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Effect of Carbon Dosage and Contact Time of Activated Carbon Produced from Palm Kernel on Adsorption of Lead.

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Abstract: *This study shows the effect of adsorbent dosage and contact time of activated carbon produced from palm kernel for adsorption of lead. Investigation shows that adsorption of lead by the activated palm kernel reached a maximum after 132 minutes where 67% of lead in the solution was adsorbed. This occurred at an activated carbon concentration of 0.5g/l. Generally, adsorption rate was shown to increase with increase in concentration of the activated carbon until the optimal was reached. The adsorption of lead by the activated palm kernel (APK) followed the Langmuir isotherm and the Freundlich isotherm but deviates from the Tempkin isotherm.*

Key Words*: Activated carbon, Contact time, Carbon dosage, lead, Isotherms.*

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I. Introduction

In 2010, hundreds of people, mostly children, were reported killed in northern Nigeria's Zamfara state due to lead poisoning (NNP, 2011). Agricultural activities like farming within affected areas has been reported to result to plant accumulation of lead and other associated heavy metals like cadmium and zinc (Abdu and Yusuf, 2013). A widely cultivated crop in northern Nigeria, Sorghum, has been reported to have the ability to accumulate high concentration of heavy metals without showing any symptom of toxicity (Prasad and Freitas, 2003). In May, 2015, Lead poisoning killed twenty eight children in central Nigeria's Niger state. All the twenty eight cases were children below the ages of five (Medical Express, 2015).

Indeed, many heavy metals are known to be toxic both to humans and other living things, with their accumulation over time causing damage to internal organs like kidney, liver, and reproductive system in addition to cancer (Lentech, 1998). Heavy metal pollution results from a number of sources, including lead in petrol, industrial effluents, and mining activities. In addition, they may arise from the purification of metals, for instance smelting of ores, preparation of nuclear fuels, and electroplating (Lef, 1998). They precipitate into soil, underground water, and surface water. Unlike organic contaminants, heavy metals do not normally undergo biological decay and are thus considered a challenge for remediation. Many governments have enacted laws to hinder discharging heavy metals into water bodies and using toxic substances such as lead (Abdelshafi and Raouf 2007). Unfortunately, heavy metals still find their way to water supplies. Accordingly, many studies have been done for removal of heavy metals. Ion exchange, reverse osmosis, and chemical precipitation have been investigated for the removal process, but they are too expensive or incapable of meeting treatment objectives. Adsorption has been proved to be a potentially feasible alternative. Adsorption by using activated carbon is the most common method, but this too may be expensive, particularly if proper raw materials are not available and therefore the carbon has to be imported (Zayat and Smith, 2009).

Motivated by cost considerations, locally generated agricultural wastes such as cotton stalks, rice straw, sugar cane bagasse, and others have been tested in the production of activated carbon in developing countries (Logan, and Yevich, 2002). The use of these raw materials in carbon production shows from the past studies that they are available at low cost, contain high carbon content, and may be effective in the removal of heavy metals and other toxic pollutants. Even then, there is still the need to produce more activated carbon from other available raw materials. The purpose of this research is to investigate the effect of carbon dosage and contact time of activated carbon produced from palm kernel on adsorption of lead.

II. Materials And Method

2.1 Activated Carbon

Palm fruits shells were collected from Emohua Local Government Area of Rivers State, and used as activated carbon through chemical activation. In this research, phosphoric acid was used as the dehydrating agent, and the activation was carried out in the Scientific Equipment Development Institute, Enugu, Nigeria. The preparation test followed the process outlined by Baccar et al (2009) and involves the crushing of 30 g of the sample to not more than 1.0 mm in diameter. The sample, as precursor, was divided into smaller samples and mixed with H_3PO_4 solution having different concentrations (30–85% H_3PO_4 in weight). The impregnation ratio was 1:1, 1.25:1, 1.5:1, 1.75:1, and 2:1 in favour of the impregnant (H_3PO_4). The impregnation was carried out in a stirred pyrex reactor equipped with a reflux condensor. Stirring was used to ensure the access of the acid to the interior of the palm kernel shell particles. The temperature and the duration of the reaction were 104 ^{0}C and 2 h, respectively. Agitation and heating were ensured by a heating magnetic stirrer with connected temperature regulator probe made of teflon. The pyrolysis of the impregnated material was conducted in a cylindrical stainless steel reactor, inserted into a tubular regulated furnace under continuous nitrogen flow (0.5 L min−1). Pyrolysis temperature was at 450 ^{0}C, while activation time was maintained at 2 h. After cooling down to room temperature, under the same flow of nitrogen, the obtained activated carbon was thoroughly washed with hot distilled water until neutral pH. The sample was then dried at 105 ^{0}C overnight, and ground to a particle size of 1.0mm and finally kept in hermetic bottle for subsequent uses.

