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ORIGINAL ARTICLE

Efficient removal of reactive Blue-19 from textile wastewater by adsorption on methyl Imidazolium modified LUS-1 and MCM-48 nanoporous

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Abstract

In this study, N-methyl-N'propyltrimethoxysilylimidazolium modified LUS-1 and MCM-48 nanoporous materials were prepared and employed as adsorbent for removing Reactive Blue-19 from aqueous solutions. LUS-1 and MCM-48 were made based on the previous procedure and modified with N-methyl-N'propyltri methoxysilylimidazolium chloride. XRD analyses did not show any lattice alteration between modified and unmodified adsorbents. A hexagonal mesophase structure with the P6mm symmetry for LUS-1 and IM-LUS-1, and a cubic Ia3d space group for MCM-48 and IM-MCM-48 were observed. UV/Vis spectrophotometry was used to determine of the dye concentration in the solution. Batch studies were conducted in order to find the optimum adsorption conditions and investigation of different empirical parameters like the pH impact, contact time, the amount of adsorbent, and concentration of dye on adsorption process. The best dye removal efficiency of the adsorbents were more than 93% at pH= 3.0-7.0 after about 3 min for IM-LUS-1 and after 30 min for IM-MCM-48. RB-19 dye was desorbed from both of the adsorbents with 10 mL of sodium hydroxide 2 M during 5 min. There was well match between the data and the Langmuir model with maximum adsorption capacities 476.2 mg/g IM-LUS-1 and 277.8 mg/g IM-MCM-48. The reusability of the sorbents were higher than 4 cycles. In addition, removal percent of RB-19 dye from 50 mL of real textile wastewater with 20 mg of IM-LUS-1 and IM-MCM-48 were 93.0 (± 0.6) and 90.2 (± 0.7), respectively. The results showed that this method might be appropriate for removing the pollutant dyes from textile wastewater.

Keywords: *Dye Removal; LUS-1; MCM-48; N-Methyl-N'propyltrimethoxysilylimidazolium; Textile Wastewater.*

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INTRODUCTION

The wastewater treatment for long time has been a main problem of the textile industry [1]. Around one million tons of synthetic dyes such as reactive dyes are created annually in the world, and 5–15 percent of these dyes are released in the form of textile wastewater [2-4]. Biological degradation of reactive dyes both in hydrolyzed form and original form is difficult, and these materials are very toxic for human beings and animals [5]. The major problem related to using reactive dyes is low affinity for textile material, so that up to 50 percent of dyes in the discarded bath are reactive dyes [6, 7]. Fig. 1 shows the molecular structure of Reactive Blue-19 (RB19). Range of its fixation efficiency in cotton is 75–80 percent, because of the competition between the vinyl sulfone formation and 2- hydroxyethylsulfone formation [8, 9]. The main problem related to the dye technology is hydrolysis of the vinyl sulfone moiety prior to the establishment of a covalent bond between fiber and dye which results in the loss of the dye's tendency to fiber. Removal of dye from wastewater by the use of common treatment systems is difficult [10].

Nowadays a various approaches have been proposed looking for effective alternatives for treatment of textile wastewater [3]. Several physical or chemical processes are used to treat wastewaters, such as photocatalytic oxidation [11], chemical or electrochemical oxidation [12, 13] and adsorption [14]. Most of dyes are stable to photo-degradation, bio-degradation and oxidizing agents [15]. But, adsorption processes seem to be an alternative process for removing organic compounds and dyes [16-23]. Adsorption is the process of transferring solute dye molecule at the interface between two immiscible stages in contact with one another [1]. Currently, different adsorbents like activated carbons, clays, ion exchange resins and zeolites have been investigated to removal of dyes [24-26]. The most of the adsorbents have showed several problems like low mechanical and thermal stability and weak chemical union with the analytes. But, mesoporous silica offer a number of potential advantages as adsorbents including larger pore volume and diameter, high surface area and regular channel type structures which increases the absorption capacity and repeatability of the results. High adsorption capacities make them ideal candidates for removal of organic compounds, heavy metal ions, and organic dyes [27-35]. Although, further studies are needed on cost effectiveness of using mesoporous silica adsorbent to removal of dye from industrial effluents, it is clear that high capacity of this adsorbents can be accommodated the cost.. Also, attentions have been drawn by the chemical adjustment of the mesoporous silica surface with specific functional groups since it is able to improve its selectivity and adsorption capacity [1]. By incorporating organic groups into the structure of the silica, it can be modified and functionalized. It is achieved by grafting silane moieties on the pre-formed silica through reaction with siloxane and surface silanol groups [36], or using substituted trialcoxysilanes in the sol-gel synthesis that co condensate with the silica source [37, 38].

