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Research Paper

Batch Adsorption Treatment of Textile Effluent using Sugarcane Bagasse Activated Carbon as Adsorbent

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ABSTRACT
The incessant generation and discharge of large volume of textile effluent wastewater containing coloured dye solution mixture by textile industries into natural water bodies or rivers have been causing environmental pollution. The aim of this study is to use sugarcane bagasse activated carbon as adsorbent to treat textile effluent. Batch adsorption study was used to treat the textile effluent by optimizing dosage, concentration, contact time, and pH of effluent discharge to obtain optimum result. The untreated and treated textile effluent samples were analyzed using ultra violet (UV) spectrophotometer instrument to determine the concentration of the textile effluent solution. The results of the treatment of textile effluent analysis showed that the ash adsorbent had high percentage removal of the coloured dye in the solution. Optimization results of pH and contact time increase result in the increase of uptake capacity and removal efficiencies while increase in dosage and concentration increase, result in the decrease in uptake capacity and increase in removal efficiency which later decrease respectively. The isotherm study revealed that the Langmuir isotherm correlation coefficient R^2 *= 0.985 is higher than the Freundlich isotherm correlation coefficient* R^2 *= 0.943. The isotherm adsorption data analyzed using Langmuir and Freundlich models are well fitted but the Langmuir isotherm is well fitted than the Freundlich isotherm, which indicate the fitness of the experiments. The fitness of Langmuir's model indicated the formation of monolayer coverage of the adsorbate on the outer surface of the adsorbent. In conclusion, bagasse activated carbon adsorbent was capable of adsorbing coloured textile effluent with high affinity and capacity which revealed its potential as a low cost alternative adsorbent.*
KEYWORD: *Textile effluent, sugarcane bagasse activated carbon, adsorbent, batch adsorption study, and ultra-violet spectrophotometer*

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I. INTRODUCTION

Textile effluent wastewater: Textile clothing material is one of the essential basic needs of man for human survival. However, textile industries have economic significance because of its contribution to job creation and industrial output. Patel and [1] used a general process diagram to describe textile industry and the associated pollutant types and effluents. Textile industry has a wide spectrum of industries ranging from small-scale units that uses traditional manufacturing method to large integrated mills using modern machines and equipment's. Textile industries transform fibers convert into fabrics or other related products, dye and finished these materials at various stages of production. During production of clothing materials, textile industry uses different type of dyes, clothing materials, chemicals, and other chemicals [2]. The uptake of textile effluent dyes onto the activated carbon is fostered by the interaction between the functional groups of the dye and activated carbon. Adsorption process depends seriously on the porous structure and surface functional groups of the activated carbon. Activated charcoal can be classified base on its methods of preparation, surface characteristics, and behavior i.e., pellet-activated charcoal, impregnated, and polymers coated, [3]. Textile effluent is the coloured wastewater generated from textile industries where fabrics and inks are being used for aesthetic work. Textile industry is one of the industries that are involved in water pollution because of the large volume of water consumption. Disposal of textile effluent discharge has being a global challenge to most of the textile industries whether local or foreign [4], [5]. Dyes are toxic organic or inorganic substances that affect human health and aquatic life even at very low concentration, and it is necessary to remove it so that water can be made available [5], [6]. Treatment of real textile wastewater has become a real challenge in the recent years. The sugarcane bagasse is basically built by macromolecules with humic and fulvic substances, lignin, cellulose, hemicelluloses and proteins that have adsorptive sites such as carbonyl, carboxylic, amine and hydroxyl groups, which are able to absorb the dyes by the ion exchange phenomena or by complexation [7]. Strong colour is one of the main difficulties in treating the textile effluents due to the non-fixing of excessive dye added to fibers during tinting operations.

Sugarcane: Sugarcane (*Saccharumofficinarum*), is an agricultural perennial crop with thick and fibrous stems; characterized with high sucrose content which is processed to obtain sugar [8], [9]. Sugarcane bagasse is a waste product used as adsorbent in the removal of textile wastes with different chemical nature of dyes such as acidic, basic, cationic, and anionic dyes [10], [4], [11], [12]. Studies have shown that the removal of Orange II dye using sugarcane bagasse ash as a low cost adsorbent [13]. Mohamed et al., [14] reported that agricultural by-products usually are composed of lignin and cellulose as major constituents and may also include other polar functional groups of lignin, which includes alcohols and ether groups.

