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Adsorption of lead ions on groundnut shell activated carbon

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ABSTRACT

This work focuses on the utilization of activated ***c****arbon prepared from groundnut shell for the removal of lead from water. The effects of temperature, contact time, and initial concentration of lead on the adsorption process have been investigated. Groundnut shell activated carbon is proven to be capable of removing lead from water with a very high efficiency under ambient conditions. Adsorption of lead onto groundnut shell activated carbon is best described by the pseudo second order kinetic model and the Langmuir adsorption isotherm model*

Keywords: Activated Carbon, Groundnut Shell, lead, Adsorption

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INTRODUCTION

Metals are found in waste water streams of various industries in large quantities [1]. Heavy metals with high relative density, they are often toxic to organisms. Their relative density ranges from 5 and above. Examples of heavy metals include; Lead, Mercury, Cupper, Cadmium, and Nickel. Heavy metals have harmful effects on human beings and ecosystem when they exceed their tolerance levels. For instance, lead influences the nervous system, slowing down nerval response. This influences learning abilities and behaviour. Children are exposed to lead right from their birth, as children in the embryonic stage receive lead from their mothers through the blood. Also, lead is known to be toxic to plants, animals and microorganisms. According to the world health organization (WHO) Standard, the concentration in a safe drinking water of lead must be below 0.01mg/L [2].

Adsorption is a widely used technique for wastewater treatment [1]. Adsorption is a process by which certain components of a fluid phase are attracted to the surface of a solid adsorbent and form attachments via physical or chemical bonds, thus removing the component from the fluid phase. In general, adsorption processes may be classified as physical or chemical depending on the nature of the forces involved [3-5]. Activated carbon is a commonly used adsorbent in water and wastewater treatment [6]. Low cost and non-conventional adsorbents include agricultural by products such as nut shells, wood, bone, peat processed into activated carbon [7, 8].

In many parts of sub Saharan Africa, groundnuts shells constitute a source of environmental pollution. The present study is aimed at investigating the kinetics and thermodynamics of lead adsorption on activated carbon prepared from groundnuts shell [9]. In order to design adsorption treatment systems, knowledge of the process kinetics and thermodynamics is essential.

MATERIALS AND METHODS

The stock solution of lead ions was prepared by mixing 1000 mg of lead nitrate ($Pb(NO_3)_2$) in a small amount of distilled water in a 1L volumetric flask and filling up with distilled water. The pH of the stock solution was adjusted from 5.2 to 4 using 1M HCl. The working solutions of 200mg/L concentration of each metal ion were prepared by serial dilution. Fresh dilutions were used for each study. Detailed synthetic procedure for the preparation and characterization of the groundnut shells activated carbon adsorbent has been published elsewhere [9].

Batch adsorption experiments were carried out in four 250 ml conical flasks by mixing 100 ml of 200mg/L of the lead solution with 2g of the groundnut shells activated carbon. The sets of samples in triplicate were then (one at a time) uniformly stirred at 250 rpm and heated to 35^0C using a hot plate for 10 minutes. The procedure was repeated for the time intervals of 20, 30, 40 and 50 minutes so as to determine the effect of contact time on the adsorption process. At the end of each adsorption experiment, the mixture was rapidly separated using vacuum filtration. The progress of the adsorption was determined by measuring the residual concentration of lead in the supernatant using flame atomic absorption spectrometer (FAAS, Model AA-650). Similar experiments were carried out at 45 °C and 55 °C in order to study the effect of temperature on the process.

Adsorption isotherms were developed by varying the initial concentrations of lead solution from 50 to 250 mg/L at intervals of 50mg/L, at a pH of 4, and maintaining the adsorbent dosage at 2 g/100 mL. The samples were then uniformly stirred and heated at 250 rpm and 35^0C for 15 minutes using a hot plate. This procedure was repeated at 45^0C and 55^0C .

