

# Removal of Maxilon Red GRL from aqueous solutions by adsorption onto silica

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**Abstract :** The adsorption of basic dyes ( maxilon red GRL) from an aqueous solutions by silica was investigated. Adsorption of maxilon red (GRL) onto silica samples was studied by batch adsorption techniques at  $24 \pm 1$  °C. The adsorption behavior of maxilon red (GRL) on silica samples was investigated using a Uv-vis spectrophotometric technique. In batch system, the effect of five different initial dye concentrations and using six different times on adsorption was evaluated. Values of the removal efficiency of the dye ranged from 47.7 to 96%. The equilibrium adsorption isotherms have been studied by Langmuir and Freundlich models. The experimental results have been fitted Langmuir and Freundlich models. Langmuir adsorption capacity,  $q_m$ , was found to be 3.03 mg/ g silica at  $24 \pm 1$  °C. Also, initial concentrations and the equilibrium concentration of dye solutions were subjected to a comprehensive colorimetric appraisal using the CIE  $L^*a^*b^*$  colour space system.

**Keywords:** Adsorption; Silica; Basic dyes; Decolorization; colour space; Adsorption isotherms

## 1. Introduction

Many Industries use dyes and pigments to color their products. The dye used this study is Maxilon Red GRL that are widely used in acrylic, nylon and wool dyeing. and their discharge waste waters from these industries into river water make the water inhibitory to aquatic life and causing visible pollution. Dyes have a tendency to sequester metals, so causing microtoxicity to fish and other aquatic organisms. Therefore the removal of dyes from waste streams before discharge to public water sources is of primary concern<sup>1</sup>.

Dyes have a tendency to sequester metals, so causing microtoxicity to fish and other aquatic organisms. Therefore the removal of dyes from waste streams before discharge to public water sources is of primary concern<sup>2</sup>. Many workers have investigated the fate of textile dyes in the activated sludge process and reported that adsorption is the main process for the partial or decolorisation of wastewater containing dyes<sup>3</sup>.

Many techniques has been found for removal of dye-containing wastewater such as chemical oxidation, membrane filtration, biodegradability, separation and adsorption techniques<sup>4</sup>. Many workers have been made to find alternative sorbents particularly for the sorption of basic dyes, such as activated carbon, unburned carbon<sup>3,4</sup>,

silica bentonite<sup>6</sup> natural adsorbents such as orange peel<sup>7</sup> palm fruit bunch<sup>8</sup> teak wood bark, cotton waste, rice husk<sup>2</sup> sugar cane dust<sup>9</sup>, chitin<sup>10</sup>, fly ash<sup>11</sup>, clay<sup>12</sup>, chitosan<sup>13</sup> and others<sup>14,15,16,17,18,19</sup> have been extensively used as adsorbents.

Silica synthesised by the sol- gel technique plays the role of selective adsorbent of organic dyes<sup>20,21</sup>. The carrier formed in this way is highly uniform and first of all, contains spherical particles of low dimensions (100-500nm). Applying a high pressure technique<sup>22</sup> silicas formed by precipitation from aqueous solutions of alkali metal silicates provide an alternative to SiO<sub>2</sub> carriers obtained by the sol- gel technique<sup>23</sup>. The silica used in this study that owing to its high surface area, fast adsorption kinetics and chemical stability under acidic conditions

## 2. Experimental technique

### 2.1. Materials

Silica was purchased from silikagel pro.Tenk.Chro. sklo union k.p. and the dye in this study is basic dye obtained from a textile firm in Turkey.

**Table 1. Chemical composition of silica used**

Chemical composition	Content %
P <sup>H</sup>	6-7
Cl	0.03
SO <sub>4</sub>	0.02
Fe	0.02
Maximum water content	10.0
SHF as Sulphate	0.05
Capacity (H <sub>2</sub> O)	71.0

