JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Gaya Region Datura Stramonium Leaves Derived Activated Carbon for Adsorption-Based Removal of Organic Dyes from Aqueous Solution for Application of Wastewater Treatment

Rekha Kumari[1], Nidhi Tripathi[1,*], Rajesh Ranjan Pandey[1]

Department of Chemistry, Anugrah Memorial College, Gaya

Abstract:

The activated carbon derived from *Datura stramonium* leaves which was collected from the Gaya region, India, is synthesized and investigated for the adsorption-based removal of Congo Red and Magenta (organic dyes) from aqueous solution for the application of wastewater treatment. The prepared porous *Datura stramonium* leaf derived carbon (DSLC) is characterized for its adsorption performance by using various experimental techniques including SEM, FTIR, pH, temperature and adsorbent dose. SEM images of Congo Red and Magenta (organic dyes) adsorbed DSLC samples confirm adsorption of dyes in porous activated carbon. FTIR analysis support the adsorption The adsorption equilibrium data are measured using Langmuir and Freundlich isotherm models. whereas, pseudo-first-order and pseudo-second-order models are analysed to describe the adsorption kinetics. Both isotherm models confirm good correlation and finds Langmuir maximum adsorption capacities of 1.0374 mg g^{-1} for Congo Red and 1.0586 mg g^{-1} for Magenta. The kinetic data have excellent agreement with the pseudo-second-order model, with R^2 values of 0.9977 and 0.9989 for Congo Red and Magenta, respectively. Thermodynamic analysis indicates favourable adsorption at 303–313 K, with negative enthalpy changes for both dyes. The above findings reveal the potential of *Datura stramonium* leaf in Gaya region-derived activated carbon as a low-cost biomass-based adsorbent for organic dye removal for the application in wastewater treatment.

Introduction

The rapid growth of textile, printing, leather, paper, pharmaceutical, and other dye-consuming industries has resulted in the increasing generation of wastewater containing a wide variety of organic contaminants.[1-7] Among these pollutants, synthetic dyes are of particular environmental concern because of their intense colour, complex molecular structures, high chemical stability, and resistance to natural degradation processes. The release of dye-containing effluents into aquatic environments can adversely affect water quality by reducing light penetration, disturbing photosynthetic activity, and altering the ecological balance of receiving water bodies. In addition, the persistence of some synthetic dyes and their transformation products raises concerns regarding their potential impacts on aquatic organisms and human health.[8,9] Therefore, the development of efficient, economical, and environmentally compatible approaches for the removal of organic dyes from contaminated water is an important requirement for sustainable wastewater management.[7, 10-14]

Several treatment technologies have been developed for the removal of dyes from wastewater, including coagulation–flocculation, membrane separation, oxidation processes, photocatalytic degradation, biological treatment, and adsorption.[15-20] Although, these techniques can provide effective way to remove contaminant under ambient conditions, but, these methods may be restricted by factors such as energy consumption, high costs in this process, tredious treatment procedures, chemical requirements, membrane fouling, and production of secondary pollutants.[13, 21, 22] Among these approaches, the use of non-reactive sustainable absorbant materials are suitable candidate and adsorption has received significant attention because of its operational simplicity, versatility, effectiveness. This process has potential for treating contaminants even at relatively low concentrations. The effectiveness of an adsorption depends mainly on the physicochemical properties of the adsorbent materials, including its pore size and structure, surface area, surface morphology, surface charge and abundance of functional groups which help wastewater treatment.[7,11,20]

Activated carbon treated with suitable acid or base reagents is one of the most extensively studied adsorbent materials for water purification owing to its non-reactive porous structure and its ability to interact mainly through physical interaction with a wide range of organic contaminants present in wastewater. However, the cost involved in the production and regeneration of activated carbon prepared by different methods can limit its large-scale application, particularly in resource-constrained settings. Consequently, considerable research interest has been directed towards the preparation of low-cost activated carbons from renewable biomass and agricultural or plant-derived wastes. Biomass-based adsorbent activated carbonoffers an attractive alternative because carbonization during biomass waste materials can utilize naturally abundant materials that might otherwise be discarded. Carbonization and activation of prepared carbon of such waste biomass can address water-pollution problems, that provids a easy and potentially sustainable route for the development of waste biomass materials.

Biomass produced from plants is particularly attractive as a raw material for preparation of carbon because of higher amount of carbon-rich content and the presence of naturally occurring oxygen-containing constituents. Thecarbonization at suitable temperature followed by activation of carbon can substantially modify the pore structure and surface morphology of the resulting crystalline carbon material and can generate functional groups capable of interacting almost physically with dissolved wastewater contaminants. Dye removal involves surface interactions between adsorbent and adsorbate and nature of interaction may be electrostatic attraction, hydrogen bonding, π–π interactions, pore filling, and other physicochemical interactions. Consequently, detailed analysis of the adsorbent material together with equilibrium, kinetic, and thermodynamic investigations for wastewater treatment applications is essential for understanding its adsorption behaviour and evaluating its suitability.

In this context, *Datura stramonium* leaf biomass represents a potentially suitable precursor for a low-cost non-reactive environmental friendly carbonaceous adsorbent. In the present study, activated porous carbonnceous material derived from *Datura stramonium* leaves (DSLC) was studied for removal of two organic dyes, Congo Red and Magenta in aqueous solution through adsorption. The characterization results showed a pronounced porous morphology in activated carbon. The carbon prepared by raw *Datura stramonium* leaf exhibits a relatively smooth surface with fewer visible pores, whereas, acid-activated DSLC shows porous morphology, providing high surface area for adsorption. The post-adsorptionanalysis will show the presence of adsorbed dye-loaded material on the DSLC surface, with the adsorbent morphology becoming substantially covered following dye uptake.

