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ADSORPTION OF SAFRANIN-O (BASIC RED DYE) IN AQUEOUS SOLUTION USING CARBONIZE AND NON-CARBONIZE EUCALYPTUS LEAVE (DOGONYARAO)

[1]Babagana M., [2]Musa M A., [2]Jones A.N and [3]Abubakar A.B.
[1]Department of Civil Engineering Technology, School of Engineering
Ramat Polytechnic Maiduguri P.M.B 1070, Borno State, Nigeria
[2]Department of Civil and Water Resource Engineering, Faculty of Engineering
University of Maiduguri P.M.B 1069, Borno State, Nigeria
[3]Department of Mechanical Engineering Technology, Ramat Polytechnic Maiduguri
P.M.B 1070, Borno State, Nigeria

Abstract: *This study investigates the adsorption efficiency of carbonized and non-carbonized eucalyptus leaves for the removal of Safranin-O (Basic Red Dye) from aqueous solutions. Safranin-O, commonly used in textile, paper, and leather industries, poses significant environmental and health risks due to its toxicity and persistence in water bodies. The study evaluates the effects of key parameters such as initial dye concentration, contact time, adsorbent dose, and pH on adsorption efficiency. The adsorbents were prepared by carbonizing eucalyptus leaves at 500°C to enhance their adsorption properties. Batch adsorption experiments were conducted, and results revealed that adsorption capacity increased with higher initial dye concentrations, prolonged contact time, and increased adsorbent dosage. Optimal dye removal (84.5%) was observed at pH 6, under acidic conditions, highlighting the influence of pH on adsorption efficiency. The findings demonstrate the potential of eucalyptus leaves as a cost-effective and eco-friendly adsorbent for Safranin-O removal, offering a sustainable solution for mitigating industrial wastewater pollution. This study provides a foundation for further research into the scalability and industrial application of natural adsorbents in wastewater treatment.*

Keywords*: Safranin-O adsorption; Eucalyptus leaves; Aqueous solutions; Wastewater treatment and Natural adsorbent*

1.0 Introduction

Water is a vital resource for the survival of all living organisms in the ecosystem. Although it appears plentiful, it remains a valuable commodity. Globally, most of the water bodies consist of salt water (oceans), making up 97.4% of the total, while only 2.6% is fresh water (UNESCO). This fresh water is also limited; a significant portion (1.98%) is trapped in ice, and only 0.6% is readily accessible as groundwater and surface water, including rivers and lakes (Kaushik, 2010). Unfortunately, human activities and rapid industrialization have led to the depletion of non-renewable resources and a substantial increase in air pollution, endangering both the environment and human health. This problem is likely to worsen, especially in developing countries, unless stringent measures are implemented. A major contributing factor is the generation and improper disposal of non-hazardous waste, which significantly affects groundwater and soil quality. Historically, rivers and streams have been used for waste disposal, with communities along their banks contributing to river pollution (Kaushik, 2010). Adsorption, a widely used environmental engineering technique, plays a vital role in removing contaminants from water. This process involves attaching dissolved substances to a solid surface, known as an adsorbent. According to recent studies, there is increasing interest in the use of natural adsorbents—especially plant materials—for the purpose of eliminating dyes from wastewater (Wang *et al*., 2016).

Because of its poisonous and carcinogenic qualities, Safranin-O, a dye that is frequently used in the paper, leather, and textile sectors, has caused serious worries about the environment and human health (Sharma, 2016). Because of the waste's bright hue and its toxicity, the discharge of wastewater from industrial activities such as textile, paper, printing, chemical, food, and power facilities is troublesome. Research indicates that when introduced into aquatic environments, contaminants such as dyes change the characteristics of the water, obstruct sunlight, and decrease photosynthesis (Wang *et al*., 2012). Water pollution is not limited to organic matter but also includes pollutants that impact aquatic organisms. Organic waste, particularly from waste treatment processes, can contain various toxic substances, including ammonia. Eutrophication, caused by the influx of nutrients into water bodies, presents another issue; phosphorus-rich substances, farm runoff, manures, and compost from intensive agriculture, along with increased nitrogen from fossil fuel combustion and soil erosion due to deforestation and recreational boating, all contribute to this problem (Harrison, 2011). Some heavy metals have a specific gravity that is at least five times greater than water, especially those included in the d block of the periodic table (Khan *et al*., 2008). A large-scale study by Khataee *et al*. (2013) found that Safranin-O could negatively affect aquatic organisms, impacting their reproductive growth. Poor disposal methods further exacerbate water pollution, degrade freshwater quality, and harm aquatic life by disrupting ecological balance (Mohammad *et al.,* 2019). The distinctive form and substantial surface area of eucalyptus leaves have made them a promising material for the removal of Safranin-O. In order to improve the adsorption process, the study looks at variables such initial dye concentration, pH, temperature, contact time, and adsorbent dosage. The use of eucalyptus leaves as an economical and environmentally friendly dye removal material offers the possibility to lessen the negative effects of industrial waste on the environment and save freshwater resources (Alves *et al.*, 2012; 2019).

