Electronic Supplementary Information

Evaluation of electrochemical processes for the removal of several target aromatic hydrocarbons from petroleum contaminated water

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Table 1/S Time table of the gradient elution used in the HPLC separation

Time (min)	Solvent A % (Water)	Solvent B % (Acetonitrile)	Flow rate (mL min^{-1})
0.00	50.00	50.00	1.0
5.00	50.00	50.00	1.0
30.00	1.00	99.00	1.0
52.00	1.00	99.00	1.0
55.00	50.00	50.00	1.0
60.00	50.00	50.00	1.0

Table 2/S HPLC detection parameters used in diode array and fluorescence detectors

Diode array detector			**Fluorescence detector**		
Signal	Wavelength (nm)	Bandwidth (nm)	Time (min)	Excitation (nm)	Emission (nm)
			0.00	256	390
			22.50	275	420
A	245	8	32.00	270	385
			38.00	290	430
Spectrum scan(nm)			55.00	305	480
	From 190 to 450		60.00	256	390

Table 5/S ANOVA results of the CCD experiments /Response: Removal/

Source of variation	Degrees of freedom	Sum of squares (Partial)	Mean squares (Partial)	F ratio	P value [a]
Model	14	5841.275	417.2339	381.2436	2.34E-36
A:Current Density	1	3585.016	3585.0156	3275.775	1.74E-38
B:Electrolyte Concentration	1	821.6822	821.6822	750.8045	1.24E-26
C:Electrolysis Time	1	425.0469	425.0469	388.3827	1.51E-21
D:pH	1	99.7668	99.7668	91.161	1.22E-11
AB	1	5.4781	5.4781	5.0055	0.0312
AC	1	21.2878	21.2878	19.4515	8.21E-05
AD	1	0.0378	0.0378	0.0346	0.8535
BC	1	44.8404	44.8404	40.9725	1.61E-07
BD	1	1.805	1.805	1.6493	0.2068
CD	1	5.0721	5.0721	4.6346	0.0377
AA	1	89.5049	89.5049	81.7843	5.17E-11
BB	1	4.7378	4.7378	4.3292	0.0443
CC	1	4.8975	4.8975	4.475	0.041
DD	1	134.3376	134.3376	122.7497	1.83E-13
Residual	38	41.5873	1.0944		
Lack of Fit	10	40.3611	4.0361	92.1675	1.03E-18
Pure Error	28	1.2262	0.0438		
Total	52	5882.862			

[a] Alpha= 0.05, S= 1.0461, R-sq = 99.69%, R-sq(adj) = 99.43%, PRESS= 77.1552

Table 3/S Factor levels used in the FFD and the total BTEX & PAHs removal percentage

Standard order	Run Order	A: ED[a] (mA cm^{-2})	B: EC[b] (g L^{-1})	C: ET[c] (min)	pH	Removal (%)
4	1	20	0.5	100	5	37.05
125	2	25	1	120	8	91.77
15	3	20	1	100	10	52.65
147	4	30	1	80	10	73.15
116	5	25	0.5	120	8	82.97
59	6	30	0.5	100	8	86.95
8	7	20	0.5	120	8	58.96
124	8	25	1	120	5	66.76
49	9	25	2	100	5	68.05
99	10	20	1	120	10	64.32
87	11	20	0.5	100	10	43.45
3	12	20	0.5	80	10	36.46
81	13	30	2	120	10	91.89
23	14	20	2	100	8	78.01
60	15	30	0.5	100	10	77.03
50	16	25	2	100	8	89.81
5	17	20	0.5	100	8	49.7
159	18	30	2	100	10	88.23
134	19	25	2	120	8	100
48	20	25	2	80	10	69.47
132	21	25	2	100	10	80.52
10	22	20	1	80	5	36.44
149	23	30	1	100	8	93.1
44	24	25	1	120	8	91.91
7	25	20	0.5	120	5	42.96
14	26	20	1	100	8	60.72
91	27	20	1	80	5	36.42
151	28	30	1	120	5	74.62
143	29	30	0.5	120	8	95.66
17	30	20	1	120	8	74.02
56	31	30	0.5	80	8	74.76
38	32	25	1	80	8	68.27
108	33	20	2	120	10	81.93
162	34	30	2	120	10	91.65
72	35	30	1	120	10	88.61
122	36	25	1	100	8	81.18
71	37	30	1	120	8	100
107	38	20	2	120	8	91.96
63	39	30	0.5	120	10	84.93
29	40	25	0.5	80	8	57.13
13	41	20	1	100	5	43.89
65	42	30	1	80	8	83.51
35	43	25	0.5	120	8	82.9
2	44	20	0.5	80	8	41.64
114	45	25	0.5	100	10	60.14
156	46	30	2	80	10	85.19
97	47	20	1	120	5	54.26
100	48	20	2	80	5	42.18
52	49	25	2	120	5	72.42
20	50	20	2	80	8	65.76
88	51	20	0.5	120	5	42.75
22	52	20	2	100	5	56.68
139	53	30	0.5	100	5	63.75
36	54	25	0.5	120	10	72.56
53	55	25	2	120	8	100
79	56	30	2	120	5	78.2
40	57	25	1	100	5	58.4
66	58	30	1	80	10	72.89
158	59	30	2	100	8	100
153	60	30	1	120	10	88.52
115	61	25	0.5	120	5	60.25
46	62	25	2	80	5	57.49
106	63	20	2	120	5	67.83
126	64	25	1	120	10	81.08
136	65	30	0.5	80	5	54.14
103	66	20	2	100	5	56.33
129	67	25	2	80	10	69.17
83	68	20	0.5	80	8	41.3
157	69	30	2	100	5	76.21
138	70	30	0.5	80	10	65.6
101	71	20	2	80	8	65.47
145	72	30	1	80	5	60
9	73	20	0.5	120	10	51.75

