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Adsorption of Two Textile Dyes from Aqueous Solution by Synthetic Gamma Alumina Particles: Isotherm, Kinetic and Thermodynamic

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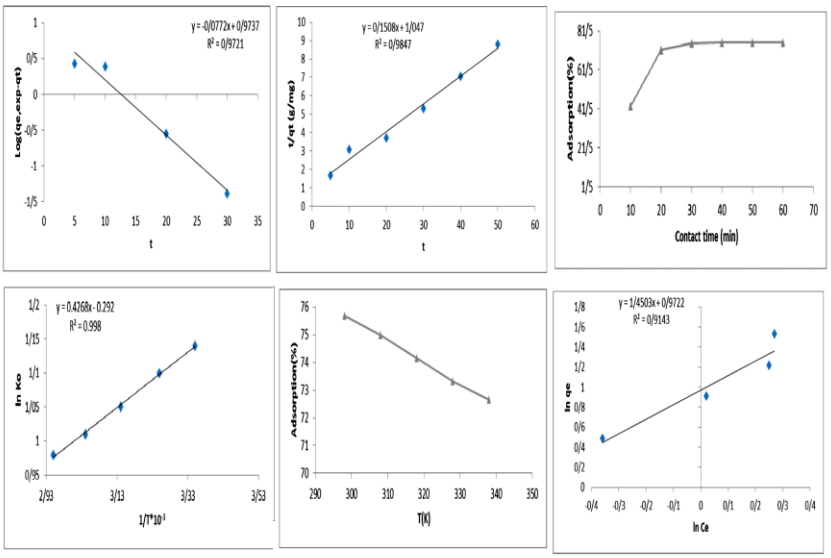
ABSTRACT

The current paper aims at investigating the adsorption of textile dyes from aqueous solution with the help of synthetic gamma alumina nanoparticles. The current study was performed on a laboratory scale. Effect of pH, contact time, dye concentration and adsorbent dose on the adsorption of Methylene Blue and Congo red dye as well as kinetics and thermodynamics of adsorption processes were examined. The dye concentration for Congo red and Methylene blue dyes in different samples was measured using 498 nm and 664 nm wavelength spectrophotometer, respectively. The experimental results showed that gamma alumina nanoparticles had a good potential for removing dye molecules. Batch adsorption study revealed that 0.04 g amount of the adsorbent was capable of removing 75.67% of Congo red (CR) and 0.05g of the adsorbent was capable of removing 78.25% of Methylene blue (MB) in 40 min. The experimental equilibrium data showed that Langmuir isotherm applied well for describing the adsorption behaviour and Kinetic studies showed best applicability of the second-order kinetic model. The results of gamma alumina nanoparticles showed synthetic alumina was found as an efficient adsorbent for the absorption of aqueous blue dyes.

GRAPHICAL ABSTRACT



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Introduction

The textile and dyeing industries consume large amounts of water and are one of the largest consumers of water [1], so that the amount of water consumption is between 25 to 250 cubic meters per ton of product [2]. Dyes (one of the main pollutants in the environment) are chemical compounds with the ability to absorb ultraviolet and visible rays. Most dyes are a complex of organic compounds. Dye molecules contain two key components: Chromospheres that produce dye are double bonded conjugates and the other is a dye that does not absorb alone and forms water-soluble molecules and increases absorption [3-5].

Gamma alumina (Al_2O_3) is an inorganic compound with a very high melting point of about 2054 °C and is chemically very stable. Extensive research has been done on this material due to its wide range of applications in the field of abrasives, catalysts, adsorbents, ceramic materials and catalysts and biological implants [6-8]. The alumina properties have made it possible to use it in many applications including:

1- High compressive strength,
2- High hardness,
3- High abrasion resistance,
4- High thermal conductivity,
5- Resistance to chemical attacks by a wide range of chemicals even at high temperatures,
6- Resistance to thermal shock,
7- High refractory,
8- High dielectric resistance,
9- High electrical resistance even at high temperatures,
10- Transparency in Equivalent to microwave radiation frequencies, and
11- Its raw material is easily accessible and its price does not fluctuate sharply [9-11].

Various sources have proposed various gamma alumina nanoparticles preparation techniques. These methods include sol-gel, hydrothermal, microwave, emulsion evaporation, solution precipitation and wet chemical methods [12].

Water scarcity, both qualitatively and quantitatively, has put people at serious risk, especially in some countries. Therefore, science and technology have joined hands to overcome this problem by developing methods. By creating a suitable bed, the conditions for access to safe, quality and affordable water can be provided. Undoubtedly, the use of new methods, especially nanotechnology, allows us to purify water with the mentioned conditions. Given the effective elimination of pollutants and the reduction of the cost of producing healthy water, the use of nanotechnology has received more attention and popularity than the old methods. Dyes are un-favourable in drinking water not only because of their appearance but also as dangerous as the origin of their production of Trihalomethane.