2.0 MATERIALS AND METHOD

2.1 Preparation and Development of the Adsorbent

High-purity Safranin-O dye, a critical component of the study, was procured from Monday Market to ensure consistency and reliability in the experiments. Fresh eucalyptus leaf waste, used as the primary adsorbent material, was sourced at no cost from the University of Maiduguri. The preparation process involved several steps to ensure the adsorbent's quality:

1. The eucalyptus leaves were thoroughly washed to remove potential contaminants.
2. The cleaned leaves were oven-dried at 80°C for 2 hours to eliminate moisture.

3. The dried sample was carbonized in a muffle furnace at 500°C for 2 hours under an inert atmosphere to enhance its adsorption properties.
4. After carbonization, the material was allowed to cool and then ground into a fine powder to increase its surface area and adsorption efficiency.

This process ensured the adsorbent's readiness for use in the subsequent experiments.

2.2 Adsorption Process

The adsorption process evaluated the efficiency of the prepared eucalyptus leaf adsorbent in removing the Safranin-O dye from solutions. As described in the introduction, agricultural waste was utilized as the primary adsorbent material. The methodology involved testing the adsorption capacity of the eucalyptus-based adsorbent under various conditions. A summary of the experimental procedure is provided in the figure below.

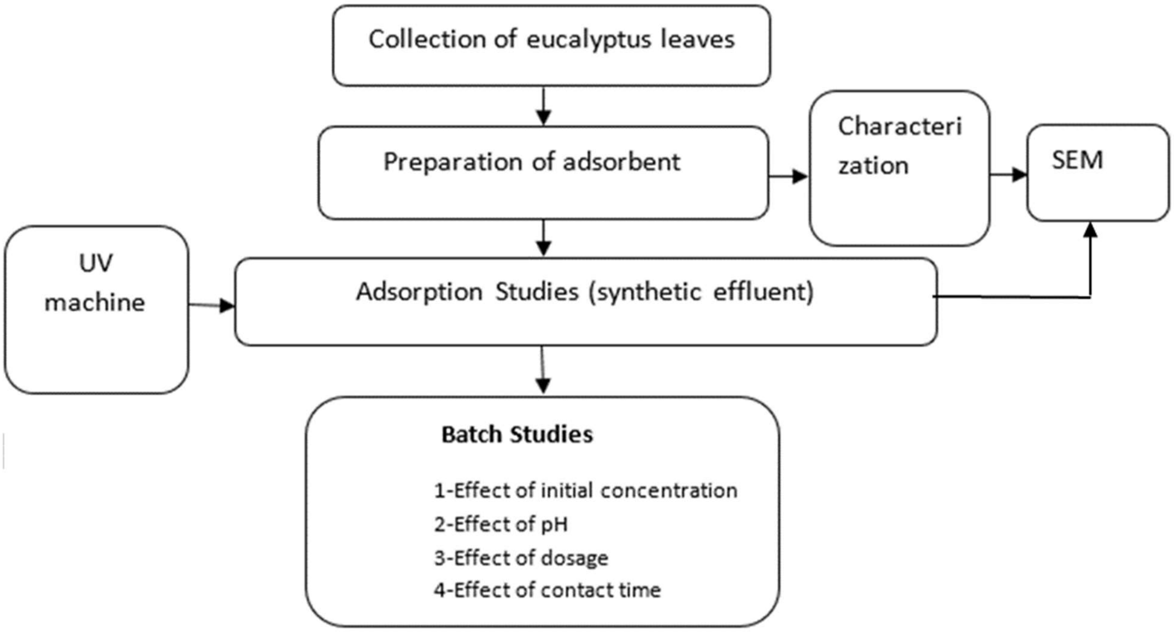

Figure 2.1: Flow chart on scope of works

2.3 Preparation of Dye Solution

One liter of distilled water was used to dissolve 1.0g of Safranin-O to create a 30ml stock solution. The stock solution was diluted with the required quantities of distilled water to get solutions with different concentrations. Every reagent used in this investigation was of the analytical variety. With a maximum wave length of 516 nm, a UV-visible spectrophotometer (Shimazdu Model UV 1601, INDIAN) was used to measure the concentration of Safranin-O dye both before and after the adsorption.

