Removal of Reactive Black 5 (RB5) Dye from Aqueus Solution using Polymeric MOF adsorbent:Characterization and Kinetic study

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Abstract— **Reactive Black 5 (RB5) is a toxic material with detrimental impact on environmental ecosystems and human health. Adsorption as an efficient technique can be employed for the removal of the mentioned anionic ions from wastewater. The supported bimetallic Al/Fe metal-organic framework (MOF) nanocomposite on the polyacrylamide as a substrate was synthesized using a facile solvothermal method in the presence of terphtalic acid (BDC). The prepared sample was analyzed by using XRD test. The removal efficiency of the prepared sample was measured to be about 98% for RB5 under the ambient operating conditions in the batch adsorption system. A kinetic behavior of the fabricated MOF was also studied for the adsorption of RB5, and the results showed the good agreement between the experimental data and the pseudo second order kinetic model.**

Key Words--Reactive Black 5 (RB5), Adsorption, Metal-organic framework (MOF),Terphtalic acid

1. Introduction

Now days, textile dye contamination of water sources is a signification contributor to environmental pollution. The production chain of these industries, particularly during the textile dyeing step, consumes a substantial amount of water. Consequently, the resulting effluents exhibit a wide range of chemical complexity and diversity[1].

The dyes increasingly employed in various industries, such as methylene blue (MB), rhodamine B (RhB), methyl orange (MO), congo red (CR) and reactive black 5 (RB5); stand out as significant sources of industrial pollutants[2].

The majority of dyes present in wastewater exhibit stability and non-biodegradability. Certain dyes can have harmful effects, such as being toxic, carcinogenic and mutagenic thereby posing risks to both human and animal health[3].

Reactive Black 5 (RB5) is a cost-effective azo dye extensively used across various industries, including paper production, textiles, colorants, leather processing, carpet manufacturing, cosmetics, plastics, ink, shoe polish and mineral processing[4].

Every year, over 1000 tons of dyes are released into natural water bodies through industrial effluents, with approximately 45% of this quantity being attributed to reactive dyes.

Compared to other types of dyes, reactive dyes are known for their greater stability. This stability arises from their ability to form strong covalent bonds with the desired materials, significantly enhancing their colorization efficiency[5-7].

Chemical oxidation, photocatalytic degradation, membrane separation and electrochemical destruction are all methods for treating pollutants but expensive and complex and some of these methods can generate by-product that are potential environmental contaminants themselves. In contrast, adsorption is an ideal alternative to these techniques due to its simplicity, cost-effectiveness and versatility in the selection of adsorbent materials with various chemical and physical properties[8, 9].

Metal-organic frameworks (MOFs) belong to a novel class of crystalline porous materials, resulting from coordination reactions between organic ligands and metal ion centers. These MOFs are distinguished by their remarkable porosity, substantial surface area, and exceptional stability, rendering them versatile and widely applicable in diverse fields[10].

In this study, polymer based MOF as an adsorbent for the removal of RB5 from aqueous solution. They investigated the resulting data from studies on equilibrium constants and applied pseudo-first-order and pseudo-second-order kinetic models to understand the adsorption process.

2. Expeimental

2.1. Materials

Reactive Black 5 ($C_{26}H_{21}N_5Na_4O_{19}S_6$, RB5) , Iron nitrate nonahydrate, Aluminum nitrate, N,N-dimethylforamide (DMF) , Terphtalic acid (BDC) and Polyacrylamid were provided Merk company.

2.2. Synthesis of 2.3Al/Fe @PAA

The Al/Fe @PAA metal-organic framework (MOF) was synthesized through the solvothermal method.

The Aluminum nitrate, Iron nitrate, BDC as a linker and Polyacrylamide were mixed together in a solution with the DMF solvent. The homogeneous mixture was then transferred to an autoclave and incubated at a temperature of 110°C for 20 hours. After completion, the resulting solid particles were washed and left to dry in oven.

2.3. Dye adsorption experiments

The adsorption of RB5 was carried out using 0.05 g of supported MOF under consistent operating conditions, which included an initial concentration of 50 mg/l, a volume of 50 ml for the contaminated solution, an adsorption temperature of 25°C, and a pH of 6.5.

