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Textile Waste Water Treatment and Colour Removal Using Chemically Activated Sawdust

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ABSTRACT

In this study, removal of direct blue dyestuff (an organic pollutant) from wastewater effluents of textile industry by adsorption was investigated. Activated charcoal was produced from sawdust using aqueous zinc chloride, ZnCl2 as the activating agent and carbonized at 500 0C for 45 minutes. The effectiveness of the AC was measured in terms of absorbance using colorimeter. The results show a very sharp reduction from 600 mg/dm3 to 40 mg/dm3. Experimental results were subjected to Langmuir and Freundlich adsorption isotherms, Langmuir model was better fitted for the equilibrium analysis with R2 value of 0.917 and physical adsorption type. The values of the dimensionless constant separation factor, RL lies between 0 and 1, thus indicate that the decolourization process is favorable.

Keyword: direct blue dyestuff, effluents, adsorption, isotherms, equilibrium

INTRODUCTION

The problem of purifying town water increases as the level of water pollutant increases, the increasing volume of synthetic organic waste especially from industries is the main challenge of surface water resources. Organic pollutants such as dyestuff are not biodegradable, and stable,
having carcinogenic action [1] and pose serious hazard to human, animal and plant life [2]. There is high concentration of dyestuff in waste water effluent of textile industry, it is very pertinent to remove the basic dyestuff before discharging into environment where there is possibility that it will mix with streams and wells. Decolourization of textile industry waste water is a global problem to which several successful treatment technologies have been applied, including oxidation and adsorption [3]. The adsorption process on commercial activated carbon and polymer resin which encompasses several physical, chemical and biological methods [4] but their use is restricted in textile industries due to their high cost and infeasibility.

Consequently, indigenous companies pay zero attention to the treatment of their waste water. There is a need to search for alternative technologies which might persuade industrialist to properly treat waste water. New technologies must be inexpensive, easy to maintain, requires no complex skills to operate and be locally or readily available. The isolation of synthetic organic colour by adsorption on to agricultural residues has recently become the subject of considerable interest by researchers since these solid wastes are abundantly available at very little or no cost, this approach has the potential to provide a low cost alternative solution to the challenge [5]. There are reports on the adsorption of dyestuffs by banana pith [6], Indian rosewood [7], walnut and cherry tree, pine [8], rattan [9] and biopolymer oak sawdust [10].

Adsorption has for centuries been known as a purifying process. The ancient Hindus filtered water with charcoal (an adsorbent). Nowadays, adsorption bleaching process is used to remove contaminants such as colour, carotenes, odour, chlorophyll e.t.c. from a solution it is contained [11]. Generally, an activated carbon which is used in any of the most common applications must have adequate adsorptive capacity (large surface area), chemical purity, mechanical strength e.t.c. and all these specifications should coexist with a low production cost [12].

Direct blue dyestuff is selected for a detailed study to assess the direct dye adsorption ability of activated charcoal. This work is primarily aim to adsorb basic dyestuff from its aqueous solution. The chemically activated charcoal produced from sawdust will be used for adsorption of disperse basic dyestuff and concentration effect on the adsorption potential will be verified. The successful completion of the research will serves as a basis to give a very cost effective and more efficient adsorption process to purify waste water effluent from textile industry to acceptable threshold limit value (TLV) and drastically reduce environmental pollution.

MATERIALS AND METHOD

Materials	Manufacturer	Source
Sawdust		Sawmill, Minna, Nigeria
Dyestuff & waste water		African Textile, Kano, Nigeria
Anhydrous zinc chloride ($ZnCl_2$)	May/Baker Limited Dagenham, England	Mekrax Chemical, Minna, Nigeria

Preparation of chemically activated charcoal (sawdust)

Activation: The sawdust was sieved in order to obtain a desirable size fraction (0.5 and 1mm). Then, the sieved sawdust was washed with distilled water to remove any residues or impurities such as dust. Subsequently, it was dried in an oven for 12 hours at 80 ^oC. 200 g of dried sawdust was weighed into 1 litre conical flask. It was then chemically activated by soaking into 0.1 molar concentrated zinc chloride solution for 24 hours. The residual $ZnCl_{2\,(aq)}$ is later removed by filteration.

Carbonization: the residue from the chemical activation process was dried in dryer and then carbonized in a furnace operated at 500 ^0C for 45 minutes. The carbonized activated charcoal was then washed using distilled water to remove excess zinc chloride solution [13].

Adsorption Experiment

Adsorption process using blue disperse dyestuff: a standard solution 50 ml, which have concentration varying from 200 to 1000 mg-dye per dm^3 was prepared. Weighed 5.0 g of activated charcoal, AC were added to the solution, shake at 150 rpm and left for residence time of 6 hours at room temperature. The residual solution was filtered off and the absorbance analysis of initial and final concentration were measured with the aid of colorimeter (with 1 cm light path glass cell at a maximum wavelength, λ = 580 nm, using distilled water as set blank).

