DYNAMIC SORPTION PROCESS OF ACID DYE ON NANOFIBERS ASSEMBLY WITH TIO_2 NANOPHOTOCATALYSIS

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Abstract

In this work, nanotechnologies including electrospun nanofibers and nanoparticles were implemented for acid dye removal from simulated wastewater. Dynamic sorption properties of polyamide 6 nanofibrous membrane (PNM) were investigated, Titanium dioxide (TiO_2) nanoparticles deposition was applied as surface modification method for PNM, and UV light was applied during the dynamic sorption process of C. I. Acid Orange 7 (AO7) on PNM. The light absorbance of influent and effluent were measured and the sorption capacity was calculated. The result shows improvement of sorption capacity after TiO_2 nanoparticles (NPs) deposition and UV light applying. Long time UV lighting can improve the sorption capacity of AO7 on PNM with NPs but destroy the material.

Keywords: Dynamic sorption, acid dye, nanofibers, nanophotocatalysis

1. INTRODUCTION

In wastewater cleaning area, nanoparticles have been widely studied, and the function mostly realized due to their outstanding adsorption and photocatalytic properties. Photocatalytic oxidation processes have been widely considered as powerful methods to remove non-biodegradable organic pollutants in water. [1] The photocatalytic processes have the potential to mineralize complicated organics and reduce toxicity without the generation of sludge and by-products and Titanium dioxide (TiO_2) is the most common and practical material as the environmental photocatalyst. [2-4]

Photocatalysis with TiO_2 nanoparticles has been studied for the degradation of wastewater pollutants. This process has several advantages including complete mineralization of organic pollutants like aliphatics, aromatics, polymers, dyes, surfactants, pesticides and herbicides to CO_2, water and mineral acids, no waste solids to dispose of and mild temperature and pressure conditions. Photocatalysis with TiO_2 nanoparticles uses two kinds of reaction systems, namely suspension and immobilized systems [5-14].

Acid orange 7 (AO7) is the most studied compound among the azo dyes as far as its photocatalytic degradation under several experimental conditions. The degradation pathways and the formation of by-products is also fully described [15-18] which shows in **Figure 1**. Thus, AO7 can be used as a model compound for oxidative degradation studies of azo dyes. [19]

In this study, dynamic sorption process with TiO_2 nanoparticles photocatalysis was performed. The effect of TiO_2 nanoparticles and UV lighting time is disscused. The results will be useful in their application to the design of polyamide 6 nanofibers assembly sorption systems.