MCM-48 and MCM-41 possess two mesoporous silicas providing large surface area, highly ordered pore structure, narrow pore size distribution, and good mechanical stability. MCM-48 is a three-dimensional channel system, while MCM-41 is a two-dimensional hexagonal array of cylindrical pores [39]. Bonneviot *et al.* proposed a novel category of MCM-41 mesoporous silica known as 'LUS' (LUS = 'Laval University Silica') with greater hydrothermal stability [40]. The hydrothermal synthesis of 'LUS' silica propose three innovative points in comparison with MCM-41: (1) instead of tetraethoxysilane, Na_2SiO_3 is employed as Si source, (2) the counter anion in

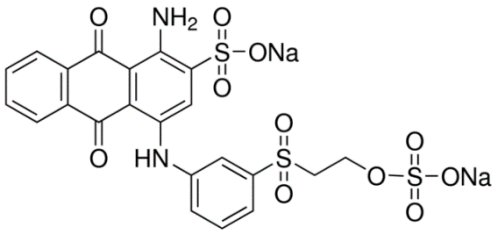

Fig. 1. The structure of the Reactive Blue-19 (RB-19).

the cationic surfactant is tosylate allowing varying spread of Si–OH groups on the surface of the silica, which results in greater stability, and (3) the synthesis needs fewer amounts of surfactant allowing higher surfactant removal following the synthesis, which provides economic advantages for the process [41].

It is noteworthy that, the effect of the dimensions and structure of the channels of adsorbent on removal efficiency has received less attention compared to modification of the functional group. We decided to look into it, too. Therefore, in this study Methyl imidazolium modified LUS-1 and MCM-48 were prepared and their efficiency toward the adsorption of Reactive Blue-19 dye was compared. Efforts have already been made to remove the Reactive Blue 19 with other adsorbents [42-44], but to the best our knowledge, this is the first application of Methyl imidazolium modified LUS-1 and MCM-48 for removal of Reactive Blue-19 dye. The application of these adsorbents was assessed in terms of the impacts of solution pH, does of adsorbent, contact time, and concentration of dye.

EXPERIMENTAL PROCEDURES

Apparatus

Bruker axs D8 diffractometer with nickel filtered Cu-Kα (λ= 1.5418 °A) was used for recording powder X-ray diffractograms in which the x-ray tube worked at 30 mA and 40 KV. The SEM images were taken using Oxford LEO 1455V STEM. Using RAYLEIGH WQF-510A apparatus, the specimens' Fourier transform infrared (FT-IR) spectra were recorded**.** The concentration of the dye in solution was detected by Varian UV/Vis double beam spectrophotometer (Cary-100). Metrohm pH-meter model 713 was used for controlling pH.

Reagents

Cetyl trimethylammonium bromide (CTAB), Hexadecyltrimethylammonium-*p*-toluene-sulfonate (CTATos), tetraethyl orthosilicate (TEOS) were purchased from Merck. N-methylimidazole and 3-(chloropropyl)trimethoxysilane were prepared from Fluka. Ludox, HS40 were obtained from Aldrich. All chemical reagents were used without further purification. Reactive Blue-19 was purchased from Bayer (Germany). In the current study, double distilled water (DDW) was utilized. The vessels and pipettes that were utilized for trace analysis were stored in dilute nitric acid for minimum of 24 hours, and then, they were rinsed four times with DDW before they are used. The dye solutions were obtained through dissolving the Reactive Blue-19 (RB-19) powder in DDW to form a stock solution and then diluting it to desired concentrations.