64	74	30	1	80	5	59.77
69	75	30	1	100	10	83.76
131	76	25	2	100	8	89.9
146	77	30	1	80	8	83.29
150	78	30	1	100	10	83.53
93	79	20	1	80	10	44.56
154	80	30	2	80	5	71.2
31	81	25	0.5	100	5	47.73
54	82	25	2	120	10	86
152	83	30	1	120	8	100
96	84	20	1	100	10	52.9
24	85	20	2	100	10	68.15
128	86	25	2	80	8	80.48
112	87	25	0.5	100	5	47.92
18	88	20	1	120	10	64.5
27	89	20	2	120	10	81.79
62	90	30	0.5	120	8	95.86
41	91	25	1	100	8	80.97
25	92	20	2	120	5	67.49
32	93	25	0.5	100	8	67.96
43	94	25	1	120	5	66.43
47	95	25	2	80	8	80.2
89	96	20	0.5	120	8	58.6
144	97	30	0.5	120	10	84.94
28	98	25	0.5	80	5	41.77
95	99	20	1	100	8	60.64
74	100	30	2	80	8	97.28
39	101	25	1	80	10	59.81
26	102	20	2	120	8	92.08
76	103	30	2	100	5	75.98
92	104	20	1	80	8	51.04
85	105	20	0.5	100	5	37.32
61	106	30	0.5	120	5	69.61
104	107	20	2	100	8	78.34
78	108	30	2	100	10	88.57
102	109	20	2	80	10	59.11
21	110	20	2	80	10	58.8
34	111	25	0.5	120	5	60.51
55	112	30	0.5	80	5	54.11
73	113	30	2	80	5	71.06
113	114	25	0.5	100	8	67.63
119	115	25	1	80	8	68.04
86	116	20	0.5	100	8	50.05
133	117	25	2	120	5	72.29
130	118	25	2	100	5	68.35
30	119	25	0.5	80	10	49.92
118	120	25	1	80	5	50.29
148	121	30	1	100	5	69.63
105	122	20	2	100	10	67.82
45	123	25	1	120	10	80.95
98	124	20	1	120	8	74.32
33	125	25	0.5	100	10	59.95
109	126	25	0.5	80	5	41.51
16	127	20	1	120	5	54.52
57	128	30	0.5	80	10	65.79
121	129	25	1	100	5	58.14
68	130	30	1	100	8	92.82
90	131	20	0.5	120	10	52
123	132	25	1	100	10	71.43
42	133	25	1	100	10	71.68
117	134	25	0.5	120	10	71.99
70	135	30	1	120	5	74.44
127	136	25	2	80	5	57.21
160	137	30	2	120	5	77.97
82	138	20	0.5	80	5	30.18
37	139	25	1	80	5	49.9
140	140	30	0.5	100	8	87.69
137	141	30	0.5	80	8	74.83
120	142	25	1	80	10	60.01
51	143	25	2	100	10	80.66
75	144	30	2	80	10	84.98
141	145	30	0.5	100	10	77.01
94	146	20	1	100	5	44.08
111	147	25	0.5	80	10	49.64
135	148	25	2	120	10	86.21
77	149	30	2	100	8	100

