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Assessment and Enhancement of Powdered and Activated Carbon Derived from Persea Nuts for Adsorptive Removal Dyes from Wastewaters

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ABSTRACT

Powdered and activated carbon prepared from persea nuts are used as economical adsorbents for the rapid removal and fast adsorption of Basic Blue 9 dye from the aqueous solutions. The adsorption behaviors of dye onto powdered and activated carbon adsorbents were studied in batch experiments as a function of contact time, pH value, initial dye concentration and temperature. Adsorption data fitted better using the Langmuir isotherm, and the calculated maximum adsorption capacities were (79.36 mg/g) for activated carbon adsorbent and of (44.44 mg/g) for powdered adsorbent. The kinetic data were better described by pseudo-second order kinetic model. The analysis of the thermodynamic parameter, positive values of enthalpy energy indicated that the adsorption process of Basic Blue 9 (0.94 k.J/mol for powdered adsorbent and was of 9.34 k.J/mol using activated carbon adsorbent) onto both adsorbents was endothermic. The positive values of ΔS^0 of (15.95 kJ/mol K for powdered adsorbent) and (66.43 kJ/mol K for activated carbon adsorbent) shows the increased disorder and randomness at the solid solution interface of BB9 with adsorbents. These results indicated that activated carbon prepared from persea species exhibited good adsorption ability and can be used as an attractive adsorbent for the removal of cationic dyes, especially Basic Blue 9.

Keywords: Adsorptive removal, Powdered, Activated carbon, Persea nuts, Cationic dye

INTRODUCTION

The pollution caused by chemical releases begets a considerable problem for the environment and for human health specially [1]. Industrial chemical releases origin may be metal, organic or inorganic chemicals in nature. Among these chemical pollutants, industrial dyes are rejected of considerable importance in aquatic environments. Several adverse effects have been elucidated in the contamination with these dyes in different sectors of water [2]. Several research groups around the world have focused for developing some industrial waste treatment to conserve the environment. It is recognized that the disposal of industrial dyes is carried out by several techniques. Among these which include; coagulation, ozonation, membrane process and ozonation [3-5].

Adsorption is the most used method and the most effective for removing industrials dyes contained in aqueous solutions. The challenge for researchers in the worldwide is to try and choose a set of materials able to have interesting properties that may eliminate industrial dyes. Once the activated carbon adsorbent was most used for the removal of industrial dyes from aqueous solutions, but this was expensive. Several promising attempts have been made in order to use materials of different origins with interesting properties to remove dyes from wastewaters. Herein, we will mention a few examples of adsorbents that have demonstrated significant adsorption capacity. Thus, Sewage sludges [6], Pineapple [7], malt bagasse [8], pistachio [9], oil shale [10]. In our laboratory, we have already carried out the removal of dyes by use of calcined bones [11], calcined mussels shells [12] and calcined eggshells [13].

Therefore, the demand for activated carbon is continuously increasing day after day. In this case, the production of activated carbons was occurred by physical activation and chemical activation. Chemical activation has been object of significant research in the recent years, as it offers several advantages compared to the so-called physical activation. Thus, at lower temperatures the activation offers high yield and very high surface area. The chemical activation has been achieved by chemical alkali (KOH, K_2CO_3, NaOH and Na_2CO_3), alkali earth metal salts ($AlCl_3$ and $ZnCl_2$) and some inorganic acids (H_3PO_4 and H_2SO_4) [14].

In this work, we have prepared a powder from persea nuts (P-PAN) and activated carbon by carbonization and chemical activation with phosphoric acid (C-PAN). Effective parameters (adsorbent dosage, dye concentration, contact time, pH and temperature), kinetics, and isotherm studies were investigated to evaluate the adsorption capacity of these adsorbents of dyes. Pseudo-first order kinetics and pseudo-second order kinetics models were attempted. The Langmuir, Freundlich and Temkin isotherms were used to fit the equilibrium data. A thermodynamic study proves necessary to complete the understanding of the adsorption on the surface of adsorbents.