The produced activated carbons were characterized to determine their Surface area, Bulk density, Iodine Number, and Methylene Blue adsorption. The procedures for these tests followed the outline given by Baccar (2009).

2.2 Preparation of lead Solution

A stock solution of lead (II) was prepared by dissolving 1.6 grammes of lead nitrate solution in 500ml distilled water to obtain a standard solution.

2.3 General procedure for contact time experiments

The effect of contact time on the removal of Pb(II) ions was studied at a pH of 6.0. A mass of 0.2grams of palm kernel activated carbon was put into a conical flask containing 500 mg/l of lead solution. The mixture was then stirred, and samples of the solution were periodically drawn at an interval of 30 minutes and analyzed using atomic adsorption spectrophotometer to establish the absorbance of un-adsorbed lead. The results were expressed in terms of adsorption rate (%).

2.4 General procedure for carbon dosage experiment

Different amounts of palm kernel activated carbon (range of 0 – 0.6 g) were put into different conical flasks containing known amounts of lead nitrate. The mixtures were then stirred for up to 200 minutes at a fixed pH. The filtrates were then collected and the absorbance of unabsorbed lead was determined using the AAS analysis. The results were expressed in terms of adsorption rate (%).

III. Results And Discussion

3.1 Properties of Activated Carbon.

Figures 1 to 3 show the specific surface area, Iodine number and Methylene blue adsorption as a function of impregnation ratio of the activated carbon. As seen in figure 1, the specific surface area is highest at an impregnation ratio of 1.75:1. Beyond this, the surface area reduces. It is important to point out that most activated carbon have been reported to have a surface area within the range of 800-1500 m^2/g (Leimkuehler, 2010). The iodine number as well as the methylene blue adsorption are also seen to increase progressively with impregnation ratio up to 1.75:1. This value of 1.75:1 can be seen therefore to be the optimal impregnation ratio of activated carbon produced from palm fruit kernels. However, the bulk density of the activated carbon was not significantly influenced by the impregnation ratio. This is because, at all impregnation ratios, the bulk density of the activated carbon was about 0.562 g/cm^3.