The molecular chemistry of DSLC is measured using Fourier-transform infrared spectroscopy (FTIR). The activated carbon exhibits characteristic bands related to O–H, C–O/C–OH, C=C, and C=O functionalities in FTIR analysis, indicating the presence of oxygen-containing functional groups in which will interact with dye molecules during adsorption. FTIR analysis of the dye-loaded adsorbent shows changes in the spectral features following adsorption of dyes, providing evidence for interactions between the adsorbed dye molecules and

functional groups present on surface of activated carbon. The X-ray diffraction (XRD) analysis further indicates a predominantly crystalline and disordered amorphous carbon structure, with crystalline diffraction features reported ~2θ ≈ 24° and 43°. Furthermore, these structural and chemical characteristics of adsorpted dyes on activated carbon provide an important basis for understanding of the wastewater treatment.

The adsorption behaviour of DSLC towards Congo Red and Magenta organic dyes is further evaluated using kinetic models, equilibrium isotherms, and thermodynamic parameters. The experimental equilibrium data are fitted to both Freundlich and Langmuir adsorption models. The better adsorption ability obtained for Magenta indicate comparatively favourable adsorption behaviour of this dye on DSLC under the different investigated conditions.

The adsorption kinetics are analysied using both pseudo-first-order and pseudo-second-order models and the experimental results establish a strong correlation with both models

In addition to kinetic and equilibrium behaviour, the influence of thermodynamic and operational parameters is examine to obtain a more comprehensive understanding of the adsorption process. The study of adsorbed samples also examinethe influence of temperature, pH, adsorbent concentration, and concentration of dyes. Dye removal is observed over the investigated pH range, while increasing the concentration of adsorbent.

Taken together, these findings demonstrate the potential of *Datura stramonium* leaf-derived activated carbon as a biomass-based adsorbent for the removal of organic dyes from aqueous systems. The combination of porous morphology, oxygen-containing surface functionalities, adsorption equilibrium behaviour, favourable kinetic correlations, and measurable responses to operational conditions supports the applicability of DSLC as an alternative low-cost adsorbent. Importantly, the comparative results obtained for Congo Red and Magenta provide an opportunity to examine how differences in dye characteristics influence their interaction with a common biomass-derived adsorbent. The original study reported comparatively better adsorption performance for Magenta than Congo Red under the investigated conditions.

Therefore, the present work aims to systematically evaluate the adsorption-based removal of Congo Red and Magenta from aqueous solution using activated carbon prepared from *Datura stramonium* leaves. The study integrates physicochemical characterization of the adsorbent using SEM, FTIR, XRD, and BET analysis with adsorption equilibrium, kinetic, thermodynamic, and operational investigations. Particular emphasis is placed on elucidating the adsorption behaviour of the two dyes and establishing the relationship between the surface characteristics of DSLC and its dye-removal performance. The study ultimately seeks to demonstrate the potential of an inexpensive plant-derived carbon material as a sustainable adsorbent and to provide a scientific basis for its possible application in adsorption-oriented wastewater treatment.

2. Experimental

2.1 Preparation of *Datura stramonium* Leaf-Derived Activated Carbon

Fresh leaves of *Datura stramonium* were collected and used as the biomass precursor for the preparation of activated carbon. The collected leaves were suitably cleaned to remove adhering soil and other extraneous materials and subsequently processed to obtain the carbonaceous precursor. The plant-derived carbon was subjected to activation treatment using an acidic activating medium, followed by appropriate washing and drying to obtain the activated *Datura stramonium* leaf carbon (DSLC). The activation process was intended to improve the surface accessibility and porosity of the carbon material and thereby enhance its ability to interact with dissolved dye molecules. The activated carbon prepared from the leaves was subsequently used as the adsorbent in all adsorption experiments. The experimental work reported the activated carbon preparation at approximately **400 °C** and used acid activation for developing the adsorbent surface.

2.2 Preparation of Dye Solutions

Congo Red and Magenta were selected as representative organic dyes for evaluating the adsorption performance of DSLC. Aqueous dye solutions of known concentrations were prepared and used in the batch adsorption experiments. The dye solutions were prepared using distilled/deionized water, and the required experimental concentrations were obtained by appropriate dilution of the stock solutions. The adsorption experiments were performed separately for Congo Red and Magenta to enable comparison of their adsorption behaviour towards the same biomass-derived adsorbent.

2.3 Batch Adsorption Experiments

The adsorption experiments were conducted using a batch equilibrium approach. A known quantity of activated DSLC was contacted with a measured volume of dye solution under controlled experimental conditions. The suspension was allowed to interact for a predetermined period to facilitate adsorption of the dye molecules onto the adsorbent surface. After the required contact time, the adsorbent was separated from the aqueous phase and the residual dye concentration was determined. The amount of dye adsorbed was calculated from the difference between the initial and equilibrium concentrations.

The adsorption capacity at equilibrium, q_e, was calculated using:

$$q_e = \frac{(C_0 - C_e)V}{m}$$

where C_0 and C_e are the initial and equilibrium concentrations of the dye (mg L^{-1}), respectively, V is the volume of dye solution (L), and m is the mass of DSLC used (g).

