KINETIC STUDIES ON THE ADSORPTIVE CAPACITY IN REGENERATION OF LOCALLY DEVELOPED ADSORBENTS

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Abstract
From many methods employed to reduce contaminant concentration in waste waters, the most economical one is the utilization of locally available waste materials as precursors for adsorbent development. This study therefore focused on the Kinetic studies of the adsorbent developed from wood and cow bone. The materials employed in this study for the development of adsorbent were sourced from Bida, Niger State while the effluents were obtained from Lagos State. Carbonization took place between 800 - 900°C. The cow bone and wood samples were divided into two portions. One portion was thermally treated and the other half was chemically activated thereby giving more samples known as thermally treated bone (TTB), thermally treated wood (TTW), chemically treated bone (CTB) and chemically treated wood (CTW). The samples were separately used to purify the effluents and the results of measurement were fitted into a Langmuir equation. The results confirmed a monolayer coverage using both bone and wood based adsorbents. Chemically developed bone and wood were found more suitable in the purification of dry-cleaning and coca-cola eft1uents.

Keywords: Carbonization, Adsorbents, Capacity, Effluents, Regeneration.

Introduction
The world environment is increasingly threatened by discharge of untreated industrial waste into the environment. The sources of these wastes are eft1uents from dry-cleaning services, bottling companies, domestic effluents, chemical and allied industrial effluents etc (Ejila & Tagang, 2001).These effluents otherwise called industrial wastewaters may contain diverse range of pollutants some of which impact specific hazards to the environment (Victor, 1999). In Nigeria for instance, a lot of hazardous effluent materials have been identified without a commensurate effort to develop technologies for their purification. These wastewaters contain organic acids or highly acidic and basic matters that are corrosive to metals and other construction materials (Roberts & Rittmeyer, 1991). They can also contribute to over-pressure from the hydraulics of systems, create exothermic runaway reactions with a rapid evolution of large amounts of vapor and heat. They equally bring about inhibition of growth of some desirable aquatic biota necessary for self-purification (re-oxygenation) by reducing the penetration of sunlight, with a consequent reduction in photosynthetic activity and primary production (Wehrum, 1993). However, adsorption processes are widely used for the removal of not only colour from textile, dyestuff, pulp and paper, tannery effluents, but also for removal of other organic pollutants and heavy metals and this method has been found to work with more than 90% efficiency (Venkata & Karthikeya, 1997). It was therefore in this regard that some locally developed adsorbents were prepared from bone and wood for the purification of effluents from coca-cola and dry -cleaning industries. Having achieved 96.6 and 75.9% purification when these wood and bone based adsorbents were tested respectively on coca-cola and dry-cleaning effluents(Okafor & Aneke, 2006), it became imperative to undertake the kinetic studies of these locally made adsorbents.

The most commonly used models to understand and predict adsorption systems are Freundlich, Langmuir and Brunauer-Emmettt-Teller (BET) equations. In this study, Langmuir model is used which is based on the equilibrium between adsorption - desorption phenomenon. Langmuir adsorption isotherm equation is,

$$\frac{1}{X} = \frac{1}{XmKC} + \frac{1}{Xm} \qquad (1)$$

where

X = amount adsorbed per unit mass of adsorbent at saturation (mg/g),

Xm = Limiting amount of solute (adsorbate) adsorbed per unit mass of adsorbent (i.e. monolayer capacity) (mg/g)

K = Langmuir constant related to energy and capacity $\left(\frac{cm^3}{g}\right)$

Ce = Concentration of solute in the solution that is in equilibrium with the adsorbent (g/cm^3).

Materials and Methods

The starting feedstock, cow bone and wood chips were obtained from new market and timber shed in Bida, Niger State, while coca-cola and dry-cleaning effluent samples were collected from Nigerian Bottling Company, Agidingbe, Ikeja and Edison Dry-cleaning services, No 23 E-close FESTAC Town respectively in Lagos State.

Carbonization

Carbonization was carried out in a specially constructed burning chamber called furnace and burning took place .in a limited supply of air. The carbonization temperatures for bone and wood were 800 and 500°C respectively for 2 hours. After cooling the charred products to room temperature, they were reduced to a workable size of 75 μm .These samples were purified using 0.5M HCI solutions and later rinsed with distilled water to remove the excess acid. These carbonized carbons were dried in an oven at 105^{o}C for one hour (Okafor & Aneke, 2006).

