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Adsorption Treatment of Textile Effluent using Sugarcane Bagasse Ash Adsorbent

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Abstract
The textile industry generate large amount of effluent wastewater containing coloured dye solution mixture which are discharged into natural water bodies or riverscausing environmental pollution. Sugarcane bagasse is a waste was used to make ash adsorbent for the treatmentof effluent wastewater discharged from textile industries. Batch adsorption study was used to treat the textile effluent by optimizing dosage, concentration, contact time, and pH of dischargedeffluentto obtain optimum result. The treated and untreated textile effluent samples were analyzed using ultra violet (UV) spectrophotometer instrument to determine the concentration of the remaining textile dye solution. The results of the treatment of textile effluent analysis showed that the ashadsorbent had high percentage removal of the coloured dye in the solution. Optimization results of pH and contact time resultsshowed increase in the uptake capacity and removal efficiencies while increase in dosage and concentration results showed decrease in uptake capacity and increase in removal efficiency which later decrease respectively. TheLangmuir isothermcorrelation coefficient $R^2 = 0.999$ was higher than the Freundlich isotherm correlation coefficient $R^2 = 0.995$. However, the adsorption data analyzed using Langmuir and Freundlich modelsare well fitted but theLangmuir isotherm was well fitted, indicating 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, sugarcane bagasse ash adsorbent was capable of adsorbing dye effluent with high affinity and capacity revealing its potential as a low cost alternative adsorbent.

Keyword:*Textile effluent, sugarcane bagasse ash adsorbent, batch adsorption study, and ultra-violet spectrophotometer*

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I. Introduction

The use of colours to enhance aesthetics and beauty of both man and his environment is as old as creativity itself. Historical records of the use of natural dyes extracted from vegetables, fruits, flowers, certain insects and fish dating as far back as 3500 BC have been discovered. Colour is the main element of attraction in any fabric. Regardless of its excellence in component constitution, the poor fabric colours would undoubtedly reduce its commercial value and merchantability.The discovery of synthetic dyes by W. H. Perkins in 1856 has provided a wide range of dyes that are colour fast and come in wider colour ranges and brighter shades. As a result of this “dye application” has become a lucrative industry today. However, due to the toxic nature and adverse effect of synthetic dyes on all forms of life, the interest in natural dyes has revived throughout the world. Nevertheless, natural dyes are of rarely low-impact due to the application of certain Mordants. Mordants are substances such as chromium which are used to “fix” colour onto the fabric. Natural dyestuffs require large volume of water for dyeing which almost equals or sometimes double the fibre’s own weight. About 80 percent of the dyestuffs stay on the fabric, while the rest go down the drain. Consequently, natural dyes prepared from wild plants and lichens can have a very high impact on the environment. Synthetic dyes are used for many purposes in our everyday activities of life and their applications are continuously growing in different industries such as textile, paint, leather, cosmetics, food, and paper (Saxena and Bharagava 2017). The discharge of colored effluents by most textile industries usually lead to surface water, groundwater, and soil pollution (Chowdhary et al. 2018, 2017; Chandra et al. 2008; Saxena et al. 2017). The discharge of synthetic dyes into the river can distress the photosynthetic activity of aquatic plants due to the reduction of sunlight penetration and due to the formation of a thin film of discharged dyes on the surface of the receiving water body to induce toxicity to aquatic life due to the presence of heavy metals, chlorides, and aromatic compounds (Bharagava and

Mishra 2018; Gill et al. 2002; Liu et al. 2004; Yadav et al. 2017). However, polluted effluents from textile industry have become a serious environmental problem due to the presence of highly toxic organic substances such as synthetic dyes. (Cueva-Orjuela et al., 2017).Textile dyes are very toxic and can be carcinogenic and mutagenic to man even at very low concentrations (Ahmed et al., 2015; Alves-de et al., 2006). If the coloured effluent is discharged in a body of water without the appropriate treatment, the purity and aesthetics of the water becomes grossly compromised. Discharges of coloured dyes alter the biosynthesis process of plants due to the reduction of sunlight penetration (Amaral et al., 2013).

