

Study on the Adsorption of Methyl Orange in Water by SA/Mwcnts Composite Materials

Zhe Li¹, Jinling Gao^{1*}, Bohao Xu¹, Wei Li¹, Xinyu Wei¹, Xin Wang¹, Xiaoshuang Che¹¹College of Science, Heilongjiang Bayi Agricultural University, Daqing 163319, ChinaDOI: <https://doi.org/10.36347/sjpm.2026.v13i04.005>

| Received: 12.03.2026 | Accepted: 25.04.2026 | Published: 29.04.2026

*Corresponding author: Jinling Gao

College of Science, Heilongjiang Bayi Agricultural University, Daqing 163319, China

Abstract**Original Research Article**

In this study, Sodium alginate was used as a dispersant to ultrasonically disperse MWCNTs, obtaining the SA/MWCNTs nanocomposite material. The adsorption of MO in the wastewater of SA/MWCNTs composite material was investigated. Starting from factors such as the dosage of adsorbent, solution pH value and adsorption time, the adsorption effect of SA/MWCNTs composite material on MO in standard water samples was examined. The research results are as follows. The optimal ingredient ratio is 0.5% (mass fraction) sodium alginate and 0.03 g multi-walled carbon nanotubes. The optimal dosage of adsorbent is 0.2 mg/mL, and the optimal adsorption time is 2 hours.

Keywords: Sodium alginate; multi-walled carbon nanotubes; Nanocomposites; Adsorption.

Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

1. INTRODUCTION

In order to effectively reduce the concentration of toxic dyes in water bodies, various water treatment technologies, such as electrochemical methods, biological methods, photocatalytic degradation, membrane filtration and adsorption methods, have been widely applied. These methods have their own advantages and limitations in industrial wastewater treatment [1]. However, all of the above methods have certain problems, such as high costs, poor recyclability, complex operation and large amounts of sludge production. In contrast, the adsorption method performs relatively well, and the sources of adsorbents are wide, and they can be modified and treated. Currently, the adsorbents studied mainly include agricultural waste, activated carbon, nanotubes and graphene [2].

The surface properties of nanomaterials, among which the most important ones are the nature and quantity of surface functional groups, will affect their adsorption efficiency. Since sodium alginate (SA) and multi-walled carbon nanotubes (MWCNTs) can both act as adsorbents for toxic substances in wastewater, in order to enhance their respective adsorption capabilities, researchers have prepared nanocomposite materials by combining the two for the study of adsorption of toxic substances in wastewater. Fu Qiu *et al.*, addressed this issue by combining sodium alginate (SA) and oxidized multi-walled carbon nanotubes (oMWCNTs) to prepare

the sodium alginate/oxidized multi-walled carbon nanotube (SA/oMWCNTs) composite material, systematically studying the influence of various factors on its adsorption effect and making a comparison. The results showed that the modified SA/oMWCNTs had better adsorption performance for Pb(II)^[3]. Wang Weili separately used chitosan (CS), sodium alginate (SA), and iron (Fe) modified carbon nanotubes (MWCNTs) to study the adsorption performance of three modified composite materials for Congo red (CR), methylene blue (MB), and phosphate ions. The results showed that the adsorption amount of the modified materials for organic dyes increased to varying degrees [4]. Due to the good adsorption properties of sodium alginate for heavy metals, when combined with nanomaterials such as carbon nanotubes with a porous structure, it has broad application prospects in heavy metal adsorption and wastewater treatment. Liu Fuqiang [5] prepared carbon nanotube sodium alginate composite materials and studied their adsorption performance for heavy metal ions in wastewater. The results confirmed that the carbon nanotube sodium alginate composite materials could better adsorb copper ions [6]. In addition, Yang *et al.*, [7] also studied the active sites for nickel ion adsorption on carbon nanotubes using density functional theory, confirming that the Stone-Wales defects on the surface of carbon nanotubes enhanced their adsorption of nickel, which also indicated that after modification, the enhancement of the defect degree of MWCNTs wall was

