AJBCPS African Journal of Biological, Chemical and Physical Sciences

Vol 3, Issue 1, 2024

ISSN: 2790-9522 (Print) | 2790-9530 (Online)
Website: https://journals.jozacpublishers.com/ajbcps/index

Adsorption kinetics of reactive dyes removal from simulated wastewater using sawdust

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Received: April 26, 2024 | **Accepted:** June 11, 2024 | **Published:** June 26, 2024

Abstract

Environmental pollution with associated health problems pose great risks. Effluent with colour are among pollutants which can be removed by adsorption unto natural/synthetic adsorbents. This research studied Adsorption kinetics of reactive dyes removal from simulated wastewater by sawdust. The characterization of the sawdust was done using Fourier Transformed Infrared (FTIR) Spectroscopy, X-ray Diffraction (XRD) as well as Scanning Electron Microscopy (SEM). Concentration effect, time and temperature of adsorption were also studied and experimental data subjected to Sorption Kinetics. The FTIR results of unloaded activated and unactivated sawdust showed similar spectra. The XRD results had similar diffraction pattern; however, activated had higher angled diffraction. The SEM of both adsorbents showed rough and vertical groove structure; unactivated had rougher surface, while activated showed more vertical grooves. The concentrations result showed increase in amount of dyes adsorbed as concentration increased for both adsorbents. Increased time increased amount of dyes adsorbed for activated and decreased for unactivated sawdust. The amounts adsorbed were decreased for both as temperature increased. Activation of adsorbent enhanced adsorption of Dylon madona 18 blue and Windsor 15 purple with maximum uptake of 49.85 and 49.7 mg/L respectively, with 49.95 and 49. 94 mg/L for blue and purple respectively. Kinetic models revealed that Pseudo-second order gave better fit for both adsorbents. External diffusion was rate determining step as intraparticle study showed R2values that ranged from 0.617 to 0.703 for blue and purple dyes and 0.797 to 0.004 for blue and purple. The study proved that sawdust was good for reactive dyes removal from wastewater.

Keywords: Adsorbents, Adsorption kinetics, Reactive dyes, Wastewater

1. Introduction

Environmental pollution and related issues have been traced to increased population, urbanization, and technological advancement (Saravanan & Rathika, 2017). Statistics have shown that health-related issues are traced to inaccessibility of portable water in developing countries of which increase in death are reported globally due to prevalence of water related sickness (Ahaja, 2009). Effluent emissions with high colour presence are among pollutants that impact negatively on human and

aquatic lives (Yu et al., 2009). Dyes also are among common pollutants present in industrial wastewater. Therefore, this study focused on the kinetics of adsorption of reactive dyes [Windsor 15 purple dye and Madonna 18 blue dye], removal from simulated wastewater by utilization of activated and unactivated sawdust, a common waste product from saw mills from Okigwe Timber Shade in Imo State, Nigeria.

2. Literature review

The industrial effluents that often contain dyes include sources such as textile, paper, leather and plastic industries (Geetha & Palanisamy, 2015). Global estimation of annual dye wastewater emission is about 750,000 tons (Ahmed et al., 2010). Dyes are usually of natural or synthetic origin mainly derived from plants, animals and mineral sources. Synthetic dyes derived from organic or inorganic compounds are mostly desired and exist in various classes which includes cationic, anionic and non-ionic (Khandare & Govindwar, 2015). Dyes are also function of their chromophore systems. Reactive dyes are mostly of azo family that is synthesized from aromatic compounds. They are characterized with presence of one or more azo group (-N=N-) and form covalent bond, while they react with the cellulosic fiber and so are difficult to remove from its substrate (Punzi et al., 2015).

Different methods have been employed for the removal of dyes from effluents (Bal & Thakur, 2022; Bilal et al., 2022). Among several techniques employed for the treatment of dye contaminated wastewater, adsorption based on carbonaceous material makes effective solution to dye contaminated wastewater remediation. However, the high cost of regeneration as well as production of active carbon led to search for low cost, more effective and easily accessible sorption material which are found in nature and mostly waste materials (Aki et al., 2013). Several researches on effective use of low cost adsorbent have been reported on treatment of wastewater: white rice husk ash (Tavlieva et al., 2013), grapefruit peel (Zou et al., 2013), corn stover (Zhang et al., 2015), Urtica dioica leaves (Tiwari et al., 2017), Salvadora persica (Ata et al., 2019), boiler fly ash (Okoronkwo et al., 2012, 2008a,b), among others. Sawdust, a by-product from agriculture wastes have been used as adsorbent for wastewater treatment (Biswas & Umesh 2015; Kapil, et al., 2016). The conversion of this biomass into activated carbon provides substitute to existing commercial adsorbent and enhance environmental management control (Raval et al., 2016). Therefore, it is very important to investigate the sorption capacity of sawdust on these reactive dyes in aqueous solutions.

3. Research methodology

3.1. Materials

The sawdust used for this study was obtained from Timber Shade Okigwe in Okigwe Local Government Area of Imo State, Nigeria. The reagents were used as purchased because they were of analytical grades. The reactive dyes procured from Port Harcourt, Rivers State, Nigeria at Mile 3 Market, were manufactured by Dylon Company. Also, no further treatment was done on the dyes before using for analysis.

