



## Adsorption of Cd(II) and Pb(II) Ions from Aqueous Solution by Activated Carbon

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### Abstract

Heavy metal consider as major environmental pollutants. Many of industrial wastewater effluents contain a wide range of these heavy metals. The adsorption of Cd<sup>2+</sup> and Pb<sup>2+</sup> metal ions from aqueous solution by activated carbon was studied. The results showed that maximum adsorption capacity occurred at 486.9×10<sup>-3</sup> mg/kg for Pb<sup>2+</sup> ion and 548.8×10<sup>-3</sup> mg/kg for Cd<sup>2+</sup> ion. The adsorption in a mixture of the metal ions had a balancing effect on the adsorption capacity of the activated carbon. The adsorption capacity of each metal ion was affected by the presence of other metal ions rather than its presence individually. The study showed the presence of other heavy metals attribute to the reduction in the activated carbon capacity, and the adsorption process was found to obeys the Freundlich isotherm for both ions.

**Keywords:** Adsorption, heavy metal ions, aqueous solution, activated carbon

### 1. Introduction

A great interest in the research for the removal of heavy metals from industrial effluents had concentrated on using materials such as activated carbon, that is easy handle, economical and durable materials. Adsorption process considered as technique for the removing of heavy-metal from industrial, mineral and petroleum industry, (Volesky and Holan, 1995). This process is mainly less cost and can be executed on site, hence, reducing the hazards of transport the toxic materials to the de-pollution sites. The adsorption process is a good alternative for the recovery of metals contained in other media (Gavrilescu, 2004).

The use of carbon for its adsorption qualities was known since 1530 B.C. when charcoal was utilized in the purification of medicines, and, in the field of water treatment, both ancient Egyptians and eighteenth century sailors utilized charcoal lined vessels to provide a clean drinking water. The use of activated carbon filters were introduced in the 1930's for the ultra pure of water in the food industry. Industry has also taken advantages of the unique ability to adsorb a

variety of organic and non-organic compounds by utilizing the activated carbon in industrial wastewater treatment (Benjamin, 1999).

The Freundlich equation has been widely used for many years. This equation which originally proposed as an empirical equation is used to describe the data for the heterogeneity in the adsorbent surfaces, in which the energy term (b) in the Langmuir equation varies as a function of surface coverage (q<sub>e</sub>), that due to variations in the heat of adsorption (Weber and Walter, 1979).

Freundlich studied the adsorption phenomenon and showed that adsorption from solution could be expressed empirically by:

$$q_e = K C_e^{1/n} \quad \dots (1)$$

When, (K and n) are constants, and n > 1 (Lucas and Cocero, 2000).

As Freundlich equation is an empirical equation then it is useful as a means for data description. Data are usually fitted to the logarithmic equations as follows:

$$\text{Log} q_e = \text{Log} K + \frac{1}{n} \text{Log} C_e \quad \dots (2)$$

This equation gives a straight line with a slope of  $(1/n)$  and an intercept equal to the value  $(\text{Log } K)$ , for  $C = 1$ . The intercept is roughly indicated of adsorption capacity.

Freundlich equation generally agrees quite well for the experimental data of a wide range of concentration (Robert and Craft, 2000).

Zenedy and Murphy (2007) found that the equilibrium data for adsorption of mercury onto activated carbon were correlated well with Langmuir and Freundlich equations.

Prasert and Parasaut (2006) found that the activated carbon can be examined for removal of copper and lead from aqueous solution and the Freundlich isotherm models well fitted the data.

Badmus and Anyate (2007) showed that the adsorption isotherm of lead onto activated carbon seemed generally to approach Freundlich models.

Diarati and Taliki (2003) showed that the Freundlich isotherm fits well the data of adsorption of cadmium by powdered activated carbon at 30°C.

Qader and Akhtars (2005) found that the adsorption kinetic study of lead and cadmium individually, the resulted data fits well Freundlich isotherm.

The mechanism of adsorption may be particle diffusion controlled (Ligwa and Addiat, 2003) or a film diffusion controlled depends on many parameters that will dominate which mechanism of the above of favourable depends on the slowest step of the adsorption process that will consider the rate step. Here the result of the amount adsorbed against time for a mixture of the metal ions.

Since adsorption is a particle diffusion controlled ((Ligwa and Addiat, 2005) and this could be effected by the following processes:

- (i) diffusion of the solute from the solution to the film surrounding the particle;
- (ii) diffusion from the film to the particle surface (external diffusion);
- (iii) diffusion from the surface to the surface to the internal sites (surface diffusion or pore diffusion), and
- (iv) Uptake which can involve several mechanisms: physicochemical sorption, ion exchange, precipitation or complexation (Digiano, 1996). The first process is bulk diffusion, the second is the external mass transfer resistance and the third is intraparticle mass transfer resistance.