1	150	20	0.5	80	5	30.37
6	151	20	0.5	100	10	43.88
12	152	20	1	80	10	44.63
155	153	30	2	80	8	97.13
142	154	30	0.5	120	5	69.97
110	155	25	0.5	80	8	57.27
19	156	20	2	80	5	41.36
161	157	30	2	120	8	100
58	158	30	0.5	100	5	63.69
67	159	30	1	100	5	69.84
84	160	20	0.5	80	10	36.19
11	161	20	1	80	8	50.77
80	162	30	2	120	8	100

[a] CD: Current density, [b] EC: NaCl concentration, [C] ET: Electrolysis time.

Table 6/S ANOVA results of the CCD experiments /Response: Energy consumption/

Source of variation	Degrees of freedom	Sum of squares (Partial)	Mean squares (Partial)	F ratio	P value [a]
Model	14	9.42E+04	6726.8346	248.9297	7.01E-33
A:Current Density	1	7642.548	7642.5478	282.8161	3.41E-19
B:Electrolyte Concentration	1	5.59E+04	5.59E+04	2068.429	9.58E-35
C:Electrolysis Time	1	365.0647	365.0647	13.5094	0.0007
D:pH	1	1.72E+04	1.72E+04	636.0856	2.46E-25
AB	1	1877.772	1877.7724	69.4879	4.15E-10
AC	1	104.2929	104.2929	3.8594	0.0568
AD	1	731.8182	731.8182	27.0813	7.01E-06
BC	1	22.9673	22.9673	0.8499	0.3624
BD	1	4376.971	4376.9707	161.9719	2.82E-15
CD	1	13.4292	13.4292	0.497	0.4851
AA	1	60.9662	60.9662	2.2561	0.1414
BB	1	765.7345	765.7345	28.3364	4.82E-06
CC	1	45.9278	45.9278	1.6996	0.2002
DD	1	860.3364	860.3364	31.8372	1.76E-06
Residual	38	1026.875	27.023		
Lack of Fit	10	1025.979	102.5979	3205.934	4.53E-40
Pure Error	28	0.8961	0.032		
Total	52	9.52E+04			