MATERIALS AND METHODS

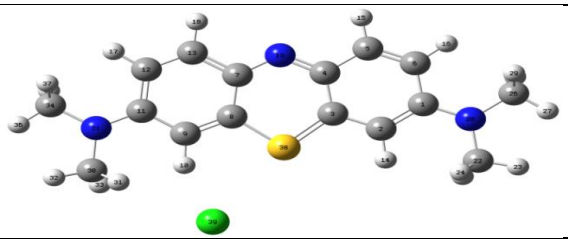
Preparation of the biosorbents based of persea species

The Persea nuts were first washed with water to remove impurities, dried at 105°C for 24 h, crushed and sieved. These later were dubbed the names Powdered Persea Nuts (P-PAN). The activation of P-PAN was carried out using an appropriate weight and 25 ml of concentrated phosphoric acid and completed by carbonization at temperature 500°C for 2 h producing a black carbonaceous residue. The activated carbon was repeatedly washed with distilled water until the pH of the washing solution reached (6-6.5). The product was dried at 105°C for 2 h, takes a name of Persea Americana Nuts Carbon (C-PAN) and kept in tightly closed plastic container for further use. The characterization of adsorbents was achieved by FT-IR spectroscopy and Scanning Electronic Microscopy (SEM) images obtained with HITACHI-S4100 equipment operated at 20 kV.

Preparation of different dyes solutions

The Basic Blue 9 dye (BB9) is a cationic dye and was purchased from Sigma-Aldrich. Its chemical structure and some data are given in Table 1. The stock of dye solution was prepared by dissolving the requisite amount of analytical grade dye without any further purification in 1000 ml of distilled water. Experimental solutions of the desired concentrations were prepared by successive dilutions.

Table 1: Some data of Basic Blue 9 dye

Usuel name	Basic Blue 9
Chemical structure	
CI Number	42015
Molecular weight (g/mol)	319.86
λ_{max} (nm)	663

Determination of pH zero point charge

The value of pH_{ZPC} is the point where the curve of ΔpH (pH_f–pH_i) versus pH_i crosses the line equal to zero. Measured pH was down by pH-Metre Basic 20+ model pH-meter. The pH zero point charge (pH_{ZPC}) of P-PAN and C-PAN adsorbents was measured using the pH drift method as described in the reference [15].

Adsorption studies and analytical method

Batch adsorption of Basic Blue 9 onto the two adsorbents (P-PAN and C-PAN) was investigated in aqueous solutions under various operating conditions such as amount of adsorbent (10 mg–25 mg), initial dye concentration (10-40 mg/l), pH 2-12 and temperature 298-328 K.

Adsorption studies were carried out by shaking 25 mg of each adsorbent to gather with 50 ml of dye solution of known concentration and pH in a 100 ml Erlenmeyer flask. The flask was then shaken in an incubator shaker at a specific temperature. At the end of the equilibrium period the solutions were centrifuged and the residual concentration of BB9 was measured by UV/Visible spectrophotometer at wavelength of 663 nm. The amount of equilibrium adsorption q_e (mg/g) was calculated using the formula:

$$q_e = \frac{C_0 - C_e}{W} V \qquad (1)$$

Where C_e (mg/l) is the liquid concentration of dye at equilibrium, C_0 (mg/l) is the initial concentration of the dye in solution. V is the volume of the solution (L) and W is the mass of dye biosorbents (g). The dye removal percentage (%) can be calculated as follows:

$$\text{Re}moval \cdot dye.(\%) = \frac{C_0 - C_e}{C_0} x100 \qquad (2)$$

Where, C_0 is the initial dye concentration and C_e (mg/l) is the concentrations of dye at equilibrium.

RESULTS AND DISCUSSION

Characterization of P-PAN and C-PAN adsorbents

The surface functional groups of both adsorbents (P-PAN and C-PAN) give information of adsorption and bond nature, number of peaks and indicating the complex nature of the adsorbents [16]. Figure 1 shows the IR spectrum of both adsorbents (P-PAN and C-PAN).

The IR spectrum of C-PAN material reveals a few peaks found at frequencies: 876, 1074, 1149, 1563, 2916 and 3415 cm^{-1}. The absorption band at 3415 cm^{-1} is attributed to the hydroxyl groups (O-H) vibration [17]. The bands at 2916 cm^{-1}, 1563 cm^{-1} and 1381 cm^{-1} correspond respectively to unsymmetrical aliphatic C–H stretching, C=C stretching of aromatic rings and aromatic C=C stretching vibration. Band at 1149 cm^{-1} is ascribed to C-O stretching in alcohol or ether or hydroxyl group [18,19].

We note in IR spectrum of P-PAN material, a band at 3392 cm^{-1} attributed to (O-H) groups. The bands at 2923 cm^{-1} and 2847 cm^{-1} are due to asymmetric stretching vibration of CH_2 and the symmetric stretching vibration of $-CH_3$, respectively, of aliphatic acids. The band around 1635 cm^{-1} is due to the C=C stretching that can be attributed to the aromatic C-C bond, while bands at 1021 and 1454 cm^{-1} are due respectively to C-O-C, P-O or P-OH stretching. Figure 2 depicts SEM images of C-PAN and P-PAN adsorbents.