The RB5 concentration was analyzed using UV-vis Spectroscopy, and the removal efficiency was subsequently calculated using the provided equation.(eq.1).

$$Re\% = \frac{(C0-Ce)}{C0} * 100 \quad (1)$$

Where C0 and Ce are the initial and equilibrium concentration of RB5, respectively.

3. Results and discussion

3.1. XRD analysis

Powder X-ray diffraction (XRD) patterns were captured for the purpose of elucidating the crystal phase and structure of the sample and the XRD pattern indicates the synthesized MOF has crystalline structure and polyacrylamide has amorphous structure [11].

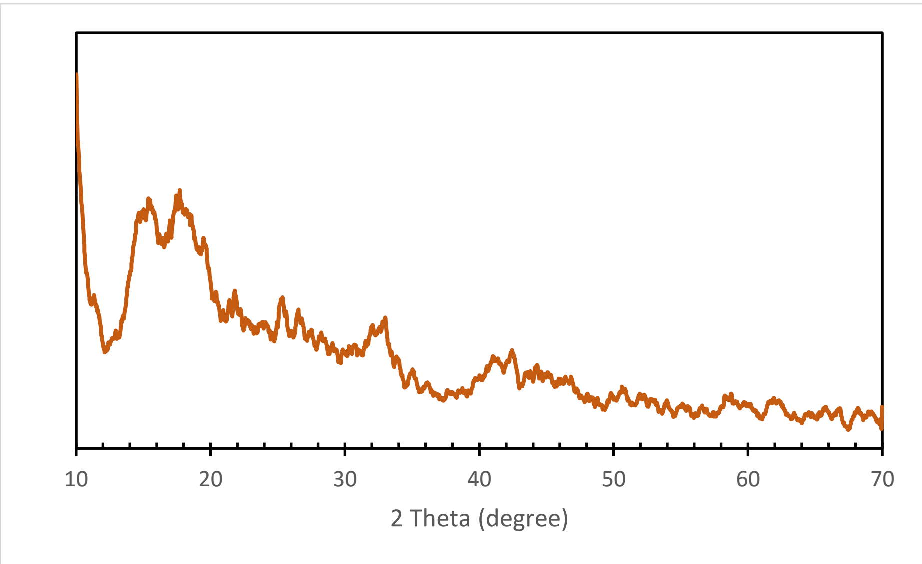

Figure 1. The XRD analysis of Al/Fe @PAA

3.2. Adsorption kinetics

The influence of contact time on RB5 adsorption in the presence Al/Fe @PAA was examined, and the outcomes are depicted in Fig. 1. The adsorption capacity exhibited agradual increase with time, showing a mild slope during the initial stages. Fig.2 illustrates pseudo-second-order model showed good agreement with the experimental data. The pseudo-second-order kinetics model (eq.3) displayed a strong fit with a high correlation coefficient (R2= 0.9987), as summarized in the table 1.

