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Adsorption Studies of Pb(II) from Aqueous Solution by Using Activated Carbon of *Datura stramonium* as An Adsorbent

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In the present investigation attempts have been made to assess the efficiency of low cost adsorbent material prepared from *Datura stramonium* for removal of Pb(II) from aqueous solution. Operating variables studied were initial metal ion concentration, pH, temperature and contact time. Equilibrium data fit well with the Langmuir and Freundlich isotherm models. Comprehensive characterization of parameters indicates *Datura stramonium* to be a good adsorbent for adsorption of Pb(II) to treat wastewaters containing low concentration of the metal.

Key Words: Pb(II), Adsorption, Adsorbent, *Datura stramonium*.

INTRODUCTION

Industrial processes generate wastewater containing heavy metal contaminants. Metal ions are the major pollutants in marine, ground, industrial and even treated wastewaters[1]. Since most of heavy metals are non-degradable into non-toxic end products, their concentrations must be reduced to acceptable levels before discharging them into environment. Otherwise these could pose threats to public health and/or affect the aesthetic quality of potable water. According to World Health Organization (WHO) the metals of most immediate concern are chromium, copper, zinc, iron, mercury and lead[2]. These heavy metals have harmful effect on human physiology and other biological systems when they exceed the tolerance levels. Lead can contaminate the environment from anthropogenic sources as well as natural geochemical processes. It can accumulate along the food chain and is not amenable to biological degradation[3,4]. According to the WHO, the maximum limit in drinking water is 0.05 mg/L. In fact there is no safe level of this metal in drinking water and even a very dilute content can cause adverse health effects. Hence, proper treatment of wastewater, which is releasing lead into the aquatic and land systems, is very important.

The most widely used methods for removing heavy metals from wastewaters include ion exchange, chemical precipitation, reverse osmosis, evaporation, membrane filtration and adsorption[5]. Among them, adsorption is found to be the most effective method. Adsorption is a strong choice for removal of heavy metals as it is operationally simple and can adapt to changing wastewater flow rates and compositions. It includes a broad range of carbonaceous materials at a high degree of porosity and large surface area[6] and finds use for the removal of toxic, biodegradable and non-biodegradable substances from wastewaters. It is attractive as it can treat wastewater to acceptable quality suitable for reuse. Many investigators have studied the feasibility of using inexpensive alternative materials like pearl millet husk,date pits,saw dust,buffing dust of leather industry, coir pith, crude oil residue, tropical grass,olive stone and almond shells, pine bark, wool waste,coconut shell *etc.*, as carbonaceous precursors for the removal of metal ion from water and wastewater[7,8]. As a result, cost-effective alternate technologies involving removal of heavy metals from wastewater are being sought to meet discharge standard.

In the present investigation, attempts have been made to assess the efficiency of low cost adsorbent material prepared from *Datura stramonium* (largely populated plant in western Rajasthan) for removal of Pb(II) from synthetic wastewater. This study determines the parameters that influence adsorption process such as pH of the solution, initial ion concentration, contact time and adsorbent dose. The equilibrium data of adsorbents used for the adsorption of metal ion from aqueous solution were analyzed in light of the various isotherm models.

EXPERIMENTAL

Preparation of activated carbon from *Datura stramonium* (ACDS): The naturally dried stems and leaves of the plant *Datura stramonium* was obtained locally. It was cut into small pieces. These were then treated with concentrated sulphuric acid (five times its volume) and kept in oven at 150 ºC for 24 h. It was filtered and washed with distilled water repeatedly to remove sulphuric acid (washing tested with two drops of barium chloride solution) and finally dried and powdered using mortar and pestle. The adsorbent is sieved to 40-60-mesh size and heated at 150 ºC for 2 h. This material was used as an adsorbent to study adsorption of metal ions at different pH. The physical characteristics of adsorbent, like particle size, pH solubility in water, solubility in 1N HCl and density are 40-60, 7.0, nil, nil and 0.431, respectively.

Preparation of stock solution: In order to have waste of uniform characteristics and to avoid interferences of other element the synthetic wastewater was prepared this is called stock solution. Different concentrations of metal ion were prepared from this stock solution. All chemicals employed for the analysis were AnalR or high grade purity. 0.825 g lead nitrate was weighed and dissolved in distilled water and the volume was made up to 1000 mL to give 50 ppm Pb(II) stock solution.

Method of batch adsorption studies: Bach adsorption studies were carried out to study the effect of pH (3, 4, 5, 6, 7 and 8), contact time (15-120 min), adsorbent dose (2-18 g/L) and initial metal ion concentration (40-150 mg/L) at room temperature using stopper bottles. The initial pH of solution was adjusted by using 0.05N HCl or 0.1N NaOH without changing the volume of the sample.