## 2.2 Batch experiments

Batch adsorption experiments were carried out at  $24 \pm 1$  °C in conical flasks (250ml) using shaken at 140rpm on a rotary shaker. The stock solution of maxilon red (100ml) was prepared and suitably diluted to the required initial concentrations (5-80mg/L). The silica (0.1g) was added into 20ml dye solutions. The data for deriving the Langmuir constants were obtained by using silica (0.1g) and dye concentrations of 5,10,20,40 and 80 mg/l. After the dye solution was separated from adsorbent and centrifuged at 6000 rpm for 20min. The final equilibrium concentrations were measured spectrophotometrically at 537nm using a Specord 40 analytik jena AG. The percentage removal of dye and amount adsorbed (mg/g) were calculated using the following relationships

$$\text{Percentage removal (\%)} = (C_o - C_e) / C_o \times 100 \quad (1)$$

$$\text{Amount adsorbed } q_e = \frac{C_o - C_e}{m} V \quad (2)$$

Where  $C_o$  and  $C_e$  are the initial and equilibrium concentration (mg/L), respectively, and  $m$  is the amount of adsorbent and  $V$  is the volume of solution.

The colorimetric data of the obtained dye solutions were documented using an instrumented colorimeter using a spectrophotometer CM-3600d. Adsorbed dye concentrations were poured into the measurement cup. The instrument provided the colour in the terms of the CIE  $L^* a^* b^*$  colour space system. In this colour space,  $L^*$  represented the lightness (or brightness),  $a^*$  and  $b^*$  were colour coordinates, where  $+ a^*$  was the red direction,  $- a^*$  was the green direction  $+ b^*$  was the yellow direction, and  $- b^*$  was the blue direction<sup>12,13</sup>

## 3. Results and discussion

### 3.1. Colorimetric properties

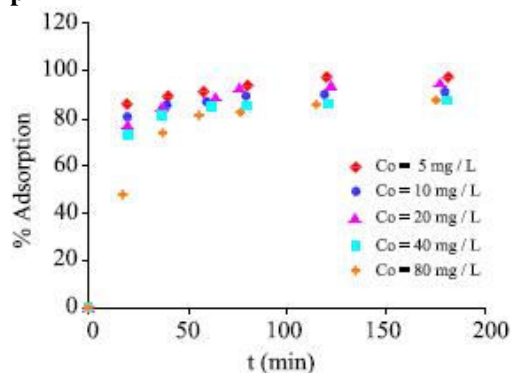
Colorimetric studies, performed in the CIE  $L^* a^* b^*$  colour space system, permitted to obtaining data on changes input of individual colours following adsorption of maxilon Red GRL onto silica (Table 1-5), and clearly increased value of lightness ( $L^*$ ) was reported. Increasing amounts of the adsorbed dye were paralleled also by an evident removal in colour of aqueous solution. Studies on adsorption of maxilon red was found by an evident change in participation of red ( $+ a^*$ ) and green ( $- a^*$ ), and yellow ( $+ b^*$ ) and blue ( $- b^*$ ) colours. With increasing adsorption of maxilon red evidently increased parameter of lightness ( $L^*$ ) and decreased parameter of  $a^*$  and  $b^*$  were reported. Indicating that adsorption process is favorable for silica adsorbents. Besides, the results of colorimetric studies indicate that the rate of color removal increased according to contact time and for dilute initial concentration, but the rate of color removal in aqueous solution is decreased according to strong initial concentration. The results are displayed in Table. 1-5

### 3.2. Effect of initial dye concentrations

The adsorption of dye by silica was studied at several different initial concentrations and different time. Initial maxilon red concentrations ranging from 5 to 80 mg/L. The results are displayed in fig.1.

The results indicate that rate of color removal increased depending on the contact time and initial dye concentrations. For silica adsorbents, decolorization of dye is speedy in the first 20 min. Then the rate of adsorption was became slowed. When the initial dye concentration was increased, adsorption efficiency decreased for same adsorbent dose. As can be seen in fig. 1 when the initial dye concentration was increased, adsorption efficiency decreased. Values of the removal efficiency of the dye ranged from 47.7 to 96 %.