one of the important factors for the increase in adsorption rate. Khachatryan Gohar *et al.*, [8] used carbon nanoscale structures to enhance the binding of chitosan/alginate to improve the mechanical properties, solubility, water absorption, and barrier (anti-ultraviolet radiation) properties of the chitosan/alginate structure. Using scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible absorption spectroscopy (UV-VIS), and color analysis, the thickness and mechanical properties of the obtained films were determined. The tests conducted showed that the nanoscale structure was uniformly distributed in the composite material, and there was no chemical interaction between the nanoparticles and the polymer. The study also proved that graphene oxide and carbon nanotubes had a positive impact on the enrichment of polysaccharide composite materials for adsorption and mechanical properties. da Costa Juliê S. *et al.*, [9] introduced the preparation and characterization of a composite aerogel with a dual network of alginate (Alg) and polyacrylamide (PAM), and filled it with multi-walled carbon nanotubes (MWCNT). The alginate and PAM networks were mixed, and then the polysaccharide was cross-linked with Ca to form a dual network structure ions. The characterization analysis indicated that compared with the original aerogel (Alg/PAM), the addition of MWCNTs led to significant changes in the thermal, morphological, mechanical, and swelling properties of the composite material. The adsorption experiments proved the effectiveness of Alg/PAM/MWCNT in removing cationic dyes (methylene blue, MB, and crystal violet, CV) from aqueous solutions. Notably, under similar experimental conditions, the adsorption capacity of the aerogel containing MWCNTs for MB and CV was 1.5 times that of Alg/PAM.

In conclusion, the material obtained by the combination of SA and MWCNTs exhibits better synergistic performance compared to the individual SA and MWCNTs adsorbents [10-11]. It can enhance the adsorption capacity of the MWCNTs adsorbent for the target analytes in the sample, thereby achieving the functions of adsorption extraction and purification. However, most of the aforementioned literature involves the preparation of SA and MWCNTs into solid adsorption materials, which will inevitably reduce the contact area between the material and water, affecting its adsorption effect. Therefore, the exploration of this influencing factor still requires further investigation.

2. MATERIALS AND METHODS

2.1 Experimental Materials

MWCNTs and Sodium alginate were purchased from Suiheng Technology and Aladdin, respectively. Other reagents are analytical pure.

2.2 Experimental Equipment

Uv spectrophotometer (T6 New Century), Supercentrifuge(JIDI-20D, Guangzhou of China),

vacuum drying oven (OHG-9140A, Shanghai of China), electronic analytical balance (AL104, Shanghai of China), circulating water multi-purpose vacuum pump (SHB-III A, LTD. co. zhengzhou Great Wall science and trade), constant temperature magnetic stirring water bath (THZ-82, LTD. co. changzhou maikonuo instrument).

2.3 Preparation of composite materials

At the temperature of 293 K, sodium alginate aqueous solutions with mass fractions of 1%, 0.5%, and 0.1% were prepared respectively. After ultrasonic dispersion for 30 minutes, 0.03g of multi-walled carbon nanotubes were added. Low-temperature ultrasonic treatment was carried out with an interval of 10 minutes every 1 hour for a total of 20 hours. The solution was then centrifuged to obtain the supernatant, which was subjected to vacuum filtration. The composite materials SA/MWCNTs were observed.

2.4 Adsorption experiment of SA/MWCNTs on MO

The aqueous solution of MO (100 mg/L, 100 mL) was prepared, with 50 mg MWCNTs added at the assistant of ultrasonic for 20 min at a constant temperature of 25°C. After filtration, the filtrate was detected to obtain the concentration of MO, after which the concentration of MO was obtained using UV spectrophotometer. The adsorption capacity of SA/MWCNTs was calculated according to Equation 1.

2.5 The confirmation of MO concentration

The equilibrium concentration of MO was ascertained according to the equation.

$$Q_e = (C_0 - C_e) / m \times V$$

Where, Q_e represents the equilibrium adsorption capacity, C_e is the equilibrium adsorption concentration, C_0 is the initial concentration of MO, m is the dosage of the adsorbent, and V is the volume of the solution.

