Adsorption Capacity of Coconut Shell Charcoal

(*Removal of Toxic Heavy Metals from Their Solutions*)

Hla Myo Min, Lecturer, Department of Chemistry, University of Mandalay, Myanmar

Abstract

Preparation of four different size mesh coconut shell charcoal (*CSC*) particles was described. Compromise size mesh *CSC* for the adsorption of heavy metal from its solution was determined by scanning electron microscope (*SEM*) images. Adsorption capacity of the compromise size mesh *CSC* was investigated. The relationship between concentration of heavy metal solution and mass of the heavy metal adsorbed on compromise size mesh *CSC* was also investigated to verify the Freundlich adsorption isotherm.

Key words: *coconut shell charcoal, SEM images, compromise size mesh, Freundlich adsorption isotherm*.

Introduction

Drain water such as Shwe-ta-chaung canal enters to the Mandalay Kan-daw-gyi and Taung-tha-man Lakes. If toxic heavy metals such as mercury, arsenic, lead, and cadmium are present and are dissolved in the such drain water, they also enter and dissolve into these lakes. This will affect and destroy most of the creatures living in these lakes, and also affect to people who consume the creatures from these lakes. In order to keep the environment save and clean, air and water should be undertaken totally free from harmful materials. Because these two items are inevitable for human beings.

Attachment of a substance (gaseous or in solution or in solid form) on the surface of the other else is adsorption. The variation of fractional coverage with pressure or concentration at a chosen temperature is known as the adsorption isotherm. The simplest isotherms, most frequently employed in adsorption experiments, are Langmuir isotherm and Freundlich isotherm.Langmuir isotherm is good for gaseous adsorption having the form of following equation.

$$\theta = Kp / 1 + Kp,$$

where θ, K, and p are fractional surface coverage, constant, and gas pressure respectively.

The Freundlich isotherm is often used in discussion of adsorption from liquid when it is expressed as follow.

$$\omega = c_1 \times c^{1/c_2},$$

where, ω = the mass of solute adsorbed per unit mass of adsorbent, c_1 and c_2 are constant, and c is concentration of solution.

Lograthmic form of this equation is shown as $\log \omega = \log c_1 + {}^{1}/c_2 \log c$.

Hence, the mass of solute adsorbed is linearly related to the concentration.

Experimental

Preparation of *CSC* samples

Coconut shell was obtained from the waste material of coconut. It was crushed and put into the earthen pot (ca 6 inches in diameter). Then the pot was covered with lid and made anaerobic condition with the muddy clay. The pot was heated strongly in charcoal furnace for an hour. Then the lid was opened and the content was sprayed with water to get the coconut shell charcoal. It was ground into powder. Finally, the *CSC* was screened out with the sieve to give four different sizes. Size mesh of each sample was determined by measuring *SEM* images. From the scale provided in *SEM* image, the size mesh of *CSC* could be determined.

Determination of compromise size *CSC* sample

Adsorption experiments were conducted with these *CSC* samples separately. 10 g of *CSC* sample were packed in the column having the diameter of 10 mm. The length of *CSC* material is found to be about 30 cm in all runs. 50 mL of test solution (lead, cadmium, mercury II nitrate) was poured down into the column already packed with *CSC* sample. The test solution resulting from column (after adsorption) was collected. Then 25 mL of distilled water was also poured down to the column. This eluent solution was combined with the test solution after adsorption. Finally, heavy metal containing in this solution (after adsorption) was determined gravimetrically. Another 50 mL of test solution (before adsorption) was used separately for gravimetric determination of heavy metal present in the solution. From the difference before and after adsorption, the mass of heavy metal that had been removed from the solution by *CSC* sample was calculated. The compromise size of *CSC* sample was evaluated from the observation of amount of the mass of heavy metal adsorbed by the sample against time required to accomplish for an experimental run.

Determination of adsorption tendency of compromise *CSC* sample

In the investigation of the adsorption tendency of compromise size *CSC* sample, the experiments were carried out by the same procedure as described in the determination of the compromise size sample. But the adsorbent *CSC* material used in the experiments remain unchanged throughout. Only test solutions were added repeatedly on the compromise *CSC* sample. From the results of these experiments, adsorption tendency of compromise *CSC* was evaluated.