Activated carbon adsorption: is a highly effective method widely used for the removal of water pollutants [15]. A major challenge of adsorption process is the high production cost of activated carbons [15]. For adsorption process to be efficient, in addition to its low cost, it is necessary to choose an adsorbent with high adsorptive capacity, high selectivity, stability and availability [16], [17]. It is important to highlight that the use of sugarcane wastes for the treatment of aqueous effluents, primarily, it act as alternative adsorbent materials which can remove inert pollutants from the wastewaters and contribute to minimizing the environmental impacts caused by inadequate disposal of these wastes.

Adsorption Treatment: Studies have been conducted on the removal of coloured dyes from aqueous solutions using different techniques such as biodegradation [18], liquid extraction [19], chemical oxidation using a Fenton-like reaction [20], nanobiocatalysts [21], membranes [22], [23], combined adsorption and photodegradation [24], liquid- electrocoagulation [25], and adsorption using different adsorbents such as wood ash [4], activated carbon [26], synthesized alumina-zirconia composite or nickel alginate/graphene oxide aerogel [27], [28]. Adsorption method is the most preferred technique because of its low cost, simple design, easy operation, and several choices of adsorbent materials that are relatively simple regeneration with high efficiency [29], [22]. Activated carbon is one of the most commonly used adsorbents due to its high specific surface area and adsorption capacity, but it suffers from high production and regeneration cost [30], [31]. Because of the adverse environmental effects of dye effluent, the use of bio-adsorbents for removal dyes from the textile wastewater has been established. Activated carbon is one of the adsorbent methods with a high cost and expensive processes [32]. To create an easily achievable result, efforts have now been made to create bio-adsorbents of considerable lower cost, such as sugarcane [33].

II. MATERIALS AND METHODS

2.1 SAMPLING AREA

Sugarcane: Sugarcane sample was collected from a sugarcane plantation located at Papalanto area in Egbado, Ogun State. The sample collection location is presented in Figure 1.

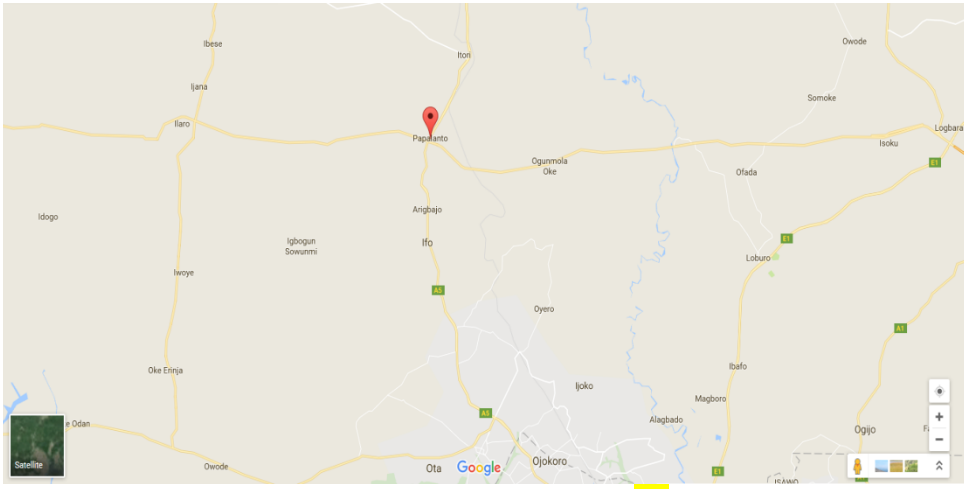

Figure 1: Map of Papalanto area, Egbeda, Ogun state.

Textile effluent wastewater: a raw textile effluent wastewater sample was collected from Nigeria textile mills, Oba Akran area in Ikeja, Lagos state. Sample was collected at the point of discharge of the textile industry with plastic sampling bottles and kept in a refrigerator in order to preserve the sample until the time for analysis. The location of the textile sample collection is presented in Figure 2.

Figure 2: Map of Oba Akranarea, Ikeja, Lagos state.