Adsorption process using sample waste water: the effect of adsorbent dosages (varied from 1 g to 5 g) on the adsorption of basic dyestuff on the adsorption potentials was investigated by employing textile waste water sample at room temperature and 6 hours contact time. The quantity of dyestuff retained on the activated charcoal phase was calculated using equation (1):

$$q_t = \frac{(C_0 - C_t)v}{1000M} \qquad (1)$$

Where C_0 and C_t are initial and final/equilibrium concentration of basic dyestuff solution respectively, v is the volume (ml) and M is mass (g) of the activated charcoal [4].

The percentage removal of the dye is given by;

$$\%\,Removal = \frac{(C_0 - C_t)\,100}{C_0} \qquad (2)$$

Adsorption Isotherms: Equilibrium analysis of adsorption process was carried out by using linearized Langmuir and Freundlich models represented by equations (3)
and (4) respectively [14, 15]:

$$\frac{1}{q_e} = \frac{1}{q_m} + \frac{1}{q_m K_L}\frac{1}{C_e} \qquad (3)$$

$$\ln(q) = \ln k_f + \frac{1}{n}\ln(C_e) \qquad (4)$$

RESULTS AND DISCUSSION

The result of basic dyestuff uptake which is the measure of the adsorption capacity with quantity adsorbed for 5.0 g adsorbent is illustrated in figure 1. It indicate that as the concentration of dyestuff is increasing, there was corresponding increment in quantity adsorbed, q for the same time considered.

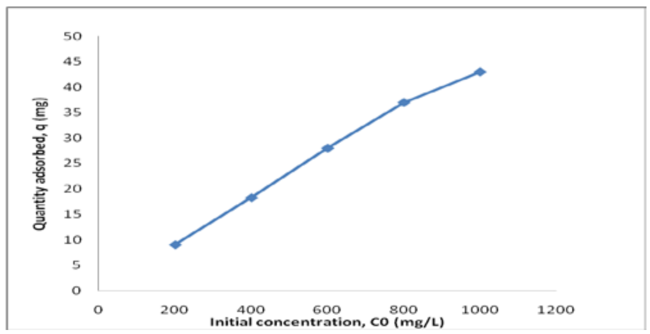

Figure 1: Plot of quantity adsorbed against initial concentration of disperse dyestuff

Similar observation reported by Kini et al., 2013. This is probably a result of improved driving force to overcome mass transfer resistance and greater interaction between activated charcoal and basic dyestuff [16, 10].

Effect of adsorbent dosage: The relationship of mass of activated charcoal, AC on adsorption of basic dyestuff is presented in figure 2. From figure 2, for an increase in AC dosage of 1-5 g/L, quantity adsorbed, q_t increase from 1.33 g to 1.74 g, whereas the percentage removal increased from 70.89 % to 92.06 % respectively. This is due to large surface area and availability of more adsorption site at higher concentration of the adsorbent [17].

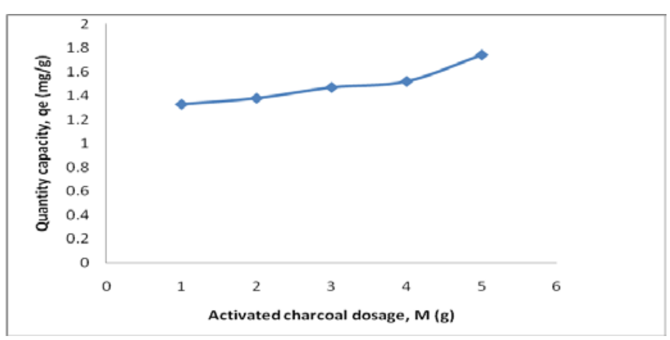

Figure 2a:

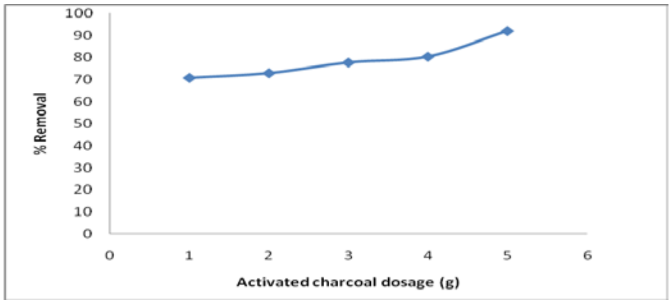

Figure 2: plot of AC dosage on the adsorption capacity of basic dyestuff (a) quantity adsorbed (b) % removal at initial concentration of wastewater of 1.89 g/dm^3:

ADSORPTION ISOTHERMS

Equilibrium analysis has been carried out based on the data of dependence of adsorption capacity to initial concentrations. This is the presentation of the result gotten for the adsorption of basic dyestuff using the activated charcoal, AC:

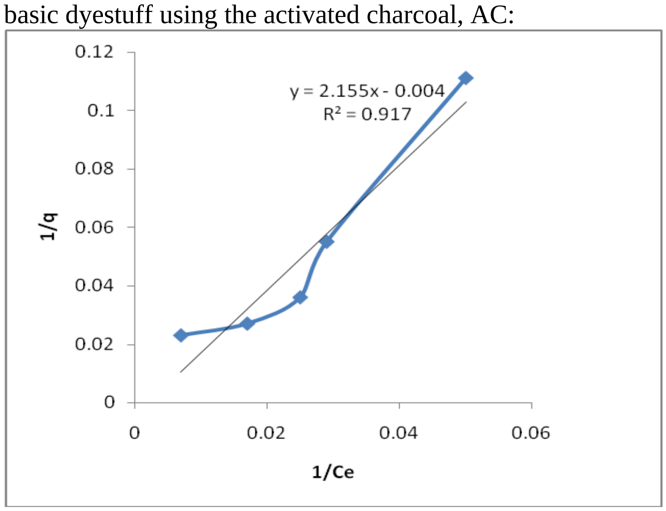

Figure 3: Langmuir adsorption isotherms

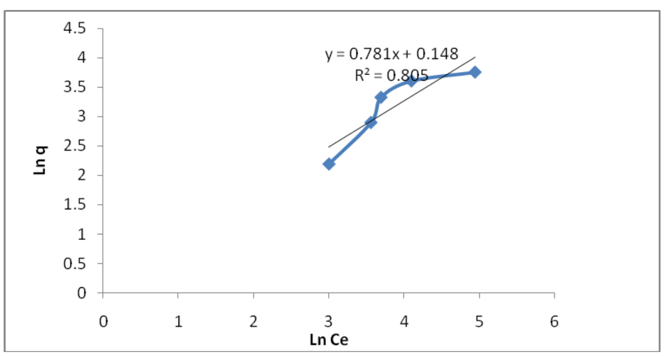

Figure 4: Freundlich adsorption isotherms

Figures 3 and 4 respectively show the results of the fitting of Langmuir and Freundlich models to the basic dyestuff uptake data. The results clearly show a good fit of the data by both models. The model adsorption parameters and the correlation coefficients are shown in Table 2. However, applicability of the isotherm model to describe the process was judged by the correlation coefficient (R^2). It was observed that the results fitted better in Langmuir model in terms of R^2 value than Freundlich model, reveals the homogeneous nature of AC surface and physical type of adsorption at lower initial concentration [18, 19]. The maximum adsorption capacity of 250 mg/g also implies that AC can be used to treat effluent from textile industry.

Also from Langmuir's model the dimensionless separation factor R_L is derived as follow [20]:

$$R_L = 1/(1 + K_L C_o) \quad (5)$$

The values of R_L lying between 0 and 1 indicates favourable or effective adsorption. Table 3 present values of R_L, the adsorption of basic dyestuff onto AC (prepared from sawdust) is favourable

Table 2: Constants of Langmuir and Freundlich models and correlation coefficients

Models	AC
Langmuir K_L, mg g^{-1}	0.0019
q_m, mg g^{-1}	250
R^2	0.9170
Freundlich K_f	1.1595
n	1.280
R^2	0.8050

Table 3: separation factor, R_L

C_o **mg/dm^3**	R_L
200	0.3378
400	0.2033
600	0.1453
800	0.1131
1000	0.0926

Conclusion

Base on these results and its analysis, the following conclusion can be made;

- The carbonaceous activated charcoal AC is quite effective as an adsorbent in the treatment of waste water effluents containing direct dyestuff
- The higher the quantity of AC, the more the particle adsorbed
- The adsorbent has high affinity and capability of absorbing organic pollutant, that is dyestuff in the waste water
- The balance characterization for the used adsorbents showed that the process of adsorption is better described by Langmuir model and here physical adsorption was the case.

This also shows that the adsorption of organic pollutant over a good adsorbent remain an unquestionable process of waste water decolourization.

Nomenclature

AC- activated charcoal

C_e – balance dyestuff content in waste water, mg dm^{-3}
C_0 – initial dyestuff content in waste water, mg dm^{-3}
K_f – Freundlich constant related to adsorption capacity, mg g^{-1}
K_L – Langmuir constant, g mg^{-1}
M – Mass of adsorbent, g
n – Freundlich constant related to adsorption intensity
q_m – maximum adsorption capacity, mg g^{-1}
q_e – balance adsorption capacity, mg g^{-1}

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