Chemical Activation

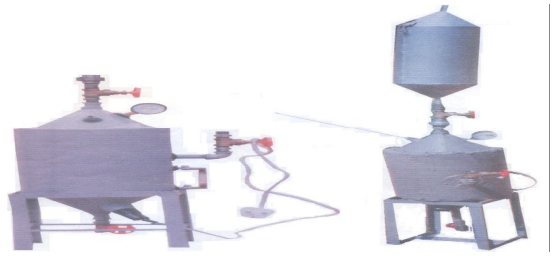
A carefully weighed 25.0g carbonized bone sample was put in a beaker containing 500cm^3 of 0.5M zinc chloride. The content of the beaker was thoroughly mixed and heated at 100^{o}C until it formed a paste. The paste formed was transferred to a crucible and placed in a furnace and heated to a temperature of 800^{o}C for two hours (Odebunmi & Okeola, 2001). It was cooled to room temperature and washed with distilled water and dried in an oven at 105°C for 3 hours. The product was kept in an air-tight vial ready for use. This procedure was repeated for wood sample at furnace temperature of 500^{o}C for two hours.

Thermal Activation

The carbonized samples were activated thermally with a locally made steam generator. The samples were placed in turn on top of the chest and steam at 100^{o}C was passed through the sample for six hours (Odebunmi & Okeola, 2001).

Regenration of Spent Adsorbent

At the equilibrium point, the adsorbent becomes exhausted and therefore needs reactivation. Regeneration is achieved using the designed and constructed steam generator shown in Fig 1.0. As the water boils inside the chest, the steam valve was opened gradually to allow contact with the adsorbent. This was done for 1hr, then the regenerated adsorbent was dried in the oven at 100^{o}C.



(a) (b)

Fig. 1 A regeneration System: (a) Steam Chest (b) Steam Chest with Column

Determination of Adsorption Capacity

Two grames of activated carbon was weighed carefully and added to 100cm^3 of effluent. The mixture was intermittently shaken and was allowed to stand for 24 hours to attain equilibrium. At the end of this interval of time, the mixture was then filtered and the concentration of the filtrate was determined using spectrophotometer (Odebunmi & Okeola, 2001).

Results and Discussion

The adsorption isotherms using the locally made adsorbents onto the effluent samples were presented in Figures 2 to 5. The shape of these isotherms is characteristic of the Langmuirian adsorption behavior. Figure 2 shows a plot of 1/X versus 1/Ce when chemically and thermally treated bone based adsorbents were used to purify dry-cleaning effluents and the slopes of the curves are 0.388 and 0.378cm^3/g respectively.

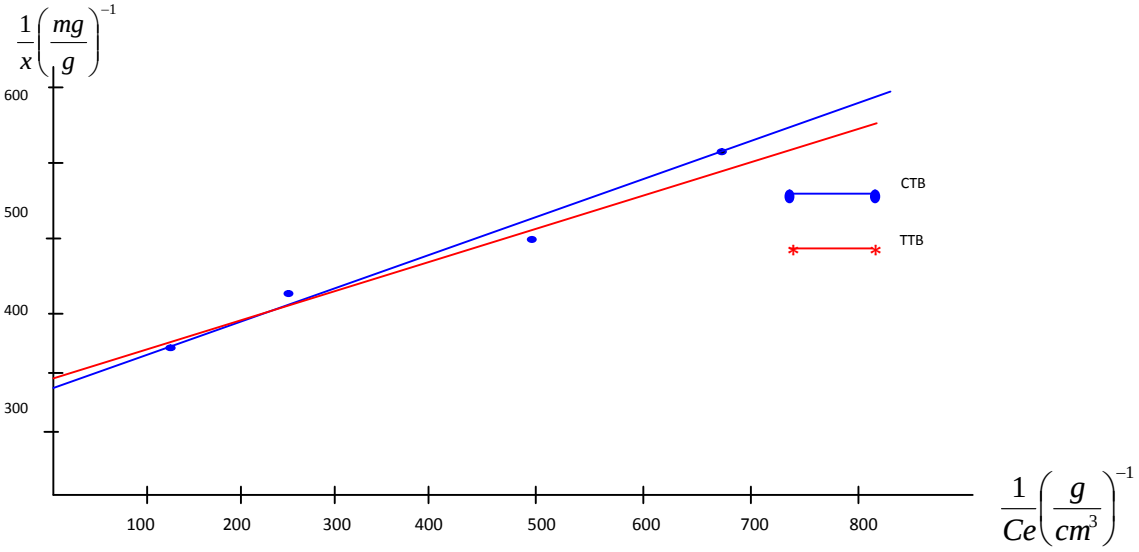


Fig. 2: A graph of 1/X vs 1/Ce using chemically and thermally treated bone based adsorbent before regeneration