Verification of Freundlich adsorption isotherm

For the verification of Freundlich adsorption isotherm, various concentration of heavy metal solutions were prepared. This was done in order to make a suggestion how much heavy metal could be removed by compromise *CSC* sample from its solution. The adsorption experiments were performed as mentioned before. From the results obtained, verification of Freundlich adsorption isotherm was justified.

Experimental conditions for a particular heavy metal solution were identical. But the conditions for different kinds of heavy metal solutions were different. In this work, nitrates of di-valence of lead, cadmium, and mercury were used as the sources for heavy toxic metal solutions. KI solution, $Na_2C_2O_4$ solution, and Na_2CO_3 solution were used as precipitating agents respectively.

Results and Discussion

Four different size particles were obtained by sieving the coconut shell charcoal powder with the sieve (ENDECOTTS Limited, London).

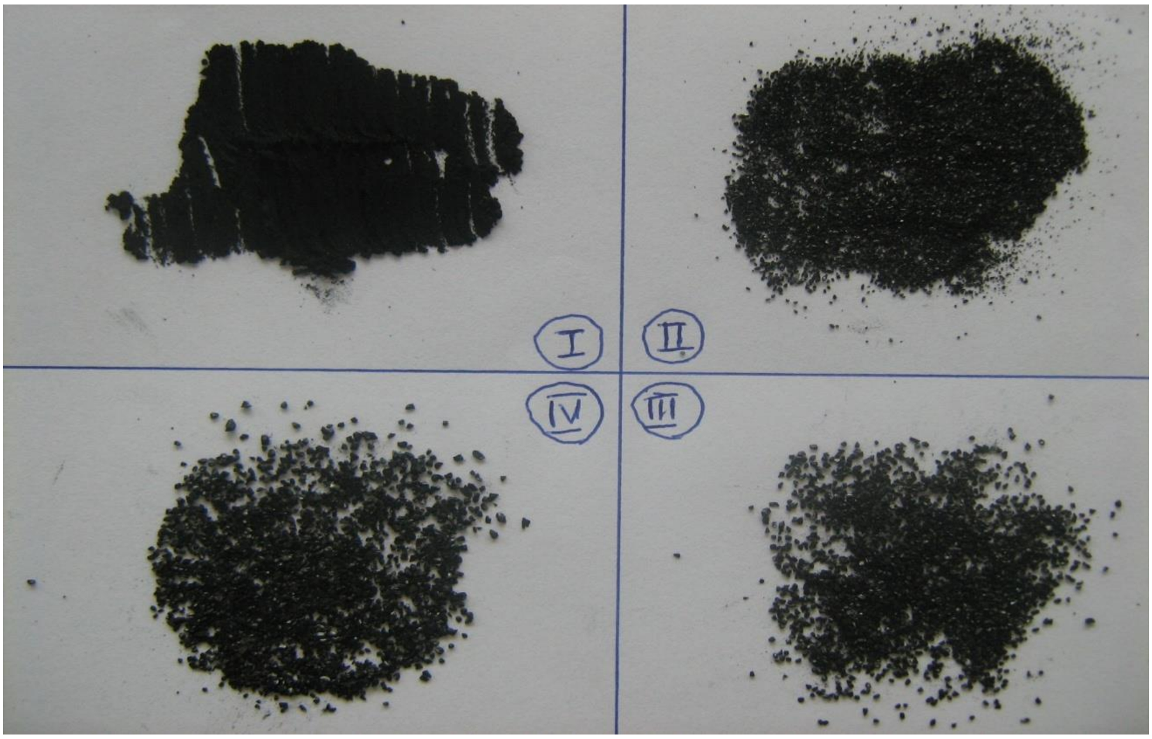

Fig. 1. Photo of the four different *CSC* samples.

In order to determine the size of each of *CSC* particles, *SEM* images of these *CSC* powder samples were measured.

