16856153
HYBRID	1340.64294770	283.11970033	282.28916313	286.33845416	286.33845265	286.33847104
MPSD	250.23972680	140.57456156	141.87562569	139.00280549	139.00280465	139.00281486
ARE	83.41324227	46.85818719	47.29187523	46.33426850	46.33426822	46.33427162
EABS	40.64891568	18.69290294	19.00691483	18.31355944	18.31355933	18.31356074
SUM	5.00000000	1.94546250	1.96359702	1.92688937	1.92688936	1.92688950

Table 1C. Pseudo-first order kinetic parameters determined by different error functions for removal of chromium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.058450	0.080072	0.097690	0.110021	0.232102	0.085190
q_e	4.063300	4.072017	3.844224	3.483097	3.025749	3.793029
R^2_{adj}	0.385137	0.676274	0.385137	0.468836	-0.091073	0.602459
ERRSQ	2.338609	1.231279	1.313534	2.020260	4.149856	1.512034
HYBRID	12.754373	6.379762	5.998466	7.991471	14.539769	7.169821
MPSD	47.770700	36.361519	36.404523	31.374623	44.337533	32.069707
ARE	14.043266	10.689282	10.701924	9.223272	13.034010	9.427608
EABS	3.539563	2.875003	3.002680	2.804068	4.338913	2.593004
SUM	4.256517	2.920429	2.945252	2.996266	4.856265	2.797744
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.069820	0.085519	0.103110	0.117129	0.115733	0.136428
q_e	4.557100	4.197413	3.988114	3.626269	3.630428	3.343875
R^2_{adj}	0.621074	0.661229	0.621074	0.452164	0.451799	0.116765
ERRSQ	1.446284	1.293020	1.372004	2.090982	2.092374	3.371133
HYBRID	7.854237	6.529099	6.184072	8.096865	8.143977	12.109533
MPSD	36.943689	34.549387	36.263300	33.734314	33.462085	39.146585
ARE	10.860424	10.156565	10.660408	9.916956	9.836928	11.508014
EABS	2.846268	2.806265	3.092731	3.131674	3.106533	3.846856
SUM	3.704968	3.417351	3.574320	3.826470	3.810330	5.000000
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.074270	0.099265	0.120214	0.154602	0.231853	0.153447
q_e	4.740200	4.260754	4.066997	3.634152	3.446454	3.637026
R^2_{adj}	0.517698	0.605329	0.517698	0.300399	0.040443	0.302603
ERRSQ	1.796709	1.470259	1.558448	2.606207	3.574615	2.597996
HYBRID	9.029136	6.705367	6.341297	8.815880	11.557863	8.806524
MPSD	39.451724	38.477327	37.363835	34.257480	35.970119	34.346260
ARE	11.597717	11.311271	10.983935	10.070753	10.574221	10.096851
EABS	3.155985	3.358428	3.452149	3.518993	3.936339	3.520709
SUM	4.085598	3.795250	3.755782	4.122503	4.823500	4.124332

Table 1C (continued). Pseudo-first order kinetic parameters determined by different error functions for removal of chromium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.071160	0.103955	0.118026	0.108035	0.107644	0.076942
q_e	4.160700	4.427359	4.301970	4.329484	4.338219	4.656614
R^2_{adj}	-0.152009	0.715297	-0.152009	0.706630	0.708105	0.629278
ERRSQ	4.177681	1.032456	1.077434	1.063885	1.058537	1.344396
HYBRID	18.777111	4.864653	4.678066	4.843683	4.837672	7.212175
MPSD	62.197604	27.287138	29.710696	27.217925	27.222229	27.162251
ARE	18.284377	8.021665	8.734124	8.001318	8.002583	7.984951
EABS	5.616791	2.416087	2.709600	2.460909	2.456695	2.160084
SUM	5.000000	1.813798	1.944814	1.825959	1.823746	1.963893
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.094860	0.132697	0.140472	0.114953	0.120750	0.201156
q_e	3.887200	4.667984	4.611790	4.782593	4.697702	4.184430
R^2_{adj}	-1.372294	0.896775	-1.372294	0.873958	0.880336	0.675850
ERRSQ	6.786071	0.295281	0.304563	0.360549	0.342304	0.927249
HYBRID	36.127652	1.890361	1.835204	2.593812	2.382482	4.316462
MPSD	80.635542	15.606574	15.952429	13.703486	13.882163	20.931368
ARE	25.758079	4.985337	5.095817	4.377418	4.434494	6.686280
EABS	6.842671	1.188697	1.248656	0.954382	0.997030	1.970377
SUM	5.000000	0.656645	0.673827	0.604289	0.606415	1.063232
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.103880	0.346255	0.351781	0.364073	0.365005	0.366778
q_e	1.150100	4.702020	4.690766	4.778457	4.778690	4.775209
R^2_{adj}	-176.932195	0.526859	-176.932195	0.417180	0.414395	0.418035
ERRSQ	93.044082	0.247414	0.248081	0.304768	45.977954	0.304320
HYBRID	408.602108	1.127615	1.124709	1.411528	1.418404	1.409206
MPSD	250.979181	11.315021	11.250882	10.300397	10.274227	10.252855
ARE	80.172359	3.614451	3.593962	3.290341	3.281981	3.275154
EABS	25.509180	1.128467	1.125846	1.022274	1.019962	1.018986
SUM	5.000000	0.139823	0.139210	0.128886	0.619481	0.128368

Table 1 D. Pseudo-second order kinetic parameters determined by different error functions for removal of chromium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.014830	0.017947	0.023884	0.026832	0.026838	0.106611
q_e	5.249890	5.002088	4.667965	4.326870	4.326630	3.269760
R^2_{adj}	0.800509	0.805164	0.793931	0.675351	0.675308	0.078918
ERRSQ	0.843064	0.823389	0.870864	1.371990	1.372172	3.892556
HYBRID	4.385072	3.993490	3.766897	5.375343	5.375608	13.398914
MPSD	29.785901	29.668067	29.984288	23.809620	23.808518	41.215039
ARE	8.756232	8.721592	8.814552	6.999371	6.999047	12.116083
EABS	2.363895	2.412136	2.505625	2.157277	2.157308	4.151290
SUM	2.558681	2.530304	2.563454	2.428692	2.428713	5.000000
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.015290	0.019478	0.025279	0.028836	0.027554	0.027967
q_e	5.405400	5.096788	4.796531	4.435256	4.497863	4.477306
R^2_{adj}	0.798875	0.807059	0.796743	0.668270	0.691529	0.684203
ERRSQ	0.852948	0.818240	0.861991	1.406832	1.308194	1.339260
HYBRID	4.431721	3.911089	3.713979	5.391273	5.105580	5.194583
MPSD	27.930927	27.849277	29.460689	25.671995	25.805955	25.762477
ARE	8.210921	8.186918	8.660629	7.546857	7.586238	7.573456
EABS	2.245502	2.316457	2.540552	2.420960	2.405295	2.410456
SUM	4.208320	4.109466	4.301605	4.695723	4.575546	4.613217
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.017130	0.023629	0.029942	0.053272	0.054282	0.051895
q_e	5.464770	5.092826	4.836231	4.152480	4.134549	4.177194
R^2_{adj}	0.766242	0.782758	0.772594	0.543977	0.533024	0.558318
ERRSQ	0.967571	0.899207	0.941280	1.887570	1.932906	1.828211
HYBRID	4.653833	3.870855	3.692312	6.097774	6.232014	5.923729
MPSD	30.913192	29.686794	28.524329	25.739100	25.661393	25.886550
ARE	9.087624	8.727097	8.385365	7.566584	7.543740	7.609930
EABS	2.616282	2.664125	2.685789	2.785386	2.788504	2.784514
SUM	4.185579	3.962385	3.888063	4.619137	4.660223	4.569727

Table 1 D (continiued). Pseudo-second order kinetic parameters determined by different error functions for removal of chromium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.018870	0.024285	0.028482	0.023182	0.021399	0.024205
q_e	5.556790	5.262814	5.090416	5.221930	5.355176	5.152667
R^2_{adj}	0.858250	0.870499	0.865410	0.855507	0.863909	0.847155
ERRSQ	0.571161	0.521809	0.542314	0.582217	0.548360	0.615870
HYBRID	2.886100	2.396740	2.310406	2.677738	2.655781	2.740910
MPSD	19.778381	20.762262	21.570660	19.039839	19.135546	19.503276
ARE	5.814297	6.103531	6.341178	5.597187	5.625322	5.733424
EABS	1.678548	1.842787	1.970167	1.712740	1.677457	1.787374
SUM	4.613210	4.538106	4.681095	4.507845	4.436229	4.747161
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.025560	0.027729	0.029253	0.080744	0.088440	0.027486
q_e	5.706450	5.607937	5.545268	4.213943	4.113099	5.624534
R^2_{adj}	0.965750	0.967986	0.970116	0.972516	0.973929	0.967646
ERRSQ	0.109720	0.104780	0.106909	2.429579	2.884997	0.105082
HYBRID	0.747978	0.680812	0.668344	10.661829	12.671591	0.685919
MPSD	8.726907	8.356051	8.491932	34.325049	37.070262	8.233216
ARE	2.787708	2.669242	2.712648	10.964735	11.841661	2.630004
EABS	0.622461	0.610167	0.640822	3.410618	3.694623	0.595564
SUM	0.736367	0.706019	0.721401	4.458560	5.000000	0.695947
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.100840	0.136150	0.138914	0.159451	0.160174	0.228123
q_e	5.150920	5.027337	5.017283	5.015560	5.011783	4.752355
R^2_{adj}	0.998968	0.999393	0.999391	0.999138	0.999148	0.997669
ERRSQ	0.106080	0.066956	0.067126	0.091523	0.090574	0.210923
HYBRID	0.522306	0.313444	0.312688	0.426213	0.421575	0.886533
MPSD	5.796140	5.797191	5.820488	5.427367	5.446038	9.634934
ARE	1.851509	1.851845	1.859287	1.733709	1.739673	3.077767
EABS	0.542681	0.567736	0.572026	0.537010	0.539522	1.014425
SUM	2.830203	2.434039	2.443057	2.570657	2.567278	5.000000