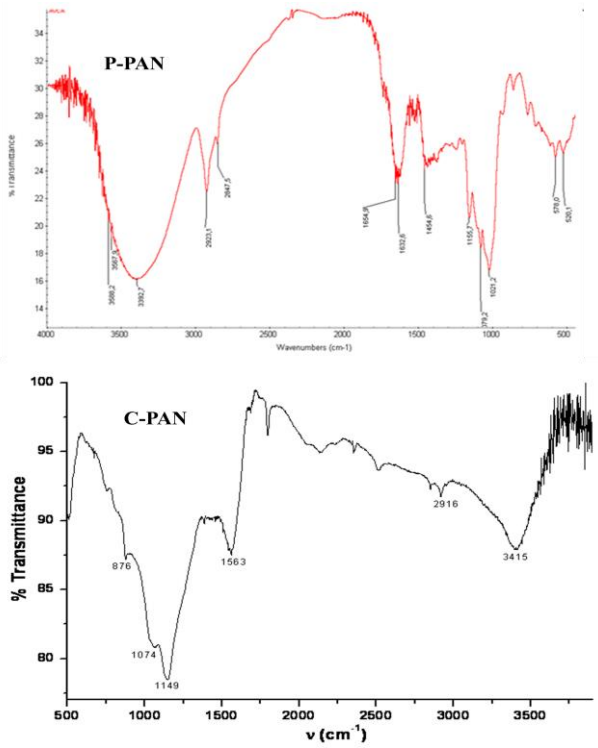


Figure 1: FT-IR spectrum of P-PAN and C-PAN adsorbents

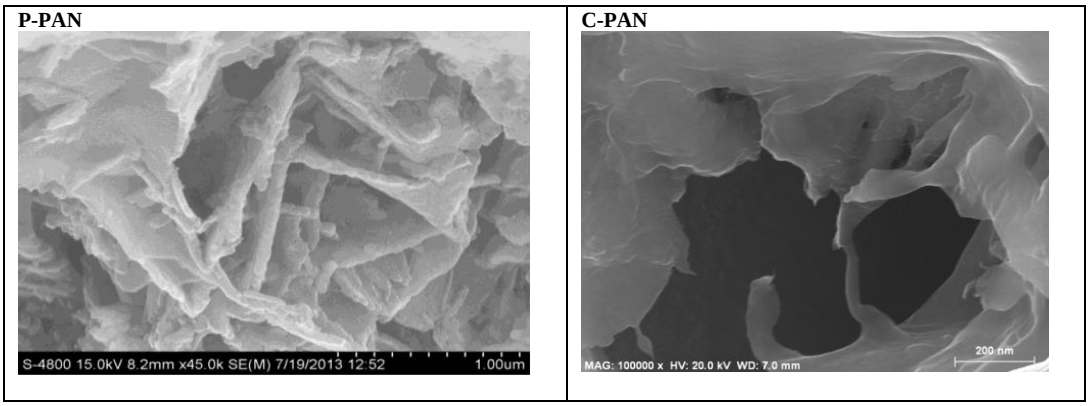
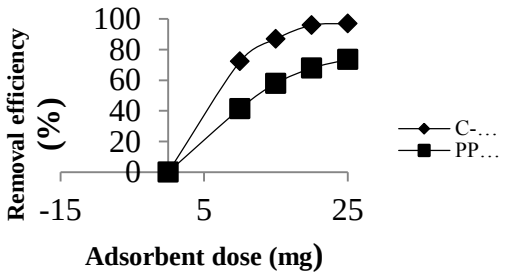


Figure 2: SEM images of C-PAN and P-PAN adsorbents



Experimental conditions: C_0=20 mg/l; V=50 ml, pH 6, ambient temperature and at equilibrium time

Figure 3: Effect of P-PAN and C-PAN adsorbent amount on the removal % of Basic Blue 9

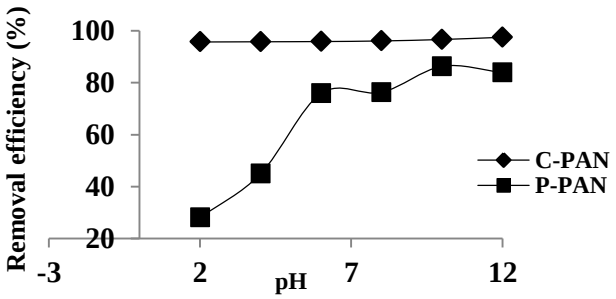
Effect of adsorbent dosage on the removal efficiency

Figure 3 depicts the effect of adsorbent dose on the % removal of BB9 onto P-PAN and C-PAN adsorbents shown at an initial dye concentration of 20 mg/l. The % removal was observed to increase as the adsorbents dose was increased from 10 to 25 mg.