3.2. Methods

The sawdust sample was air dried and kept in air tight container ready for use. Then, part of sawdust samples used was activated using 2% (v/v) nitric acid for 24 hr; after which treated sawdust was

washed using deionized water followed by air drying. 100 mg/l of the reactive dyes and Windsor 15 purple dye and Madonna 18 blue dyes solutions were also prepared as stock from the respective dyes. This was done by dissolving 0.1g of individual dyes in 1000 ml of deionized water. Serial dilutions was therefore used to obtain various concentrations of 10, 25, 50 and 75 mg/L used for the experiment. UV/Vis spectrophotometer PEC Medical U.S.A. 721(D) was used to determine concentrations in the solution after adsorption. Residual concentrations were determined from the calibration curve using Beer Lambert equations.

a. Characterization of Adsorbent

Fourier Transformed Infrared (FTIR) spectrum analysis with spectrometer in the scanning range of 4000 - 500cm^{-1} analyzed functional groups present. The X-ray Diffraction (XRD) analysis was done using X'PERT diffractometer; while Scanning Electron Microscopy (SEM) was used in measuring micrographs of adsorbents. All analyses were carried out on activated and unactivated sawdust before adsorption (unloaded activated and unactivated sawdust), as well as on adsorbents after adsorbate uptake (loaded activated and unactivated sawdust).

b. Contact Time Effect

Dye concentration of 50 mg/L was used to study in the above regard. 50 ml volume was put into a conical flask followed by the addition of 2 g sample of the sawdust into the solution. These mixtures were kept in a rotary shaker of constant speed at 100 rpm, 30^0C with a pH of 7.5 for 10, 20, 30, 60 and 120 mins. Afterward, the sample mixtures were filtered rapidly and the concentration of the dye in the filtrates determined. This was repeated for the different samples of the activated and unactivated sawdust.

c. Initial Dye Concentration Effect

The sorption experiment was done using 10, 25, 50, 75, and 100 mg/L concentrations with 2 g adsorbent for this experiment. 50 ml of the various concentrations were poured into conical flasks and 2 g adsorbent was added and left in a rotary shaker at 100 rpm for 60 mins at pH of 7.5 and temperature of 30^0C. The mixture was filtered and dye concentration was determined. The process was repeated for activated and unactivated adsorbents.

d. Effect of Temperature

To study this, 2 g adsorbent was put into a clean reagent bottle with the addition of a constant initial concentration of 50 mg/L into the reagent bottle which was put into constant speed shaking water bath for 1 hour maintained at various temperatures of 50, 60, 70, 80 and 100^oC. After a fixed time of 60 mins, the mixture was filtered and the dye concentration was determined. Also, this was repeated for the different samples of the activated and inactivated sawdust samples.

4. Results and discussion

4.1. Adsorbent characterization

Loaded and unloaded FTIR Spectra for unactivated and activated adsorbents are presented in Figures 1- 3. The result of the spectroscopy on the unloaded activated and unactivated sawdust showed

similar spectra which suggest similarities in chemical structure of the sawdust; however, unactivation of the adsorbent caused shift to lower field of the spectra. The unloaded activated and unactivated samples showed broad peak assigned to hydroxyl in the range of 3396 cm^{-1} for activated sawdust and 3421 cm^{-1} for unactivated sawdust. Peaks at 2921 cm^{-1} for activated as well as 2920 cm^{-1} for unactivated correspond to methyl and methylene group. The group for 1730 cm^{-1} for activated sawdust and 1729 $cm^{-1}$for unactivated correspond to carbonyl functional group while 1037 and 1023 cm^{-1} correspond to the oxidized carbon. The reduction in the intensity of the functional groups and shift in wave number is an indication that the functional groups actively participated in adsorption of the reactive dyes. The variation could be linked to the nature of the adsorbate which invariably will affect degree of ionization as well as alter the nature of interaction between adsorbent and adsorbate.