2.6 Single factor experiments

2.6.1 The influence of the concentration of the sample solution on the adsorption of

MO Prepare a 100 mg/L methyl orange aqueous solution stock solution. Use a pipette to measure 10 mL of the methyl orange stock solution and add it to a 100 mL volumetric flask. Add water to reach the mark to prepare a 10 mg/L methyl orange intermediate solution. Use a pipette to separately measure 0.00 mL, 5.00 mL, 10.00 mL, 15.00 mL, 20.00 mL, and 25.00 mL of the methyl orange stock solution in the 100 mL volumetric flask, and add water to reach the mark. Prepare methyl orange dilution solutions with concentrations of 0.00 mg/L, 0.50 mg/L, 1.00 mg/L, 1.50 mg/L, 2.00 mg/L, and 2.50 mg/L. Take 25 mL of the methyl orange solution, place it in a 30 °C constant temperature water bath for 45 minutes of shaking, then perform vacuum filtration. Take the filtrate and use a UV-visible spectrophotometer to measure its absorbance. The data obtained from each gradient are calculated using the formula and plotted using Origin.

2.6.2 The influence of adsorbent dosage on the adsorption of MO

Prepare 100 mL of 0.01 g/mL methyl orange solution, and prepare five 100 mL beakers. Add 100 mL of methyl orange solution to each beaker, and then add the composite material in the following order: 0.0000 g, 0.0100 g, 0.0150 g, 0.0200 g, 0.0250 g. After shaking in a 30 °C constant temperature water bath for 60 minutes, perform vacuum filtration. Take the filtrate and measure its absorbance using a UV-visible spectrophotometer. Use the formula to calculate the adsorption amount of each gradient. The obtained data will be plotted using Origin.

2.6.3 The influence of adsorption time on the adsorption of MO

Prepare 100 mL of 0.01 g/mL methyl orange solution, and prepare four 100 mL beakers. Add 20 mL of methyl orange solution to each beaker, and 0.0150 g of the composite material. Place them in a 30 °C water bath and shake for 5, 15, 30, 45, and 60 minutes respectively. Perform vacuum filtration, and take the filtrate to measure its absorbance using a UV-visible spectrophotometer. Use the formula to calculate the adsorption amount of each gradient. The obtained data will be plotted using Origin.

3 RESULTS AND DISCUSSIONS

3.1 Analysis of the Optimal Ingredient Ratio for Composite Materials

Table 1: Preparation results and analysis of composite materials

Temperature	SA mass fraction SA ($\omega\%$)	MWCNTs dosage/g	Experimental phenomenon
25 °C	1%	0.03 g	The dispersion is not very good, and most of the SA has not dissolved
25 °C	0.5%	0.03 g	The dispersion is good, and the solution is uniform without any precipitation or floating substances
25 °C	0.1%	0.03 g	The dispersion is poor, and most of the MWCNTs float on the surface of the solution

The test results show that when the SA mass fraction is 0.5% and the MWCNTs dosage is 0.03 g, the prepared solution has the best dispersion performance.

3.2 Thermogravimetric Analysis of Composite Materials and Raw Materials

As shown in Figure 1, the weight of the composite material(b) significantly decreases at temperatures ranging from 300 to 500 degrees Celsius. This corresponds to the breakage of the main chain in the composite material, resulting in the generation of volatile

products. At temperatures ranging from 500 to 800 degrees Celsius, the weight loss trend slows down and coincides with the temperature range of the weight loss of multi-walled carbon nanotubes. Therefore, it is concluded that the residue is a carbon nanotube and the carbonization product of the composite material. The total weight loss rate of multi-walled carbon nanotubes is 98.44%, and the total weight loss rate of the composite material is 81.83%. This indicates that the carbon nanotubes(a) are of high purity and the composite material introduces another component.