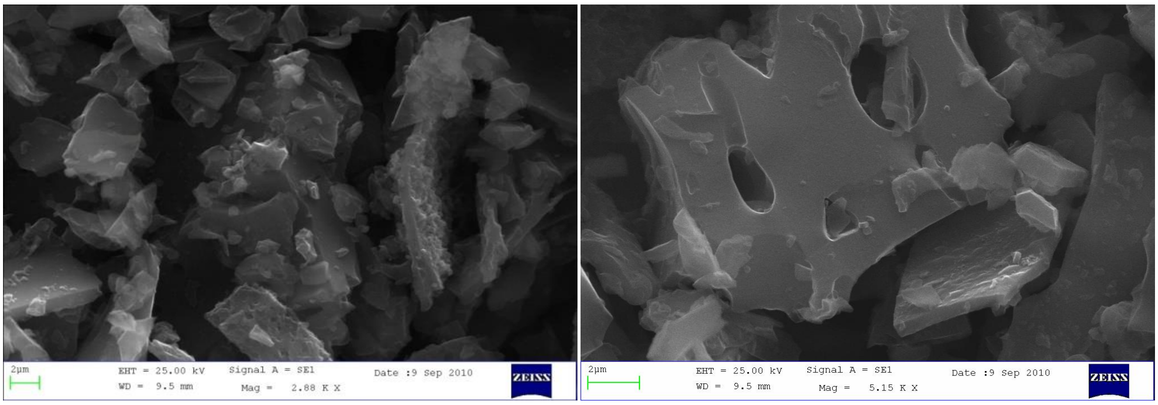

Fig. 2. *SEM* images of *CSC* sample (I).

According to the size specified by the manufacturer of sieve and the scale provided, size mesh of sample I is assigned as 120.

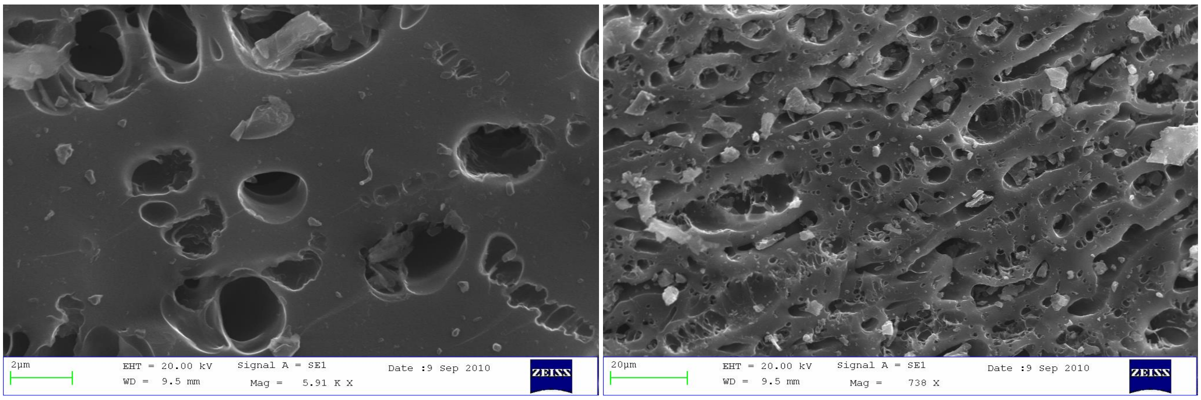

Fig. 3. *SEM* images of *CSC* sample (II).

Size of the *CSC* sample II was assigned as 90 mesh.

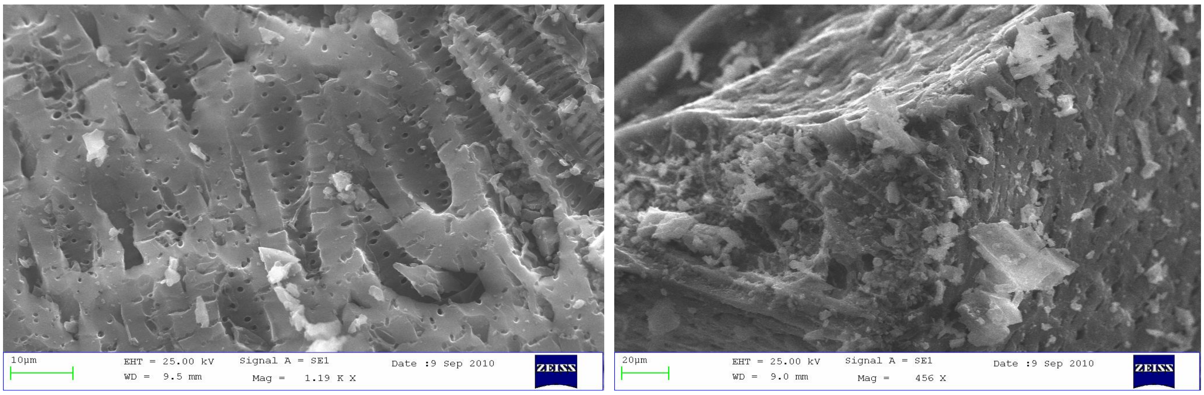

Fig. 4. *SEM* images of *CSC* sample (III).