Sugarcane (*Saccharumofficinarum*), is a perennial crop with thick and fibrous stems; it is characterized with high sucrose content which is processed to obtain sugar (Ramírez, 2008; Cueva-Orjuela et al., 2017). Sugarcane bagasse is an agricultural waste product from sugarcane used as adsorbent in the removal of textile pollutants with different chemical nature of dyes such as acidic, basic, cationic, and anionic dyes (Kanawade , 2011; Khoo et al., 2012; Zhang et al., 2012). Treatment of textile wastewater has become a real challenge in the recent years. One of the main difficulties in treating the textile effluents is the strong colour which is due to the non-fixing of excessive dye added to fibers during tinting operations. Previous study has reported the removal of Orange II dye using sugarcane bagasse ash as a low cost adsorbent (Khandelwal and Gaikwad (2011).Due to the adverse environmental effects, removal dyes from the textile wastewater have been established by making use of bio-adsorbents. Activated carbon is one of the adsorbent methods with high costs and expensive processes (Ong et al., 2011). For this process to be efficient, it is necessary to choose an adsorbent with high adsorptive capacity, high selectivity, stability and availability (Crini, 2006).

II. MATERIALS AND METHODS

2.1 SAMPLING AREA

Sugarcane: Sugarcane sample was collected from sugarcane plantation located at Papalantoarea inEgbedo, Ogun State.The sample collection location is presented in Figure 1.

Figure 1: Location of sugarcane sample collection at Papalanto

Textile effluent wastewater: raw textile effluent wastewater sample was collected from Nigeria textile mills, Oba Akran area in Ikeja, Lagos state.Samplewas collected at the discharge point of the textile industrywith sampling bottles and placed in a refrigerator to preserve it for analysis. The location of the textile sample collection is presented in Figure 2.

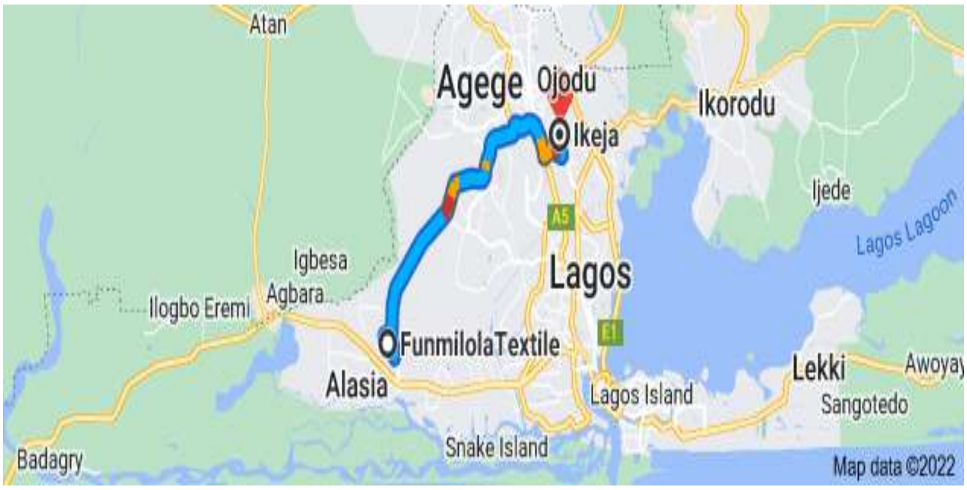

Figure 2: Location of textile effluent sample collection at Ikeja

2.2 Sample

The samples used for this study are dye textile effluent, and sugarcane bagasse ash

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 impuritiesand the juice was extracted from the sugarcane stem 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 wasburntto ashes in a muffle furnanceat high temperature between 650-750 ^{0}C for about 2 hours.

2.2.2 Dye Effluent

The 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 of the factory in a polyethylene container and kept in a regulated refrigerator 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 bagasse ash biosorbent: the sugarcane bagasse waste biomass was collected from an area called Papalanto in Egbedo, to be used as a biosorbent after the extraction of the juice. The waste material was cut into pieces in moderate sizes, washed rinsed several times with tap water before and rinsed with distilled water to remove any traces 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 650 to 750 ^{o}C to burn biomass to form bagasse ash. The sugarcane bagasse ash formed was grounded and sieved to obtain fine powder.

