



Research Article

Adsorptive properties of Flamboyant seed pod activated carbon for the removal of anionic dye in wastewater

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ABSTRACT

Flamboyant seed pods were used as a sustainable and cost-effective adsorbent for the removal of anionic dyes from wastewater. The activated carbon was obtained via Carbonization and subsequent chemical activation with Sodium Hydroxide at 600 ° C for 60 minutes. The adsorbent was characterized using scanning electron microscopy (SEM) and Fourier transform infrared (FTIR) spectroscopy. Optimization of adsorption parameters, including dosage, contact time, and initial concentration were performed to determine the optimum adsorption performance of the activated carbon. It is evident from the result that, there were good enhancements in pores of the absorbent FS-AC due to alkali impregnation in addition the several functional groups that took part in the adsorption process. The adsorption capacity of methyl orange increased with contact time until it reaches the saturation limit and later decrease, indicating that the adsorbent can no longer adsorbed more dye beyond it saturation limit. There was a decrease in the dye uptake with increase in dosage of the FS-AC. The amount of methyl orange adsorbed onto FS-AC increased with time and subsequently decreased at some point in time with maximum uptake at 100 mg/L.

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INTRODUCTION

The pollution of water bodies by dyes originating from various industrial processes poses a significant environmental challenge. Anionic dyes, in particular, are notorious for their persistence and adverse effects on aquatic ecosystems (Wu *et al.*; 2007). The need for effective and sustainable methods to treat wastewater contaminated with anionic dyes has spurred the exploration of innovative solutions, including the utilization of activated carbon as an adsorbent material (Poland *et al.*; 1992). Activated carbon has long been recognized for its exceptional adsorption properties and is widely employed in wastewater treatment due to its high surface area, porosity, and chemical reactivity (Afroze *et al.*, 2018). However, the production of activated carbon from conventional precursors can be resource-intensive and costly. Therefore, there is a growing interest in the utilization of unconventional and renewable sources as precursors for activated carbon synthesis, offering not only economic benefits but also promoting sustainable waste management practices (Grajalekshmi *et al.*, 2016). The flamboyant tree (*Delonix regia*), known for its vibrant red flowers, produces seed pods that contain lignocelluloses biomass. These seed pods have shown promise as a potential precursor for the synthesis of activated carbon (Sing *et al.*, 2014). By harnessing the inherent carbonaceous structure within the seed pods and subjecting them to controlled thermal processes, activated carbon with desirable adsorption properties can be obtained. This study aims to investigate the synthesis and characterization of activated carbon derived from flamboyant seed pods (*Delonix regia*) for the removal of anionic dyes in wastewater. The potential of the synthesized activated carbon derived from flamboyant seed pods for anionic dye removal will be evaluated through batch adsorption experiments using model dye solutions. The adsorption efficiency will be analyzed to assess the performance of the activated carbon

and its potential application in real-world wastewater treatment scenarios. By utilizing a renewable precursor material and exploring the potential of flamboyant seed pods *Delonix regia* for activated carbon synthesis, this research contributes to the development of sustainable and cost-effective adsorbents for the removal of anionic dyes in wastewater. The findings of this study may have significant implications in mitigating water pollution and promoting eco-friendly practices in the textile, dyeing, and related industries.

MATERIALS AND METHODS

Precursor and Adsorbent Preparation

The Flamboyant seed pod was obtained from Faculty of agriculture university of Maiduguri campus. The seed pods were cleaned by removing any visible impurities or debris. They were later rinsed with distilled water to remove any surface contaminants. The seed pods were dried at a suitable temperature (e.g., 50-60 °C) until a constant weight was achieved. The pod was Grind into fine particles using a grinder or mortar and pestle. A Sieve Was used to obtain a uniform size fraction (e.g., 40-60 mesh) for subsequent experiments.

The carbonization was carried out at temperature of 600 °C for one hour to obtain a purely carbonized material and was impregnated with 0.1M NaOH. The impregnated material was allowed to stay for 24 hours for the purpose of development of pores and active site on the material, the activated material was later washed several times to achieve neutrality with distilled water. The material was later dried in an oven at 105 °C and was later stored in a polyethylene bag for further usage, this was designated as FS-AC.

