Synthesis and Performance Evaluation of Chitosan Prepared from Persian Gulf Shrimp Shell in Removal of Reactive Blue 29 Dye from Aqueous Solution (Isotherm, Thermodynamic and Kinetic Study)

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ABSTRACT: *This study was aimed to investigate the amount of reactive blue 29 (RB29) dye removal from aqueous solution by Chitosan extracted from Persian Gulf shrimp shell. The effect of parameters such as pH, the concentration of reactive blue 29 dye, contact time, and adsorbent dosage in dye removal was studied. Isotherm, Thermodynamics, and kinetics of adsorption process were also investigated. The results of this study showed that the optimum condition of the adsorption process occurred in 50mg/L of RB29 dye concentration, pH=4, contact time of 90 minutes and adsorbent dosage of 0.2 g/L. The maximum adsorption capacity in optimum condition was estimated to 87.74 mg/g. Lab data displayed that the results were in compliance with Langmuir isotherm. According to the results of thermodynamic studies, standard entropy changes (ΔS°) was 66.67 J/mol K and standard enthalpy changes (ΔH°) was 19158.3 kJ/mol. Also, the standard Gibbs free energy (ΔG°) was negative and kinetics of adsorption process follows the pseudo-second-order model.*

KEYWORDS: *Reactive blue29 dye; Chitosan; Isotherm; Thermodynamics; Kinetics.*

INTRODUCTION

Many industries use dye to paint final products. As a conclusion outflow wastewater is highly colored and disposal of this swage into receiving waters make damage to the aquatic environment [1]. Today's, more than 10000 various types of dye are commercially produced [2]. It has been estimated that 1.6 million tons of dyes are annually produced, from which 10-15% are disposed into waste water [3]. Researches reveal that produced wastewater of textile industries is about 4-8 million cubic meters per year[4]. The most principal characteristic of textile wastewater is its color [5]. Removal of dye from textile wastewater is one of the major environmental problems which because of treatment problems of these wastewaters by physicochemical and biological treatment,