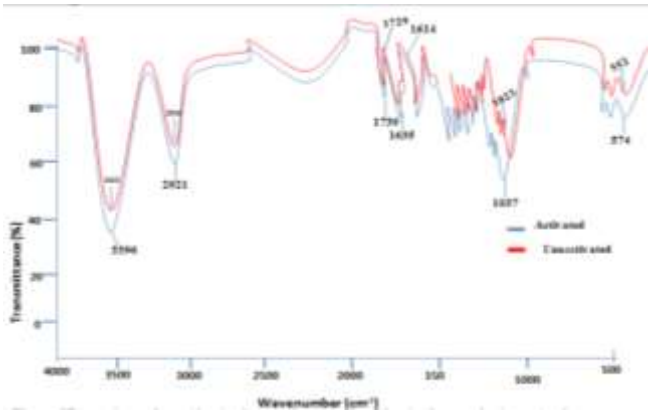

Figure 1: FTIR spectra of unloaded activated and unactivated sawdust

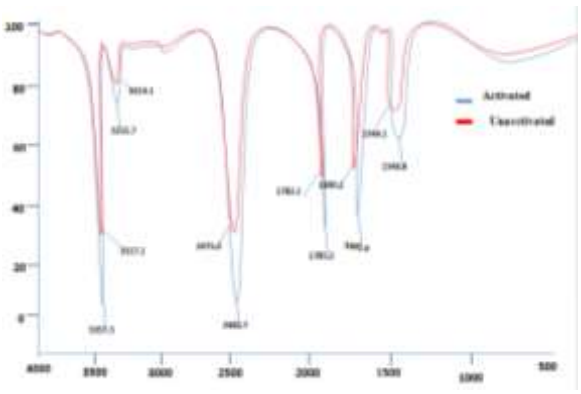

Figure 2: FTIR spectra of loaded sample with blue dye

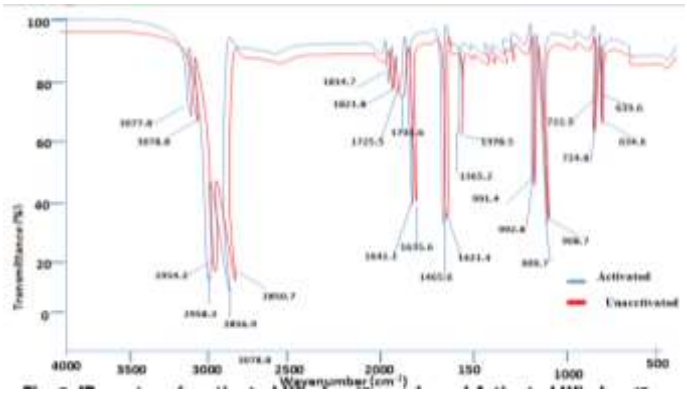

Figure 3: FTIR spectra of loaded sample with Purple dye

The elemental analysis performed on both unactivated and activated sawdust showed that the materials contain mostly carbon, iodine and silver. The XRD results showed similar diffraction patterns in the unactivated and activated sawdust which showed that their crystalline structures are similar. Two main peaks common for carbon materials appeared at approximately 24 and 39° at 2θ of cu. This similarity indicates that the unactivated and activated sawdust have graphite structure being cellulose based with micro crystallinity. The XRD of activated sawdust showed diffraction peaks slightly higher angled than the unactivated. This is due to the fact that preparation of activated sawdust could lead to carbon increase and eventually higher organized structure (Shrestha et al., 2013).

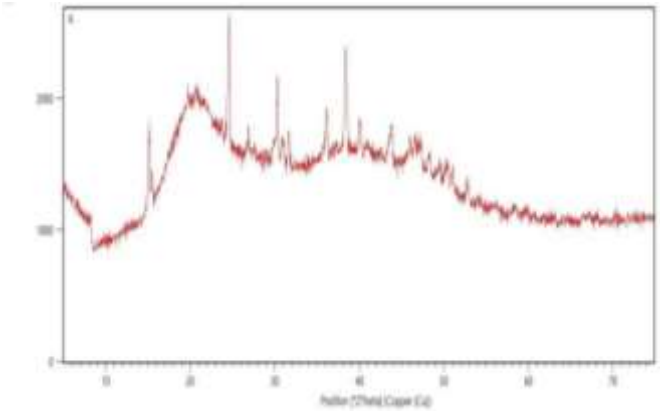

Figure 4: XRD Spectra of Unactivated Sawdust

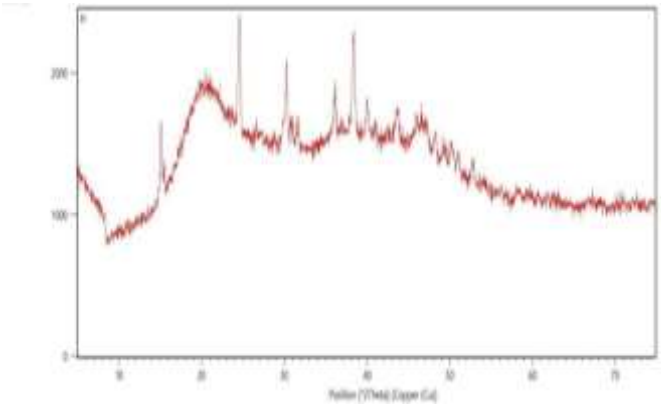

Figure 5: XRD Spectra of Activated Sawdust

The result of the SEM is shown in Figures 6 and 7. The unactivated sample had rougher surface than the activated. The rough surface of the sawdust is because of the presence of high amount of lignin. The SEM of activated sawdust showed more vertical grooves than the unactivated. According to Zheng (2014), the vertical grooves of biomass in the sawdust are due to the removal of all the cell wall components thereby causing a widespread thinning of the wall. The morphology facilitates the adsorption of dyes due to the irregularity of the surface structure therefore making adsorption possible in different part of the unactivated sawdust more than the activated sawdust.

