Removal of acidic Yellow Dye of wastewater by Moringa Peregrina

Negar Saraei¹*, Mostafa Tizghadam Ghazani²

Abstract

Industrial textile treatment is one of the most important and complex parts of wastewater treatment. Absorption is considered a desirable method in separating pollutants and dyes from water. In this study, the effectiveness of Moringa Peregrina seeds as a natural, non-toxic, and environment-friendly adsorbent in the treatment of colored wastewater has been investigated. First, the isotherm model and absorption kinetics were investigated, and then influential variables such as major and minor factors in the absorption process were identified. During the experiment, the amount of dye removal efficiency was measured by a spectrophotometer. Optimization of three important factors including color concentration, pH, and adsorbent dosage was done using the design of the composite central method, the response surface in the Design-Expert software. The optimal model for describing the adsorption process, the Freundlich and the pseudo-second-order model are obtained as a result and the adsorption capacity of moringa peregrina is 22.85 mg / g. In the end, code 19 acidic yellow dye with a concentration of 250 mg/L, pH=8, and adsorbent in the amount of 0.875 g was purified to 80% of an aqueous solution. The results were obtained under constant conditions with a mixing speed of 200 rpm and a duration of 60 minutes with a reliability of 0.93. According to the test results, on average, Moringa Peregrina is effective in removing pigments from aqueous solutions under the mentioned conditions.

¹ M.Sc. Candidate, Faculty of Civil, Water and Environmental Engineering, Shahid Beheshti University, Tehran, Iran. Email: saraeinegar@gmail.com
² Assistant Professor, Faculty of Civil, Water and Environmental Engineering, Shahid Beheshti University, Tehran, Iran. Email: mtizghadam@gmail.com
1. Introduction

Throughout the world, there are 100,000 different forms of dye exceeding the one million tons annual production limit (Tunc, Tanacı et al. 2009). Millions of liters of colored effluent are produced daily by the dyeing industry and associated factories. Each liter of these colored effluents has indestructible materials that cause environmental problems if not treated before discharge (Sismanoglu, Kismir et al. 2010).

Removing dyes from sewage in the last decade is one of the most challenging topics for water and wastewater treatment. Colored wastewater produced by various industries, including textile, paper, rubber, and plastics, may cause significant environmental problems in the event of discharge to the environment (Sarayu and Sandhya 2012). Such dyes are human health threats because they are carcinogenic and mutagenic in nature. Besides its apparent reduction in water transparency, turbidity also constitutes a disorder in the ecosystem of the region (Aravind, George et al. 2010). Hence, the use of purified water has increased and many residents in non-urban areas are forced to prepare healthy, turbid-free water.

It is typically used to extract color from aqueous solutions such as physical, chemical, and biological processes or compliant methods. In the biological method, the contamination caused by textile wastewater is removed by the activity of microorganisms (Manai, Miladi et al. 2017). Bacillus and Aeromonas hydrophilia microorganisms in aqueous solutions decreased the concentration of dispersing blue and acidic yellow dyes to less than 1.5 mg / L for 48 hours (Sandhya, Padmavathy et al. 2005). The lack of versatility of this approach is a time for the
activity of microorganisms (Jiang, Sun et al. 2008). Nevertheless, due to high costs and how to
dispose of effluent, biological methods have not been completely accepted (Kodam, Soojhawon et
al. 2005, Bhatia, Sharma et al. 2017). Chemical methods include coagulation, flocculation,
oxidation, and ozonation, or in the form of a compilation. The drawbacks of these approaches are
usually hazardous substance formation, sludge production, and high investment costs (Chatterjee,
Lim et al. 2010). In general, membrane methods (such as nanofiltration and reverse osmosis) and
adsorption are common physical techniques. Membrane methods such as filtration systems are not
appropriate for the removal of dye since the chemical composition of the dye remains within the
microfilter product effluent (Ye, Lin et al. 2018). Adsorption, unlike membrane methods, is
efficient in eliminating sewage colors and is fairly easy to implement, and needs a small design
cost (Salmani, Ehrampoush et al. 2013).

