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Adsorption of Lead from Industrial Wastewaters using Sterculia Foetida Shell Activated Carbon

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Abstract: Activated carbon prepared from agricultural wastes has often proved to be effective in the removal of heavy metals from industrial wastewaters. This study has focused on the adsorption of lead using carbonized shells of the fruit of *Sterculia foetida*. The initial concentration of lead ions was varied and the influence of contact time, adsorbent dosage, pH and initial metal concentration on adsorption process were studied. The temperature and agitation speed were kept constant at 27 ± 2 °C and 200 rpm respectively. The maximum lead removal percentage was observed to be 96.68 % at an adsorbent dosage of 0.6 g per 50 ml of solution, pH 5, initial lead concentration of 65 mg/l and contact time of 110 minutes.

Keywords: Heavy metals, industrial waste-waters, lead ions, *Sterculia foetida*, adsorption

I. INTRODUCTION

The discharge of heavy metals present in industrial wastewaters to the environment has posed a serious problem because of their toxicity to all forms of life. Often, investigations have been carried out to treat heavy-metal bearing waste-water effectively and economically.

Lead is a heavy metal which is used as the raw material for the manufacture of storage batteries, printing, paints, pigments, photographic materials, matches and explosives. These manufacturing processes produce lead bearing waste water which has to be treated before being released.

Various processes have been proposed for the removal of lead from wastewaters such as precipitation, coagulation, ion exchange and reverse osmosis. However, there has always been a limitation to these methods. Heavy metal removal using activated carbon is simple in design and efficient in operation. It is identified as one of the most efficient ways for wastewater treatment. In order to resolve the issue of high cost of activated carbon, researchers came up with the idea of preparing activated carbon to remove heavy metals from industrial wastewaters.

This study has focussed on the use of dry *Sterculia* shells, an agricultural waste, for preparing low-cost adsorbent material for the removal of lead from aqueous solutions. The effect of parameters such as pH, contact time, adsorbent dose and initial metal concentration on adsorption has been studied.

II. EXPERIMENTAL PART

A. Materials and Methods

Sterculia foetida shells were collected and sun dried for 5 days. They were broken into small pieces and then put inside a furnace at 800 °C for 2.5 hours, so that carbonization can take place. The activated carbon particles were washed with distilled water and put inside an oven at 100 °C for 10 minutes, so as to remove moisture present in them.

Different samples of lead solutions were prepared by varying the initial concentration from 20 ppm to 120 ppm. Contact time was varied to study the effect of contact time, and adsorbent dosage was differed to study the effect of adsorbent dosage. Atomic Adsorption Spectroscopy (AAS) was used to analyze the treated samples.

100 mL flasks were used to carry out the experiments. The total volume of the mixture was kept at 50 mL. pH values were varied from 2 to 8 and effect of contact time on adsorption was investigated. The amount of adsorbent dosage was varied between 0.1 and 1 mg/ 50 mL of solution.

The temperature was 27 ± 2 °C and agitation speed was kept at 200 rpm for all experiments. After equilibrium, 20 mL of samples were taken from the flasks and filtered through filter paper. The concentration of heavy metals in the solutions was determined using Atomic Adsorption Spectrophotometer (AAS). The percentage removal of lead ions was determined using the formula:

$$\% \text{ removal} = \frac{C_0 - C_e}{C_0} * 100 \quad (1)$$

III. RESULTS AND DISCUSSIONS

A. Effect of pH

One of the most important factors in the study of adsorption of ions is the pH of the solution. In order to study the effect of pH on metal adsorption, the adsorption was carried at various pH. It is observed from fig.1 that rate of adsorption increases with increase in pH from 2 to 6, and decreases on increasing pH from 6 to 8. This is because when pH is less than 2, higher concentration of H^+ ions compete with $Pb(II)$ ions for the surface of adsorbent which hinders $Pb(II)$ ions from getting adsorbed. At pH greater than 6, the $Pb(II)$ ions get precipitated due to hydroxide anions forming lead hydroxide precipitate. The optimum pH value was found to be 5.

B. Influence of Contact Time

A lead solution of concentration 60 ppm was taken and 0.6 gram of the adsorbent was added to it. The solution was stirred at a constant rotational speed of 200 rpm for various time durations ranging from 20, 40, 60, 80, 100, 110, 120, 140, 160, 180 and 200 min. Then, the mixture was filtered and the filtrate analyzed using the AAS. A graph was plotted to study the effect of contact time on adsorption. It can be clearly seen from fig. 2 that the optimum contact time is 110 minutes.