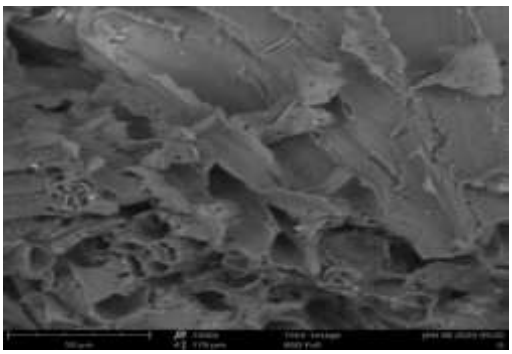

Figure 6: SEM of Unactivated Sawdust

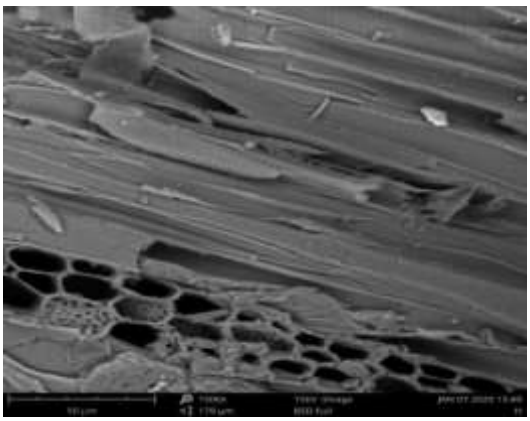

Figure 7: SEM of Activated Sawdust

4.2. Effects of operating conditions

The graph (figure 8) showed that initial concentration had a significant effect on the two reactive dyes removal from solution on both unactivated and activated sawdust. There was proportional increase in amount of dye removed as concentration increased for both dyes unto activated and unactivated sawdust. Okoronkwo et al. (2008a) reported similar trend for the adsorption of dyes onto thiolated boiler fly ash. This may be explained by reason of increased concentration providing driving force to overcome mass transfer resistance; and as such, higher concentration dye tends to enhance adsorption capacity of sawdust.

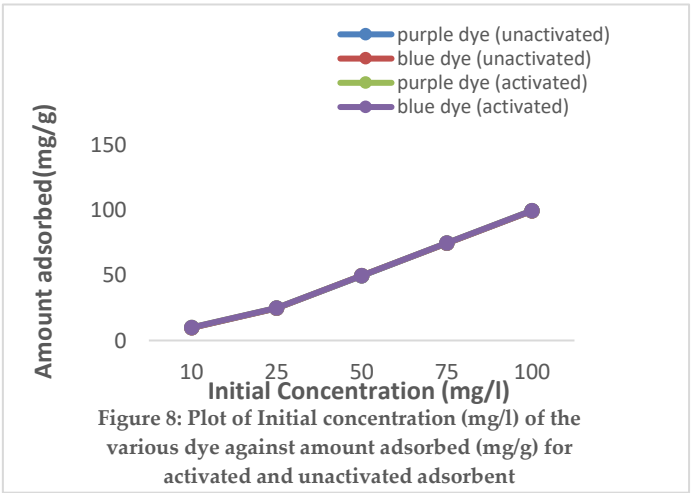

Figure 8: Plot of Initial concentration (mg/l) of the various dye against amount adsorbed (mg/g) for activated and unactivated adsorbent

The impact of varying contact time is shown in Figure 9, the result showed that the amount of Madona 18 blue dye adsorbed was greater than that of Windsor 15 purple dye. The variations in degree of adsorption could be linked to the molecular weight of the individual dye which could affect their degree of ionization in aqueous solution. Generally, the amount of dye adsorbed is very high with the both sawdust indicating that the adsorbent is a very good adsorbent for the treatment of the two dyes but the activated showed better result. Hence, dye molecules, as Tan *et al.* (2010), have reported encounter initial boundary layer effect before diffusing onto an adsorbent surface and finally into porous structure of adsorbent in process of dye adsorption; and shown in Figure 9, dye adsorption was rapid at the initial contact time of 10 mins before reducing significantly. At this point, sorption process has attained saturation (Okoronkwo et al., 2008b; Ben Hamissa et al., 2008). Figure 8 also showed a higher amount of dye adsorbed unto activated sawdust than unactivated sawdust. This similar trend was obtained for the treatment of methylene blue and brilliant green unto activated and unactivated carbon (Ahmed et al. 2017).

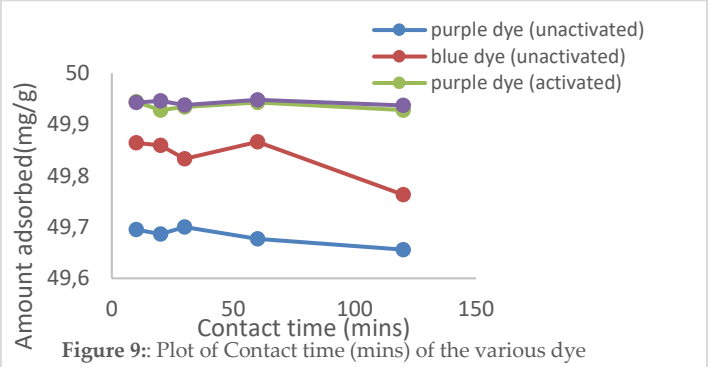

Figure 9:: Plot of Contact time (mins) of the various dye against amount adsorbed (mg/g) for activated and unactivated adsorbent

Figure 10 showed that the mount of dyes adsorbed is greater with activated adsorbent. Figure 10 also showed a decrease in amount adsorbed for the reactive dyes as temperature was increased. The maximum dye uptake recorded was at 50^{0}C for the unactivated adsorbent. The result could be attributed to increased kinetic energy and mass transfer of the dye molecules at this temperature (50^{0}C) for the unactivated adsorbent. (El-Halwan, 2010). Result also suggested that the required activation energy for effective chemical bonding was established at 50^{0}C for the unactivated and 70^{0}C for activated adsorbent for the reactive dyes.