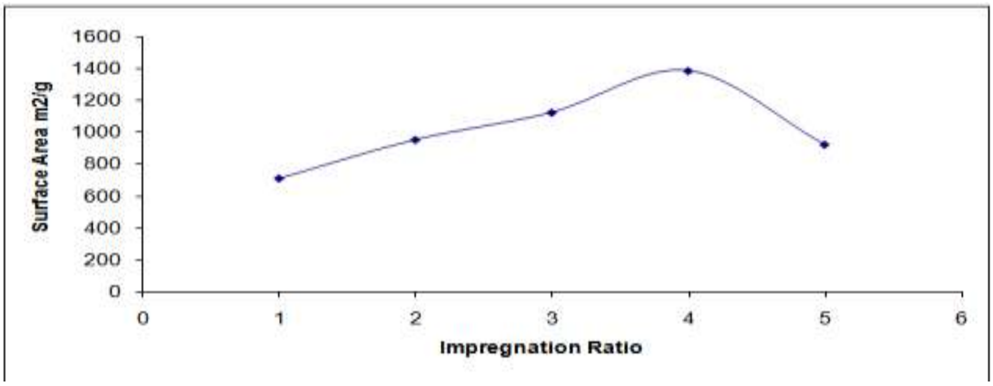

Fig 1: Influence of impregnation ratio on surface area of activated carbon

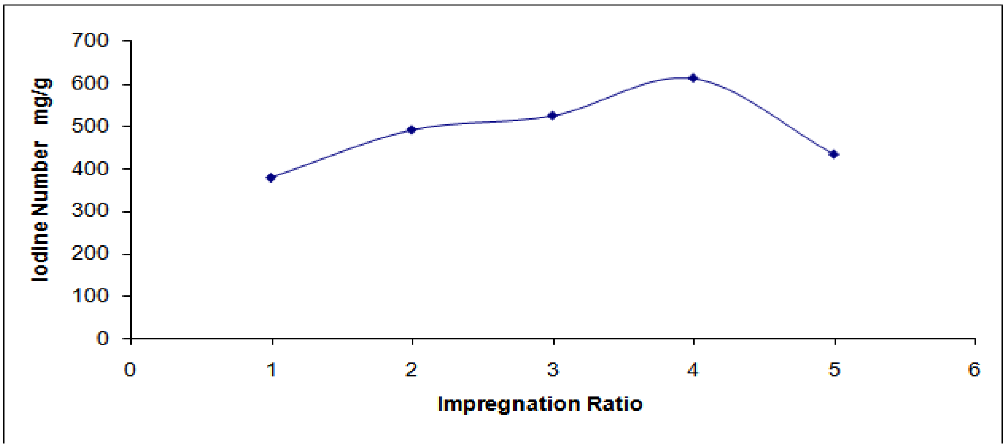

Fig 2: Effect of impregnation ratio on iodine number of activated carbon

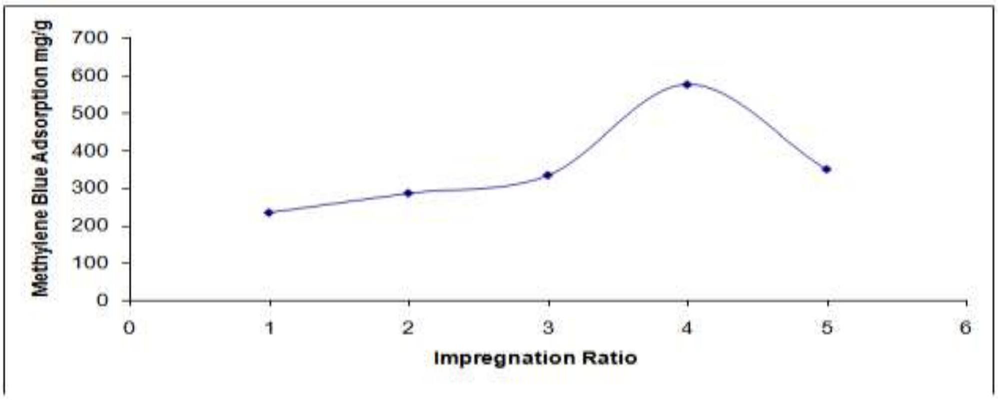

Fig 3: Effect of impregnation ratio on methylene blue of activated carbon

3.2 Contact time effect on adsorption

Adsorption of 500mg/l lead solution using 0.2 grammes of palm kernel activated carbon with an impregnation ratio of 1.75:1 gives the graph presented in figure 4. It is clear from Figure 4 that the removal of metal ion increases as the contact time increases. At first, the rate of uptake is fast. Equilibrium was attained in 132 minutes. Further increase in contact time results to decrease in the percentage of adsorption.