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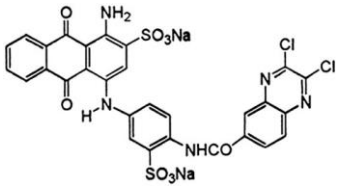
physical methods are common [6-8]. Stability and difficult degradation of color is due to complex aromatic structure of them [9]. In current time, synthetic dyes in many industries including textile, leather, sanitary and beauty, pulp and paper, inject printing, plastic, pharmaceutical and food industry are extensively used [10]. Dyes were generally categorized, with regard to structure or functional groups and color and also ionic charge upon dissolving in aqueous solution [3]. Azo dyes are widely applied in textile processes [11]. It is estimated that over 50% of total world production of color is azo dye [12]. Different types of azo dyes such as acid, basic, direct and reactive are found [13]. These dyes have one or more azo bonds (-N-N) and due to low cost, simple dyeing and low toxicity are widely used to dye fibers. These dyes and their intermediate products are toxic, carcinogenic and mutagenic for life of aquatics [14]. It is reported that the human eye can detect 0.005mg/L of reactive dye concentrations in water [15]. Moreover, most of these dyes can cause allergy, dermatitis and itchy skin and also accelerate occurring cancer and mutation in human beings [16]. Colored wastewater make some of operation problems in treatment plants such as create foam and stable color, increasing pH, temperature and heavy metals [17]. Various chemical-physical methods like flocculation, coagulation, membrane filtration and surface adsorption are used for decolorizing textile wastewaters [18]. There are numerous problems in removal of reactive dyes which even are recognizable in low concentration 0.005ppm. Furthermore, these dyes are not easily biodegradable and most likely remain in wastewater, even after extensive treatment [19]. Among outflow of textile wastewater, reactive dyes under aerobic conditions are hardly removed and under anaerobic conditions are changed to carcinogenic aromatic amines [20]. Removal of these dyes by using chemical coagulation method due to their high solubility in water is difficult [21]. Adsorption is one of the most important and acceptable techniques to decrease concentration of dissolved dyes from aqueous solutions [22]. Adsorption process in comparison with other methods is a better procedure in terms of cost, simplicity in design and operation, availability, effectiveness and lack of sensitivity to toxic substances [23, 24]. Recently, efforts have been made to use more affordable substances as adsorbent in tertiary treatment of colored wastewater. Chitosan is one of the most abundant and low cost polymers across the world which has some properties as an ideal absorbent to remove pollutants from wastewater [25]. In various studies, Chitosan is used to remove different contaminants, such as: Adsorption of dyes and heavy metal ions by chitosan composites [26], Dye removal from colored textile wastewater using chitosan in binary systems [27], adsorption of copper, lead, and nickel using chitosan immobilized on bentonite [28]. Defluoridation of drinking water using chitosan based mesoporous alumina [29], adsorption of humic acid onto chitosan-H_2SO_4 beads [30]. Chitosan or poly-(1-4)-2-amino-2-deoxy-b-d-glucose is a biopolymer which can be introduced as a cationic, linear, heterogeneous and nontoxic chemical substance and a biodegradable polysaccharide with high molecular weight [31]. In addition to being natural and abundant, Chitosan have certain features which lead to perform as an effective biosorbent in removing dye with high capacity [32]. It has two reactive groups: one amino group and two primary and secondary hydroxyl groups which are at C-3, C-2 and C-6 carbon position respectively. Its advantage over other polysaccharides is its chemical structure which makes possible occurring special change especially in carbon position number two(C-2), without much difficulty. These functional groups allow direct replacement reactions and chemical changes that causes it finds application in various domains [33]. This polysaccharide which is acetylated form of chitin shows, in side of its features, high potential for surface adsorption of dyes, metal ions and protein; therefore, it might be a good candidate for removing pollutants from water and sewage. Some of potential applications of this biopolymer are summarized in areas such as medical, pharmacy, water treatment, membrane, hydrogel, glue, antioxidants, biosensors and food packaging [34]. In this study, efficiency of Chitosan as an adsorbent to remove reactive blue 29 dye was investigated. Polymer structure of Chitosan and characteristics of reactive blue29 dye are illustrated in Fig. 1 and Table 1 respectively.

EXPERIMENTAL SECTION

This experimental study was carried out in a batch condition in which Chitosan performance as an adsorbent in removal of reactive blue 29 dye from aqueous solutions was evaluated in lab scale. Commercial reactive blue 29 dye with molecular weight 788g/mol was purchased from Sigma-Aldrich Company and used

Table 1: Characteristics of reactive blue 29 dye [36].

Chemical structure	
symbol	RB29
Chemical formula	$C_{29}H_{15}C_{12}N_5Na_2O_9S_2$
The Wavelength of maximum adsorption λmax (nm)	589
Molecular weight g/mol	788

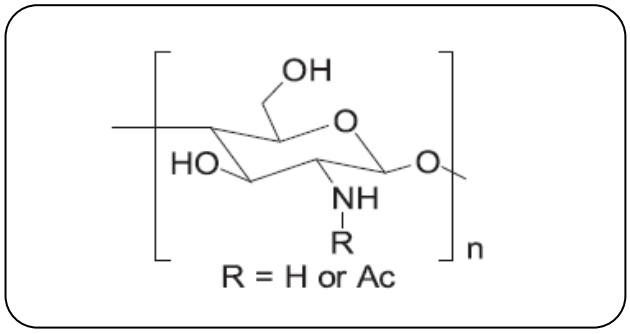


Fig. 1: Polymer structure of Chitosan [35].

without purification. Also required chemical materials including NaOH, HCl were prepared from Merck Company. Scanning Electron Microscopy (SEM) was used for scrutiny and seeing samples with high-resolution and magnification. For analyze the characteristics of the adsorbent structure such as size and shape was prepared X-Ray Diffraction (XRD) from Chitosan. XRD device model was X 'Pert Pro, the Panalytical Company, using Ni filter Cu Kα radiation source (λ=0.154nm), set at scan rate of 10 θ/min, using a voltage of 40 kV and a current density of 40 mA. The relative intensities were recorded within the range of 0-80(2θ).