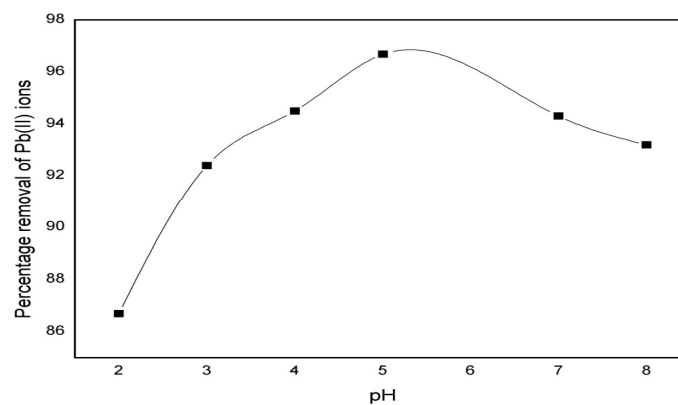


Fig. 1 Effect of pH on adsorption rate of $Pb(II)$ ions onto activated carbon prepared from *Sterculia foetida* shells

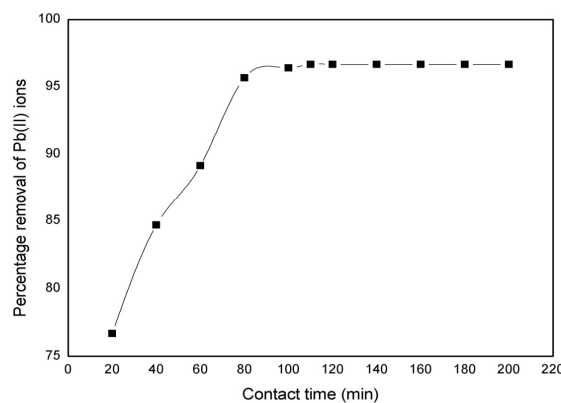


Fig. 2 Effect of contact time on adsorption rate of $Pb(II)$ ions onto activated carbon prepared from *Sterculia foetida* shells

C. Influence of Adsorbent Dosage

From fig.3, it is observed that as the amount of adsorbent is increased gradually from 0.1 g to 1 g, the adsorption of lead ions increases linearly. The maximum adsorption is observed at the adsorbent dose of 0.6 g when 96.68 % of lead removal takes place. Furthermore, it is seen that increase in adsorbent dosage beyond 0.6 g does not increase lead removal beyond 96.68 %. Therefore, it can be seen that 0.6 g of the adsorbent is sufficient to remove the maximum possible lead ions using *Sterculia* shells. For the 0.1 g to

0.6 g of adsorbent, the adsorption rate increases for the 0.1 g to 0.6 g of adsorbent due to the increasing availability of more adsorbing sites at high doses.

D. Effect of Initial Lead Concentration

The initial concentration of a metal ion in solution has a great effect on the rate of adsorption. Different concentrations of lead ions (20 ppm, 40 ppm, 60 ppm, 70 ppm, 80 ppm, 100 ppm and 120 ppm) were studied for their rates of adsorption. It is observed from fig.4 that the rate of adsorption increases with increase in the initial lead concentration upto a point where the adsorbent becomes saturated. At higher initial concentration, there is an increase in the affinity of lead ions towards the active sites. Since the number of active sites is limited, they become saturated at a certain concentration. It is seen from fig. 4 that at an initial lead concentration of 65 ppm, the percent removal of lead ions is 96.68 %.

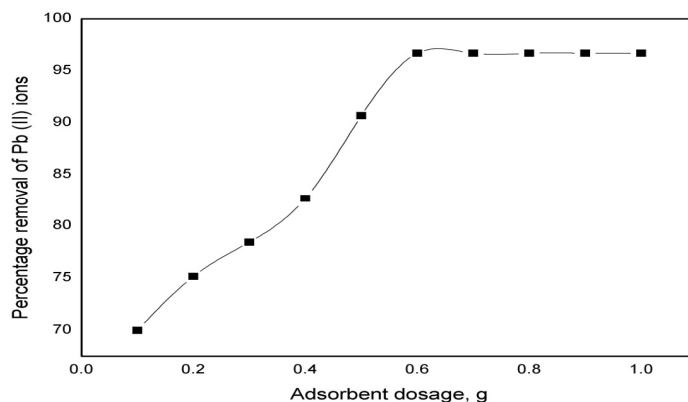


Fig. 3 Effect of adsorbent dosage on adsorption rate of Pb(II) ions onto activated carbon prepared from *Sterculia foetida* shells