[a] Alpha= 0.05, S= 4.1984, R-sq = 99.22%, R-sq(adj) = 99.02%, PRESS=1255.403

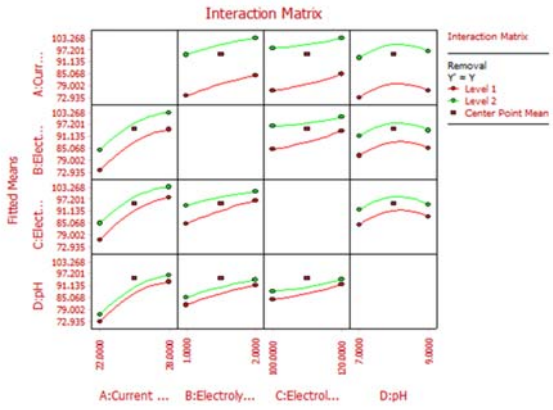


Fig.1/S Interaction matrix for removal efficiency in CCD design

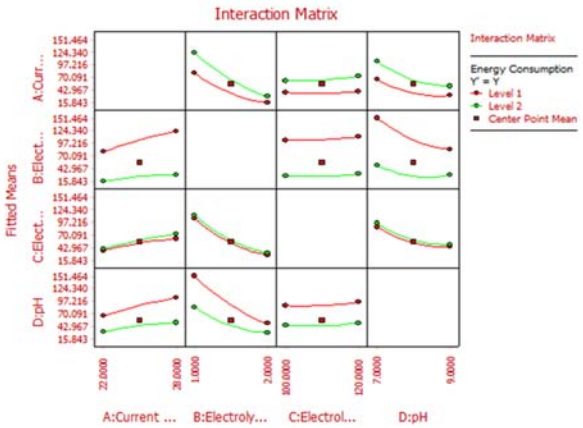


Fig.2/S Interaction matrix for energy consumption in CCD design

Table 4/S A 2^4 design plus central point used in CCD

Standard Order	Run Order	Point Type	A: ED[a] (mA cm^{-2})	B: EC[b] (g L^{-1})	C: ET[c] (min)	pH	Removal (%)	Energy Consumption (Kwh g^{-1} $x10^{-3}$)
53	1	0	25	1.5	110	8	95	55.3
3	2	1	22	2	100	7	75.33	35.59
52	3	0	25	1.5	110	8	94.85	55.39
37	4	1	22	1	120	9	76.88	69.61
33	5	1	22	1	100	9	66.31	67.39
41	6	-1	22	1.5	110	8	78.89	43.45
1	7	1	22	1	100	7	63.09	120.4
26	8	1	28	1	100	7	84.72	174.53
47	9	-1	25	1.5	110	7	86.02	84.46
21	10	-1	25	1.5	100	8	89.79	53.39
31	11	1	22	2	120	7	81.32	39.48
30	12	1	28	1	120	7	92.69	191.05
39	13	1	22	2	120	9	83.9	22.96
18	14	-1	28	1.5	110	8	100	54.84
14	15	1	28	1	120	9	95.57	106.9
4	16	1	28	2	100	7	95.21	54.95
28	17	1	28	2	100	7	94.99	55.08
7	18	1	22	2	120	7	81.53	39.38
40	19	1	28	2	120	9	100	35.42
11	20	1	22	2	100	9	78.58	20.47
50	21	0	25	1.5	110	8	94.69	55.48
35	22	1	22	2	100	9	78.49	20.49
19	23	-1	25	1	110	8	86.16	94.71
17	24	-1	22	1.5	110	8	78.64	43.59
45	25	-1	25	1.5	100	8	89.52	53.56
12	26	1	28	2	100	9	100	29.57
13	27	1	22	1	120	9	77.06	69.44
20	28	-1	25	2	110	8	99.11	34.96
24	29	-1	25	1.5	110	9	90.85	46.75
38	30	1	28	1	120	9	95.74	106.71
8	31	1	28	2	120	7	100	62.66
16	32	1	28	2	120	9	100	35.42
2	33	1	28	1	100	7	84.45	175.09
29	34	1	22	1	120	7	73.28	124.14
43	35	-1	25	1	110	8	86.2	94.66
34	36	1	28	1	100	9	89.11	95.73
15	37	1	22	2	120	9	84.14	22.9
27	38	1	22	2	100	7	75.14	35.68
25	39	1	22	1	100	7	62.88	120.81
42	40	-1	28	1.5	110	8	100	54.84
5	41	1	22	1	120	7	73	124.62
44	42	-1	25	2	110	8	98.92	35.03
10	43	1	28	1	100	9	88.93	95.92
48	44	-1	25	1.5	110	9	90.61	46.88
32	45	1	28	2	120	7	100	62.66
23	46	-1	25	1.5	110	7	86.29	84.2
49	47	0	25	1.5	110	8	94.74	55.45
6	48	1	28	1	120	7	92.45	191.54
51	49	0	25	1.5	110	8	95.07	55.26
46	50	-1	25	1.5	120	8	98.83	58.1
36	51	1	28	2	100	9	100	29.57
9	52	1	22	1	100	9	66.15	67.55
22	53	-1	25	1.5	120	8	100	57.42

[a] CD: Current density, [b] EC: NaCl concentration, [C] ET: Electrolysis time.