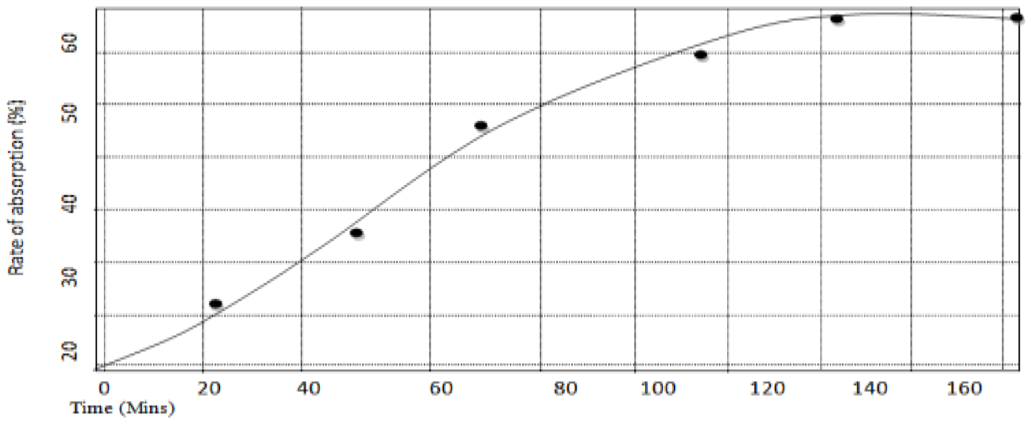

Fig 4: Plot of rate of adsorption against time

3.3 Effects of Carbon dosage on adsorption

The adsorption of 500mg/l of lead using different amounts of palm kernel activated carbon (with an impregnation ratio of 1.75:1) for 30 minutes gave the plot in Figure 5. It was observed that increase in concentration of activated carbon increased the rate of adsorption until a point when no amount of increment made any difference in the adsorption rate. At this point the adsorption reached its equilibrium. This happened at a carbon concentration of 0.5 g/l where there was a 67% rate of adsorption.

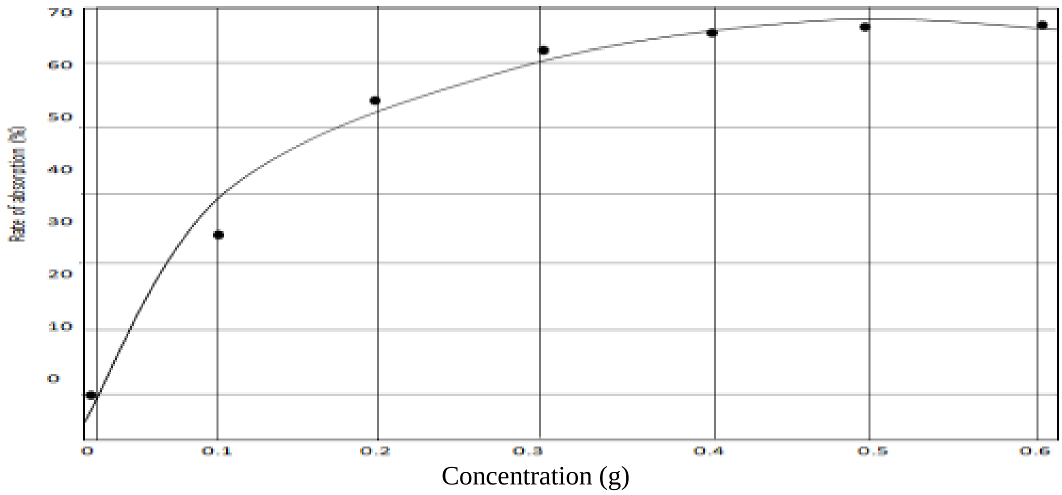

Fig 5: Plot of rate of adsorption against concentration

3.4 Adsorption Isotherms

An adsorption isotherm, according to Limousinet et al (2007) and Allen et al (2004) is an invaluable curve describing the phenomenon governing the retention or mobility of a substance from the aqueous porous media or aquatic environments to a solid-phase at a constant temperature and pH. Adsorption equilibrium (the ratio between the adsorbed amount with the remaining in the solution) is established when an adsorbate containing phase has been contacted with the adsorbent for sufficient time, with its adsorbate concentration in the bulk solution is in a dynamic balance with the interface concentration. Typically, the mathematical correlation, which constitutes an important role towards the modeling analysis, operational design and applicable practice of the adsorption systems, is usually depicted by graphically expressing the solid-phase against its residual concentration. Its physicochemical parameters together with the underlying thermodynamic assumptions provide an insight into the adsorption mechanism, surface properties as well as the degree of affinity of the adsorbents.

Three different isotherms were used in this study. These iosotherms and their linear mathematical expressions are shown in table 1.