The percentage removal of dye was calculated according to:

$$\text{Removal (\%)} = \frac{C_0 - C_e}{C_0} \times 100$$

These parameters were used to evaluate the adsorption efficiency of DSLC towards both Congo Red and Magenta.

2.4 Effect of Experimental Conditions

The adsorption performance was evaluated under different experimental conditions to determine the factors governing dye removal. The influence of **solution pH, temperature, adsorbent dose, initial dye concentration, and contact time** was investigated. The original experimental study examined the effect of pH over approximately **3.8–7.4**, while the influence of temperature, adsorbent dose, and initial dye concentration was also systematically investigated.

For the pH experiments, the initial pH of the dye solution was adjusted to the required value before contact with DSLC, and the resulting change in dye removal was evaluated. The temperature-dependent experiments were performed at different temperatures to determine the effect of thermal conditions on adsorption. The reported experiments covered the temperature range around **308–328 K** for evaluating dye removal.

The effect of adsorbent dosage was examined by varying the amount of DSLC added to the dye solution. The original study investigated DSLC quantities in the range of approximately **0.5–1.0 g**, and an increase in dye removal was observed with increasing adsorbent quantity.

The effect of initial dye concentration was evaluated by varying the concentration of Congo Red and Magenta while maintaining the other experimental conditions as appropriate. The adsorption was observed to be

relatively rapid during the initial period, followed by a slower stage as the available adsorption sites became progressively occupied and the system approached equilibrium.

2.5 Adsorption Equilibrium Studies

The equilibrium adsorption data were analysed using **Langmuir and Freundlich isotherm models** to investigate the relationship between the equilibrium concentration of dye in solution and the amount adsorbed by DSLC.

The linear form of the Freundlich equation was expressed as:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e$$

where $K_F$represents the adsorption capacity and $1/n$represents the adsorption intensity. The linear regression of $\log q_e$against $\log C_e$was used to determine the corresponding Freundlich parameters.

The Langmuir model was subsequently applied to evaluate the maximum adsorption capacity and adsorption affinity of DSLC towards the dyes. The experimental data were fitted to the linearized Langmuir relationship, and the corresponding maximum adsorption capacity ($Q_{\max}$) and Langmuir constant (b) were determined from the regression analysis.

2.6 Adsorption Kinetic Studies

The adsorption kinetics of Congo Red and Magenta onto DSLC were evaluated using **pseudo-first-order and pseudo-second-order kinetic models**. These models were applied to determine the rate-controlling characteristics of the adsorption process and to compare the agreement between experimentally observed and model-predicted adsorption capacities.

The pseudo-first-order model was used to evaluate the rate constant associated with the initial adsorption process, whereas the pseudo-second-order model was applied to examine the adsorption kinetics based on the experimentally determined equilibrium capacity. The suitability of each model was assessed from the corresponding linear regression coefficient (R^2) and the agreement between calculated and experimental adsorption capacities.

2.7 Adsorption Thermodynamics

The thermodynamic feasibility of the adsorption process was investigated at different temperatures. The thermodynamic parameters, including **Gibbs free-energy change (ΔG), enthalpy change (ΔH), and entropy change (ΔS)**, were evaluated from the temperature-dependent equilibrium data. The relationship between the equilibrium constant and temperature was used to obtain the thermodynamic parameters through a van't Hoff-type analysis. The original study evaluated the adsorption thermodynamics over the temperature range of **303–333 K**.

The Gibbs free-energy change was used to assess the thermodynamic feasibility of the adsorption process, while the enthalpy change was used to evaluate the energetic nature of adsorption and the entropy change to assess changes in the degree of disorder associated with dye adsorption.

2.8 Characterization of the Adsorbent

The prepared DSLC was characterized before and after dye adsorption to evaluate its physicochemical properties and to obtain evidence regarding changes associated with dye uptake. The characterization results were used to support the interpretation of the adsorption behaviour and the proposed adsorbent–adsorbate interactions. **The individual characterization techniques and their detailed procedures are not elaborated here, as they will be presented separately in the characterization subsection of the manuscript.**

2.9 Data Analysis and Comparison of Dye Adsorption

The adsorption data obtained for Congo Red and Magenta were analysed comparatively to determine the relative adsorption performance of DSLC towards the two dyes. Equilibrium, kinetic, thermodynamic, and operational-parameter results were considered collectively to assess the adsorption behaviour. The experimental results reported in the study indicated that both dyes could be effectively adsorbed by DSLC, with Magenta showing comparatively better adsorption behaviour in the equilibrium studies.

Overall, the methodology was designed to evaluate DSLC not only in terms of its dye-removal efficiency but also with respect to **adsorption capacity, equilibrium behaviour, adsorption kinetics, thermodynamic feasibility, and the influence of important operating parameters**. This integrated approach provides a basis for assessing the suitability of *Datura stramonium* leaf-derived activated carbon as a low-cost biomass-based adsorbent for organic dye removal and its potential implications for wastewater treatment.

3. Results and Discussion

3.1 Adsorbent characteristics and their relevance to dye adsorption

The adsorption performance of a biomass-derived carbon is strongly dependent on the accessibility of its surface, pore structure, and the chemical functionalities available for interaction with the adsorbate. In the present study, activation of *Datura stramonium* leaf carbon resulted in a visibly different surface morphology compared with the raw carbon.