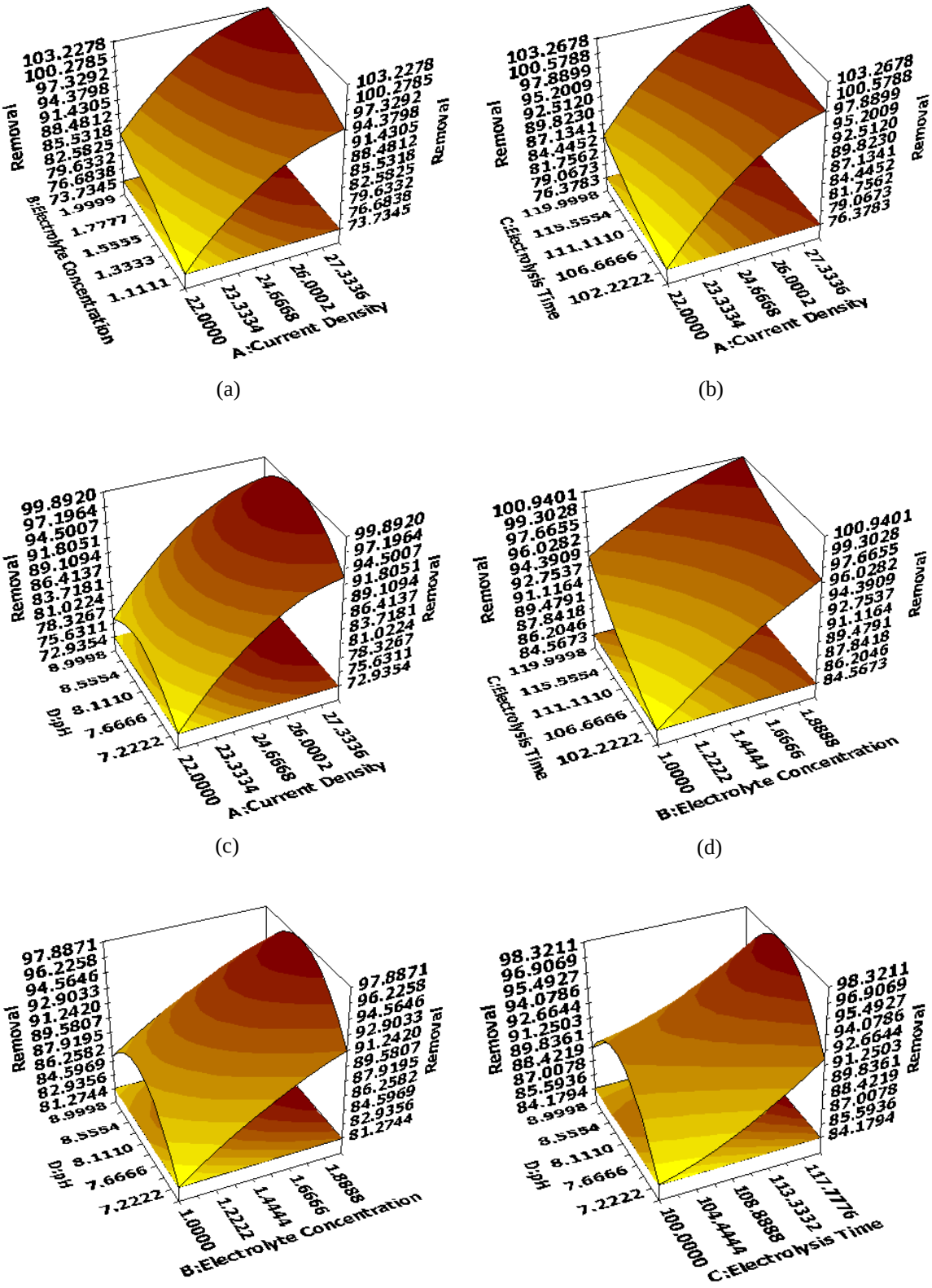
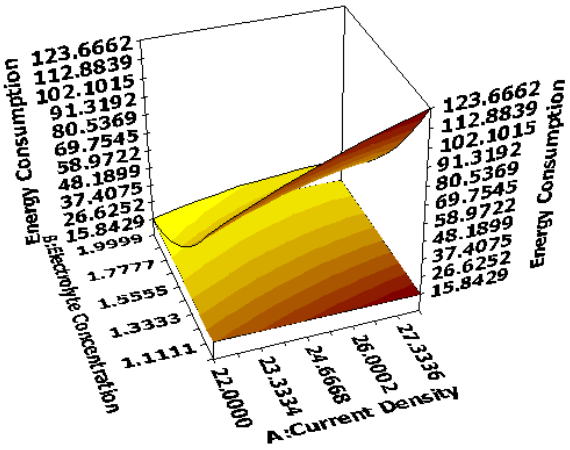


Fig.3/S Response surface plot resulted from CCD /removal efficiency/, (a) current density vs. electrolyte concentration, (b) current density vs. electrolysis time, (c) current density vs. pH, (d) electrolyte concentration vs. electrolysis time, (e) electrolyte concentration vs. pH, (f) electrolysis time vs. pH