Adsorption is an adequate alternative approach for the removal of dyes, which is the process of
transferring molecules that occurs in the accumulation of two substances in the liquid and solid
phases (De Gisi, Lofrano et al. 2016). The adsorbent may then be regenerated or stored in a dry
area without any interaction with the environment. Essentially, the process of adsorption is not
prone to poisonous compounds, but its use is limited by the high price of adsorbents.

A variety of different adsorbents are used to adsorb kinetic dyes. Surface adsorbents are classified
into two types: industrial and natural adsorbents. Industrial materials are used to a great degree
owing to excessive chemical stability, however, the origin of their production is from non-
renewable sources that are destructive to the environment (Hongjie, Jin et al. 2009). Activated
carbon as the most powerful industrial accessible adsorbent can remove wastewater pollution, but
it is not effective at reducing dispersing and vat dyes (De Gisi, Lofrano et al. 2016). Herbal products
and agricultural waste are considered to be inexpensive and environmentally friendly
adsorbents (de Andrade, Oliveira et al. 2018). Products such as rice bran and pomegranate peel have a dye removal capacity of 99% and 55% of the aqueous solution, respectively (Ahmad, Puad et al. 2014). Therefore, the usage of wastewater treatment plants tends to be rational and more affordable than industrial adsorbents.

There is a wide range of ways to measure and reduce turbidity. Water turbidity in laboratory processes is now removed by coagulation and adsorption (Aravind, George et al. 2010). For centuries villages discover that some plants like Moringa have the power to purify the opaque water. Moringa Oliefra, another branch of the Moringa plant, is a suitable coagulant for removing water turbidity (Bhuptawat, Folkard et al. 2007). In addition to coagulation, the Moringa plant is also effective in the adsorption of heavy metals (Bhatti, Mumtaz et al. 2007, Sumathi and Alagumuthu 2014). Owing to the structural similarity of Moringa Oliefra and moringa peregrina, it seems that the two functions in the field of wastewater removal are the same but in a different method (Sreelatha and Padma 2009).

Moringa Peregrina has also been observed in hot and humid areas such as Saudi Arabia, India, South Africa, and the southern provinces of Iran (Sistan and Baluchestan and Hormozgan). This plant can be found either at a height of 0 to 300 meters above sea level or higher elevations (1600 to 2200 meters above sea level) (Alfarhan, Al-Turki et al. 2005). Due to the initial presence of a xerophytic substance that helps propagate, the plant is drought resistant (AL-GOHARY and HAJAR 1996). Moringa plant is quite well known in the world mostly for benefits in the medicinal, pharmaceutical, food, and agricultural industries. This plant has a higher nutritional value than Moringa Oliefra, and its low-fat content has created a major role in healthy diets (Wangcharoen and Gomolmanee 2011). Moreover, high doses of antioxidants in plant oil activate the battle
against the free radicals in the human body and prevent cancer cells from emerging (Senthilkumar, Karuvantevida et al. 2018).

Acid yellow 19 (AC) is widely used in textile factories for the dyeing of cotton, silk, modified acrylic, and wool fibers. This pigment is called acidic due to the massive presence of sulfonic acid or carboxylic acid (Shindy 2016). Acid yellow belongs to azo clusters of pigments which are of potential concern to the environment. In most studies, acid yellow indicates satisfactory performance in research as an absorbent (Malik 2003). The Acid yellow chemical structure is shown in Fig. 1.

![Acid Yellow 19](image)

Fig. 1 Chemical structure of AC

Effects of various variables, including initial pH, adsorbent dose, initial dye concentration, and contact time, were studied and the experimental results obtained were correlated with three adsorption isotherm models, namely Langmuir, Freundlich, and BET. The optimization of initial pH, adsorbent dose, and dye concentration, as influential parameters, were carried out via Central Composite Face-Centered RSM experimental design.

2. Materials and Methods

2.1. Dyestuff
Analytical grade (Merck, Germany) of AC was described with molecular weight 601.35 g/mol and \( \lambda_{\text{max}} = 234 \, \text{nm} \). The AC\((C_{20}H_{12}C_{12}NaNa_{2}O_{7}S_{2})\) C.I no is 18967. Dye solutions with concentrations ranging from 100 to 300 mg/L were prepared for the treatment procedure. Assessments with specific pH values were performed by changing this solution to the individual pH using HCl 0.5 M and NaOH 0.5 M.