As shown in **Figure 1**, the *Datura stramonium* leaf (DSLC) exhibits a more porous and developed surface morphology than the raw material. The development of pores during activation is particularly important because it can increase the accessibility of adsorption sites and facilitate the diffusion of dye molecules from the aqueous phase towards the carbon surface. The original SEM observations also indicate that the activated material possessed a more porous and lustrous powder-like morphology, supporting its suitability as an adsorbent. Following adsorption, the surface morphology changed considerably, with dye-loaded material covering portions of the adsorbent surface, as observed in **Figure 2**. The appearance of a relatively continuous dye layer on the carbon surface suggests substantial interaction of the dye molecules with the available adsorption sites and provides visual evidence of dye uptake by DSLC.

Figure 1: Datura stramonium leaf carbon

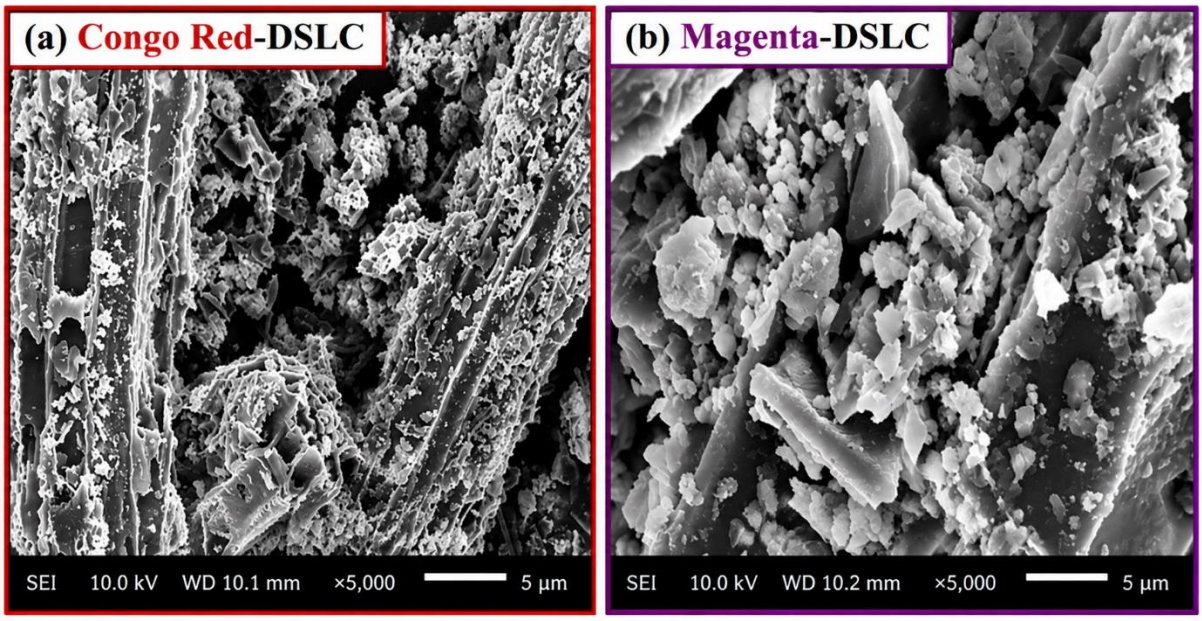

Figure 2: Dye-loaded material covering portions of the adsorbent surface

The surface chemical characteristics of DSLC further support its adsorption capability. The FTIR spectrum presented in **Figure 3** shows several characteristic absorption bands associated with oxygen-containing and carbon-based functional groups. The broad absorption region around 3788–3585 cm^{-1} was attributed to O–H/C–OH stretching, while bands near 3030 and 1826 cm^{-1} were associated with C=C and C=O functionalities, respectively. Additional bands were observed around 1500, 1342, and 1211 cm^{-1}. These functional groups are important because the surface chemistry of activated carbon can provide sites capable of interacting with dye molecules through hydrogen bonding and other surface interactions. Importantly, FTIR spectra obtained after adsorption of Congo Red and Magenta showed changes in the characteristic spectral features (see Figure 4 and Figure 5). The dye-treated adsorbents exhibited changes in peak intensity and additional spectral contributions associated with the adsorbed dye species, supporting the occurrence of interactions between the dyes and the DSLC surface. The broad region reported between approximately 2944 and 3743 cm^{-1} was particularly influenced after dye treatment, while features associated with amine and azo-containing groups of the dyes were observed. Thus, the combined morphological and spectroscopic observations indicate that both the porous structure and surface functional groups of DSLC contribute to its ability to retain Congo Red and Magenta from aqueous solution.

3.2 Adsorption equilibrium behaviour

The equilibrium adsorption behaviour of Congo Red and Magenta was evaluated using the Freundlich and Langmuir isotherm models. The experimental data showed good correlations with both models, indicating that the adsorption process can be described from the perspectives of both heterogeneous surface interactions and finite adsorption-site occupancy. For the Freundlich model, the correlation coefficients were **0.9622 for Congo Red and 0.9726 for Magenta**, with corresponding K_F values of **0.6864 and 0.7784**, respectively. The Freundlich n values were **1.0402 for Congo Red and 1.5435 for Magenta**. The higher n value obtained for Magenta suggests a comparatively more favourable adsorption intensity for this dye under the investigated conditions.