Table 2 A. Langmuir isotherm parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/ oxide hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	13.469828	12.726803	12.070369	12.866801	10.342335	13.481515
b	0.286674	0.349410	0.432903	0.317811	0.735040	0.289185
R^2_{adj}	0.833138	0.846276	0.832649	0.841525	0.608741	0.832439
ERRSQ	3.813137	3.512909	3.824313	3.621483	8.941076	3.829119
HYBRID	16.020038	13.017351	11.915856	14.358625	20.825031	15.926679
MPSD	25.713681	26.054020	26.386337	25.402564	30.240838	25.327167
ARE	8.571227	8.684673	8.795446	8.467521	10.080279	8.442389
EABS	3.289387	3.691429	4.105178	3.488187	5.996393	3.242534
SUM	3.444897	3.356687	3.429601	3.356259	5.000000	3.408825
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	12.512513	9.921179	9.418281	9.706686	9.705535	9.706975
b	0.362581	2.335326	3.151903	3.569233	3.570318	3.565278
R^2_{adj}	0.106122	0.305173	0.266562	0.275519	0.275493	0.275683
ERRSQ	18.571143	14.435658	15.237854	15.051760	15.052299	15.048360
HYBRID	84.910020	44.085912	41.463277	43.820902	43.812284	43.809801
MPSD	58.744944	51.652059	47.804642	43.758013	43.758617	43.778445
ARE	19.581648	17.217353	15.934881	14.586004	14.586206	14.592815
EABS	7.350870	8.227157	8.262973	7.580804	7.582013	7.582504
SUM	4.889616	4.050709	3.936365	3.733784	3.733878	3.734371
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	12.408487	10.146187	9.554595	9.847654	9.804420	9.847711
b	0.347146	1.397465	2.046986	2.438883	2.460377	2.438855
R^2_{adj}	0.222996	0.371021	0.330968	0.322118	0.322467	0.322117
ERRSQ	15.842228	12.824172	13.640804	13.821245	13.814139	13.821263
HYBRID	71.047898	40.361815	37.311483	40.642667	40.271276	40.643176
MPSD	55.647597	49.673930	46.070825	41.211865	41.273159	41.212285
ARE	18.549199	16.557977	15.356942	13.737288	13.757720	13.737428
EABS	7.156699	7.602583	7.779134	7.019363	7.065280	7.019398
SUM	4.919987	4.140194	4.042007	3.827982	3.830412	3.828010

Table 2A (continued). Langmuir isotherm parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	10.687186	9.501463	9.251749	9.263290	9.243737	9.264027
b	0.437959	1.101187	1.307886	1.584483	1.591494	1.584215
R^2_{adj}	0.402669	0.679036	0.666040	0.635479	0.635254	0.635484
ERRSQ	7.337774	3.942812	4.102461	4.477874	4.480641	4.477810
HYBRID	34.425528	13.093491	12.481246	13.744781	13.689301	13.746975
MPSD	39.852066	28.897569	27.690747	24.721196	24.811770	24.718558
ARE	13.284022	9.632523	9.230249	8.240399	8.270590	8.239519
EABS	4.868753	4.228907	4.295130	4.024802	4.051065	4.023946
SUM	5.000000	3.236496	3.193505	3.076819	3.085524	3.076565
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	11.584801	10.114067	9.528674	9.436142	9.436089	9.413069
b	0.272088	0.564902	0.780614	1.059899	1.059993	1.065192
R^2_{adj}	0.459696	0.561875	0.531980	0.481945	0.481922	0.481045
ERRSQ	8.397797	6.809657	7.274321	8.051997	8.052354	8.065986
HYBRID	38.715673	24.690643	22.888631	25.457636	25.458872	25.373606
MPSD	42.647477	41.672781	39.211972	35.119795	35.120768	35.197761
ARE	14.215826	13.890927	13.070657	11.706598	11.706923	11.732587
EABS	5.201384	5.861541	5.970884	5.634881	5.635017	5.663918
SUM	4.871125	4.384607	4.296304	4.207084	4.207227	4.215099
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	11.970314	11.188397	10.509669	9.574463	9.600243	12.293694
b	0.185184	0.233686	0.299658	0.477168	0.474744	0.162162
R^2_{adj}	0.772912	0.789782	0.771924	0.655449	0.658837	0.755129
ERRSQ	3.431692	3.176757	3.446618	5.206752	5.155548	3.700414
HYBRID	15.820115	12.902768	11.843081	15.408747	15.345906	18.171759
MPSD	29.416269	29.858800	29.571527	27.161467	27.041460	28.138798
ARE	9.805423	9.952933	9.857176	9.053822	9.013820	9.379599
EABS	3.564439	3.911758	4.182887	4.419605	4.386289	3.271839
SUM	4.590460	4.653403	4.755807	4.667278	5.367300	4.554668

Table 2 B. Freundlich isotherm parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	4.48673067	0.87568730	0.88205427	0.70108912	0.70108909	0.85817011
1/n	0.31849000	0.78328353	0.81688806	1.00000000	1.00000000	0.81695820
R^2_{adj}	-5.26388082	-1.59613069	-1.64461930	-1.60544589	-1.60544584	-1.60544587
ERRSQ	2986.29586027	59.32690461	60.43496867	59.53977592	59.53977493	59.53977552
HYBRID	2110.33242587	215.42663847	212.89814080	213.69588590	213.69588882	213.69588707
MPSD	189.81849357	119.16704150	117.86052360	117.37839098	117.37839309	117.37839063
ARE	63.27283119	39.72234717	39.28684120	39.12613033	39.12613103	39.12613021
EABS	116.09858998	17.12556477	191.40999402	16.87623784	16.87623797	16.87623763
SUM	5.00000000	1.52504642	3.01162945	1.50330412	1.50330414	**1.50330411**
30 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
K_F	5.84561219	0.72363730	0.80561648	0.76552273	0.76639551	0.80520997
1/n	0.19410000	0.88868459	0.82945208	0.85722674	0.85625042	0.81497552
R^2_{adj}	-2.92877661	-1.70847614	-1.73945190	-1.71694331	-1.71694322	-1.71694314
ERRSQ	1873.03840169	56.27107435	56.91462418	56.44698771	56.44698571	56.44698403
HYBRID	1542.75514590	224.53690396	223.02901174	223.37234933	223.37235361	223.37235720
MPSD	171.31739992	115.27216525	113.78828267	113.54080043	113.54079888	113.54079759
ARE	57.10579997	38.42405508	37.92942756	37.84693348	37.84693296	37.84693253
EABS	96.47555507	15.68840811	207.65789624	15.44103970	15.44103863	15.44103774
SUM	4.46458891	1.59684939	2.50334308	1.57478486	1.57478484	1.57478482
40 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
K_F	5.54242723	0.83213104	0.74075716	1.00000000	0.56406789	0.59685799
1/n	0.21015000	0.75145692	0.87591370	1.00000000	1.00000000	0.94506195
R^2_{adj}	-3.06957315	-1.62623346	-1.65512332	-8.95264920	-1.82196373	-1.82196446
ERRSQ	1940.16294299	53.54592772	54.13495920	202.92325223	57.53664637	57.53666123
HYBRID	1573.76906389	216.91814122	215.52087531	526.75992560	233.65855282	233.65860160
MPSD	173.20982358	117.01990871	117.66032114	172.26670897	115.35298399	115.35298377
ARE	57.73660786	39.00663624	39.22010705	57.42223632	38.45099466	38.45099459
EABS	98.48273888	15.96330531	191.90152337	29.58405684	15.02132015	15.02131899
SUM	4.51319415	1.59980960	2.52343511	2.58257602	1.58834749	1.58834752

Table 2 B (continued). Freundlich isotherm parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	5.16249923	0.65854749	0.70582592	0.59522811	0.59526020	0.59546827
1/n	0.19705000	0.68517940	0.66269828	0.71649667	0.71645804	0.71620756
R^2_{adj}	-2.59325805	-4.61299249	-4.64915659	-4.69406352	-4.69406358	-4.69406411
ERRSQ	1713.08042804	68.95153746	69.39578720	69.94743623	69.94743694	69.94744347
HYBRID	1480.69021944	269.46270604	268.30815311	275.50823595	275.50823903	275.50826732
MPSD	163.94055553	134.42998594	135.69101479	132.54191190	132.54191123	132.54190505
ARE	54.64685184	44.80999531	45.23033826	44.18063730	44.18063708	44.18063502
EABS	88.65136490	18.21291773	247.62883915	17.65845272	17.65845252	17.65845071
SUM	4.35800097	1.93576833	2.87708263	1.91515985	1.91515984	1.91515978
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	4.57098715	0.74232216	0.74640026	0.64095247	0.65782749	0.78012201
1/n	0.24157000	0.65681243	0.67973762	0.80892111	0.78817020	0.66461390
R^2_{adj}	-2.80921388	-2.17903511	-2.21698599	-2.27163960	-2.27163984	-2.27163929
ERRSQ	1816.03704894	49.41091508	50.00077564	50.85024253	50.85024623	50.85023770
HYBRID	1517.67822934	150.71165728	199.01215073	199.49147168	199.49147510	199.49146721
MPSD	169.40535266	101.37185938	111.97655233	110.04666239	110.04666011	110.04667139
ARE	56.46845089	38.46999699	37.32551744	36.68222080	36.68222004	36.68222380
EABS	94.44755765	15.28742957	181.14359580	14.56600037	14.56600038	14.56600158
SUM	4.52139606	**1.49056970**	2.48065769	1.53906834	1.53906832	1.53906845
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	3.57470329	0.66952635	0.73003192	0.58076170	0.61135747	0.63514679
1/n	0.31264000	0.67988184	0.65155927	0.75948385	0.72148706	0.69445233
R^2_{adj}	-2.85899987	-1.31892504	-1.36536576	-1.34104205	-1.34101898	-1.34104195
ERRSQ	1839.77244574	35.04290673	35.74470500	35.37713243	35.37678376	35.37713093
HYBRID	0.03378162	150.71165728	148.84555834	154.17597149	154.17370058	154.17596176
MPSD	170.24647047	101.37185938	101.43352164	101.32930632	101.32932828	101.32930618
ARE	56.74882349	33.79061979	33.81117388	33.77643544	33.77644276	33.77643539
EABS	95.33968244	12.72450200	137.20989379	12.51978438	12.51989114	12.51978479
SUM	3.69506465	2.28019864	3.17646329	2.30085827	2.30084439	2.30085821

