Mechanism of Basic Violet 3 Adsorption on Used Black Tea Leaves from Neutral Solution

Md. Tanim-al-Hasan, Md. Lokman Hossain and Mohammad Abul Hossain,Essim Noura

Abstract— Adsorption mechanism for the removal of Basic Violet 3 (BV3) from neutral solution using Used Black Tea Leaves (UBTL) was studied in batch process. The effects of initial concentration of dye, solution pH, processing temperature and the presence of electrolytes on equilibrium adsorption were evaluated. Equilibrium adsorption isotherm was analyzed using different models equations: Langmuir, Freundlich, Dubinin-Radushkevic, Temkin, Harkins-Jura and Halsey. The characteristic parameters for each isotherm were determined. The adsorption isotherm for BV3-UBTL system was well expressed by the Langmuir equation. The maximum dye adsorption capacity of UBTL from Langmuir equation was found 345.7 mg/g at 30 °C which gradually increased with the increase in temperature. The values of separation factor (R_b) were found from 0 to 1 which supports the adsorption process is favorable. From Temkin isotherm, the heat of adsorption was estimated to be 55.52 J/mol and the minimum value activation energy of adsorption (E_{ad} = 0.092 kJ/mol <8 kJ/mol) prominently proved that the adsorption of BV3 on UBTL followed a physical process. Different thermodynamic parameters, such as Gibb's free energy (ΔG^o), enthalpy (ΔH^o) and entropy ($\Delta^o S$) were evaluated. The thermodynamic parameters of BV3 adsorption suggested that the adsorption process was found to be less spontaneous. The endothermic nature of the adsorption might be due to the fragmentation of less amount of BV3 at UBTL surface.

Key words— Basic Violet 3, used black tea leaves, equilibrium adsorption, different isotherm models, activation energy, thermodynamics and mechanism.

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1 Introduction

Fresh and clean water is indispensable for human being and aquatic life. At present days, most of industries such as synthetic dyes manufacturing industries, paper and pulp, paint, plastic, petroleum, textiles industries, tanneries, food and beverage companies, coating, packaging industries are widely discharged colored wastewater in which dyes imparts highly hazardous and carcinogenic effects on aquatic life due to non-degradable properties of colored wastewater. Several biological, physical and chemical techniques have been proposed such as adsorption [1], biological treatment [2], chemical-thermal process [3], chemical oxidation [4], coagulation [5] flocculation [6], electrochemical techniques [7], membrane separation [8], ozonation [9], and photo-degradation [10] for removal of colored from waste water. Amongst all, adsorption is the best technique to remove colored from waste water of industrial effluents [11].

Basic Violet 3 (BV3), triarylmethane cationic dye is widely used in paper industries, printing and packaging industries, to classify bacteria in Gram staining, to develop fingerprints, veterinary medicine [12] and also used production of colorized products such as fertilizers, antifreezes, washing powder and leather [13]. Like other dyes, BV3 is not highly toxic, mutagenic or carcinogenic to living organisms [14]. But, from the view point of environmental safety it is needed to remove this dye from contaminated industrial effluents before it discharge into aquatic system. Recently, most of adsorption study based on liquid-solid phase interaction on surface of adsorbent materials is of great interest for focusing low cost materials with having maximum adsorption capacity. Many adsorbent materials like palm kernal fibre [15], sepiolite [16], Agriculture waste [17], pine tree leaves [18], wood shells [19] Luffa cylindrica fiber [20], sunflower seed hull [21], soy meal hull [22], hazelnut shell [23] neem sawdust [24], Guava leaf powder [25], rice husk [26] Pearl Millet Husk [27], sugarcane bagasse pith [28], rice straw [29] pumpkin seed hull [30] and coconut husk [31]. But as an adsorbent, used black tea leaves (UBTL) is highly encouraged to use due to its large amounts of availability, potentially less expensive, high adsorption capacity, simple to recover and easy degradability [32]. In the present study, the adsorptive removal of Basic Violet 3 (BV3) from industrial waste water by used black tea leaves was investigated in batch adsorption. Here the equilibrium adsorption and thermodynamic studies were performed to evaluate the efficiency of the adsorptive removal of BV3 from neutral aqueous system by UBTL under different experimental conditions such as the effect of concentration, solution pH and temperature, presence of electrolytes, etc. The main focus of this study was to evaluate the feasibility as well as potentiality of using UBTL as versatile natural adsorbent to remove BV3 dyes.