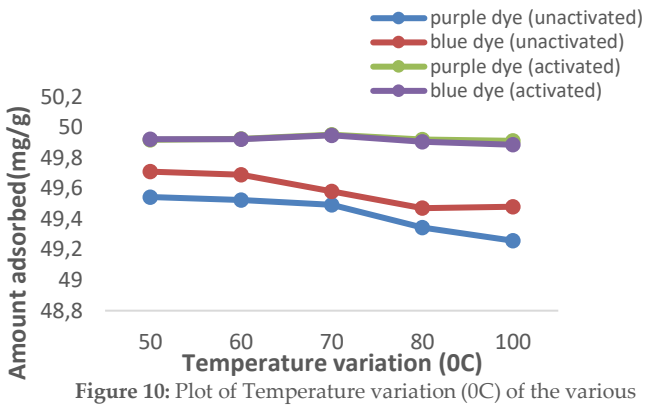

Figure 10: Plot of Temperature variation (0C) of the various dye against amount adsorbed (mg/g) for activated and unactivated sawdusr

4.3. Sorption Kinetics and Intraparticle Diffusivity

The integrated forms of sorption kinetic equations used to do the analysis are Pseudo-first order kinetics (Ho & Mckay, 1998), Pseudo-second order kinetics (Ho, 2004) and Ritchie second order kinetic models (Ritchie, 1977) are represented in equations below respectively:

$$\text{Iog}\,(q_e - q_t) = \text{Iog}\,q_e - K_1 t/2.303 \quad (1)$$

$$t/q_t = 1/h_o + t/q_e \quad (2)$$

$$1/q_t = 1/Kq_e t + 1/q_e \quad (3)$$

where q_e and q_t (mg/g) = amount of dyes adsorbed at equilibrium and time, t (min) respectively. K_1 = rate constant for Pseudo first order equation. h_o = initial sorption rate for Pseudo second order equation given as:

$$h_o = K_2 q_e^2 \quad (4)$$

where K_2 = rate constant Pseudo second order equation. K = rate constant for Ritchie's second order equation. The plots of the kinetics are shown in Figures 11 to 13.

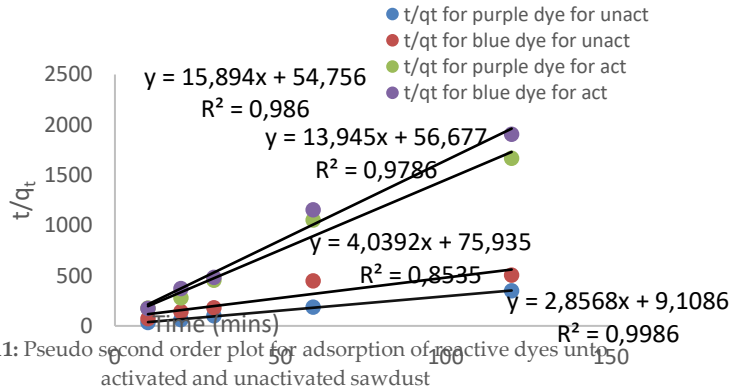

Figure 11: Pseudo second order plot for adsorption of reactive dyes unto activated and unactivated sawdust

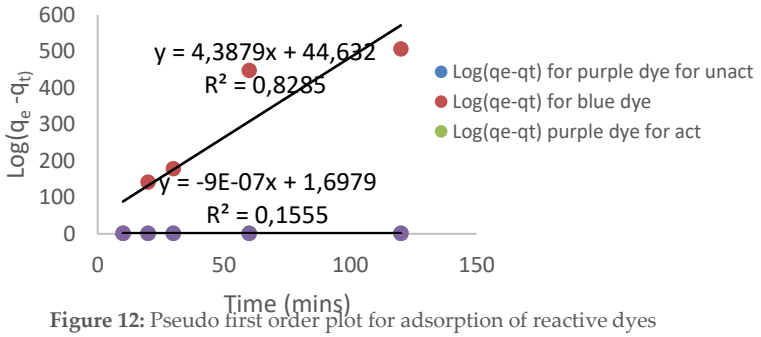

Figure 12: Pseudo first order plot for adsorption of reactive dyes unto activated and unactivated sawdust

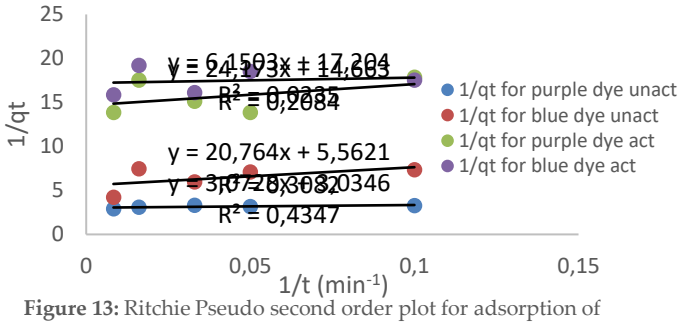

Figure 13: Ritchie Pseudo second order plot for adsorption of reactive dyes unto activated and unactivated sawdust

From the above figures 11-13, three of the equations gave straight lines which were fairly good to the kinetic sorption study. The values of the kinetic constants are calculated from the slopes and intercepts of the plots and results shown in Table 1.