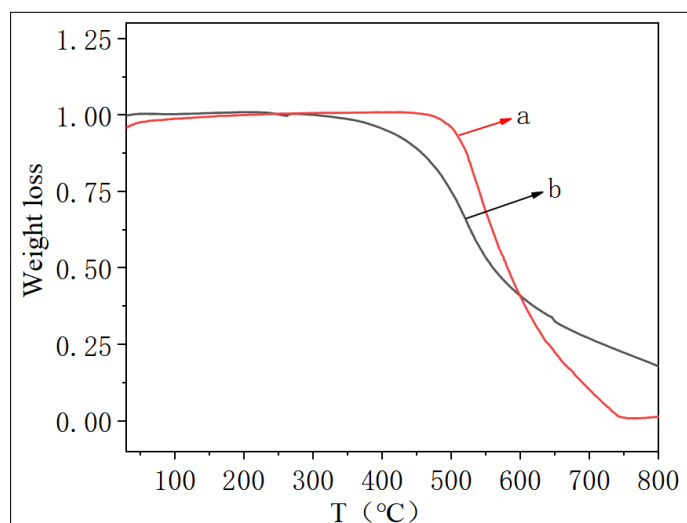


Fig. 1: The rmogravimetric analysis of composite materials and raw materials

3.3 Analysis of Results from Single Factor Experiments

3.3.1 Results and Analysis of the Effect of the Concentration of the Sample Solution on the Adsorption of MO

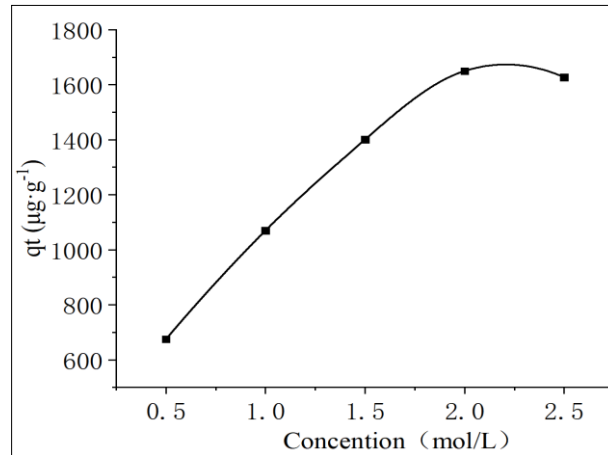


Fig. 2: The relationship between the concentration of the liquid to be measured and the adsorption amount

As shown in Figure 2, when the concentration of MO solution is less than 2.0 mg/L, the adsorption amount increases with the increase of concentration. At this time, the active sites on the surface of the adsorbent are abundant. When the concentration is 2.0 mg/L, the adsorption amount reaches its peak of 1650 µg/g. When the concentration of the sample solution exceeds 2.0 mg/L, the adsorption amount decreases monotonically with the increase of the sample solution concentration. This is because there are no vacancies on the active sites of the adsorbent at this time, which leads to a decrease in the adsorption amount. Therefore, the optimal concentration of the sample solution is 2.0 mg/L.

3.3.2 The results and analysis of the influence of adsorbent dosage on the adsorption of MO

As shown in Figure 3, when the adsorbent dosage is less than 0.0150 g, the adsorption amount increases monotonically with the increase of adsorbent dosage, and the MO concentration gradually decreases. When the adsorbent dosage is greater than 0.0150 g, the adsorption amount decreases rapidly with the increase of adsorbent dosage. This is because there are van der Waals forces between carbon nanotubes. When the amount of carbon nanotubes exceeds the threshold, due to the influence of van der Waals forces, the carbon nanotubes attract each other and eventually undergo agglomeration, resulting in a significant reduction in the active sites on the surface of the composite material, and thus leading to a sharp decrease in the adsorption amount. Therefore, the optimal adsorbent dosage is 0.0150 g.

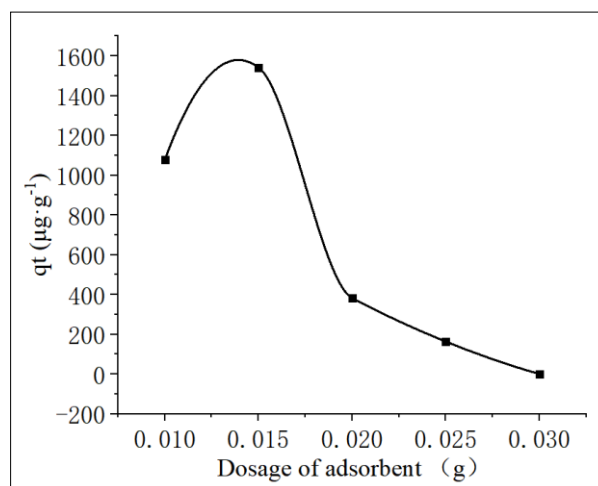


Fig. 3: The relationship between the dosage of adsorbent and the quantity of adsorption

