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PRODUCTION OF COST-EFFECTIVE ADSORBENTS FROM NATIVE MATERIALS

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ABSTRACT

The adsorption of methyl red by activated carbon produced from five native materials: Ram horn, plantain peels, Sugar cane chaff, Car tyre and Ram hair were studied invivo. Methyl orange was significantly adsorbed by all the activated carbons and the rate increased with time until equilibrium was reached after 24 h. The Freundlich's adsorption parameters were determined to be 1.71 (plantain peel), 1.20 (car tyre), 1.14 (ram hair), 1.02 (sugar cane chaff) and 1.00 (ram horn). In this study, plantain peel has the highest adsorptive capacity while ram horn has the least. The order of adsorptive capacity is plantain peel>car tyre>ram hair>sugar cane chaff>ram horn. The use of these native materials as adsorbents will lead to cost efficiency and reduce operational cost.

Keywords: Activated carbon, Native materials, Adsorbents, Methyl red, Freundlich, Carbonisation.

Contribution/ Originality

The paper's primary contribution is finding that locally available adsorbents are cheaper and can be used as substitutes for industrial adsorbents which are more costly. All the adsorbents investigated showed favourable adsorptive capacities. These non-conventional, low cost adsorbents are readily available as wastes in many Nigerian localities.

1. INTRODUCTION

Investigating adsorption is a continuing concern within pollution control, separation technology and industrial catalysis [1]. Through adsorption, the purification of contaminated solutions has been possible. Solid adsorbents may adsorb materials either from the liquid or solid phase. The amount of material adsorbed by a given mass of adsorbent depends on the physical conditions of the adsorbents; when the solid is porous or finely divided. Recently, researchers have shown an increased interest in the preparation of low cost adsorbents in waste water treatments [2] because most of the developing nations cannot afford the use of the expensive ones like alum, ferric chloride and coal based activated carbons, although more preferred. This has

led to the preparation of some low cost native adsorbents like coir pith [3], agricultural waste materials and activated carbon from fabric cloth [4], and Giridih coal and crushed coconut shell [5]. Many industries make use of dyes to colour their products like rubbers, plastics, paper, printing inks and drugs [6]. As a result, these industries generate a lot of waste which needed to be treated with cost effectiveness [3]. Along with many other uses, the adsorption of gasses in gas masks and the decolourization of sugar solutions in refining process are significant applications of active charcoal as an adsorbent.

A considerable amount of literature has been published on Adsorption which includes: Adsorption of gasses by solids [7], adsorption from ternary liquid mixtures on solids [8] or solids by solid [9] . The amount of the adsorbate onto the surface of the adsorbent varies with the surface properties of the adsorbents, for example, the more the porosity of the adsorbent, the more the adsorption. Through adsorption, the purification of contaminated solutions has been possible. For instance, charcoal , a carbonized wood has been used to decolourize solutions and in gas masks [10]. Adsorption occur on surfaces, therefore, the more the surface area of the adsorbent, the more is its adsorptive capacity. Finely divided adsorbents have large surface area and are more porous. For some adsorbents like charcoal, the surface is so large that almost every atom is exposed to the pore [11]. The research to date has tended to focus on plant based adsorbents rather than animal based adsorbents. Recent developments in stringent industrial waste water disposal laws have heightened the need for more effective adsorbents. This study is one of very few studies which have investigated the adsorption capacities of low cost adsorbents that are locally available. This study seeks to compare adsorptive capacities of some plant based adsorbents (sugar cane chaff, plantain peel) and animal based adsorbents (ram horn, ram hair) locally available in Nigeria. The synthetic car tyre is the control. Freundlich adsorption isotherm is a curve that relates the concentration of a solute on the surface of an adsorbent to the concentration of the solute in liquid with which it is in contact with. The Freundlich adsorption parameters of these locally available adsorbents will be determined and compared with each other.

2. MATERIALS AND METHODS

The materials used for this research work were obtained from the following locations. The plantain peels were obtained from the plantain market Kwararafa, sugar cane chaff from Angwan Rogo, Ram hairs and Ram horn from Abattoir meat market and the car tyre form Angwan rogo, all in Jos, Plateau State, Nigeria. Jos is the state capital of Plateau state, its geographical coordinates are 9° 55' 0" North, 8° 54' 0" East. Kwararafa market is the major plantain market in Jos, all the surrounding villages bring their harvested plantain to this market. Angwan rogo is one of the major settlement that consumes sugar cane in jos, with several sugar cane markets. Abattoir meat market is the only recognized meat market in Jos.