At a low dose of 10 mg P-PAN and C-PAN, there is tight competition between the BB9 molecules of dye due to the limited number of available binding sites; hence a low % removal was attained. An increase in adsorbent dose of P-PAN and C-PAN would cause a corresponding increase in % removal due to more adsorption sites that are available for BB9 uptake. As can be seen in Figure 3, removal % of BB9 onto P-PAN increased from 41-97% with a variation of adsorbent dose from 10-25 mg. Therefore, removal % of BB9 onto C-PAN increased from 72-97% when the amount of adsorbent varied from 10-25 mg. Luna et al. have described the same results for studying the removal of EBT onto waste rice hulls [20]. The removal % increases from 73-97% when going from P-PAN to C-PAN adsorbent, indicating a great adsorptive character of C-PAN in comparison with P-PAN.

Effect of initial pH for the removal efficiency of Basic Blue 9

It is already recognized in many studies that pH of the adsorbate solution is one of the contributory factors affecting adsorption of dye on adsorbent. Dyes have different optimum pH depending on the type of adsorbent under investigation. Because of this assertion, pH dependence studies of BB9 dye removal from aqueous solution (400 mg/l) using P-PAN and C-PAN were carried out in the pH range of 2 and 12 (Figure 4). The percentage of BB9 dye removal increased from 25% (pH 2.0) to 84% (pH 12) for P-PAN. No similar pattern was observed for C-PAN, removal % (97%) is constant for all studied range pH. To explain this behavior, we determine the pH_{ZPC} values of P-PAN and C-PAN and are 5 and 1.5, respectively (Figure not shown). The pH_{ZPC} of P-PAN indicated that the surface of the adsorbent positively charged at pH less than 5 and negatively charge at pH values above 5. At this pH, a significantly high electrostatic attraction phenomenon exists between positively charged cationic dye and the negatively charged surface of adsorbent resulting a higher uptake of BB9. For C-PAN there is a low pH_{ZPC} indicating a negative charge density at all range of studied pH and very high adsorption efficiency.



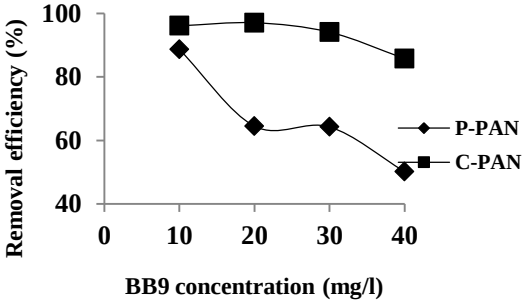
Experimental conditions: C_0=20 mg/l, W=25 mg, V=50 ml, equilibrium time and ambient temperature

Figure 4: Effect of pH on the removal % of Basic Blue 9 onto P-PAN and C-PAN

The percentage of BB9 dye removal increased from 25% (pH 2.0) to 84% (pH 12) for P-PAN. No similar pattern was observed for C-PAN, removal % (97%) is constant for all studied range pH. To explain this behavior, we determine the pH_{ZPC} values of P-PAN and C-PAN and are 5 and 1.5, respectively (Figure not shown). The pH_{ZPC} of P-PAN indicated that the surface of the adsorbent positively charged at pH less than 5 and negatively charge at pH values above 5. At this pH, a significantly high electrostatic attraction phenomenon exists between positively charged cationic dye and the negatively charged surface of adsorbent resulting a higher uptake of BB9. For C-PAN there is a low pH_{ZPC} indicating a negative charge density at all range of studied pH and very high adsorption efficiency.

Effect of initial Basic Blue 9 concentration for the removal efficiency

Experiments were under taken to study the effect of varying initial concentration of dye ranged from (10-40 mg/l) at ambient temperature on BB9 removal by adsorption onto P-PAN and C-PAN with different intervals times. Figure 5, depicts these results. For the both adsorbents it was observed that the removal efficiency % of BB9 is decreased with the increase of initial dye concentration.



Experimental conditions: Adsorbent dose: 25 mg, V=50 ml and ambient temperature

Figure 5: Effect of Basic Blue 9 concentrations on the removal efficiency (%)

For BB9 adsorption using P-PAN, the percentage of colour removal decreased from 88.7-50.16% as the BB9 concentration increase from 10 mg/l to 40 mg/l. Similar trend was found using C-PAN adsorbent, where the percentage of BB9 removal decreased from 96.1-85.77% as dye concentration was increased from 10-40 mg/l. It is because of the fact at higher concentration, the ratio of the initial number of dye molecules to the available surface area is high subsequently the fractional biosorption becomes dependent of initial concentration. However, at lower concentration the available sites of biosorption becomes fewer and hence the removal dye dependents upon concentration.