$$PFO: (Qe - Qt) = \ln Qe - k_1 t \quad (2)$$

$$PSO: \frac{t}{Q_t} = \frac{1}{k_2 Q^2{}_e} + \frac{t}{Q_e} \quad (3)$$

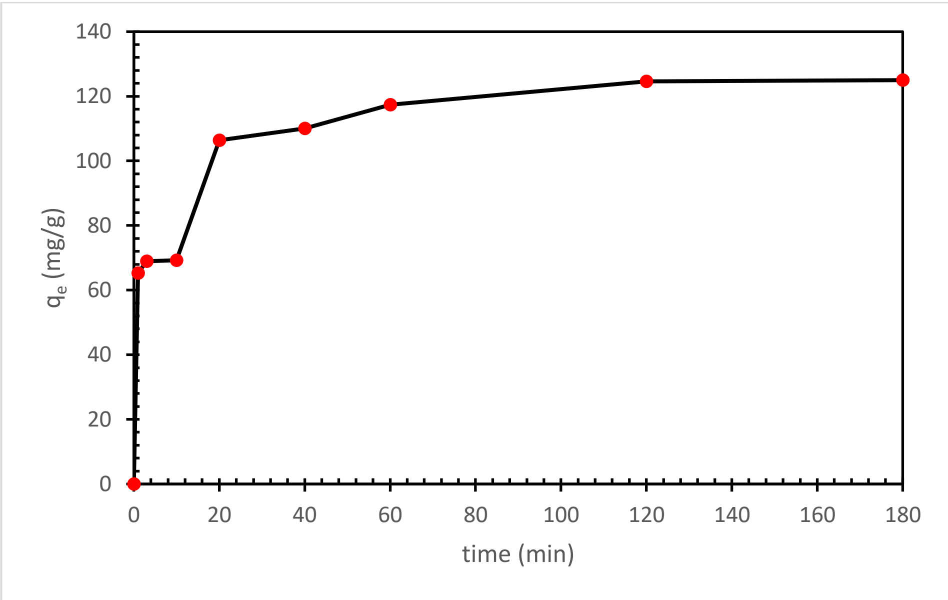

Figure 2. Adsorption kinetic of RB5 on Al/Fe @PAA

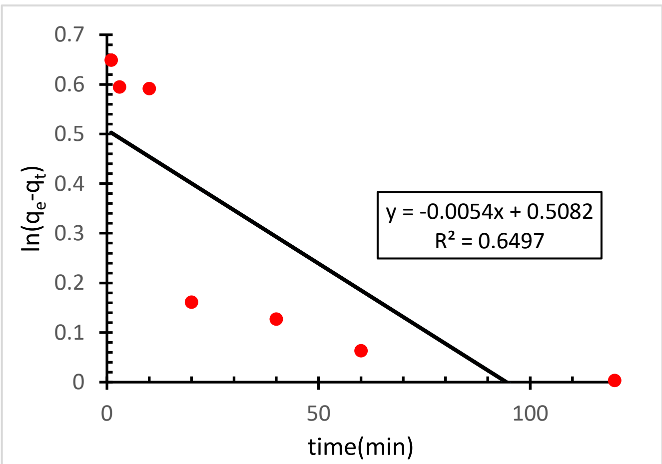

Figure3. Pseudo-first-order kinetic model

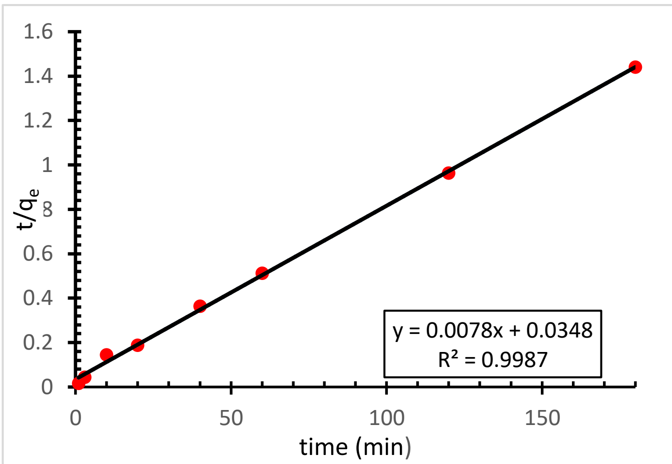

Figure 4. Pseudo-second-order kinetic model

Table 1. Kinetic parameters for the adsorption of RB5

Kinetic models	Parameter	Al/Fe @PPA
Pseudo-first-order	K_1	0.0179634
	Q_e	1.662296
	R^2	0.6497
Pseudo-second-order	K_2	1.7482
	Q_e	128.2051
	R^2	0.9987

4. Conclusions

In this study, a polymer-based metal-organic framework was synthesized using the solvothermal method to removal of RB5 from aqueous solutions. The XRD analysis revealed that the obtained compounds consisted of the polymer substrate and the MOF positioned adjacently to each other.

The kinetic behavior of the adsorption process was studied by analyzing the experimental data using pseudo-first-order and pseudo-second-order equations. Comparing the correlation coefficients obtained from these kinetics models revealed that the pseudo-second-order equation effectively describes the adsorption of RB5.

5. **References**

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