2.4 Batch Adsorption Studies

Every experiment in this study was run at room temperature. A variety of starting concentrations (20-100 ppm), contact times (15-75 minutes), pH (pH meter model

PHS-25, USA) ranging from 2 to 12, adsorbent doses (0.5-2.5g), and an orbital shaker operating at a constant speed of 150 rpm were tested using 250 mL stopper cork conical flasks filled with 100 mL of adsorbate. A double beam UV-Vis spectrophotometer (Model GENESYS-10-UV) operating at a wavelength of 516 nm was used to record the dye's final concentrations. Equation (2.1) was used to determine the quantity of biosorption at equilibrium, or qe (mg/g), and Equation (2.2) was used to determine the percentage of dye removed (Tsai *et al.,* 2004);

$$q_e = \frac{(C_o - C_f)V}{M} \tag{2.1}$$

Where M is the mass of the adsorbent utilized (g), V is the volume of the dye solution (L), and q is the equilibrium dye concentration on the adsorbent at any given time (mg/g).

$$\%\,Removal = \frac{C_o - C_f}{C_O} \times 100 \tag{2.2}$$

where C_f is the sample's equilibrium dye concentration (mg/L) and C_O is the sample's starting dye concentration (mg/L).

3.0 Results and Discussion

This section presents the results of the study, highlighting the effects of initial dye concentration, contact time, adsorbent dose, and pH on the adsorption efficiency of Safranin-O using carbonized eucalyptus leaves

3.1 Effect of Initial Concentration and Contact Time

Figure 3.1 illustrates the influence of initial Safranin-O concentration and contact time on carbonized eucalyptus adsorption performance across a range of initial concentrations (20–100 ppm). The experiments were conducted with an agitation speed of 150 rpm and an adsorbent dose of 1 g, while the contact time varied from 15 to 75 minutes.

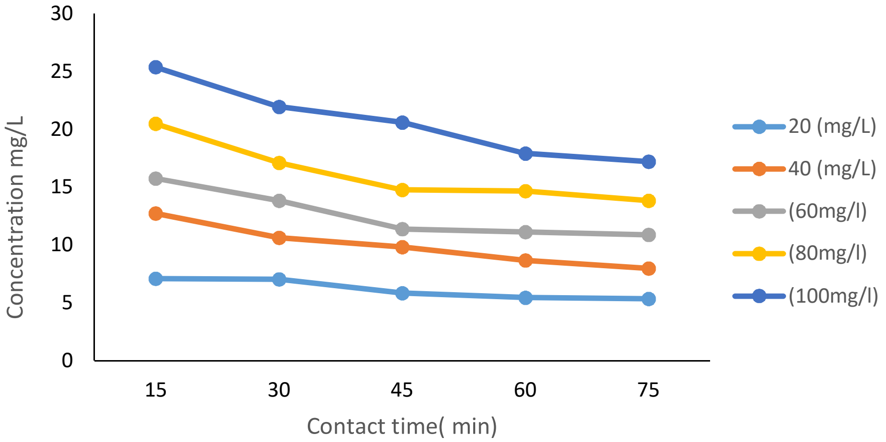

Figure 3.1: ***Effects of initial Concentration and contact time on the amount of adsorbed Safranin-O (Adsorbent dose: 1 g; agitation speed: 150 rpm)***

The relationship between initial dye concentration and contact time, as shown in Figure 3.1, indicates a direct correlation between the initial dye concentration and the adsorbent's removal efficiency. The adsorption capacity of the sorbent increased from 3.95 mg/g to 12.37 mg/g as the initial dye concentration rose from 20 mg/L to 100 mg/L. This increase in adsorption capacity is likely due to the higher dye concentration gradient, which enhances the driving force for mass transfer (Yeddou-Mezenner, 2010; Rafatullah et al., 2010; Shen *et al*., 2009). Furthermore, the data reveals a rapid initial adsorption rate that gradually slows over time. This trend can be attributed to the initial availability of abundant surface sites on the adsorbent and the higher concentration gradient of the dye. Over time, as surface sites become occupied, the adsorption rate decreases due to limited availability of active sites and increased repulsion between adsorbed dye molecules (Hamdaoui *et al.,* 2008).

3.2 Percentage Uptake of Safranin-O at Different Initial Concentrations

The percentage uptake of Safranin-O increases with the initial dye concentration, demonstrating a clear relationship between the two variables. Figure 3.2 shows the percentage adsorption of Safranin-O at various initial concentrations over time.