2.2 Sample
The samples used for this batch adsorption study are dye textile effluent, and sugarcane bagasse activated carbon

2.2.1 Sugarcane Bagasse
Sugarcane was purchased from a sugarcane plantation farm located at Papalanto, Egbado local government area, Ogun State, Nigeria and the bagasse. The sample was washed with tap water to remove most of the impurities and the juice was extracted from the sugarcane stem was used for making sugar or any other desired product. The fiber was soaked and washed with water and finally soaked with distilled water and 15 mL of concentrated HNO_3 to acidify the water and remove the remaining impurities present before it was sun dried and ready for burning. The sugarcane bagasse was burnt to ashes in a muffle furnance at high temperature between 650-750 ^{0}C for about 2 hours.

2.2.2 Dye Effluent
The textile dye effluent sample was collected from the premises of Nigerian Textile Mill Plc, Ikeja, Lagos State, Nigeria. The sample was collected at the discharge point in the factory in a polyethylene container and kept in a refrigerator regulated at 4 ^{0}C until it is required for treatment and analysis.

2.3 Chemicals
All chemicals were used as received and they include sodium hydroxide, hydrochloric acid, and nitric acid purchased from TUNNEX chemical company.

2.4 Preparations,

2.4.1 Sample Preparation
Preparation of activated carbon biosorbent: the sugarcane bagasse is a waste biomass collected from Papalanto area in Egbedo, Ogun State and used as a biosorbent material after the extraction of juice from the sugarcane stem. The waste material was cut into pieces in moderate sizes, washed rinsed several times with tap water before rinsing with distilled water to remove any trace of sand, dust and foreign particles. The clean washed bagasse was dried in sunlight for 6 hours and oven dried overnight at 80 °C. The dried bagasse was placed in a muffle furnance regulated to a temperature of 500 to 550 ^{o}C to burn biomass to form bagasse carbon. The sugarcane bagasse carbon formed was charged by soaking it with 5M nitric acid for 24 hours before drying in a regulated oven for 12 hours. The dried bagasse activated carbon was grounded to small size particles and sieved to obtain fine powder to be used for adsorption process.

2.5 Batch Adsorption Study
Batch adsorption study was conducted on the treatment of textile effluent sample using sugar cane bagasse activated carbon adsorbent material to determine the absorption capacity, and percentage removal of dosage, concentration, contact time and pH of the samples to purify the wastewater. The optimization of dosage, concentration, contact time and pH were determined as the major parameters affecting the removal efficiency of the adsorption process. Batch adsorption studies was conducted on dosage by shaking 0.2, 0.4, 0.6, 0.8, and 1.0 g of sorbent material in each container with 50 mL of the dye solution for a period of 2 hours with a shaker at 200 rpm. The solution was filtered off and the filtrate was placed in the spectrophotometer for analysis and the experiment was carried out at room temperature. The batch adsorption studies was conducted for other parameters such as concentration within the range of 20, 40, 60, 80, and 100 ppm, contact time 20, 40, 60, 80, and 100 minutes, and pH within the range of 2, 4, 6, 8, 10, were optimized like dosage with the same procedure. The absorbance of the samples was measured between 200 nm and 540 nm using a UV Visible Spectrometer to determine the dye concentration.

The removal efficiency was calculated using this equation;
Removal efficiency (%) = $(C_i - C_f)/C_i$ x 100
Where: C_i = Concentration of textile effluent in the sample solution before treatment.
C_f = Concentration of textile effluent in the sample solution after treatment.

2.6 Analytical Technique
2.6.1 UV-visible spectrometer
The spectrum of the dye solution was analyzed by using UV-visible spectrometer (Thermo Scientific NanoDrop™ 2000/2000c) at a wavelength of 540.0 nm which is λmax of the dye solution.

III. RESULTS
3.1 Absorbance of Standard Dye Solution
The absorbance of the standard textile solution presented in Figure 3 was determined using ultra violet visible spectrometer and the correlation coefficient R^2 = 0.999 which indicate.