· *Dr. Mohammad Abul Hossain is currently Professor, Department of Chemistry, Dhaka University, Dhaka-1000, Bangladesh, Ph : +88-01911098529, E-mail: hossainabul@yahoo.com ; hossainabul@du.ac.bd*
· *Md. Tanim-al-Hasan and Md. Lukman Hossain completed Masters degree program in Chemistry Department. University of Dhaka, Bangladesh, Ph : +8801675269242, E-mail: tanimhassan@yahoo.com*

2 Experimental

2.1 Adsorbent

Used black tea leaves were prepared from frash tea leves. Fresh black tea leaves were collected from local market at Dhaka City in Bangladesh. About 300 g fresh black tea leaves were added to about 500 mL of distilled water and were boiled for about 8 hours. Boiled tea leaves were washed in several times by hot distilled water followed by cold distilled water until the tea color was completely removed. The colorless solid was dried in an oven at 105 ^{o}C for 12 hours. The tea leaves were then sieved through the metallic sieve of mesh size (425 - 500 mm) and screened out. Prepared used black tea leaves (UBTL) was kept in an air tight bottle.

2.2 Adsorbate and chemicals

Analytical grade Basic Violet 3 (BV3) was purchased from Sigma-Aldrich and was used without further purification. It is a violet colored triarylmethane basic dye which appears as dry powder. In neytral media, Basic violet 3 act as a cationic dye. IUPAC name of Basic Violet 3 is Tris(4-(dimethylamino)-phenyl)methylium chloride. Aniline violet, Gentian violet, Baszol Violet 57L, Brilliant Violet 58, Hexamethyl-*p*-rosaniline chloride, Methylrosanilide chloride, Crystal Violet, Methyl Violet 10B, Methyl Violet 10BNS and Pyoktanin are synonyms of Basic Violot 3. Its molecular formula is $C_{25}H_{30}N_3Cl$ and formula weight is 407.98 g/mol. The dye is soluble in water. The structural formula of Basic Violot 3 is given in Fig. 1. All chemicals used in the study were analytical grade.

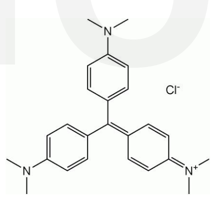

Fig. 1. Structural formula of Basic Violet 3.

2.3 Analysis of Adsorbate

A stock solution of 1000 mg/L was prepared by dissolving required amount of BV3 in distilled water. A number of standard solutions were prepared from the stock solution at about neutral pH 6.0 and their absorbance values were recorded using UV-visible spectrophotometer (UV-1650A, Shimadzu, Japan) at a pre-determined λ_{max} of 582 nm. The absorbance were then plotted against the corresponding concentrations to construct a calibration curve from which absorption coefficient was found as 0.109 L/(mg×cm) and the range of concentration was indicated as 0.1 to 30 mg/L.

2.4 Equilibrium Adsorption Experiments

Equilibrium adsorption experiments were performed in batch process. Equilibrium time is very important to know where the progress of adsorption and desorption is quite steady. To performe the batch adsorption experiments, 0.05 g dried UBTL was taken in a series of adsorption bottles containing 25 mL 25 to 900 mg/L BV3 solutions. Before addition of UBTL, pH of BV3 solutions were adjusted at pH 6.0 by drop-wise addition of 0.05 mol/L HNO_3 or 0.05 mol/L NaOH solution. All bottles were shaken at 150 rpm in a thermostated mechanical shaker (NTS-4000 EYELA, Japan) at 30 ^{o}C. After 6 hours of shaking as a predetermined equilibrium time, the UBTL was separated from solutions. The separated solutions were diluted as required concentration in calibration limit and pH of the diluted solutions were adjusted at 6.0 before measuring their absorbance using UV-vis Spectrophotometer (Model 1800A, Shimadzo) at 582.0 nm wavelength, due to the construction of calibration curve at pH 6.0. The initial concentrations of BV3 in each solution were also analyzed in same procedure. The amount adsorbed of BV3 ($q_e = x/m$) on UBTL at different contact times for different initial concentration was calculated from the following equation:

$$q_e = (C_o - C_e) \times \frac{V}{m} \qquad (1)$$

where, C_o is the initial concentration of BV3 mg/L, C_e is the concentration of BV3 at time t (mg/L), q_e is the amount adsorbed at time t (mg/g), V is the volume of solution in liter and m is the mass of adsorbent in g.

Effect of temperature: To evaluate the effect of temperature on adsorption isotherm, equilibrium adsorption experiments were performed at 30, 40 and 50 ^{0}C and keeping other experimental parameters such as shaking time, shaking speed and pH of solution were constant.

Effect of pH: The effect of pH on equilibrium adsorption was evaluated by constructing adsorption isotherm at different pH of BV3 solution at 30 ^{o}C and other experimental parameters were shaking constant.