Table 2 C. Pseudo-first order kinetic parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.040694	0.376077	0.380126	0.412431	1	0.380126
q_e	1.373599	6.254717	6.246091	6.200046	1	6.246091
R^2_{adj}	-321.8269	0.51575	0.514984	0.479151	-305.1344	0.514984
ERRSQ	280.17079	0.420265	0.420929	0.452028	265.68391	265.68391
HYBRID	571.42919	0.84074	0.839377	0.888794	538.429	538.429
MPSD	305.43319	9.98213	9.888269	9.20316	295.86616	295.86616
ARE	571.42919	2.823373	2.796825	2.603047	83.683588	83.683588
EABS	52.925943	1.742694	1.729913	1.634121	1.63405	51.43714
SUM	5	0.073521	0.072926	0.068731	3.03654	3.977536
30 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
k_1	0.053798	0.318509	0.322541	0.346875	1	0.322541
q_e	1.524228	6.368376	6.360654	6.348565	1	6.360654
R^2_{adj}	-212.03185	0.743574	0.742994	0.723873	-218.96498	0.742994
ERRSQ	264.22804	0.318051	0.31877	0.342486	272.82736	272.82736
HYBRID	533.4709	0.646928	0.645368	0.688538	546.29748	546.29748
MPSD	293.75667	8.593447	8.496158	7.948708	296.38258	296.38258
ARE	533.4709	2.430594	2.403076	2.248234	83.829653	83.829653
EABS	51.392377	1.491849	1.479489	1.407498	1.407509	52.081268
SUM	4.967661	0.09669	0.095826	**0.090557**	2.215402	4.142415
40 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
k_1	0.053337	0.349484	0.353926	0.373332	1	0.353926
q_e	1.539324	6.292051	6.282767	6.308986	1	6.282767
R^2_{adj}	-212.03185	0.590076	0.589282	0.568144	-258.70799	0.589282
ERRSQ	258.65579	0.422543	0.423361	0.44515	267.70238	267.70238
HYBRID	526.45596	0.8616	0.859895	0.910375	540.57919	540.57919
MPSD	292.85398	9.922974	9.919821	9.262392	295.99479	295.99479
ARE	526.45596	2.806641	2.805749	2.6198	83.719969	83.719969
EABS	50.855225	1.715836	1.720081	1.613956	51.612811	51.612811
SUM	4.914791	0.075272	0.075342	0.070886	4.159026	4.159026

Table 2 C (continued). Pseudo-first order kinetic parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.066672	0.381565	0.384142	0.392634	1	0.384142
q_e	1.334627	6.171963	6.166865	6.200029	1	6.166865
R^2_{adj}	-357.97407	0.663158	0.662815	0.64426	-360.7956	0.662815
ERRSQ	255.50383	0.239751	0.239995	0.253202	257.51209	257.51209
HYBRID	527.58524	0.494063	0.493554	0.525737	528.92301	528.92301
MPSD	295.24927	7.617661	7.609878	7.076068	295.14839	295.14839
ARE	527.58524	2.1546	2.152399	2.001414	83.480571	83.480571
EABS	50.533117	1.305667	1.306362	1.215546	50.656378	50.656378
SUM	4.987239	0.057525	0.057508	0.053733	4.15789	4.15789
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.047258	0.384751	0.388608	0.406151	1	0.388608
q_e	1.209344	6.021113	6.013693	6.040185	1	6.013693
R^2_{adj}	-361.59286	0.5261	0.525414	0.505181	-335.47129	0.662815
ERRSQ	261.80837	0.342177	0.342673	0.357282	242.94742	242.94742
HYBRID	553.99518	0.729431	0.728378	0.765313	511.18456	511.18456
MPSD	306.3383	8.665101	8.66709	8.06274	293.69991	293.69991
ARE	553.99518	2.450861	2.451423	2.280487	83.070879	83.070879
EABS	51.163289	1.438328	1.441634	1.34441	49.196353	49.196353
SUM	5	0.063446	0.063518	0.059459	3.920931	3.920931
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.075308	0.442516	0.444735	0.459742	1	0.444735
q_e	1.275675	5.83697	5.833591	5.833075	1	5.833591
R^2_{adj}	-597.05535	0.5821	0.581824	0.575931	-599.55405	0.581824
ERRSQ	226.70135	0.158411	0.158515	0.16075	227.64852	227.64852
HYBRID	492.59605	0.341527	0.3413	0.345945	492.54329	492.54329
MPSD	292.49133	6.55175	6.512039	6.275261	292.18333	292.18333
ARE	492.59605	1.853115	1.841883	1.774912	82.641925	82.641925
EABS	47.608361	1.071604	1.06606	1.031639	47.662155	47.662155
SUM	4.994711	0.050034	0.049759	0.048111	4.166608	4.166608

Table 2 D. Pseudo-second order kinetic parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.072653	0.148272	0.148010	0.200399	0.145382	0.145700
q_e	6.761325	6.582324	6.580597	6.105291	6.548319	6.546251
R^2_{adj}	-0.252828	0.830397	0.830327	0.857709	0.810167	0.809084
ERRSQ	1.087288	0.147193	0.147254	0.053937	0.164750	0.165690
HYBRID	2.326977	0.297367	0.297241	0.116545	0.329388	0.331157
MPSD	15.499318	6.291445	6.286697	3.533651	6.221183	6.222071
ARE	4.383869	1.779489	1.778146	0.999467	1.759616	1.759867
EABS	2.601670	1.095971	1.095782	0.577906	1.094087	1.094376
SUM	5.000000	1.496259	1.495576	0.777795	1.516377	1.518227
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.077893	0.124291	0.121122	0.111750	0.103248	0.381441
q_e	6.815239	6.723126	6.730487	6.693685	6.732283	6.358122
R^2_{adj}	0.217423	0.789875	0.789216	0.730231	0.708405	0.358318
ERRSQ	0.679172	0.260622	0.261440	0.334601	0.361672	0.795893
HYBRID	1.443158	0.541123	0.539309	0.670773	0.724174	1.745106
MPSD	13.044696	8.112672	8.076297	7.848190	7.737295	13.157267
ARE	3.689597	2.294610	2.284322	2.219803	2.188438	3.721437
EABS	2.208206	1.389010	1.386870	1.377310	1.367879	2.219324
SUM	4.658200	2.496596	2.490090	2.618364	2.661871	5.000000
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.076463	0.133786	0.132331	0.128284	0.128709	0.121836
q_e	6.768190	6.642807	6.644732	6.594312	6.590823	6.649988
R^2_{adj}	0.014611	0.839080	0.838912	0.794996	0.792590	0.820408
ERRSQ	0.855187	0.165873	0.166047	0.211315	0.213794	0.185120
HYBRID	1.825679	0.337446	0.337063	0.422216	0.427034	0.371560
MPSD	14.060204	6.150838	6.078582	5.686722	5.688337	5.661698
ARE	3.976826	1.739720	1.719283	1.608448	1.608905	1.601370
EABS	2.367365	1.065777	1.054996	1.004482	1.004924	0.997556
SUM	5.000000	1.703919	1.689080	1.711577	1.717532	1.646715

Table 2 D (continued). Pseudo-second order kinetic parameters determined by different error functions for removal of chromium by nano crystalline iron oxide/hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.107563	0.176422	0.173170	0.142418	0.146599	0.137911
q_e	6.510417	6.439555	6.442781	6.483789	6.455741	6.517554
R^2_{adj}	0.200004	0.740375	0.739967	0.681894	0.672748	0.682041
ERRSQ	0.694290	0.184791	0.185081	0.226416	0.232925	0.226311
HYBRID	1.438523	0.383608	0.382965	0.460492	0.473356	0.460519
MPSD	12.733334	6.670032	6.646219	6.391020	6.403042	6.380050
ARE	3.601531	1.886570	1.879835	1.807653	1.811054	1.804551
EABS	2.182718	1.133935	1.131718	1.108192	1.111978	1.103929
SUM	5.000000	2.099981	2.095195	2.157763	2.179704	2.153954
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.091801	0.168689	0.167244	0.169639	0.169631	0.189201
q_e	6.429628	6.308338	6.308695	6.239100	6.239103	6.155859
R^2_{adj}	-1.064212	0.784308	0.784151	0.722348	0.722326	0.597331
ERRSQ	1.791462	0.155739	0.155853	0.200478	0.200493	0.290745
HYBRID	3.741103	0.329358	0.329103	0.416126	0.416159	0.598787
MPSD	22.217730	6.581847	6.521095	5.692769	5.692969	7.395860
ARE	6.284123	1.861627	1.844444	1.610158	1.610215	1.804551
EABS	3.798984	1.098452	1.089614	0.968020	0.968052	1.267573
SUM	5.000000	1.056602	1.048802	0.990401	0.990445	1.276054
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.136215	0.231700	0.230443	0.200399	0.210823	0.225557
q_e	6.121824	6.055559	6.056207	6.105291	6.067903	6.020373
R^2_{adj}	-2.149012	0.880851	0.880807	0.857709	0.866927	0.832884
ERRSQ	2.565318	0.045165	0.045182	0.053937	0.050443	0.063348
HYBRID	5.202696	0.098323	0.098285	0.116545	0.109067	0.136357
MPSD	28.279955	3.657100	3.651737	3.533651	3.562652	3.874983
ARE	7.998779	1.034384	1.032867	0.999467	1.007670	1.096011
EABS	4.913596	0.594006	0.593426	0.577906	0.583787	0.637499
SUM	5.000000	0.416030	0.415532	0.410945	0.411394	0.454689

