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Study on adsorption kinetics of rhodamine B in water with pomelo peel as adsorbent

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Key words: Pomelo peel; Rhodamine B; Adsorption; Kinetics.

Abstract: The effect of pomelo peel on the adsorption of organic dye rhodamine B (RB) was explored through a series of experiments. The influence of factors including pH value, initial concentration of RB, dosage of pomelo peel, and temperature upon adsorption of RB in aqueous solution was studied. The results of experiments indicate that the optimal conditions for pomelo peel as the biologic material to absorb RB include 0.6 g pomelo peel, 20 mg/L RB, initial solution pH value of 3 and reaction time of 20 minutes, where the removal (adsorption rate) reaches 60.9%. The second-order dynamic adsorption model well describes the adsorption dynamics process of RB by pomelo peel. As the concentration of RB increases, the absorption capacity rises.

Introduction

Dye has a wide range of applications in papermaking, printing, textile and other industries. Many factories will discharge directly or indirectly a large number of dye wastewater into the natural water bodies. Some dyes can also be carcinogenic and mutation which can be serious to affect the natural environment. [1,2].

The common methods of dye wastewater treatment include adsorption method, electrochemical method, chemical oxidation and Fenton reagent method, etc.[3] The adsorption method is the most appropriate and more widely used. Using the agricultural waste as a low-cost adsorbent has many advantages. On the one hand, it can reduce the waste disposal cost, on the other hand, it can also solve the pollution problem of dye wastewater. So pomelo peel was studied to remove organic dyes RB in the waste water in this paper.

Experimental section

Materials. All reagents including rhodamine B (99%), sodium hydroxide (NaOH, 96.0%), and hydrochloric acid (HCl, 36-38%) were of analytical reagent grade.

Preparation of pomelo peel adsorbent. First of all, the pomelo peel for experiment which was bought from market, was made to natural dry. Then, the pomelo peel was soaked with tap water to remove surface impurities, put in the oven to 90 ^{O}C for drying to constant weight, grinded and sifted out of 100 meshes sieve, and finally the pomelo peel powder was put in dryer. [4]

Experimental method. RB analysis were sampled and analyzed immediately by measuring absorbance at 552nm where RB is strongly absorbent with a WFJ2100 UV-vis spectrophotometer (Unico Co., Shanghai). The A-C regression equation of RB was obtained (A=0.4607C, R^2 =0.9993) . There is a good linear relationship between concentration and absorbance of RB.

The determination of removal rate and the adsorption quantity. A different amount of RB solution were diluted to 100 ml at pH 6.5. The pomelo peel powder was added accurately into the RB aolution. The samples were oscillated in uniform magnetic in 20 minutes. The absorbance of

the samples were measured after filtering. The calculation of removal (W) was based on Eq. 1 and the calculation of adsorbent (Q) was based on Eq. 2.

$$W = [(A_0 - A_T)/ A_0] \times 100\% \quad (1)$$

W: removal (%); A_0: initial absorbance of RB; A_T: absorbance after the adsorption of RB .

$$Q = [(C_0 - C) \times V]/ m \quad (2)$$

C_0: concentration of RB (mg/mL); C: concentration of RB after adsorption (mg/mL); V: volume of the adsorption solution (mL); M: mass of adsorbent (g); Q: adsorption quantity (mg/g).

Experimental results and analysis

Effect of pomelo peel on the RB removal. The different mass of pomelo peel was added into the 100 mL 10 mg/L RB solution at pH 6.5. Afterward they reacted at room temperature. The relationship between the adsorption effect and the mass of pomelo peel was showed in Fig. 1. It was found that the removal of RB stepped up with pomelo peel in 0.2 ~ 0.6 g. The removal rate reached maximum (56.0%) with 0.6 g pomelo peel. After that, the removal was decreased with more than 0.6 g pomelo peel. So the best adsorption effect was obtained with 0.6 g pomelo peel.