3.3.3 The results and analysis of the influence of adsorption time on the adsorption of MO

As shown in Figure 4, when the adsorption time is less than 45 minutes, the adsorption amount increases rapidly with the adsorption time. This is because the composite material has a large surface area and abundant

surface-active sites. After the adsorption time exceeds 45 minutes, the growth rate of the adsorption amount significantly decreases. When it approaches 60 minutes, the adsorption amount even slightly decreases. This is because after the adsorption time exceeds 45 minutes, there are no remaining active sites on the adsorbent

surface. However, since the adsorption and desorption processes are reversible, the adsorbent and MO reach a

dynamic equilibrium in the solution. Thus, the optimal adsorption time is 45 minutes.

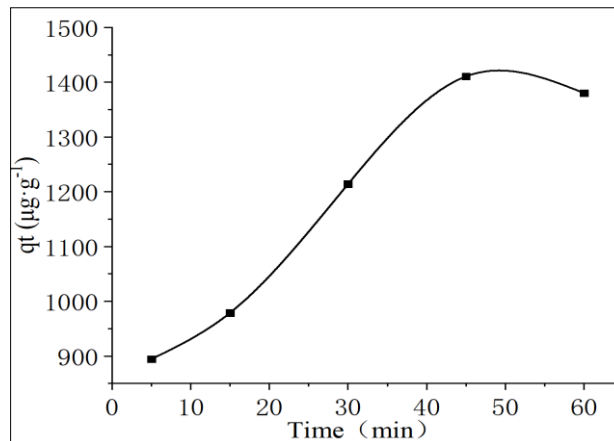


Fig. 4: The relationship between adsorption time and adsorption capacity

3.4 Orthogonal test results and analysis

On the basis of single factor experiment, the orthogonal test of three factors and the interaction terms of adsorbent dosage, and the experiment was carried out

according to the orthogonal test table. The specific scheme and results of the orthogonal test were shown in Table 2, and the optimal scheme of influencing factors was finally obtained.

Table 2: Orthogonal test

Groups	Factors			q_e (µg/g)
	A	B	C	
1	1	1	1	3919.6
2	1	2	2	3441.2
3	1	3	3	4519.4
4	2	1	2	2348.3
5	2	2	3	2614.4
6	2	3	1	2966.4
7	3	1	3	2167.7
8	3	2	1	1970.3
9	3	3	2	2096.2
K_1	11880.2	8435.64	8856.3	
K_2	7929.14	8025.9	7885.74	
K_3	6234.2	9582	9301.5	
k_1	3960.07	2811.88	2952.1	
k_2	2643.05	2675.3	2628.58	
k_3	2078.07	3194	3100.5	
R	1882	518.7	471.92	

From Table 2, according to the range analysis, the factor that has the greatest impact on the adsorption amount is the amount of adsorbent, followed by the adsorption time, and then the adsorption temperature and the concentration of the sample solution. Therefore, the ranking of the influence on the adsorption amount of MO in water is: adsorbent amount > adsorption time > adsorption temperature > sample solution concentration. The optimal combination of the adsorption process is $A_1B_3C_3$, that is, the adsorbent amount is 0.010 g, the adsorption time is 60 min, the adsorption temperature is 35 °C, and the sample solution concentration is 2.0 mg/L. Under these conditions, three parallel experiments were conducted, and the adsorption amount reached 4520.1 µg/g.

