

## Appendix I

### Percentage removal of heavy metals under various experimental conditions

**Table 1 Effect of contact time on percentage removal of Pb(II) by PSAP**

<b>Time</b>	<b>10mg/L (%)</b>	<b>20mg/L (%)</b>	<b>30mg/L (%)</b>	<b>40mg/L (%)</b>	<b>50mg/L (%)</b>	<b>60mg/L (%)</b>	<b>70mg/L (%)</b>
<b>5</b>	77.90	80.01	79.19	75.01	70.79	69.21	65.89
<b>10</b>	87.11	84.11	82.33	78.67	75.19	72.05	70.00
<b>15</b>	93.21	89.32	85.93	82.38	78.99	77.23	72.02
<b>20</b>	96.01	93.19	91.26	89.45	87.16	83.19	81.18
<b>25</b>	96.79	96.24	94.35	91.00	89.07	85.49	85.49
<b>30</b>	99.01	98.22	96.47	92.22	91.05	88.36	87.19
<b>35</b>	98.70	97.73	95.88	91.90	90.70	87.93	86.94
<b>40</b>	98.90	97.86	95.88	91.81	90.83	87.93	86.85
<b>45</b>	99.07	98.09	96.08	92.02	91.11	88.44	87.03
<b>50</b>	99.05	98.05	96.07	92.32	91.44	88.22	87.05
<b>55</b>	98.09	98.08	96.08	92.03	91.37	87.85	87.25
<b>60</b>	99.03	97.77	95.66	91.93	91.42	87.97	87.45

**Table 2 Effect of contact time on percentage removal of Cu(II) by PSAP**

<b>Time</b>	<b>10mg/L (%)</b>	<b>20mg/L (%)</b>	<b>30mg/L (%)</b>	<b>40mg/L (%)</b>	<b>50mg/L (%)</b>	<b>60mg/L (%)</b>	<b>70mg/L (%)</b>
<b>5</b>	54.76	51.29	49.49	43.89	41.35	38.22	35.78
<b>10</b>	61.04	58.16	54.39	51.27	45.36	41.85	37.04
<b>15</b>	68.03	65.38	61.29	55.63	51.83	46.97	42.37
<b>20</b>	76.26	72.00	65.65	61.12	58.05	54.33	49.19
<b>25</b>	83.27	79.2	70.01	67.49	63.17	60.00	54.06
<b>30</b>	87.52	82.78	74.48	71.18	66.26	62.34	58.04
<b>35</b>	91.11	86.39	79.25	75.00	71.99	67.41	63.52
<b>40</b>	93.31	88.27	82.39	78.18	74.39	68.89	65.41
<b>45</b>	92.97	87.95	81.98	77.95	74.02	68.85	65.02
<b>50</b>	92.77	87.74	81.76	77.92	74.08	68.81	65.04
<b>55</b>	93.27	88.43	82.38	78.04	73.84	68.93	65.15
<b>60</b>	93.42	88.15	82.27	78.19	73.79	68.95	65.17

**Table 3 Effect of contact time on percentage removal of Cd(II) by PSAP**

<b>Time</b>	<b>10mg/L (%)</b>	<b>20mg/L (%)</b>	<b>30mg/L (%)</b>	<b>40mg/L (%)</b>	<b>50mg/L (%)</b>	<b>60mg/L (%)</b>	<b>70mg/L (%)</b>
<b>5</b>	61.18	57.78	53.31	48.94	44.78	43.72	40.01
<b>10</b>	67.29	62.25	58.38	53.92	49.15	44.83	41.18
<b>15</b>	75.36	71.1	67.34	62.46	54.04	48.91	43.77
<b>20</b>	80.04	76.42	72.24	68.25	60.41	56.44	46.74
<b>25</b>	89.33	86.19	82.73	76.23	70.22	62.08	50
<b>30</b>	96.19	92.32	88.88	82.95	75.37	64.37	54.42
<b>35</b>	96.05	92.22	88.54	83.03	75.39	64.42	54.16
<b>40</b>	96.44	92.33	88.87	82.84	74.89	64.49	53.65
<b>45</b>	95.76	91.78	89.07	82.34	74.74	63.87	53.83
<b>50</b>	95.84	91.85	89.03	82.44	74.76	64.18	53.85
<b>55</b>	96.41	92.18	88.63	83.39	75.06	64.03	53.79
<b>60</b>	96.33	91.67	89.44	83.41	75.07	63.69	54.39