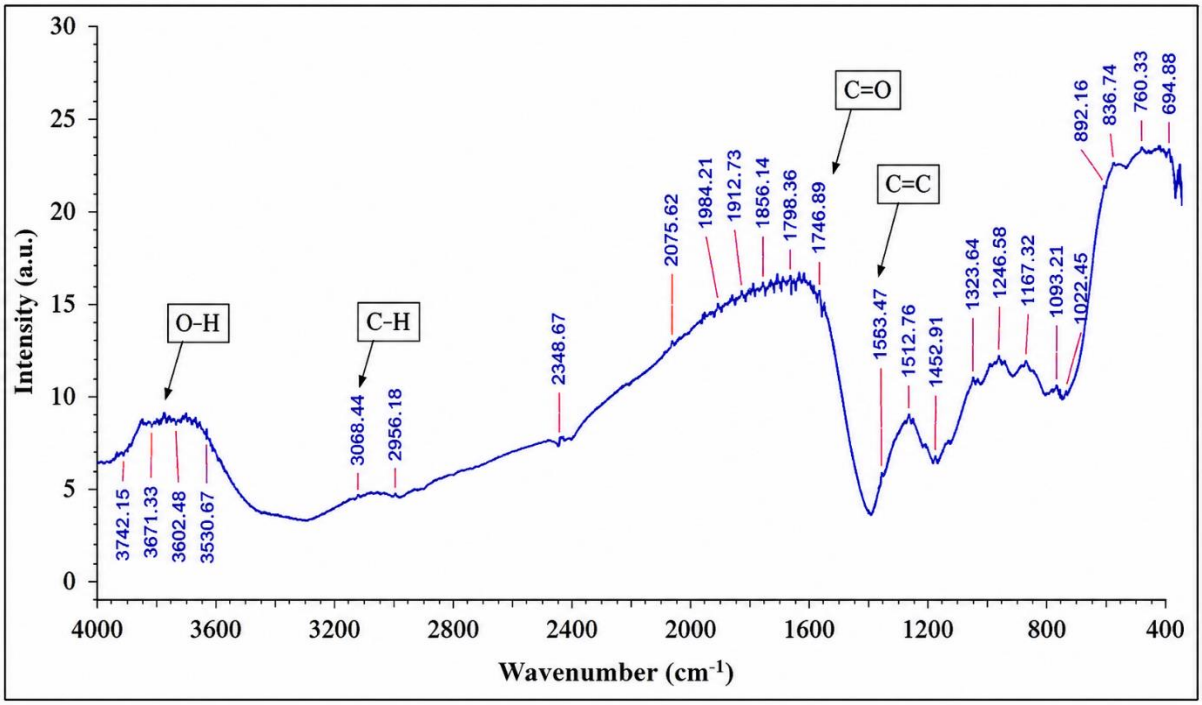

Figure 3: ***FTIR spectra of DSLC***

The Langmuir model also provided satisfactory correlations, with R^2values of **0.9247 for Congo Red and 0.9586 for Magenta**. The calculated maximum adsorption capacities (Q_{max}) were **1.0123 mg g⁻¹ for Congo Red and 1.0145 mg g⁻¹ for Magenta**, while the corresponding Langmuir constants were 0.1254 and 0.1245, respectively. The slightly higher $Q_{max}$and Langmuir constant obtained for Magenta indicate that DSLC exhibited somewhat greater equilibrium adsorption performance towards Magenta than Congo Red. The better fit of the Freundlich model compared with the Langmuir model for both dyes also suggests that the heterogeneous nature of the biomass-derived carbon surface may play an important role in adsorption. This interpretation is consistent with the presence of different surface functionalities identified by FTIR and the heterogeneous porous morphology observed by SEM. Overall, the equilibrium results demonstrate that DSLC possesses a measurable affinity towards both investigated dyes, while the comparative parameters indicate somewhat more favourable adsorption of Magenta.

3.3 Adsorption kinetics and equilibrium attainment

The adsorption kinetics provide important information regarding the rate at which dye molecules are transferred from the aqueous phase to the adsorbent surface. The adsorption profiles showed a relatively rapid initial uptake followed by a slower adsorption stage as the system approached equilibrium. Such behaviour can be associated with the initial availability of a larger number of vacant adsorption sites on DSLC, followed by progressive occupation of these sites as adsorption proceeds. The concentration gradient between the aqueous phase and adsorbent surface is also expected to be more pronounced during the initial stage, favouring faster mass transfer. As the adsorption sites become increasingly occupied, the driving force for further adsorption decreases and the rate of uptake becomes slower. The original study similarly reported rapid adsorption initially, followed by a gradual decrease in adsorption rate and eventual approach towards equilibrium.