### 2.2. Preparation of adsorbent

Moringa Peregrina (MP) purchased from Fanouj, Sistan and Baluchestan, Iran, was washed and then the kernels of the seeds were removed. The seeds were sieved in powder and used as an adsorbent. In the following, the seed oil was extracted with a Soxhlet extractor machine to minimize the existing oil. After oil extraction, the adsorbent was dried in the oven for 24 hours at 60°C to reach the lowest moisture content and preserved in a locked container for re-use. Scanning electron microscopy (SEM) was used to establish the adsorbent’s structural properties. Fig 2 also shows the FTIR spectrum of adsorbents (after oil extraction). The peaks showed a composition of different groups related to adsorption characteristics.
2.3. Method

2.3.1. Batch studies for RSM experiment

Primarily, the sorption mixture consisted of pH=8 with a unique adsorbent size (mesh 30-60) was conflated at 200 rpm for 1 h under the required temperature. The pH influences study on adsorption was undertaken by adjusting the pH to values in the range 8-12. The effect of the dye concentration was accomplished with an initial concentration range of 100-300 mg / L and the effect of the adsorbent varied from 0.5-2 g.

2.3.2. Equilibrium studies for isotherm model

For determining isotherm and kinetic models, studies were conducted at 25±1°C. Five adsorbent dosages of 0.5, 1, 1.5, 2, and 2.5 g and initial dye concentrations of 100 mg/l were considered. The pH was set to the amount of 8. After mixing, a shaker operated at 200 rpm was used to rotate solutions for 1 hour. The design process was equipped UV-VIS spectrophotometer (URMIN-1240) setting at a wave-length of 234 nm to calculate the overall absorption wavelength of the final dye. After the final concentration was defined using a spectrophotometer, the volume of dye absorbed was computed using the following relationship:

$$q_e = \frac{(c_i - c_f)}{m} \times V$$

(1)

Where

$q_e$ = dye absorbed (mg dye/ g adsorbent)

$V$ = total solution volume(mL)

$c_i$, $c_f$ = initial and final dye concentration(mg/L)
m=Sum of the adsorbent applied on a dry basis (g)

Kinetic tests were carried out by stirring 1 g adsorbent with 100 mg/L of dye solution on a magnetic stirrer at 200 rpm. Samples were investigated for 10, 20, 30, 50, 60, 80, 90, 100, 120, and 180 minutes to ascertain the best contact time and the best kinetic model. The concentration of the dye was ultimately determined. This procedure was done at constant temperature and pH, 25±1°C, and 8, respectively.

2.4. Experimental design for the optimization process

According to the Central Composite Centered (CCD) specification, the optimization of the adsorption capacity was performed by three selected independent control parameters such as initial pH, adsorbent dose, initial dye concentration. The CCD option was designed by factorial experiment with two-star points and five replicates at center points. The quadratic equation model for estimating the optimum point was described according to Eq (2):

\[
Y = \beta_0 + \sum_{i=1}^{k} \beta_{ii}x_i^2 + \sum_{i=1}^{k} \sum_{j=i+1}^{k} \beta_{ij}x_i x_j + \varepsilon
\]  

(2)

Where

\( Y \) = response

\( \beta_0 \) = constant coefficient

\( \beta_{ii}, \beta_{ij}, \beta_{ij} \) = Coefficients for linear, quadratic and interaction effect

\( x_i, x_j \) = factors

\( \varepsilon \) = error
The levels and rates of the variables involved in the analysis are presented in Table 1. Thirty-three assays were conducted in parallel, according to the model. Regression and graphic interpretation of the data were done by the design Expert (version 10.0.7, Stat Ease, Inc., USA). The variation of the independent variables was demonstrated by the multiple coefficients of determination, $R^2$. Optimum conditions of the chosen variables were achieved by integrating the regression equation and evaluating the surface contour response plots (Montgomery 2017).