Trihalomethane combined with chlorine forms chloroform and other harmful and carcinogenic halogen compounds. The dye in natural water changes the physical properties and quality of water after the decomposition of these acids due to the presence of mineral acids. Most common water treatment methods are not able to separate the above materials, but with the use of nano-membranes, up to 99% of such materials can be easily separated from the water. Research has also shown that the use of nanotechnology in water treatment can greatly reduce treatment costs. One of the most important issues is the entry of outgoing fluids into the textile industry. There are more than ten thousand different types of synthetic dyes that are produced annually and are widely used in various industries. Therefore, their effluent contains significant amounts of pigmented organic compounds. The presence of organic dyes in industrial effluents causes irreparable damage to the environment due to the prevention of light penetration into the water and disruption of photosynthesis and their toxic effects. Therefore, treatment of collared effluents is necessary before discharging them to the environment. Removal of dyes and reduction of their concentration is done by methods such as coagulation, adsorption, oxidation processes and nano filtration [13-15]. The current study aimed at using synthesize gamma alumina nanoparticles in the laboratory as a dye adsorbent (Congo red and methylene blue). Then, by optimizing the necessary conditions, we reviewed

the kinetic and thermodynamic adsorption process. Library and Internet studies have shown that:

1- Adsorbents have been used to remove these dyes;
2- This adsorbent has been used to remove dyes [16].

Ansari et al (2018) used magnesium oxide nanoparticles coated on sawdust to remove the methylene blue pigment from the aqueous solution. The results showed that this adsorption process follows a quasi-quadratic kinetics and Freundlich adsorption isotherm model [17]. Zandipak et al (2016) examined magnetic nickel nanoparticles to remove methyl orange dye from aqueous solution. The results showed that the best pH in this process of adsorption was 2 and followed the Langmuir adsorption isotherm [18]. Moreover, Rao et al. (2016) examined Congo red dye adsorption from aqueous solution by crab shell. The maximum elimination for Congo red dye from the aqueous solution was reported to be 124.9 mg/g according to the Langmuir nonlinear isotherm [19-21].

Given the water crisis, it is very important to remove dye from the sewage of related industries. Dyes, with their ability to absorb UV and visible rays, are one of the most important groups of biodegradable chemicals. The presence of dyes in industrial wastewater if not treated by a suitable system, pollutes water resources and reduces the quality of and groundwater due to the solubility and high stability of dyes in water. The presence of textile industry wastewater causes the formation of sludge layers containing fibres. Pigments in wastewater interfere with biological treatment due to their very low biodegradability. Some of their salt compounds are toxic and carcinogenic. Various methods have been used to remove dyes from industrial wastewater, each of which has problems such as cost, sludge, and so on. The current experimental study aimed at examining a non-toxic, affordable way with high contact synthetic adsorbent [22].

Material and methods

This experiment was conducted in the laboratory of Islamic Azad University of Kazerun in 2019. Having examined library and internet contents, we collected the necessary data for calculating the functions and variables in the laboratory by performing the necessary experiments. The current study used gamma alumina nanoparticles as adsorbents. The amount of 30 g of aluminum nitrate salt dissolved in 50 cc of distilled water, and then ammonia was added drop by drop to this solution. Then the solution was stirred with a glass mixer until the pH reached 9 and produced a milky gel. In the next step, the gel was kept at room temperature for a day to reduce the humidity, and then left in the oven for 24 hours to dry at 100 degrees. Finally, it was placed in a furnace at 600 °C for 4 hours to produce gamma alumina nanoparticles. To determine the maximum wavelength of the Congo red and the standard concentration range for this dye, we prepared a sample of 5 mg per liter of Congo red to determine its maximum wavelength in the spectral range of 200 to 800 nm. We reported a maximum wavelength of 498.

Result and Discussions

The optimal pH conditions of contact time, adsorption mass, temperature, and suitable adsorption isotherm in optimal conditions for several dyes concentrations were determined. Finally, the kinetics of the adsorption process and its mechanism studied and the thermodynamic functions of adsorption were calculated [23-25].

In this research work, we intended to synthesize gamma alumina nanoparticles in a laboratory and use them as adsorbents for Congo red and methylene blue dyes. Then, we optimized the absorption process by optimizing the necessary conditions for kinetic and thermodynamic study.

Effect of pH changes on Congo red adsorption on gamma alumina

The results of the effect of changes in the pH of the solution on the adsorption rate of Congo red in 50 ml of dye at a concentration of 6 mg/l are shown in Table 1 and Figure 1.

Table 1: Effect of pH changes on Congo red adsorption on gamma alumina (t = 40, T = 298 K, m = 0.01 gr)

PH	2	4	6	8	10
Adsorption (%)	47.16	53.51	59.32	47.97	38.37

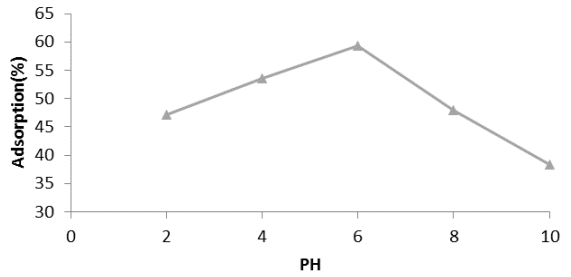

Figure 1: Effect of pH changes on Congo red adsorption on gamma alumina

The results showed that the best pH was six.

The effect of adsorbent changes on Congo red adsorption on gamma alumina

The data obtained to determine the optimal amount of Congo red adsorbent for the purpose of adsorption with a concentration of 6 mg/l are shown in Table 2 and Figure 2.