Synthesis and preparation of adsorbent:

Shrimp shell was prepared in a fishery waste of shrimp fished from the waters of Persian Gulf. Preparation of chitin is performed in two basic stages including: 1) Demineralization: eliminating minerals by dilute inorganic acid and 2) Deproteinization: eliminating organic materials [37]. Mineralization was completely carried out during 15 minutes in ambient temperature and in presence of HCl of 0.25 molar (with solid to liquid ratio 1/40 (w/v)) and deproteinization was easily achieved by sodium hydroxide of one molar during 24 hours in temperature about 70ºC [38]. Obtained chitin is dried out in ambient temperature and then comes in powder form. Extraction of Chitosan from chitin was carried out by 70% concentrated sodium hydroxide [39].

Preparation of reactive blue 29 dye stock solution

Reactive blue 29 dye stock solution was made by dissolving reactive blue 29 dye in distilled water. Stock solution was prepared with a concentration of 200 mg/L.

EXPERIMENTAL SECTION

Adsorption experiments

Reactive blue 29 dye stock solution of 200 mg/L was prepared by adding a specified amount of dye to 1L of deionized water. Various parameters such as pH, initial dye concentration, adsorbent dose, contact time, adsorption isotherm, temperature effect and thermodynamics and kinetics of adsorption process were considered. Different parameters including five initial concentrations of reactive blue 29 dye (10, 20, 30 and 50 mg/L), five ranges of pH (3, 4, 5, 7 and 9), five different dosage of Chitosan (0.2, 0.3, 0.4, 0.5 and 0.75 g/L) and nine different contact times (2, 5, 10, 15, 30, 45, 60, 75 and 90 minutes) were analyzed. The effect of each parameter in all stages of experiment, assuming other mentioned parameters are fixed and changing considered parameter, was studied and then models of adsorption isotherm were determined. In order to study the effect of temperature on the efficiency of the adsorption process dye solutions RB29 was made with initial concentration of 50 mg/L. Then, pH of solutions set on optimal pH. 0.2g/L Chitosan was added to any of

the dye solutions reactive blue 29 dye and in temperatures of 15, 30, 40 and 50º C was stirred inside of incubator shaker for 90 mi. Finally, used erlens were discharged from incubator shaker and samples was filtrated by Whatman filter paper with pore size of 40 micrometers and final concentration of reactive blue 29 was determined by using +UV/VIS Spectrometer in wavelength of 589nm. Experiments repeated two times and results represent average of obtained data. Reactive blue 29 dye adsorption capacity by Chitosan was calculated as follows [10]:

$$qe = \frac{(C_0 - C_e)}{m} \times V \quad (1)$$

Where:

C_0: Initial reactive blue29dyeconcentration (mg/L).

C_e: Final reactive blue 29 dye concentration (mg/L)

m: Adsorbent dosage (g)

V: Solution volume (L)

For the study of thermodynamics of reactive blue 29 dye adsorption by Chitosan following equations were used [40]:

$$\Delta G = -RTLnK_d \quad (2)$$

$$LnK_d = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT} \quad (3)$$

Where

ΔG: Changes of Gibbs free energy

R: Universal gas constant = 8.314J/mol/k

T: Temperature (K)

K_d: Thermodynamic equilibrium constant

ΔS: Standard entropy (J/mol k)

ΔH: Standard enthalpy changes (kJ/mol)

R: Universal gas constant (J/mol K)

After calculating thermodynamic equilibrium constant for different temperatures and computing free energy diagram ln K_d against 1/T was plotted. Slope and intercept of this diagram are used to determine ΔH and ΔS respectively.