Effect of pH on the RB removal. Fig. 2 showed that the removal of RB reduced gradually with the increase of pH at reaction of 20 minutes. It has high efficiency under the acid solution. H^+ was adsorbed by pomelo peel, which was combined with Cl^- of RB molecules because of the positive charge in the acidic solution. The OH^- was adsorbed by pomelo peel and the Cl^- of RB molecules became linked due to the electrostatic interactions of the negative charged ions, which tend to repel each other when the pH increased [5]. Finally the best adsorption effect with pH 3.0 was obtained.

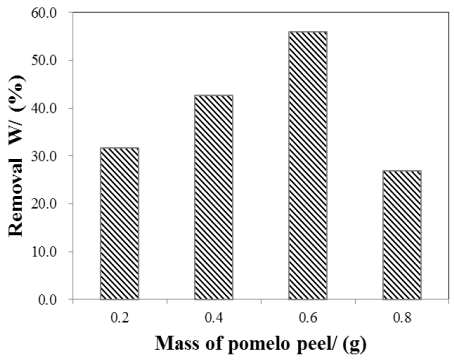

Fig. 1 Effect of pomelo peel on the removal

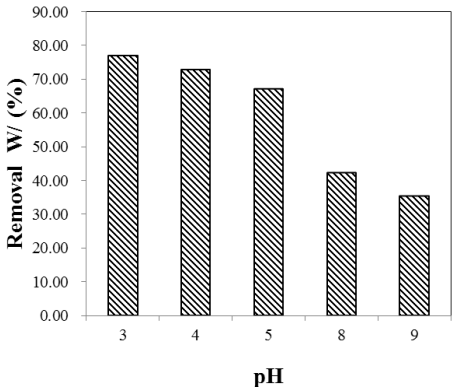

Fig.2 Effect of pH on the removal

Effect of initial concentration of RB on the removal. Fig. 3 shows the effect of RB concentration on the removal of RB wastewater under conditions of 0.6 g pomelo peel powder, 5 minutes reaction time, and pH 3.0. The concentration of RB solution reduced gradually and the removal was increasing from 57.3% to 60.9% with increasing initial concentration of RB from 10 mg/L to 20 mg/L. This may be due to that high RB concentration increased the contact opportunities between RB and the surface of pomelo peel, thus enabling absorption sites of pomelo peel has been fully used.

Fig. 4 was obtained based on Eq. 2 and Fig. 3. Adsorption (Q) rised gradually with the increasing initial concentration of the RB.

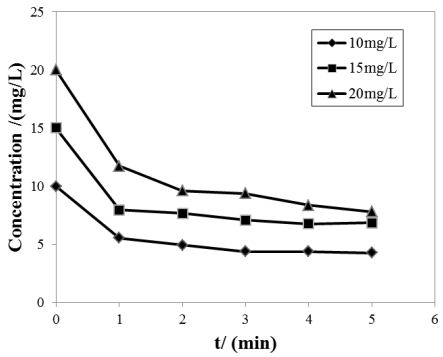

Fig. 3 Effect of initial concentration of RB on the removal.

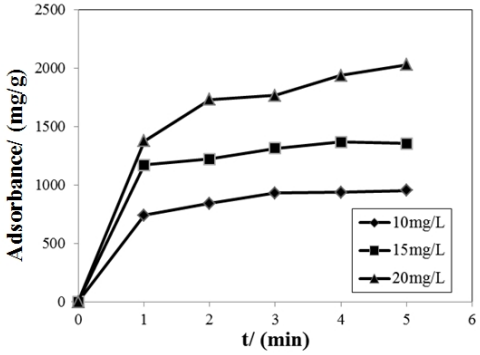

Fig. 4 The adsorption kinetics of RB by pemole peel

Dynamic experiment. First-order adsorption kinetic model (Eq.3) is widely used in the description of the adsorption kinetics of aqueous solution. It stands for that the adsorption and solution concentration would affect the adsorption rate. Fig. 5 and Table 1 were obtained based on Eq.3.

$$\ln(Q_e-Q_t)=\ln Q_e - k_1 t \quad (3)$$

Q_e: the amount of adsorption equilibrium (mg/g), Q_t: adsorption capacity (mg/g), k_1: first-order adsorption rate constant (1/min). k_1 and Q_e were obtained by the slope and intercepted of a fitting line.