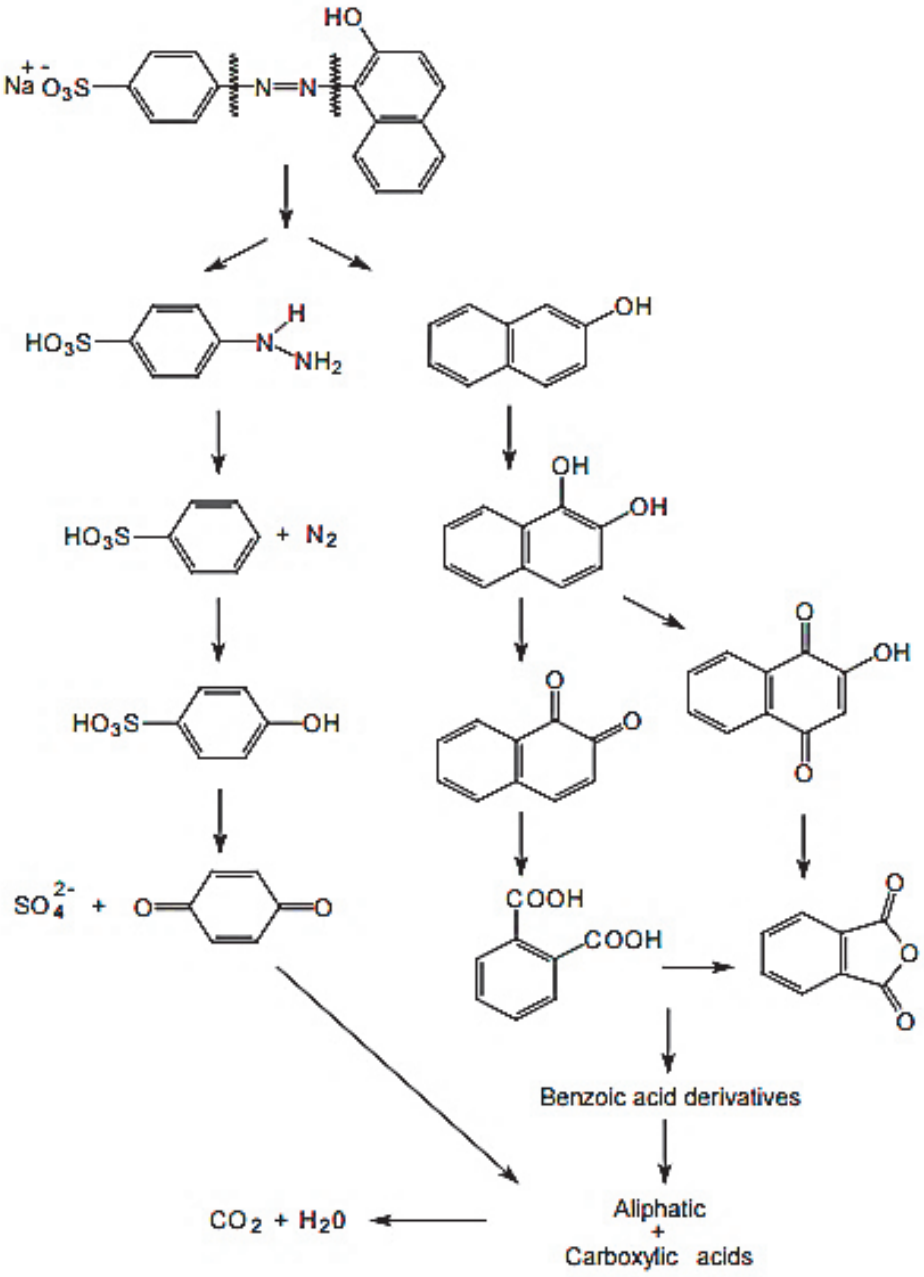


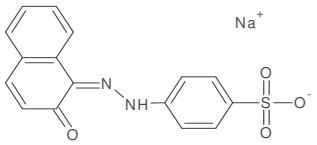
Figure 1 Major photocatalytic pathways of C. I. Acid Orange 7, a representative azo dye for phenyl-azonaphthol chemical group, based on the identification of by-products from previous reported degradation studies. [5, 15, 20]

2. MATERIALS AND METHOD

2.1. Materials

Polyamide 6 nanofibrous membrane with areal density 2.5 g/m^2 (PNM2.5) purchased from ELMARCO s. r. o were mainly used as sorbent. C. I. Acid Orange 7 with purity over 85% purchased from Sigma-Aldrich was used as a pollutant model. The dye properties are shown in **Table 1.** TiO_2 (P25), anatas:rutile 70:30, with particles diameter of 21 nm, purchased from Degussa Ltd., was used as catalyst.

Table 1 Physical and chemical characteristics of selected dyestuff

Abbreviation	CAS No.	Molecular weight (g/mol)	Molecular formula	Maximum UV-Vis absorbance wavelength (nm)	Molecular structure
AO7	633-96-5	350.3	$C_{16}H_{11}N_2NaO_4S$	483	

2.2. Apparatus assembled

Dynamic sorption photocatalysis apparatus was a combination of vacuum sorption apparatus, inlet supplying system, and UV lighting system. The diameter of working area was 10 cm. Flow rate range was 0.05-40 mL/min which can be adjusted by peristaltic pump shown in **Figure 2.** The UV irradiation system was assembled with a lamp from Bandelin Co. D-69168 Wieslich, type N-36 K and frame for supporting. It gives radiation with wavelength 254 nm and performance 4×6 W.