**Fig. 1. Effect of contact time and initial dye concentration on dye removal. Silica dose 0.1 mg natural initial P<sup>H</sup> at  $24 \pm 1$  °C agitation speed 140 rpm**



### 3.3. Adsorption isotherms

The adsorption equilibrium data of Maxilon Red GRL onto silica were arranged to the Langmuir and Freundlich isotherm forms. Langmuir and Freundlich models has written the form as follows (Marungrueng and Pavasant, 2007)

$$q_e = \frac{q_m b C_e}{1 + b C_e} \quad (3)$$

$$q_e = K_f C_e^{1/n} \quad (4)$$

Where  $q_m$ ,  $b$ ,  $C_e$ ,  $K_f$  and  $n$  representing the maximum amount of dye uptaken per unit mass of the sorbent, Langmuir constant and equilibrium concentration of the in the solution,  $K_f$  and  $n$  Freundlich constants, respectively.

Where Eqs.(3) and (4) were linearized, which has the form as follows

$$\frac{1}{q_e} = \frac{1}{q_m} + \left(\frac{1}{b q_m}\right) \left(\frac{1}{C_e}\right) \quad (5)$$

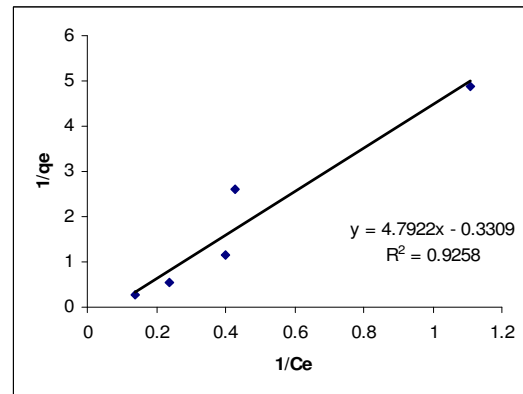
$$\text{Log } q_e = \text{log}K + 1/n \text{ log } C_e \quad (6)$$

Plot  $1/q_e$  vs.  $1/C_e$  for Maxilon blue GRL, from the slope of line,  $q_m$  and from the y- intercept of the line  $b$  isotherms values have been calculated. Fig.2-3 clearly shows that the Langmuir and freundlich model can describe the experimental data. The finding suggested that the sorption of Maxilon red onto silica was monolayer coverage. The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless constant separation factor or equilibrium parameter  $R_L$ , which is defined by Nassar and Magdy (Nassar and Magdy, 1997), ( Eren and Acar, 2006) as

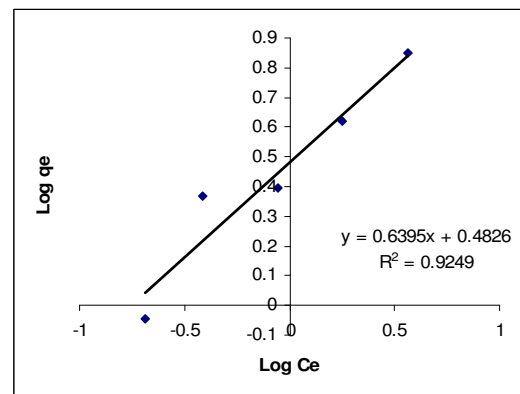
$$R_L = 1 / (1 + b C_0) \quad (7)$$

The  $R_L$  values (Eq. (7)) dictate favorable adsorption for  $0 < R_L < 1$  ( Nassar and Magdy, 1997), ( Eren and Acar, 2006). The data in table 6 show that the  $R_L$  values ranged between 0.746 and 0.155 indicating that silica is favorable for Maxilon Red dye. Similarly, from the of linear correlation between the alues  $\text{log } q_e$  and  $\text{log } C_e$ , Freundlich constants ( $K_f$  and  $n$ ) have been calculated. The parameters  $K_f$  and  $n$  for listed in table. 6. Parameters of Langmuir and Freundlich model constants are shown in table 6. The results display that the Langmuir and Freundlich isotherms are fit for adsorption of Maxilon red onto silica.

**Fig. 2. Langmuir plots corresponding to the adsorption of maxilon red dye onto silica**



**Fig. 3. Freundlich plots corresponding to the adsorption of maxilon red dye onto silica**



As shown in table .6. Where  $q_m$  is a parameter related to the Langmuir adsorption capacity and parameter  $b$  Langmuir constant and  $R^2$  Correlation coefficient, similarly,  $K_f$  is a parameter related to the Freundlich adsorption capacity and  $n$  Freundlich constant. This shows that the adsorption isotherm and models fit by Freundlich and Langmuir equation are depicted.

