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Removal of Lead from Aqueous Solution using Unglazed Porcelain

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Abstract: A detailed study was conducted to remove lead from aqueous solution by using unglazed porcelain. The optimum dose of unglazed porcelain adsorbent can remove 96% Pb, from aqueous solution containing 10 mg/l of initial concentration. The effect of pH range on adsorbent sample was selected between pH 2 to pH 12 and optimum value of this parameter was pH 6. The granular porcelain was used adsorbent in suspension form was filtered and filtrate was analysed for the Lead (Pb) concentration in aqueous solution with help of atomic absorption spectrophotometer using air acetylene gas. Column operations were also carried out on the actual waste for evaluation of break through capacity and lead removal from actual waste. The data collected during experiments have shown good results for different parameters, at optimum concentration (10 mg/l) for optimum pH 6, at the optimum does (400 mg/l). The percentage adsorption was maximum (99%) under these conditions. The data also follows the Langmuir and BET isotherms and their equations.

Keywords: Unglazed porcelain, Lead, Wastewater, pH, Isotherm

I. INTRODUCTION

The awareness of increasing water pollution implies studies concerning water treatment. Removal of heavy metals from industrial wastewater is of primary importance. The use of natural materials for heavy metals removal is becoming a concern in all countries. The application of low-cost natural adsorbents including carbonaceous materials, agricultural products and waste by-products has been investigated in many previous studies [1-3] which have been recognized as potential alternative to the conventional technologies such as precipitation, ion exchange, solvent extraction and liquid membrane for removal of heavy metals from industrial wastewater because these processes have technical and /or economic constraints. The important toxic metals i.e., Cd, Zn Cr, Cu and Pb finds its way to water bodies through from such industries as metal plating industries of cadmium, nickel and lead battery industries, pigments, stabilizers and alloys [4].

Lead is used as prime material for lead storage batteries and it is present in aqueous solution as waste water generated from battery manufacturing industries. Lead poisoning can cause convulsions, coma and even death. Intermediate lead poisoning may results in gastrointestinal, haematological and cardiovascular disorders while low level toxicity is associated with decrease intelligence impaired neurobehavioral development stunted growth and decreased hearing capacity.

The conventional methods for heavy metal removal from aqueous solution of wastewater include reduction, precipitation, ion exchange, electrochemical reduction evaporation reverse osmosis and adsorption. Most of these methods involve high capital cost with recurring expenses, which are not suitable for small scale industries. Studies on effluents of aqueous solution bearing heavy metals have revealed that the adsorption to be highly effective, cheap and easy method among the physico-chemical treatment processes owing to high cost and difficult procurement of activated carbon efforts are being directed towards finding efficient and low cost materials.

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Removal of lead by adsorption by using fly ash [5], sawdust [6] soil [7] clay [8] modified Acacia bark [9], chlorella vulgaris coconut coir dust [10], blast furnace slag [11] groundnut hull treated with EDTA [12], waste tyre- rubber [13], saw dust and jute dust treated with dyes, montimorllointe and kaolinite [14] china clay [15], waste tea leaves [16] and fruit peel of orange [17].

The present study is aimed at selection of a low cost adsorbent, i.e., unglazed porcelain which can adsorb lead from the aqueous solution of wastewater. In all batch studies, the granular porcelain was used adsorbent in suspension form was filtered and filtrate was analysed for the Lead (Pb) concentration in aqueous solution of wastewater with help of atomic absorption spectrophotometer using air acetylene gas. Column operations were also carried out on the actual waste for evaluation of break through capacity and lead removal from aqueous solution of actual waste. Final concentration of Lead (Pb) from different samples of aqueous solution of actual waste were analysed with help of atomic absorption spectrophotometer.

In order to assess the performance of the adsorbent, a number of parameters like the effect of pH, contact time, adsorbent concentration, thermodynamics study, and metal ion /adsorbent ratio were also investigated.

II. MATERIALS AND METHODS

Adsorbent

In the present study unglazed porcelain was used as an adsorbent for removal of Pb from aqueous solution. This adsorbent was obtained by broken pieces of heater coil plates (i.e., waste material). These porcelain pieces were crushed and washed thoroughly with double distilled water to remove the adhering dirt and finally dried in an oven at 100-105°C for 24 hr. After drying the adsorbent was sieved through IS mesh size sieve and used as such.

Adsorbate Solution

To avoid non uniform characteristics of synthetic waste stock solution of lead was prepared (1000 mg/l) by dissolving the desired quantity (1.5941 g) of lead nitrate in distilled water.