Kinetic study

In order to investigate the adsorption process of BB9 onto P-PAN and C-PAN adsorbents, Lagergren pseudo first-order model was used for describing the transfer behavior [21]. The pseudo-first-order equation (linearized form) can be written as:

$$\log(q_e - q_t) = \log(q_e) - \frac{k_1}{2.303}t \qquad (3)$$

Where, q_e is the amount of dye adsorbed at equilibrium (mg/g), q_t is the amount of dye adsorbed at time t (mg/g), k_1 is the first-order rate constant (min^{-1}) and *t* is time (min). Pseudo-second-order equation based on equilibrium adsorption [22] can be expressed as:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e}t \qquad (4)$$

Where, k_2 is the pseudo-second-order rate constant (g/mg/min).

Table 2, shows the comparison of adsorption kinetic data for pseudo-first order and pseudo-second order models with different initial BB9 concentration at different times. Both k_1 and k_2 values can be obtained from the slopes of the plots log (q_e–q_t) versus *t* (pseudo-first order) and a plot of t/q_t versus *t* (pseudo-second order), respectively. Figure 6 shows the pseudo-second plot for Basic Blue 9 removal onto P-PAN and C-PAN adsorbents. The adsorption capacity at calculated time t, $q_{t,cal}$ from both models are compared with the experimental values $q_{t,exp}$.

Table 2: Kinetic data for Basic Blue 9 removal onto P-PAN and C-PAN adsorbents

	C_0 of BB9 (mg/l)	Pseudo-first-order				Pseudo-second-order		
		$q_{e,exp}$	$q_{e,cal}$	k_1	R^2	$q_{e,cal}$	k_2	R^2
P-PAN	10	17.74	7.1	0.084	0.935	18.05	0.014	0.999
	20	29.43	13.45	0.066	0.924	29.94	0.017	0.998
	30	38.55	21.53	0.075	0.966	39.68	0.010	0.998
	40	40.12	23.02	0.110	0.940	40.98	0.018	0.999
C-PAN	10	19.22	3.81	0.123	0.892	19.30	0.173	1.000
	20	38.83	18.22	0.113	0.938	39.52	0.024	0.999
	30	56.47	41.06	0.089	0.947	58.82	0.006	0.997
	40	68.62	54.2	0.065	0.984	72.99	0.002	0.991

The results show that the pseudo-second order model fits the experimental data better for both biosorbent P-PAN and C-PAN with higher regression coefficients R^2 values compared to those of pseudo-first order kinetic models. The second-order rate constant values show that the adsorption system is a pseudo-second order model as the values of $q_{t,exp}$ and $q_{t,cal}$ are very close from the initial stage of the adsorption process until the final stage. Therefore, the pseudo second-order kinetics model is more appropriate to describe the adsorption behavior of Basic Blue 9 on both P-PAN and C-PAN adsorbents.

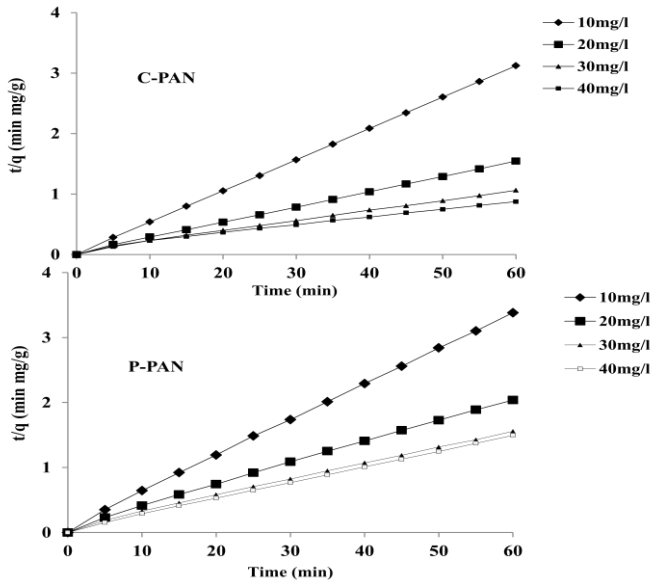


Figure 6: Plot of kinetic data for the adsorption of BB9 onto P-PAN and C-PAN adsorbents

Adsorption isotherm

The adsorption isotherm gives the relationship between mass of adsorbate adsorbed per unit weight of adsorbent in equilibrium and liquid-phase equilibrium concentration of the adsorbate. It is a basic requirement for the design of adsorption system. Adsorption data were analyzed with three adsorption isotherm models, namely Langmuir, Freundlich and Temkin isotherms.