The limiting amount of adsorbate (i.e. monolayer capacity) is higher in the chemically treated bone i.e. 0.006 mg/g while the thermally activated one is 0.005 mg/g. At the point of exhaustion (equilibrium) these adsorbents were regenerated using steam from the steam chest. The plot is shown on figure 3.0.

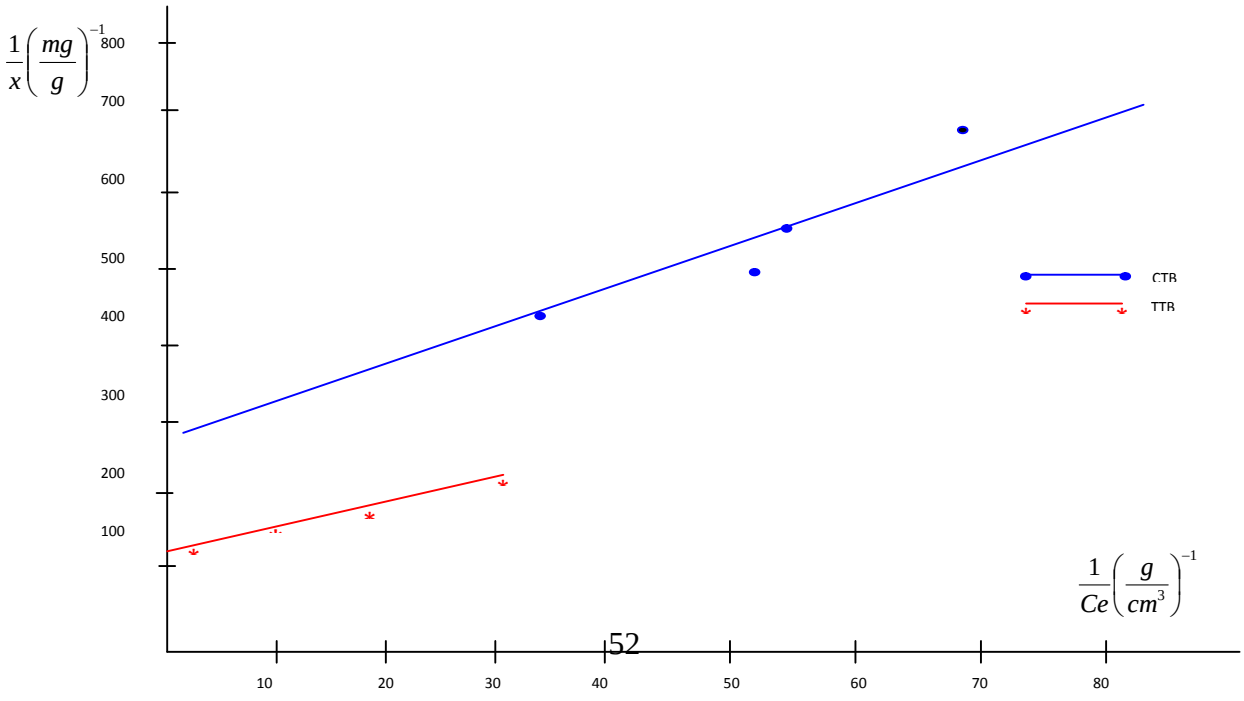


Fig. 3: A graph of 1/X vs 1/Ce using chemically and thermally treated bone based adsorbent after regeneration

The slope of CTB shows a serious improvement with values of 7.122cm^3/g while that of TTB is 1.148cm^3/g for the regenerated adsorbents in the purification of dry-cleaning wastewaters. This also resulted in an increased value of the limiting adsorbate (0.008 mg/g) using chemically treated bone while it remained about the same with the value obtained when the fresh adsorbent was employed (0.004 mg/g) for the thermally treated one.