For the studies of adsorption isotherms, experiment data by using five adsorption isotherm models including Langmuir, Freundlich, BET, Temkin and Dubinin-Radushkevich was analyzed. The following equations represent the mathematical model of these isotherms:

Langmuir equation:

$$q_e = \frac{q_{max} K_L C_e}{1 + K_L C_e} \quad (4)$$

Where:

q_{max} is the maximum adsorption capacity (mg /g); K_L is the experimental constant (coefficient of Langmuir equation). q_e is the mass ratio of the solid phase, which is the ratio of the adsorbed mass to the mass of adsorbent (mg /g), C_e is equilibrium concentration (mg/L).

Freundlich equation:

$$q_e = KC_e^{1/n} \quad (5)$$

Where:

K is the experimental constant (Freundlich equation coefficients); C_e and q_e parameters are similar to Langmuir isotherm.

BET equation:

$$q_e = \frac{q_{max} K_b C_e}{(C_s - C_e)\left[1 + (K_b - 1)(C_e / C_s)\right]} \quad (6)$$

Where:

C_s is the saturation concentration of soluble material (mg / L); k_b is a constant that is achieved by the linear equation and states the energy between the adsorbate and the surface of adsorbent; q_{max} is the amount of adsorbate per unit of mass of adsorbent (g) to form a single molecular layer on the surface of adsorbent, (mg/g).

Temkin equation:

$$q_e = \frac{RT}{b_T} \ln(A_T C_e) \quad (7)$$

Where:

B_T is Temkin's constant and is expressed in units of J/mol and is related to the temperature of adsorption; A_T is the constant of Temkin isotherm (L/g); R is the universal constant of gases and T is absolute temperature (K).

Dubinin-Radushkevich equation:

$$q_m = e^{-\beta s^2} q_e \quad (8)$$

Where:

q_m is the adsorption capacity of single-layer and β (constant of the equation) is the factor of porosity; ε is called Polanyi potential.

For kinetic study on adsorption, two common kinetic model including pseudo first and pseudo second order kinetic were used. Correlation coefficient (R^2) is considered as a criterion of correspondence between experimental data and two proposed kinetic models. Pseudo first order kinetic model is as follows [38-40]:

$$\mathrm{Log}\left(q_e - q_t\right) = \mathrm{Log}\,q_e - \frac{k_1 t}{2.303} \quad (9)$$

Where:

q_t and q_e: are amount of absorbed material on the adsorbent in time t and in equilibrium time (mg/g), respectively.

K_1: Pseudo first order adsorption rate constant (1/min).

Plotting Diagram Log (q_e-q_t) against (t) is used to determine amount of constant K and coefficient R^2.

Pseudo second order equation is as follows [39-41]:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \quad (10)$$

Where K_2 is pseudo second order adsorption rate constant (g/mg min). Plotting diagram of t/q_t against (t) is used to achieve rate parameters and obtained results suggest the correspondence of this kinetic model with experimental data. Values of q_e and K_2 are determined from calculation of slope and intercept of this diagram.

RESULTS AND DISCUSSION

Characterizations of Chitosan

Fig. 2 shows the SEM images of Chitosan. For determination of the accurate diameter of Chitosan, the SEM method was used. This technique gives information regarding surface morphology of the samples.

According to Fig. 2, minimum particle size of Chitosan was around 78 nm and distribution in the range of 78-185 nm. It is clear that Fig. 2 has a considerable numbers of pores and there is a good possibility for dyes to be adsorbed in to these pores. The crystalline structure and phase purity of polymers can be identified by x-ray diffraction pattern [42]. As can be seen in Fig. 3, the X-ray diffraction patterns of chitosan gives two characteristic crystalline bands at $2\theta = 10^\circ$ and $2\theta = 20^\circ$. These bands created because of presence–OH and $–NH_2$ groups in the Chitosan structure, which could form stronger inter and intra molecular hydrogen bonds and the Chitosan structure has certain regularity, so that the molecules form crystalline regions easily[43] which was similar to the results reported by *Vijayalakshmi* and his colleagues [44].