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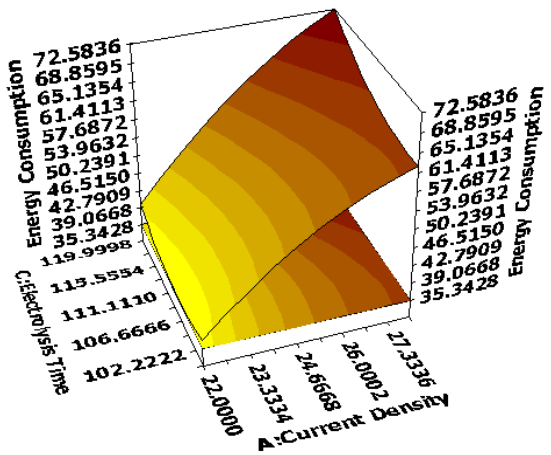

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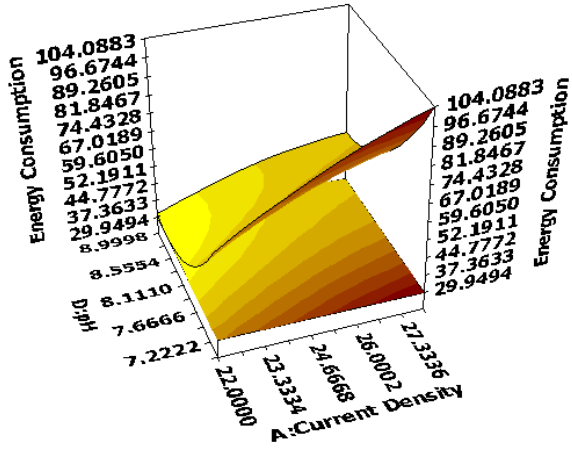

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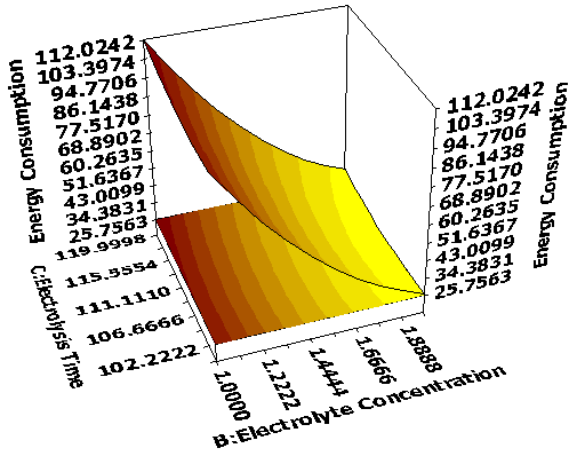

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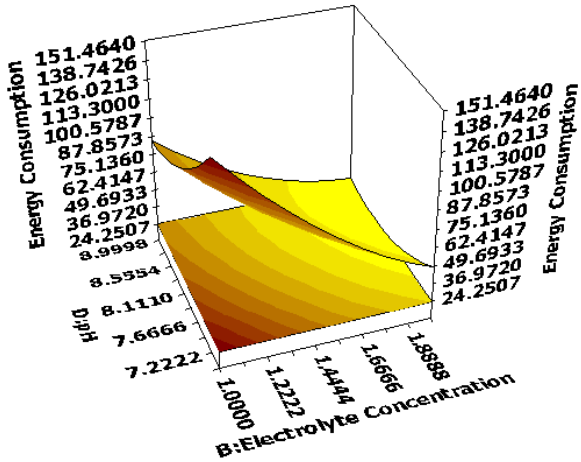

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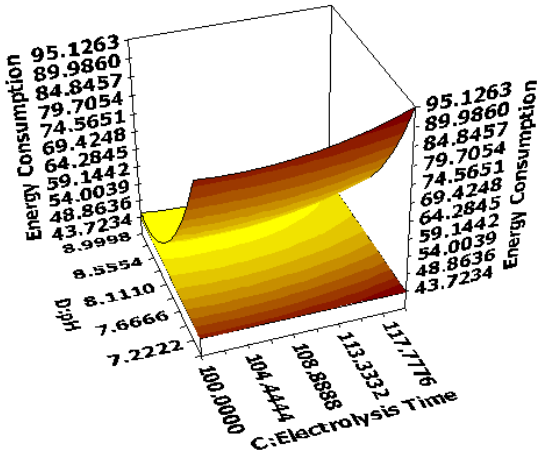

(l)

Fig.4/S Response surface plot resulted from CCD /energy consumption/, (g) current density vs. electrolyte concentration, (h) current density vs. electrolysis time, (i) current density vs. pH, (j) electrolyte concentration vs. electrolysis time, (k) electrolyte concentration vs. pH, (l) electrolysis time vs. pH