Adsorption Studies

Adsorption studies were carried out by batch-processes. A 0.5 g sample of adsorbent was placed in a conical flask in which 50 ml solution of metal ion of desired concentration was added and mixture was shaken in shaker. The mixture was then filtered and final concentration of metal ion was determined in the filtrate by atomic absorption spectrophotometer (Model GBC – 902). The amount of metal ions adsorbed was calculated by subtracting final concentration from initial concentration.

Effect of Concentration

The effect of concentration on adsorption of lead was studied as follows:
100 ml lead solution of desired initial concentration was prepared by diluting the stoke solution. 50 ml of this solution was taken in a conical flask and treated with 0.5 g adsorbent and left for 24 hr contact time.

Effect of pH

The effect of pH on adsorption of lead was studied as follows:
100 ml lead solution was taken in a breaker. The pH of solution was adjusted by adding dilute solution of HCL or NaOH. 50 ml of (10 ppm) this solution was taken in conical flask and treated with 0.5 g adsorbent and after equilibrium the final concentration of lead was determined.

Effect of Adsorbent Dose

The effect of adsorbent dose on adsorption of lead was studies as follows:

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100 ml lead solution was taken in a beaker, 50 ml of this solution was taken in a conical flask and treated with 0.1 g adsorbent dose and final concentration of lead was determined. This process was repeated by varying the dose amount up to 1.0 g.

Breakthrough Capacity
Break through capacity of adsorbent was analyse as follows: 250-ml of lead solution (10 ppm) was passed through the column containing 1.0 g adsorbent with a flow rate of 5 ml/min. The effluent was collected in 10 ml fractions and lead (Pb) was determined in each fraction.

Removal of Pb Through
Synthetic water: Removal of lead from aqueous solution of synthetic wastewater was carried out by batch as well column operations. 50 ml aqueous solution of synthetic wastewater containing 10 mg/l of lead was taken in conical flask and its pH was adjusted to 6.0 and then treated with 1 gm adsorbent final concentration of wastewater was determined.
Actual water: Removal of lead from aqueous solution of actual wastewater was carried out by batch and column process. 50 ml aqueous solution of actual wastewater was taken in a conical flask then measured its pH after which it was treated with 1 gm adsorbent does then final concentration of wastewater was determined.

III. RESULTS AND DISCUSSION

Effect of Concentration
The effect of concentration on adsorption behaviour of metal ion is shown in Fig. 1, Percentage adsorption decreases with increase in concentration. It can be concluded that maximum adsorption of Lead at 10 mg/l percent removal nearly constant. This constant removal nature of curve shows due to exhaustion of capacity of unglazed porcelain for higher concentration in aqueous solution. Data is shown in Table 1.

Table 1. Effect of initial Pb concentration on percentage adsorption.

Intial concentration (ppm)	Final concentration (ppm)	Adsorption (%)
5	0.6	88
10	0.8	92
20	3.2	87.4
30	6	80
40	11	72.5
50	29	58
60	35	41.6
70	41	41.4
80	46	42.5
90	52	42.2
100	58	42

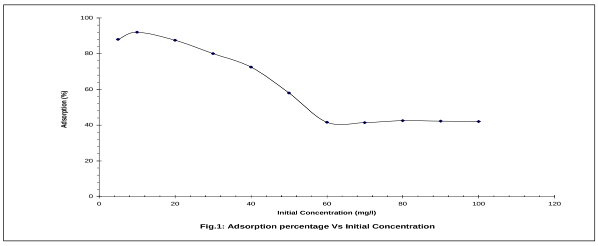

Fig. 1. Adsorption percentage vs. initial concentration.

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Effect of pH

The effect of pH on adsorption of Lead by unglazed porcelain is presented in Fig. 2. The pH of aqueous solution is an important controlling factor in the adsorption process. At lower pH value the H+ ion compete the metal cation for exchange sites in the system, thereby partially releasing latter. The heavy metal cations are completely released under circumstances of extreme acidic condition. The percent adsorption is minimum at pH 2.4 and increases as aqueous solution pH increased. The maximum adsorption occurs at pH 6 (99%) but adsorption became constant when aqueous solution pH is increased further. The minimum adsorption at low pH (2.4) may be competitive adsorption of H+ ions due to their high mobility and concentration in aqueous solution. The hydrogen ions are preferentially adsorbed compared to metal ions. The data is shown in Table 2.

Table 2. Effect of pH on adsorption of lead (conc. of Pb = 10 ppm).