2.1. Carbonisation

The local materials were carbonised at various temperatures in a muffle furnace: Ram horn (350 °C), Sugar cane chaff (200 °C), Plantain peel (260 °C), Ram hair (300 °C) and Car tyre (350

°C). The yield of charcoals decrease with increase in temperature, therefore, the minimum temperatures for carbonisations were used. The sieve sizes used were 60 mm and 115 mm.

2.2. Activation

The samples were activated by adding HCl (1M, 10 g) to each of the carbonised local materials. The mixture was heated until effervescence stopped. The samples were washed with distilled water until the samples became neutral to litmus paper.

2.3. Adsorption

Methyl red (1 g) was dissolved in ethanol-distilled water (600 ml: 400 ml) with stirring for 2 h. To 100 ml of the solution above was added 1g of the activated adsorbent in six sets. The activated carbons were gently filtered off using a clean cotton fabric after 2 h, 4 h, 8 h, 12 hrs, 24 h and 48 h respectively at room temperature (20 °C). The adsorbents were oven dried at 105 °C to constant weight. The weights of methyl red adsorbed after each period was then recorded in table 1.This procedure is repeated for all the five samples.

Table 1 shows that methyl red was adsorbed significantly by all the adsorbents prepared. Equilibrium was established after 24 h, because the adsorptions remain constant between 24 and 48 h. Adsorption increases with increase in time; equilibrium was attained between 24 and 48 hours for all the five adsorbents. The results further showed that the shape of the adsorption isotherms conform to the Langmuir isotherm curves; hence a monolayer adsorption could be postulated.

($logx = logk + 1/nlogc$). A plot of log x against log c gives intercept of log k and slope of 1/n. K and n are the parameters gotten from the graph.

Plantain peel has the largest value of k while ram horn has the least.

3. RESULTS AND DISCUSSION

Analysis of the results above show that adsorption by the five native adsorbents increases with time until equilibrium was established after 24 h. When the adsorbents were left for further 24 h (after 48 h) no further adsorption took place. The results further show that the Freunlich adsorption isotherms were in agreement with Langmuir adsorption isotherm curves [12], hence, a monolayer adsorption could be postulated. Conformity with the Freundlich adsorption isotherm also revealed that adsorption increased indefinitely with increasing concentration [13]. The effect of solubility on adsorption is expected because solute-solvent bond must be broken for adsorption to occur. The greater the solubility, the stronger are these bonds and hence the smaller the extent of adsorption [14]. Analysis of the Freundlich adsorption isotherm(Figure-3), $\log x = logk + 1/nlogc$, for the locally available adsorbents indicate that the value of k is highest with plantain peel and lowest with ram horn. A plot of log x against log c gives intercept of log k and slope of 1/n. k and n were determined from the graph.

k represents the amount of adsorbate adsorbed per unit weight of adsorbent and at unit adsorbate concentration while the n derived from the slope represents the amount of adsorbate

adsorbed for a given concentration change. Plantain peel (n = 3.12, k = 1.71 mg/g) Car tyre (n = 3.12, k = 1.20 mg/g), and ram hair (n = 3.12, k 1.14 mg/g) have the highest value of n (affinity), the binding energy, followed by ram horn (n = 2.38, k = 1.00) and least with sugar cane chaff (n = 2.04, k = 1.02 mg/g). Results of the adsorption of methyl red at various concentrations at the equilibrium time of 24 hours showed that the adsorption was a physical adsorption because the binding energy is within the range of between 0-20 KJ. Also, the shape of the adsorption isotherm conforms to Freundlich isotherm, meaning that the amount adsorbed increased indefinitely with increasing concentration.