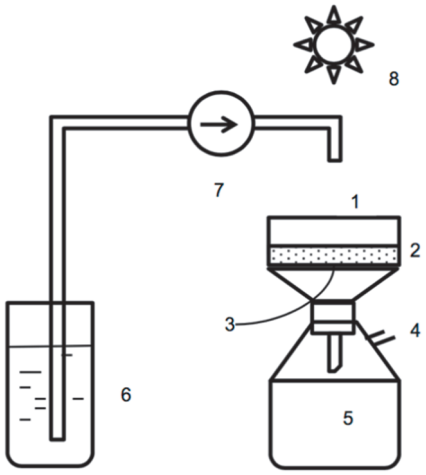


Figure 2 Apparatus for dynamic sorption process with UV lighting. 1) funnel; 2) sorbent; 3) sorbent supporting unit; 4) vacuum pressure port; 5) vacuum flask; 6) container with original solution; 7) peristaltic pump; 8) UV lighting system

2.3. Method

Apparatus described above was used for deposition of TiO_2 nanoparticles and dynamic sorption experiment of AO7 on PNM2.5.

Table 2 Sample code of dynamic sorption experiment with TiO_2 nanophotocatalysis

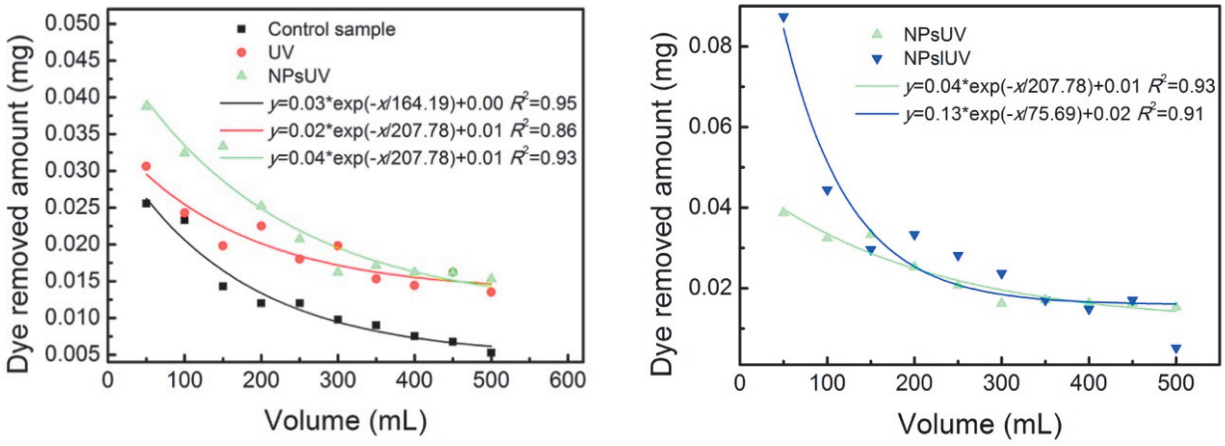
Sample code	Amount of TiO_2 solutions	UV lighting time	Flow rate
	mL	min	mL/min
Control	0	0	17
UV	0	65	17
NPsUV	100	65	17
NPslUV	100	200	8.3

100 mL of TiO_2 NPs solution with concentration 0.01 g/L was filled into the funnel while the vacuum pump working. AO7 solution was prepared with concentration 0.002 g/L, and 10 times 50 mL AO7 solution were pumped for one experiment. 17 and 8.3 mL/min of flow rate were used for the experiment, which has been described in detail in **Table 2**.

The absorbance of influent and effluents after each 50 mL AO7 solution inserted were detected with Spectrometer, Spekol 11, ZP 100027. The dye removal amount and sorption capacity were calculated and compared.

3. RESULT AND DISCUSSIONS

The absorbance of influent and effluents after each 50 mL AO7 solution went through the dynamic sorption photocatalysis apparatus were detected. The dye removed amount, and dye sorption capacity were calculated and the results were shown in **Figure 3** and **Figure 4**. Data points were fitted with exponential equation and square of correlation coefficient (R^2) was given in the figures.