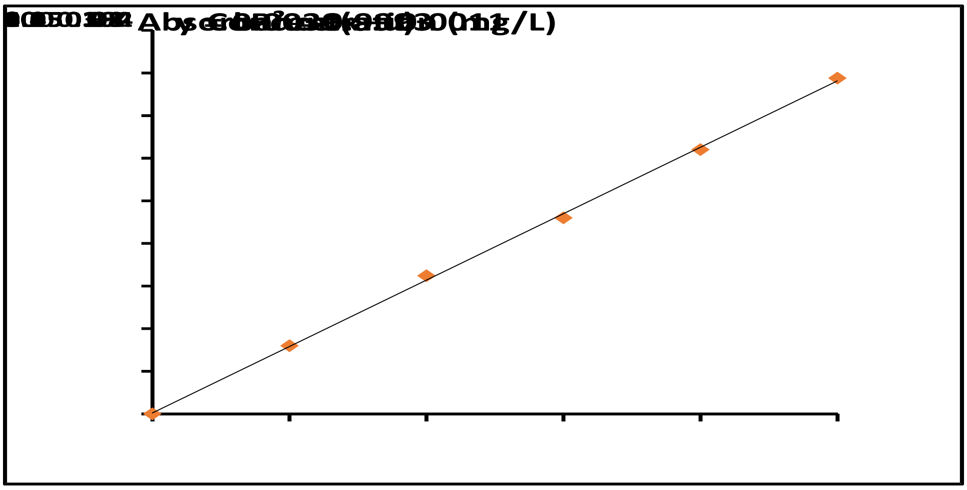

Figure 3: Absorbance of Standard Dye

3.2 BATCH ADSORPTION STUDIES
Sugarcane bagasse activated carbon was used to treat textile dye effluent wastewater generated from Nigeria textile mill industry in Ikeja an industrial estate, Nigeria. This study was conducted to optimize the dosage, concentration, contact time, and pH in order to determine their effect in the treatment process.

3.2.1 Dosage Optimization
The result of dosage effect of textile effluent treatment using bagasse activated carbon is presented in Figure 4. At 0.2 g, minimum removal efficiency of 31.44 % was obtained with uptake capacity of 7.86 mg/g with further increase in dosage, a gradual increase in removal efficiencies and increase in uptake capacities at 0.4 g, 65.05% (8.13 mg/g), at 0.60 g, 87.31% (7.28 mg/g), at 0.80 g, 98.70% (6.17 mg/g), and at 1.00 g, 99.90% (4.99 mg/g). Therefore, the optimum dosage for the removal of colours from textile effluent dye solution was 0.6 g. As the dosage increase, the removal efficiency decreases and adsorption capacity increased and later decreased.

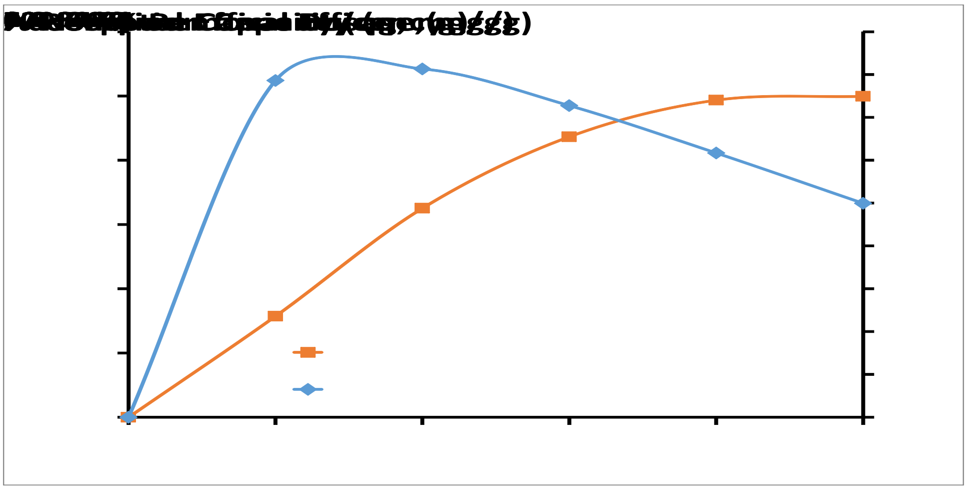

Figure 4: Sugarcane bagasse activated dosage treatment of textile effluent

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3.2.2 Concentration Optimization

Concentration effect of the treatment of textile effluent solution with 0.6 g optimum sugarcane bagasse activated carbon adsorbent dosage is presented in Figure 5. At 20 mg/L, maximum removal efficiency of 96.91 % was obtained with uptake capacity of 1.62 mg/g with further increase in concentration, a gradual decrease in removal efficiencies and increase in uptake capacities at 40 mg/L, 95.90% (3.20 mg/g), at 60 mg/L, 80.17% (4.01 mg/g), at 80 mg/L, 59.16% (3.94 mg/g), and at 100 mg/L, 42.72% (3.56 mg/g). Therefore, the optimum concentration obtained for the removal of colours from textile effluent dye solution was 60 mg/L. As the concentration increase, the removal efficiency decreases and uptake capacity increase and later decrease.

