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Preparation of polyaniline/activated carbon composite for removal of reactive red 198 from aqueous solution

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Abstract: In this study, preparation of polyaniline (PAni) composite containing activated carbon and its capability to removal of reactive red 198 (RR198) from aqueous solution was studied. PAni was synthesized in the presence of potassium iodate (KIO_3) as an oxidant and coated on prepared activated carbon. The removal of RR198 was investigated using PAni/activated carbon (PAni/AC) composite. The products were investigated in terms of morphology and chemical structure with scanning electron microscope (SEM). Batch studies were performed to evaluate the influence of various experimental parameters like *p*H, adsorbent dosage and contact time. Optimum conditions for RR198 removal were found to be *p*H 3, adsorbent dosage of 1 g/L and equilibrium time 60 minute.

Keywords: Activated carbon, Polyaniline, Reactive red 198, Removal.

Introduction

Dyes are widely used in various fields (textiles, paper, rubber, plastics and leather) and their discharge into water causes environmental pollution. The treatment and disposal of dye-contaminated wastewater is one of the most serious environmental problems [1]. To minimize the risk of pollution generated by such effluent, this effluent must be treated before discharged into the environment [2]. Many treatment methods have been developed to remove dyes from wastewater. These treatment methods can be divided into physical, chemical and biological schemes. Although chemical and biological approaches are effective in removing dyes, they require special equipment and are usually energy intensive. Additionally, these processes often generate large amounts of byproducts. Among all existing techniques, adsorption is considered the most efficient [1], economy [3], simple, easy to perform and insensitive to toxic substances [4]. A large variety of natural materials or the wastes/by-products of industries has been employed as inexpensive adsorbents for dye removal [5]. The waste materials seem to be viable option for dye removal because of their economic and eco-friendly traits, availability in abundance, low cost, regeneration of the bio sorbent and the possibility of dye recovery. In this connection, special attention have been given to agricultural wastes like orange peel, banana pith, banana peel, plum kernels, apple pomade, wheat straw, sawdust, coir pith, sugarcane bagasse, tea leaves, bamboo dust, etc. [5]. In India, rice husk is an easily available agricultural waste material, produced in large quantities as a by-product of rice milling and create potential environmental problems. The annual generation of rice husk has been estimated to be 18–22 million tones [6]. Rice husk possesses a granular structure, is insoluble in water, has chemical stability, high mechanical strength and accounts for about 20% of the whole rice. It consists of about 32% cellulose, 21% hemicelluloses, 21% lignin, 20% silica and 3% crude protein [7,8].

Conducting polymers have become one of the most attractive subjects of investigation in recent years.

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Their unique properties such as electrical conductivity and possibility of both chemical and electrochemical synthesis make them useful in wide area of applications, such as environmental applications [9]. polyaniline is one of the most famous conducting polymers [9-13]. Polyaniline is a poly aromatic amine that can be easily synthesized chemically from bronsted acidic aqueous solutions [14]. The aim of present work is to investigate the removal of reactive red 198 from aqueous media using activated carbon coated by polyaniline.

Results and discussion

Surface morphology:

The morphology of activated carbon before and after coating with PAni is shown in Figures **1** and **2**, respectively. The coating with conducting polymer produced by surface polymerization is very visible. The coating of activated carbon has always been found to be uniform by visual inspection.