Table 1: Kinetic constant of adsorption of blue and purple dyes on unactivated and activated sawdust

Kinetic equation/ constant	**Unactivated**		**Activated**	
	Blue	**Purple**	**Blue**	**Purple**
Pseudo First Order				
K_1	10.103	-13.818	-20.727	-20.727
q_e	4.265	49.317	49.773	49.770
R^2	0.828	0.155	0.155	0.155
Pseudo Second Order				
K_2	0.216	0.896	0.017	3.501
h_o	0.013	0.109	0.017	0.071
Qe	0.247	0.350	1.014	0.071
R^2	0.853	0.998	0.986	0.978
Ritchie's Second Order				
K	0.269	0.990	2.808	-0.628
Qe	0.179	0.329	0.058	0.068
R^2	0.308	0.434	0.023	0.208

From the analysis, R^2 value of Pseudo second order model gave best fit compared to that of Pseudo first and Ritchie second orders. The use of kinetic sorption equation models on sorption of dyes from solutions have been reported (Muhammad *et al*., 2015; Igwe *et al*., 2018; Hanafiah *et al*., 2012) among others.

Intraparticle diffusion equations employed include: Penetrant transport, Elovich equation and Mackay/Poot. Penetrate transport equation is given by (Abia *et al*., 2007).

$$\text{Iog } R = \text{Iog } K_{id} + n \text{ Iog } t \quad (5)$$

where R = percent adsorbed and K_{id} = rate constant for intraparticle diffusion.

Elovich equation as given by Malkoc and Nuhoglu (2007) is represented as:

$$qt = 1/\beta \text{ In } (\alpha\ \beta) + 1/\beta \text{ In } t \quad (6)$$

α and β = Elovich coefficients, which represents initial sorption rate and desorption constant respectively. β = extent of surface coverage and activation energy for chemisorptions (Ozacar *et al.,* 2008).

The Mackay and Poot equation as given by Ozacar *et al.,* (2008) is as follows

$$Qt = X_i + K_1 t0.5 \quad (7)$$

where X_i = boundary layer diffusion effect; K_1 = MacKay and Poots constant. The plots of the models are shown below; the slope and intercept of the respective plots were used to determine the intraparticle diffusion constants.

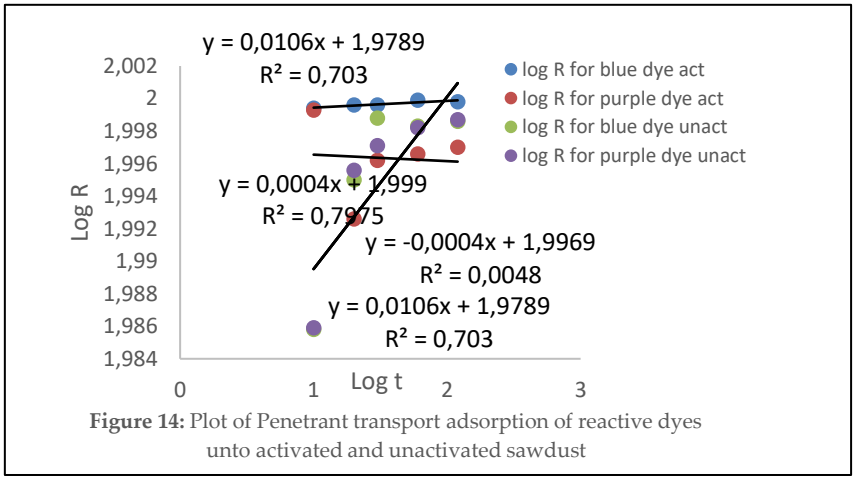

Figure 14: Plot of Penetrant transport adsorption of reactive dyes unto activated and unactivated sawdust

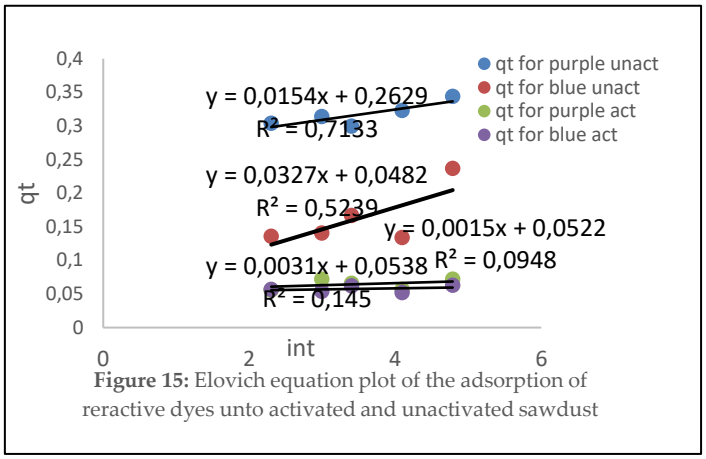

Figure 15: Elovich equation plot of the adsorption of reractive dyes unto activated and unactivated sawdust