Adsorption Experiment and Characterization of the Adsorbent

A series of working solutions with different initial concentrations of methyl orange by diluting the stock solution with distilled water was prepared. Separately, a fixed volume of the prepared working solution of 50 mL were

poured and mixed with the desired amount of FS-AC. The containers are placed on a shaker for a uniform agitation at a constant speed and temperature for a predetermined contact time. After the adsorption period, the adsorbent is

$$q_e = \frac{(C_o - C_e)V}{w} \quad (i)$$

Where V is the solution volume (mL), W is the adsorbent mass used (g), q_e , C_o , and C_e (mg/L) are the equilibrium adsorption capacity, initial and equilibrium concentrations respectively,

A Digi lab Fourier Transform Infrared spectrophotometer (Model Excalibur FTS2000) was used to verify the organic structure of FS-AC and FS-AC after adsorption. The obtained FTIR spectra are in the range of relevant wave numbers (4000-400 cm^{-1}). The Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Fluorescence (EDXRF) of FS-AC and FS-AC after adsorption were determined using Phenom Prox, manufactured by phenom World Eindhoven, Netherlands to ascertain the morphology and elemental composition.

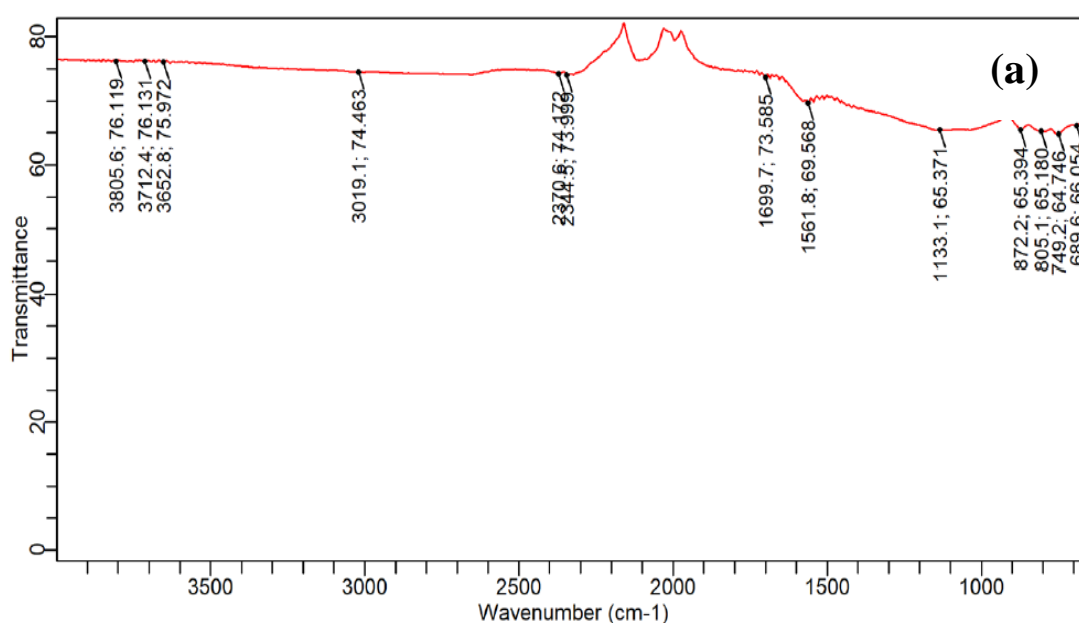
RESULT AND DISCUSSION

Characterization of FS-AC Adsorbents

Figure 1(a and b) shows the FTIR spectra of FS-AC adsorbent before and after adsorption.

separated from the solution using a filtration method. The methyl orange concentration was analysed using a UV Visible spectrophotometer. The amount of adsorption at equilibrium was obtained using equation (i)

The FS-AC before adsorption identified a band at 749 cm^{-1} indicating the presence of Aromatics (C-H) out of plane. The band at 872 cm^{-1} can be attributed to the weak C-H bond out of plane stretch (Xu *et al.*, 2013). The band at 1133 cm^{-1} can be attributed to the C-O bond stretch (Cheraghi *et al.*, 2015). The band at 1699 cm^{-1} is associated with C=O stretch. The band at 1559 cm^{-1} is attributed to the C-O stretch this justify the fact that oxygen-containing functional groups contribute to the adsorption potential of activated carbon using interactions such as hydrogen bonds and π - π interaction (Wang *et al.*, 2020). The band at 3019 cm^{-1} can be attributed to the OH in plane bend. For the Flamboyant seed after adsorption, there is an attenuation of the bands in the spectrum after adsorption. It is important to highlight the band at 1159 cm^{-1} assigned to CH stretching vibrations.