When the adsorption is particle diffusion controlled, it means that intraparticle mass

transfer resistance is rate limiting. Therefore, in the presence of a mixture of the metal ions, the metal ions (i.e. compete) for the adsorption sites on the adsorbent. This competition affects the diffusion properties of the metal ions, hence decreases the adsorption capacity of the metal ions. Thus, the metal ion that successfully reaches the adsorption site faster depends on the above factors and also on the ionic radii of the metal ions. Competition among the metal ions for adsorption sites deviously affected the adsorption capacity (Ligwa and Addiat, 2003).

It seems that surface attachment might also be taking place on the functional groups on the surface of the adsorbent. More of what happens is volumetric filling of the micro-pores found in the adsorbents. Since adsorption takes place in these micro-pores (Motoyuki, 1990), these results decreases in the amount of metal adsorbed with time, by inspection of the plots, the application of the Lagergren equation (equation 3) shows a zero order reaction. This is true since amount adsorbed remain fairly constant with increased time. The Lagergren equation is given by:

$$\text{Log } (q_e - q) = \text{Log } q_e - K_{ad} t / 2.303 \quad \dots (3)$$

Where  $q$  is amount adsorbed (mg/g) at time  $t$ ,  $q_e$  is amount adsorbed (mg/g) at equilibrium time and  $K_{ad}$  is the rate constant of adsorption ( $\text{min}^{-1}$ ) (Ligwa and Addiat, 2003).

## 2. Scope of Study

In this work activated carbon used as adsorbent for the removal of Cd(II) and Pb(II) ions and the mechanism of sorption were investigated respectively. The effect of having two metal ions in the wastewater had been studied. Since the pollution of the environment with heavy metals is important and as result of many human industrial, agricultural and petroleum activities, it means that these effluents would carry heavy metal ions in solution.

## 3. Materials and Method

All materials used are from the Iraqi market, a solution of  $\text{Cd}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$  and  $\text{Pb}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$  were prepared with initial concentration of 1000 mg/l by the dissolving 2.75 gm of  $\text{Pb}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$  in 2.5 l of distilled water and 1.82 gm of  $\text{Cd}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$  in 2.2 l distilled water. The average particle size used is 400  $\mu\text{m}$ ,

the process of screening was held in the petroleum research and development center lab / Ministry of Oil using screen shaker of type (BAUS). 20 ml of each of two metal ions were mixed and put in a conical flask containing 0.5 g of activated carbon. The flask was uniformly agitated at a temperature of 25oC and optimum pH of 7 using a rotary shaker. Figure (1.a) shows the agitation process using rotary shaker at constant agitation speed.



Fig.1.a. Agitation Process for Different Flasks

The experimental set-up was repeated for time intervals of 20, 30, 40, 50, and 60 min after the end of every (10min) a sample was taken from the flask and the concentration of (Pb, Cd) in the filtrate water was measured using atomic absorption device in the Baghdad environmental directory / Ministry of Environment. Figure (1.b) shows the samples after treatment with activated carbon.



Fig.1.b. The Samples After Treatment with Activated Carbon

#### 4. Results and Discussion

The amount of the adsorbate adsorbed at different time interval for both Cd, Pb ions were

measured and table (1) indicates the values of these amounts.

Table 1, Amount of Adsorbate Adsorbed by Activated Carbon

| Time (min) | Amount Cd adsorbed (mg/kg)×10 <sup>3</sup> | Amount Pb adsorbed (mg/kg)×10 <sup>3</sup> |
|------------|--|--|
| 10         | 548.80                                     | 486.90                                     |
| 20         | 515.20                                     | 477.11                                     |
| 30         | 547.31                                     | 473.20                                     |
| 40         | 542.01                                     | 471.75                                     |
| 50         | 530.57                                     | 475.54                                     |
| 60         | 545.71                                     | 436.71                                     |

Figure (2) show the amount of metal adsorbed against time for activated carbon, 1000 mg/l initial metal ions concentration and 400 μm average particle size.