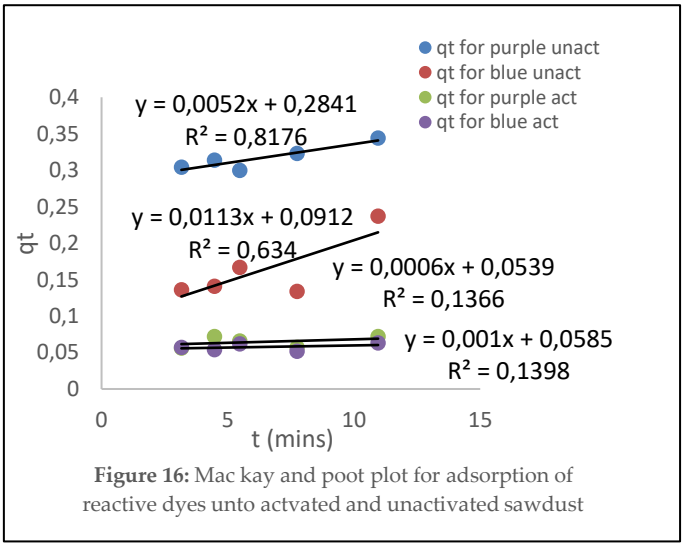

Figure 16: Mac kay and poot plot for adsorption of reactive dyes unto actvated and unactivated sawdust

Table 2: Result of intraparticle diffusion study for the two reactive dyes

Intraparticle diffusion /constant	**Unactivated**		**Activated**	
	Blue	**Purple**	**Blue**	**Purple**
Penetrant Transport				
K_{id}	95.279	95.060	99.77	99.08
n	0.010	0.010	0.000	-0.000
R^2	0.617	0.703	0.797	0.004
Elovich				
α	0.435	4.158	7.528	3.041
β	31.25	66.66	1000	333.33
R^2	0.523	0.713	0.094	0.145
MacKay and Poot				
Xi	0.091	0.284	0.053	0.058
K_1	0.011	0.005	0.000	0.001
R^2	0.634	0.817	0.136	0.139

From Table 2, the result showed that penetrant K_{id} values for the reactive dyes unto activated and unactivated sawdust are all > 1, being highest for blue dye unto activated sawdust. Also, n values for the activated and unactivated sawdust are all < 1. Studies reported penetrant n-values show possibility and degree of strive: n > 1 shows presence of high strive, n = 1 moderate strive while for n < 1, shows adsorption process may not be owing to adsorbate core strive (Abia et al., 2007). Similarly, penetrant K_{id} values of adsorption systems are generally < 1 for an interaction between adsorbent and adsorbate which is dominated by ion-exchange. If α >1, this suggests that dipole induced dipole interactions are prevailing in the adsorption process (Igwe *et al.,* 2018). From the table α value is >1 except for blue dye unto unactivated sawdust. This implies that the sorption process of the reactive dyes removal from solution by the sawdust is predominated by dipole induced interactions.

4.4. Adsorption Isotherm

Three adsorption isotherms namely: Langmuir, Freundlich, and Dubinin-Radushkevich (D-R) were used to analyze experimental equilibrium sorption studies. To estimate maximum adsorption capacity corresponding to complete monolayer coverage on biomass surface, Langmuir equation was used (Ozacar et al., 2005) and to estimates adsorption intensity of the sorbate towards biomass, Freundlich Isotherm was used as represented by Baup et al. (2002) while D-R isotherm was used to estimate characteristic porosity of biomass and apparent energy of adsorption as given by Mackay (2006) model which are represented as follow:

$$C_e/q_e = 1/q_{max}K_L + C_e/q_{max} \quad 8$$

where K_L (L/g) = constant of adsorption/desorption energy; q_{max} = maximum sorption upon complete saturation of the biomass surface. By plotting Ce/qe against Ce, the experimental data were fitted into Langmuir linearized equation.

Another isotherm chosen to model the experimental data is te Freundlich model (Baup *et al.,* 2002).

$$\text{Iog } q_e = \text{Iog } K_f + 1/n \text{ Iog } Ce \quad 9$$

where K_F and n = Freundlich constants. The value of n indicates the affinity of the sorbate towards the biomass. Freundlich isotherm is obtained by plot of log qe against log Ce

D-R isotherm model is given by Mackay (2006) as follows:

$$\text{In}q_e = \text{In } q_D - \beta\varepsilon^2 \quad 10$$

where q_D = D-R isotherm constant of degree of sorbate sorption by the sorbent surface; ε = Polyanyi potential given by:

$$\varepsilon = RT \text{ In } (1+ 1/C_e) \quad 11$$

and β = constant related to free energy of sorption per mole (E) of sorbate as it migrates to the surface of the biomass from infinite distance in the solution given by

$$E(KJ/mol) = (2\beta)^{-1/2} \quad 12$$

The adsorption isotherm constants values for the blue and purple dye unto activated and unactivated sawdust are presented in Table 3 below.

Table 3: Adsorption Isotherm Constant for Blue and Purple Dyes unto Activated and Unactivated Sawdust

Isotherm models/constants	**Unactivated**		**Activated**	
	Blue	**Purple**	**Blue**	**Purple**
Langumuir				
q_m	13.333	6.896	-100.	-15.625
K_L	8.333	4.679	0.00	-32.0
R^2	0.210	0.128	0.07	0.594
Δq	82.18	96.17	100.00	151.57
Freundlich				
N	- 2.183	-0.898	0.984	0.3161
K_L	0.119	-0.003	0.522	0.831
R^2	0.035	0.016	0.289.	0.857
Δq	110.62	111.83	111.57	111.57
Dubinin-Radushkevich (D-R)				
B	3E-08	4E-09	-3E-08	-8E-08
qD	1.185	1.268	1.745	2.297
E	12909.9	$4.85x10^{-10}$	2909.9	7905.6
R^2	0.031	0.023	0.270	0.877
Δq	106.74	108.50	106.35	184. 69