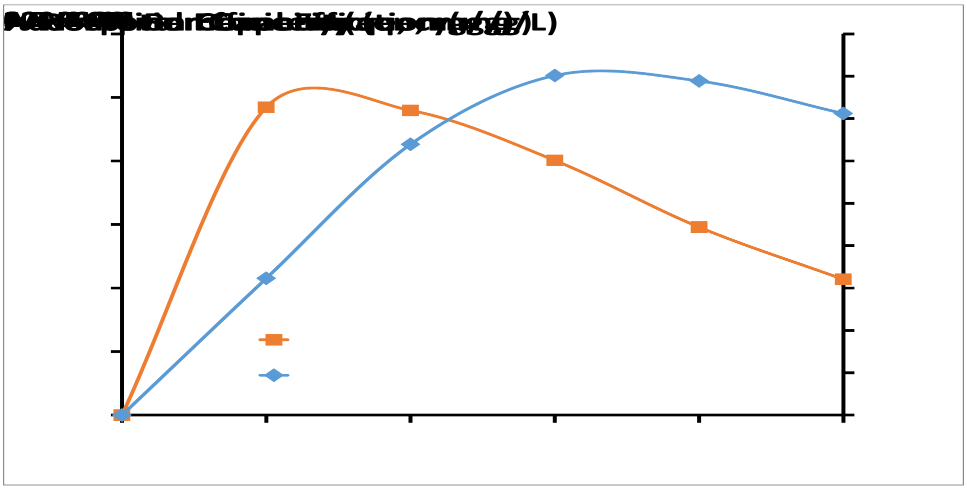

Figure 5: Sugarcane bagasse activated concentration treatment of textile effluent

3.2.3 Contact Time Optimization

Contact time effect of the treatment of textile effluent solution with 0.6 g optimum sugarcane bagasse activated carbon adsorbent dosage, and optimum concentration 60 mg/L are presented in Figure 5. The effect of contact time for using the adsorbent to treat the textile effluent solution to remove color from solution is presented in Figure 6. The results showed the treatment of the textile effluent effect of varying the contact time from 20 to 120 minutes. At 20 minutes, minimum removal efficiency of 26.90 % was obtained with uptake capacity of 0.45 mg/g with further increase in contact time, a gradual increase in removal efficiencies and increase in uptake capacities at 40 minutes, 51.3% (1.71 mg/g), at 60 minutes, 91.03% (3.06 mg/g), at 80 minutes, 89.45% (5.96 mg/g), at 100 minutes, 90.03% (7.50 mg/g), and at 120 minutes, 92.09% (9.21 mg/g). Therefore, the optimum contact time obtained for the removal of colour from textile effluent dye solution was 40 minutes. As the contact time increase, removal efficiency increase and adsorption capacity increase.

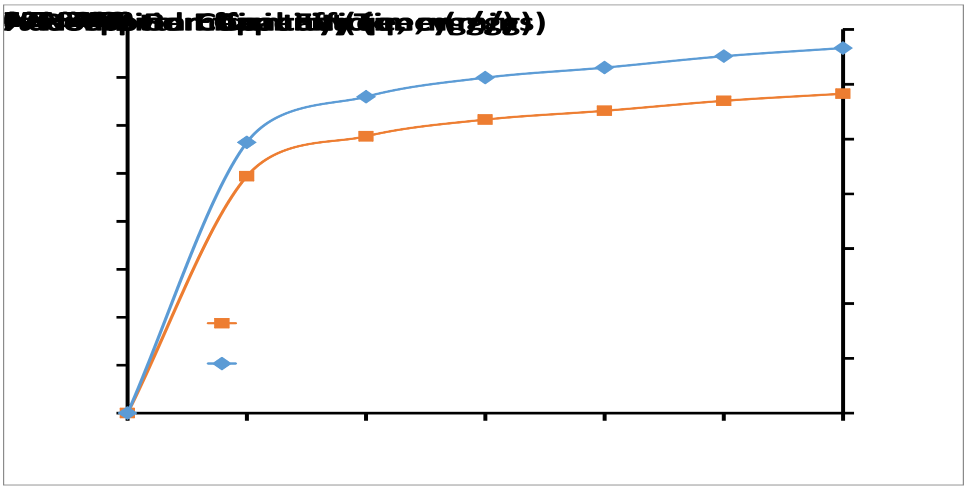

Figure 6: Sugarcane bagasse activated carbon of contact time treatment of textile effluent