Table 3 A (continued). Langmuir isotherm parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	3.188555	3.170709	2.940551	3.308068	3.323868	3.435922
b	8.531489	7.932849	12.953026	6.257553	6.159616	5.542239
R^2_{adj}	0.901497	0.904275	0.878716	0.896133	0.894645	0.879424
ERRSQ	0.619880	0.602397	0.763238	0.653639	0.663001	0.758787
HYBRID	7.135882	7.288362	6.500465	8.372929	8.467467	9.236324
MPSD	60.084074	59.220940	58.247646	59.064169	59.120570	59.439141
ARE	16.994343	16.750211	16.474922	16.705870	16.721823	16.811928
EABS	2.103222	2.018422	2.401193	1.898483	1.894691	1.868809
SUM	4.460668	4.390224	4.642665	4.519617	3.558452	4.750985
30 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
Q_o	3.140059	3.135859	3.021110	3.075542	3.078619	3.151625
b	7.253649	6.717300	8.373580	6.523788	6.386645	5.956100
R^2_{adj}	0.940636	0.942924	0.935485	0.937872	0.936691	0.939162
ERRSQ	0.355953	0.342233	0.386836	0.372524	0.379606	0.364791
HYBRID	4.302034	4.423294	4.129923	4.683759	4.791881	4.928859
MPSD	48.243738	48.027691	46.823686	47.010630	47.297576	47.750967
ARE	13.645390	13.584283	13.243738	13.296614	13.377775	13.506013
EABS	1.701045	1.641414	1.734982	1.569295	1.576378	1.560100
SUM	4.773432	4.719240	4.779037	4.766658	4.822881	4.821787
40 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
Q_o	3.188270	3.359543	3.320432	3.320500	3.320486	1.000000
b	6.532080	4.634801	4.714509	5.138016	5.138358	1.000000
R^2_{adj}	0.896158	0.918010	0.917337	0.915471	0.915467	-4.704159
ERRSQ	0.670488	0.529395	0.533739	0.545788	0.545812	36.830657
HYBRID	6.819967	5.787906	5.769486	5.933236	5.933445	185.578379
MPSD	56.546971	52.671827	52.888953	50.495661	50.497089	299.965874
ARE	15.993899	14.897842	14.959255	14.282330	14.282734	84.843162
EABS	2.043375	1.884510	1.916759	1.796432	1.796452	17.948546
SUM	0.545823	0.501743	0.505006	0.483554	0.483567	5.000000

Table 3 A (continued). Langmuir isotherm parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	2.865850	2.893300	2.842456	2.897149	2.895984	2.898365
b	5.019520	4.332701	4.805559	4.257400	4.259947	4.245333
R^2_{adj}	0.965183	0.970857	0.968861	0.970779	0.970773	0.970758
ERRSQ	0.159235	0.133282	0.142411	0.133642	0.133669	0.133739
HYBRID	3.002948	2.994191	2.923028	3.023490	3.023157	3.028372
MPSD	35.296957	29.075412	32.632520	28.344962	28.334550	28.356757
ARE	9.983487	8.223768	9.229870	8.017166	8.014221	8.020502
EABS	0.894196	0.620139	0.791543	0.588382	0.588139	0.587092
SUM	4.991605	4.166718	4.593786	4.101749	4.100946	4.103196
60 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
Q_o	2.574280	2.545124	2.510878	2.518993	2.514737	2.545552
b	4.524120	4.945687	5.181215	5.633431	5.644662	4.477419
R^2_{adj}	0.920155	0.921689	0.920681	0.918002	0.918076	0.918006
ERRSQ	0.292952	0.287323	0.291022	0.300852	0.300578	0.300835
HYBRID	1.911512	1.792043	1.768062	1.895853	1.887711	1.963449
MPSD	28.127009	26.958074	26.805557	25.910021	25.960387	27.237891
ARE	7.955519	7.624895	7.581756	7.328461	7.342706	7.704039
EABS	1.348829	1.330011	1.360919	1.354126	1.360666	1.293174
SUM	4.938407	4.761905	4.773852	4.802941	4.806270	4.886944
70 mg/l	**LTFM**	**ERRSQ**	**HYBRID**	**MPSD**	**ARE**	**EABS**
Q_o	2.563400	2.514460	2.428693	2.462735	2.462790	2.470231
b	4.462310	4.942169	6.061601	5.826497	5.822228	5.317120
R^2_{adj}	0.900059	0.902098	0.894743	0.897947	0.897982	0.900493
ERRSQ	0.362488	0.355092	0.381770	0.370150	0.370020	0.360913
HYBRID	3.100377	2.802679	2.567237	2.590146	2.590148	2.665745
MPSD	38.616829	36.199487	33.897666	33.319435	33.300386	34.573746
ARE	10.922489	10.238761	9.587708	9.424159	9.418772	9.778932
EABS	1.486803	1.457508	1.536896	1.471331	1.470334	1.443993
SUM	4.916899	4.657249	4.583631	4.487974	4.486000	4.535338

Table 3B. Freundlich isotherm parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	2.57717000	1.07040532	1.05322121	0.99647479	0.99647479	0.99647562
1/n	0.28328772	1.09361985	1.14694813	0.99649584	0.99649584	0.99649500
R^2_{adj}	-2.63805904	-1.71337953	-1.71967611	-1.85562051	-1.85562051	-1.85562051
ERRSQ	20.37469854	17.07530742	17.11493183	17.97043038	17.97043039	17.97043041
HYBRID	124.12545340	103.79476917	103.63221229	109.01219989	109.01219990	109.01220000
MPSD	245.92372538	222.18867869	224.14582154	220.66264763	220.66264763	220.66264766
ARE	139.11546710	125.68889712	126.79602431	124.82564360	124.82564360	124.82564361
EABS	12.81738865	11.36911678	11.56333510	11.06404897	11.06404897	11.06404897
SUM	5.00000000	4.36825243	4.39995698	4.41800733	4.41800733	4.41800733
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	2.46429000	1.03888588	1.05139655	0.95494040	0.95686849	0.95947195
1/n	0.29680989	1.06972845	1.09256999	0.97925711	0.97728392	0.97463197
R^2_{adj}	-2.63158888	-1.63524272	-1.64247036	-1.79566590	-1.79566588	-1.79566617
ERRSQ	22.48882718	15.80109592	15.84443332	16.76300427	16.76300413	16.76300587
HYBRID	131.01340843	97.91521982	97.73353879	103.65966451	103.65966384	103.65967266
MPSD	253.08250085	218.29573685	220.88272768	217.12468095	217.12468102	217.12468017
ARE	143.16508204	123.48671666	124.95013967	122.82426741	122.82426745	122.82426697
EABS	13.63230019	10.99923769	11.24292284	10.70996004	10.70996006	10.70995982
SUM	5.00000000	3.98193442	4.02079417	4.03807901	4.03807900	4.03807912
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	2.48780000	1.05014192	1.06322062	1.20418435	1.13769690	1.06281356
1/n	0.32575730	1.07930290	1.10272181	0.92333315	0.97729310	1.04615085
R^2_{adj}	-3.17365674	-1.85522083	-1.86209653	-1.85732005	-1.85732005	-1.85732006
ERRSQ	28.28403710	18.43561003	18.48000508	18.44916430	18.44916429	18.44916431
HYBRID	151.96792686	106.34810261	106.16366348	106.60823730	106.60823716	106.60823744
MPSD	257.64256500	228.45805904	229.02004381	228.14753482	228.14753496	228.14753468
ARE	145.74464387	129.23539421	129.55330080	129.05973519	129.05973526	129.05973511
EABS	14.46919325	12.08503289	12.17066377	12.03771763	12.03771765	12.03771760
SUM	5.00000000	3.96028360	3.97092021	3.95679402	3.95679402	3.95679401

Table 3B (continued). Freundlich isotherm parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	2.05853000	0.93179743	0.97242051	2.97271136	2.15189467	0.71491588
1/n	0.30637630	0.92735639	0.92036284	0.33523532	0.46310718	1.03562831
R^2_{adj}	-1.99807902	-1.54987724	-1.55935006	-1.72424551	-1.72424562	-1.70202120
ERRSQ	12.94917991	11.66178052	11.70510415	12.45924814	12.45924865	12.35760598
HYBRID	88.33419444	79.98646650	79.78496508	81.96651813	81.96651994	84.83788782
MPSD	218.94165697	210.22682677	210.15876073	209.93479872	209.93479863	210.49961033
ARE	123.85210426	118.92225184	118.88374787	118.75705582	118.75705577	119.07656152
EABS	10.23795066	9.90203051	9.93376014	10.03816215	10.03816219	9.77486988
SUM	5.00000000	4.69365900	4.69720098	4.78828800	4.78828807	4.79238663
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	1.78014000	1.00000000	0.88044322	2.55471009	1.93223248	0.62354580
1/n	0.31496261	1.00000000	0.81907456	0.38729447	0.51206316	0.92965184
R^2_{adj}	-1.67175016	-3.03211481	-1.59620962	-2.93131204	-2.93131204	-1.83918004
ERRSQ	9.83292216	14.79381708	9.52548528	14.42397203	14.42397205	10.41694302
HYBRID	74.55272322	94.64251682	70.51646636	92.84734227	92.84734239	76.72598462
MPSD	210.01658130	206.27743654	207.36498987	205.59158884	205.59158883	208.30014364
ARE	118.80331904	116.68813935	117.30335242	116.30016530	116.30016529	117.83235527
EABS	9.20068610	9.53135000	9.29338027	9.46767947	9.46767947	9.20146842
SUM	4.41770178	4.96439191	4.333874687	4.90721250	4.90721250	4.49760772
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	1.77544000	0.87744136	0.88036917	1.00525038	1.00525038	0.79504678
1/n	0.30026063	0.80174625	0.81938637	1.00529583	1.00529583	0.83025666
R^2_{adj}	-2.03323233	-1.38574472	-1.39107384	-2.95822338	-2.95822338	-1.41714151
ERRSQ	10.62888266	8.65314143	8.67247023	14.35655139	14.35655139	8.76701818
HYBRID	78.90043779	66.52589058	66.42529274	92.75351719	92.75351719	67.60692084
MPSD	212.13508064	198.62368177	198.28040341	192.72695259	192.72695259	199.45690503
ARE	120.00172324	112.35852182	112.16433426	109.02282807	109.02282807	112.82986408
EABS	9.30507939	8.56626390	8.56724822	8.58317221	8.58317221	8.56387471
SUM	4.59099700	4.11318025	4.11031139	4.73943899	4.73943899	4.14036600