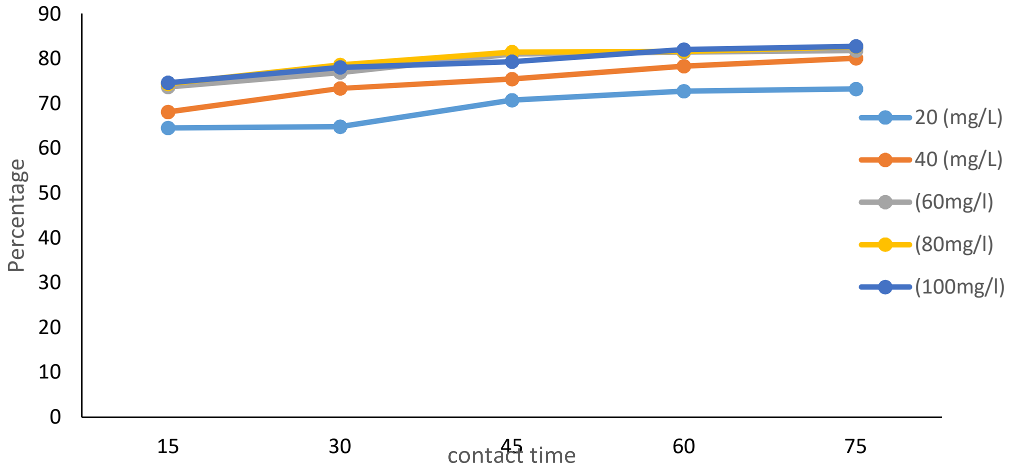

Figure 3.2: ***Percentage uptake of Safranin-O at different initial concentrations (Adsorbent dose: 1 g; agitation speed: 150 rpm)***

As the initial dye concentration increased from 20 to 100 mg/L, the percentage uptake rose from 64.56% to 73.26%. This increase is due to the higher dye concentration, which enhances the driving force for adsorption.

3.3 Effect of Adsorbent Dose

The relationship between adsorbent dosage and dye removal efficiency was explored by varying the dose of carbonized eucalyptus leaves from 0.5 g to 2.5 g. Figure 3.3 illustrates the effect of adsorbent dose on the adsorption of Safranin-O.

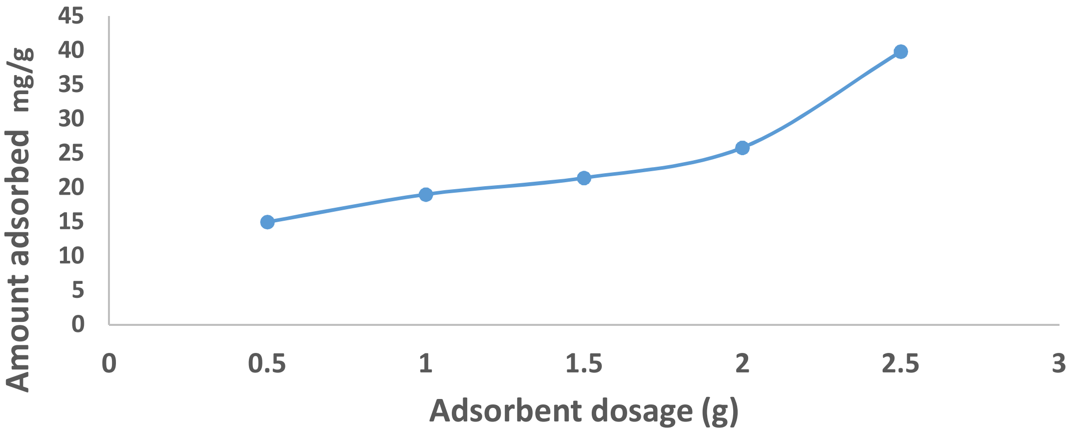

Figure 3.3: ***Effect of adsorbent dose on the uptake of Safranin-O (Initial concentration: 50 ppm; adsorbate volume: 100 mL; agitation speed: 150 rpm; contact time: 75 minutes)***

The results indicate a direct correlation between adsorbent dose and dye adsorption. At 0.5 g of adsorbent, the adsorption capacity was 7.48 mg/g, which increased to 19.8 mg/g at 2.5 g. This phenomenon can be explained by the increase in surface area and available sorption sites with a higher adsorbent dose (Gandhi et al., 2012; Vinod et al., 2012; Saidutta et al., 2013). Additionally, the percentage removal of Safranin-O rose from 14.9% at 0.5 g to 39.8% at 2.5 g. The increased availability of sorption sites relative to dye molecules likely accounts for this trend. Similar findings were reported by Saka (2011).