Table 1 Experimental range and level of independent variables

| Factors             | Range and levels |
|---------------------|------------------|
|                     | -2  | -1  | 0   | +1  | +2  |
| Dye Concentration(mg/L) | A   | 100 | 150 | 200 | 250 | 300 |
| pH                  | B   | 7   | 8   | 9   | 10  | 11  |
| Adsorbent dose(g)   | C   | 0.5 | 0.875 | 1.25 | 1.625 | 2   |

3. Results and discussions

3.1. Characteristics of the adsorbent

According to Fig. 2, the FTIR analysis results for the description of the MP are presented as following: The peak of 1052 cm$^{-1}$ can be referred to as the presence of alkyl halide, which is linked to halogens and typically has a justification for plant photosynthesis. The recorded peak at 1639 cm$^{-1}$ could confirm the $c = c$ bond and the peak 3292 cm$^{-1}$ can be attributed to free fatty acids in the sample and the presence of this functional group may indicate the ability to exchange ions in
the adsorption process. SEM test was also done which involves the use of high-energy electrons to display images of larger adsorbent surface. SEM images of MP display in Fig.3, a, and b reveal surface texture before and after oil extraction. To evaluate the extracted oil of moringa seed, SA Muyibi and the authors stated that the reduction of the water turbidity in the extracted oil sample was higher than the other samples and that it was reported to be 97.9 percent (Muyibi, Mohd. Noor et al. 2002). According to Warhurst, F (Warhurst, Fowler et al. 1997), the more porosity, the more absorption is produced to minimize turbidity. Therefore, more porosity allows permeability and absorption to increase. In picture b, a porous structure with excessive porosity that is made up of very small aggregated components can be implicated. Fig.3 a and b also indicates that the adsorbent has heterogeneous pores on the surface.

Fig. 3 SEM test result before and after oil extraction of adsorbent

3.2. Adsorption isotherm studies

Within the Langmuir model, it is assumed that there is single layer adsorption (Vijayaraghavan, Padmesh et al. 2006) and Langmuir is not the case for natural adsorbents due to their heterogeneous chemical groups. Whereas Freundlich expresses adsorption in circumstances where the adsorption
is multilayer and heterogeneous (Tu, Yu et al. 2017). Moreover, in the Langmuir model enthalpy and the energy absorption of molecules is constant. The Langmuir model can be described as:

\[ \frac{1}{q_e} = \left( \frac{1}{Q_0} \right) + \left( \frac{1}{KQ_0} \right) \left( \frac{1}{C_e} \right) \]  

(3)

where \( C_e \) is the concentration of adsorbate (mg/l) at equilibrium, \( q_e \) the amount of solute adsorbed at equilibrium (mg/g), constant \( Q_0 \) signifies the adsorption capacity (mg/g) and \( k \) (l/mg) is related to the energy of adsorption.

The Freundlich isotherm is more commonly used but does not include details about the monolayer adsorption capacity as opposed to the Langmuir model and can be defined as:

\[ \log q_e = \log K_F + \frac{1}{n} \log C_e \]  

(4)

where \( q_e \) is the amount of adsorbate at equilibrium (mg/g), \( C_e \) the adsorbate concentration in the solution (mg/L) at equilibrium, and \( K_F \) and \( n \) are constants incorporating all factors affecting the adsorption process such as adsorption capacity. If \( n \) is close to 1, the heterogeneity of the surface could be considered to be less important and, as \( n \) reaches 10, the heterogeneity of the surface will become more substantial. As the \( K_F \) value rises, the adsorption capacity of the adsorbent increases for the provided adsorbate. In the BET model, the possibility of multilayer absorption is investigated. This model is classified as a subcategory based on Langmuir model assumptions. The BET model can be expressed in its linear form as:

\[ \frac{C_e}{q(C_s - C_e)} = \left( \frac{1}{BQ_0} \right) + \left( \frac{B - 1}{BQ_0} \right) \left( \frac{C_s}{C_s} \right) \]  

(5)

B is constantly proportional to the energy of the surface interaction and \( C_s \) is the absorbed saturated concentration.
Parameters related to each isotherm have been evaluated using a linear regression model and a