Synthesis of N-methyl-N'propyltrimethoxysilylimid azolium modified LUS-1 and MCM-48

LUS-1 was made based on the procedure described in the previous works [45]. Addition of Ludox (15.5 g) to sodium hydroxide (2 g) was done in distilled water (50 mL). Then, it was stirred at 313 °C°K until clear (almost 24 h). The second solution of CTATos (2.5 g) in distilled water (90 mL) was stirred for one hour at 333 °K. The addition of the first solution to the second solution was done in a drop wise manner. Afterward, they were stirred at 333 °K for two hours. The obtained sol-gel was heated using an autoclave at 373 °K for 24 hours. The as-made solid was dried at 353 °K after it was filtered and rinsed with distilled water. The extraction of surfactant was performed with 0.1 N HCl/ethanol solution [46].

MCM-48 was prepared based on the synthetic procedure described in the previous works [47]. Typically, CTAB (5.2 g) was added to distilled water (240 mL) and ethanol (100 mL) under stirring. Then, aqueous ammonia solution (24 mL) was added to the clear solution, and it was allowed to mix (about 5 min). Afterward, TEOS (7.2 mL) was added under vigorous stirring (about 1 h) and then transferred in an autoclave and heated up to 373 °K (for 3 days). The as-made solid was dried at 353 °K after it was distilled and rinsed with distilled water. The surfactant was extracted with 0.1 N HCl/ethanol solution.

N-methyl-N'propyltrimethoxysilylimidazo lium chloride (IM) was similarly synthesized according to the literature [48]. A mixture of 3-(chloropropyl)trimethoxysilane (137.17 g) and N-methylimidazole (56.7 g) is typically stirred in a flask at 100 °C for 24 h under nitrogen. The extraction of liquid was performed with ether. A yellow viscid liquid (so-called IM) was obtained.

The synthetic of IM-LUS-1 and IM-MCM-48 is summarized in Fig. 2. To a mixture containing dry LUS-1 (or MCM-48) (5 g) and dry toluene (100 mL), IM (4 mL) was added. The mixture was refluxed for 24 h. Afterward, the solid was filtered and saxhalted with toluene and ethanol for 24 h. Ultimately, drying was done in the oven at 100 °C for two hours.

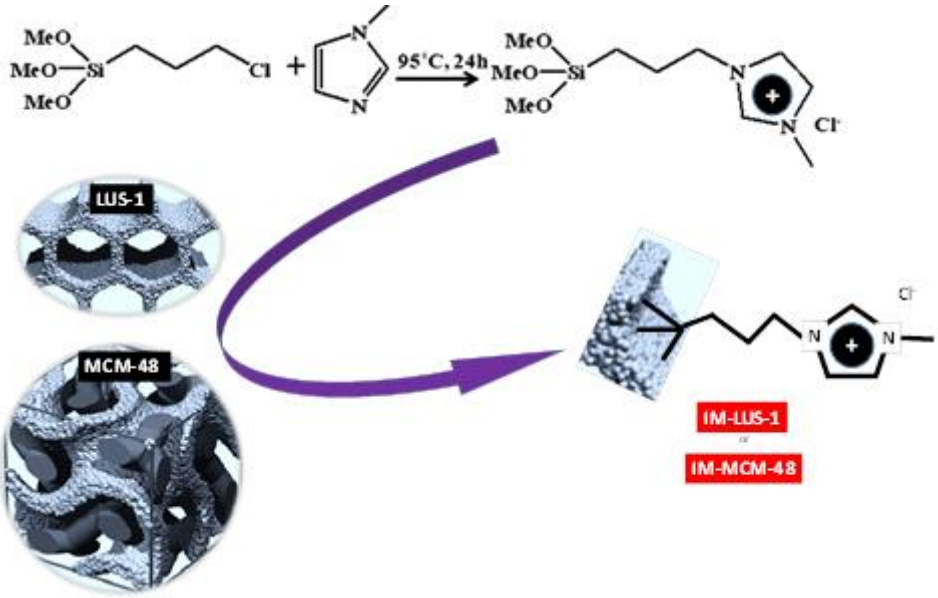

Fig. 2. schematic synthetic route of IM-LUS-1 and IM-MCM-48.