2.5 Batch Adsorption Study

Batch adsorption study was carried out onthe treatment of textile effluent sample using sugarcane bagasse ashto determine the absorption capacity, and percentage removal of dosage, concentration, contact time and pH of the samples to purifythe wastewater. The optimization of dosage, concentration, contact time andpH were examined as the major parameters affecting removal efficiency of the adsorption processes.Batch adsorption experiment was conducted by shaking0.2, 0.4, 0.6, 0.8, and 1.0 g of adsorbent each with 50 mL of the dye solution for a time 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 dosagewith 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 (%) = (Ci- Cf)/Ci 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.

2.6Analytical Technique

2.6.1 UV-visible spectrometer

The spectrum of the dye solution was analyzed by using UV-visible spectrometer (Thermo Scientific NanoDrop^{TM} 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 3was determined using ultra violet visible spectrometer and R^2 = 0.999 which indicate the correlation coefficient.

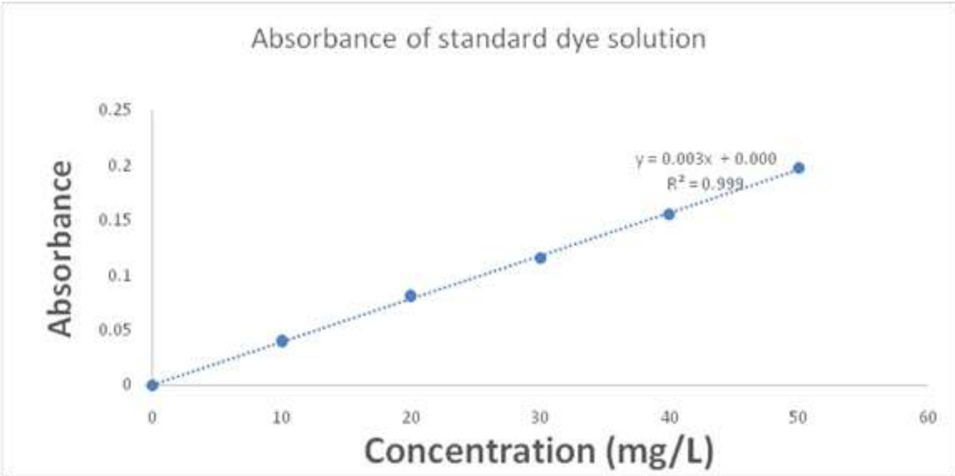

Figure 3: Absorbance of standard dye solution

3.2 BATCH ADSORPTION STUDIES

It was carried out to treat dye effluent waste water generated from textile 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 ash is presented in Figure 4. At 0.2 g, minimum removal efficiency of 14.35 % was obtained with uptake capacity of 3.59 mg/g with further increase in dosage, a gradual increase in removal efficiencies and increase in uptake capacities at 0.4 g, 54.92% (6.87 mg/g), at 0.60 g, 96.31% (8.03 mg/g), at 0.80 g, 98.71% (6.17 mg/g), and at 1.00 g, 98.67% (4.93 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 uptake capacity increase and later decrease.