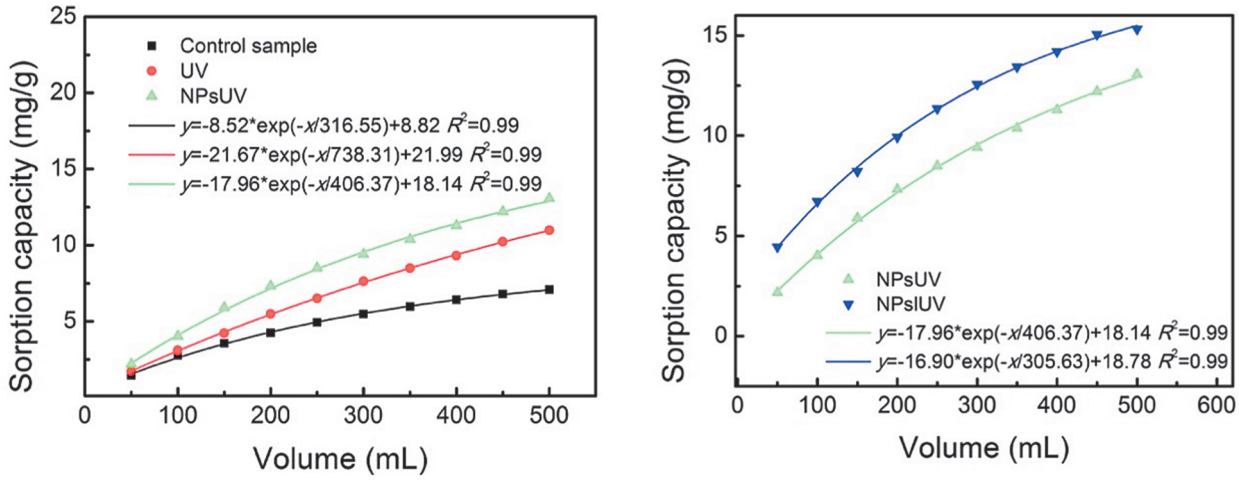
a) b)

Figure 3 Dye removed amount comparison of different samples: a) comparison among control sample, UV, and NPsUV; b) samples with different UV treating time

As shown in **Figure 3a,** the dye removed amount of three samples were compared. The figure shows that the dye removed amount decreased while more dye solution pumped through the PNM2.5, and it became stable after around 300 mL solution went through for PNM2.5 samples with UV light treatment. It is obviously indicated that UV light treatment improved dye removed amount of AO7 on PNM2.5, and TiO_2 NPs photocatalysis improved the dye removed amount at the beginning of dynamic sorption process by 26.5%.

Figure 3b shows that while prolonging the UV treating time, same trend was found and the initial dye removed amount improved over 125%. However, PNM2.5 was broken after around 300 mL solution processed due to too long time UV heating, which was shown in the figure as a sudden drop after the volume reached 300 mL and even worse drop appeared after the last 50 mL dye solution processed.

After calculation of accumulated dye removed amount, sorption capacity versus volume were plotted in **Figure 4. Figure 4a** showed that after 500 mL AO7 dye solution pumped through PNM2.5, TiO_2 NPs photocatalysis improved the sorption capacity of PNM2.5 from 7.09 to 13.07 mg/g. Moreover, **Figure 4b** showed that comparing with the photocatalysis sample, after prolonging the UV treating time, value of dye sorption capacity reached up to 15.32 mg/g.



a) b)

Figure 4 Sorption capacity comparison of different samples: a) comparison among control sample, UV, and NPsUV; b) samples with different UV treating time

4. CONCLUSION

TiO_2 nanoparticles photocatalysis was proved to be one method for improving the dynamic sorption capacity of C. I. Acid Orange 7 on polyamide 6 nanofiberous membrane. The initial sorption amount can be improved by prolonging the UV light treating time, however, the material cannot withstand long time aging with UV light.

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