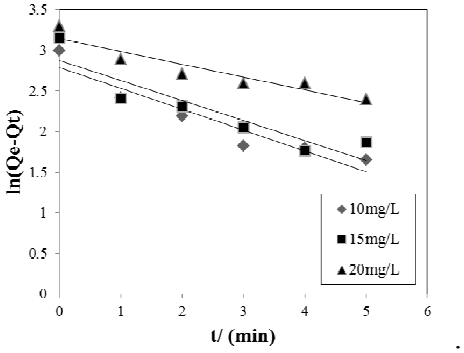

Fig. 5 The pseudo-first-order kinetic equation simulation of RB adsorption

Table 1 Pseudo-first-order kinetic equation fitting parameters

Concentration of rhodamine B（mg/L）	Pseudo-first-order kinetic equation	
	k_1(1/min)	R^2
10	0.2557	0.9009
15	0.2467	0.8389
20	0.1574	0.8789

Second-order-adsorptive kinetic model (Eq. 4 and Eq. 5) is also widely used for adsorption kinetics. It shows the adsorptive process is complete, and its limiting factors is adsorption mechanism [6]. Fig. 6 and Table 2 were obtained based on Eq.4 and Eq. 5.

$$t/Q_t = 1/(k_2 Q_e^2) + t/Q_e \quad (4)$$

$$V_0 = k_2 Q_e^2 \quad (5)$$

k_2: the second-order adsorption rate constant (g/(mg · min)), V_0: the initial adsorption rate (mg/(g· min)), Q_e, k_2 and V_0 are obtained according to the slope and intercept of the fitting line.

Table 1 and Table 2 show R^2 of the pseudo-second-order adsorptive kinetics equation is bigger than R^2 of the pseudo-first-order adsorptive kinetics equation. The pseudo-second-order kinetic parameters k_2 were 0.005, 0.00245, 0.00125 g/(mg · min) in 10 mg/L, 15 mg/L, 20 mg/L RB solutions respectively. Adsorption kinetics of secondary model was built on the basis of the

hypothesis that chemical reaction mechanism is the rate-controlling step. Therefore，the adsorption reactions of RB wastewater by pomelo peel should contain chemical adsorption.

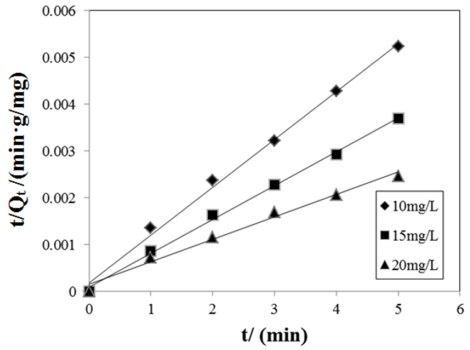

Fig. 6 The pseudo-second-order kinetic simulation of RB adsorption

Table 2 Second-order kinetic fitting parameters.

Concentration of rhodamine B（mg/L）	Pseudo-second-order kinetic	
	k_2(g/(mg · min))	R^2
10	0.005	0.9957
15	0.00245	0.9974
20	0.00125	0.9872

Conclusion

For RB adsorption, the optimum dosage of pomelo peel was 0.6 g. The removal of RB was reduced with pH increasing and the best effect was obtained at pH 3.0. The absorption amount(Q) of RB by pomelo peel increased with increasing the initial concentration of RB. The secondary adsorption dynamics model was better to describe RB adsorption dynamics process using pomelo peel as low-cost adsorbent and R^2 reached more than 0.98. The adsorption reactions of RB wastewater by pomelo peel should contain chemical adsorption.

Acknowledgements

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