For coca-cola effluent purification using wood based activated carbons, the trend is similar with the thermally treated wood having a higher slope of 0.373 while that treated chemically is 0.29. Surprisingly for these instances their limiting sorbate (average) amounts were equal (0.007) Fig. 4.0.

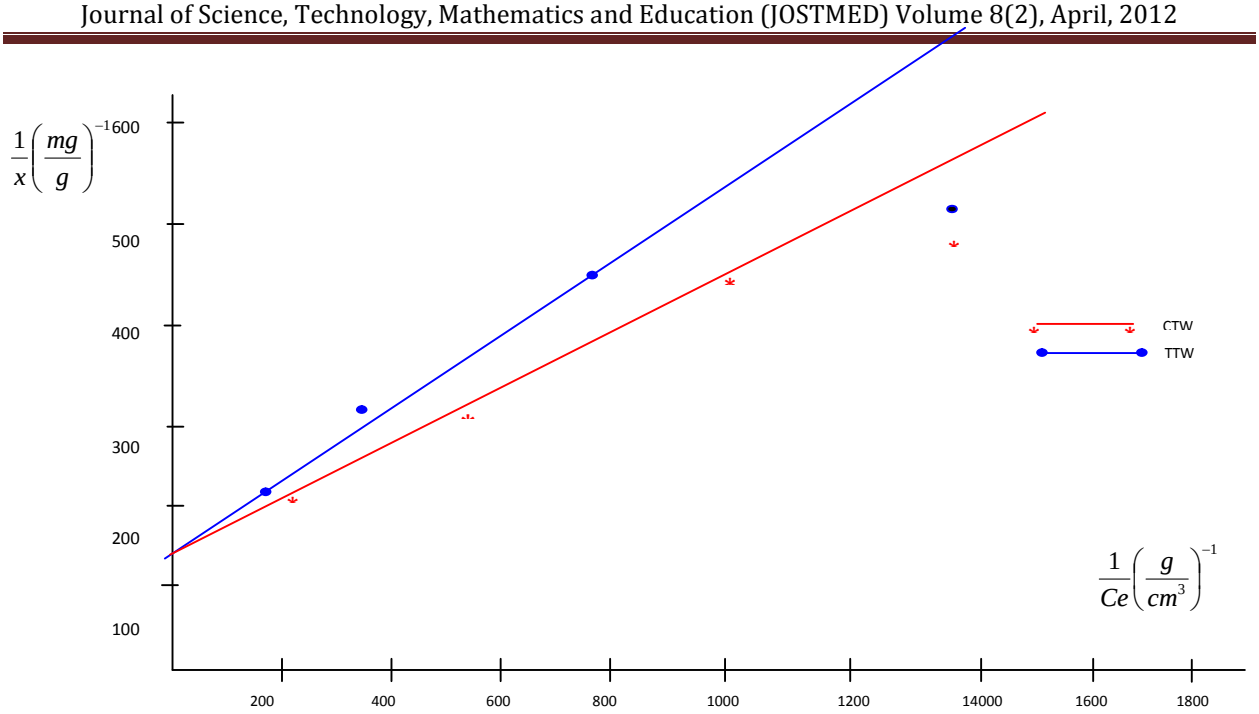


Fig. 4: A graph of 1/X vs 1/Ce using chemically and thermally treated wood based adsorbents before regeneration

However, on regeneration having attained breakthrough points, the slopes were 9.783 and 5.965 for chemically and thermally activated samples respectively. The plot is shown below in Figure 5.0.