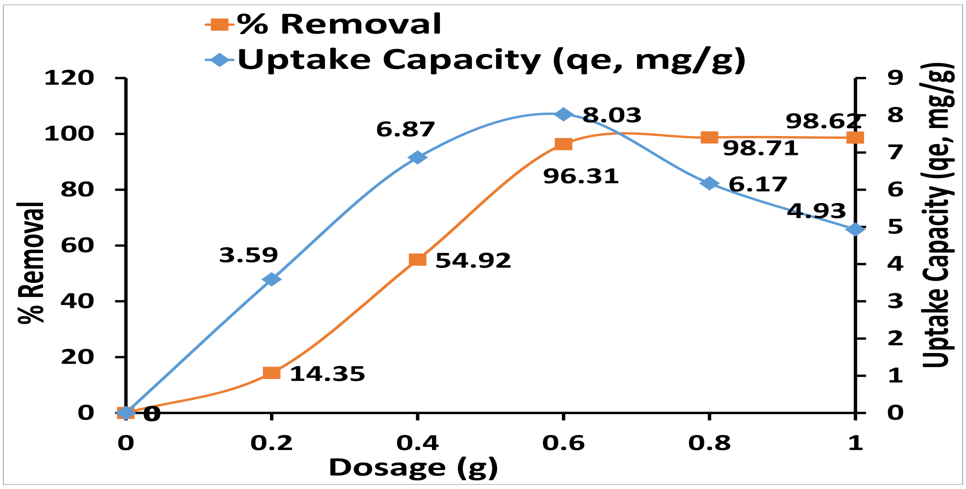

Figure4:Dosage treatment of textile effluent

3.2.2 Concentration Optimization

Concentration effect of the treatment of textile effluent solution with 0.6 g optimum sugarcane bagasse ash adsorbent dosage is presented in Figure 5.At 20 mg/L, maximum removal efficiency of 99.98 % was obtained with uptake capacity of 1.67 mg/g with further increase in concentration, a gradual decrease in removal efficiencies and increase in uptake capacities at 40 mg/L, 98.45% (3.28 mg/g), at 60 mg/L, 64.7% (3.24 mg/g), at 80 mg/L, 41.53% (2.77 mg/g), and at 100 mg/L, 30.72% (2.56 mg/g). Therefore, the optimum contact time obtained for the removal of colours from textile effluent dye solution was 40 mg/L. As the concentration increase, the removal efficiency decreases and uptake capacity increase and later decrease.

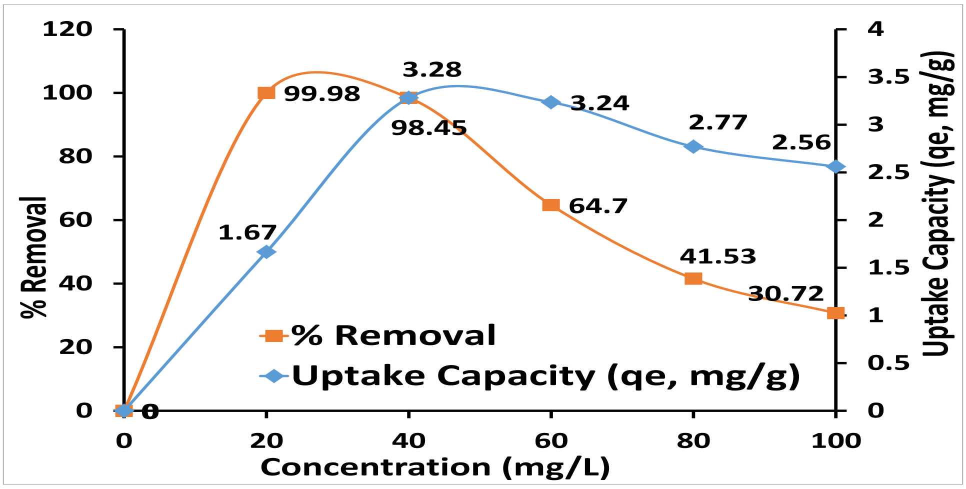

Figure 5: Concentration treatment of textile effluent

3.3.3 Contact Time Optimization

The effect of the contact time of agitating the adsorbent with the effluent solution to remove color from textile effluent 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, 79.20% (3.96 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 uptake capacity decrease.