Initial pH	Final pH	Adsorption (%)
2.45	1.9	44
4	4.2	77
5	4.9	88
6	6.1	99
7	6.2	99
8	6.6	99
10	6.8	99
12	-	99

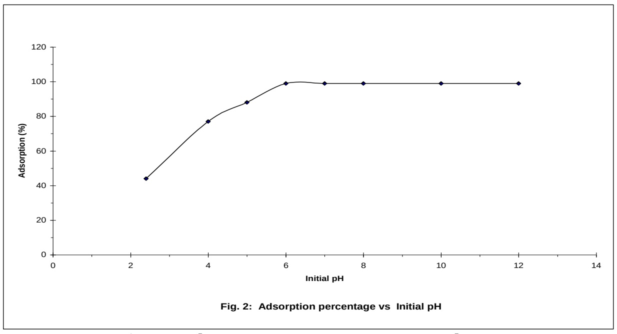

Fig. 2. Adsorption percentage vs. initial pH.

Effect of Adsorbent Dose

The effect of adsorbent dose in aqueous solution on adsorption behaviour of metal is shown in Fig. 3. Adsorption increases with increasing adsorbent dose amount in aqueous solution. The maximum adsorption of metal ion occurs at 0.4 g but adsorption remains constant when dose in aqueous solution is increased further. The Data is shown in Table 3.

Table 3. Effect of adsorbent dose on adsorption of lead (V = 50 ml, Conc. of Pb 10 ppm).

Dose	Final concentration (ppm)	Adsorption (%)
100	1.2	88
200	0.8	92
300	0.5	95
400	0.4	96
600	0.4	96
800	0.4	96
1000	0.4	96

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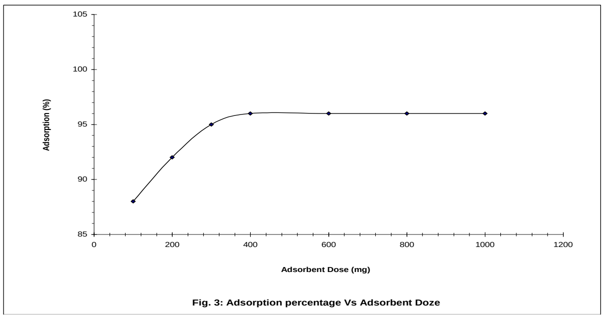

Fig. 3: Adsorption percentage Vs Adsorbent Doze

Fig. 3. Adsorption percentage vs. adsorbent dose.

Adsorption Isotherm

The adsorption data has been analysed in the light of Langmuir and Freundlich adsorption models. The Langmuir equation may be written as:

$$x/m = \frac{abc}{1+ac}$$

Where is metal up take per unit weight of adsorbent c is the equilibrium concentration of metal ions (mg/l) a and b are Langmuir constants relating to adsorption, Capacity and adsorption energy respectively. Basically Langmuir isotherm is valid for monolayer adsorption on the surface of adsorbent containing a finite numbers of identical sites. The plot of 1/(x/m) against 1/C gives a straight-line (Fig. 4) showing the applicability of Langmuir isotherm.

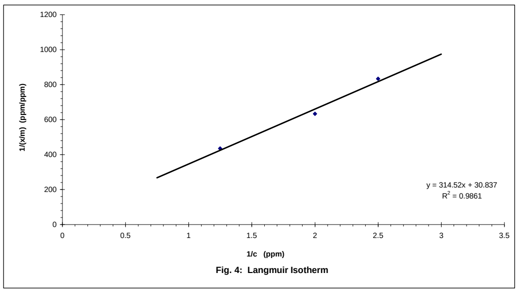

Fig. 4: Langmuir Isotherm

Fig. 4. Langmuir isotherm.

The Freundlich adsorption isotherm was also applied for the adsorption of lead (Pb) metal ion.

$$\text{Log } x/m = \log k + 1/n \log c$$

Where c is equilibrium concentration (mg/l), x/m is amount adsorbed per unit weight of adsorbent (mg/l), k and n are Freundlich constants. The linear plot of (x/m) vs. C on log-log graph indicates that adsorption of metal ions also follows Freundlich isotherm (Fig. 5). In the adsorption study, BET adsorption isotherm was also drawn for the Lead removal.