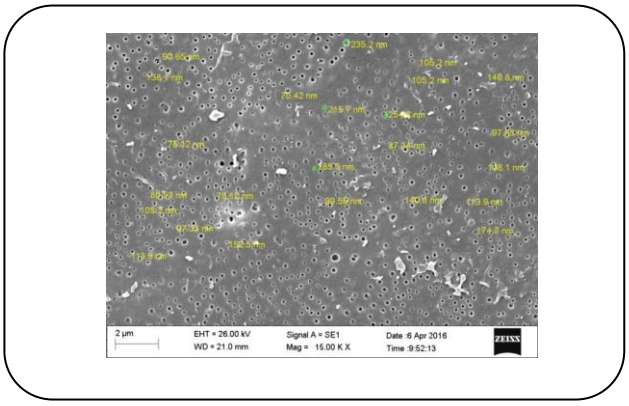


Fig. 2: SEM images of Chitosan.

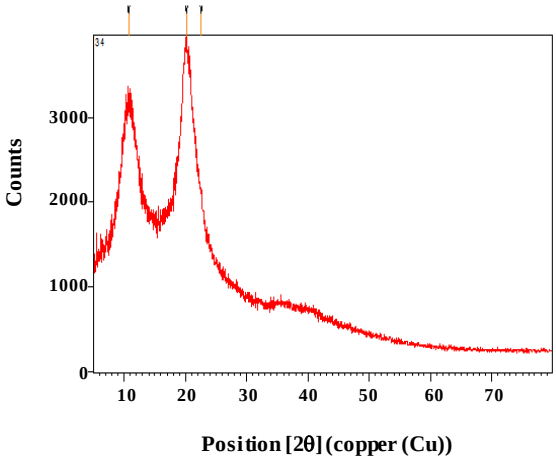


Fig. 3: X-ray diffraction spectrum of Chitosan.

The study of the effect of pH on reactive blue 29 dye adsorption by Chitosan

In this study, the effect of pH of the solution in ranges of 3-9 on removal of reactive blue 29 dye by Chitosan was investigated. Reactive blue 29 dye solution with concentration of 10mg/L was made and adsorbent dose 0.2 g/L and contact time of 60 minutes used for all solutions. Results from the effect of pH on adsorption of reactive blue 29 dye have been presented in Fig. 4.

As in Fig. 4 presented, the adsorption capacity of Chitosan for reactive blue29 dye adsorption in dye concentration of 10mg/L and at pH=4 was 32.2 mg/g. Results obtained from this diagram indicate that as the pH increases, amount of dye adsorbed on chitosan was found to be decreasing. Hasan and colleagues concluded that the efficiency of dye adsorption in acidic conditions was higher. A lower pH means higher protons and amino groups in Chitosan create proton. Therefore, electrostatic

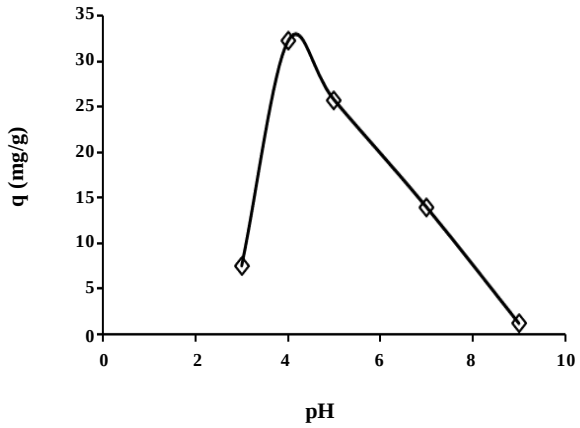


Fig. 4: The effect of initial solution pH on removal of reactive blue 29 dye by Chitosan.