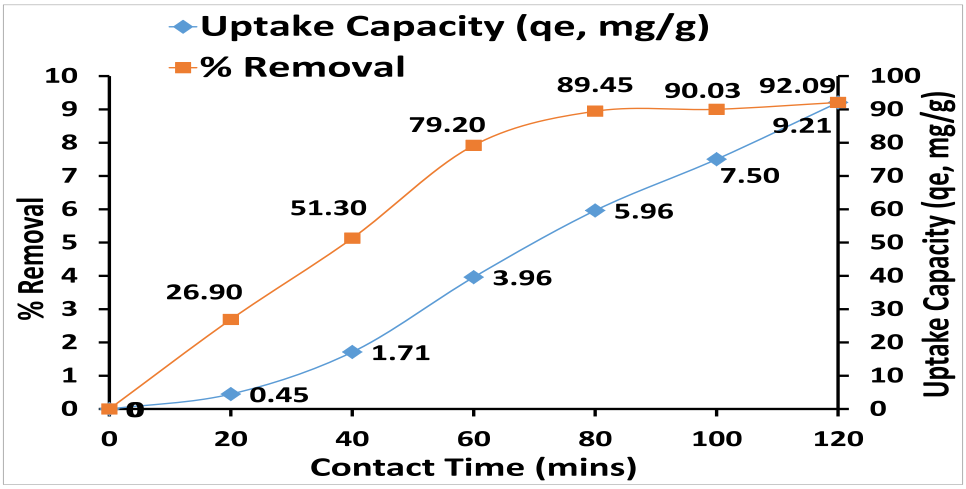

Figure 6: Contact time treatment of textile effluent

3.3.4 pHOptimization

The effect of pH on the uptake capacity and percentage removal efficiency of the colour from textile effluent solution is presented in Figure 7. The results showed the treatment of the textile effluent effect of varying thepH 2.00 to 10.00. Minimum adsorption of 28.92% was obtained at pH 2.0 with uptake capacity of 1.45 mg/g with further increase in pH, a gradual increase in removal efficiencies and uptake capacities at pH 4.00,92% (2.83 mg/g), at pH 6.00, 82.18% (4.11 mg/g), at pH 8.00,87.85% (4.39 mg/g), and at pH 10.00, 89.37% (4.47). The bagasse ash treatment of textile effluent at different pH revealed optimum pH was 2.00. The result revealed thatas the pH increase, the percentage removal and uptake capacities increase.

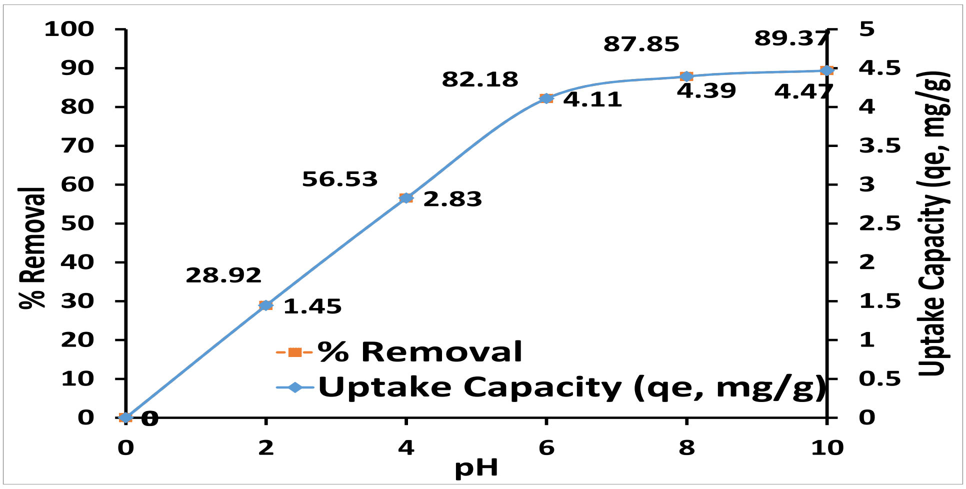

Figure 7: Effect of pH on Sugarcane bagasse ash

LANGMUIR ISOTHERM

Sugarcane bagasse ash adsorbent is seen as a low cost material used for treatment or removal of contaminants. Langmuir isotherm will help us discover if the adsorption treatment is favoured by this process. The Langmuir isotherm of the sugarcane bagasse ash adsorption of colour from waste dye effluent
The equation for Langmuir isotherm is given as:

$1/Q_e = (1/Q_0kl)(1/C_e) + (1/Q_0)$ ………………………………. Eqn 1

Where Ce is the equilibrium concentrations (mg/L) of dye
Qe is the amount of dye adsorbed per gram of adsorbent at equilibrium (mg/gram)
Q_0 and kl is Langmuir constants related to the capacity and energy of adsorption respectively. The plot of 1/Qe Vs 1/Ce is shown in Fig. 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.