3.2.4 pH Optimization

pH effect of the treatment of textile effluent with 0.6 g optimum sugarcane bagasse activated carbon adsorbent dosage, optimum concentration 60 mg/L, and optimum contact time 40 minutes are presented in Figure 7. The effect of pH on the adsorption capacity and percentage removal efficiency of the colour from textile effluent solution are presented in Figure 7. The results showed the treatment of the textile effluent effect of varying the pH 2.00 to 10.00. Minimum adsorption of 37.25% was obtained at pH 2.0 with uptake capacity of 1.86 mg/g with further increase in pH, a gradual increase in removal efficiencies and uptake capacities at pH 4.00, 63.20% (3.16 mg/g), at pH 6.00, 80.52 % (4.03 mg/g), at pH 8.00, 87.02 % (4.35 mg/g), and at pH 10.00, 88.2% (4.41). The baggase activated carbon treatment of textile effluent at different pH revealed that the optimum pH was 2.00. The result treatment revealed that as the pH increase, the percentage removal efficiencies and adsorption capacities also increase.

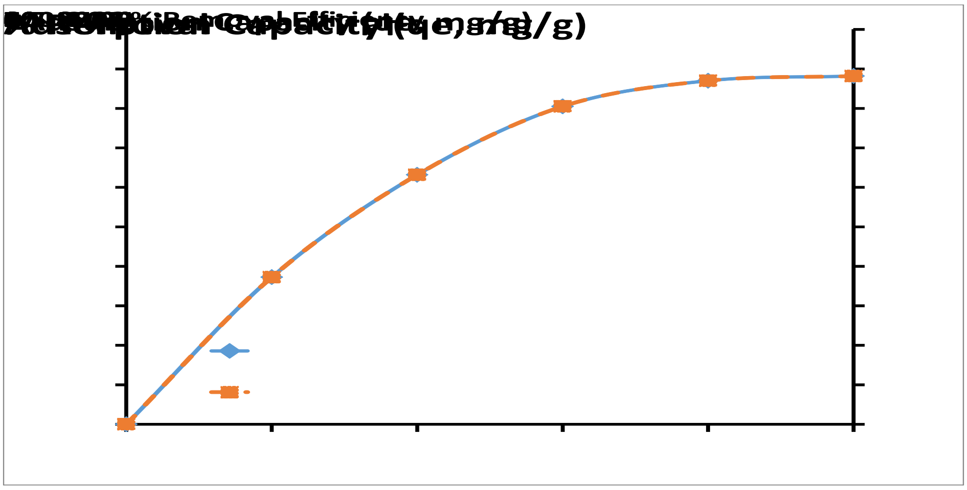

Figure 7: Effect of pH Sugarcane bagasse activated carbon of pH treatment of textile effluent

3.3 ISOTHERM STUDY

It is essential to model experimental adsorption isotherm data is a way of predicting the mechanism of the adsorption process. Several models have been studied to describe experimental data of adsorption isotherm but we are looking at two of the major ones Langmuir and Freundlich were used for interpretation adsorption data obtained.

3.3.1 Langmuir Isotherm

Activated carbon adsorbent from sugarcane bagasse is a low cost agricultural material used for the treatment or removal of pollutants wastewater. Langmuir isotherm will help us know if the adsorption treatment is favoured by this process. The Langmuir isotherm of the sugarcane bagasse activated carbon adsorption of colour from textile waste effluent.

The equation for Langmuir isotherm is given as:

$1/Q_e = (1/Q_0k_l)(1/C_e) + (1/Q_0)$ ………………………………. Eqn 1

Where Ce is the equilibrium concentrations (mg/L) of dye solution

Qe is the amount of dye adsorbed per gram of adsorbent at equilibrium (mg/gram)

Q_0 and k_l is Langmuir constants related to the capacity and energy of adsorption respectively. The plot of 1/QeVs 1/Ce is shown in Figure 8. The linear plot suggests the applicability of the Langmuir Isotherm for this system. It also indicates the formation of monolayer coverage at the outer surface of the adsorbent. The values of Q_0 and kl, Langmuir constants are calculated from the slope and intercepts of the graph presented in Figure 8.