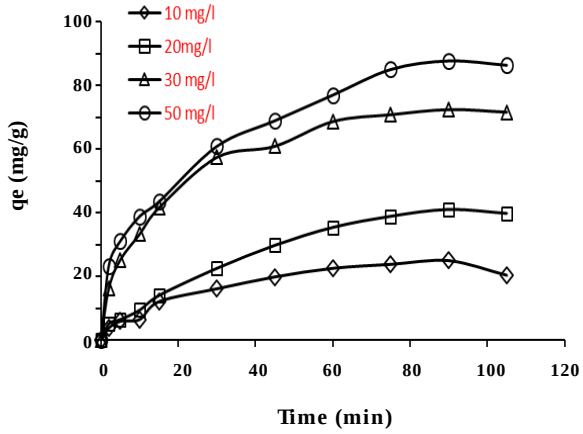


Fig. 5: The effect of initial reactive blue 29 dye concentration on its adsorption in various contact times by Chitosan.

adsorption between dyes with negative charge and active sites with positive charge is increased [45]. pH influences adsorbent surface charge [46]. It can be seen that aqueous solution pH plays an important role in the adsorption of dyes onto Chitosan. The result of the study done by Mahmoodi and colleagues entitled removal of Direct Red 23 and Acid Green 25 dyes using Chitosan in binary systems from colored textile wastewater matches with current study [27].

The study of the effect of initial reactive blue 29 dye concentration on its adsorption by Chitosan in various times

Results obtained from the study of initial reactive blue 29 dye concentration on its adsorption by Chitosan in various contact times have been provided in Fig. 5.

According to Fig. 5 adsorption capacities in all concentrations after passing 90 minutes have been equilibrated. In RB29 dye concentrations of 10, 20, 30, 50 mg/L the adsorption capacity at equilibrium time were 25.14, 41.25, 72.65 and 87.74 mg/g, respectively. Regarding obtained results in Fig. 5, increase in contact time leads to the increasing adsorption capacity and it achieves equilibrium within the 90 minutes contact times. Guibal and his colleagues reported that equilibrium time for adsorption of anionic dyes on cross-linked chitosan is after 45 minutes[47]. *Cestari* and colleagues in a study declared that reaction time is between 60-200 minutes and adsorption behavior of anionic dyes are directly correlated with dimensions of organic chains of dye, value and position of sulfate groups and adsorption temperature [48]. Dye adsorption in primary stages of treatment is fast and after that near the equilibrium point becomes slow which it is occurred due to many empty surface sites available for adsorption in primary stages. After passing time, occupation of empty maintained surface sites due to repulsive force between molecules of dye adsorbed on the solid and dye molecules present in the solution phase becomes difficult[32].

The study of the effect of adsorbent dosage on reactive blue 29 dye concentration by Chitosan

In this study, reactive blue29 dye solutions with concentration of 50 mg/L were made and pH of all solutions set on 4. Adsorbent dosages of 0.2, 0.3, 0.4, 0.5 and 0.75g/L was used and within the 90 minutes contact time the amount of reactive blue 29 dye adsorption was measured by Spectrophotometer at wavelength of 589 nm. Results obtained from calculating amount of dye adsorption at various Chitosan masses have been presented in fig. 6.

Considering the results of the experiment about the effect of adsorbent dose on reactive blue 29 dye adsorption by Chitosan, it can be observed that as the adsorbent dose increases, adsorption capacity was found to be decreasing. Maximum adsorption capacity was found at chitosan dosage of 0.2 g/L. therefore, this value is selected as optimal adsorbent dose in experiments.

According to Fig. 6 the adsorption capacity of Chitosan which used with masses of 0.2, 0.3, 0.4, 0.5 and

0.75 g/L were 148.7, 126.3, 106.3, 90.8 and 62 mg/g, respectively. As the results show as adsorbent mass increases adsorption capacity was found to be decreasing. Mirmohseni and his colleagues concluded that adsorption capacity decreases with incresing number of hollow core fibers. The first reason for this phenomenon is that adsorption sites remain unsaturated during process [49]. Li and his colleagues concluded that decrese in adsorption capacity occures when chitosan dose is limited to more than 0.01g [50].

The study of adsorption isotherm models

In this part, the results and adsorption isotherm constants of the most common isotherms including Freundlich, Langmuir, BET, Temkin and Dubinin-Radushkevich have been illustrated in Table 2. Isotherm is assumed to be the most important parameter in desinging adsorption systems and describes the relation between adsorbate concentration and adsorption capacity of a adsorbent.