4. CONCLUSIONS

Through thermogravimetric analysis of multi-walled carbon nanotubes and the composite material, it can be seen that the composite material significantly loses weight at temperatures ranging from 300 to 500 degrees Celsius, corresponding to the chain breakage of the main chain and the generation of volatile products. The total weight loss rate of multi-walled carbon nanotubes is 98.44%, and the total weight loss rate of the composite material is 81.83%. This indicates that the carbon nanotubes are of high purity and the composite material introduces another component. The results of the single-factor test show that the optimal adsorption conditions are as follows: the concentration of the

solution to be tested is 2.0 mg/L, the dosage of the adsorbent is 0.015 g, the adsorption time is 45 min. Under the above conditions, the maximum adsorption capacity of the experiment was 3571.1 $\mu\text{g/g}$. The results of orthogonal experiments show that the order of influence on the adsorption capacity of MO in water is as follows: adsorbent dosage > adsorption time > concentration of the solution to be tested. The optimal combination of the adsorption process is A1B3C3, that is, the adsorbent dosage is 0.010g, the adsorption time is 60 min, and the concentration of the test solution is 2.0 mg/L. Under the above conditions, the average adsorption capacity is obtained as 4520.1 $\mu\text{g/g}$, which is higher than the adsorption capacity under the optimal conditions of the single-factor test.

Fund projects: Heilongjiang Province College Students Innovation and Entrepreneurship Training Program Project (No. 202310223061), Heilongjiang Province Ecological Environment Protection Research Project (HST2024S019), and Heilongjiang Bayi Agricultural University Three erticals Scientific Research Support Program (ZRCPY202322).

Acknowledgement: This work was supported by Heilongjiang Bayi Agricultural University Physical and Chemical Provincial Experimental Demonstration Teaching Center.

REFERENCES

1. He Changhan, Wang Juan, Qu Lijun, *et al.*, Research Progress on the Removal of Heavy Metals and Dyes from Water by Nano-Adsorbents [J]. *Analytical Chemistry*, 2023, 51(11): 1724-1734.
2. ZENG X, ZHANG G, WEN J, *et al.*, Simultaneous removal of aqueous same ionic type heavy metals and dyes by a magnetic chitosan/polyethyleneimine embedded hydrophobic sodium alginate composite: Performance, interaction and mechanism[J]. *Chemosphere*, 2023, 318:137869.
3. Fu Qiuping, Zhang Rongbin, Zhan Fengliu, *et al.*, Study on the Adsorption Performance of Pb(μ) by Oxidized Multi-walled Carbon Nanotubes/Sodium Alginate Composite Materials [J]. *New Chemical Materials*, 2022, 50(08): 235-239.
4. Wang Weili. Adsorption of Water Pollutants by Modified Carbon Nanotubes and Sodium Alginate [D]. Zhengzhou University, 2019.
5. Liu Fokang. Study on the Adsorption Performance of Carbon Nanotubes/Sodium Alginate Composite Materials for Heavy Metal Ions in Wastewater [D]. Qingdao: Qingdao University, 2010.
6. Wu Huiling, Zhang Shuping. Research and Application Progress of Sodium Alginate Nanocomposite Materials [J]. *Chemical Industry Progress*, 2014, 33 (04): 954-959.
7. Ho S Y, Ho W S, Ku J K. Ni adsorption on Stone-Wales defect sites in single-wall carbon nanotubes. [J]. *The Journal of chemical physics*, 2006, 125(8):084705.
8. Gohar K, Karen K, Joanna S, *et al.*, Design of Carbon Nanocomposites Based on Sodium Alginate/Chitosan Reinforced with Graphene Oxide and Carbon Nanotubes [J]. *Polymers*, 2023, 15 (4): 925-925.
9. R.S. D S D, *et al.*, Composite aerogels of alginate/poly(acrylamide)/carbon nanotubes with enhanced performance for cationic dyes adsorption[J]. *Materials Science Engineering B*, 2023, 298.
10. KHACHATRYAN G, KHACHATRYAN K, SZCZEPANKOWSKA J, *et al.*, Design of Carbon Nanocomposites Based on Sodium Alginate/Chitosan Reinforced with Graphene Oxide and Carbon Nanotubes [J]. *Polymers*, 2023, 15(4):925.
11. Juliê S. da Costa, Jaqueline F.de Souza, Débora R.S. dos Santos, *et al.*, Composite aerogels of alginate /poly(acrylamide)/carbon nanotubes with enhanced performance for cationic dyes adsorption[J]. *Materials Science and Engineering: B*, 2023, 298:116820.