Table 2: Effect of adsorbent value changes on adsorption under conditions (PH = 6, t = 40 min, T = 298 K)

Adsorbent (g)	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**
Adsorption (%)	59.32	60.94	68.51	75.67	70.40	68.64	64.68

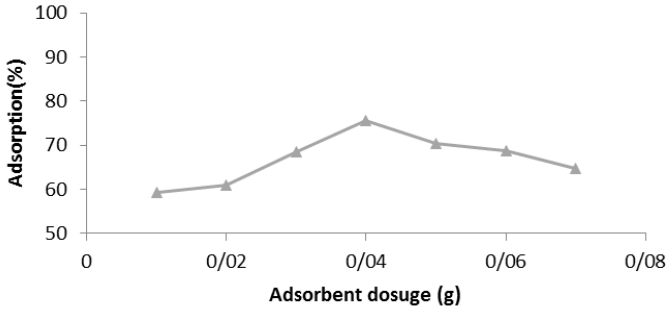

Figure 2: Effect of adsorbent value changes on adsorption

The results showed that the change for adsorbent caused changes in the rate of adsorption because with increasing the adsorbent value, the number of available adsorption sites increased and so did the adsorption efficiency for adsorption of the dye (The optimal absorber gram was 0.04 gr) [26-28].

The effect of temperature changes on Congo red adsorption on gamma alumina

The results of the effect of temperature changes on the rate of adsorption of Congo red in 50 ml of dye at a concentration of 6 mg/l are shown in Table 3 and Figure 3.

Table 3: Effect of temperature changes on adsorption (t= 40 min, m=0.04 gr, and PH: 6)

Temperature (K)	**298**	**308**	**318**	**328**	**338**
Adsorption (%)	75.68	75	74.16	73.33	**72.66**

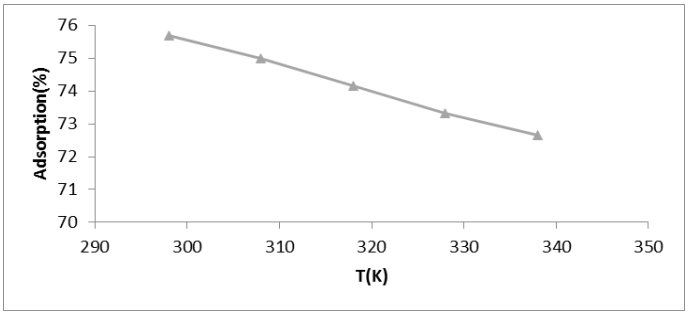

Figure 3: Effect of temperature changes on adsorption

The effect of time changes on Congo red adsorption on gamma alumina

The results of the effect of time changes on the rate of adsorption of Congo red in 50 ml of dye at a concentration of 6 mg/l are illustrated in Table 4 and Figure 4.

Table 4: The effect of time changes on adsorption (T = 298 K, m = 0.04 gr, PH = 6)

Time (min)	**10**	**20**	**30**	**40**	**50**	**60**
Adsorption (%)	43.11	71.89	75.13	75.67	75.67	75.67

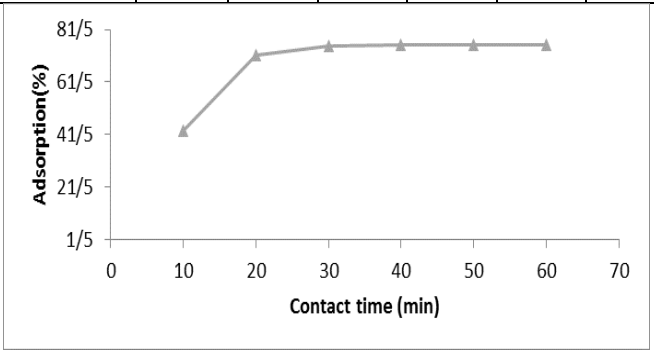

Figure 4: Effect of time changes on adsorption

Examine Congo red Langmuir, Freundlich, and Temkin isotherms diagrams

Table 5: Equations of Langmuir, Freundlich, and Temkin

Langmuir	Freundlich	Temkin
$\frac{1}{q_e}=\frac{1}{K_L q_m}(\frac{1}{C_e})+\frac{1}{q_m}$	$\ln q_e=\ln K_F+\frac{1}{n}(\ln C_e)$	$q_e=B_T \ln A_T+B_T(\ln C_e)$

C_e (mg L^{-1}) is the concentration at equilibrium, q_e (mg.g^{-1}) is the amount adsorbed at equilibrium, q_m (mg.g^{-1}) is the maximum quantity adsorbed and K_L (L.mg^{-1}) is the Langmuir (Table 5).