Size of *CSC* sample III was assigned as 60 mesh.

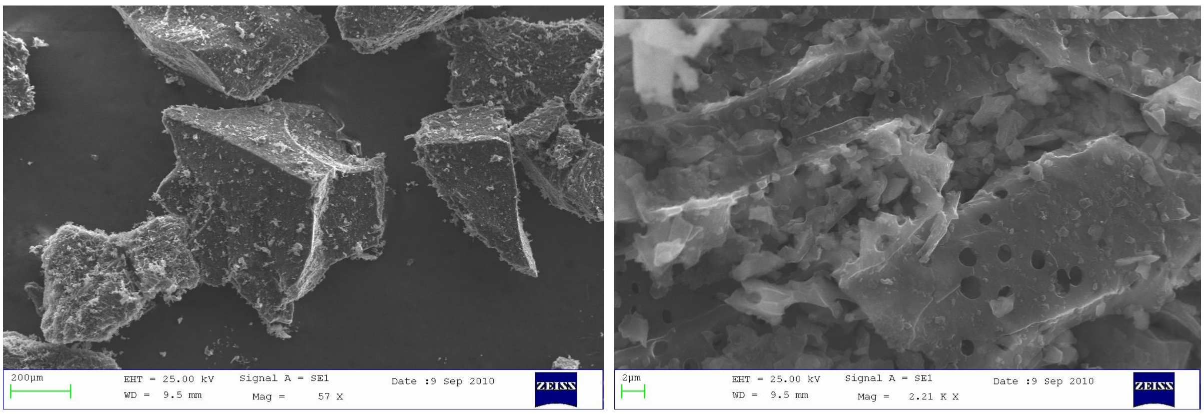

Fig. 5. *SEM* images of *CSC* sample (IV)

Size of *CSC* sample IV was assigned as 30 mesh. These size mesh assignment was taken by the aid of the conversion list between mesh-inch-micrometre, shown in Table 1. The common feature in these *CSC* samples is that they all have great number of porous across the surface of sample. The presence of these porous accounts principally for the adsorption capacity of *CSC*.

Table 1. Conversion chart list

U.S. MESH	INCHES	MICRONS	MILLIMETERS
3	0.2650	6730	6.730
4	0.1870	4760	4.760
5	0.1570	4000	4.000
6	0.1320	3360	3.360
7	0.1110	2830	2.830
8	0.0937	2380	2.380
10	0.0787	2000	2.000
12	0.0661	1680	1.680
14	0.0555	1410	1.410
16	0.0469	1190	1.190
18	0.0394	1000	1.000
20	0.0331	841	0.841
25	0.0280	707	0.707
30	0.0232	595	0.595
35	0.0197	500	0.500
40	0.0165	400	0.400
45	0.0138	354	0.354
50	0.0117	297	0.297
60	0.0098	250	0.250
70	0.0083	210	0.210
80	0.0070	177	0.177
100	0.0059	149	0.149
120	0.0049	125	0.125
140	0.0041	105	0.105
170	0.0035	88	0.088
200	0.0029	74	0.074
230	0.0024	63	0.063
270	0.0021	53	0.053
325	0.0017	44	0.044
400	0.0015	37	0.037

Table 2. Adsorption(%) against time required for an experimental run with four different size of *CSC* samples

Size of sample (mesh)	Adsorption for Pb		Adsorption for Cd		Adsorption for Hg	
	(%)	Time (min)	(%)	Time (min)	(%)	Time (min)
120	90.66	6000	71.19	5400	94.41	6000
90	62.88	5400	64.04	1800	92.47	1500
60	20.83	15	23.25	15	89.47	30
30	6.73	5	7.96	5	76.55	10