**Table 4 Effect of initial metal ion concentration on percentage removal of Pb(II) by PSAP**

<b>Initial Pb(II) concentration</b>	<b>% Removal of Pb(II)</b>	<b>Adsorption capacity (mg/g)</b>
10	99.03	1.98
20	97.50	3.90
30	94.66	5.68
40	93.25	7.46
50	91.80	9.18
60	88.16	10.58
70	86.71	12.14

**Table 5 Effect of initial metal ion concentration on percentage removal of Cu(II) by PSAP**

<b>Initial Cu(II) concentration</b>	<b>% Removal of Cu(II)</b>	<b>Adsorption capacity (mg/g)</b>
10	93.35	1.87
20	87.50	3.50
30	82.33	4.94
40	77.62	6.21
50	73.82	7.38
60	68.58	8.23
70	65.42	9.16

**Table 6 Effect of initial metal ion concentration on percentage removal of Cd(II) by PSAP**

<b>Initial Cd(II) Concentration</b>	<b>% Removal of Cd(II)</b>	<b>Adsorption capacity (mg/g)</b>
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10	96	1.92
20	92.25	3.69
30	88.66	5.32
40	83.12	6.65
50	74.6	7.46
60	63.75	7.65
70	54.78	7.67

**Table 7 Effect of adsorbent dose on percentage removal of Pb(II) by PSAP**

Dose (g/L)	% Removal of Pb(II)	Adsorption capacity (mg/g)
1	66.12	6.61
2	83.02	4.15
3	88.9	2.96
4	94.95	2.37
5	99.01	1.98
6	99.07	1.65
7	98.91	1.42
8	98.87	1.23

**Table 8 Effect of adsorbent dose on percentage removal of Cu(II) by PSAP**

Dose (g/L)	% Removal of Cu(II)	Adsorption capacity (mg/g)
1	63.71	6.37
2	72.03	3.6
3	76.48	2.56
4	88.71	2.21
5	92.84	1.86
6	92.78	1.55
7	92.83	1.33
8	93.04	1.16

**Table 9 Effect of adsorbent dose on percentage removal of Cd(II) by PSAP**

Dose (g/L)	% Removal of Cd(II)	Adsorption capacity (mg/g)
1	56.34	5.61
2	66.72	3.34
3	79.32	2.64

4	87.01	2.18
5	96.32	1.93
6	96.17	1.6
7	96.02	1.37
8	96.11	1.2

**Table 10 Effect of solution pH on percentage removal of Pb(II) by PSAP**

pH	10mg/L (%)	20mg/L (%)	30mg/L (%)	40mg/L (%)	50mg/L (%)	60mg/L (%)	70mg/L (%)
1	65.29	63.25	62.26	61.38	56.77	55.12	52.45
2	76.52	76.18	74.69	71.48	70.03	68.02	61.01
3	83.71	82.71	81.04	74.86	73.15	71.39	68.32
4	98.31	96.11	91.81	87.36	84.99	79.22	73.88
5	92.06	88.26	86.94	85.13	81.28	78.40	68.89
6	86.13	83.48	78.29	74.19	73.37	69.94	68.36
7	79.41	77.49	74.85	71.00	70.23	65.66	66.30