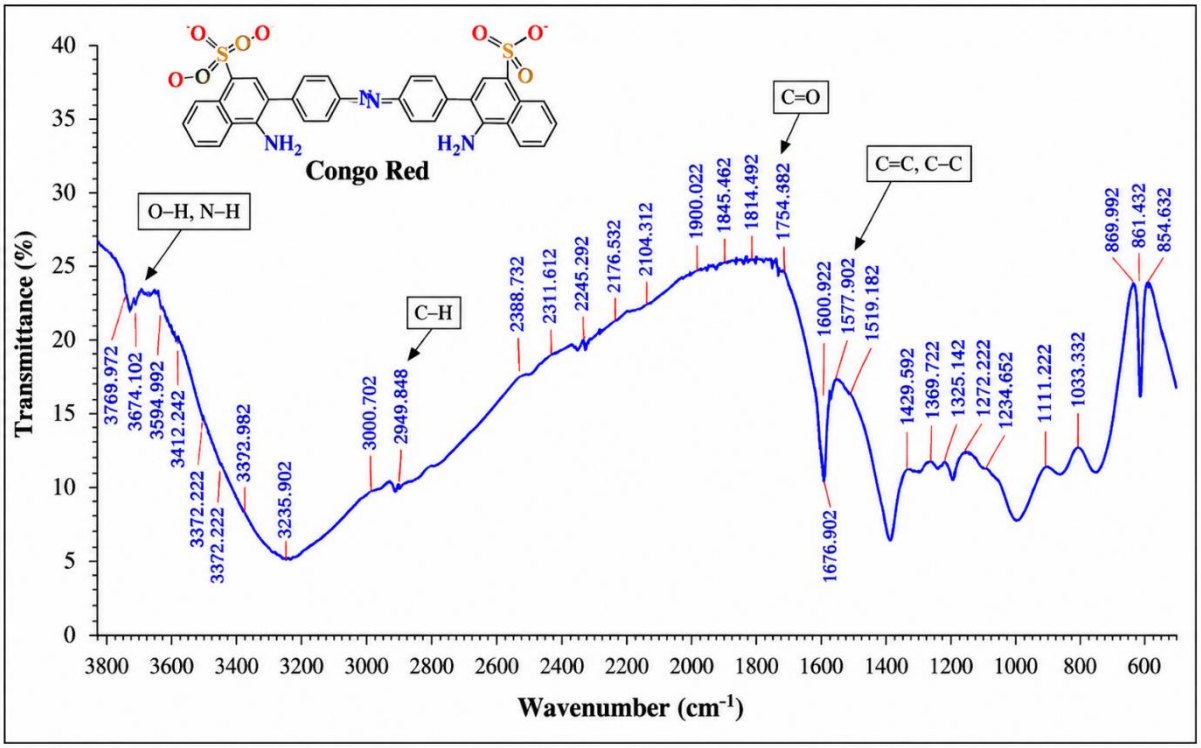

Figure 4: FTIR spectra of Congo red dye

The kinetic behaviour was evaluated using pseudo-first-order and pseudo-second-order models. Both models provide reasonably good descriptions of the adsorption process; however, the pseudo-second-order model provides the stronger correlation. The pseudo-first-order model yielded R^2values of **0.9858 for Congo Red and 0.9893 for Magenta**, whereas the corresponding pseudo-second-order R^2values increased to **0.9977 and 0.9989**, respectively. The calculated pseudo-second-order adsorption capacities were **9.281 mg g^{-1} for Congo Red and 8.458 mg g^{-1} for Magenta**, with rate constants of **0.1337 and 0.1308 g mg^{-1} s^{-1}**, respectively. The substantially high correlation coefficients obtained from the pseudo-second-order model indicate that this model provides the more appropriate mathematical description of the experimental kinetic data. It should be emphasized, however, that a better fit to a pseudo-second-order equation alone does not by itself establish a specific molecular adsorption mechanism; rather, it indicates that the temporal adsorption behaviour is better represented by this kinetic model under the experimental conditions employed.