Effect of electrolytes: To evaluate the effect of ionic strength on BV3 adsorption on UBTL, equilibrium adsorption experiments were performed in presence of different concentrated NaCl in about 100 mg/L BV3 solution at pH 6.0 and 30 ^{0}C, keeping other experimental parameters constant. Similler experiment was performed in presence of different concentrated $NaNO_3$.

3 Results and Discussions

The used black tea leaves (UBTL) was considered as a low cost adsorbent. Cellulose, hemicelluloses and lignin are the main composition of prepared UBTL (Hossain, 2006). The BV3 dye can be adsorbed on different parts of the heterogeneous surface of UBTL.

3.1 Effect of Concentration and Adsorption Isotherm

The effect of conceentrtion on the equilibrium adsorption of BV3 on UBTL was studied by determining the equilibrium

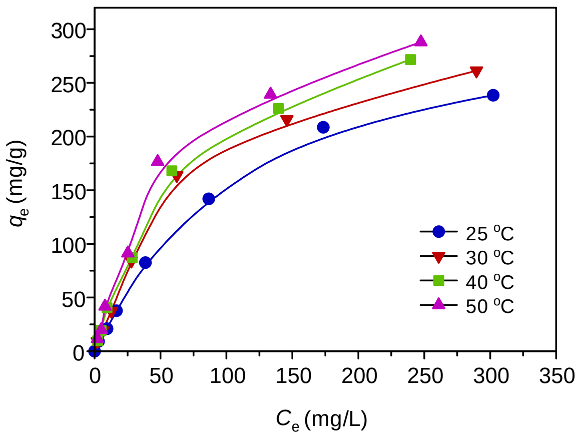

Fig. 2. Adsorption isotherms of BV3 on UBTL from neutral solution at different temperatures.

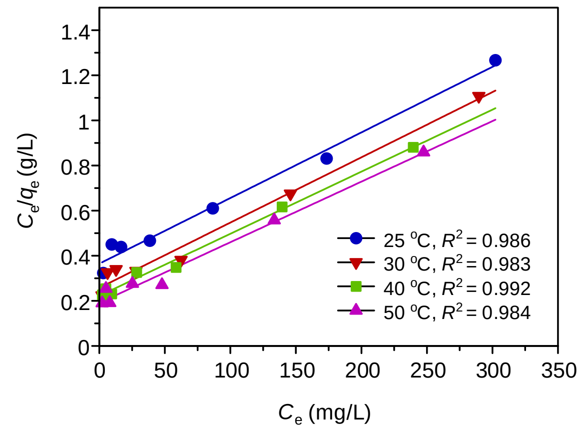

Fig. 3. Langmuir isotherms of BV3 on UBTL from neutral solution at different temperatures.

amount adsorbed for different initial concentration at contant temperature of 30 °C. The amount adsorbed was ploted as a function of equilibrium concentration known as an adsorption isotherm shown in Fig. 2. A comparison of the adsorption isotherms at different temperatures is presented in same Fig. 2 to evaluate the effect of temperature on equilibrium adsorption.

3.2 Analysis of Adsorption Isotherm

Adsorption isotherm is an important characterist to evalute the adsorption behavior of a system. There are many adsorption isotherm equations such as Langmuir, Freundlich, Temkin, D-R, Harkin-Jura and Halsey isotherms used to evaluate feasibility of the adsorption process. The parameters obtain from these different models provide substantial information of adsorptive capacity of UBTL as well as its surface property and adsorption mechanism.

Langmuir Isotherm: The Langmuir isotherm is successfully applied to many adsorbent in adsorption system for removal of carcinogenic and hazardous materials from industrial effluents. The main focus of Langmuir assumption is that formation of molecular monolayer occurs at specific sites on adsorbent surface containing single molecule per site in adsorption process [35]. The linear form of the Langmuir isotherm is expressed by the following equation-2.

$$\frac{C_e}{q_e} = \frac{1}{q_m\, b} + \frac{C_e}{q_m} \qquad (2)$$

where, C_e (mg/L) is the equilibrium concentration of BV3, q_e (mg/g) is the equilibrium amount adsorbed of BV3, q_m (mg/g) is the maximum adsorption capacity for complete monolayer and b (L/mg) is the Langmuir constant related to adsorption equilibrium constant. The value of q_m and b obtained from the slope and intercepts of the linear plots of C_e/q_e against C_e at different temperatures shown in Fig. 3 are given in Table-1. The values of R^2 in the range of 0.983- 0.992 suggested that the adsorption of BV3 onto UBTL is quite consistent with Langmuir equation. The values of q_m is increased with the increase of temperature suggested that the adsorption is endothermic.