Table 1: Adsorption Isotherms models

S/N	Isotherms	Linear Forms	Forms	References
1	Langmuir	$\frac{c_e}{q_e} = \frac{1}{bQ_o} + \frac{c_e}{Q_o}$	$\frac{c_e}{q_e} \quad V_s \;\; c_e$	Langmuir, 1916
2	Freundlich	$\log q_e = \log K_F + \frac{1}{n} \log c_e$	$\log q_e \;\; V_s \;\; \log c_e$	Freundlich, 1906
3	Tempkin	$q_e = \frac{RT}{b_T} \ln A_T + \frac{RT}{b_T} \ln c_e$	$q_e \;\; V_s \;\; \ln c_e$	Tempkin, 1940

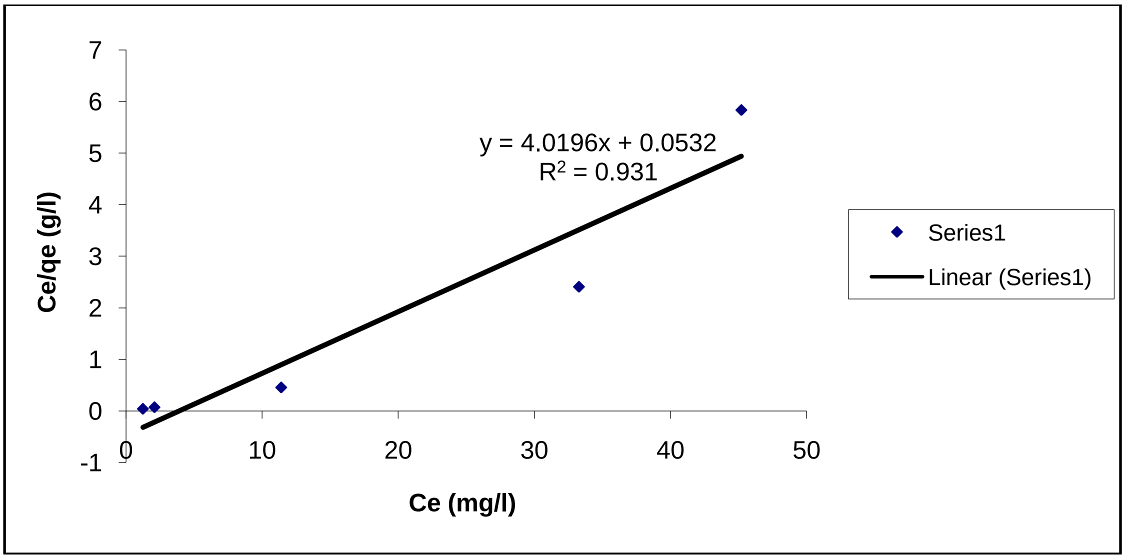

Fig 6: Langmuir isotherms for the adsorption of lead on activated palm kernel

From figure 6, a linear relationship exists from the plot of $\frac{C_e}{q_e}$ against C_e with R^2 value of 0.931.This shows that the adsorption of lead ions on activated carbon produced from palm kernel fits the Langmuir isotherm. The Langmuir constant, b, shown in table 2 was calculated to be 0.0132. This constant was then used to calculate the separation factor using equation 1.

$$R_L = \frac{1}{1+bC_o} \qquad 1$$

According to Foo and Hameed (2010), adsorption is said to be favourable for $0 < R_L < 1$. For this research, R_L was calculated to be 0.6. This confirms that the adsorption of lead on palm kernel activated carbon is a favourable phenomenon.