### 4. Conclusions

This study shows that the silica is a potential adsorbent for Maxilon Red removal in aqueous solutions. In addition, it is a locally available low-cost adsorbent in Turkey. Colorimetric studies, performed in the CIE  $L^* a^* b$  system, evidently increased parameter of lightness ( $L^*$ ) was indicated.

For the adsorption equilibrium, it was found that Langmuir and Freundlich models were fitted. The monolayer adsorption capacity of silica was found to be 3.03mg/g

**Table 2. Colorimetric data for the initial (5ppm) and equilibrium concentration of dye solutions**

	Concentration	Time	Colorimetric data		
			$L^*$	$a^*$	$b^*$
Initial concentration	5 ppm		20.79	20.08	-4.69
Equilibrium concentration of dye solutions	5 ppm	20	45.35	2.13	-0.61
	5 ppm	40	47.21	1.58	-1,38
	5 ppm	60	47.10	2.02	-1.45
	5 ppm	80	40.68	1.56	-0.31
	5 ppm	120	42.30	0.63	-2.29
	5 ppm	180	42,20	0.55	-2,31

**Table 3. Colorimetric data for the initial (10ppm) and equilibrium concentration of dye solutions**

	Concentration	Time	Colorimetric data		
			$L^*$	$a^*$	$b^*$
Initial concentration	10 ppm		17.57	29.27	-3.77
Equilibrium concentration of dye solutions	10 ppm	20	45.35	2.13	-0.61
	10 ppm	40	42.64	4.49	-1,35
	10 ppm	60	43.38	0.78	-2.08
	10 ppm	80	42.69	4.44	-2.07
	10 ppm	120	43.43	4.13	-2.29
	10 ppm	180	44.16	1.07	0.68

**Table 4. Colorimetric data for the initial (20ppm) and equilibrium concentration of dye solutions**

	Concentration	Time	Colorimetric data		
			$L^*$	$a^*$	$b^*$
Initial concentration	20 ppm		21.76	39.77	2.54
Equilibrium concentration of dye solutions	20 ppm	20	39.23	14.81	-2.90
	20 ppm	40	45.02	5.47	-0,89
	20 ppm	60	42.75	8.81	-2.41
	20 ppm	80	40.14	12.08	-2.39
	20 ppm	120	40.63	11.45	-2.23
	20 ppm	180	44.57	1.84	1.32

**Table 5. Colorimetric data for the initial (40ppm) and equilibrium concentration of dye solutions**

	Concentration	Time	Colorimetric data		
			$L^*$	$a^*$	$b^*$
Initial concentration	40 ppm		17.92	34.02	8.05
Equilibrium concentration of dye solutions	40 ppm	20	44.03	5.78	-2.27
	40 ppm	40	33.39	1.55	-1.89
	40 ppm	60	34.76	22.91	-0.49
	40 ppm	80	37.80	15.60	-1.36
	40 ppm	120	34.98	19.34	-1.05
	40 ppm	180	42.36	4.13	0.94

**Table 6. Colorimetric data for the initial (80ppm) and equilibrium concentration of dye solutions**

	Concentration	Time	Colorimetric data		
			$L^*$	$a^*$	$b^*$
Initial concentration	80 ppm		23.39	41.31	25.9
Equilibrium concentration of dye solutions	80 ppm	20	38.04	20.71	2.26
	80 ppm	40	37.04	19.67	1.32
	80 ppm	60	31.81	23.67	2.86
	80 ppm	80	33.83	23.94	1.61
	80 ppm	120	37.80	16.27	-0.83
	80 ppm	180	39.00	9.50	2.19

**Table 7. Langmuir and Freundlich constants for Maxilon Red dye**

	Langmuir model				Freundlich model			
	$q_m$ mg/g	$b_{L/mg}$	$R^2$	$R_L$	$C_o$ , mg/L	$n$	$K_f$ L/g	$R^2$
Maxilon Red	3.03	0.068	0.92	0.746	5	1.563	0.486	0.92
				0.595	10			
				0.423	20			
				0.268	40			
				0.155	80			

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