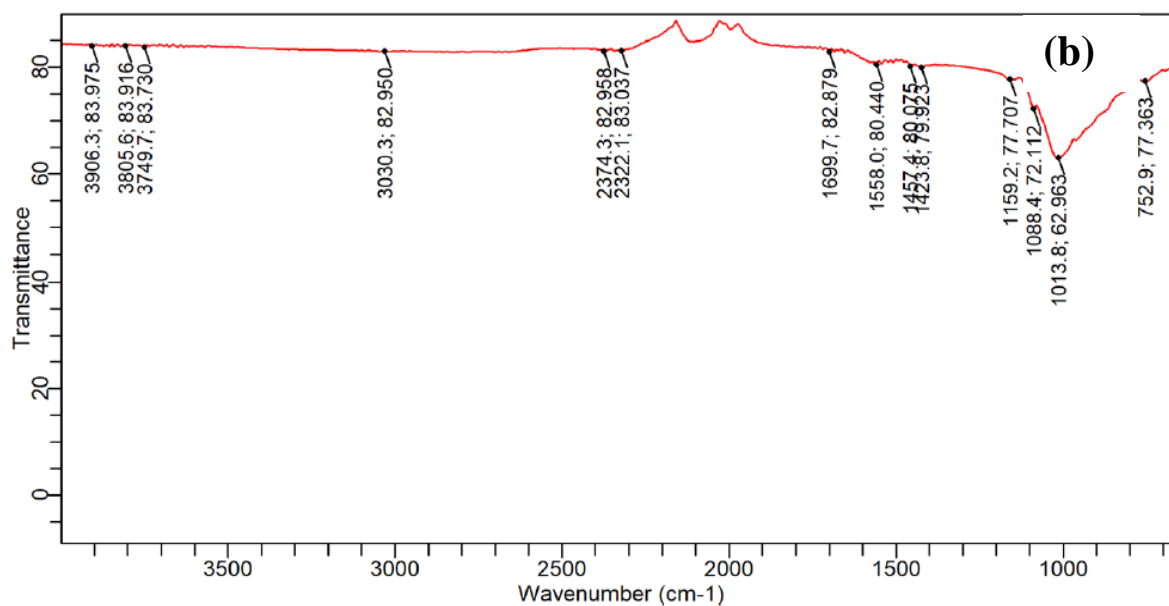


Figure 1: FTIR spectra of FS-AC (a) Before Adsorption (b) After Adsorption

Plate 1 depicts the surface morphology and EDX profiles of FS-AC adsorbent before adsorption (a) and after adsorption (b). The pores and cavities can be easily observed, and the pore is deep and more open structure indicating the porous nature of the adsorbent. Such characteristics are important for the adsorption process since it makes active sites

more accessible and allows larger dye molecules to be diffused. However, it can be observed from Plate 1b that the physical structure is a bit different with Plate 1a in terms of porosity, this is attributed to the fact that adsorption of Methyl orange must have occurred on the surface of the adsorbent (Boadu *et al.*, 2018).

Effects of operating parameters on adsorption of methyl orange

Effect of adsorbent dosage

Figure 2 shows the effect of dosage on adsorption capacity of methyl orange at different dosages. The removal rate decreases as the amount of FS-AC mass in the solution is increased. Furthermore, the amount of methyl orange adsorbed at equilibrium (q_e) firstly increases from 50 mg/g with 0.1 g/L dosage for beginning methyl orange concentration of 100 mg/L and then it increases from 50 to 368 mg g⁻¹ with increasing of the amount flamboyant seed dosage from 0.1 to 1 g/L. This behaviour explains that the increase in dosage of the

adsorbent has no contributory effect on the methyl orange adsorption because the increase in the dosage of FS-AC has a little or no effect on the methyl orange in the solution and this is because the active sites on the adsorbent at 0.1 g/L is sufficient to absorb a quite number of methyl orange solution. Adsorption of methyl orange by activated carbon reported that adsorption increases with increase in adsorbent dosage (Pathania *et al.*, 2017). Thus, due to the dosage of 0.1 g/L of FS-AC making it possible to have the highest adsorption capacity of the methyl orange, the ideal dose of FS-AC was considered for further experiments.