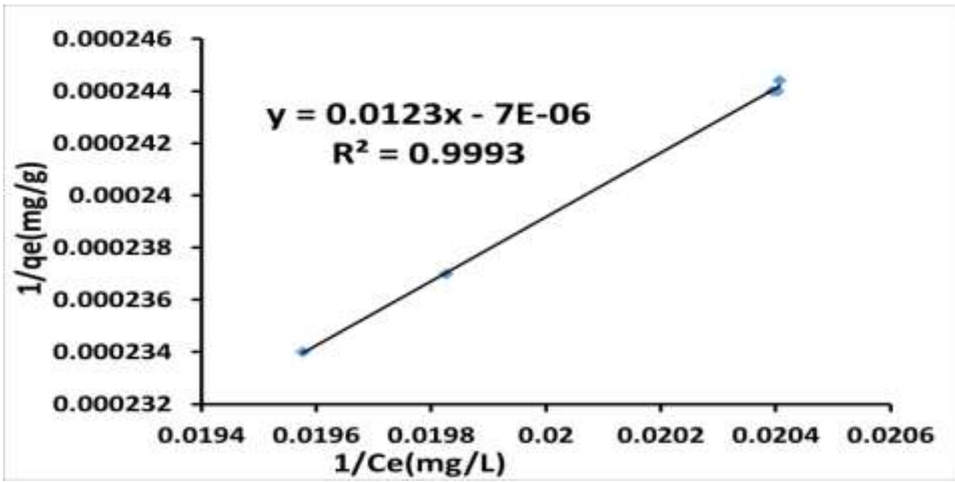

Figure 8: Langmuir isotherm

The result of the Langmuir isotherm of the ash adsorption of colour from effluent from a textile industryin Figure 8shows that the bagasse ash is suitable for treatment. Furthermore, the results revealed that the Langmuir isotherm model was more suitable for the experimental data than Freundlich isotherm because of the high value of correlation coefficient (R^2 = 0.999 and 0.985). This shows that the adsorption of textile dye onto bagasse ash and activated carbon bagasse occur as a monolayer adsorption on the adsorbent surface. Kumar*et al*. (2007) and Theivarasu, C., &Mylsamy, (2011) reported similar phenomenon. Such type of adsorbent is economically good for the removal of dyes from industries' effluents.

Table 1: Langmuir isotherm and Freundlich isotherm

	Langmuir Isotherm Model				Freundlich Isotherm Model			
Bagasse ash	Q_0 (mg/g)	K (LI/mg)	R^2	C_0(mg/L) Adsorbent	RL	K_F (mg/g)	1/n	R^2
	1.428	0.000583	0.999	51.08	0.972	1.8489	0.9596	0.995

FREUNDLICH ISOTHERM

Sugarcane bagasse ash adsorbent is a low cost material used for the treatment and removal of waste water contaminants. Freundlich isotherm will help to know if the adsorption is favoured by this process. The Freundlich isotherm of the bagasse ash adsorption of colour from dye waste effluent is presented in Figure 9.
Applicability of the Freundlich Isotherm for this present system has also been found by correlating the results using the Freundlich equation as

lnQe = ln Kf + 1/n(ln Ce) ……………………………………….. Eqn 2

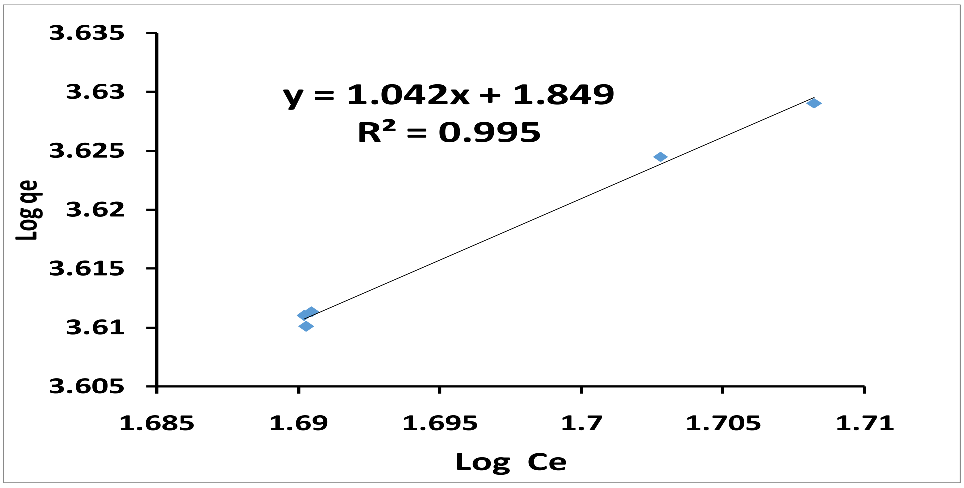

Figure 9: Langmuir isotherm for sugarcane bagasse ashdye adsorption at room temperature.