Regarding to Table 2 and values of linear regression coefficients, The amounts of R^2 in Langmuier isotherm for RB29 dye adsorption by chitosan was higher than the amount of R^2 for other isotherms. So it can be said with certainty that RB29 dye adsorption by chitosan follows this isotherm. Langmuir model estimated that the maximum amount of RB29 dye adsorption capacity (q_{max}) by chitosan was 169.6 mg/g. The amounts of K_L for the adsorption of humic acid by montmorillonite nanoparticles are more than the amounts of K_L for adsorption of humic acid by bentonite nanoparticles. K_L is a constant that increases when the size of adsorbent molecules increased [51]. If dimensionless parameter of R_L= 0, the adsorption is irreversible and if 0< RL<1, the adsorption is desirable and if R_L=1, the adsorption is linear and if RL>1, then the adsorption is undesirable. According to the results of the Langmuir isotherm for adsorption of RB29 dye, the amounts R_L for chitosan was between 0 and 1, so RB29 dye adsorption by chitosan is desirable [52].

Lazaradis and his colleageuses concluded that dye adsorption process is better described by Langmuir isotherm [53]. Study by *Wong* and his colleageuses [54] and also *Radaie* and his colleageuses [55] match with present study.

Table 2: Coefficients of isotherm models for reactive blue 29 dye adsorption by Chitosan.

Isotherms	Constants	Values
Langmuir	q_{max} (mg/g)	169.6
	K_L (L/mg)	0.03
	R_L	0.50
	R^2	0.95
Freundlich	k_f (mg/g)	8.19
	1/n	0.71
	n	1.42
	R^2	0.91
BET	1/A.Xm	0.05
	(A-1)/(A.Xm)	0.04
	A	1.0
	Xm (mg/g)	25
	R^2	0.05
Temkin	A_T, L/mg	0.38
	b_T (J/mole)	70.24
	B	35.27
	R^2	0.90
Dubinin-Radushkevich	β, $mole^2/kJ^2$	5.637E-06
	E, kJ/mole	0.30
	q_m, mg/g	74.26
	R^2	0.81

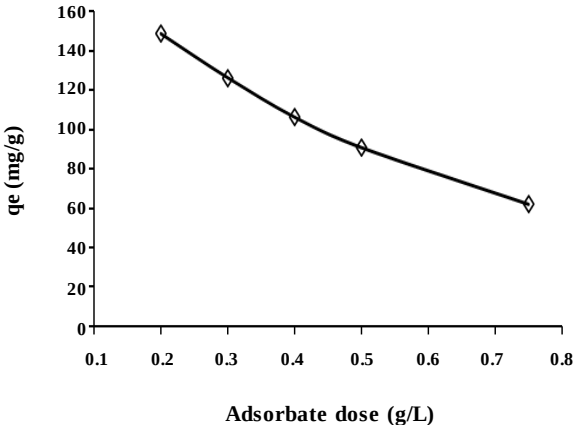


Fig. 6: The effect of adsorbent dose on adsorption of reactive blue 29 dye by Chitosan.

Table 3: Thermodynamic parameters calculated for reactive blue 29 dye adsorption by Chitosan.

T(K)	constant(K_d)thermodynamic equilibrium	G (kJ/mol)Δ	S (J/mol K)Δ	H (kJ/mol)Δ
288	0.12	-0.29	66.67	19158.3
303	0.29	-0.74		
313	0.51	-1.33		
323	1.05	-2.82		

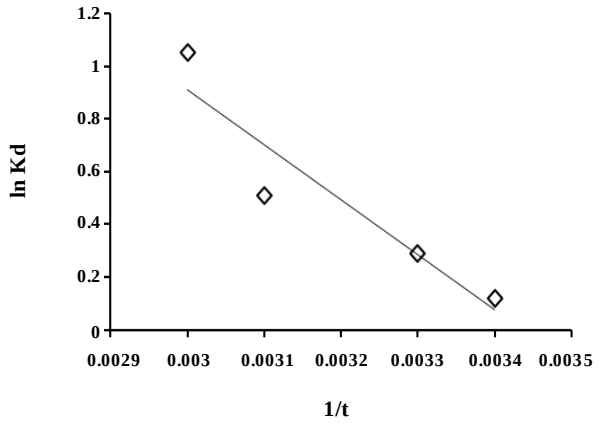


Fig. 7: Linear plot In K_d against I/T for the reactive blue 29 dye adsorption by Chitosan.