Freundlich isotherm: The Freundlich isotherm equation applicable where adsorption process takes place on a heterogeneous system with a multilayer adsorption mechanism [36]. The linear form of Freundlich equation is mathematically given by equation -3.

$$\ln q_e = \ln k_f + \frac{1}{n} \ln C_e \qquad (3)$$

where, k_f is the proportionality constant and n is considered as heterogeneity constant and the others parameters is previously described in Langmuir equation. The values of n were calculated from the slope of lnq_e vs lnC_e plot shown in Fig. 4 for different temperatures which were found in above unity indicated the adsorption process is favourable. The values K_f estimated from the intercept of the plot are presented in Table -1.

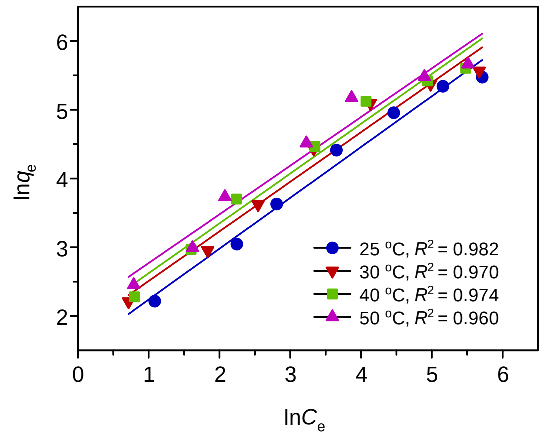

Fig. 4. Freundlich isotherms of BV3 on UBTL from neutral solution at different temperatures.

Temkin isotherm: The Temkin isotherm model represents to test effective adsorption capacity of adsorbate on the adsorbent surface. This isotherm model predicts that the heat of adsorption of all the molecules in the layer decrease linearly by increase coverage layer of adsorbate onto the surface of adsorbent due to the interaction [37]. The linear form of Temkin isotherm is given by equation-4.

$$q_e = B\ln A + B\ln C_e \qquad (4)$$

where, $B = RT/b$ (J/mol) is the Temkin constant related to the heat of adsorption, T (K) is the absolute temperature, R (8.314 J/mol.K) is the molar gas constant, A (L/g) is the equilibrium binding constant related to the maximum binding energy. The constants of A and B were determined from the intercept and the slope of the plot of q_e vs lnC_e, respectively as shown in Fig. 5. Calculated parameters are presented in Table-1.

Dubinin-Radushkevich (D-R) isotherm: Dubinin-Radushkevich (D-R) isotherm predicts the adsorption process whether it takes place physical or chemical in nature, biomass porosity as well as adsorption energy. The Dubinin-Radushkevich (D-R) isotherm is expressed equation- 5

$$\ln q_e = \ln q_{DR} - g\varepsilon^2 \qquad (5)$$

where, q_{DR} (mg/g) is the maximum adsorption capacity of adsorbent, g (mol^2/kJ^2) is Dubinin-Radushkevich isotherm

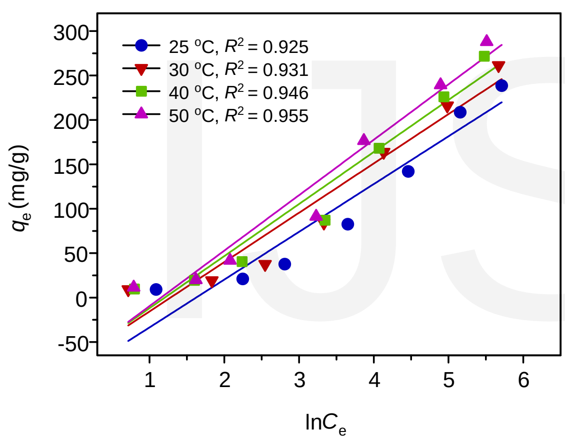

Fig. 5. Temkin isotherms of BV3 on UBTL from neutral solution at different temperatures.

constant corresponding to the mean adsorption energy E and ε (J/mol) is the Polanyi potential that is determined by RT ln (1+1/C_e). Fig. 6 represents the linear plot of lnq_e vs ε^2 for adsorption of BV3 on UBTL which allows estimation of Dubinin-Radushkevich isotherm parameters g and q_{DR} from the slope and the intercept, respectively. Based on the value of Dubinin-Radushkevich isotherm constant, $g$the mean adsorption energy, E (kJ/mol) can be estimated from the following equation-6 [38],

$$E = -\frac{1}{\sqrt{2g}} \qquad (6)$$

The obtained values of adsorption energy, E was limited within the range of 0.0886-0.0993 kJ/mol which address BV3-UBTL adsorption process is physiosorption in nature.