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correlation coefficient square ($R^2$) has been figured. A list of the parameters collected along with

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the values of $R^2$ is reported in Table 2. It was identified that the ideally appropriate isotherm
equation was Freundlich with $R^2= 0.975$. The Freundlich equation model is regarded as

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relationship 3 and the lowest correlation is related to the Langmuir model with $R^2=0.91$. It was

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noticed that the best-suited isotherm equation was Freundlich. According to the Freundlich model,

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the final equation for regression is equation 6:

\[
\ln(q) = 9.2631 - 1.9395 \ln(c) \quad (6)
\]

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Table. 2 Regression parameters for three popular isotherm model

| Isotherm model | $R^2$ | Equation          |
|---------------|-------|-------------------|
| Langmuir      | 0.91  | $y=-38.31x+0.92$  |
| Freundlich    | 0.975 | $y=-1.9395x+9.26$ |
| BET           | 0.96  | $y=1.37x-0.20$    |

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The n-parameter of the Freundlich equation indicates that the adsorption sites have a restricted
distribution of energy as their amount was close to 1 ($n = 1.939$). On this assumption, the

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information obtained shows that the Freundlich equation can be fitted with a favorable $R^2=0.975$

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with a multilayer capacity of 22.85 mg / g. Aminna A. Attia achieved a value of 75 mg/g for the

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removal of yellow acidic dye by activated carbon at 25°C(Attia, Rashwan et al. 2006). In contrast,

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According to a 2017 study based on acid yellow uptake using natural zeolite, an adsorption capacity of 1.17
230
mg/g has been reported(Mirzaei, Hadi et al. 2016). It would imply the superiority of MP in AC removal

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in comparison to other adsorbents.
3.3. Kinetic studies

Batch trials were performed to investigate the rate of AC adsorption by MP of 1 g at pH 8.0 and initial dye concentrations of 100 mg/l. Generally, after contact time there is no significant improvement in the amount of adsorbent and dye concentration. So, the equilibrium time for acid yellow, 60 minutes has been estimated. In comparison with kinetic models such as pseudo-first-order and Elovich, dye abstraction from the aqueous phase by a certain adsorbent is represented by pseudo-first-order kinetics. The coefficient determination of pseudo-second-order is 0.99 which indicates the highest R² between models, therefore the model is based on reaction. The Pseudo-Second-Order Kinetic Model is represented as:

\[
\frac{t}{q_t} = \frac{1}{k_{2p}q_e^2} + \frac{1}{q_e} t
\] (7)

where \(k_{2p}\) (g/min mg) is the rate constant of pseudo-second-order model adsorption. If pseudo-second-order kinetics is valid, the \(t / q_t\) versus \(t\) plot will have a linear relationship. Fig.4 displays the exceptional kinetic model and distinguishes the final relationship:

\[
\frac{t}{q_t} = -59.754 + 20.71t
\] (8)
3.4. The statistical analysis

Results based on the experimental design at each point were reported in Table 3. Considering that the full quadratic model could not meet the requirements, the model was modified by minimizing additional terms. The following model Adsorption demonstrated an analytical relationship between the answer and the independent variables:

\[
\text{remove}^{1.49} = +0.31 + 0.014A - 0.084B + 0.037C - 0.076\times A + 0.063\times BC + 0.1A^2 - 3.822E + 0.11C^2
\]  