The removal efficiency (E) of adsorbent was defined as:

$$E\ (\%) = \frac{(C_o - C_e)}{C_o} \times 100$$

where; C_o and C_e are the initial and equilibrium concentration of metal ion solution (mg/L), respectively.

RESULTS AND DISCUSSION

Effect of contact time: In adsorption system, the contact time play a vital role irrespective of the other experimental parameters, affecting the adsorption kinetics. There was an appreciable increase in per cent removal of lead up to 75 min as shown in Fig. 1, thereafter further increase in contact time, the increase in removal was very small. Thus the effective contact time (equilibrium time) is 75 min for Pb(II) and it is independent of initial concentration.

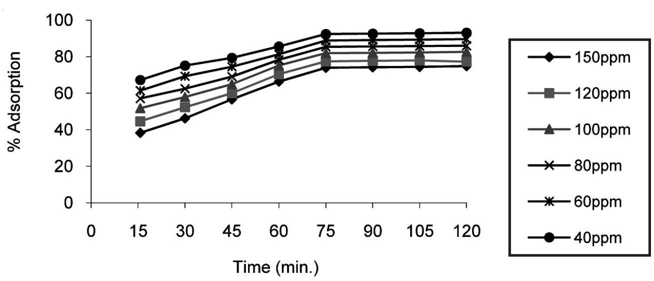

Fig. 1. Effect of contact time on removal Pb(II) at different concentration by activated carbon of *Datura stramonium* at constant pH 7

Effect of adsorbate concentration: Effect of initial lead concentration over the per cent removal of lead is shown in Fig. 2 and shows that as the concentration of lead in solution increases, the per cent removal of lead decreases. The per cent removal with *Datura stramonium* was found to be 92.4 % at the lead concentration of 40 ppm. Hence the effective adsorbent concentration of lead is 40 ppm.

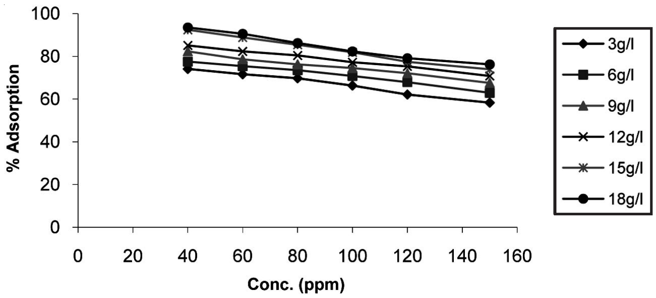

Fig. 2. Effect of initial concentration of Pb(II) on percent removal by15 g/L of activated carbon of *Datura stramonium* at equilibrium contact time 75 min and at pH 7

Effect of pH: The adsorption of metals was found to be strongly dependent on the pH of the solution. The adsorptive capacity of the activated carbon of *Datura stramonium* was dependent on the pH of the lead solution; at low pH adsorption percentages are small. In between pH values 6 to 7 these percentages increase sharply, attaining values that stay almost constant as shown in Fig. 3. There after the per cent removal decreases with increase in pH.

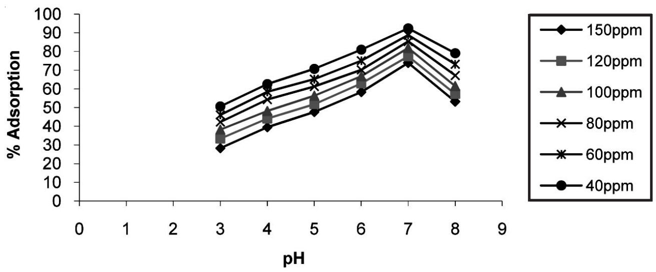

Fig. 3. Effect of pH on removal of Pb(II) at different concentration by 15g/L of activated carbon of *Datura stramonium* at constant contact time 75 min

Effect of adsorbent dose: The effect of adsorbent dose on per cent removal of Pb(II) is shown in Fig. 4. Adsorbent dose was varied (3, 6, 9, 12, 15, 18 g/L) and performing the adsorption studies at pH 7. The present study indicated that the amount of Pb(II) adsorbed on activated carbon of *Datura stramonium* increase with increase in the activated carbon of *Datura stramonium* dose up to 15 g/L and thereafter further increase in dose the increase in removal was very small. Thus the optimal dose is 15 g/L.

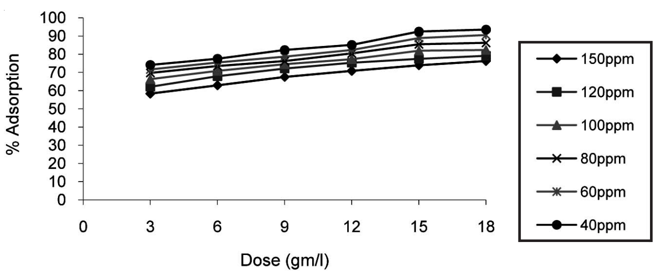

Fig. 4. Effect of activated carbon of *Datura stramonium* dose on per cent removal of Pb(II) at equilibrium contact time 75 min and at effective pH 7

Adsorption isotherm models for Pb(II): The Langmuir adsorption isotherm and the Freundlich isotherm are two common isotherms used to describe equilibria.