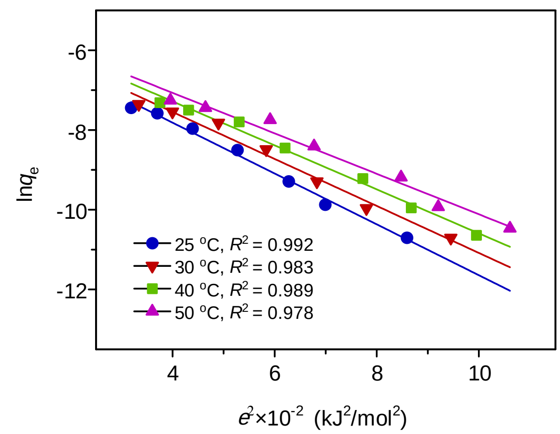

Fig. 6. Dubinin-Radushkevich isotherms of BV3 on UBTL from neutral solution at different temperatures.

Harkin-Jura isotherm: The Harkin-Jura isotherm assumes that a heterogeneous pore distribution takes place in adsorbent surface resulting of multilayer adsorption [39]. The Harkin-Jura adsorption isotherm can be expressed as equation-7.

$$\frac{1}{q_e^2} = \frac{B_{HJ}}{A_{HJ}} - \left(\frac{1}{A_{HJ}}\right)\log C_e \qquad (7)$$

where, B_{HJ} and A_{HJ} are the Harkin-Jura isotherm constants. The Harkin-Jura isotherm parameters, B_{HJ} and A_{HJ} can be achieved from the slop and the intercept by plotting of 1/q_e^2 versus log-C_e, respectively. Fig. 7 shows the large deviation of BV3 adsorption on UBTL data from Harkin-Jura equation.

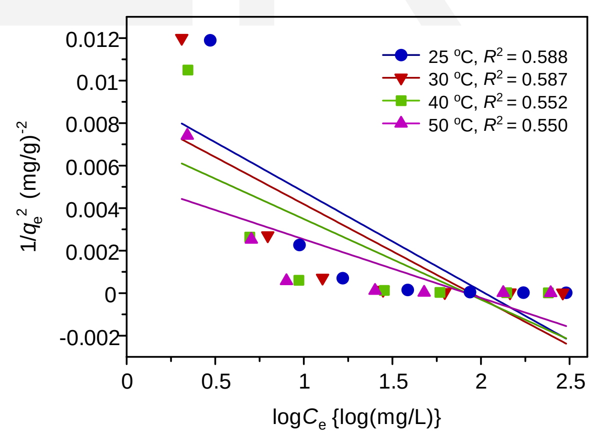

Fig. 7. Harkin Jura isotherms of BV3 on UBTL from neutral solution at different temperatures.

Halsey isotherm: The Halsey adsorption isotherm equation (equation-8) is applicable when the multilayer adsorption occurs at a relatively large distance from the adsorbent surface [40-41].

$$\ln q_e = \left(\frac{1}{n_H}\right)\ln k_H - \left(\frac{1}{n_H}\right)\ln C_e \qquad (8)$$

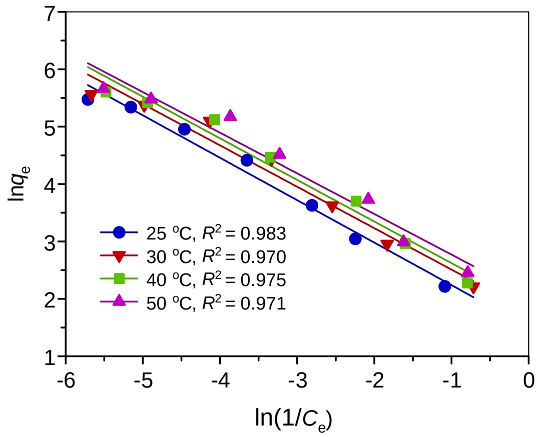

Fig. 8. Halsey isotherms of BV3 on UBTL from neutral solution at different temperatures.

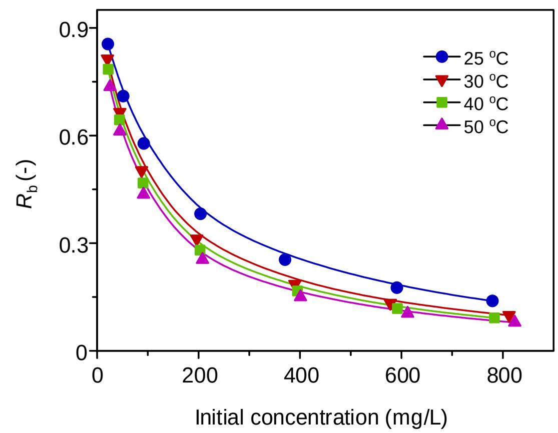

Fig. 9. Effect of initial concentration of BV3 on separation factor, R_b at different temperatures.

where, k_H and n_H are the Halsey constants. The constants parameters were calculated from the slope and the intercept of the linear plot of lnq_e vs lnC_e, respectively as shown in Fig. 8 and presented in Table-1.