Isotherm constants of the models were derived from slope and intercepts of Lagumuir, Freundlich and Dubinin-Radushkevich isotherms linear plots graphs. Langmuir isotherm (q_{max}) for maximum monolayer coverage were negative for the reactive dyes unto activated sawdust. The result showed a positive (q_{max}) value for purple and blue dye unto unactivated sawdust. The R^2 showed poor values ranged from 0.070 to 0.594. The Freundlich isotherm constant (K_F) gave values ranging from 0.522 and 0.831 for activated sawdust and between -0-003 and 0.119 for unactivated sawdust. Okoronkwo et al. (2010) reported higher adsorption intensity for higher K_F value. The values of n from the Freundlich Isotherm were all less than 1. However, values of n between 1 and 10 signify useful adsorption. The values of the apparent mean biosorption energy are 12909 and 4.85 $x10^{-10}$for unactivated sawdust while apparent energy for activated sawdust revealed values between 2900. 0and 7905.6. Studies have shown that physiosorption process generally have less than 40 KJ/mol as adsorption energies of which values above that connotes that sorption process is of chemisorption mechanism (Horsfall *et al.,* 2004). Therefore, sorption process of the dyes followed chemisorption mechanism except for purple dye unto unactivated sawdust. Several studies have also reported on the determination of mechanism of sorption of pollutants from aqueous solutions by apparent mean biosorption energy (Tan et al., 2010; Geetha et al., 2015; Igwe et al., 2018).

Again, the validity of each of the isotherm model more efficiently was compared using a normalized standard deviation Δq (%) of root mean square residual error as given by the following equation (Abd *et, al.,* 2006; Ncibi *et. al.,* 2007a):

$$\Delta q\ (\%) = 100 \times \sqrt{(\sum[(q_e{}^{exp} - q_e{}^{cal})/q_e{}^{exp}]^2/ n-1} \qquad 13$$

where "exp" and "cal" = experimental and calculated values respectively; n = number of measurements.

The values of Δq are also shown in Table 3, lowest value were obtained for blue and purple dyes were 106.24 for D-R, 100.00 for Langmuir isotherm, and 111.57 for Freundlich isotherm for activated sawdust. The lowest value obtained for Δq(%) unto unactivated sawdust include 82.18 for Langumuir isotherm(blue) and 96.17 for Langumuir isotherm (purple). Although the value obtained with the unactivated is less than the activated, none of the value of Δq (%) is below 10%. Isotherm model is considered to satisfactorily fit the sorption process if the value of Δq (%) is less than 10%. Hence, from the values of Δq (%) in Table 3, it could be seen that none of the isotherms gave a satisfactory fit to the sorption data for all the reactive dyes.

5. Key findings of the study

The FTIR studies revealed similar structure for both activated and unactivated sawdust. The XRD analysis showed graphite structure with micro crystallinity with that of activated sawdust having diffraction slightly higher angled, suggesting carbon increase with activation of the adsorbent. SEM morphology of both showed porous and vertical grooves which were useful for uptake of the reactive dyes. The independent variables as concentration, contact time and temperature affected adsorption of reactive dyes. Activated sawdust was found to have higher uptake reactive dyes than the unactivated. The optimal conditions were 10 minutes for the unactivated and activated purple dye and 60 minutes for the blue dye. Those of temperature were 50^0C for unactivated adsorbent and 70^0C for the activated adsorbent. The experimental data modeled with pseudo first, pseudo second and Ritchie's second order kinetics sorption equations revealed that sorption process was best described by Pseudo second order with highest correlation coefficient. The dynamic studies carried out with Mackay and Poot equations, Penetrant transport and Elovich equations; indicate that the sorption process is more of film diffusion mechanism, suggesting that the rate determining step was external diffusion. The adsorption isotherms used to evaluate the experimental data which included Langumuir, Freundlich as well as Dubinin Radushkevich revealed unfavorable adsorption. Also, none of the isotherms satisfactorily fit sorption data as shown by the values of root mean square of normalized standard deviation (Δq%).

6. Contribution of the study

The study provides information on the treatment of simulated waste water with [Windsor 15 purple dye (purple dye) and Madonna 18 blue dye (blue dye) which are reactive dyes with unactivated and activated sawdust as adsorbents. This is geared at sourcing for good adsorbents that are of natural origin for dyes removal from wastewater that will invariably reduce dye pollution in the environment.

7. Implications of the study

The study sought to use sawdust, a common waste which is of natural origin, to produce adsorbents capable of dyes removal from wastewater that will reduce dye pollution in the environment as well as reduce pollution caused by sawdust by conversion of the biomass into activated carbon that

will provide substitute to existing commercial adsorbent and enhance environmental management and control.

8. Recommendations

The researchers recommend further researches on sawdust conversion into activated carbon for adsorption of common dyes from industrial waste which are more frequently used in the industrial production processes.

9. Conclusion

The treatment of simulated waste water with [Windsor 15 purple dye (purple dye) and Madonna 18 blue dye (blue dye) which are reactive dyes with unactivated and activated sawdust, which is a common waste product from saw mills, were successfully evaluated in this study. Findings proved that unactivated and activated sawdust were good adsorbents for reactive dyes removal from wastewater though variations in conditions for optimal uptake exist.

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