**Table 11 Effect of solution pH on percentage removal of Cu(II) by PSAP**

pH	10mg/L (%)	20mg/L (%)	30mg/L (%)	40mg/L (%)	50mg/L (%)	60mg/L (%)	70mg/L (%)
1	72.11	71.37	68.88	64.39	60.07	58.19	54.92
2	77.16	74.56	70.04	67.84	64.19	61.46	59.13
3	87.51	78.94	75.34	70.66	68.32	64.59	61.23
4	90.44	83.47	79.21	76.53	71.38	67.82	63.24
5	93.98	89.28	82.18	79.24	73.52	69.41	67.25
6	93.01	88.13	81.73	78.71	72.94	68.88	66.79
7	92.87	87.03	79.82	76.29	72.22	68.06	64.12

**Table 12 Effect of solution pH on percentage removal of Cd(II) by PSAP**

pH	10mg/L (%)	20mg/L (%)	30mg/L (%)	40mg/L (%)	50mg/L (%)	60mg/L (%)	70mg/L (%)
1	57.11	52.77	49.11	41.93	37.24	35.52	31.64
2	68.52	64.88	57.03	53.03	48.98	38.02	35.32
3	79.77	71.58	70.68	64.27	56.44	42.10	39.05
4	86.15	79.81	78.41	77.00	61.83	51.48	44.16

5	94.03	86.77	84.23	82.15	75.03	57.20	49.47
6	96.01	92.22	89.22	83.21	76.11	63.59	53.78
7	95.66	91.24	89.01	83.08	75.71	61.95	53.72

**Table 13 Percentage removal of Pb(II) with increasing concentrations of Cu(II)**

<b>Cu(II) (mg/L)</b>	<b>Pb 20 mg/L (%)</b>	<b>Pb 40 mg/L (%)</b>	<b>Pb 60 mg/L (%)</b>
0	98.01	93.04	88.02
20	91.98	90.11	82.87
40	90.03	88.88	78.02
60	87.00	84.44	75.05

**Table 14 Percentage removal of Pb(II) with increasing concentrations of Cd(II)**

<b>Cd(II) (mg/L)</b>	<b>Pb 20mg/L (%)</b>	<b>Pb 40 mg/L (%)</b>	<b>Pb 60 mg/L (%)</b>
0	96.09	91.17	87.38
20	95.36	89.06	85.23
40	92.85	88.04	84.42
60	92.00	86.07	80.94

**Table 15 Percentage removal of Cu(II) with increasing concentrations of Pb(II)**

<b>Pb(II) (mg/L)</b>	<b>Cu(II) 20 mg/L (%)</b>	<b>Cu(II) 40mg/L (%)</b>	<b>Cu(II) 60 mg/L (%)</b>
0	88.06	77.79	69.05
20	81.06	74.44	59.06
40	71.55	70.34	57.44
60	69.42	65.13	54.36

**Table 16 Percentage removal of Cu(II) with increasing concentrations of Cd(II)**

<b>Cd(II) (mg/L)</b>	<b>Cu(II) 20 mg/L (%)</b>	<b>Cu(II) 40mg/L (%)</b>	<b>Cu(II) 60 mg/L (%)</b>
0	88.06	77.79	69.05
20	74.48	73.02	63.85
40	72.76	71.74	62.68
60	70.45	69.42	60.06

**Table 17 Percentage removal of Cd(II) with increasing concentrations of Pb(II)**

<b>Pb(II) (mg/L)</b>	<b>Cd 20mg/L (%)</b>	<b>Cd 40 mg/L (%)</b>	<b>Cd 60 mg/L (%)</b>
0	92.15	83.14	63.74
20	89.24	80.74	57.75
40	87.75	77.38	57.37
60	86.5	77.38	56.13

**Table 18 Percentage removal of Cd(II) with increasing concentrations of Cu(II)**

<b>Cu(II) (mg/L)</b>	<b>Cd(II) 20mg/L (%)</b>	<b>Cd 40 mg/L (%)</b>	<b>Cd 60mg/l (%)</b>
0	92.15	83.14	63.74
20	85.53	82.26	60.33
40	77.72	74.24	58.58
60	67.67	65.15	53.91

**Appendix II**

**BET analysis data**

Quantachrome® ASiQwin™- Automated Gas Sorption Data  
Acquisition and Reduction  
© 1994-2012, Quantachrome Instruments  
version 3.0