K_F and n are experimental constant Freundlich isotherm. B_T and A_T are constant Temkin isotherms. We used Congo red under optimal conditions (pH, amount of adsorbent, time and temperature) solutions with different concentrations. Figures 5, 6 and 7 and Table **6** of Langmuir, Freundlich, and Temkin isotherms are presented as follows:

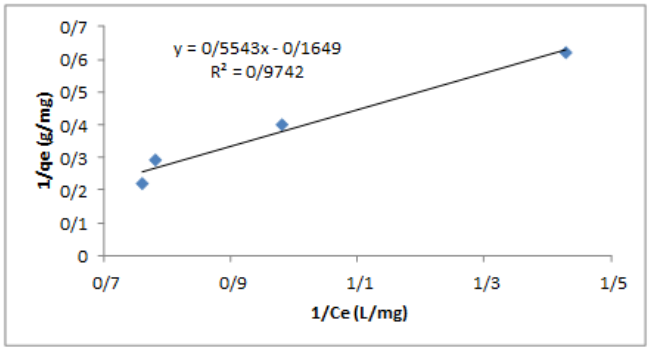

Figure 5: Congo red adsorption Langmuir isotherm

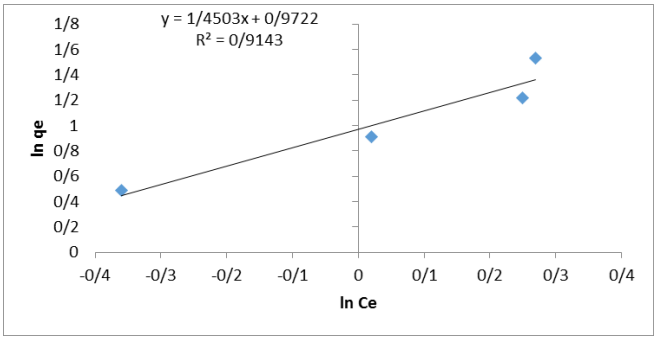

Figure 6: Congo red adsorption Freundlich isotherm

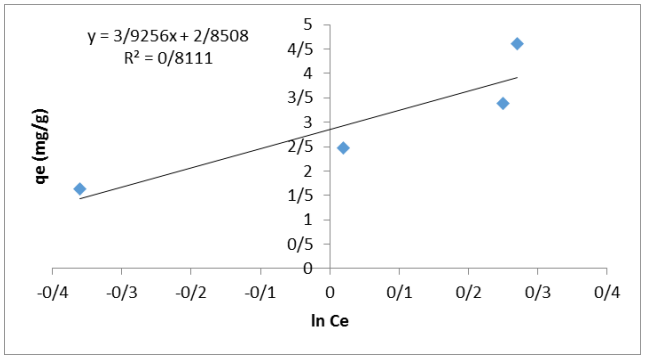

Figure 7: Congo red adsorption Temkin isotherm

Table 6: Langmuir, Freundlich and Temkin isotherm constants for adsorption of CR dye on gamma alumina (t=40 min, m=0.04 gr, pH=6, T=298 K)

Isotherm model	parameter	Parameter value
Langmuir	q_m (mg/g)	6.06
	K_L(L/mg)	0.30
	R^2	0.9742
Freundlich	n	0.69
	K_F(L/mg)	2.64
	R^2	0.9143
Temkin	A_T (Lm/g)	2.07
	B_T (J/mol)	3.93
	R^2	0.8111

Comparing the quadratic power of different isotherms, we can say that the Congo red absorption well follows the Langmuir isotherm.

Concord thermodynamic diagram

According to the following relationship and drawing Ln K_0 diagram in terms of 1/T, ΔH ads and ΔS ads can calculate with a good approximation.

$$\ln K_0=\frac{\Delta S_{ads}}{R}-\frac{\Delta H_{ads}}{R}(\frac{1}{T})$$

Adsorption of Congo red solution with a concentration of 50 mg / l under optimal conditions of temperature, time, adsorbent mass and pH at different temperatures was used to obtain thermodynamic values. Then, the values of K_0 and G Δ were calculated. The LnK_0 diagram was also drawn. According to the slope and width from the origin, we obtained the graph of ΔH and ΔS. The results are as Figure 8:

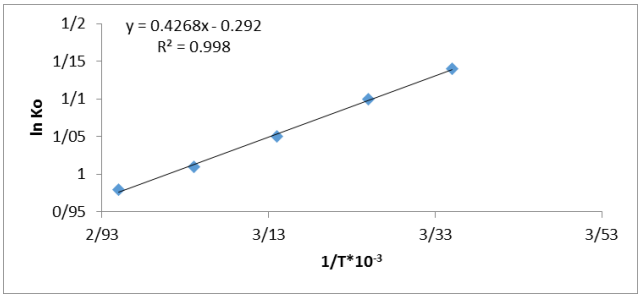

Figure 8: Congo red thermodynamic diagram

Table 7: Thermodynamic parameters for adsorption of CR dye on gamma alumina (t=40 min, m=0.04 gr, pH=6)

T(K)	LnK	ΔG_{ads}(J.mol^{-1})	ΔH_{ads}(J.mol^{-1})	ΔS_{ads}(J.mol^{-1}K^{-1})
298	1.14	-2812.58		
308	1.10	-2813.23		
318	1.05	-2787.42		
328	1.01	-2758.17	-3.55	-2.43
338	098	-2746.74		

According to the negative value of ΔG and ΔH, adsorption of CR dye on gamma alumina is spontaneous and exothermic (Table 7).

Examine Congo red Kinetic

Table 8: Equations of kinetic models

pseudo first order	pseudo second order	Elovich
$\log(q_{e/\exp} - q_t) = \log q_{e/cal} - \frac{K_1}{2.303}(t)$	$\frac{t}{q_t} = \frac{1}{K_2 q_{e/cal}^2} + \frac{1}{q_{e/cal}}(t)$	$q_t = \frac{1}{\beta}\ln\alpha\beta + \frac{1}{\beta}(\ln\ t)$

Where K_1 is the rate constant of the pseudo first order adsorption (min^{-1}), K_2 is the rate constant of the pseudo second order adsorption (gmg^{-1}min^{-1}), q_e and q_t are the number of days adsorbed (mg g^{-1}) at equilibrium and at time t (min) respectively. α (g.mg^{-1} time^{-1}) is the initial rate of surface adsorption as a constant and β (g mg^{-1}) is constant and absorbable in Elovich model (Table 8) [19].