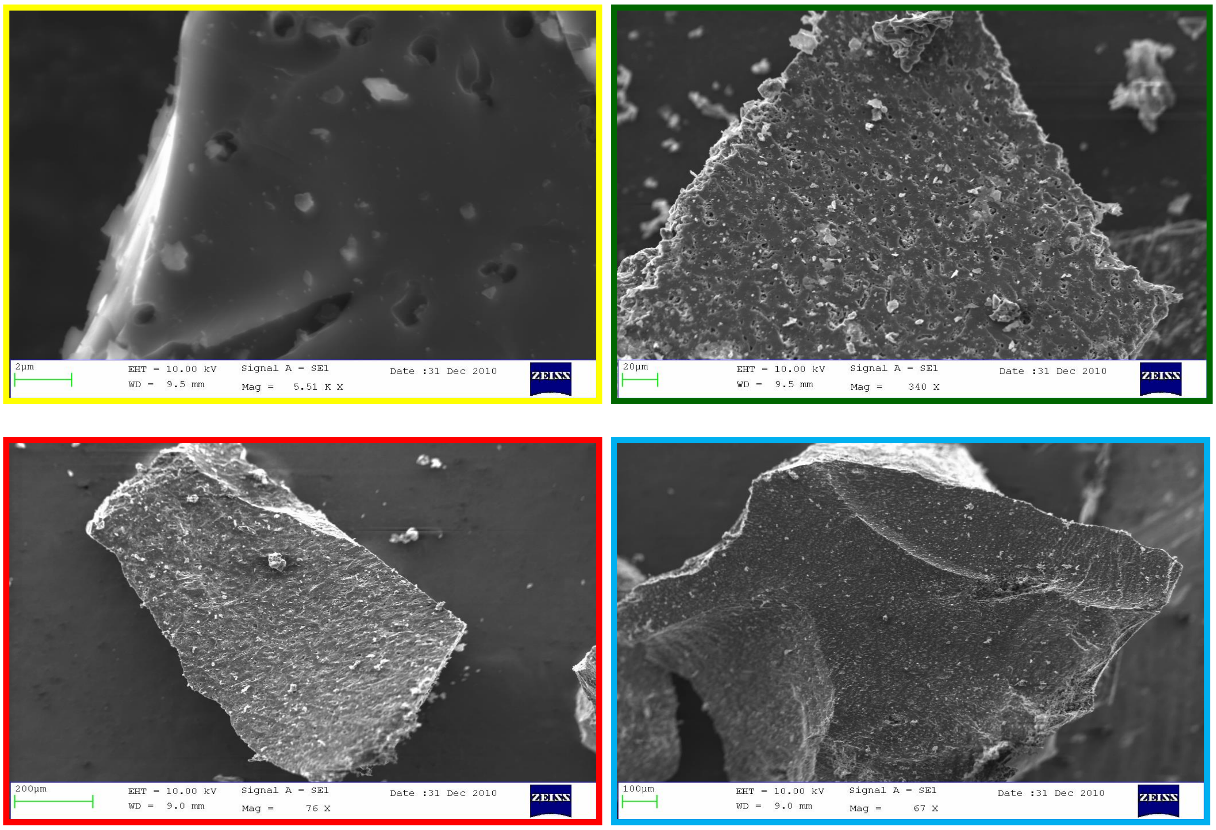

Fig. 6. *SEM* images after adsorption of heavy metal by four size *CSC* samples:
Upper left = 120 mesh, Upper right = 90 mesh, Lower left = 60 mesh, Lower right = 30 mesh

It is noticable that heavy metals are entrapped in the porous of *CSC* sample. Indeed, this is the normal process of adsorption tendency of *CSC* sample. The smaller the size, the greater the existence of porous in the sample. Hence the result is the better the adsorption capacity of *CSC* sample. But on the basis of time required to complete one experimental run, *CSC* sample with 60 mesh is assigned to be the compromise size for the removal of heavy metals from their solutions.

Table 3. Repeated adsorption capacity of compromise size *CSC* (60 mesh)

No. of exp.	% Adsorption for Pb (20.7 mg/mL)	% Adsorption for Cd (10 mg/mL)	% Adsorption for Hg (14.8 mg/mL)
1	20.83	23.25	89.47
2	16.50	13.42	78.30
3	12.42	6.51	57.69
4	10.82	5.33	48.16
5	9.77	3.83	36.02

Different concentrations of metal solutions were used. Adsorption capacity of *CSC* showed good for all experments. But these results represent irregular pattern between concentration and adsorption percent. Concentration of Cd solution is low and so its capacity of adsorptiion. In the case of Pb solution, highest concentration in all experiment, adsorption tendency is not as high as in case of Hg eventhough it has lower concentration than that of Pb. Nevertheless, *CSC* sample with 60 mesh can be used for adsorption of these heavy metals from their solution repeatedly, that is, *CSC* sample can be used for a long time (one month or more) for this purpose.

