ADSORPTION OF CRYSTAL VIOLET DYE FROM AQUEOUS SOLUTION ONTO ACTIVATED CARBON PREPARED FROM PALM KERNEL SHELL

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ABSTRACT

An activated carbon was prepared from palm kernel shells (PKS) and used for the removal of Crystal violet dye (CV) from aqueous solutions. The influence of various factors such as adsorbent dosage, initial dye concentration, contact time, pH, and temperature was studied. The experimental data were analyzed by the Langmuir, Temkin and Freundlich isotherm models. The sorption capacity of the activated carbon prepared from palm kernel shell for CV was found to be 224.30 mg g^{-1} at 55 ^{0}C. Two simplified kinetic models including pseudo-first-order and pseudo-second-order equation were selected to follow the adsorption processes. Kinetic studies showed that the adsorption followed pseudo-second order kinetic model. Various thermodynamic parameters such as ΔH, ΔS, and ΔG were evaluated. The results in this study indicated that activated carbon prepared from palm kernel shell could be employed as an adsorbent for the removal of CV dye from aqueous solutions.

Keywords: Crystal violet, Palm kernel shell, Adsorption kinetics, adsorption thermodynamics.

1.0 INTRODUCTION

Dye residues from industrial out-fall from different sources such as; tannery, paper and pulp industries, textile industries, pharmaceutical industries, Kraft bleaching industries, dye and dye intermediates industries etc. are regarded as a wide collection of organic pollutants been discharged into the natural water bodies or wastewater treatment systems. Textile industry and dye intermediates industries are considered the major sources with critical environmental pollution problems globally [1].

Just like other types of dye, basic dyes spent solution is toxic to both aquatic and terrestrial life. There are many of basic dyes with variety of application such as Rhodamine B, Methyl violets (Methyl violet 2B, violet 6B) of recent; Crystal violet (CV) dye is a synthetic cationic dye and conveys violet color in aqueous solution and it has has gained popularity in the area of toxicology as being biohazard.

There are many categories of techniques that had been explored for the removals of this organic pollutants, among these are; Chemical methods such as: reverse osmosis, electrochemical oxidation process, electrocoagulation, biological treatments performed in aerobic or anaerobic or combined anaerobic/aerobic conditions and physical treatments such as micro-filtration and ultra-filtration [2].

Palm kernel shell (PKS) is an agricultural waste that can be converted into an excellent adsorbent because of its abundance, hard granular structure, high carbon content, insolubility in water, chemically stable, insensitive towards toxicity, mechanically durable and locally available at almost costless [3][4].

The study therefore is aimed at investigating the adsorption potential of activated carbon produced from Palm kernel Shell as adsorbent in the removal of crystal violet dye from aqueous solution.