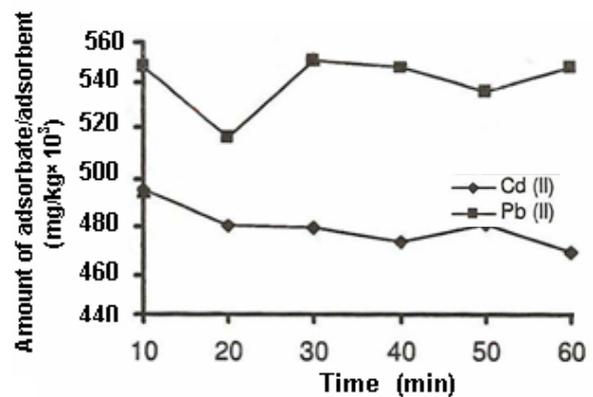


Fig.2. Amount Adsorbed (mg/kg) Verse Time (min) for Cd(II), Pb(II) Ions on Activated Carbon of 400μm Average Particle Size at 1000 mg/l Initial Mixed Metal Ion Concentration

From Figure (2), its clear that the adsorption was unsteady for Pb(II) but varied a little for Cd(II) on activated carbon. The adsorption will expected to become less varied in the curve behaviour as preceding the time interval.

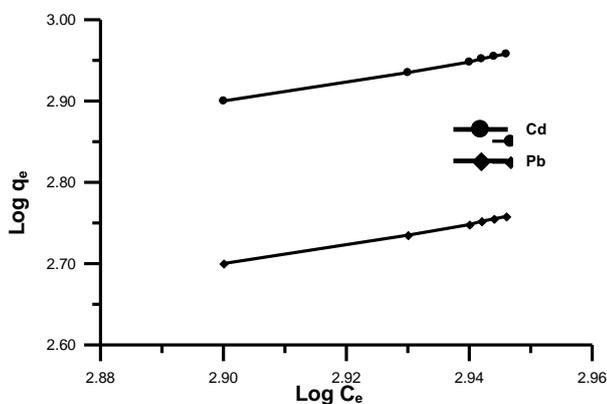
By applying (equation 1) the equilibrium concentration for each ions  $C_e$  at different  $q_e$  values were calculated and tabulated in Table (2).

By applying the linearized form of Freundlich isotherm model, Equation (2) to the data in Tables (1) and (2) and plotting the equation, a straight line will be resulted according to the model isotherm as in Figure (3) which refers to a good

fitting of the data with Freundlich isotherm for both Cd and Pb.

**Table 2,**  
**Equilibrium Concentration  $C_e$  (mg/l) for Cd and Pb**

| Cd     | Pb     |
|--------|--------|
| 862.60 | 878.20 |
| 871.20 | 880.70 |
| 863.17 | 881.70 |
| 864.49 | 882.06 |
| 866.07 | 881.11 |
| 863.57 | 890.89 |



**Fig.3. The Linearized Form of the Equilibrium Concentration for Both Cd and Pb**

## 5. Conclusion

The amount of Cd(II), Pb(II) metal ions in aqueous solutions adsorbed did not increase as time increased as expected. Rather, the amount adsorbed remained fairly constant with time during the competitive sorption. This was attributed to the fact that all the metal ions, will have to be struggling for the same number of adsorption sites at the same time. Therefore, this study significantly reveals that the presence of other heavy metals and chemicals are influential factors and should be design parameters in the treatment and management of heavy metal pollutants using activated carbon.

Furthermore, the fluctuation in the amount of Cd adsorbed with respect to time rather than Pb may attribute to the high affinity of the Pb rather than Cd for adsorption onto activated carbon due to the variation in the electro-charges properties of

both ions. As Pb is more attracted (attached) than Cd on the vacant sites of the activated carbon due to is less positively than Cd. Both Cd and Pb obeys well Freundlich isotherm.

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## دراسة عملية الامتزاز لأيوني الكاديوم والرصاص من محلول مائي باستخدام الكربون المنشط

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### الخلاصة

تعتبر المعادن الثقيلة من اهم الملوثات البيئية وهناك العديد من الصناعات التي تحتوي مياهاها الصناعية على طيف واسع ومختلف من المعادن الثقيلة . يهدف البحث الى دراسة عملية الامتزاز لكل من ايون الكاديوم والرصاص ضمن محلول مائي باستخدام الكربون المنشط وقد وجد ان اعلى قيمة للامتزاز بلغت (3-10×486.9 ملغم/كغم) لايون الرصاص و(3-10×548.8 ملغم/كغم) لايون الكاديوم . وان سعة الامتزاز للايونين بصورة منفردة تقل عند مقارنتها مع سعة الامتزاز عند تواجد الايونين مع بعضهما البعض ضمن المحلول المائي وان تواجد الايونين مع بعضهما البعض ضمن المحلول المائي يؤدي الى الموازنة في التأثير لكل من الايونين على سعة الامتزاز مما تؤدي الى تقليل من سعة الامتزاز ، وان عملية الامتزاز لكلا الايونين يخضعان لموديل فريندلتش الرياضي للامتزاز .