The study of the effect of temperature and thermodynamics of reactive blue 29 dye adsorption by Chitosan

The results of the study about the effect of solution temperature on efficiency of reactive blue 29 dye removals by chitosan have been shown in Fig. 7 and Table 3. As can be seen in Table 3 increasing the solution temperature leads to increased dye adsorption which it illustrates that reactive blue 29 dye removal process was endothermic.

After calculation of thermodynamic equilibrium constant for different temperatures and calculation of free energy, diagram of $\ln k_d$ against I/T was plotted. We observed that with increase in the temperature from 288 K to 323 K, there was an increase in dye removal efficiency which shows that removal reaction of reactive blue 29 dye is endothermic. Negative sign of Gibbs free energy changes (ΔG) indicates that adsorption process is spontaneous [56]. Positive value of ΔH shows that adsorption process is naturally endothermic and adsorption capacity increases with increasing temperature [57]. Positive value of ΔS indicated adsorbent tendency towards adsorbate in the solution and some structural changes in adsorbent and adsorbate [58]. Positive values of standard entropy changes (ΔS) indicates that freedom degree at the interface of solid-liquid state during adsorption process has been increased [40]. According to the study of *Fan* and his colleagues the adsorption process is spontaneous and endothermic [59]. Other observations reported positive values in ΔH [60] and in ΔS [61].

Kinetic study of the reactive blue 29 dye adsorption by Chitosan

Kinetic Parameters obtained from the study of adsorption process have been shown in Table 4. As can be seen regarding comparison of values of R^2 coefficient in two kinetic models, adsorption process with pseudo second order kinetic model is better described.

In this research, applicability of Pseudo first order and second order kinetic model by kinetic study on various initial concentrations of adsorbate was discussed. Comparison of coefficient values R^2 in two studied kinetic models show that adsorption process matches with pseudo second order kinetic model. On the other hand, with studying the pseudo second order equations, it can be seen that there is little difference between capacity of adsorption under empirical equilibrium conditions (q_{cal}) and the capacity of adsorption under calculation based conditions (q_{exp}). So, pseudo second order kinetic model can be used properly for explaining the kinetics of adsorption this dye onto chitosan. The result of study performed by Hang and his colleagues [62] and the result of study conducted by *Uzun et al*. [63] are in accordance with present study.

CONCLUSIONS

Comparison of maximum quantity of q_e with other used adsorbents in other researches shows that extracted chitosan used in the present study has a suitable and high

Table 4: Coefficients of kinetic models calculated for reactive blue 29 dye adsorption by Chitosan.

Pseudo-first-order kinetic				Pseudo-second-order kinetic			q_e,exp(mg/g)
C_0(mg/l)	K_1(min^{-1})	q_e,cal (mg/g)	R^2	K_2(g/mg min)	q_e,cal (mg/g)	R^2	
10	0.02	11.34	0.35	0.00	25.92	0.94	25.14
20	0.03	16.91	0.40	0.00	62.99	0.54	41.25
30	0.03	20.33	0.45	0.00	103.22	0.53	72.65
50	0.03	25.71	0.38	0.00	122.95	0.55	87.94

efficiency to remove the reactive dye 29. By studying the effect of various parameters in adsorption process, optimal parameters including contact time, initial pH, adsorbent dosage and initial dye concentration achieved 90minutes, 4, 0.2 g/L and 50 mg/L, respectively. Adsorption isotherm and kinetic study suggest that mentioned process matches with pseudo second order kinetic and Langmuir isotherm.

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