RESULTS AND DISCUSSION

The Removal efficiency of lead was calculated using the equation below:

Removal efficiency = $[C_0 – C_t / C_0] \times 100$

Where C_0 and C_t are the concentrations of lead before and after adsorption for a period of time, t, respectively. Table 1 presents data on the effect of contact time and temperature on the removal efficiency of lead by groundnut shell activated carbon. From the table it is seen that the removal efficiency of lead by groundnut shell activated carbon increases with increase in contact time and temperature.

Table 1 Effect of contact time and temperature on the removal efficiency of lead by groundnut shell activated carbon

Time (min)	45 °C			Time (min)	55 °C		
	C_o (mg/L)	C_e (mg/L)	Efficiency (%)		C_o (mg/L)	C_e (mg/L)	Efficiency (%)
10	200	1.5	99.4	10	200	3.0	98.5
20	200	1.0	99.0	20	200	2.6	98.7
30	200	0.9	99.5	30	200	2.0	99.0
40	200	0.8	99.6	40	200	1.6	99.2
50	200	0.8	99.7	50	200	0.8	99.8

Kinetic models help one to understand the mechanism of metal adsorption and evaluate the performance of various adsorbents for metal removal. A number of kinetic models have been developed to describe the kinetics of heavy metal removal. These mostly include a pseudo-first-order kinetic model of Lagargren and a pseudo-second-order kinetic model [10].

The sorption kinetics of pseudo-first-order was gotten from the Lagargren equation:

$$\log (q_e - q) = \log (q_e) – k_1 t/2.303$$

Where q_e the amount of solute adsorbed at equilibrium per unit weight of adsorbent (mg/g), q is the amount solute adsorbed at any time (mg/g) and k is the adsorption constant. The plots of the pseudo-first-order kinetics models are shown in figure 1 for three different temperatures (35°C, 45°C and 55°C). As reported in table 2, the correlation coefficients (R^2) were very low (<0.99) at all the temperatures for the pseudo-first-order kinetic fit, suggesting that the adsorption process does not follow the pseudo-first-order kinetics.

The pseudo-second-order kinetic model is described by the equation below:

$t/q = 1/h + t/q_e$

where $h = k_2 q_e^2$, k_2(g $mg^{-1}min^{-1}$) is the rate constant, q_e and q are the amount of solute adsorbed at equilibrium and at any time (mg/g) respectively. The straight line plot of t/q_e versus t is used to obtain the constants for the pseudo-second-order reaction. Figure 2 presents the pseudo-second-order kinetics plot.

Table 2 Kinetic modelling data for lead adsorption on groundnut shell activated carbon

	Parameters	45 °C	55 °C
Pseudo First Order Kinetics	q_e	5.043	7.065
	K_1	0.0347	0.0250
	R^2	0.876	0.891
Pseudo Second Order Kinetics	q_e	7.489	10.233
	K_2	0.0532	0.0359
	R^2	0.991	0.996
	H	2.984	3.759