Kinetic diagrams

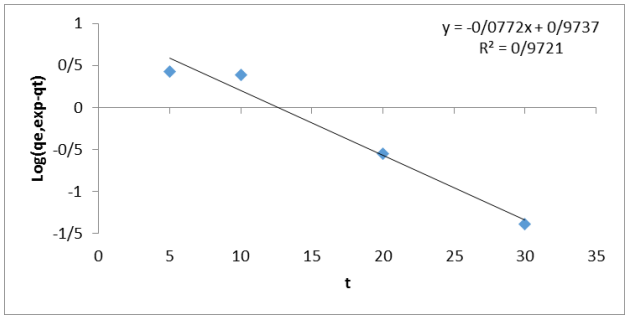

Figure 9: Congo red quasi-first order kinetic adsorption model diagram

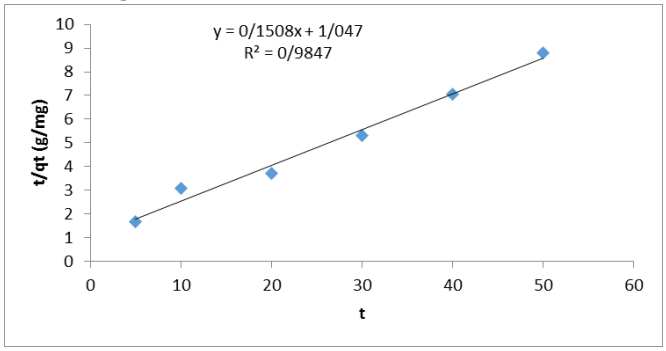

Figure 10: Congo red Quasi-second order kinetic adsorption model diagram

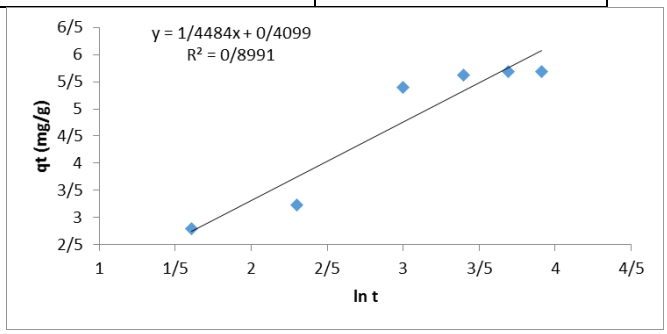

Figure 11: Congo red Elovich kinetic adsorption model diagram

Table 9: Results of kinetic model adsorption parameters of CR (C_0=6 mg/l, m=0.04, pH=6, T=298 K)

kinetic model	parameters	value
Quasi-first order	$q_{e,cal}$ (mg/g)	9.41
	K_1 (min^{-1})	0.20
	R^2	0.9721
Quasi-second order	$q_{e,cal}$ (mg/g)	6.63
	K_2 (mg/g min)	0.02
	R^2	0.9847
Elovich	α (mg/g min)	1.92
	β (mg/g)	0.69
	R^2	0.8991

The results showed that adsorption of CR dye on gamma alumina followed the quasi-second order model well (Figures 9, 10 and 11, Table 9).

Methylene blue dye

To determine the maximum methylene blue wavelength and standard concentration range for this dye, we prepared a sample of 5 mg/l methylene blue solution to determine its maximum wavelength

in the spectral range of 400 to 800 nm. We reported the maximum wavelength of this dye as 664 nm.

Effect of pH changes on methylene blue adsorption on gamma alumina

The results of the effect of changes in the pH of the solution on the adsorption rate of methylene blue at 50 ml of dye at a concentration of 5 mg/l are illustrated in Table 10 and Figure 12, under conditions of 50 ml of dye with a concentration of 5 mg/l (temperature: 298 °K, time: 40 minutes and adsorption value: 0.01 g).

Table 10: Effect of pH changes on methylene blue adsorption on gamma alumina (t=40 min, m=0.01g, T=298 K)

PH	2	4	6	8	10	12
Adsorption (%)	23.50	42.53	63.56	72.76	71.08	69.17

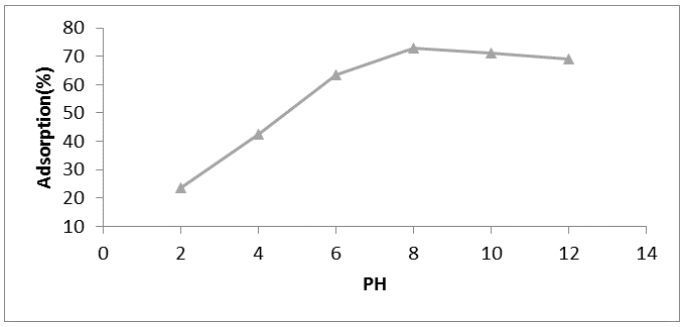

Figure 12: The effect of pH changes on methylene blue adsorption on gamma alumina the optimum pH was determined eight

The effect of adsorbent values changes on adsorption

Effect of adsorbent changes on the adsorption of 50 ml of solution with a concentration of 5 mg/l methylene blue under the following conditions was investigated (temperature: 298 °K, time: 40 minutes and pH: 8) (Figure 13, Table 11).