(9)
Table 3: Experimental design and results for dye removal

| Trial no | Coded values of the variables | Dye removal (%) |
|----------|------------------------------|-----------------|
|          | Dye concentration (A) | pH (B) | Adsorbent dose (C) | (R)  |
| 1        | +1             | -1    | -1              | 78   |
| 2        | -1             | +1    | -1              | 75   |
| 3        | 0              | 0     | +2              | 59   |
| 4        | 0              | 0     | -2              | 81   |
| 5        | -1             | -1    | +1              | 79   |
| 6        | 0              | 0     | 0               | 44   |
| 7        | -2             | 0     | 0               | 85   |
| 8        | -1             | +1    | +1              | 77   |
| 9        | +1             | +1    | +1              | 64   |
| 10       | 0              | 0     | 0               | 50   |
| 11       | +1             | +1    | -1              | 56   |
| 12       | -1             | -1    | -1              | 70   |
| 13       | 0              | 0     | 0               | 71   |
| 14       | -2             | 0     | 0               | 71   |
| 15       | -1             | +1    | +1              | 66   |
| 16       | +1             | -1    | +1              | 71   |
| 17       | +1             | -1    | -1              | 10   |
The analysis of the response variance was summarized in Table 4. To verify the perfection of the model, the coefficient of variation (the ratio of the standard error of estimation to the mean value expressed as a percentage) and the F-value tests were also carried out. The coefficient of determination ($R^2 = 0.8746$) was moderately strong, as proven by 87.46% of the total variance in response. In an overall estimate, the proposed model is valid and significant if “Prob>F” is less than 0.05. Also, based on being the non-significant value of lack of fit, the conclusion is that the
model is sufficiently descriptive of the data for the elimination of dye. The validity of the coefficients of the parameter and the associated standard error of any Eq term is set out in Table 5. According to p values (< 0.05 is meaningful), it can be recognized that all the main second-order effects (A² and C²) are incredibly significant. Furthermore, the negative coefficient of the first order parameters indicates the maximum response value within the specified parameters ranges. Other factors, such as AB and B², had a negligible effect on the removal of AC owing to p values of more than 0.05.

Table 4 Analysis of variance for the quadratic model for dye removal

|                      | Sum of square | DF² | Mean square | F-Value | Prob.>F |
|----------------------|---------------|-----|-------------|---------|---------|
| Model                | 0.58          | 1   | 0.082       | 14.94   | <0.0001 |
| Residual             | 0.083         | 15  | 5.506E-003  |         |         |
| Lack of fit          | 0.010         | 6   | 1.745E-003  | 0.22    | 0.9614  |
| Pure error           | 0.072         | 9   | 8.013E-003  |         |         |
| Total                | 0.66          | 22  |             |         |         |

R²=0.8746, CVᵇ=14.06%.

²DF= degree of freedom

ᵇCV= coefficient of variation

Table 5 significance of the components in modified model

| Factor (coded) | Coefficient Estimate | Standard error (SE) | p value |
|----------------|----------------------|---------------------|---------|
| A              | 0.014                | 0.016               | 0.0376  |
| B              | -0.084               | 0.015               | <0.0001 |
|   |   |   |   |
|---|---|---|---|
| C | 0.037 | 0.019 | 0.0774 |
| AC | -0.076 | 0.021 | 0.0025 |
| BC | 0.063 | 0.021 | 0.0094 |
| A² | 0.10 | 0.014 | <0.0001 |
| C² | 0.12 | 0.018 | <0.0001 |

3.5. The optimization of the adsorption process

To obtain a better perception of the AC adsorption process, the contour plots were studied. Curved contour lines represent that there is an interaction between initial concentration, dose adsorbent, and pH. In each graph, the influence of two factors on the adsorption potential was examined while the other variable remained at the optimum value. The response surface of adsorption is shown in Figs 5 and 6. Fig. 5 demonstrates the combined influence of the initial dye concentration and pH on the AC adsorption efficiency. In solutions with a dye concentration of about 200 to 250 mg/L and with a pH of about 8-9, the best dye removal mode occurs. In addition, the AC adsorption capacity decreases in constant initial concentration with pH augmentation. The zero charge point (pzc) is commonly defined as the pH at which the net charge of the total particle adsorbent surface is equal to zero (Sen, Afroze et al. 2011). It seems that pH_pzc is equal to 8 and the percentage of dye removal is higher at high pH since the adsorbent surface has a positive electrical charge and is appropriate for acidic yellow, which is considered ionic dye. In the acidic zone, competition between H+ and acidic dyes leads to a decrease in the sorbet surface area of the active sites due to dyes. Other AC adsorption research also reported that an increase in pH could lead to an increase in adsorption capacity (Yu, Han et al. 2017). The reason for this phenomenon is the separation of the OH⁻ bond and the uptake of oxygen by functional groups of acidic dye. In the specific and
constant pH as 8, the increase of initial concentration is the cause of the increase in dye removal efficiency up to 75%.