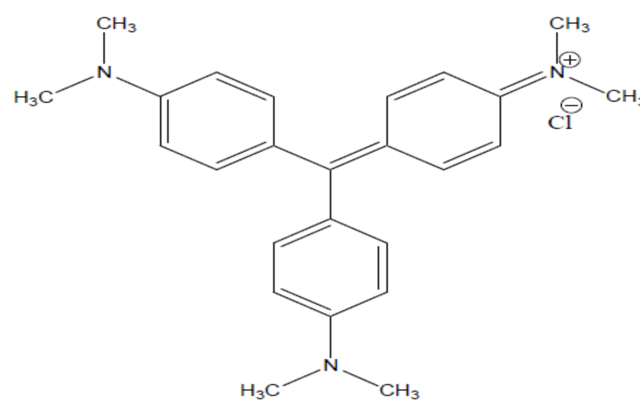


Figure 1. structure of crystal violet dye

2.0 MATERIALS AND METHODS

2.1 Preparation of Activated Carbon

A large quantity of palm Kernel shell (PKS) was obtained from a FADAMER palm Kernel Oil mill in Oosun, Moba local government area of Ekiti State. The physical debris and other relatively big physical foreign materials were handpicked and the whole PKS was thoroughly washed with hot water to remove dust and other particles and sun dried, the PKS was crushed and sieved with 0.2mm sieve size [5]. A 100g of pretreated sample was weighed in to a crucible and carbonized at 600°C for 2 hours in a muffle furnace to obtain char. A desired weighed 5g of the chars was impregnated with 1M (H_3PO_4) in ratio 1:1 in a water bath for 2 hours at 100°C. The impregnated carbons were severally washed with distilled water to constant pH of 7 in other to remove base, to remove metals, alkali impurities and other soluble component in the carbon. The sample was then dried in an oven. The dried sample was pyrolyzed at temperatures of 400°C for 2 hours in a muffle furnace to obtain activated carbon [6].

2.2 Preparation of Crystal Violet Dye Solution

A stock solution of 1000 mg/l was prepared by dissolving an exact 1.0g of Crystal violet dye in 1000mL of distilled water. Subsequently, all other working solutions with lower concentrations were prepared from the parent solution by serial dilution.

2.3 Batch Adsorption Experiments

A 20mg to 1000mg adsorbent was brought into intimate contact with 25mL of the crystal violet dye solution of varying concentrations between 5 and 700 mg/L. The mixtures were allowed to equilibrate in a mechanical shaker at 120 rpm for predetermine time, temperature and pH. The mixture was filtered through whattman filter paper, and the filtrate was analyzed for residual dye using UV- visible at a wavelength of 590 nm.

The removal of the dye was calculated using material balance equation,

$$q_e = \frac{Co-Ce}{m}V \quad (1)$$

$$qt = \frac{Co-Ct}{m}V \quad (2)$$

Where *Co* and *Ce* are initial and final equilibrium concentrations (mg/L) respectively, C_t is the concentration at t=t, *V* is the volume of dye solution (L), and *m* is the mass of adsorbent (g).

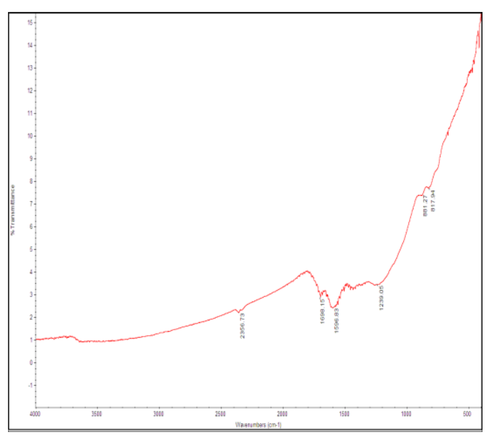
3.0 RESULTS AND DISCUSSION

3.1 Physicochemical and Spectroscopic Characterizations of Adsorbents

The pH of adsorbent is the degree of acidity or basicity of that adsorbent and Point zero charge is a condition in adsorption process when the electrical charge density on a surface is zero [7]. The ash content was 2.35% which indicate the decrease in the sample volatile matter. The pH and pH_{pzc} are 6.9 and 6.9 respectively. At a pH below pH_{pzc} of adsorbent, the surface of the adsorbent become positive and attracts anions, at a pH above pH_{pzc} the surface of the adsorbent become negative and attracts cations [8].

The value of BET surface area of the adsorbent was 1074.692m^2g^{-1}; this high value suggested that the adsorbent possessed micro porous property of an activated carbon, therefore the dye adsorption is likely to be through microporous sorption. The result from EDX elemental analysis revealed high content of carbon 77.51% which is a characteristic of a good adsorbent. The FTIR of the activated carbon revealed a broad adsorption band at 3693 cm^{-1} and it was due to surface O-H stretching frequencies. Peaks positioning at 2356.7306cm^{-1} and 2363.06cm^{-1} (C≡C) revealed the presence of alkyne group, peaks at 1595.83 cm^{-1} signified the presence of alkene group while the band at 1698.18 cm^{-1} suggested the presence of carboxylic group. These absorption frequency bands are characteristic peaks of hemicelluloses and lignin group from agricultural wastes as reported by [9].