The result of theFreundlich isotherm of the bagasse ash adsorption treatment of colour from dye effluent in Figure 9showed that thebagasse ash is suitable for treatment. The result revealed that Freundlich isotherm model was suitable because of the high value of correlation coefficient (R^2 = 0.995). The adsorption of textile dye onto bagasse ash occurs as a monolayer adsorption on the adsorbent surface and it is economically suitable for the removal of dyes from industrial effluents.The linear plot of lnQeVslnCe in Fig 9 also suggests that the system follows Freundlich Isotherm, The values of n and K, the Freundlichconstants are shown in Table 1.

IV. CONCLUSION

It can be concluded from the results obtained from this study that the utilization of bagasse ash as adsorbent may offer a practical means for an effective treatment of textile dye effluent and wastewater contaminated with dye solution:

- The better fit of the experimental data obtained by the Langmuir isotherm indicates the homogeneous nature of adsorbents surface and demonstrates the formation of monolayer coverage of dye molecules on the outer surface of the adsorbents. The R^2value of the Langmuir isotherm was higher than the Freundlich which means that Langmuir isotherm fits the experimental data well.
- The findings revealed that textile dye was removed from effluent using bagasse ash yield tends 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 and the adsorption of textile effluent removal is highly dependent on pH.
- Langmuir and Freundlich adsorption isotherm were used to describe the equilibrium data. Langmuir Isotherm of the bagasse ash is higher than that of Freundlich isotherm. Both Langmuir and Freundlich isotherms have high correlation coefficient R^2 of 0.9993 and 0.995 respectively which indicate they are both good adsorbents for adsorption study.
- The research confirmed that bagasse ash a low cost adsorbentcould be employed for the removal of textile effluent with greater percentage uptake.

The adsorption isotherms and correlation coefficient values are good fit with the experimental data. This type of adsorbent is economically suitable for the removal of dyes from industrial effluents and it can be concluded result obtained from this study are:bagasse ash is a good adsorbent of textile effluent treatment, it is a cheap source of adsorbent for cleaning contaminated water and the efficiency and effectiveness of the bagasse ash was high.

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REFERENCES

[1]. Saxena, G., Chandra, R., and Bharagava, R.N(2017). Environmental pollution, toxicity profile and treatment approaches for tannery wastewater and its chemical pollutants. Reviews of Environmental Contamination and Toxicology 240: 31–69.

[2]. Chandra, R., Bharagava, R.N., and Rai, V. (2008). Melanoidins as major colorant in sugarcane molasses based distillery effluent and its degradation. Bioresource Technology. 99: 4648–4660.

[3]. Chowdhary, P., Raj, A., and Bharagava, R.N. (2018). Environmental pollution and health hazards from distillery wastewater and treatment approaches to combat the environmental threats: A review. Chemosphere 194: 229–246.

[4]. Chowdhary, P., Yadav, A., Kaithwas, G., and Bharagava, R.N(2017). Distillery wastewater: A major source of environmental pollution and it's biological treatment for environmental safety. In: Singh, R. & Kumar, S. (Eds.), Green Technology and Environmental Sustainability. Springer International (ISBN: 978-3-319-50653-1).

[5]. Bharagava, R.N. and Mishra, S. (2018). Hexavalent chromium reduction potential of Cellulosimicrobium sp. Isolated from common effluent treatment plant of tannery industries. Ecotoxicology and Environmental Safety 147: 102–109

[6]. Liu, W., Chao, Y., Yang, X., Bao, H., and Qian, S. (2004). Biodecolorization of azo, anthraquinonic and triphenylmethane dyes by white-rot fungi and a laccase secreting engineered strain. Journal of Industrial Microbiology and Biotechnology 31: 127–132.

[7]. Yadav, A., Chowdhary, P., Kaithwas, G., and Bharagava, R.N. (2017). Toxic metals in the environment, their threats on ecosystem and bioremediation approaches. In: Das, S. & Singh, H.R. (Eds.), Handbook of Metal-Microbe Interaction and Bioremediation. CRC Press, Taylor & Francis Group, USA, pp. 128–141.