Langmuir adsorption model is based on the assumption that maximum adsorption takes place at specific homogeneous sites within the adsorbent. The linear form of Langmuir isotherm [23] equation is given as:

$$\frac{C_e}{q_e} = \frac{1}{Q_0 K_L} + \frac{1}{Q_0} C_e \qquad (5)$$

Where, C_e (mg/l) is the equilibrium concentration of the BB9, q_e (mg/g) is the amount of dye adsorbed par unit mass of adsorbent. Q_0 (mg/g) and K_L (L/mg) are Langmuir constants related to adsorption capacity and rate of adsorption, respectively.

The linear plot of C_e/q_e versus C_e suggests the applicability of the Langmuir model for the present system. The essential characteristics of the Langmuir isotherm can be expressed in terms of separation factor R_L, a dimensionless constant:

$$R_L = \frac{1}{1 + K_L C_0} \qquad (6)$$

Where C_0 is the initial dye concentration. The R_L value implies whether the adsorption is: Unfavorable: R_L >, Linear: R_L=1, Favorable: 0 < R_L < 1, Irreversible: R_L=0,

It was observed that all the R_L values obtained were between 0 and 1, showing that the adsorption of BB9 onto both P-PAN and C- PAN adsorbents was favorable.

Freundlich model is an empirical equation that assumes heterogeneous adsorption due to the diversity of adsorption sites. The linearized Freundlich equation [24] is given as:

$$\log(q_e) = \log(K_f) + \frac{1}{n} \log(C_e) \qquad (7)$$

Where K_f and n are Freundlich constants related to adsorption capacity and adsorption intensity respectively.
In general, n > 1: illustrates that adsorbate is favorably adsorbed on the adsorbent. Whereas, n < 1: demonstrates the adsorption process is chemical in nature.

The plot of log (q_e) versus log (C_e) gave a straight line with slope of 1/n and intercept of log (K_f). In this study, the values found for n were inferior to 1, which prove that the adsorption is favorable and process is chemical in nature. The Freundlich isotherm was studied under the same condition as the Langmuir isotherm. The values of K_f and n are listed in Table 3. Both the values are calculated from the intercept and slope of the plot of Ln (q_e) versus Ln (C_e). The values of n are more than 1 indicating favorable adsorption condition.

The Temkin isotherm model postulates the following: (i) the heat of adsorption of the surface molecules decreases linearly rather than logarithmically with coverage; (ii) the adsorption process is characterized by a uniform distribution of binding energies at the adsorbent surface; and (iii) this model covers the adsorbate-adsorbent interaction. The linear form of Temkin model [25] is given by Equation:

$$q_e = \frac{RT}{b_T} Ln(a_T) + \frac{RT}{b_T} Ln(C_e) \qquad (8)$$

Where b_T is the Temkin constant related to heat of adsorption (J/mg) and a_T the Temkin isotherm constant (L/g). R (8.314 k.J/mol) is the universal gas constant and T (K) is the absolute solution temperature. A plot of q_e versus *Ln* (C_e) is used to determine the constants a_T and b_T. Table 3 summarizes all the constants and correlation coefficients R^2 values obtained from the three models applied for the adsorption of BB9 onto the both P-PAN and C-PAN adsorbents.

Table 3: Isotherm constants for the adsorption of Basic blue 9 onto P-PAN and C-PAN adsorbents

	Langmuir			Freundlich			Temkin		
Adsorbent	**q_{max} (mg/g)**	**R_L**	**R^2**	**K_f**	**n**	**R^2**	**b_T**	**K_T**	**R^2**
P-PAN	44.44	0.099	0.991	17.26	3.32	0.972	08.17	07.49	0.959
C-PAN	79.36	0.041	0.989	37.88	2.40	0.806	17.09	11.88	0.922

The Langmuir isotherm shows a very high regression coefficient for both adsorbents which indicating a monolayer and homogeneous adsorption. Freundlich and Temkin model are failed to explain the adsorption isotherm compared to other isotherm (Langmuir) due to its poor fit for the experimental data.