4. CONCLUSION

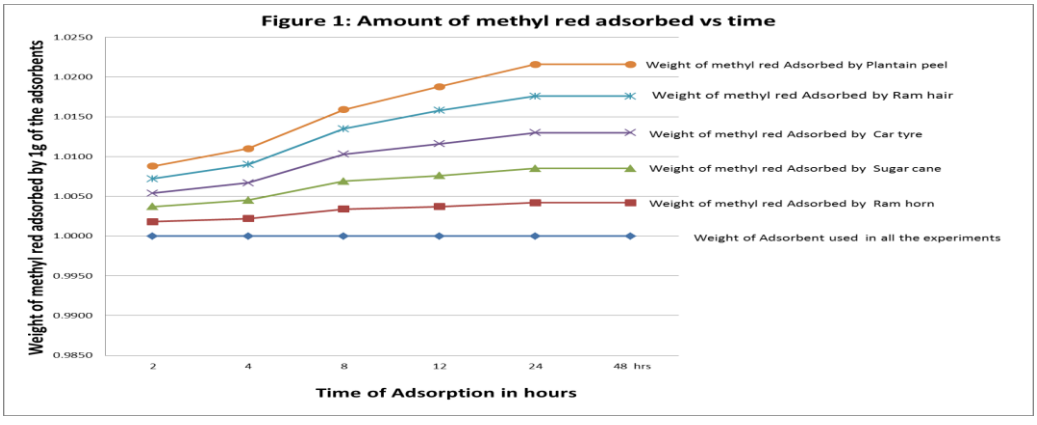
Commercially available activated carbons are limited in their use as a result of high cost. This has led to researches on alternative, non-conventional adsorbents, especially low cost materials native to an area [15, 16] [16] [17]. Among the locally available, native adsorbents analysed, plantain peel (k = 1.71 mg/g) has the highest value of k, and therefore, the adsorbent with the highest adsorptive capacity. Sugar cane chaff is the adsorbent with the least value of k (1.00 mg/g).

Table-1. Adsorption by the locally prepared Activated carbons

Time (hours)	Weight of adsorbent used	Adsorption by Ram horn	Adsorption by sugar cane chaff	Adsorption by car tyre	Adsorption by ram hair	Adsorption by plantain peel
2 h	1.0000	0.0018	0.0019	0.0017	0.0018	0.0016
4 h	1.0000	0.0022	0.0023	0.0022	0.0023	0.0020
8 h	1.0000	0.0034	0.0035	0.0034	0.0032	0.0024
12 h	1.0000	0.0037	0.0039	0.0040	0.0042	0.0030
24 h	1.0000	0.0042	0.0043	0.0045	0.0046	0.0040
48 h	1.0000	0.0042	0.0043	0.0045	0.0046	0.0040

Source: Materials collected from Angwan Rogo, Kwararafa market and Abbatoir, all in Jos.

Figure-1. Adsorption of methyl red by all the adsorbents prepared.



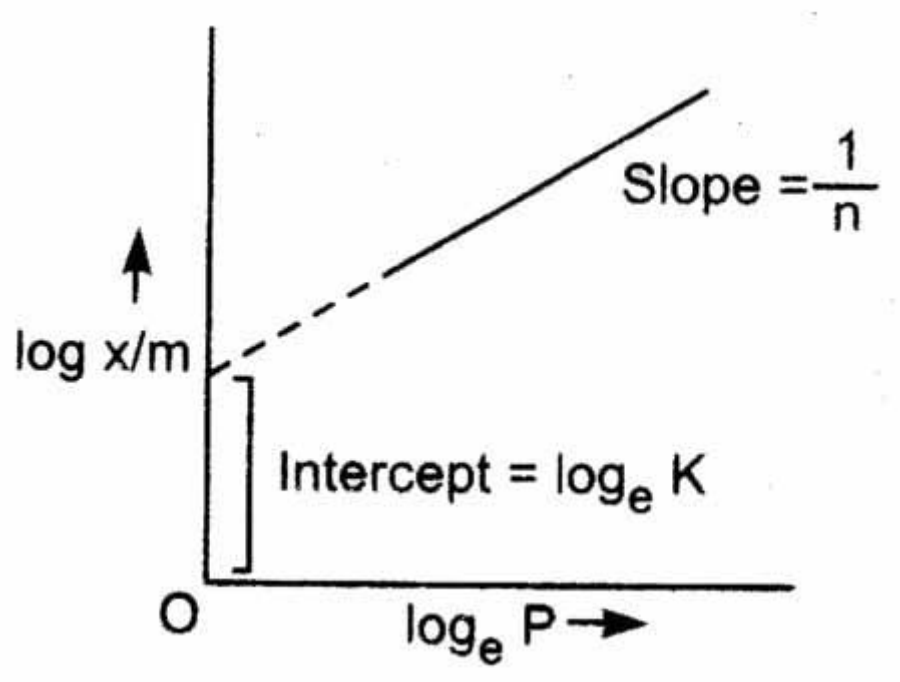
Source: Excel plot of Freundlich adsorption parameters