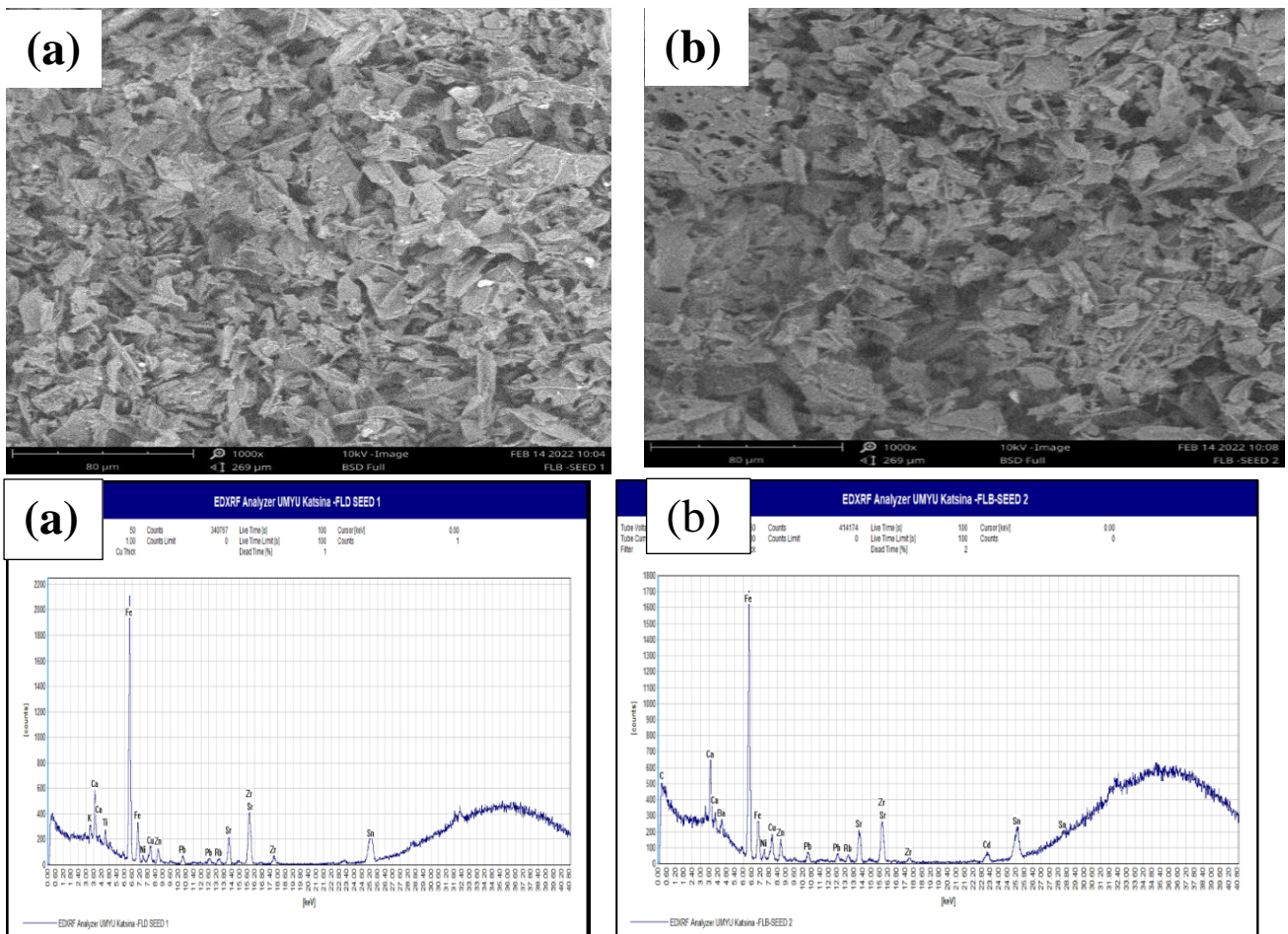


Plate 1: SEM and EDX images/profiles of FS-AC (a) Before Adsorption (b) After Adsorption