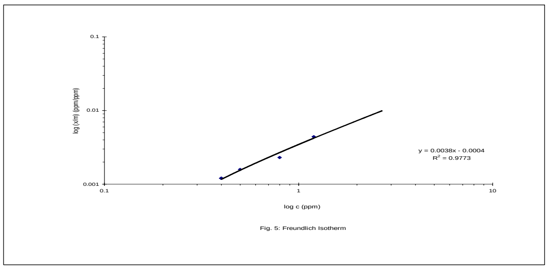

Fig. 5: Freundlich Isotherm

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Fig. 5. Freundlich isotherm.

$$\frac{x}{m}=\frac{AC.Xm}{(Co-C)[1+(A+1)(C/Co)]}$$

Or, $$\frac{C}{(Co-C)(x/m)}=\frac{1}{A(Xm)}+\frac{A-1}{A(Xm)}(C/Co)$$

Where,

x	=	amount of solute adsorbed (mg)
m	=	weight of adsorbent (mg)
Xm	=	amount of solute adsorbed in forming a complete monolayer (mg/g)
C_o	=	saturation concentration of solute (mg/1)
C	=	concentration of solute in solution at equilibrium (mg/1)
A	=	a constant to describe the energy of interaction between the solute and the adsorbent surface.

The data yields a straight line (Fig. 6) on the BET isotherm, which shows multilayer adsorption (more than one thick layer) without affecting the neighbouring adsorption sites on the surface of adsorbent.

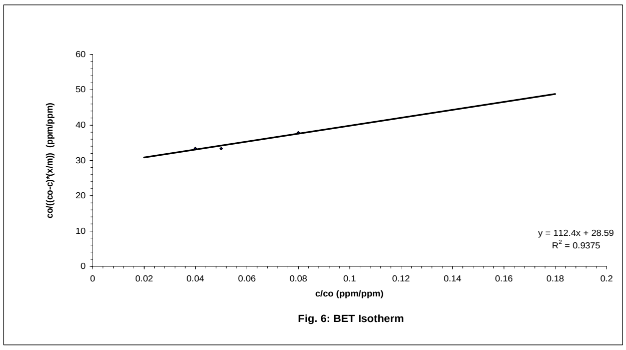

Fig. 6. BET isotherm.

Break Through Capacity

In order to explore the practical utility of the adsorbent, its break through capacity was determined. It was found that 60 ml of water contains 0.6 mg of Pb can be removed from aqueous solution of wastewater without detecting Pb in effluent.

Removal/Recovery of Lead from Aqueous Solution of Battery Wastewater

Unglazed porcelain as an adsorbent was utilized for removal and recovery of lead from battery wastewater by column operation. The aqueous solution of battery wastewater collected from battery industry in Aligarh (India) was analysed in the laboratory (Table 4) and characteristics of actual battery waste results are shown in Table 5.

Table 4. Characteristics of acid battery waste.

S. No.	Sample	Concentration (mg L^{-1})
1	Zinc (Zn)	8.8
2	Cadmium (Cd)	0.1
3	Chromium (Cr)	3
4	Nickel (Ni)	8.7
5	Lead (Pb)	136
6	Copper (Cu)	5.9

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7	pH	3.68

Table 5. Removal of lead from actual battery waste.

Sample	Volume	Initial Concentration (ppm)	Final Concentration (ppm)	Percentage removal
1	50	136	97	30

IV. CONCLUSION

In the present study, characterization and treatment of acid batteries waste in aqueous solution using unglazed porcelain as an adsorbent, the following conclusions were made. Unglazed porcelain shows good adsorption potential for Pb metal removal from aqueous solution. It can be utilized for treatment of lead containing industrial effluent It is found that synthetic waste at 10 mg/l of initial concentration of lead, the percentage removal of lead is maximum. The result shows that maximum lead removal efficiency (99%) was achieved at optimum pH 6. The optimum dose of unglazed porcelain adsorbent (400 mg) can removed 96% Pb, from wastewater containing 10 mg/l of initial concentration. The data collected during experimental studies, fit for Langmuir, Freundlich and also BET isotherm, their equations are given below:

$$x/m = \frac{abc}{1+ac} \qquad \text{(Langmuir Eqn.)}$$

$$\log x/m = \log k + 1/n \log c \qquad \text{(Freundlich Eqn.)}$$

$$\frac{x}{m} = \frac{AC.Xm}{(Co - C)[1 + (A+1)(C/Co)]} \qquad \text{(BET Eqn.)}$$

The concentration of lead in actual waste was 136 mg/l and because of higher concentration, it gives lower efficiency. The data obtained from Lab scale study is quite helpful in designing and analysing the performance of the adsorbent. According to present study, it is suggested that unglazed porcelain adsorbent can be used in practice with two-stage process for treatment of battery industry effluent due lower removal efficiency at higher concentration in aqueous solution of wastewater. Adsorption potential of unglazed porcelain material for lead is promising and needs further study and standardization of treatment process.

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