Thermodynamic study

Thermodynamic parameters are crucial for determining the spontaneity of an adsorption process. These parameters were estimated to check the temperature effect on the adsorption capacity of BB9 dye onto both P-PAN and C-PAN adsorbents. The distribution coefficient K_d was calculated from the following equation:

$$K_d = \frac{q_e}{C_e} \qquad (9)$$

Where, q_e is the solid phase concentration (mg/g), and C_e is the liquid phase concentration (mg/l) at equilibrium. Changes in the standard enthalpy, ΔH^0 (k.J/mol) and entropy ΔS^0 (k.J/mol) were calculated from the Van't Hoff plot form the following equation:

$$Ln(K_d) = \frac{\Delta S^0}{R} + \frac{\Delta H^0}{RT} \qquad (10)$$

T is the temperature expressed in Kelvin and R (8.314 J.mol/K) is the universal gas constant. The values of ΔH^0 and ΔS^0 were obtained from the slope and intercept of Van't Hoff plots. The obtained parameters are listed presented in Table 4. The positive value of ΔH^0 was found to be (0.94 k.J/mol) for P-PAN and was of (9.34 k.J/mol) using C-PAN. These results show that the adsorption was endothermic in nature. The positive values of ΔS^0 of (15.95 k.J/mol K for P-PAN) and (66.43 k.J/mol K for C-PAN) shows the increased disorder and randomness at the solid solution interface of BB9 with adsorbents that bring about some structural changes in the dye and the both adsorbents. The ΔG^0 (Gibbs free energy change, k.J/mol) values were obtained from Equation:

$$\Delta G^0 = \Delta H^0 - T\Delta S^0 \qquad (11)$$

Table 4: Thermodynamic data for the adsorption of Basic Blue 9 using P-PAN and C-PAN adsorbents

Adsorbent	Temperature (K)	ΔG^0 (k.J/mol)	ΔH^0 (k.J/mol)	ΔS^0 (k.J/mol K)
P-PAN	298	- 3.813	0.94	15.95
	308	- 3.972		
	318	- 4.132		
	328	- 4.292		
C-PAN	298	- 10.45	9.34	66.43
	308	- 11.12		
	318	- 11.78		
	328	- 21.78		

As can be seen in Table 4, all calculated values of ΔG^0 were negatives when using P-PAN or C-PAN. The value of ΔG^0 decreases from (-3.813 k.J/mol) to (-4.292 k.J/mol) for P-PAN and from (-10.45 k.J/mol) to (- 21.78 k.J/mol) for C-PAN when the temperature increases from 298 K-328 K showing that the adsorption process of BB9 dye molecules onto P-PAN and C-PAN becomes more favorable at higher temperatures. All these attempts confirm the spontaneity and feasibility for the adsorption of BB9 onto P-PAN and C-PAN adsorbents. Finally, the values of ΔG^0 obtained with C-PAN are lower than obtained with P-PAN suggested that the adsorption of BB9 onto C-PAN was better than P-PAN.

Generally, the magnitude of ΔH^0 changes for absolute physical adsorption was less than (20 k.J/mol), while chemisorption was in the range of (20-200 k.J/mol) [26-28]. For our study, the adsorption of BB9 onto P-PAN and C-PAN adsorbents were absolute physical adsorption in nature.

Reusability of P-PAN and C-PAN adsorbents

The stability and regeneration ability of the used prepared adsorbents P-PAN and C-PAN during the adsorption process are essential to its practical application. Interestingly, to achieve the potential and applicability of adsorbents, we have examined and studied the variation of adsorption efficiency % versus cycle number. As depicted in Figure 7, the removal % decreases for each new cycle after regeneration. The yield of removal of BB9 dye decreases of from 75.25-5% for P-PAN and from 97-23% for C-PAN after five cycles. Therefore, C-PAN shows excellent adsorption performance and regeneration due to the high surface area to the activated carbon.

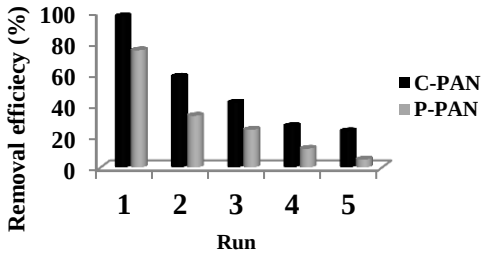


Figure 7: Reusability of adsorbents: Experimental conditions: C_0=20 mg/l, V=50 ml, ambient temperature and at equilibrium time

CONCLUSION

The investigations showed a comparison between two adsorbents derived from persea species powdered and activated carbon abbreviated as P-PAN and C-PAN respectively to remove a cationic dye Basic Blue 9 from aqueous solutions.

The experimental data produced perfect fit with Langmuir isotherm for both the adsorbents, this suggest the monolayer coverage of Basic Blue 9 with adsorption capacity was (79.36 mg/g) and (44.44 mg/g) for C-PAN and P-PAN respectively. The kinetics data for the adsorption of BB9 dye onto the both adsorbents follows a second order model.