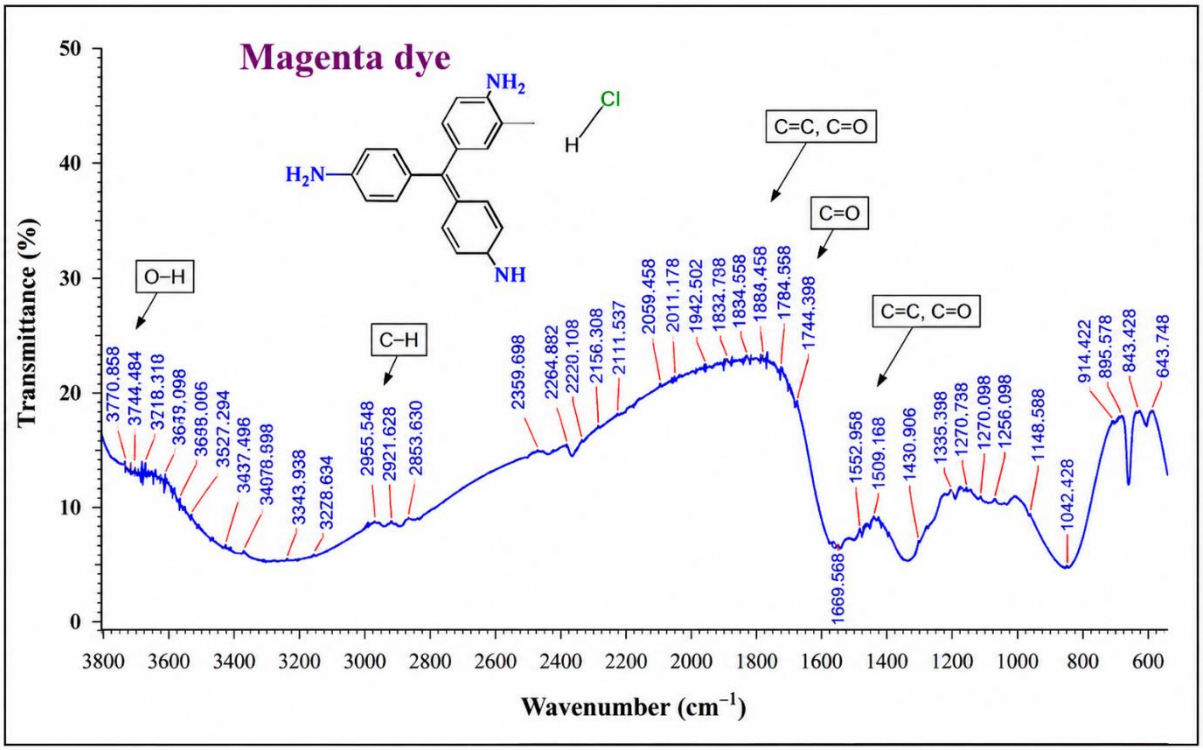

Figure 5: FTIR spectra of Magenta dye

3.4 Effect of pH, temperature, adsorbent dose and initial dye concentration

pH is an important parameter governing adsorption because it can modify both the surface characteristics of the adsorbent and the chemical state of the dye molecules. The effect of pH on dye removal was investigated over the range of approximately 4.1–7.8. The adsorption behaviour changed with pH, demonstrating that the interaction between DSLC and the dyes is sensitive to the aqueous chemical environment. At lower pH, the greater concentration of hydrogen ions can influence the protonation state of surface functional groups and consequently alter the interaction between the adsorbent and dye molecules. As the pH changes, the availability and charge characteristics of surface sites may also change, affecting the attraction or repulsion of dissolved dye species. The study observed dye adsorption up to approximately pH 7.4, indicating that DSLC retained adsorption capability over a relatively broad near-neutral pH region.

Temperature exerted a noticeable influence on dye removal. The adsorption efficiency increased with increasing temperature within the investigated experimental range. The reported removal efficiency for the two dyes increased from approximately 64.3% to 86.1% between 310 and 330 K. The increase in dye removal with temperature suggests that elevated temperature favoured the overall dye-removal process under these experimental conditions. Temperature can influence diffusion of dye molecules through the aqueous boundary layer and into the accessible pores of the carbon, as well as the equilibrium distribution of the dye between the aqueous and solid phases. Nevertheless, the thermodynamic results discussed below indicate that the temperature dependence should be interpreted together with the calculated free-energy values rather than solely from the percentage-removal trend.

The amount of adsorbent is another important operational parameter because increasing the adsorbent dose increases the number of potentially available adsorption sites. The experiments conducted using DSLC doses between approximately 0.4 and 1.2 g showed an increase in dye removal with increasing adsorbent quantity. This behaviour is expected because a greater mass of DSLC provides a larger total surface area and a greater number of accessible adsorption sites. However, adsorption capacity expressed per unit mass does not necessarily increase proportionally with adsorbent dose because, at higher doses, the available dye concentration may become insufficient to saturate all adsorption sites. Thus, optimization of adsorbent dose is

important for practical application because excessive adsorbent usage can increase treatment cost without producing a proportional increase in contaminant removal.

The initial dye concentration also affected adsorption behaviour. Both dyes exhibited rapid initial adsorption followed by a slower approach towards equilibrium. The initial increase in adsorption can be attributed to the availability of a large number of vacant adsorption sites and a strong concentration gradient between the aqueous dye solution and DSLC surface. With increasing dye concentration, the driving force for mass transfer becomes greater; however, progressive occupation of the available sites eventually leads to saturation behaviour. The observed concentration dependence therefore reflects the balance between the driving force for adsorption and the finite availability of adsorption sites on the carbon surface.

3.5 Thermodynamic behaviour of dye adsorption

Adsorption temperature dependence data was used for the evaluation of the thermodynamic properties of the adsorption process. The calculated thermodynamic parameters give clues to the energetic feasibility and dependence of the adsorption process with temperature. The calculated enthalpy change for Congo Red was found to be −14.7286 kJ mol−1 and the entropy change was found to be −53.2 J mol−1 K−1. The enthalpy and entropy changes for Magenta were found to be −11.8467 kJ mol^{-1} and −41.7 J mol^{-1} K^{-1} respectively. The negative enthalpy change values also suggest that the overall adsorption process is exothermic as per the thermodynamic analysis reported, and the negative entropy change value suggests that the degree of freedom of the dye molecules decreases due to adsorption on the surface of the DSLC.

The Gibbs free-energy values also exhibited temperature-dependent behaviour, as reported. In the same manner, at lower investigated temperatures, −3.5874 and −2.9618 kJ mol−1, respectively, for Congo Red and Magenta, the adsorption was thermodynamically favourable, but at higher investigated temperatures, the values were positive. The temperature-dependent behaviour should be taken into account with the experimental temperature-removal results, giving a clue that the efficiency of adsorption and thermodynamic spontaneity do not necessarily have to correspond to each other at all experimental conditions.

Conclusion

Leaves of Datura stramonium collected from Gaya region were found to be effective source for activated carbon which showed good adsorption capacity to remove Congo Red (CR) and Magenta (MG) from water solution. The adsorption behaviour was well described by both Freundlich and Langmuir models and the pseudo-second-order model gave the best description of the adsorption kinetics. Various factors such as pH, temperature, adsorbent dose and initial dye concentration affected the adsorption performance. Comparative analysis revealed that Magenta was slightly more balance adsorbed than Congo Red. In general, the study emphasized that the use of Datura stramonium leaf based activated carbon is a low-cost and possible sustainable adsorbent to remove the organic dye in wastewater treatment.