Figure-2. Freundlich adsorption isotherms for the local adsorbents

Adsorbent	Slope, 1/n	log k(Intercept)	n	k mg/g
Car tyre	0.32	$7.99x10^{-2}$	3.12	1.20
Ram horn	0.42	0.000	2.38	1.00
Sugar cane chaff	0.49	$3.33x10^{-3}$	2.04	1.02
Ram hair	0.32	$1.16x10^{-1}$	3.12	1.14
Plantain peel	0.32	$2.33x10^{-1}$	3.12	1.71

Source: Freundlich parameters of the local adsorbents

Figure-3. Freundlich adsorption parameters from figure-2



Source: http://www.sciencehq.com/wp-content/uploads/Freundlich-Adsorption.jpg

REFERENCES

[1] J. Rouquerol, F. Rouquerol, P. Llewellyn, G. Maurin, and K. S. Sing, *Adsorption by powders and porous solids: Principles, methodology and applications*: Academic Press, 2013.

[2] S. Pollard, G. Fowler, C. Sollars, and R. Perry, "Low-cost adsorbents for waste and wastewater treatment: A review," *Science of the Total Environment*, vol. 116, pp. 31-52, 1992.

[3] C. Namasivayam and D. Kavitha, "Removal of congo red from water by adsorption onto activated carbon prepared from coir pith, an agricultural solid waste," *Dyes and Pigments*, vol. 54, pp. 47-58, 2002.

[4] D. Mohan, K. P. Singh, and V. K. Singh, "Trivalent chromium removal from wastewater using low cost activated carbon derived from agricultural waste material and activated carbon fabric cloth," *Journal of Hazardous Materials*, vol. 135, pp. 280-295, 2006.

[5] A. K. Bhattacharya and C. Venkobachar, "Removal of cadmium (II) by low cost adsorbents," *Journal of Environmental Engineering*, vol. 110, pp. 110-122, 1984.

[6] S. Khanna and D. MUKU, "Toxicity, carcinogenic potential and clinico-epidemiological studies on dyes and dye intermediates," *Journal of Scientific & Industrial Research*, vol. 50, pp. 965-974, 1991.

[7] S. Brunauer, P. H. Emmett, and E. Teller, "Adsorption of gases in multimolecular layers," *Journal of the American Chemical Society*, vol. 60, pp. 309-319, 1938.

[8] C. Minka and A. L. Myers, "Adsorption from ternary liquid mixtures on solids," *AICHE Journal*, vol. 19, pp. 453-459, 1973.

[9] J. Rouquerol, *Adsorption by powders and porous solids: principles, methodology and applications*: Academic Press, 2013.

[10] R. C. Bansal and M. Goyal, *Activated carbon adsorption*: CRC Press, 2010.

[11] S. M. Manocha, "Porous carbons," *Sadhana*, vol. 28, pp. 335-348, 2003.

[12] T. Nwufo and E. U. Onche, "Determination of langmuir adsorption parameters of activated carbon produced from local materials," *International Journal of Chemistry*, vol. 20, pp. 83-90, 2010.

[13] M. Y. Arıca and G. Bayramoğlu, "Cr (VI) biosorption from aqueous solutions using free and immobilized biomass of< i> Lentinus</i>< i> sajor</i>-< i> caju</i>: Preparation and kinetic characterization," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 253, pp. 203-211, 2005.

[14] B. T. Nwufo, "Adsorption of atropine and hydrosine on magnesium trisilicate," *International Journal of Chemistry*, vol. 1, pp. 472-473, 1995.

[15] B. Amarasinghe and R. Williams, "Tea waste as a low cost adsorbent for the removal of Cu and Pb from wastewater," *Chemical Engineering Journal*, vol. 132, pp. 299-309, 2007.

[16] S. Babel and T. A. Kurniawan, "Low-cost adsorbents for heavy metals uptake from contaminated water: A review," *Journal of Hazardous Materials*, vol. 1, pp. 219-243, 2003.

[17] G. Crini, "Non-conventional low-cost adsorbents for dye removal: A review," *Bioresource Technology*, vol. 97, pp. 1061-1085, 2006.