The thermodynamic study reveals that the adsorption of BB9 dye on the adsorbents surface (C-PAN and P-PAN) was endothermic, spontaneous and was in absolute physical adsorption. After five cycles, C-PAN shows a good performance in comparison with P-PAN indicating the applicability of activated carbon to be used several times for dyes adsorption efficiency.

REFERENCES

[1] F.H. Fernandesa, E.B. Obregonb, D.M.F. Salvadori, *Reprod. Toxicol*., **2015**, 53, 75-81.
[2] A.V. Patil, J.P. Jadhav, *Chemosphere.*, **2013**, 92, 225-232.
[3] Y.M. Slokar, A.M.L. Marechal, *Dyes. Pigments.*, **1998**, 37, 335-356.
[4] E.G. Solozhenko, N.M. Soboleva, V.V. Goncharuk, *Water Res*., **1995**, 29, 2206-2210.
[5] F.I. Hai, K. Yamamoto, F. Nakajima, K. Fukushi, L.D. Nghiem, W.E. Price, B. Jin, *Bioresour. Technol*., **2013**, 141, 29-34.
[6] E. Kacan, *J. Environ. Manag*., **2016**, 166, 116-123.
[7] S.L. Chan, Y.P. Tan, A.H. Abdullah, S.T. Ong, *J. Taiwan Inst. Chem. Eng*., **2016**, 61, 306-315.
[8] K.B. Ontana, E.S. Chaves, J.D.S. Sanchez, E.R.L.R. Watanabe, J.M.T.A. Pietrobelli, G.G. Lenzi, *Ecotoxicol. Environ. Saf*., **2016**, 124, 329-336.
[9] F. Deniz, R.A. Kepekci, *J. Mol. Liq*., **2016**, 219, 194-200.
[10] E.T. Acar, S. Ortaboy, G. Atun, *Chem. Eng. J*., **2015**, 276, 340-348.
[11] R. Slimani, A. Anouzla, Y. Abrouki, S. El Antri, R. Mamouni, S. Lazar, M. El Haddad, *J. Mater. Environ. Sci*., **2011**, 2, 77-87.
[12] M. El Haddad, A. Regti, R. Laamari, R. Slimani, R. Mamouni, S. El Antri, S. Lazar, *J. Taiwan Inst. Chem. Eng*., **2014**, 45, 533-540.
[13] R. Slimani, I. El Ouahabi, M. El Haddad, A. Regti, R. Laamari, S. El Antri, S. Lazar, *J. Taiwan Inst. Chem. Eng*., **2014**, 45, 1578-1587.
[14] H. Saygılı, F. Güzel, Y. Onal, *J. Clean. Prod*., **2015**, 93 84-93.
[15] K.Y. Foo, B.H. Hameed, *Bioresour. Technol*., **2012**, 112, 143-150.
[16] B.H. Hameed, D.K. Mahmoud, A.L. Ahmad, *J. Hazard. Mater*., **2008**, 158, 499-506.
[17] S. Liang, X. Guo, Q. Tian, *Desalination*, **2011**, 275, 212-216.
[18] J. He, Y. Ma, J. He, J. Zhao, J.C. Yu, *Appl. Cat. B. Environ*., **2002**, 39, 211-220.
[19] D.L. Pavia, G.M. Lampman, G.S. Kaiz, W.B. Saunders Company, **1987**.
[20] M.D.G. Luna, E.D. Flores, D.A.D. Genuino, C.M. Futalan, M.W. Wan, *J. Taiwan Inst. Chem. Eng*., **2013**, 44, 646-653.
[21] L. Yu, Y. Luo, *J. Environ. Chem. Eng*., **2014**, 2, 220-229.
[22] R. Ocampo-Perez, R. Leyva-Ramos, J. Mendoza-Barron, R.M. Guerrero-Coronado, *J. Colloid. Interf. Sci*., **2011**, 364, 195-204.
[23] I. Langmuir, *J. Am. Chem. Soc*., **1916**, 39, 2221-2295.
[24] M.F. Freundlich, *J. Phys. Chem*., **1906**, 57, 385-470.
[25] M.I. Tempkin, V. Pyzhev, *Acta Phys. Chem. USSR*., **1940**, 12, 327-356.
[26] X.K. Wang, C.L. Chen, W.P. Hu, A.P. Ding, D. Xu, X. Zhou, *Environ. Sci. Technol*., **2005**, 39, 2856-2860.
[27] S. Karagoz, T. Tay, S. Ucar, M. Erdem, *Bioresour. Technol*., **2008**, 99, 6214-6222.
[28] G.G. Sonai, S.M.A. Guelli, U. de Souza, D. de Oliveira, A.A. Souza, *J. Environ. Manag*., **2016**, 168, 149-156.