From the comparison of regration factor (R^2) in table-1 for the fitness of different isotherm model equations, it is very clear that the adsorption of BV3 on UBTL well expressed by Langmuir equation. The maximum adsorption capacity was calculated from the plot and the value 345.66 mg/g is compared (Table 2) with other adsorbents in literatures [42-55] which exhibits high adsorption capacity of UBTL to BV3 from neutral solution. Separation factor and thermodynamic parameters were also calculated from the Langmuir constants at different temperatures as follows.

3.3 Separation Factor

Adsorption system is characterized whether it is favorable or not by determining the separton factor, (R_b) from Langmuir constant (b). Dimensionless constant, R_b indicated isotherm acceptability to be favorable ($0<R_b<1$), unfavorable ($R_b>1$), irreversible ($R_b=0$) and linear ($R_b=1$) [56]. The separton factor, R_b was determined by the following equation -9 [57].

$$R_b = \left(\frac{1}{1+bC_o}\right) \tag{9}$$

where b is Langmuir constant and C_o is the initial concentration of BV3 dye in aqueous solution. The calculated value of R_b decreases with increase in initial concentration of BV3 dye for different temperatures are prsented in Fig. 9. At low concentration and low temperature, R_b values were found near to 1 indicting that the adsorption is favorable at this condition.

3.4 Adsorption Thermodynamics

Thermodynamic parameters such as standard free energy (ΔG^o), enthalpy (ΔH^o) and entropy (ΔS^o) were calculated by using Langmuir constant values, b and equations 10 and 11.

$$\Delta G^o = -RT\ln b \tag{10}$$

$$\ln b = \frac{\Delta S^o}{R} - \frac{\Delta H^o}{RT} \tag{11}$$

TABLE 1
COMPARISON OF THE PARAMETERS DERIVED FROM DIFFERENT ISOTHERM MODELS FOR PROCESSING TEMPERATURE AT PH 6.0.

Isotherm Model	parameters	Temperatures (°C)			
		25	30	40	50
Langmuir	q_m (mg/g)	344.83	345.66	357.14	372.16
	b×10³ (L/mg)	7.947	11.253	12.596	14.121
	R^2 (-)	0.986	0.983	0.992	0.985
Freundlich	K_f (L/mg)	4.482	5.977	6.666	7.862
	1/n (-)	0.739	0.721	0.724	0.708
	R^2 (-)	0.982	0.970	0.974	0.960
Temkin	B (-)	53.77	55.52	58.60	62.41
	A (-)	0.197	0.278	0.300	0.316
	R^2 (-)	0.925	0.931	0.946	0.955
Dubinin-Radushkevich	q_m× 10³ (mol/g)	5.375	5.566	6.251	6.493
	γ (mol²/kJ²)	63.70	58.90	55.10	50.70
	E (kJ/mol)	0.0886	0.0921	0.0953	0.0993
	R^2 (-)	0.992	0.983	0.989	0.978
Harkin-Jura	B_{HJ} (-)	2.00	1.95	1.92	2.00
	A_{HJ} (-)	212.77	227.27	263.16	909.09
	R^2 (-)	0.588	0.587	0.552	0.550
Halsey	n_H (-)	1.35	1.39	1.38	1.28
	k_H (-)	2.03	2.48	2.62	1.92
	R^2 (-)	0.983	0.970	0.975	0.971

TABLE 2
COMPARISON OF MAXIMUM ADSORPTION CAPACITIES (q_m) OF DIFFERENT ADSORBENTS FOR BASIC VIOLET 3.

Adsorbent	Saturation capacity (mg/g)	Reference
Wood apple shell	130.00	44
H_2SO_4 activated Rice husk	64.87	45
$ZnCl_2$ activated Rice husk	61.57	45
Bottom ash	12.10	46
TS, NaOH-TS	118. 20	47
Ananas comosus (pineapple) leaf powder	158.73	48
Sulphuric acid activated carbons (SAAC)	85.84	49
Activated carbon	15.7-19.8	50
ZBA	17.6	51
Cocoa (theobroma cacao) shell (CSAC)	43.50	52
Phosphoric acid activated carbons (PAAC)	60.42	49
ZFA	19.6	51
Magnetic fluid modified peanut husks	80.9	53
nano-Titanium Tannate Complex (TTC)	58.8	54
Magnetically modified activated carbon	67.1	12
Nanomagnetic iron oxide	16.5	12
Ferrofluid modified sawdust	51.16	55
Magnetic charcoal	10.0	56
Magnetically modified spent coffee grounds	68.1	57
Used black tea leaves	345.66	Present study