Table 4. Results of adsorbed mass against concentration for Pb solution

No.	**Conc. (mg/mL), c**	**log c**	**Adsorbed mass (μg) , ω**	**log ω**
1	20.7000	1.3152	4982	3.697
2	10.3500	1.0146	2484	3.395
3	5.175	0.7140	1281	3.108
4	2.587	0.4126	827.4	2.918
5	1.294	0.1115	725	2.860

The results obtained from the experiments showed a good agreement with Freundlich adsorption isotherm. The mass of Pb ions adsorbed on *CSC* is linearly increases with increase ion concentration of Pb solution. The same results were obtained in the experiments of both Cd and Hg solutions. They are represented in Table 5 and 6 respectively.

Table 5 Results of adsorbed mass against concentration for Cd solution

No.	Conc. (mg/mL), c	log c	Adsorbed mass (mg) , ω	log ω
1	25	1.3979	178.4	2.2513
2	20	1.3010	135.1	2.1306
3	15	1.1761	106.1	2.0256
4	10	1.0000	92.8	1.9675
5	5	0.6990	58.32	1.7656

Table 6. Results of adsorbed mass against concentration for Hg solution

No.	Conc. (mg/mL), c	log c	Adsorbed mass (mg) , ω	log ω
1	14.82	1.17	283.6	2.45
2	11.86	1.07	249.7	2.39
3	8.89	0.94	198.8	2.29
4	5.93	0.77	135.0	2.13
5	2.96	0.47	56.1	1.74

When the mass of metal adsorbed on *CSC* sample was plotted against the concentration of solutions, a straight line was observed for each of metals under investigation. This means that adsorption of these metals by *CSC* follows Freundlich adsorption isotherm.

A remarkable feature of these graphs is that, the slopes of the straight lines are the same in all metals. This is probably due to the use of same adsorbent (*coconut shell charcoal 10g)* in all experiments. Eventhough the different concentrations with different metals were utilized in this study, the adsorption capacity of the adsorbent, *CSC*, was found to be the same for all metals. From the results obtained, the slope of *CSC* sample 10 g for adsorption of heavy metal solutions such as Pb, Cd, and Hg is calculated to be about 0.85. When this value is substituted in Freundlich equation, $\omega = c_1 \times c^{1/c2}$, the mass of solute adsorbed becomes $\omega = c_1 x\, c^{0.85}$. This relationship can be changed into $\omega \propto c^{0.85}$. On the basis of this study, it can be stated that, on an average, the heavy metals can be removed conveniently and effectively by a 10 g of *CSC* sample from their solutions by nearly first order like fashion.. These data are valid on limit of this study. The efficiency of the adsorption capacity of the sample *CSC* can be changed if the amount of *CSC* is varied.