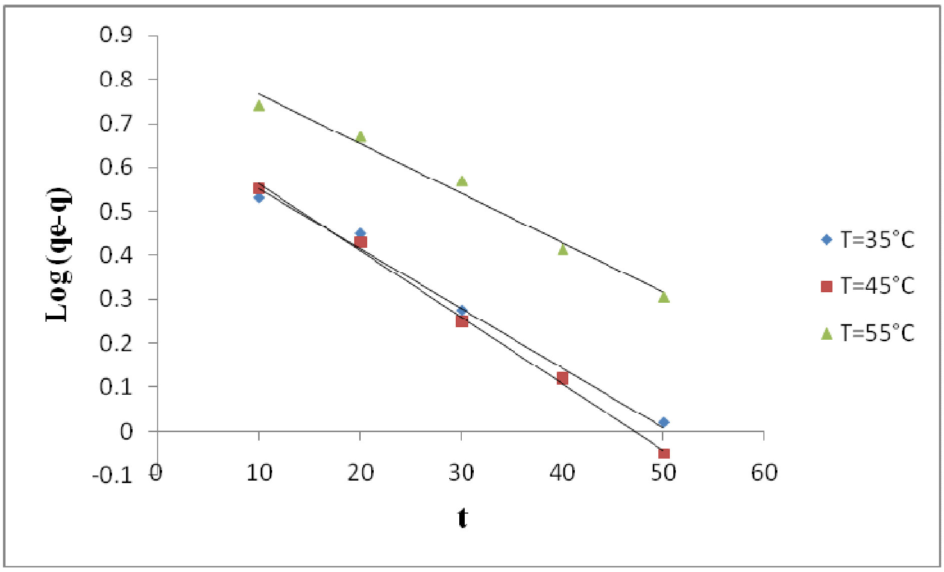

Figure 1 Pseudo first order kinetics plot for lead adsorption on groundnut shell activated carbon

Table 3 Adsorption Isotherm data for lead adsorption on groundnut shell activated carbon

Isotherms		35 °C	45 °C	55 °C
Freundlich	N	3.935	6.671	1.001
	K_f	29.85	41.78	19.25
	R^2	0.653	0.786	0.879
Langmuir	q_m	64.345	65.529	86.249
	K_a	0.0580	0.0095	0.0070
	R^2	0.901	0.954	0.976

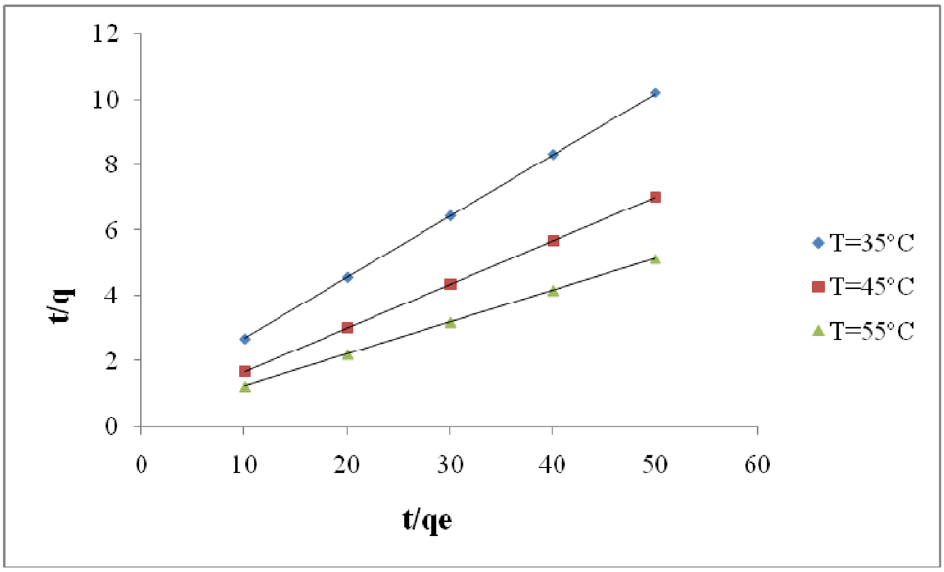

Figure 2 Pseudo second order kinetics plot for lead adsorption on groundnut shell activated carbon

Adsorption isotherms show the partition of adsorbate between solution and adsorbent at equilibrium [10]. The analysis of the isotherms data by fitting them into different isotherm models is an important step to find the suitable model that can be used to design adsorption process. Langmuir and Freundlich isotherms are the most widely used adsorption isotherms [10].

The linear plots of the Freundlich and Langmuir isotherm models for adsorption of lead on groundnut shell activated carbon are presented in figures 3 and 4. Table 3 displays the adsorption parameters for lead adsorption onto groundnut shell activated carbon derived from the linear plot of C_e/q_e versus C_e for Langmiur isotherm and the linear plot of log q_e versus log C_e for Freundlich isotherms at 35°C, 45°C and 55°C, respectively. From the correlation coefficients values obtained it was clear that adsorption of lead onto groundnut shell activated carbon at all temperatures obeys the Langmuir isotherm.