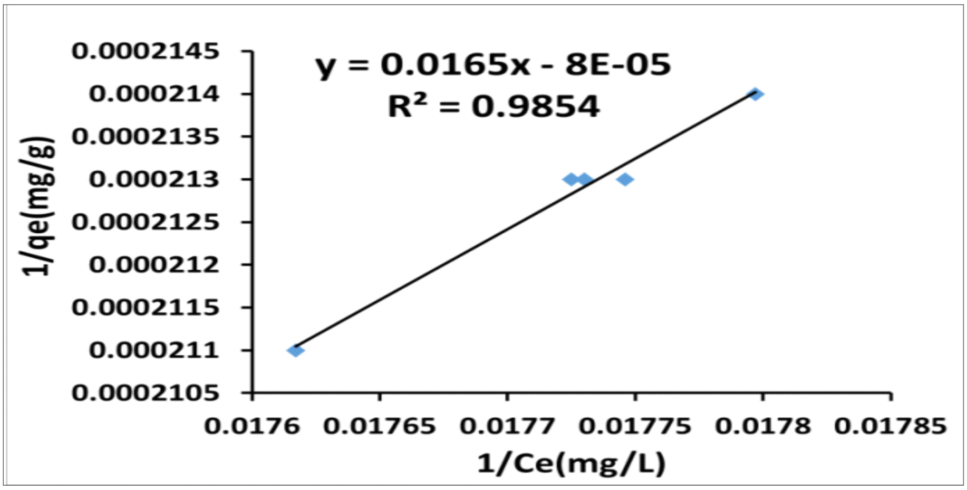

Figure 8: Langmuir isotherm for sugarcane activated carbon

From the Langmuir isotherm graph of bagasse activated carbon adsorption treatment of textile effluent presented in Figure 8 revealed that the model for activated carbon showed a high value of correlation coefficient of R^2 = 0.985. It implies that the adsorption of textile effluent dye onto bagasse activated carbon occurs as a monolayer adsorption on the adsorbent surface [34]. These adsorbents are economically suitable for the removal of dyes from industrial effluents. Applicability of the Freundlich Isotherm for this present system has also been found by correlating the results using the Freundlich equation as

$\ln Qe = \ln Kf + 1/n(\ln Ce)$ ……………………………………….. Equation 2

Table 1: Langmuir isotherm and Freundlich isotherm model

	Langmuir	Isotherm	Model		Freundlich	Isotherm	Model	
Adsorbent	**Q_0 (mg/g)**	**K (LiI/mg)**	**R^2 Adsorbent**	**C_0 (mg/L)**	**R_L**	**K_F (mg/g)**	**1/n**	**R^2**
bagasse activated carbon	1.251	0.005	0.985	47.32	0.8086	3.168	0.9370	0.943

3.3.2 Freundlich Isotherm

Sugarcane bagasse activated carbon adsorbent is a low cost agricultural material used for the treatment or removal of pollutants. The Freundlich isotherm will help to know if the adsorption treatment is favoured by this process. The Freundlich isotherm of the bagasse activated carbon adsorption of colour from textile waste effluent is presented in Figure 9.