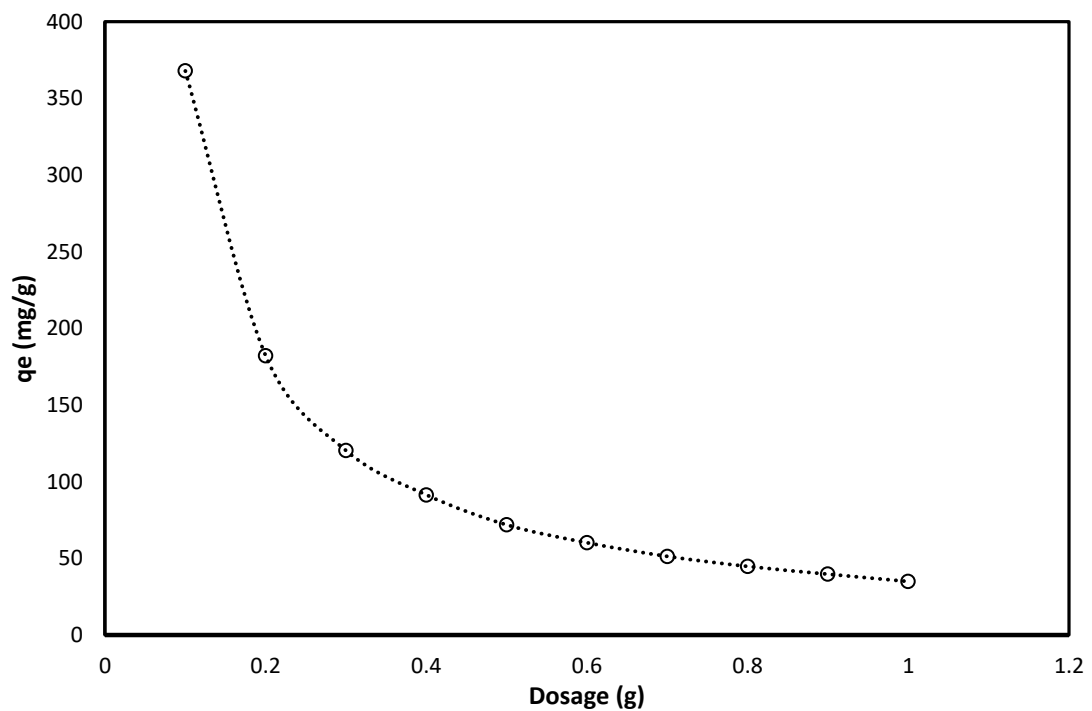


Figure.2: Effect of adsorbent dosage

Effect of contact time and initial concentration

Figure 3 presents the effect of the contact time and initial concentration on methyl orange adsorption of FS-AC at 30 °C. It was observed that, the maximum adsorption took place at 100 mg/L. In the time interval between 20 and 40 min, the adsorbate removal was encouraging and later there was a significant raise in the Methyl orange removal from 60 min to 80 min and there seems to be the maximum adsorption capacity. Furthermore, there was a drastic drop in the adsorption capacity of the adsorbent at a higher contact time. The pattern explains that contact time is one of the most effective factors in batch adsorption process as it can be seen from the graph the removal was very fast at the beginning and it gradually decreased, this pattern indicates that after 80 min of contact time there are no available active sites on the adsorbent. From the contact time of 60 min to 80 min there was no significant difference in the methyl orange removal rate; this situation is understood due to the saturation of the adsorbent's active sites (Egbosiuba *et al.*, 2020). The decrease in adsorption with increase in sample concentration could be explained on the basis that methyl orange removal depended on the availability of the binding sites on FS-AC surface. The initial dye concentration provides the necessary driving force to overcome the resistances to the mass transfer of methyl orange between

the aqueous and solid phases (Srivastava *et al.*, 2016). Furthermore, there was a drastic drop in the adsorption capacity of the adsorbent at a higher contact time. The pattern of the graph explains that contact time is one of the most effective factors in batch adsorption process as it can be seen from the graph the removal was very fast at the beginning and it gradually decreased, this pattern indicates that after 80 min there are no available active sites on the adsorbent

The effect of varying concentrations on adsorption is shown in Figure 4. The adsorption capacity of FS-AC was highly dependent on the initial concentrations in the solutions. The maximum adsorption took place at 100 mg/L. The decrease in adsorption with increase in sample concentration could be explained on the basis that methyl orange removal depended on the availability of the binding sites on FS-AC surface. The initial dye concentration provides the necessary driving force to overcome the resistances to the mass transfer of methyl orange between the aqueous and solid phases (Srivastava *et al.*, 2016). A similar phenomenon was observed for the adsorption of methylene dye onto banana stalk waste (Hameed *et al.*, 2018). For a fixed amount FS-AC, total available adsorption sites were used at 100 mg/L concentration. Further adsorbate remained un-adsorbed in the solution resulting into constant adsorption (Li, *et al.*, 2013).