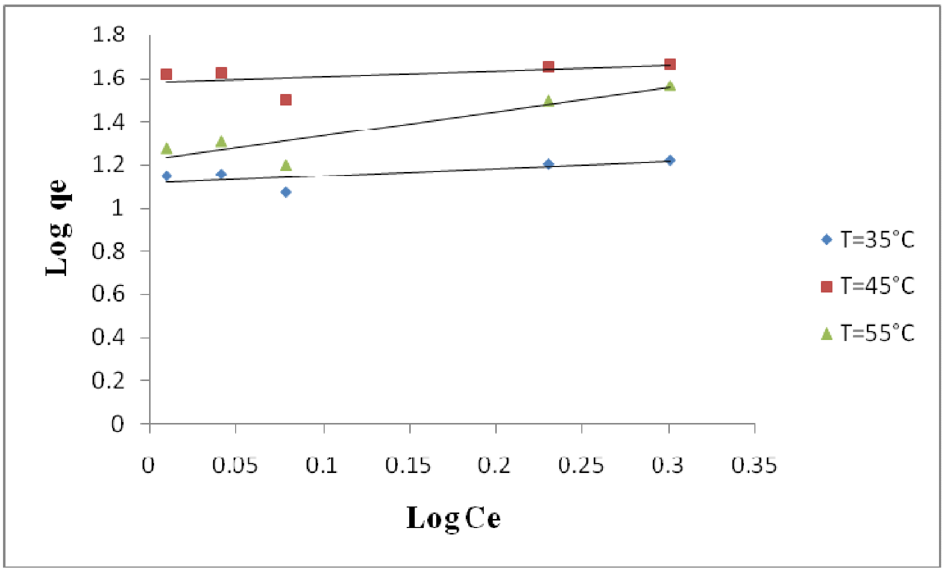

Figure 3 Freundlich Isotherm for lead adsorption on groundnut shell activated carbon

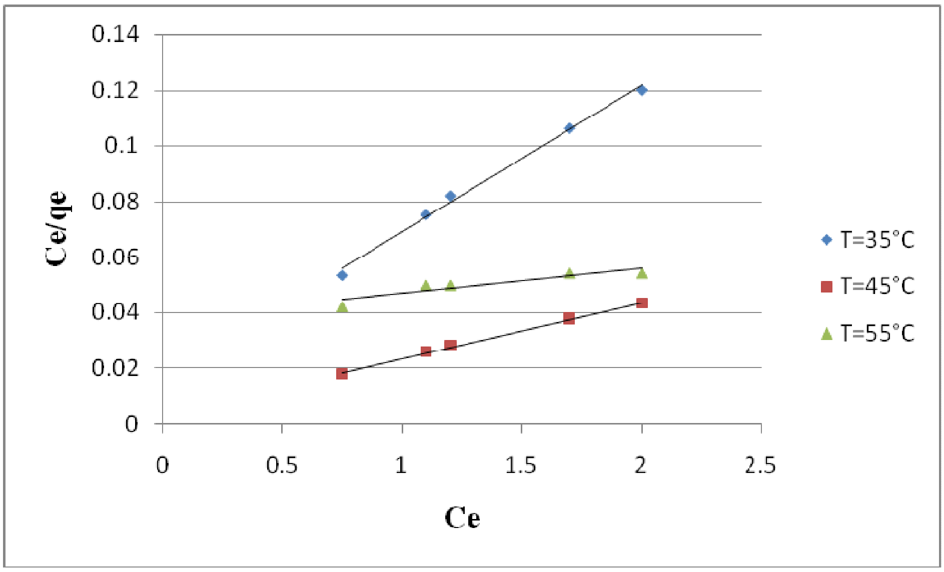

Figure 4 Langmuir Isotherm for lead adsorption on groundnut shell activated carbon

CONCLUSION

Activated **c**arbon prepared from groundnut shell is proven to be capable of removing lead from water with a very high efficiency. Adsorption of lead onto groundnut shell activated carbon is best described by the pseudo second order kinetic model and the Langmuir adsorption isotherm model

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