Table 11: The effect of adsorbent value changes on adsorption (t=40 min, pH=8, T=298 K)

Adsorbent values (g)	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
Adsorption (%)	72.76	73.95	75.03	76.58	78.25	76.94	75.63	75.63

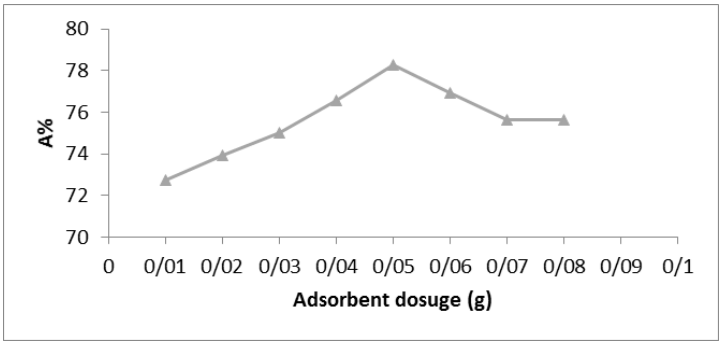

Figure 13: The effect of changes in adsorbent values on adsorption. According to the figure 13 optimal adsorbent value is 0.05 g

The effect of temperature changes on adsorption

Effect of temperature changes on the adsorption of 50 ml of solution with a concentration of 5 mg/l methylene blue under the following conditions was investigated (time: 40 minutes and adsorbent: 0.05 g and pH: 8) (Figure 14, Table 12).

Table 12: The effect of temperature changes on adsorption (t=40 min, m=0.05 gr, pH=8)

Temperature (K)	298	308	318	328	338
Adsorption (%)	78.25	76.70	74.32	71.56	69.65

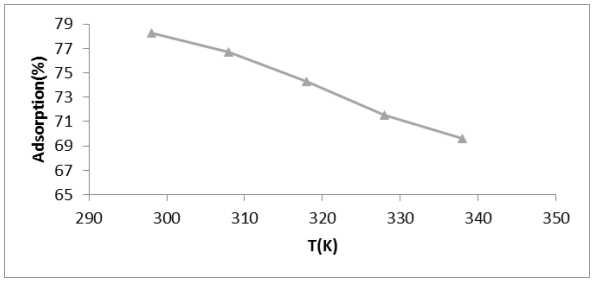

Figure 14: Effect of Temperature changes on adsorption, optimal temperature of 298 degrees

The effect of time changes on absorption

The effect of time changes on the adsorption of 50 ml of solution with a concentration of 5 mg/l methylene blue under the following conditions was investigated (temperature 298 degrees Kelvin, adsorbent value: 0.05 g and pH: 8) (Figure 15, Table 13).

Table 13. Effect of time changes on adsorption (T=298 K, m=0.05 gr, pH=8)

Time(min)	10	20	30	40	50	60
Adsorption (%)	63.80	69.41	75.98	78.25	78.25	78.25

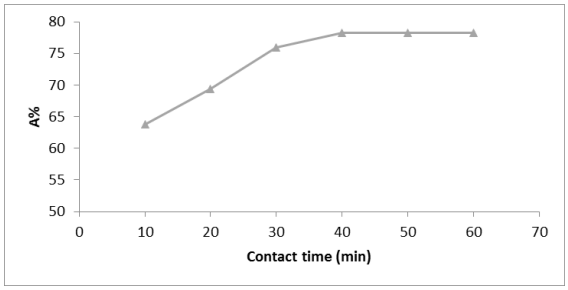

Figure 15: Effect of time changes on adsorption

Draw Methylene Blue Langmuir, Freundlich, and Temkin isotherms diagrams

Figure 16, 17 and 18 are Langmuir, Freundlich, and Temkin isotherms of MB:

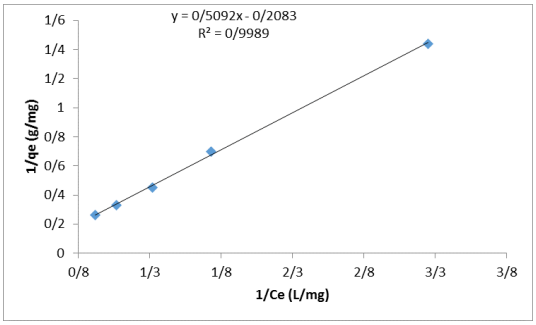

Figure 16: Methylene blue adsorption Langmuir isotherm

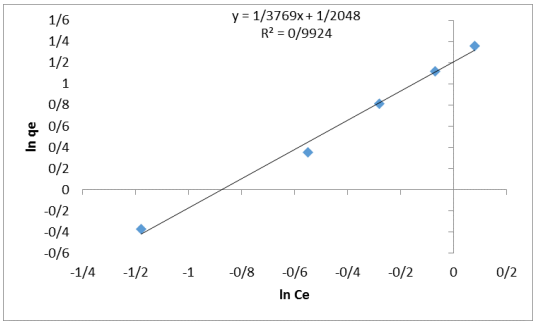

Figure 17: Methylene blue adsorption Freundlich isotherm

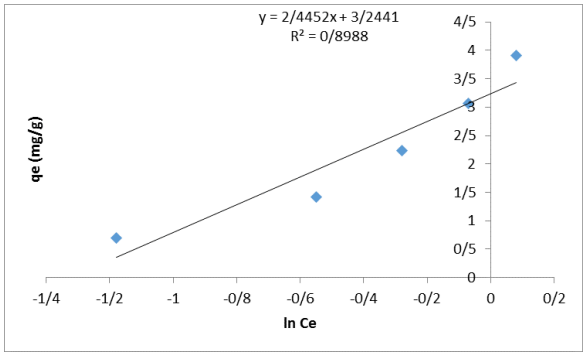

Figure 18: Methylene blue adsorption Temkin isotherm

Table 14: Langmuir, Freundlich and Temkin isotherm constants for adsorption of MB dye on gamma alumina (t=40 min, m=0.05, pH=8, T=298 K)

Isotherm model	parameter	Parameter value
Langmuir	q_m (mg/g)	4.8
	K_L(L/mg)	0.41
	R^2	0.9989
Freundlich	n	0.73
	K_F(L/mg)	3.33
	R^2	0.9924
Temkin	A_T (Lm/g)	3.77
	B_T (J/mol)	2.44
	R^2	0.8988

Comparing the quadratic power of different isotherms, we can say that the Methylene blue absorption well follows the Langmuir isotherm (Table 14).

Methylene blue Thermodynamic diagram

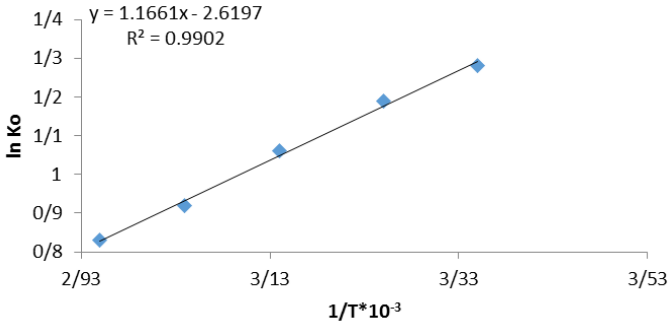

Figure 19: Methylene blue Thermodynamic diagram

Table 15: Thermodynamic parameters for adsorption of MB dye on gamma alumina (t=40 min, m=0.05, pH=8)

T(K)	LnK	ΔG_{ads}(J.mol^{-1})	ΔH_{ads}(J.mol^{-1})	ΔS_{ads}(J.mol^{-1}K^{-1})
298	1.28	-3172.02	-9.96	-2.78
308	1.19	-3050.96		
318	1.06	-2809.54		
328	0.92	-2516.30		
338	0.83	-2334.34		

According to the negative value of ΔG and ΔH, adsorption of MB dye on gamma alumina is spontaneous and exothermic (Figure 19, Table 15).

Examine Methylene blue kinetic

Methylene blue quasi-first-order kinetic diagram (Figures 20, 21 and 22, Table 16).

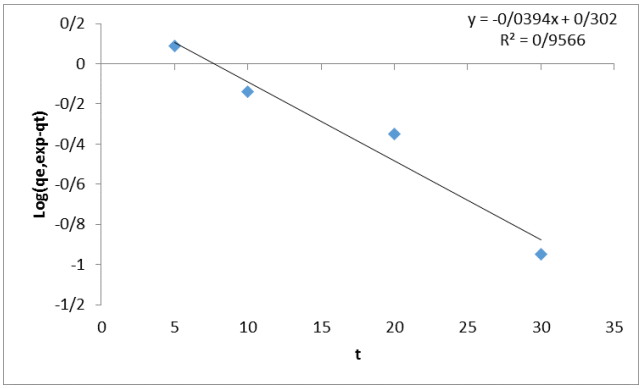

Figure 20: Methylene blue adsorption quasi-first-order kinetic model

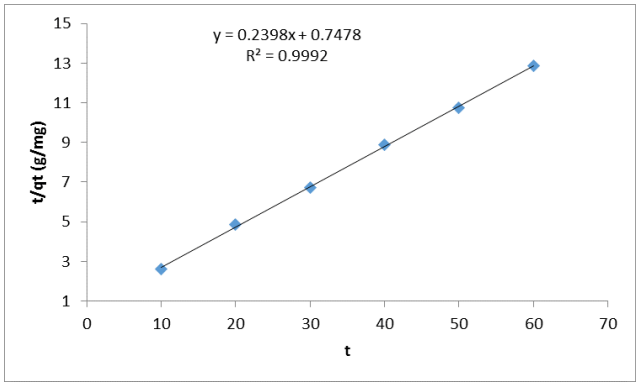

Figure 21: Methylene blue adsorption quasi-second -order kinetic model

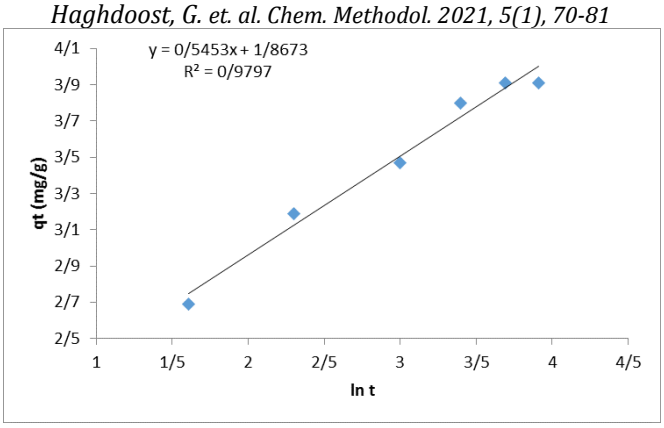

Figure 22: Methylene blue Alovich Kinetic model

Table 16. Results of kinetic model adsorption parameters of MB (C_0=5 mg/l, m=0.05, pH=8, T=298 K)