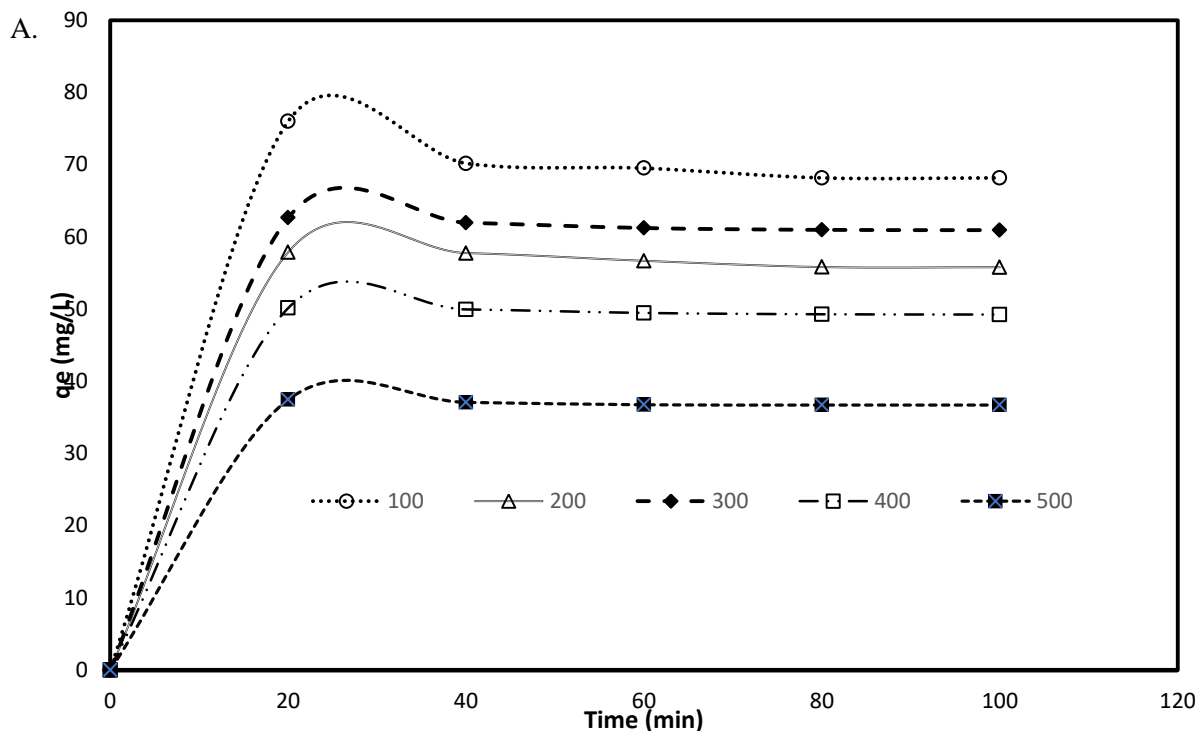


Figure 3: Effect of contact time and initial concentration

CONCLUSION

This study investigated the adsorptive properties of flamboyant seed pods (*Delonix regia*) and its efficiency in the removal of anionic dyes from wastewater. The FS-AC was prepared by carbonisation and subsequent impregnation with NaOH. The FS-AC before adsorption identified a band at 749 cm^{-1} indicating the presence of Aromatics (C-H) out of plane. The band at 1559 cm^{-1} is attributed to the C-O stretch this justify the fact that oxygen-containing functional groups contribute to the adsorption potential of activated carbon using interactions such as hydrogen bonds and π - π interaction. The surface shows pores and cavities can be easily observed, and the pore is deep and more open structure indicating the porous nature of the adsorbent. It is observed that the methyl orange uptake decreases with increase in the FS-AC dosage. The amount of Methyl orange adsorbed onto FS-AC increased with time and subsequently remained constant at some point in time with maximum uptake at 100 mg/L. The maximum adsorption took place at 100 mg/L. The decrease in adsorption with increase in sample concentration could be explained on the basis that methyl orange

removal depended on the availability of the binding sites on FS-AC surface.

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