Fig. 5 Response surface contour plot indicating the effect of interaction between dose adsorbent and pH on dye removal while holding other factors at its level as follows: initial concentration, 250 mg/L.
Fig. 6 Response surface contour plot indicating the effect of interaction between dye concentration and pH on dye removal while holding other factors at its level as follows: initial concentration, 0.875 g.

It was also noticed that the impact of the interaction between pH and the adsorbent dose was also very important, as shown by the corresponding p-value (0.0094). Fig. 6 shows that at constant adsorbent dosage, a relatively higher dye concentration and a very low pH contribute to higher dye removal. The highest removal efficiency was about 70%. This process is initially performed very quickly and the majority of the dye is eliminated by the adsorbent in the first few minutes. Observation can be explained in terms of the amount of MP molecules existing in the solution. The explanation for this phenomenon is to fill active adsorption sites by increasing dye molecules (Sarma, Gupta et al. 2019).

In addition to Fig. 5 and Fig. 6, Fig. 7 can be considered to define the final relationship at constant pH (=8). In Fig. 7, simultaneous factors such as dye concentration and adsorbent dose are displayed.
in a 3D graph to estimate the dye removal efficiency. Dye removal efficiency increases with increasing adsorbent content and decreasing dye concentration, and these two variables are inversely related to reducing dye removal. This is likely the result of the more activity of the surface sites, mobility of dye molecules, and the change in adsorbent pores size (Shwetharani, Poojashree et al. 2018). However, between 0.875 g to 1.175 g of adsorbent, dye removal efficiency has a reverse result. The reason behind this is the accumulation of absorbent molecules and the formation of the overwhelming adsorption surface (Chowdhury and Fatema 2016).

Fig. 7 The effect of the initial dye concentration and adsorbent dosage on dye removal of AC (pH=8).

The design was given a set of solutions (Table 6) to achieve the optimum conditions of the operation. Based on the solution provided by the design, four experiments were carried out under fixed conditions. It was observed that the maximum removal dye or adsorption of AC of 80% was
obtained when 250 mg/L of initial dye concentration and 0.875 g of MP were used and the optimum pH value was found to be 8.

Table 6 Optimum conditions defined by the design expert for the adsorption process

| Run | A       | B       | C       | Removal efficiency (%) | Desirability |
|-----|---------|---------|---------|-------------------------|--------------|
| 1   | 250.00  | 8.00    | 0.875   | 80.5                    | 0.93         |
| 2   | 250.00  | 8.00    | 0.878   | 80.3                    | 0.92         |
| 3   | 250.00  | 8.01    | 0.878   | 80.1                    | 0.92         |
| 4   | 248.98  | 8.00    | 0.875   | 80.0                    | 0.92         |

3. Conclusions

The research focused on the adsorption of acidic yellow dye (AC) by Moringa Peregrina (MP) from the aqueous solution. MP adsorption was studied in batch mode and was found to be highly reliant on the pH value of the solution, the adsorbent dosage, and the initial dye concentration. The most significant results of this study are summarized as follows:

- Freundlich isothermal model showed better equilibrium data than the Langmuir isotherm.
- The pseudo-second-order model adequately represented the adsorption kinetics.
- Optimum conditions were identified as an initial pH of 8, an initial dye concentration of 250 mg/L, an adsorbent dose of 0.875 g, and maximum removal efficiency of 80 percent.
The findings of the RSM technique are based on evaluation results that showed that RSM ($R^2 = 0.875$) is a valid and effective method for predicting adsorption.

- Moringa Peregrina is considered a natural and inexpensive adsorbent and is efficient in eliminating dye materials from aqueous solutions.

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Authors' information:

Negar Saraei: M.Sc. Candidate, Faculty of Civil, Water and Environmental Engineering, Shahid Beheshti University, Tehran, Iran. Email: saraeinegar@gmail.com

Mostafa Tizghadam Ghazani: Assistant Professor, Faculty of Civil, Water and Environmental Engineering, Shahid Beheshti University, Tehran, Iran. Email: mtizghadam@gmail.com