References:

[1] A.M. Osman, S.A.M. Metwally, Preparation and application of some new sulphur dyes, Journal of Applied Chemistry and Biotechnology 24 (1974) 181. https://doi.org/10.1002/jctb.2720240402
[2] V.J.P. Poots, G. McKay, J.J. Healy, The removal of acid dye from effluent using natural adsorbents—I peat, Water Research 10 (1976) 1061. https://doi.org/10.1016/0043-1354(76)90036-1
[3] K.K.H. Choy, G. McKay, J.F. Porter, Sorption of acid dyes from effluents using activated carbon, Resources, Conservation and Recycling 27 (1999) 57. https://doi.org/10.1016/s0921-3449(98)00085-8
[4] T. Robinson, G. McMullan, R. Marchant, P. Nigam, Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative, Bioresource Technology 77 (2001) 247. https://doi.org/10.1016/s0960-8524(00)00080-8
[5] S. Karcher, A. Kornmüller, M. Jekel, Anion exchange resins for removal of reactive dyes from textile wastewaters, Water Research 36 (2002) 4717. https://doi.org/10.1016/s0043-1354(02)00195-1

[6] V.K. Gupta, Suhas, Application of low-cost adsorbents for dye removal – A review, Journal of Environmental Management 90 (2009) 2313. https://doi.org/10.1016/j.jenvman.2008.11.017
[7] C.A. Martínez-Huitle, E. Brillas, Decontamination of wastewaters containing synthetic organic dyes by electrochemical methods: A general review, Applied Catalysis B: Environmental 87 (2009) 105. https://doi.org/10.1016/j.apcatb.2008.09.017
[8] M.F. Abid, M.A. Zablouk, A.M. Abid-Alameer, Experimental study of dye removal from industrial wastewater by membrane technologies of reverse osmosis and nanofiltration, Iranian Journal of Environmental Health Science & Engineering 9 (2012). https://doi.org/10.1186/1735-2746-9-17
[9] B. Lellis, C.Z. Fávaro-Polonio, J.A. Pamphile, J.C. Polonio, Effects of textile dyes on health and the environment and bioremediation potential of living organisms, Biotechnology Research and Innovation 3 (2019) 275. https://doi.org/10.1016/j.biori.2019.09.001
[10] A. Baban, A. Yediler, N.K. Ciliz, Integrated Water Management and CP Implementation for Wool and Textile Blend Processes, CLEAN – Soil, Air, Water 38 (2010) 84. https://doi.org/10.1002/clen.200900102
[11] N. Abdel-Raouf, A.A. Al-Homaidan, I.B.M. Ibraheem, Microalgae and wastewater treatment, Saudi Journal of Biological Sciences 19 (2012) 257. https://doi.org/10.1016/j.sjbs.2012.04.005
[12] A.K. Verma, R.R. Dash, P. Bhunia, A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters, Journal of Environmental Management 93 (2012) 154. https://doi.org/10.1016/j.jenvman.2011.09.012
[13] M. Shaban, M.R. Abukhadra, S.S. Ibrahim, M.G. Shahien, Photocatalytic degradation and photo-Fenton oxidation of Congo red dye pollutants in water using natural chromite—response surface optimization, Applied Water Science 7 (2017) 4743. https://doi.org/10.1007/s13201-017-0637-y
[14] G.L. Stephens, J.M. Slingo, E. Rignot, J.T. Reager, M.Z. Hakuba, P.J. Durack, J. Worden, R. Rocca, Earth's water reservoirs in a changing climate, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 476 (2020). https://doi.org/10.1098/rspa.2019.0458
[15] M.R. Mostafa, Adsorption of Mercury, Lead and Cadmium Ions on Modified Activated Carbons, Adsorption Science & Technology 15 (1997) 551. https://doi.org/10.1177/026361749701500801
[16] A.S. Özcan, B. Erdem, A. Özcan, Adsorption of Acid Blue 193 from aqueous solutions onto Na–bentonite and DTMA–bentonite, Journal of Colloid and Interface Science 280 (2004) 44. https://doi.org/10.1016/j.jcis.2004.07.035
[17] C. Namasivayam, S. Sumithra, Removal of direct red 12B and methylene blue from water by adsorption onto Fe (III)/Cr (III) hydroxide, an industrial solid waste, Journal of Environmental Management 74 (2005) 207. https://doi.org/10.1016/j.jenvman.2004.08.016
[18] Ö. Gerçel, A. Özcan, A.S. Özcan, H.F. Gerçel, Preparation of activated carbon from a renewable bio-plant of Euphorbia rigida by H2SO4 activation and its adsorption behavior in aqueous solutions, Applied Surface Science 253 (2007) 4843. https://doi.org/10.1016/j.apsusc.2006.10.053
[19] M.J. Iqbal, M.N. Ashiq, Adsorption of dyes from aqueous solutions on activated charcoal, Journal of Hazardous Materials 139 (2007) 57. https://doi.org/10.1016/j.jhazmat.2006.06.007
[20] K.Y. Foo, B.H. Hameed, Insights into the modeling of adsorption isotherm systems, Chemical Engineering Journal 156 (2010) 2. https://doi.org/10.1016/j.cej.2009.09.013
[21] Z. Carmen, S. Daniel, Organic Pollutants Ten Years After the Stockholm Convention - Environmental and Analytical Update, InTech, 2012.
[22] M. Ismail, K. Akhtar, M.I. Khan, T. Kamal, M.A. Khan, A. M. Asiri, J. Seo, S.B. Khan, Pollution, Toxicity and Carcinogenicity of Organic Dyes and their Catalytic Bio-Remediation, Current Pharmaceutical Design 25 (2019) 3645. https://doi.org/10.2174/1381612825666191021142026