Table 3 C. Pseudo-first order kinetic parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.12344080	1.75777030	1.78028869	1.01931356	1.01932133	1.01930342
q_e	0.08105504	0.46476717	0.46384871	0.46861743	0.46861742	0.46861884
R^2_{adj}	0.93397499	0.99987243	0.93397499	0.99956626	0.99956627	0.99956625
ERRSQ	2.18576988	0.00471981	0.00472907	0.01200637	0.01200612	0.01200647
HYBRID	43.50812802	0.09782350	0.09764183	0.26614045	0.26613476	0.26614307
MPSD	352.17000506	13.58642198	13.54418952	14.47485328	14.47488820	14.47493035
ARE	89.84736686	3.46623569	3.45546113	3.69289671	3.69290562	3.69291637
EABS	5.32928299	0.20179686	0.20161614	0.20860376	0.20860433	0.20860446
SUM	5.00000000	0.11943172	0.11915802	0.13295671	0.13295678	0.13295739
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.20107493	1.30130102	1.36198057	0.91471873	0.91471897	0.91489675
q_e	0.16667866	0.45538641	0.45260315	0.46789969	0.46789967	0.46789975
R^2_{adj}	0.95626470	0.99964617	0.95626470	0.99944087	0.99944087	0.99944099
ERRSQ	1.36239434	0.01140118	0.01148321	0.01443566	0.01443565	0.01443274
HYBRID	28.25612973	0.24518496	0.24346286	0.33570285	0.33570271	0.33562292
MPSD	289.24853698	23.70472834	23.79623018	22.73121085	22.73121267	22.73280457
ARE	73.79452833	6.04766844	6.07101284	5.79929980	5.79930027	5.79970640
EABS	4.20713020	0.33706515	0.34110474	0.31009909	0.31009913	0.31012373
SUM	5.00000000	0.26106892	0.26266105	0.25335874	0.25335875	0.25337065
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.09704842	0.72359563	0.75027555	0.60958834	0.61479052	0.60959563
q_e	0.14511423	0.45855543	0.45644450	0.45995607	0.45993749	0.45995605
R^2_{adj}	0.94398750	0.99977450	0.94398750	0.99968780	0.99969627	0.99968781
ERRSQ	1.62037255	0.00666380	0.00672490	0.00843462	0.00824925	0.00843435
HYBRID	34.45717272	0.17712838	0.17558630	0.23974035	0.23397785	0.23973203
MPSD	326.16241787	17.08724035	17.47295715	15.89805983	15.94814913	15.89810935
ARE	83.21218160	4.35938192	4.45778791	4.05599226	4.06877129	4.05600489
EABS	4.57091433	0.21044477	0.21729415	0.18952682	0.19042554	0.18952780
SUM	5.00000000	0.16007051	0.16392712	0.15111219	0.15133431	0.15111230

Table 3 C(continued). Pseudo-first order kinetic parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.07111664	1.01530326	1.07520015	0.85326703	0.84643285	0.84643319
q_e	0.13682958	0.38064058	0.37758811	0.37403502	0.37517991	0.37517986
R^2_{adj}	0.94377530	0.99967064	0.94377530	0.99963990	0.99963328	0.99963328
ERRSQ	1.22015921	0.01010066	0.01019526	0.01210020	0.01193013	0.01193014
HYBRID	30.51308122	0.25705738	0.25460958	0.31513705	0.31243489	0.31243498
MPSD	331.42490766	24.25752247	23.51605136	21.42392824	21.37092409	21.37092575
ARE	84.55477422	6.18870003	5.99953222	5.46577935	5.45225666	5.45225709
EABS	3.97571136	0.28453933	0.27780034	0.25206372	0.25076654	0.25076659
SUM	5.00000000	0.23465528	0.22848310	0.21292950	0.21205543	0.21205546
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.09716357	0.52015527	0.59406881	0.55650959	0.55718546	0.55651062
q_e	0.24910933	0.40397175	0.39520676	0.38938989	0.38913293	0.38938989
R^2_{adj}	0.96694968	0.99939597	0.96694968	0.99958274	0.99958497	0.99958274
ERRSQ	0.71054130	0.01755069	0.01816685	0.01911261	0.01916872	0.01911260
HYBRID	18.29799532	0.46723450	0.44978729	0.47656705	0.47738164	0.47656638
MPSD	260.42495539	32.47184648	32.86650888	29.56038576	29.57203784	29.56036209
ARE	66.44091254	8.28437931	8.38506755	7.54159294	7.54456568	7.54158690
EABS	3.03097822	0.37666393	0.38512017	0.35041071	0.35076456	0.35041059
SUM	5.00000000	0.42388244	0.42961695	0.39556974	0.39589945	0.39556947
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.15623552	0.86613421	0.91389893	0.83797271	0.83797154	0.83797251
q_e	0.14314955	0.41694507	0.41470569	0.41679542	0.41679564	0.41679565
R^2_{adj}	0.95214398	0.99980816	0.95214398	0.99980671	0.99980671	0.99980671
ERRSQ	1.18356792	0.00502381	0.00510719	0.00507015	0.00507015	0.00507014
HYBRID	27.45087220	0.12533431	0.12297317	0.12936230	0.12936241	0.12936222
MPSD	302.84269209	17.23488144	17.64189528	16.93169376	16.93167359	16.93168493
ARE	77.26273693	4.39704885	4.50088825	4.31969810	4.31969295	4.31969584
EABS	3.91769342	0.21407962	0.22245710	0.20898568	0.20898526	0.20898544
SUM	5.00000000	0.17727539	0.18208615	0.17415875	0.17415852	0.17415863

Table 3 D. Pseudo-second order kinetic parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	4.980821	2.207200	8.234320	6.723048	6.559478	6.547558
q_e	0.492383	0.499900	0.482173	0.482379	0.483383	0.483459
R^2_{adj}	0.458327	-4.568996	0.839712	0.764088	0.750415	0.749357
ERRSQ	0.003087	0.030825	0.001299	0.001799	0.001816	0.001817
HYBRID	0.068642	0.678399	0.027120	0.038407	0.039017	0.039067
MPSD	7.489663	29.653919	6.837141	6.563530	6.506237	6.508296
ARE	1.910800	7.565456	1.744326	1.674520	1.659904	1.660429
EABS	0.107530	0.422552	0.100809	0.096164	0.095012	0.095025
SUM	5.000000	31.717932	3.579030	3.789371	3.777646	3.779533
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	2.676760	4.586176	4.818338	4.058760	4.061911	4.059226
q_e	0.503094	0.484096	0.481822	0.491293	0.491230	0.491282
R^2_{adj}	0.449369	0.761225	0.771391	0.712026	0.712573	0.712122
ERRSQ	0.007162	0.003716	0.003742	0.003956	0.003952	0.003956
HYBRID	0.174851	0.082554	0.082004	0.090542	0.090434	0.090524
MPSD	13.407607	12.527186	12.939763	11.474158	11.474266	11.474246
ARE	3.420616	3.195998	3.301257	2.927344	2.927372	2.927367
EABS	0.175347	0.175371	0.182641	0.156240	0.156270	0.156246
SUM	4.960061	3.819887	3.921714	3.637254	3.636220	3.637090
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.499990	2.447848	2.443162	3.001619	3.019033	3.018281
q_e	2.207216	0.495838	0.495358	0.486549	0.485737	0.485773
R^2_{adj}	-653.462936	0.922468	0.922612	0.908845	0.909184	0.909171
ERRSQ	27.900937	0.002959	0.002964	0.003568	0.003594	0.003593
HYBRID	583.445654	0.076893	0.076800	0.094278	0.094537	0.094524
MPSD	1330.936951	11.711793	11.704401	8.888691	8.879497	8.873005
ARE	339.555268	2.987971	2.986085	2.267727	2.265382	2.263725
EABS	18.843800	0.147816	0.147486	0.111368	0.111223	0.111123
SUM	5.000000	0.025681	0.025653	0.019557	0.019536	0.019521

Table 3 D (continued). Pseudo-second order kinetic parameters determined by different error functions for removal of cadmium by nano crystalline zirconia