Dyes removal experiment

The calibration curve for RB-19 was gained by recording absorbance values of dyes solutions in a range of certain concentrations at the wavelength of maximum absorbance (λ = 593 nm). A UV–Vis spectrophotometer was used for the measurement of absorbance. Key parameters like pH of the solution, dye concentration, dye concentration dose of adsorbent, and initial concentration of dye were studied in RB-19 removal batch tests under the following experiments. For each experiment, a sufficient amount of IM-LUS-1 or IM-MCM-48 nanoporous adsorbents were added to 10 mL of 20 mg/L of reactive dye solutions. The mixed solution was gently shacked at room temperature for 3 and 30 min for IM-LUS-1 and IM-MCM-48 respectively. The supernatant was centrifuged for five minutes at 4000 rpm when the adsorption period was ended. The residuals of Reactive Blue-19 in the solution were measured by spectrophotometry at 593 nm. All of the adsorption experiments were conducted in triplicate.

The adsorption percent for dye, that is, the dye removal efficiency, was specified by the relation below:

$$\% R = [(C_0 - C_t) / C_0] X 100 \quad (1)$$

C_0 and C_t denote the initial and final (after adsorption is ended) dye concentration (mg/L).

All the tests were conducted at room temperature. The impacts of contact time, pH, concentration of dye, and the amount of adsorbent on adsorption were investigated. For adsorption isotherm, the dye solution with varying concentrations in the 50-1000 mg/L range was agitated until the achievement of the equilibrium.

The following equation was used for calculating the adsorbed amounts (q_e) of dye:

$$q_e = (C_0 - C_e / m) X V \quad (2)$$

Where C_e and C_0 represent the equilibrium and initial concentrations of dye in mg/L, V represents the solution volume (L), and m denotes the adsorbent mass (g).

The principle of adsorption isotherms is finding the relationship between the solute concentration in the solution and the mass of the solute adsorbed per unit mass of adsorbent (qe) at equilibrium. Langmuir, Freundlich and Temkin isotherm models were used for analyzing equilibrium isotherms. Langmuir Adsorption Isotherm provides a quantitative description for forming a monolayer adsorbate on the adsorbent's outer surface, and no more adsorption occurs after that. The Langmuir isotherm has validity for monolayer adsorption onto a surface that contains a finite number of identical areas. The linearized form of the Langmuir is as follows [49]:

$$C_e / q_e = 1/b\, q_m + C_e / q_m \quad (3)$$

Where q_m denotes the maximum adsorption capacity equivalent to total monolayer coverage,

and b denotes the constant of the equilibrium (L/mg).

Freundlich Adsorption Isotherm is extensively employed for describing the adsorption features for the heterogeneous surface with a non-uniform distribution of heat of adsorption over the surface, The Freundlich model can take the following linearized form [50]:

$$\text{Log } q_e = \log K_f + \frac{1}{nf} \log C_e \quad (4)$$

Where K_f denotes an index of the adsorption capacity and $1/n_f$ represents as a measure of adsorption intensity or surface heterogeneity, which becomes more heterogeneous when its value becomes closer to zero.

The Temkin isotherm model, on the other hand, is commonly utilized in the heterogeneous surface energy systems, in which the distribution of sorption heat is not homogeneous [51]. As observed in the equation, characterization of its derivation is done by a homogenous distribution of binding energies (up to highest binding energy). It is performed by plotting the quantity adsorbed qe against In Ce. In addition, the intercept and slope specified the constants. The Temkin isotherm linearized form is:

$$q_{e=} \text{ B Ln } k_t + \text{B Ln } C_e \quad (5)$$

Where B = RT/b represents a constant beings as a function of the sorption heat (J/mol) and determined from the Temkin plots (qe vs. ln Ce), b and R are the Temkin isotherm constant and universal gas constant (8.314 J/mol. K), T shows the temperature (K) and K_t denotes the isotherm's equilibrium binding constant (L/g).

To obtain the adsorption isotherm data, different solutions of the target ions, with concentrations in the range of 50-1000 mg L^{-1} at pH=6 were prepared. The removal process was done in optimum condition for all of the solutions and the residuals of dye in the solutions were specified using spectrophotometry. Finally, adsorption capacities of IM-LUS-1 and IM-MCM-48 for RB-19 were calculated.