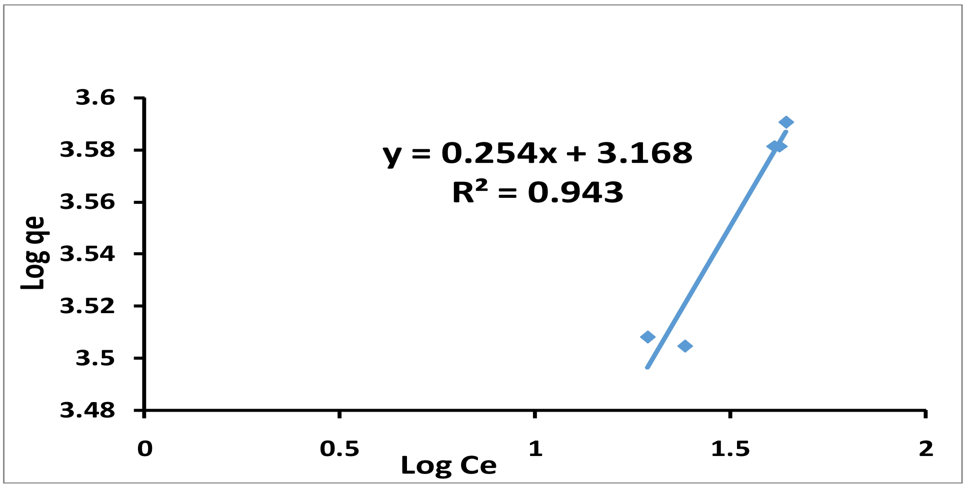

Figure 9: Freundlich isotherm for bagasse activated carbon

Applicability of the Freundlich Isotherm for this present system has also been found by correlating the results using the Freundlich equation as

lnQe = lnKf + 1/n(lnCe) ……………………………………….. Equation 2

The result of the Freundlich isotherm of sugarcane bagasse activated carbon adsorption is presented in Figure 9 shows that it is suitable for the sugarcane bagasse activated carbon.

Furthermore, the results revealed that the Freundlich isotherm model was suitable because of the high value of correlation coefficient ($R^2 = 0.943$).

The Langmuir isotherm result showed that the adsorption of textile dye onto sugarcane bagasse activated carbon occurs as a monolayer adsorption on the adsorbent surface. This type of sorbent material is economically good for the removal of dyes from industrial effluents. The adsorption isotherm is used to describe the interaction of adsorbates with adsorbents, and the equilibrium distribution of adsorbate molecules between the liquid and solid phases. In this study, two isotherm models, Langmuir, and Freundlich equations were applied to simulate the isotherm data. However, the Langmuir isotherm model is based on the assumption of a homogeneous adsorbent surface with identical adsorption sites [17], [35].

IV. DISCUSSION

The values of correlation coefficient (R^2) obtained for Langmuir isotherms for bagasse activated carbon was 0.985 while the Freundlich isotherm value for activated carbon adsorbent was 0.943 for dye textile effluent solution treatment. The results indicated that Langmuir's models as well as Freundlich's model are both highly applicable and suitable for the present sorption process. The high value of Langmuir isotherm correlation coefficient confirmed that the Langmuir isotherm is best fitted than the Freundlich isotherm onto sugarcane bagasse ash and also the high value. Freundlich correlation coefficient confirmed that the Freundlich isotherm for ash is best fitted isotherm than onto bagasse activated carbon. The result of this study is clearly showed that the bagasse activated carbon used to treat textile effluent was effective for removing colours in textile coloured solution. The efficiency increases with increase in the contact time and the dosage of adsorbent until the equilibrium is established. The adsorption isotherms and correlation coefficient values is well good fitted with the experimental data. This type of adsorbents is economically good for the removal of dye colours from industrial effluents.

V. CONCLUSION

From the results obtained from this study, it may be concluded that the utilization of bagasse ash and bagasse activated carbon as adsorbent may offer a practical means for an effective treatment of dye effluent and wastewater contaminated with dye solution.

- The findings revealed that textile dye was removed from effluent using bagasse activated carbon obtained from a sugar cane farm at Papalanto, Egbeda, Ogun State, Nigeria. Batch adsorption was carried out at different concentrations of 20, 40, 60, 80 and 100 mg/L. Percentage of bagasse ash and bagasse activated carbon yield tend to decrease with increase in contact time. The dosage treatment shows that the percentage removal of the dye increased with increase in the dosage of the adsorbent. The adsorption removal of textile effluent is highly dependent on pH.
- Sugarcane bagasse activated carbon showed higher removal efficiency in the adsorption of coloured dye in the treatment of textile effluent than the activated carbon adsorbent.

- Langmuir and Freundlich adsorption isotherm were used to describe the equilibrium data. Langmuir Isotherm of the sugarcane bagasse activated carbon was higher than the Freundlich. The Langmuir and Freundlich isotherms correlation coefficient are high and they are both good adsorbents for adsorption study.
- Langmuir isotherm correlation coefficient values of the sugarcane bagasse $R^2 = 0.985$ was higher than the Freundlich isotherm correlation coefficient values of the bagasse activated carbon $R^2 = 0.943$.
- The research further confirmed that bagasse activated carbon, is a low cost adsorbent that could be employed for the removal of textile dye effluent with greater percentage removal efficiency.

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