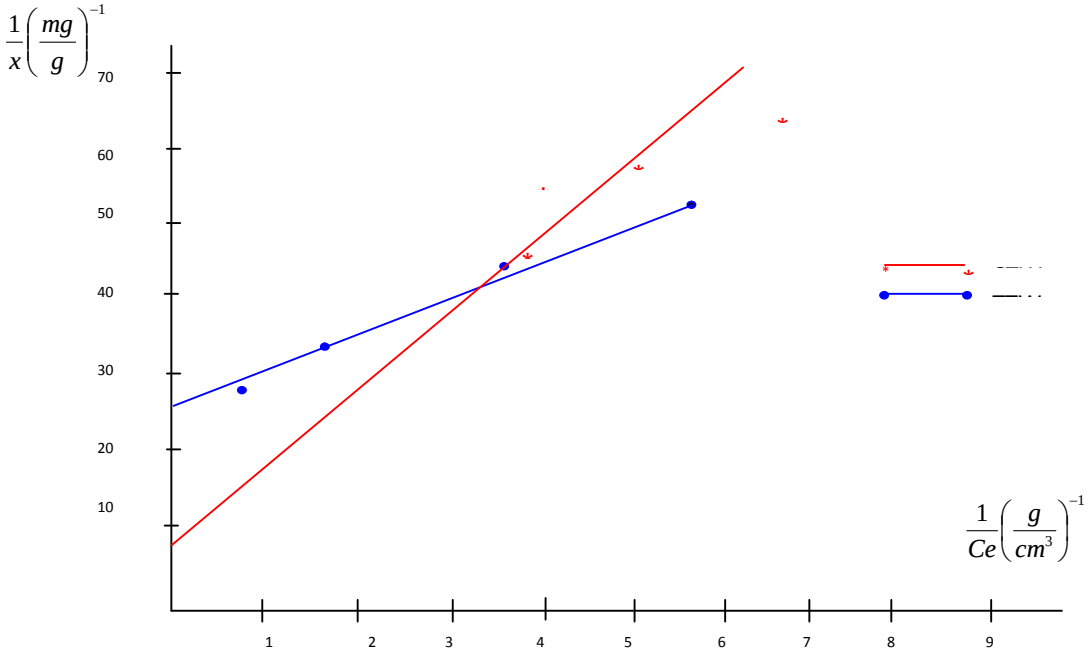


Fig. 5.0: A graph of 1/X vs 1/Ce using chemically and thermall treated wood based adsorbents after regeneration

Again there was a significant enrichment on the slopes and consequently an enhanced adsorption capacity. The adsorption capacity after regeneration are 0.087 for chemically activated wood (CAW) but 0.043 for the thermally treated one. The k values were numbered k_1, k_2, k_3, k_4, k_5, k_6, k_7, k_8 and were found to be 529, 429.6, 108.9, 35.1, 383, 492.6, 3.9 and 0.9995 (≅1.0)g/cm^3 respectively.

k is also a measure of 'eddy' and diffussional resistance offered at every stage of the adsorption process. It is therefore observed that all the regenerated adsorbents that were chemically treated had smaller values of these resistances (i.e. k_3, k_4, k_7 and k_8). (Eleangovan & Saseetharan, 1997).

Conclusion

The kinetic studies show that the data generated fitted well into Langmuir model equation. This adsorption process is monolayer type with the Langmuir constants very adequate to justify their use in the purification of coca-cola and dry-cleaning effluents especially where the carbonaceous materials were activated with chemicals and steam.

References

Ejila, A. & Tagang, J. (200). Treatment of tannery effluents. *Journal of Chemical Society of Nigeria, 26 (2), 169 – 172.*

Elangovan, R. S. (1997). *Unit operations in environmental engineering*, 1st Edition. New Delhi, India: New Age International (P) Ltd. Publishers. Pp 125-138.

Gimba, C. E., Olayemi, J. Y. & Kagbul, J. A. (2001). Adoption of dyes by powdered and granulated carbon from coconut shell. *Journal of Chemical Society of Nigeria, 26(1), 24 – 27.*

Odebunmi, E. O. & Okeola, O. F. (2001). Preparation and characterization of activated carbon from waste material. *Journal of Chemical Society of Nigeria*, 26 (2),149 – 154.

Okafor, J. O. & Aneke, N. A. G. (2006). Characteristics of adsorbents for the purification of coca-cola effluent. *Journal of Nigerian Society of Chemical Engineers, 21, (1 & 2),19 – 24.*

Roberts, W. & Rittmeyer, P. E. (1991). Waste minimization - Part I. *Chemical engineering progress*, U.S.A: CEP, Pp. 56 – 62.

Venkata, S. M. & Karthikeya, J. (1997). Removal of lignin and tannin Colour from aqueous solution by adsorption onto activated charcoal, biochemical and environmental engineering group. *India Institute of Chemical Technology, India., ELSEVIER, 92, (1&2),183 – 187.*

Victor, H. Edwards, (1999). *Avoid process hazards in wastewater systems.* U.S.A: Chemical Engineering Progress.

Wehrum, W. L. (1993). *Case study of a hydrogen peroxide related deflagration in a wastewater treatment tank, Paper 8b,* presented at the Al Ch.E Spring National Meeting, 27th Loss Prevention Symposium, Houston, Texas, U.S.A.