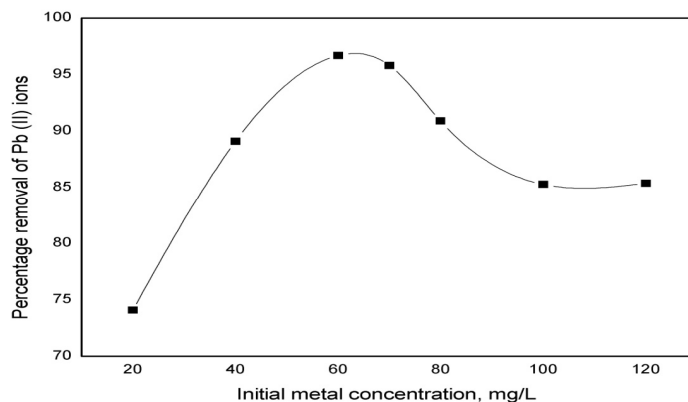


Fig. 4 Effect of initial metal concentration on adsorption rate of Pb(II) ions onto activated carbon prepared from *Sterculia foetida* shells

IV. ADSORPTION ISOTHERMS

Langmuir adsorption isotherm and Freundlich adsorption isotherms have been used to relate the amount of adsorbed metal ions per unit mass of adsorbent (q_{eq}) and the metal concentration in solution (C_{eq}) at equilibrium.

A. Langmuir adsorption isotherm

The mathematical model of Langmuir adsorption isotherm is given by

$$q_e = \frac{q_m b C_e}{1 + b C_e} \tag{2}$$

where q_e is the adsorbed metal ions (mg/g), q_m is the maximum sorption capacity for monolayer coverage (mg/g), b is the constant related to the affinity of the binding site (L/mg), and C_e is metal ions concentration in the solution at equilibrium (mg/L).

B. Freundlich Adsorption Isotherm

The Freundlich equation is an empirical relationship where it is assumed that the adsorption energy of binding to a site on an adsorbent depends on the occupation of the adjacent sites.

The mathematical model of this isotherm is

$$q_e = KC_e^{1/n} \tag{3}$$

where q_e is the adsorbed metal ions (mg/g), C_e is metal ions concentration in the solution at equilibrium (mg/L), K (mg/g) (L/mg)^{1/n} and n are Freundlich constants related to adsorption capacity and adsorption intensity respectively.

The batch adsorption isotherms for Pb(II) ions using the above models have been shown in table 1.

The value of R^2 for Langmuir adsorption isotherm is more nearer to 1 than Freundlich adsorption isotherm. This indicates that Langmuir adsorption isotherm better suits the experimental data.

Table I : Batch adsorption isotherms for the removal of Pb(II) ions onto activated carbon prepared from *Sterculia foetida* shell

Model	Parameters	Value
Freundlich equation	$K(\text{mg/g})(\text{L/mg})^{(1/n)}$	6.9853
	n	1.708
	R^2	0.9552
Langmuir equation	$q_m(\text{mg/g})$	104.834
	b (L/mg)	0.1611
	R^2	0.9812

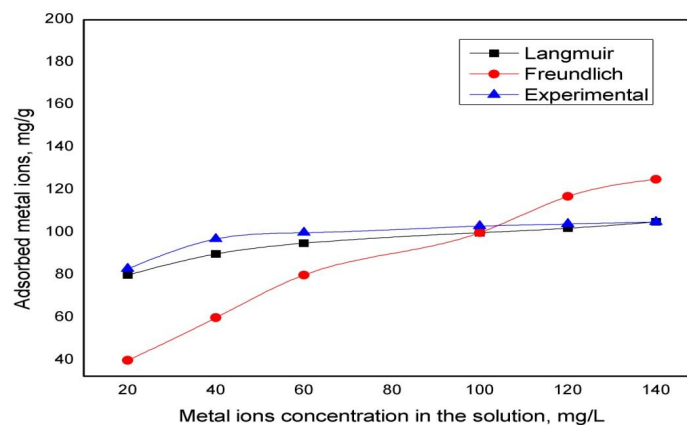


Fig. 5 Comparison of the adsorption isotherms with the experimental data

V. CONCLUSIONS

The present study shows the batch adsorption of lead ions onto activated carbon prepared from the dried shells of *Sterculia foetida*. The rate of adsorption was found to be dependent upon pH, contact time, adsorbent dosage and initial lead concentration. The maximum adsorption of lead ions was found between pH values of 4 and 6. The experiments show that the rate of adsorption was rapid and the adsorption equilibrium was achieved in 110 min of contact time. Langmuir adsorption isotherm was found to better suit the experimental data than Freundlich isotherm. The maximum adsorption was found to occur at 0.6 g of adsorbent. The maximum adsorption capacity was found to be 104.74 mg lead/gram of adsorbent. Thus, agricultural wastes such as *Sterculia foetida* shells can be used as good adsorbents for removing lead ions from industrial wastewaters for reduction in environmental pollution.



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