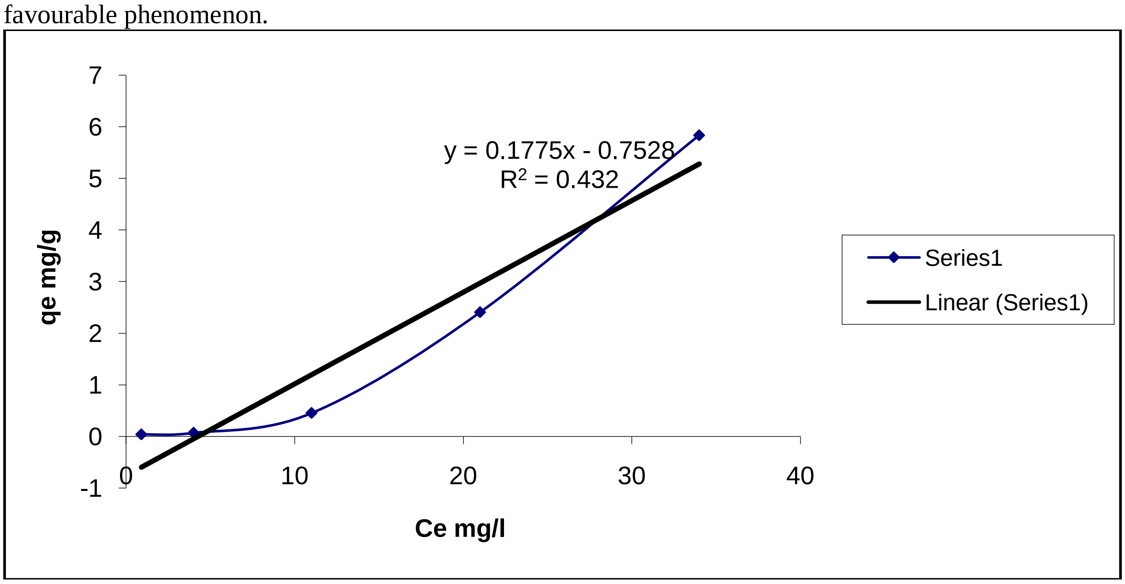

Fig 7: Tempkin adsorption Isotherm for the adsorption of lead on APK

As seen in figure 7, the R^2 value for the Tempkin isotherm is 0.432. This value shows that the adsorption of lead on activated palm kernel does not follow the Tempkin isotherm. Foo and Hameed (2010) have stated that the Tempkin isotherms are excellent only for gas phase equilibrium.

Finally, the Freundlich isotherm model was plotted to determine of the adsorption process on it. As seen in figure 8, the R^2 value is 0.9251. The Freundlich is, by this value, seen to have been followed by the adsorption of lead ions on activated palm kernel.

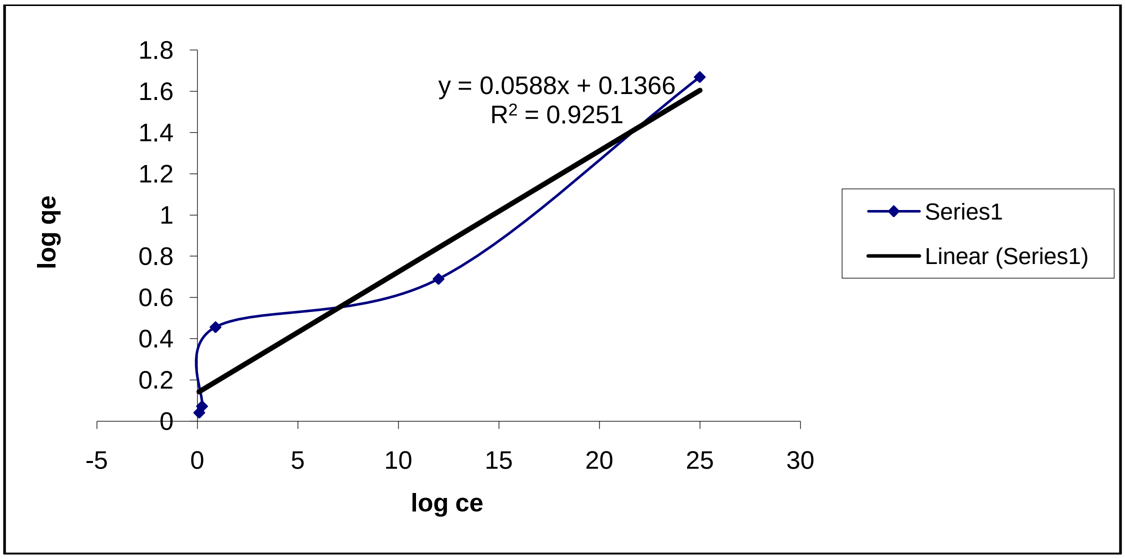

Fig 8: Freundlich isotherm for the adsorption of lead on activate palm kernel

IV. Conclusion

The following conclusions can be drawn from this study:

1. Activated palm kernel carbon is an effective adsorbent for the removal of lead from aqueous solution. Its adsorption capacity is moderately high.
2. The adsorption of lead from aqueous solution by the activated palm kernel carbon increases with contact time up to a maximum at 132 minutes were equilibrium is reached.
3. The rate of adsorption of lead by palm kernel activated carbon increased steadily with the concentration of the adsorbent until equilibrium was reached at 0.5 g/l.
4. The adsorption of lead by palm kernel activated carbon followed the Langmuir and Freundlich isotherms but not the Tempkin isotherm.

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