RESULTS AND DISCUSSION

Characterization of IM-LUS-1 and IM-MCM-48

Fig. 3 indicates the low angle XRD powder patterns of IM-LUS-1, LUS-1, IM-MCM-48, and MCM-48. The MCM-48 and IM-MCM-48 samples show good consistency with the samples that have been reported for cubic Ia3d space group

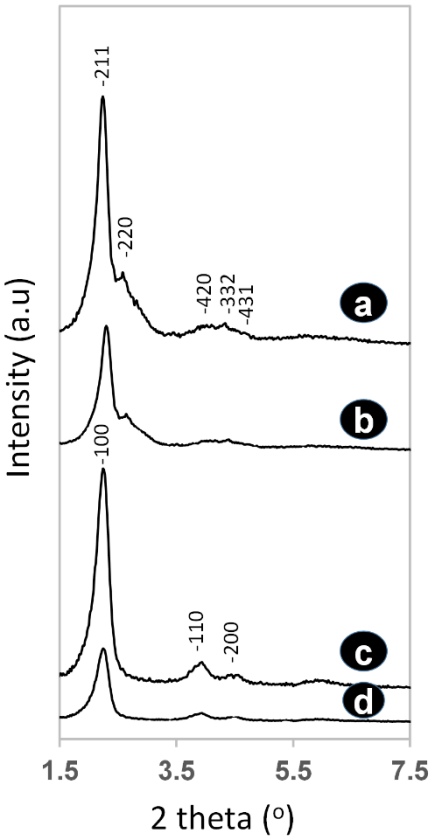

Fig. 3. Low angle XRD patterns of a) MCM-48, b) IM-MCM-48, c) LUS-1, and d) IM-LUS-1.

(Fig. 3a, 3b). No significant changes were observed between MCM-48, and IM-MCM-48, except for the intensity of XRD reflections. It provides evidence that functionalization occurred mainly inside the mesopore channels. The IM-LUS-1 and LUS-1 (Fig. 3c, 3d) samples show a typical of a hexagonal mesophase with the *P6mm* symmetry feature of MCM-41 [47]. Any lattice alteration was not seen between LUS-1 and IM-LUS-1.

The SEM images of functionalized material (Fig. 4) are typical for mesoporous silica LUS-1 and MCM-48. The SEM images of IM-LUS-1 (Fig. 4a) and of IM-MCM-48 (Fig. 4b) show texture form morphology and uniform spheres particles, respectively. Both of them can be concluded that morphology of nanoporous materials was saved without change during the functionalized of surface.

The incorporation of organic functional groups in the silica frameworks was verified by FT-IR (Fig. 5). The peaks at about 800 and 1100 cm^{-1}

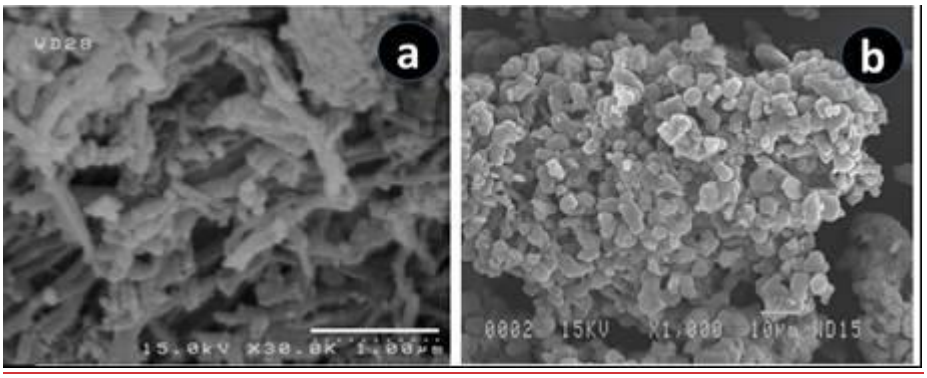

Fig. 4. SEM image of a: IM-LUS-1 and b: IM-MCM-48.