The surface morphology SEM analysis show that there was well developed porous structure with exterior opening, while a clustered image of the loaded adsorbent in figure 3b confirmed the adsorption of dye on the surface of the adsorbent.



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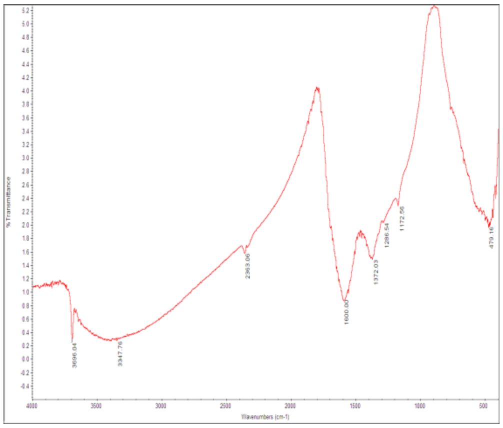

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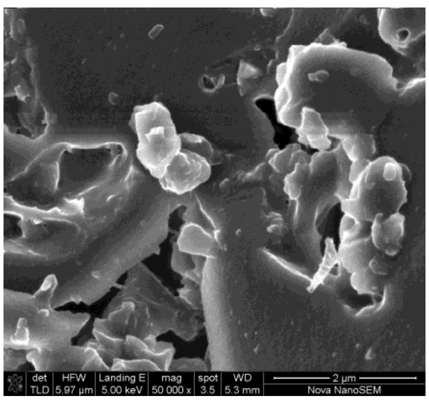
Figure 2: FT-IR Spectrum of PKS AC sample (A) and FT-IR Spectrum of PKS AC after adsorption (B)



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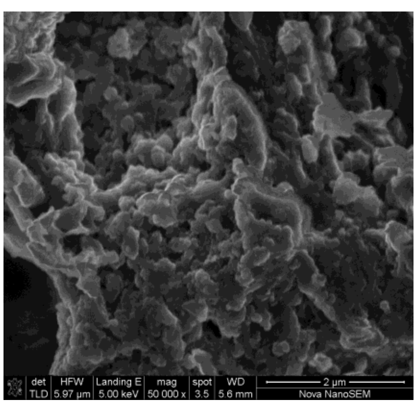

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Figure 3: SEM micrograph of activated carbon sample (A) and SEM micrograph of activated sample after adsorption (B)

3.2 Batch Adsorption Experimental Results

The result from the batch adsorption experiments shows that the maximum adsorption capacity of crystal violet dye onto PKS was 220mg/L at pH 6. The maximum quantity of dye adsorbed was 180 mg/L with 0.5 g of adsorbent, while 225 mg/L at 40 minutes was observed as maximum time for the removal of crystal violet dye from aqueous solution.

The above experiment were subjected to Langmuir, Freundlich and Temkins adsorption isotherm models, the best line fit was Langmuir with R^2 value of 0.988, this suggested that the Langmuir monolayer isotherm was favourable. The kinetic models shows that the pseudo-second order model was best fit than first order due to the R^2 value of 0.997 observed. This kinetic studies results compliment the fact that the sorption system was physiosorption. The thermodynamic studies shows that ΔG value of crystal violet dye adsorbed was negative and the negative value of ΔG suggested feasibility and spontaneity of the adsorption process within the working temperatures [10].

3.0 CONCLUSION

Adsorption of Crystal Violet (CV) onto palm kernel shell activated carbon was optimum at a pH of 6. Adsorption increased with contact time and equilibrium was reached within 40 minutes. Adsorption capacity decreased with increasing adsorbent dosage but increased with increase in initial dye concentration and temperature. Adsorption isotherm followed Freundlich, Langmuir and Temkin. The sorption system followed pseudo second order kinetics. The negative value of the ΔG supported the feasibility and spontaneity of the adsorption system. Therefore, palm kernel shell is a potential and viable adsorbent for the removal of crystal violet (CV) dye from aqueous solution.

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