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.431369	4.277685	4.535515	6.165145	5.729535	3.616794
q_e	2.179091	0.407283	0.404446	0.394653	0.395486	0.411033
R^2_{adj}	-1814.410196	0.787907	0.810447	0.827700	0.846134	0.742086
ERRSQ	28.016592	0.004621	0.004656	0.005540	0.005301	0.004924
HYBRID	684.606251	0.113289	0.112386	0.129953	0.123384	0.125720
MPSD	1545.422783	15.455880	15.112326	14.469582	14.562939	15.465175
ARE	394.275963	3.943181	3.855532	3.691552	3.715370	3.945552
EABS	18.804130	0.183900	0.180875	0.177633	0.178180	0.182396
SUM	5.000000	0.030112	0.029507	0.028560	0.028692	0.030073
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.485604	1.650022	1.877070	2.071251	1.788214	1.746596
q_e	1.006216	0.451386	0.442267	0.426546	0.432874	0.433933
R^2_{adj}	-50.236067	0.859851	0.891164	0.939947	0.910866	0.904061
ERRSQ	2.026380	0.007791	0.008019	0.009966	0.010013	0.010083
HYBRID	48.387240	0.196330	0.189969	0.220698	0.237153	0.241875
MPSD	402.029509	22.301652	21.807106	18.741811	18.768942	18.764552
ARE	102.567772	5.689708	5.563538	4.781504	4.788426	4.787306
EABS	4.929130	0.260784	0.259516	0.229736	0.226122	0.225461
SUM	5.000000	0.171754	0.169018	0.149323	0.149088	0.149064
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	2.654376	3.245763	3.313450	3.508510	3.522201	3.538841
q_e	0.456552	0.448717	0.447791	0.446817	0.446330	0.445742
R^2_{adj}	0.948842	0.981517	0.982462	0.978243	0.979330	0.980503
ERRSQ	0.000994	0.000483	0.000487	0.000572	0.000569	0.000569
HYBRID	0.029048	0.011570	0.011438	0.013179	0.013052	0.012988
MPSD	7.251265	5.144831	5.058836	4.702796	4.709531	4.717595
ARE	1.849979	1.312575	1.290635	1.199801	1.201519	1.203576
EABS	0.083112	0.064508	0.064275	0.062243	0.062460	0.062721
SUM	5.000000	3.078772	3.052540	3.074417	3.071625	3.075321

Table 4 A. Langmuir isotherm parameters determined by different error functions for removal of cadmium by nano crystalline iron oxide/ hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	9.178522	8.819844	8.788571	8.971476	8.972358	8.972829
b	1.415303	2.355058	2.418447	2.419003	2.417793	2.415995
R^2_{adj}	0.156448	0.540342	0.538852	0.427375	0.426668	0.426733
ERRSQ	0.910224	0.495988	0.497595	0.617883	0.618647	0.618577
HYBRID	4.149926	2.127358	2.120922	2.704243	2.707651	2.707359
MPSD	13.142910	9.113284	9.021678	8.005993	8.005709	8.010597
ARE	4.552838	3.156934	3.125201	2.773357	2.773259	2.774952
EABS	1.722678	1.245360	1.237135	1.087552	1.087420	1.087991
SUM	5.000000	3.167252	3.148753	3.180075	3.181615	3.182543
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	9.159187	8.779024	8.749236	8.863209	8.838112	8.883791
b	1.527206	2.739805	2.815313	2.915544	2.958728	2.880950
R^2_{adj}	-0.008331	0.526614	0.525081	0.462223	0.475731	0.449150
ERRSQ	1.047284	0.491673	0.493265	0.558552	0.544522	0.572130
HYBRID	4.773990	2.087798	2.081423	2.411674	2.344568	2.474873
MPSD	13.642812	8.942603	8.847326	7.876378	7.879506	7.874116
ARE	4.726009	3.097809	3.064804	2.728457	2.729541	2.727674
EABS	1.790012	1.230085	1.221293	1.084833	1.088059	1.082227
SUM	5.000000	2.904958	2.886264	2.799207	2.774015	2.823623
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	9.465215	8.992000	8.958779	9.063548	9.065119	9.062890
b	1.612484	3.201859	3.302613	3.470649	3.448899	3.479488
R^2_{adj}	-0.182791	0.572770	0.571061	0.517054	0.519726	0.515966
ERRSQ	1.480047	0.534600	0.536739	0.604319	0.600975	0.605680
HYBRID	6.747769	2.218136	2.209677	2.542312	2.528194	2.548063
MPSD	14.044500	9.025373	8.963372	8.007822	8.047526	7.991925
ARE	4.865158	3.126481	3.105003	2.773991	2.787745	2.768484
EABS	1.835950	1.267457	1.265922	1.128979	1.133581	1.127141
SUM	5.000000	2.665535	2.656062	2.540353	2.544163	2.538860

Table 4 A (continued). Langmuir isotherm parameters determined by different error functions for removal of cadmium by nano crystalline iron oxide/ oxide hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	10.109180	9.207785	9.149799	8.768906	8.921245	10.529087
b	3.059696	87.446158	90.731335	117.797714	106.864862	1.640053
R^2_{adj}	-16.819503	0.075194	0.069268	-0.264837	-0.069614	-19.738547
ERRSQ	39.033977	2.025806	2.038786	2.770650	2.343011	45.428200
HYBRID	173.218426	7.529880	7.482503	9.531153	8.219586	201.917537
MPSD	58.629187	17.657378	17.525816	16.830266	16.970596	57.458997
ARE	20.309746	6.116695	6.071121	5.830175	5.878787	19.904380
EABS	7.850088	2.765180	2.762656	2.767937	2.747953	7.607190
SUM	4.717113	1.036475	1.031716	1.034918	1.021250	4.929140
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	10.095900	9.669619	9.639493	9.953582	9.850567	9.976930
b	4.220281	10.094534	10.356056	9.563112	10.074380	9.575626
R^2_{adj}	-0.752199	0.711319	0.710140	0.581420	0.646151	0.556073
ERRSQ	3.729076	0.614380	0.616888	0.890833	0.753071	0.944777
HYBRID	16.278299	2.234922	2.225664	3.364764	2.825366	3.571888
MPSD	21.997269	10.178755	10.112181	9.256860	9.306055	9.402741
ARE	7.620078	3.526024	3.502962	3.206670	3.223712	3.257205
EABS	3.041846	1.599128	1.598933	1.415978	1.448426	1.440957
SUM	5.000000	1.753214	1.747201	1.752728	1.697789	1.801393
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
Q_o	10.070490	9.813071	9.791033	10.046016	10.009720	9.988972
b	5.896674	10.781385	10.943496	10.102361	10.244551	10.327591
R^2_{adj}	0.079861	0.778063	0.777512	0.705648	0.725273	0.735074
ERRSQ	2.071456	0.499633	0.500874	0.662657	0.618476	0.596412
HYBRID	8.733243	1.790247	1.785848	2.450360	2.282211	2.197205
MPSD	18.231698	7.648514	7.652504	6.949808	7.027686	7.072076
ARE	6.315646	2.649523	2.650905	2.407484	2.434462	2.449839
EABS	2.601482	1.235360	1.242214	1.088375	1.107792	1.118873
SUM	5.000000	1.760094	1.763262	1.781232	1.756657	1.745401

Table 4 B. Freundlich isotherm parameters determined by different error functions for removal of cadmium by nano crystalline iron oxide/hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	6.725584000	0.935814130	0.942871802	0.877654809	1.113323418	0.760509209
1/n	0.10034000	0.86533039	0.87490699	0.86652438	0.68309825	1.00000000
R^2_{adj}	-66.960562054	-60.205382248	-60.290378163	-61.106248349	-61.106248438	-61.106251168
ERRSQ	73.331975439	66.042885051	66.134598806	67.014953097	67.014953194	67.014956139
HYBRID	325.223121782	290.616505747	290.260859924	296.701651304	296.701651796	296.701666724
MPSD	122.339132737	119.650054768	120.807382737	115.882259433	115.882259618	115.882265245
ARE	42.379518731	41.447994797	41.848904966	40.142792207	40.142792271	40.142794220
EABS	16.275011207	16.099204870	16.293439330	15.466855395	15.466855418	15.466856123
SUM	5.000000000	4.739429361	4.770440999	4.670945834	4.670945841	4.670946062
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	6.836440000	0.873723829	0.945715622	0.891657490	0.885369223	0.920820977
1/n	0.094300034	0.930938694	0.875735482	0.852916401	0.858974147	0.825903531
R^2_{adj}	-75.979525197	-65.148870662	-65.232373139	-66.212705712	-66.212706680	-66.212705736
ERRSQ	79.953316905	68.704263963	68.790992220	69.809195966	69.809196971	69.809195991
HYBRID	352.962880617	301.807423697	301.471938718	308.476471275	308.476476254	308.476471401
MPSD	125.869788703	121.510510872	122.671995390	117.364782341	117.364784108	117.364782386
ARE	43.602573834	42.092475697	42.494825736	40.656353207	40.656353819	40.656353222
EABS	16.764055228	16.388317854	16.581788342	15.697756670	15.697756891	15.697756675
SUM	5.000000000	4.622693446	4.652823827	4.548341376	4.548341444	4.548341378
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	7.035500000	0.910790417	0.929138149	0.899953852	0.899953852	0.899953654
1/n	0.0978899814	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000
R^2_{adj}	-70.946079202	-58.023191305	-58.111394459	-58.053959546	-58.053959546	-58.053960671
ERRSQ	90.027387440	73.856751758	73.967121908	73.895252596	73.895252596	73.895254003
HYBRID	390.729365337	320.068515753	319.654619723	320.701808490	320.701808490	320.701822700
MPSD	132.548819294	120.828851480	122.099866790	120.078181750	120.078181750	120.078193440
ARE	45.916257900	41.856341957	42.296634576	41.596302334	41.596302334	41.596306384
EABS	17.968067241	16.516428206	16.737975231	16.385580703	16.385580703	16.385582186
SUM	5.000000000	4.381907515	4.413582299	4.365347053	4.365347053	4.365347364