where, R is the molar gas constant (8.314 J/K·mol), T is the absolute temperature (K), b is Langmuir constant (L/g) and ΔG^o is the standard free energy (kJ/mol), ΔH^o is the standard enthalpy (kJ/mol) and ΔS^o is the standard entropy (J/K ·mol). Standard free energy, ΔG^o values were calculated by using equation-10 and ΔH^o as well as ΔS^o values were calculated from the slope and intercept of the plot of ln$b$ vs 1/T based on the Van't Hoff equation-11 [58] which were presented in Fig. 10 and Table-3. The positive values of ΔG^o indicated the uptake of BV3 onto UBTL was non-spontaneous in nature. The positive value of enthalpy, ΔH^o meant that the adsorption process played significant role for endothermic nature [59]. Positive value entropy ΔS^o indicated the fragmentation of BV3 molecoles might occurred at the solid-liquid interface between UBTL surface and BV3 dye [60].

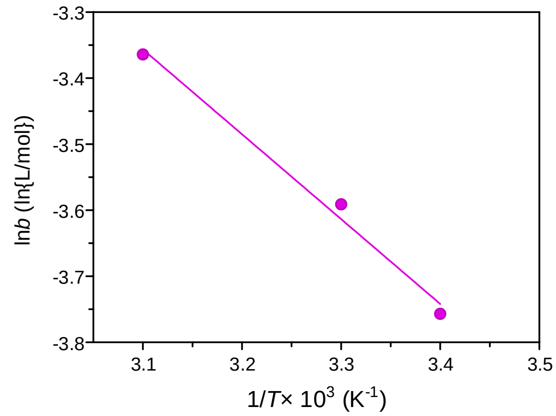

Fig. 10: A plot of ln$b$ vs 1/T at pH 6.0

TABLE 2
THERMODYNAMIC PARAMETERS TO ADSORB OF BV3 ONTO UBTL FOR DIFFERENT TEMPERATURES AT PH 6.0.

Temperature (K)	ΔH^o (kJ/mol)	ΔG^o (kJ/mol)	ΔS^o (kJ/mol·K)
298		+9.757	
303	+5.213	+9.046	+0.011
323		+9.034	

3.5 Effect of pH

The pH of an aqueous solution influence on the surface properties of the adsorbent and ionization or / dissociation of functional groups on the adsorbate molecule, which play important role in the whole adsorption process. The effect of solution pH on the adsorption of Basic Violet 3 on UBTL was studied by constructing adsorption isotherms at different solution pH in the range of 2.0 to 10.0. The equilibrium amount adsorbed were calculated using Langmuir isotherms at different pH of solution and the variation of amounts adsorbed with solution pH is presented in Fig. 11. It is observed that the amount adsorbed of BV3 increase with the increase in pH of the dye solution, appreciably up to pH 6.0 (Fig. 11) due to neutral nature of UBTL surface and cationic nature of BV3. A further increase in solution pH from 6.0 to 10.0, the amount adsorbed is decreased. The observed finding may be explained on the basis of the fact that when the pH of the solution is quite low i.e. 2.0, the presence of excess H^+ ions compete with the cationic dye ($BV3^+$) molecules in the solution and preferably occupy the binding sites available in the adsorbent particles by H^+ ions. As the pH of the adsorbate solution increases number of H^+ ions decreases thus making the adsorption process more favorable. At pH more than 7.0, UBTL surface become negatively charged and BV3 become neutral by taking electron from OH^-. So, interaction between BV3 and UBTL surface decreases and amount adsorbed decreases. A proposed mechanism of BV3 adsorption on UBTL is presented at different initial pH in Fig. 12.

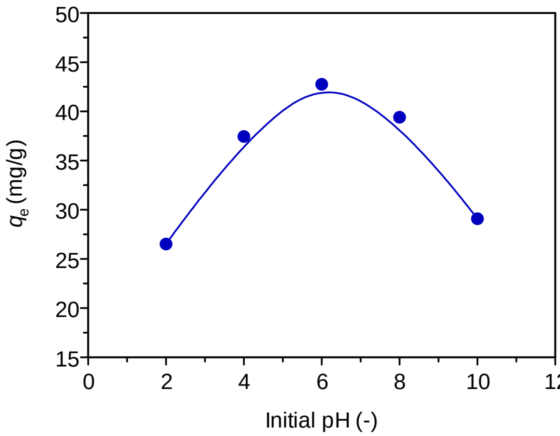

Fig. 11. Variation of equilibrium amount adsorbed (q_e) with initial pH of solution for the adsorption of BV3 on UBTL at 30°C.