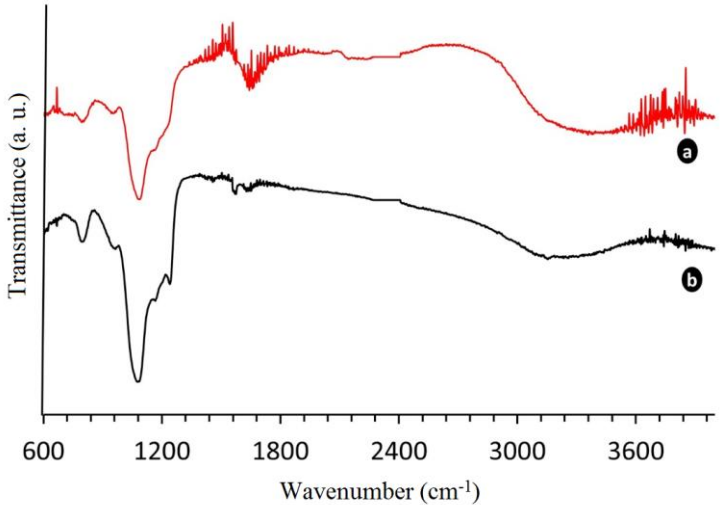

Fig. 5. FT-IR spectrum of a: IL-LUS-1, b: IL-MCM-48.

are assigned to the stretching vibration of Si-O-Si bonds of condensed silica network. The C=C and C=N vibrations of imidazole (at about 1450 and 1570 cm^{-1}) were difficulty observed due to the small amount of organic cation and high adsorbed water on the surface [52]. Moreover, the large amount of water on the surface that can be observed at 1600 cm^{-1} and broad peak at 3300 cm^{-1}**.**

The influence of the pH on the dye removal efficiency

Fig. 6 shows the impact of pH on the dye adsorption from pH 3.0 to 9.0. pH values of the samples were varied and the removal experiments were performed in 10 mL solution of 20 mg/L of dye. The NaOH and HCl were used for adjustment of pH, and measurement of pH was done using digital pH meter. According to the results, the highest removal efficiency of RB-19 was at pH < 7.0 for both adsorbents. Reactive Blue-19 is known as anionic dye due to its existence in the sulfonate form. The sulfonate ($–SO_3^-$) groups of Reactive Blue-19 dye are easily dissociated and have negative charges in the aquatic environment. Hence, the electrostatic attraction between the RB-19 molecules (with the negative charge) and adsorptive sites on the surface of IM-MCM-48 and IM-LUS-1 (with the positive charge) could cause facilitation of the RB-19 removal. Therefore, the removal percentage was sharply decreased at higher pH, suggesting the OH^- formation in alkaline condition and their competitive adsorption on the adsorptive areas. A maximum adsorption efficiency of 93-94% was observed at pH= 3.0-7.0, so the natural pH of dye solution (about 6) was

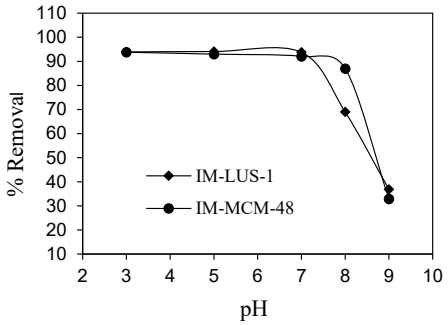

Fig. 6. The effect of pH on the adsorption of RB-19 on IM-LUS-1 and IM-MCM-48.

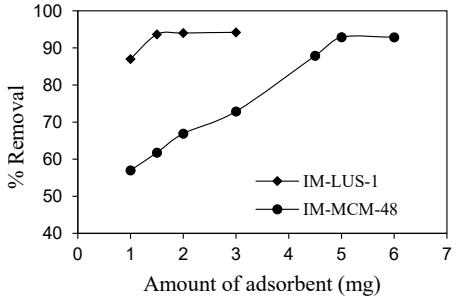

Fig. 7. The effect of different amount of adsorption on removal efficiency of RB-19.

