Supporting information

Application of Fe_3O_4@THAM-CH_2CH_2Cl magnetic nanoparticle as a new adsorbent in ultrasonically assisted removal of Congo red from aqueous solutions

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1. Methods

Design-Expert 10 software was applied in this research to design the experiments and analyze data. RSM was applied to optimize the variables to remove Congo red from the water environment by the proposed adsorbent. Standard stock solutions of Congo red (500 mg L^{-1}) were prepared, and working solutions were prepared daily by diluting the standard stock solutions with double distilled water. The chemical structure of CR is shown in Fig. S1.

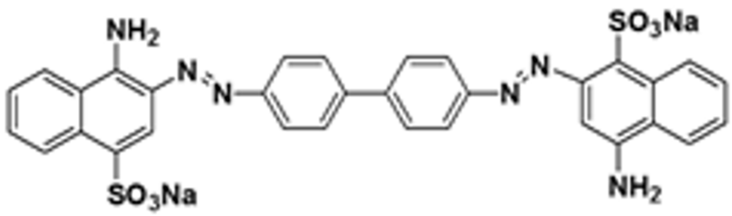

Fig. S1. The chemical structure of CR.

2. Synthesis and properties of nanoparticle adsorbent

Fe_3O_4@THAM MNP was synthesized as a chemical intermediate for the preparation of the MNPs catalyst [25]. The synthesis and characterization of Fe_3O_4 MNPs have been discussed and confirmed using techniques such as FT-IR, EDS, MAP, SEM, XRD, BET, and VSM [25].

Briefly, the preparation of Fe_3O_4@THAM-CH_2CH_2Cl MNPs includes three steps: (1) First, Fe_3O_4 nanoparticles were prepared by the co-precipitation method.(2) Then, the magnetite Fe_3O_4 NPs were coated by tris(hydroxymethyl) aminomethane (THAM). (3) Finally, Fe_3O_4@THAM-CH_2CH_2Cl was prepared.

Fig. S2 shows the Scheme and FE-SEM image of the prepared Fe_3O_4@THAM-CH_2CH_2Cl NPs.

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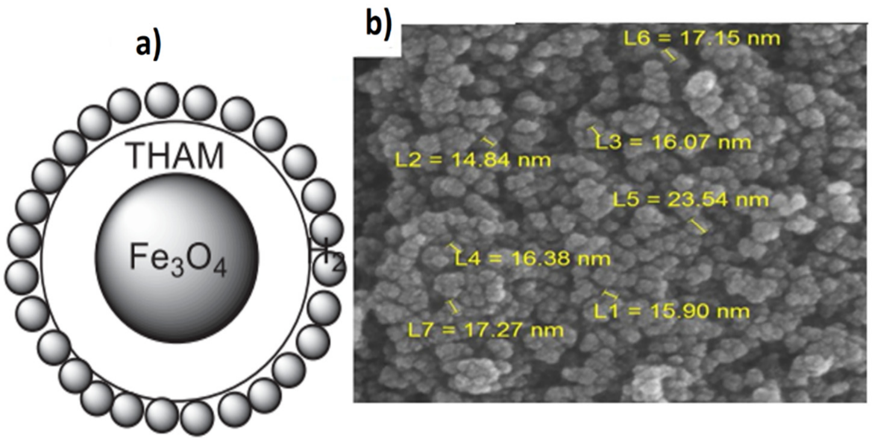

Fig. S2. Scheme (a) and FE-SEM images (b) of Fe_3O_4@THAM-CH_2CH_2Cl.

Based on the FE-SEM image, Fe_3O_4 @ THAM-CH_2CH_2Cl MNPs show spherical nanoparticles. Based on the VSM, the value of saturation magnetization (Ms) of Fe_3O_4 MNPs was 116.6 emu.g^{-1}. Also, the BET measurements confirmed the specific surface area of 121.79 $m^2.g^{-1}$, total pore volume of 27.9 $cm^3.g^{-1}$, and the mean pore size of 8.14 nm. Due to pores on the Fe_3O_4 @ THAM-CH_2CH_2-Cl adsorbent surface, the proposed adsorbent can remove Congo red from the aqueous environment by trapping the pollutant in its pores.

3. Recovery of adsorbent

In this work, the possibility of reusing the proposed adsorbent to remove Congo red was investigated in terms of the number of absorption and desorption times.

According to the results (Fig. S3), about a 5% change in adsorbent efficiency is observed after 6 runsof adsorption and desorption. This confirms that the proposed adsorbent can be regenerated and reused.

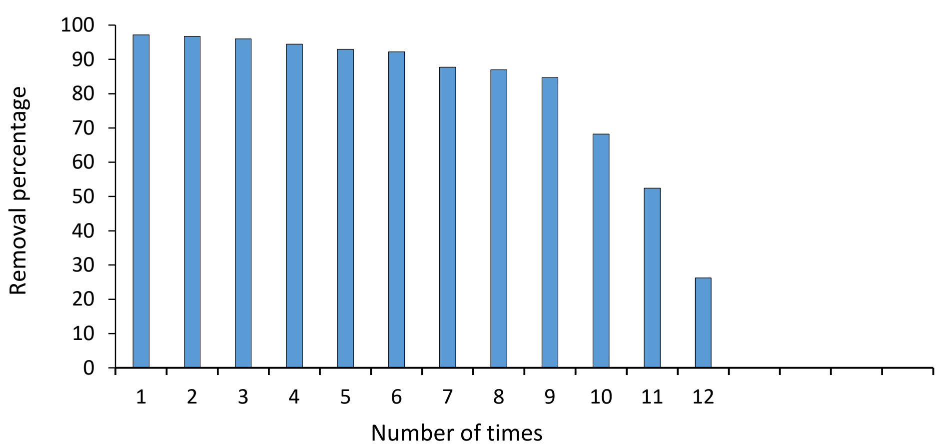

Fig. S3. Recovery of adsorbent.

Also, the isotherm for the adsorption process of Congo red by the proposed adsorbent was assayed. According to the results (Table S1), the Langmuir adsorption isotherm has a larger correlation coefficient (R^2 = 0.9987), which indicates the best fit with the experimental data and that the proposed adsorbent is more suitable for the Congo red adsorption process.

Table S1. Isotherm models constants for the adsorption process of Congo dye red on the adsorbent.

Isotherm	Equation	Plot	Parameters	Value
Langmuir	$C_e/q_e = C_e/q_m + 1/(q_m k_L)$	C_e/q_e against C_e	$q_m\,(\mathrm{mg.g^{-1}})$	137
			$k_L\,(\mathrm{L.mg^{-1}})$	1.4
			R^2	0.9987
Freundlich	$\log q_e = \log k_F + (1/n)\log C_e$	$\log q_e$ against $\log C_e$	n	1.05
			$k_F\,(\mathrm{L.mg^{-1}})$	159.8
			R^2	0.966