Analysis Report  
Operator: Tezpur University Date:2016/05/12 Operator: Tezpur University Date:2016/05/19  
Sample ID: pavonina\_seed Filename: pavonina\_seed.qps

Sample Desc: Comment: station 1  
 Sample Weight: 0.2194 g Instrument: Autosorb iQ Station 1  
 Outgas Time: 1.0 hrs Outgas Temp.: 100 °C  
 Analysis gas: Nitrogen Non-ideality: 6.58e-05 1/Torr CellType: 6mm w/o rod  
 Analysis Time: 14:45 hr:min Bath temp.: 77.35 K  
 Analysis Mode: Standard VoidVol Remeasure:off  
 VoidVol. Mode: He Measure Cold Zone V: 0 cc Warm Zone V: 0 cc  
 Data Reduction Parameters  
 Thermal Transpiration: onEff. mol. diameter (D): 3.54 Å Eff. cell stem diam. (d): 4.0000 mm

t-Method Calc. method: de Boer  
 BJH/DH method Moving pt. avg.: off Ignoring P-tags below 0.35 P/Po  
 Adsorbate Nitrogen Temperature 77.350K  
 Molec. Wt.: 28.013 Cross Section: 16.200 Å<sup>2</sup> Liquid Density: 0.808 g/cc

Radius	Pore Volume	Pore Surf	dV(r)	dS(r)	dV(logr)	dS(logr)
Å	cc/g	m <sup>2</sup> /g	m <sup>2</sup> /Å/g	cc/g	cc/g	cc/g
16.3654	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
18.3067	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
20.5594	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
23.2416	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
26.5379	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
30.6960	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
36.1195	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
43.5291	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
54.8362	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00	0.0000e+00
72.5322	1.9711e-03	5.4351e-01	9.2200e-05	2.5423e-02	1.5286e-02	4.2150e+00
109.5547	1.3865e-02	2.7148e+00	2.2583e-04	4.1226e-02	5.5852e-02	1.0196e+01
863.9021	2.6657e-01	8.5652e+00	1.7356e-04	4.0181e-03	2.3646e-01	5.4741e+00

BJH adsorption summary

Surface Area = 8.565 m<sup>2</sup>/g  
 Pore Volume = 0.267 cc/g  
 Pore Radius Dv(r) = 109.555 Å

**Appendix III**

**List of publications**

1. Sen, B., Sarma, H. P., & Bhattacharyya, K. G. (2015). Equilibrium sorption isotherm for Cu(II) on *Adenanthera pavonina* seeds. *Archives of Applied Science Research*, 7(6), 74-80.
2. Sen, B., Sarma, H. P., & Bhattacharyya, K. G. (2015). Kinetic Study of Cu (II) Adsorption on *Adenanthera pavonina* seeds. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 9(8), 1-5.

3. Sen, B., Sarma, H. P., & Bhattacharyya, K. G. (2016). Effect of pH on Cu (II) removal from water using Adenanthera pavonina seeds as adsorbent. *International Journal of Environmental Sciences*, 6(5), 737-745.
4. Sen, B., Goswami, S., Devi, G., Sarma, H. P., & Bind, A. (2018). Valorization of Adenanthera pavonina seeds as a potential biosorbent for lead and cadmium removal from single and binary contaminated system. *Geology, Ecology, and Landscapes*, 1-13.



## Appendix IV

### Periodic Table (Source: Internet)

Periodic Table of the Elements

1																	18
1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.93	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.73	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.09	35 Br Bromine 79.90	36 Kr Krypton 84.80
37 Rb Rubidium 84.49	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium [209]	85 At Astatine 209.98	86 Rn Radon 222.02
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

  

57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 144.91	62 Sm Samarium 150.36	63 Eu Europium 151.97	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
89 Ac Actinium 227.03	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.05	94 Pu Plutonium 244.06	95 Am Americium 243.06	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.08	99 Es Einsteinium [254]	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium [262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Semimetal
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