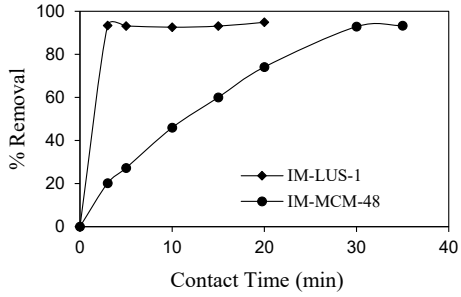

Fig. 8. The effect of contact time on the removal of RB-19 by IM-LUS-1 and IM-MCM-48.

used in all experiments.

Optimization of adsorbent amount

The impact of the amount of IM-MCM-48 and IM-LUS-1 nanoporous as adsorbent on the RB-19 dye removal was specified at pH=6 at room temperature by changing the amount of the adsorbents from 0.001 to 0.003 g for IM-LUS-1 and 0.001 to 0.006 g IM-MCM-48 in 10 mL solution of 20 mg/L of dye. According to the results (Fig. 7), the removal efficiency of dyes initially showed increase as the amount of adsorbent due increased to the availability of higher adsorption areas. Then, the removal percentage stayed intact with more increase in the dose of the adsorbent. The 2 mg IM-LUS-1 had a removal efficiency of 94%, while 5 mg IM-MCM-48 had a removal efficiency of more than 93% for RB-19 dye.

Impact of contact time on yield of removal

The contact time impact on the level of dyes adsorbed was studied at pH 6 at the initial concentration of 20 mg/L of dyes at ambient temperature. The dye concentrations were measure periodically in up to 20 min for IM-LUS-1 and 35 min for IM-MCM-48. Fig. 8 indicates the contact time impact on the removal yield of dyes by the functionalized nanoporous adsorbent. As it is evident, the adsorption amount shows a rapid increase during the initial phase of adsorption, and

Table 1. Isotherm parameters for adsorption of RB-19 on IM-LUS-1 and IM-MCM-48.

Isotherm	Parameters	IM-LUS-1	IM-MCM-48
Langmuir	q_m (mg/g)	476.2	277.8
	b (L/mg)	0.0193	0.0086
	R^2	0.9908	0.9982
Freundlich	1/n	0.352	0.424
	K_f (mg/g)	47.2	15.4
	R^2	0.8053	0.9512
Temkin	B	92.85	55.21
	K_t (L/g)	0.185	0.103
	R^2	0.9033	0.9857

then the increase continues at an approximately slow speed with the increase in the contact time. It can be seen that after about 3 min for IM-LUS-1 and after 30 min for IM-MCM-48, 93% of dye became adsorbed.

Adsorption isotherms

The equilibrium adsorption isotherm is the basic requirement in the adsorption systems design. The adsorption capacities of RB-19 at different dye concentration were measured individually at pH 6. As it is clear, the adsorption capacity of RB-19 on the functionalized nanoporous is dependent on the concentration of the dye. It can be attributed to the extent of a driving force of concentration gradients with the rise in the concentration of the dye. As the sites are available, adsorption increases with the increase in the dye concentrations, but by the occupation of all sites, the amount of dyes on adsorbents would not be increased by a further increase in the dye concentrations.

The data was matched with these isotherms: Langmuir, Temkin, and Freundlich. Using linear regression analysis, the constants are specified, which are given in Table 1. It is observed in Table 1 that the Freundlich and Temkin model are not appropriate to be used for describing the adsorption equilibrium of dye by IM-LUS-1 and IM-MCM-48. The Langmuir isotherm model provided the best match with the highest R^2 value in comparison with the Freundlich and Temkin model.

Also, as the results show, the maximum adsorption capacities in the studied concentration range are 476.2 and 277.8 mg/g for IM-LUS-1 and IM-MCM-48, respectively. The difference between the hexagonal mesh framework structure for LUS-1 and a cubic structure for MCM-48 appears in their adsorption capacity. According to Benhamou *et al.* previous results [39], the adsorption capacity of IM-LUS-1 was more than IM-MCM-48.