3.4 Effect of pH

pH plays a crucial role in the adsorption of Safranin-O, as it affects both the dye's structural stability and the adsorbent's surface properties. The experiment investigated pH levels ranging from 2 to 12, revealing significant adsorption behavior at pH 6, where 84.5% dye removal was achieved.

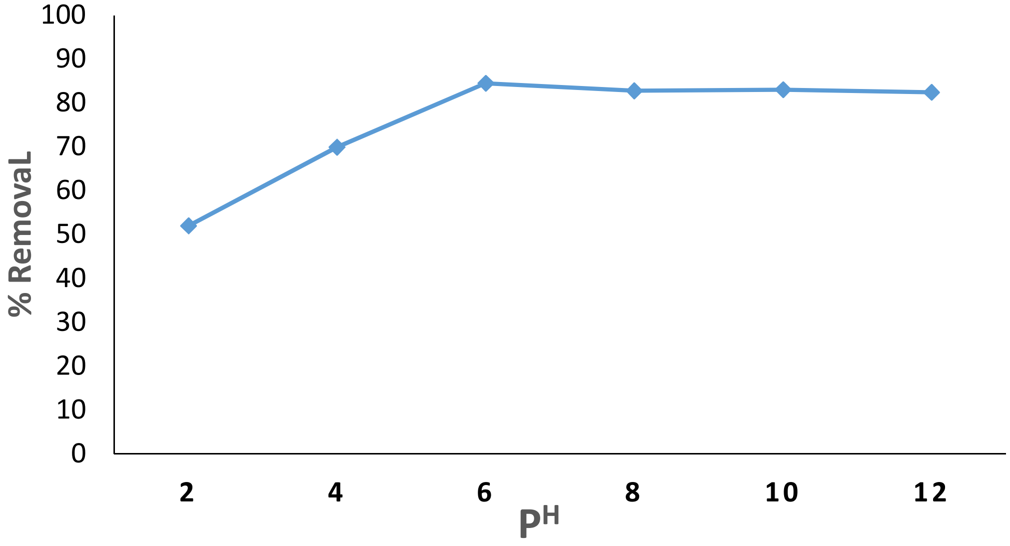

Figure 3.4: ***Effect of pH on Safranin-O adsorption (Initial concentration: 60 ppm; agitation speed: 150 rpm; adsorbent dose: 1 g; contact time: 75 minutes)***

At pH values above 6, permanent changes in the dye's color were observed, indicating structural alterations in its molecules. The optimal dye removal at pH 6 suggests that acidic conditions favor adsorption. This behavior is influenced by surface charges, active sites, and the dye's chemical properties in solution, highlighting the complexity of the adsorption process.

4.0 Conclusion and Recommendations

4.1 Conclusion

This study demonstrates the effectiveness of carbonized and non-carbonized eucalyptus leaves as adsorbents for removing Safranin-O (Basic Red Dye) from aqueous solutions. The research findings indicate that the adsorption efficiency is influenced by several factors, including initial dye concentration, contact time, adsorbent dosage, and pH. Key findings include:

1. **Initial Dye Concentration and Contact Time:** The adsorption capacity increases with higher initial dye concentrations and prolonged contact time, showcasing a strong correlation between dye availability and adsorption efficiency.
2. **Adsorbent Dose:** An increase in adsorbent dosage enhances adsorption efficiency, attributed to the greater surface area and availability of active sorption sites.
3. **pH Influence:** The optimal adsorption was observed at pH 6, where acidic conditions favored dye removal. Extreme pH values caused structural changes in the dye, impacting adsorption efficiency.

The results validate the potential of carbonized eucalyptus leaves as an economical, efficient, and

4.2 Recommendations

1. **Optimization for Industrial Applications:** Future studies should focus on scaling up the adsorption process to evaluate its feasibility in industrial wastewater treatment facilities.
2. **Economic and Environmental Assessment:** Conduct a comprehensive cost-benefit analysis to establish the economic viability of using eucalyptus leaves in large-scale operations and assess the environmental impact of the disposal of spent adsorbents.
3. **Improving Adsorbent Efficiency:** Explore chemical or physical modifications of the eucalyptus adsorbents to enhance their adsorption capacity and reusability.
4. **Exploration of Other Adsorbents:** Investigate the potential of other agricultural wastes or natural materials with similar properties environmentally friendly adsorbent for dye removal from industrial wastewater, offering a sustainable solution to mitigate environmental pollution.to broaden the scope of eco-friendly adsorbents.
5. **Long-Term Environmental Monitoring:** Monitor the environmental effects of treated wastewater to ensure the sustainable use of this adsorption method

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