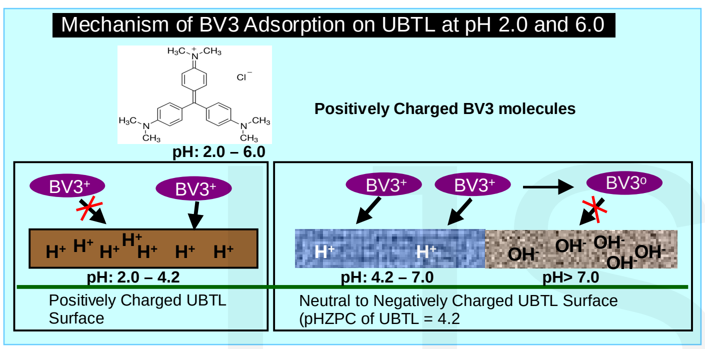

Fig. 12. Proposed mechanism for BV3 adsorption on UBTL at different initial pH of solution.

3.6 Effect of Electrolytes

To identify the involvement of protonation/deprotonation mechanism or electrostatic force of attraction between BV3 (adsorbate) and UBTL (adsorbent), the effect of electrolytes on the adsorption was investigated. Adsorption experiments were carried out for a constant contact time and specific concentration of adsorbate (100 mg/L) in presence of two electrolytes with a range of concentrations at pH 6.0. Fig. 13 shows that the amount adsorbed is exponentially decreased with the increase of electrolytes concentration at pH 6.0 both for Cl^- and NO_3^-. Due to presen ce of large amount of Cl^- ion in solution, positively charged BV3 become neutral by electrostatically attached with Cl^- ions and finally the amount adsorbed decreases. Again in case of $NaNO_3$ electrolyte, nitrate ions (NO_3^-) become positively charged and strongly repelled positively charged BV3 due to resonance structure and finally the amount adsorbed decreases. These two effects can be explained by Fig. 14 which is the proposed mechanism of BV3 adsorption in presence of electrolytes at nearly neutral pH 6.0.

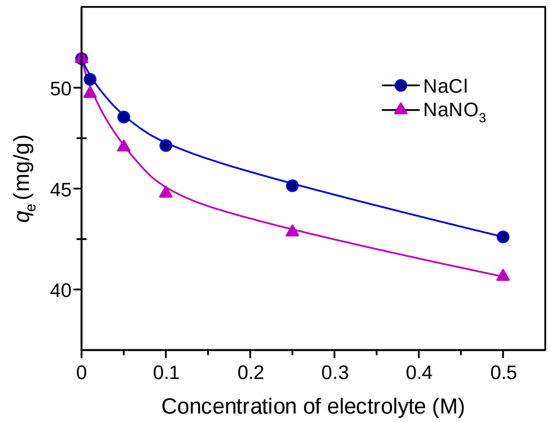

Fig. 13. Variation of equilibrium amount adsorbed (q_e) with different concentrations of electrolytes for the adsorption of VB3 on UBTL at pH 6.0

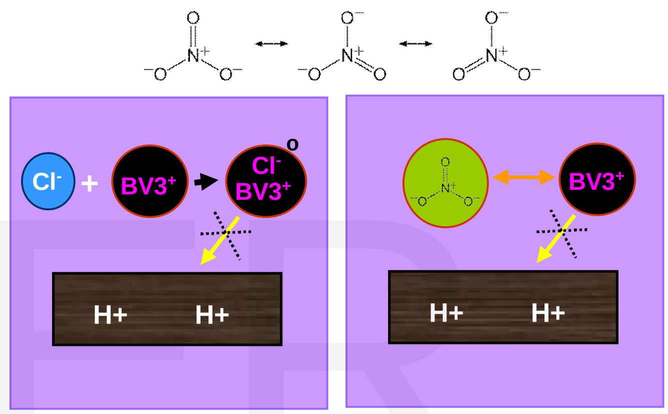

Fig. 14: Mechanism of BV3 adsorption neutral media (pH 6.0) in presence of electrolytes (Cl^- and NO_3^-).

4 Conclusion

This study comprised the high adsorptive capacity of UBTL for adsorption of Basic Violet 3 dye from neutral aqueous solution. The equilibrium adsorption data follows the isotherm equations in the sequence of Langmuir > D-R > Halsey > Freundlich > Temkin > Harkin-Jura, based on the values of R^2. Values of separation factor in the range of 0.079-0.855 implied that the BV3 dye adsorption process is favorable. The maximum adsorption of BV3 onto UBTL occurred 345.7 mg/g at initial pH 6.0 due to neutral nature of UBTL surface and cationic nature of BV3. Thermodynamic studies indicated that adsorption of BV3 onto UBTL is physical, non-spontaneous and endothermic.

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