Desorption and reuse study

The regeneration of the pollutant-loaded adsorbent provides a cost-effective and more economical process of adsorption. The dye molecules are desorbed from the adsorbent surface during the regeneration, and these molecules are transmitted to the neighboring liquid. In the current study, RB-19 desorption was done by washing the dye being loaded on IM-LUS-1 and IM-MCM-48 using sodium hydroxide solutions. For this purpose, 10 mL of 1.0 M and 2 M sodium hydroxide solutions was added to the 5.0 mg of adsorbent being loaded by dye in a beaker. After 5 min, the dye concentration was measured in the desorbed solution by spectrophotometry. According to the results, desorption efficiencies with sodium hydroxide 2 M were higher. It is noticeable that the desorption equilibrium was obtained rapidly during almost 5 min. DDW was used for rinsing the adsorbent following the elution of adsorbed dyes, and it was dried at 25 $^{\circ}$C under vacuum. Then, the adsorbent was used again for the removal of dyes. The results showed that the reusability of the sorbent was higher than 4 cycles with no loss observed in the sorption capacity. Thus, IM-LUS-1 and IM-MCM-48 can be introduced as suitable economical and reusable sorbents.

Removal of dyes from Textile wastewater sample

The application of the adsorbents for removal of RB-19 from real sample was examined by dyeing wastewater of Textile. For this aim, 0.020 g of IM-LUS-1 or IM-MCM-48 was added to 50 mL wastewater of Textile which their pH were adjusted at 6. The mixed solution was mildly

Table 2. Removal of RB-19 dye from textile wastewater with IM-LUS-1 and IM-MCM-48.

Adsorbents	Initial concentration (mg L^1)	Final concentration (mg L^1)	%Removal
LUS-1	96.0(± 0.5)[a]	6.7 (± 0.4)	93.0 (± 0.6)
MCM-48	96.0 (± 0.5)	9.4 (± 0.5)	90.2 (± 0.7)

[a] %RSD based on three replicate analysis

shacked at room temperature for 3 and 30 min for IM-LUS-1 and IM-MCM-48 respectively. After centrifugation, the residuals of dye in the solution were specified by spectrophotometry. Because of matrix effect, the dyes' primary concentration and residual concentration in the samples (before and after removal with the recommended procedure) was determined by standard addition method. Standard addition procedures are especially helpful for analysis of complex samples in which the probability of matrix impacts is considerable. A typical standard addition procedure involves preparing various solutions containing the same amount of the analyte, but different amounts of a standard. In this study, four 100 mL volumetric flasks were each filled with 15 mL of textile wastewater samples. Then, the different amounts of the standard (0, 3, 5 and 10 mL of 100 mg/L) were added and the solutions in the flasks were diluted to the mark and mixed well. The dye amounts in the solution were next spectrophotometrically specified and the absorption versus standard concentration was plotted. A simple Linear Least Squares analysis was conducted using the slope and intercept functions of Microsoft Excel. To find the original concentration of the unknown, the value of X at y=0 from y= mX+b was calculated. The results are given in Table 2. As shown, the method proposed here can be used successfully for the removing of RB-19 dye in Textile wastewater samples with acceptable efficiency.

CONCLUSION

An easy and efficient system was developed for removing RB-19 from aqueous solutions using methyl imidazolium modified LUS-1 and MCM-48 nanoporous materials. The best dye removal efficiency of the adsorbents were more than 93% at pH= 3.0-7.0 after about 3 min for IM-LUS-1 and after 30 min for IM-MCM-48. RB-19 dye was desorbed from both of the adsorbent with 10 mL of sodium hydroxide 2 M during 5 min. The adsorbents were very effective in removing dye and the data fitted well to the Langmuir model. The IM-LUS-1 had an improved maximum adsorption capacity for RB-19 of 476.2 mg/g as compared to 277.8 mg/g for IM-MCM-48. This increased adsorption capacity can be attributed to the difference between the hexagonal structure for LUS-1 and cubic structure for MCM-48. The reusability of the adsorbents was higher than 4 cycles with no loss observed in the sorption capacity. Removal percentage of RB-19 dye from 50 mL of real textile wastewater with 20 mg of IM-LUS-1 and IM-MCM-48 were 93.0 (± 0.6) and 90.2 (± 0.7), respectively. The results obtained in this study show that both adsorbent are suitable for the adsorption of RB-19 dye in textile wastewater samples with good and acceptable efficiency.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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