[8]. Cueva-Orjuela, J. C., Hormaza-Anaguano, A., & Merino-Restrepo, A. (2017). Sugarcane bagasse and its potential use for the textile effluent treatment. Dyna, 84(203), 291-297

[9]. Ahmed, M.B., Zhou, J.L., Ngo, H.H., Guo, W., 2015. Adsorptive removal of antibiotics from water and wastewater: progress and challenges. Sci. Total Environ. 532, 112e126.

[10]. Alves-de Lima, R.O., Bazo, A.P., Salvadori, D.M.F., Rech, C.M., Palma-Oliveira, D. de, and Aragão-Umbuzeiro, G. de., (2007). Mutagenic and carcinogenic potential of a textile azo dye processing plant effluent that impacts a drinking water source. Mutation Research Genetic Toxicology and Environmental Mutagenesis, 626(1-2), pp. 53-60, 2007. DOI: 10.1016/j.mrgentox.2006.08.002.

[11]. 11. Amaral CF, Fernandes AA, Cammarota MC, Coutinho KF and Coelho AA (2013).Decolorization of Dyes from textile wastewater. Journal of Environmental Technology. 25- 13-20.

[12]. Ramírez, M.Á., (2008). Cultivospara la producciónsostenible de biocombustibles: Unaalternativapara la generación de empleos e ingresos. ServicioHolandés de Cooperación Al Desarrollo SNV, I pp. 16.

[13]. Kanawade, S.M., (2011). Low cost Sugarcane Bagasse Ash as an Adsorbent for dye removal from dye effluent. International Journal of Chemical Engineering and Applications, 1(4), pp. 309- 318, 2010. DOI: 10.7763/IJCEA. V2.103.

[14]. Khoo, E.C., Ong, S.T. and Ha, S.T., (2012). Removal of basic dyes from aqueous environment in single and binary systems by sugarcane bagasse in a fixed-bed column. Desalination and Water Treatment, 37(1–3), pp. 215-222, 2012. DOI:10.5004/dwt.2219.

[15]. Zhang, Z., O'Hara, I.M., Kent, G.A. and Doherty, W.O.S., (2013). Comparative study on adsorption of two cationic dyes by milled sugarcane bagasse. Industrial Crops and Products, 42(1), pp. 41- 49. DOI: 10.1016/j.indcrop.2012.05.008.
[16]. Zhang, Z., Moghaddam, L., O'Hara, I.M. and Doherty, W.O.S., (2011). Congo Red adsorption by ball-milled sugarcane bagasse. Chemical Engineering Journal, 178 pp. 122-128, 2011. DOI: 10.1016/j.cej.10.024.
[17]. Khandelwal SK and Gaikwad RW (2011). Removal of dyes from dye effluent using sugarcane bagasse ash as an adsorbent. International J. Chemical Engineering and Applications. 23-09-317.
[18]. Ong, S. T., Khoo, E. C., Keng, P. S., Hii, S. L., Lee, S. L., Hung, Y. T., & Ha, S. T. (2011). Plackett–Burman design and response surface methodological approach to optimize basic dyes removal using sugarcane bagasse. Desalination and Water Treatment, 25(1-3), 310-318.
[19]. S.T. Ong, E.C. Khoo, S.L. Hii and S. T. Ha, (2010). Utilization of sugarcane bagasse for removal of basic dyes from aqueous environment in single and binary systems. Desal. Wat. Treat., 20, 86–95.
[20]. Crini NM, Namasivayam CN, and Upathan ES (2006), Non-conventional low-cost adsorbents for dye removal. A review Bioresource Technology. 97- 106-185.
[21]. Kumar, A., Kumar, S., Kumar, S., & Gupta, D. V. (2007). Adsorption of phenol and 4-nitrophenol on granular activated carbon in basal salt medium: equilibrium and kinetics. Journal of hazardous materials, 147(1-2), 155-166.
[22]. Theivarasu, C., &Mylsamy, S. (2011). Removal of malachite green from aqueous solution by activated carbon developed from cocoa (Theobroma Cacao) shell-A kinetic and equilibrium studies. E-Journal of chemistry, 8(S1), S363-S371.