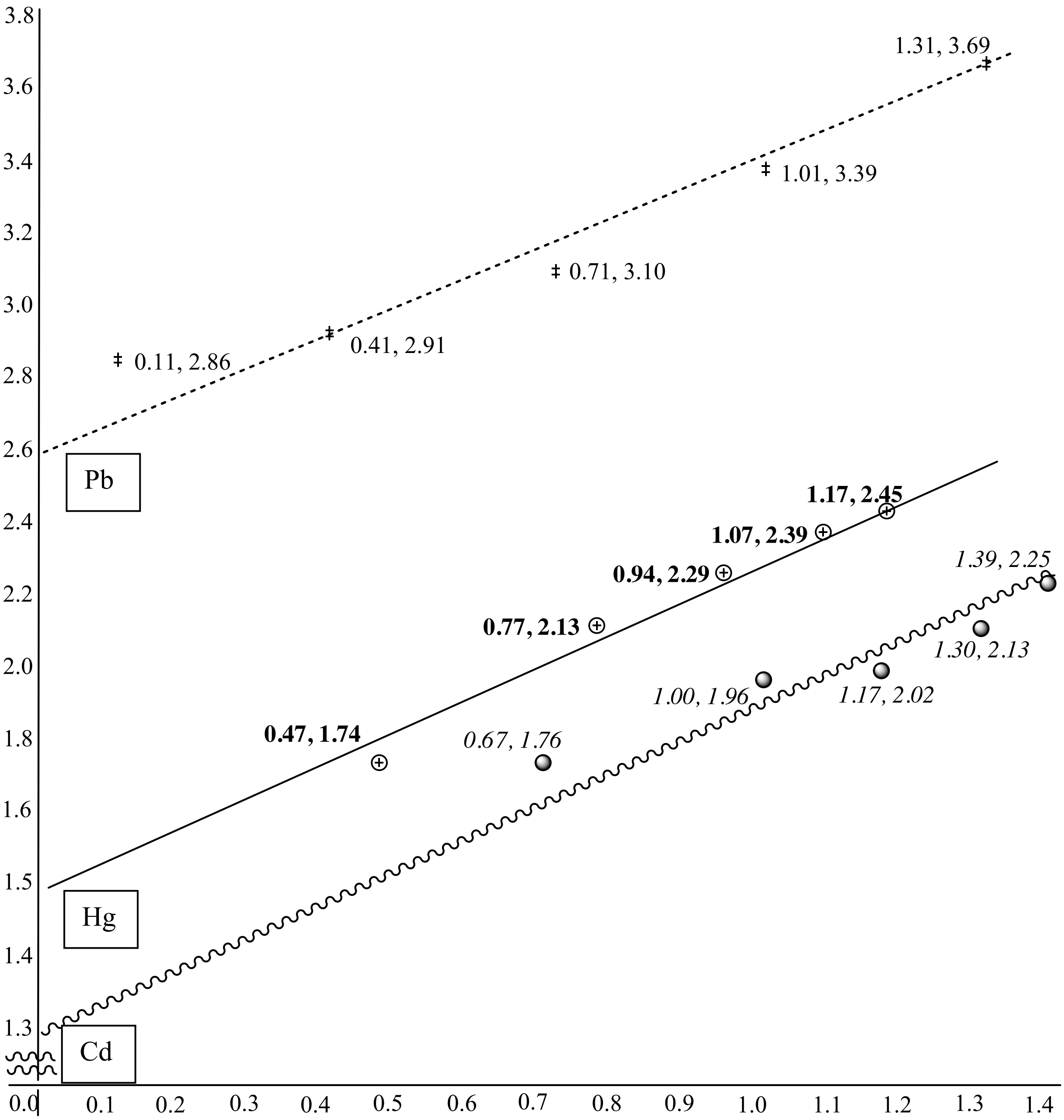

Fig. 7. The plot of log of adsorbed mass (logω, Y-axis) Vs log of concentration (log c, X-axis)

The mass adsorbed for Pb is represented by μg scale while other two are given in mg scale. Although the adsorbed mass of heavy metals are shown by different untis, the physical interpretation of the adsorption behavior is the same for each of metals under investigation..

Research Outcome

CSC sample with size **60 mesh** is found to be optimal for removal of heavy toxic metals from their solutions. Adsorption tendency of the *CSC* to all of the metals show that *the sample CSC* can be used repeatedly for the adsorption of toxic metals from the solution. The effectiveness of *CSC* is approximated to be 80%.

Conclusion

In accordance with the results obtained from this work, coconut shell charcoal can be considered as an effective material for the removal of toxic heavy metals from the solution. This material can be used in treatment of waste water as well as in leaching out the metals such as gold from its solution.

Acknowledgements

The author would like to say many thanks to Professor Dr Myint Myint Sein, Head of the Department of Chemistry, University of Mandalay for her allowance to use research facilities in the Department and providing all the requirements for the preparation of this research area. The author should also need to express his thanks to Professor Dr San San Yi from Department of Chemistry, Moe Nhyin Degree College for her adaptation to measure *SEM* images of *CSC* samples in DSSTR, Pyin Oo Lwin. Author finally wish to describe his heartful thanks to Wah Wah Soe, Swe Zin Nyein, and Htay Su Mar, M. Res. Candidates in 2011, 2012, and 2013 Academic Year respectively, for each of their contributions to this work.

References

1. Atkin, P. W., "Physical Chemistry", 6th Edt., Freeman, New York, 1990, pp. 899-905.

2. Tyagi, O. D. and Mehra, M., "A Text Book of Environmental Chemistry" Anmoi Publications Pvt. Ltd., New Delhi 110.002, India, 2002, p. 117

3. M. Murugan and E. Subramanian, "Studies onDefluoridation of Water by Tamarind Seed, an unvonventional biosorbent ", *J. Of Water and Health*, **04.4,** 2006, p. 453.

Website

1. http://www.ejbiotechnology.equipu.cl/index.php/ejbiotechnology/article/view/v10n5-11/119http://www.ejbiotechnology

2. http://www.filterwater.com

3. http://www.lead.com

4. http://www.cadmium.com

5. http://www.mercury.com