Freundlich isotherm is represented by the following equation[9]:

$$\log q_e = \log K_f + 1/n \log C_e$$

where: q_e = the amount of the adsorbate adsorbed per unit mass of adsorbent (mg adsorbate/g adsorbent); K_f = adsorption capacity; C_e = equilibrium concentration of adsorbate (mg/L); n = adsorption intensity.

Langmuir Isotherm is represented by the following equation[10]:

$$C_e/q_e = 1/Q_m b + C_e/Q_m$$

Q_m and b is Langmuir constants.

Langmuir and Freundlich isotherms for Pb(II) were found to be linear showing the applicability of the isotherms. Value of n, is 2.3568 for Pb(II) at effective dose and contact time, indicates good adsorption potential of the activated carbon of *Datura stramonium*. Value of R_L was 0.0780 for 40 ppm Pb(II) solution. Values of R_L show the adsorption to be more favourable. Therefore from the present adsorption study, it can be stated that Freundlich and Langmuir adsorption equations are found to be better fitted (r = 0.999) as shown in Tables 1 and 2.

TABLE-1
LANGMUIR AND FREUNDLICH CONSTANTS FOR ADSORPTION OF ION AT 30 °C

Ion	Langmuir			
	Q_m (mg/g)	b (L/mg)	R_L	r^2
Pb(II)	8.928	0.0983	0.0780	0.9839
Ion	Freundlich			
	K_f	N	r^2	r
Pb(II)	1.567	2.356	0.9973	0.9986

r = Correlation coefficient; r^2 = Coefficient of determination.

TABLE-2
LINEAR REGRESSION DATA FOR LANGMUIR AND FREUNDLICH ADSORPTION ISOTHERM FOR ADSORPTION OF Pb(II)

Adsorbent dose (g/L)	Langmuir isotherm (Linear equation)	Freundlich isotherm (Linear equation)
3	Y = 0.0215x + 0.8154	Y = 0.5965x + 0.4144
6	Y = 0.0385x + 1.3730	Y = 0.6163x + 0.1502
9	Y = 0.0551x + 1.6689	Y = 0.5980x + 0.0611
12	Y = 0.0740x + 1.7553	Y = 0.5767x + 0.0209
15	Y = 0.1120x + 1.1383	Y = 0.4243x + 0.1953
18	Y = 0.1326x + 1.2167	Y = 0.4126x + 0.1531

Adsorption kinetics of Pb(II)

Pseudo second order equation:

$$t/q_t = 1/h_0 + 1/(q_e)t$$

where: h_0 is the initial adsorption rate (mg/g min); q_e is the amount of metal ion adsorbed at equilibrium (mg/g); q_t is the adsorbed at time t (mg/g).

The initial adsorption rate, h_0, as $t \rightarrow 0$ is defined as:

$$h = K_2 q_e^2$$

where: K_2 is the Pseudo second order rate constant for the adsorption process (g/mg min).

The present Pb(II) adsorption experimental data at pH 7 are tested for kinetic modeling by linear regression plots.

The estimated model and the related statistic parameters are based on linear regression ($R^2 > 0.98$) values, the kinetics of Pb(II) adsorption onto activated carbon of *Datura stramonium* can be described well by pseudo second order (R^2 = 0.9999, 1, 1). The values of K_2 for Pb(II) are 9.009×10^{-3}, 1.2857×10^{-2}, 1.5743×10^{-2}, respectively for 40, 60, 80 ppm solution. The results clearly indicate that this model fit progressively well with increasing adsorbate concentration. The experimental adsorption data fits well with pseudo second order kinetic model as shown in Table-3.

TABLE-3
PSEUDO SECOND ORDER KINETIC MODELS AND OTHER STATISTICAL PARAMETERS AT pH 7

Kinetic model	Parameters	40 ppm	60 ppm	80 ppm
Pseudo second order	q_e	53.76344	66.66667	82.64463

Conclusion

The study indicates that activated carbon of *Datura stramonium* has rapid adsorption rate and good adsorption capacity for lead. The Pb^{2+} adsorption was found to be dependent on initial lead concentration, contact time, pH, temperature and amount of adsorbent. The adsorption of lead follows Freundlich and Langmuir isotherm models. Kinetic of lead adsorption obeyed the pseudo-second order model, which suggests chemisorption as the rate-determining step in adsorption process. Maximum adsorption 92.4 % of lead occurred at pH 7. Since *Datura stramonium* plant are highly abundant and its activated carbon can be easily synthesized at relatively low cost, the adsorbent could be applied for the removal of lead from wastewaters.

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