Table 4 B (continued). Freundlich isotherm parameters determined by different error functions for removal of cadmium by nano crystalline iron oxide/ oxide hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	8.496303000	1.319686094	1.344791505	1.662777270	1.662777270	1.662776481
1/n	0.04914000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000
R^2_{adj}	-108.649341916	-46.622969682	-46.671001255	-55.593358011	-55.593358011	-55.593316741
ERRSQ	240.189067462	104.319063642	104.424277760	123.968877949	123.968877949	123.968787547
HYBRID	927.350757717	432.928381206	432.565698704	490.750180340	490.750180340	490.749891518
MPSD	229.425317035	140.984918627	140.371969501	132.608340762	132.608340762	132.608360031
ARE	79.475261129	48.838608433	48.626276627	45.936876742	45.936876742	45.936883417
EABS	34.503817329	20.393026254	20.319342749	19.386065660	19.386065660	19.386067977
SUM	5.000000000	2.721228379	2.713796470	2.763183456	2.763183456	2.763183003
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	8.280947000	1.324180670	1.347842510	1.663098204	1.663229271	1.666171547
1/n	0.07948001	1.00000000	1.00000000	1.00000000	0.99992189	0.99815597
R^2_{adj}	-91.383882741	-58.702643914	-58.743894757	-67.165635012	-67.165692920	-67.165678630
ERRSQ	196.613839113	127.060756454	127.148547596	145.071919447	145.072042689	145.072012276
HYBRID	769.549649003	515.549501685	515.250167420	568.385719608	568.386110479	568.386014021
MPSD	202.846420245	155.354021448	155.035040117	150.785130562	150.785114930	150.785118788
ARE	70.268061200	53.816211662	53.705713287	52.233501432	52.233496017	52.233497353
EABS	30.366995624	22.769055413	22.735521616	22.288738095	22.288736451	22.288736857
SUM	5.000000000	3.597718316	3.593526522	3.697118861	3.697119788	3.697119559
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
K_F	8.452010000	1.340221952	1.360371940	1.964348602	2.036562729	0.986199043
1/n	0.07662002	1.00000000	1.00000000	1.00000000	0.96454109	0.98889769
R^2_{adj}	-95.210682554	-64.112229208	-64.138549287	-89.363493482	-89.363479213	-72.747118539
ERRSQ	216.593527455	146.583383781	146.642636647	203.430089952	203.430057829	166.022609131
HYBRID	834.810787651	583.843950006	583.643223965	763.984154933	763.984049624	656.967980955
MPSD	210.619718405	170.348937883	170.305996304	169.018863500	169.018863875	171.126728588
ARE	72.960810671	59.010603086	58.995727686	58.549851804	58.549851934	59.280037689
EABS	31.890250658	25.362729627	25.367325840	25.505092916	25.505092876	25.279479514
SUM	5.000000000	3.789050140	3.788819624	4.259127880	4.259127608	3.971168693

Table 4 C. Pseudo-first order kinetic parameters determined by different error functions for removal of cadmium by iron oxide/ hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.232258	1.477969	1.518913	1.639481	1.702439	1.621277
q_e	1.438401	4.740006	4.723540	4.848494	4.778288	4.870045
R^2_{adj}	-128.461349	0.382212	0.379762	0.216498	0.323911	0.166078
ERRSQ	189.678128	0.905141	0.908731	1.147935	0.990560	1.221807
HYBRID	315.572059	1.563954	1.557937	2.035607	1.732173	2.170324
MPSD	319.955022	20.073321	20.174124	18.945185	18.865049	18.966439
ARE	76.907616	4.825026	4.849256	4.553856	4.534593	4.558965
EABS	53.333037	3.277270	3.309241	3.046399	3.078947	3.035899
SUM	5.000000	0.196653	0.197882	0.188047	0.186365	0.188799
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.261206	1.561067	1.590424	1.749198	1.786425	1.759464
q_e	1.053222	4.822646	4.812069	4.888296	4.856178	4.883054
R^2_{adj}	-203.207765	0.462944	0.461576	0.356578	0.400136	0.363809
ERRSQ	229.498694	0.603570	0.605108	0.723110	0.674157	0.714983
HYBRID	373.304363	1.051180	1.048655	1.275347	1.183333	1.260469
MPSD	344.398591	14.548979	14.853221	11.863091	12.580188	11.920730
ARE	82.783119	3.497139	3.570270	2.851532	3.023901	2.865387
EABS	58.660910	2.383145	2.443390	1.914156	2.054172	1.927061
SUM	5.000000	0.130561	0.133355	0.108090	0.114181	0.108569
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.223644	2.031740	2.046810	2.142038	2.141502	2.136368
q_e	0.725805	4.856745	4.852725	4.866797	4.867159	4.870498
R^2_{adj}	-553.205601	0.497238	0.496767	0.482676	0.482429	0.479856
ERRSQ	272.631756	0.247325	0.247557	0.254489	0.254610	0.255876
HYBRID	436.676889	0.402965	0.402593	0.416005	0.416258	0.418826
MPSD	369.393544	9.246652	9.356882	8.697901	8.697935	8.698781
ARE	88.791158	2.222618	2.249115	2.090715	2.090723	2.090927
EABS	63.945852	1.586240	1.607476	1.495293	1.495188	1.494295
SUM	5.000000	0.076700	0.077629	0.072363	0.072362	0.072363

Table 4 C (continued). Pseudo-first order kinetic parameters determined by different error functions for removal of cadmium by iron oxide/ oxide hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.348306	1.972989	1.983885	2.084938	2.068707	2.069824
q_e	0.636136	4.926241	4.923366	4.960478	4.976243	4.975440
R^2_{adj}	-601.782960	0.607912	0.607655	0.548151	0.505719	0.508136
ERRSQ	282.288353	0.183618	0.183739	0.211605	0.231476	0.230344
HYBRID	445.716613	0.309441	0.309249	0.358183	0.391280	0.389413
MPSD	370.627497	6.921924	6.967191	5.685974	5.660611	5.660827
ARE	89.087763	1.663824	1.674704	1.366738	1.360642	1.360694
EABS	65.062232	1.180964	1.190155	0.964557	0.957337	0.957533
SUM	5.000000	0.056848	0.057234	0.047061	0.046958	0.046954
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.535954	1.713677	1.983885	2.084938	2.068707	1.797467
q_e	1.370566	4.929627	4.923366	4.960478	4.976243	4.981371
R^2_{adj}	-290.680438	0.771150	0.770851	0.739355	0.692489	0.691381
ERRSQ	196.137632	0.153888	0.154089	0.175268	0.206783	0.207528
HYBRID	311.254617	0.256277	0.309249	0.291732	0.344239	0.345463
MPSD	310.385916	6.832148	6.858113	5.869230	5.657693	5.656200
ARE	74.607489	1.642244	1.648485	1.410787	1.359940	1.359581
EABS	54.240441	1.162800	1.169730	1.003857	0.959932	0.959609
SUM	5.000000	0.067069	0.067536	0.058157	0.056314	0.056306
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_1	0.261114	2.270661	2.277328	2.353420	2.349446	2.349493
q_e	0.174590	4.964477	4.962933	4.988797	4.990890	4.990836
R^2_{adj}	-1278.923555	0.620403	0.620276	0.573859	0.568223	0.568387
ERRSQ	344.246238	0.102096	0.102130	0.114614	0.116130	0.116086
HYBRID	537.243094	0.169314	0.169261	0.190593	0.193081	0.193009
MPSD	404.513103	3.949302	4.009674	2.891705	2.871447	2.871607
ARE	97.232849	0.949294	0.963806	0.695079	0.690210	0.690249
EABS	71.839473	0.679175	0.690345	0.492194	0.488342	0.488374
SUM	5.000000	0.029592	0.030046	0.021836	0.021691	0.021692

Table 4 D. Pseudo-second order kinetic parameters determined by different error functions for removal of cadmium by iron oxide/ oxide hydroxide

20 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.342145	0.550210	0.570419	0.422719	0.425779	0.427007
q_e	5.129520	4.987197	4.973184	5.093321	5.089145	5.086839
R^2_{adj}	0.985960	0.992551	0.992518	0.990608	0.990735	0.990794
ERRSQ	0.512523	0.271917	0.273142	0.342847	0.338196	0.336052
HYBRID	0.987011	0.481769	0.479647	0.639116	0.630133	0.626124
MPSD	8.906907	9.641302	9.880146	8.512332	8.509217	8.510499
ARE	2.299753	2.489373	2.551043	2.197875	2.197070	2.197402
EABS	1.450775	1.669005	1.718904	1.421445	1.422876	1.424027
SUM	4.647002	3.941278	4.018896	3.866534	3.848559	3.841243
30 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.556448	0.648153	0.659667	0.692810	0.707581	0.691245
q_e	5.070480	5.032669	5.026120	5.052121	5.046712	5.052712
R^2_{adj}	0.995305	0.995808	0.995800	0.995186	0.995135	0.995191
ERRSQ	0.170129	0.151912	0.152189	0.174435	0.176308	0.174274
HYBRID	0.308945	0.269129	0.268664	0.308219	0.311245	0.307965
MPSD	6.004263	6.359106	6.499394	5.694426	5.729744	5.698186
ARE	1.550294	1.641914	1.678136	1.470294	1.479414	1.471265
EABS	1.022937	1.100210	1.128424	0.971653	0.979873	0.972221
SUM	4.722986	4.668197	4.736467	4.604570	4.643185	4.604489
40 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	0.715079	1.073204	1.087236	0.879715	0.880095	0.879451
q_e	5.059961	4.994153	4.991287	5.040067	5.039869	5.040206
R^2_{adj}	0.996157	0.998573	0.998571	0.998063	0.998066	0.998061
ERRSQ	0.138029	0.051256	0.051326	0.069584	0.069475	0.069660
HYBRID	0.243125	0.084324	0.084208	0.118977	0.118791	0.119108
MPSD	4.449628	3.884584	3.908478	3.479631	3.479219	3.479927
ARE	1.148889	1.002995	1.009165	0.898437	0.898330	0.898513
EABS	0.781008	0.711808	0.717175	0.621800	0.621764	0.621827
SUM	5.000000	3.375602	3.393239	3.353650	3.351867	3.354907