kinetic model	parameters	value
Quasi-first order	$q_{e,cal}$ (mg/g)	2.00
	K_1 (min^{-1})	0.09
	R^2	0.9566
Quasi-second order	$q_{e,cal}$ (mg/g)	4.20
	K_2 (mg/g min)	0.08
	R^2	0.9992
Elovich	α (mg/g min)	16.74
	β (mg/g)	1.83
	R^2	0.9797

The results showed that adsorption of MB dye on gamma alumina followed the quasi-second order model well [21-22].

The results showed that gamma alumina nanoparticles were a good adsorbent for dye removal from aqueous solutions. PH was a very important parameter in increasing the adsorption efficiency. Therefore, methylene blue dye had the highest amount of dye absorption at the basal pH. The rate of absorption increased by increasing pH. This increase in adsorption with increasing amount of ambient hydroxide ions (alkaline pH), was the outcome of changes in adsorbent charge and ionization rate of pigments in solution. Experiments showed pH=8 and pH=6 were considered for methylene blue and Congo red dyes, respectively. Increase in PH caused Anion adsorbent charge and the adsorbent got hydroxyl functional groups. In this case, the strong gravity force forms between the adsorbent (negatively charged) and the methylene blue dye molecule (positively charged) happened. This maximum electrostatic gravity caused more favorable absorption of pollutants on the adsorbent particles than acidic conditions (Strong repulsive force).

These results are consistent with that of Yan Hui et al. (2013). They studied the methylene blue dye adsorption with three carbon adsorbents (Activated carbon, graph oxide and carbon nanotubes) and reported methylene dye removal efficiency increased with increasing PH from 5 to 9. Hejazifar et al. (2012) and Ozer et al. (2013) reported the use of activated carbon produced from the bark of the grape tree and activated carbon produced from Hazelnut peel to eliminate methylene blue dye, respectively.

Similar results were reported by Solak et al. (2007). The researchers concluded that by increasing the PH in the range of 4-10, the dye absorption rate increases ranged from 13.9 to 15.28 mg/g.

Contact time is one of the most important parameters in absorption processes. In reactions based on the absorption of pollutants, an optimal contact time can obtain or set a balance time for the desired reaction. Equilibrium time is the time when the amount of pollutant absorption reaches a

constant value and if the process contact time is too long, it will not be economically viable since the amount of absorption is very small [23-26].

The current study showed that the efficiency of the process increases with increasing contact time, and the in contact time of 40 minutes the absorption rate of 40 mg / g reached equilibrium. Ozer et al., (2013) reported the equilibrium time to remove methylene blue dye using active carbon produced of hazelnut shells to be 2 hours [27-29].

Shokoohi et al., examined the efficiency of activated carbon prepared from cypress tree in dye removal and determined that with increasing contact time, the dye removal efficiency increased and reached equilibrium at the contact time of 90 minutes. In the current inquiry, equilibrium time observed was 40 minutes. This indicates higher efficiency of nanoparticles [30-31].

Conclusion

The amount of dye absorbed in the unit of adsorbent mass reduced by increasing the adsorbent dose, though the amount of dye remaining decreased with increasing adsorbent dose. With increasing the adsorbent dose, the amount of adsorption, pollutants reduced per unit mass of adsorbent due to the unsaturation of some active sites of the adsorbent target. This has reduced intra-particle emission. These results are consistent with that of Baraka et al. (2011) and Kumar et al (2007). The current paper showed that tannins of gamma alumina particles are effective in removing methylene blue cationic dye from contaminates effluents of textile and dyeing. The adsorption process of methylene blue with this type of adsorbent is strongly influenced by the PH of the solution and at basal PH s the absorption rate increases. The absorption process reaches equilibrium after about 30 minutes with the gamma alumina nanoparticles amount of dye absorption was 40 mg /g. According to the number R_2, the adsorption kinetics of Congo red and Methylene blue on the gamma-alumina adsorbent follows the quasi-quadratic kinetic model. In addition, the high value of the width of the origin in this model indicates the predominance of adsorption compared with infiltration within a particle. The general results of the research showed that the adsorption of methylene blue dye using this adsorbent was fast and its adsorption capacity was also at a desirable level, thermodynamically the adsorption of both dyes was exothermic, and with increasing temperature, the adsorption of dyes by the adsorbent decreased. The reason is that the thermal chemical method was used to prepare gamma alumina nanoparticles. Therefore, the use of heat furnaces produces acidic gases and may be detrimental to health, so more caution needs to be taken.

Conflict of Interest

We have no conflicts of interest to disclose.

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