Table 4 D (continued). Pseudo-second order kinetic parameters determined by different error functions for removal of cadmium by iron oxide/ oxide hydroxide

50 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	1.361301	1.106393	1.107390	1.230498	1.227507	1.235431
q_e	5.032966	5.054675	5.053964	5.047478	5.048975	5.045022
R^2_{adj}	0.998463	0.998885	0.998885	0.998738	0.998733	0.998743
ERRSQ	0.055398	0.040181	0.040186	0.045495	0.045674	0.045290
HYBRID	0.094474	0.067990	0.067982	0.077348	0.077669	0.076962
MPSD	2.590319	2.671769	2.678088	2.291019	2.291428	2.290349
ARE	0.668818	0.689848	0.691479	0.591539	0.591644	0.591366
EABS	0.466551	0.484646	0.485862	0.417060	0.417077	0.417032
SUM	4.894707	4.437762	4.444994	4.209287	4.216261	4.200959
60 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	1.298086	0.864691	0.864367	0.887372	0.887316	0.886706
q_e	5.033979	5.085253	5.085159	5.078186	5.078233	5.078540
R^2_{adj}	0.997682	0.999660	0.999660	0.999649	0.999649	0.999650
ERRSQ	0.084004	0.012331	0.012332	0.012726	0.012723	0.012696
HYBRID	0.148381	0.019733	0.019732	0.020401	0.020396	0.020354
MPSD	3.903417	1.875416	1.875610	1.793901	1.793820	1.796571
ARE	1.007858	0.484230	0.484280	0.463183	0.463162	0.463873
EABS	0.687706	0.351682	0.351684	0.337804	0.337785	0.338271
SUM	5.000000	1.752075	1.752179	1.699332	1.699186	1.700710
70 mg/l	LTFM	ERRSQ	HYBRID	MPSD	ARE	EABS
k_2	2.720534	1.566975	1.561585	1.662655	1.660936	1.659246
q_e	5.019324	5.057229	5.057161	5.052114	5.052760	5.053112
R^2_{adj}	0.997705	0.999025	0.999025	0.999003	0.999003	0.999003
ERRSQ	0.082447	0.035011	0.035018	0.035816	0.035826	0.035820
HYBRID	0.138039	0.056848	0.056838	0.058398	0.058426	0.058419
MPSD	3.063138	2.670083	2.684626	2.465896	2.462399	2.462863
ARE	0.790899	0.689412	0.693167	0.636691	0.635789	0.635909
EABS	0.555456	0.500271	0.502959	0.462522	0.461817	0.461922
SUM	5.000000	3.480496	3.494833	3.300197	3.296978	3.297349

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Undertaking from the Candidate

*I, **Deepak Gusain,** research scholar under the supervision of Prof. Y.C. Sharma, Department of Chemistry, IIT (BHU) Varanasi give undertaking that the thesis entitled "**Synthesis and characterization of some nano adsorbents and their application in removal of selected metallic pollutants from aqueous solutions**" submitted by me for the degree of Doctor of Philosophy is a record of first-hand research work carried out by me during the period of study.*

I avail myself to responsibility such as an act will be taken on the behalf of me, mistakes, errors of facts, and misinterpretation are of course entirely my own.

Date……

Place: Varanasi ***(Deepak Gusain)***

ANNEXURE-E

Candidate's Declaration

I, Deepak Gusain, certify that the work embodies in this Ph.D. thesis is my own bonafide work carried out by me under the supervision of Prof. Y. C. Sharma, Department of Chemistry, IIT (BHU) Varanasi for a period of approximately 5 years and 2 months from (March, 2011 to May, 2016) at Indian Institute of Technology (Banaras Hindu University), Varanasi. The matter embodied in this Ph.D. thesis has not been submitted for the award of any other degree / diploma.

I declare that I have faithfully acknowledged, given credit to and referred to the research workers wherever their works have been cited in the text and the body of the thesis. I further certify that I have not willfully lifted up some other's works, para, text, data, results, etc. reported in the journals, books, magazines, reports, dissertations, thesis, etc., or available at websites and included them in this Ph.D. thesis and cited as my own work.

Date:

Place : Varanasi *(Deepak Gusain)*

Certificate from the Supervisor/Co-supervisor

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(Prof. V. K. Singh)
Co-supervisor

(Prof. Y. C. Sharma)
Supervisor

(Prof. R. B. Rastogi)
Head

ANNEXURE-F

PRE SUBMISSION SEMINAR COMPLETION CERTIFICATE

This is to certify that ***Mr. Deepak Gusain****, a bonafide research scholar of Department of Chemistry, Indian Institute of Technology (Banaras Hindu University) Varanasi, has successfully completed the pre-submission seminar requirement on the topic "****Synthesis and characterization of some nano adsorbents and their application in removal of selected metallic pollutants from aqueous solutions****" on dated 19-05-2016 which is a part of this Ph.D. programme.*

Date:	*(Prof. Y. C. Sharma)*	*(Prof. R. B. Rastogi)*
Place: Varanasi	*Supervisor*	*Head*

ANNEXURE-F

Course Work / Comprehensive Examination / Pre Submission Seminar Completion Certificate

This is to certify that ***Mr. Deepak Gusain****, a bonafide research scholar of Department of Chemistry, Indian Institute of Technology (Banaras Hindu University), Varanasi has successfully completed the course work / comprehensive examination / pre-submission seminar requirement which is a part of his Ph.D. programme.*

Date:

Place: Varanasi

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ANNEXURE-G

Copyright Transfer Certificate

Title of the Thesis: "Synthesis and characterization of some nano adsorbents and their application in removal of selected metallic pollutants from aqueous solutions".

Candidate's Name: Deepak Gusain

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List of Symbols

$€_r$	Error of prediction in regression equation
°	Degree for measurement of plane angle
A	Arrhenius factor
Å	Angstrom
A_1	Constant (0.509 $mol^{-1/2}$ $kg^{1/2}$)
AAS	Atomic absorption spectroscopy
AdjMS	Adjusted mean squares
AdjSS	Adjusted sum of squares
ANOVA	Analysis of variance
ARE	Average relative error
b	Langmuir constant
B	Calculable mathematical function of F (fractional attainment)
BBD	Box-Behnken design
Bt	Calculable mathematical function of F(t) at different time t
ca.	Circa or approximately
CCD	Central composite design
CCF	Face centered central composite design
C_e	Concentration of adsorbate at equilibrium
C_i	Initial concentration of adsorbate
C_b	Intercept of Boyd plot
C_s	Concentration of adsorbate in solid
cm^{-1}	Wavenumber
cm^3/g	Centimeter cubed per gram
Coef	Coefficient
Conc.	Concentration
C_w	Concentration of adsorbate in liquid
DF	Degree of freedom
D^i	Effective diffusion constant
DTA	Differential thermal analysis
E_a	Activation energy
EABS	The sum of the absolute errors
emu/g	Magnetization per gram
ERRSQ	The sum of the square of the errors
eV	Electron volt
F	F Value by dividing the factor mean square by the error of mean square
F(t)	Fractional attainment at time t

FTIR	Fourier transform infrared spectroscopy
g	Gram
g L^{-1}	Gram per litre
h	Hour
HYBRID	Hybrid fractional error function
IARC	International agency for research on cancer
I_e	Ionic strength
K	Kelvin
k	Number of factors
k_1	Pseudo- first order rate constant
k_2	Pseudo- second order rate constant
k_{diff}	Intraparticle diffusion rate constant
K_F	Freundlich constant
kg	Kilogram
kJ mol^{-1}	Kilo Joule per mole
kJ mol^{-1} K^{-1}	Kilo Joule per mole per kelvin
K_L	Thermodynamic equilibrium constant
km^3	Cubic kilometer
K_p or K_c	Thermodynamic equilibrium constant derived from partition method
L	Litre
LTFM	Linear transform
M	Molar
m^2/g	Square meters per gram
mg	Milligram
mg L^{-1}	Milligram per litre
min	Minute
mol	mole
MPSD	Maquardt percent standard deviation
MS	Mean square
N	Number of runs
NTP	National toxicology program
nm	Nanometer
n_o	Number of central runs
OEHHA	Office of environmental health hazard assessment
p	p value or calculated probability
pH_{zpc}	pH at zero point of charge
PRESS	Predicted sum of squares

q_e	Amount of adsorbate adsorbed on per unit gram of adsorbent at equilibrium
Q_o	Langmuir constant
q_t	Amount of adosrbate adsorbed at time t in per unit gram of adsorbent
r	Radius of the particle
R	Gas constant (8.314 J $mol^{-1}K^{-1}$)
R^2	Coefficient of determination
R^2_{adj}	Adjusted coefficient of determination
rpm	Rotations per minute
RSM	Response surface methodology
R-Sq(pred)	Predicted coefficient of determination
S	Square root of error mean square
SE Coef	Standard error of coefficient
SEM	Scanning electron microscope
Seq SS	Sequential sum of squares
SS	Sum of squares
t	Time
T	Temperature
TEM	Transmission electron microscope
Temp.	Temperature
TGA	Thermogravimetric analysis
USEPA	United states environmental protection agency
V	Volume
W	Weight
W_1	Full width at half maxima
WHO	World health organization
X1	Variable studied in RSM
X2	Variable studied in RSM
X3	Variable studied in RSM
X4	Variable studied in RSM
X_i	Coded in dependent process variable
X_j	Coded independent process variable
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
z	Charge on ion
β_0	Offset term in regression equation
β_i	Linear effect in regression equation

β_{ii}	Square effect in regression equation
β_{ij}	Interaction effect in regression equation
γ_e	Activity coefficient
ΔG^o	Change in standard free energy
ΔH^o	Change in standard enthalpy
ΔS^o	Change in standard entropy
θ	Plane angle
θ/s	Plane angle per second
λ	Wavelength of X-ray
π	Mathematical constant