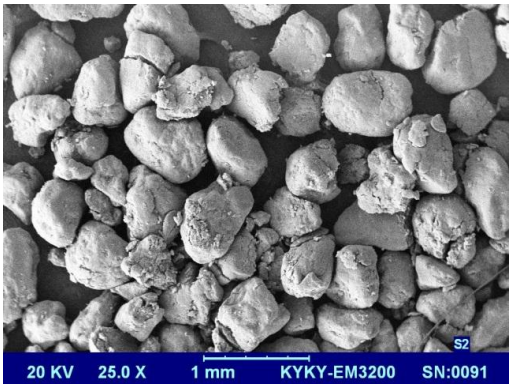

Figure 1: SEM image of activated carbon

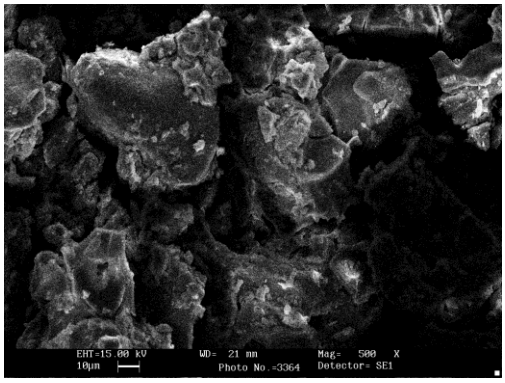

Figure 2: SEM image of PAni/activated carbon

Effect of pH:

The *p*H value of the aqueous solution is an important controlling parameter in the adsorption process. These *p*H values affect the surface charge of adsorbent during adsorption. In order to evaluate the influence of this parameter on the adsorption, the experiments were carried out at different initial pH ranging from 2 to 12. The experiment was performed by PAni/activated carbon composite, with an initial concentration of 20 mg/L, at room temperature with contact time of 60 min. The results are shown in Figure **3**. Removal of RR 198 increases with decreasing *p*H and a maximum value was reached at an equilibrium *p*H of around 3, as can be seen in Figure **3**.

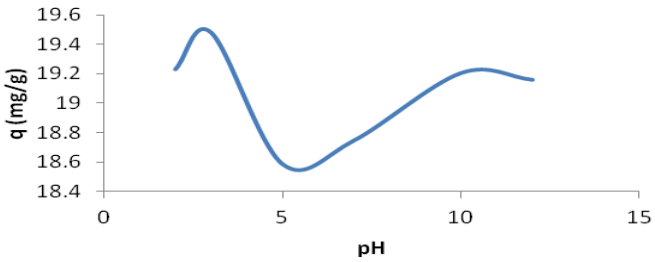

Figure 3: The effect of pH on the removal efficiency with: PAni/AC (The initial concentration, contact time, volume of solution and amount of adsorbent was 20 mg/L, 60 min, 100 mL and 0.1 g, respectively).

Influence of sorbent dosage:

The removal percentage of RR 198 was studied by PAni/AC dose between 100 and 1000 mg/L at dye concentration of 20 mg/L. Results are presented in Figure **4**. The RR 198 removal efficiency increases up to an optimum dosage beyond which the removal efficiency does not significantly change. This result was anticipated because for a fixed initial solute concentration, increasing adsorbent doses provides greater surface area and more adsorption sites, whereas the adsorbed RR 198 quantity per unit weight of the sorbent decreased by increasing the composite quantity. At very low adsorbent concentration, the absorbent surfaces become saturated with the dye and the residual dye concentration in the solution was high.

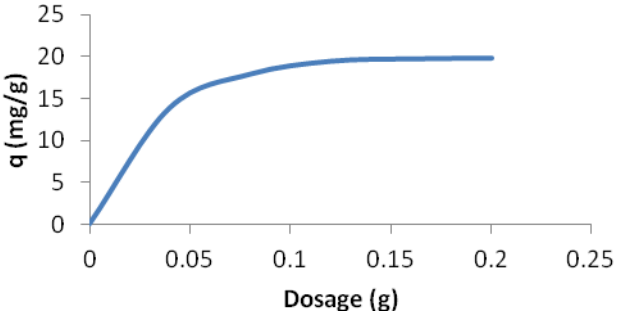

Figure 4: The effect of adsorbent dosage on the removal efficiency with: PAni/AC (the initial concentration, *p*H,

contact time and volume of solution was 20 mg/L, 3, 60 min and 100 mL, respectively).

Effect of contact time:

Figure **5** shows the effect of contact time on sorption of RR 198 by PAni/AC. For these cases, initial dye concentration was 20 mg/L and pH of 3 was used for dye solution. Also PAni/AC dose of 0.1 g in 100 mL were used. For dye sorption rate reaches up to 95% by PAni/AC, when contact time was 60 min, and then little change of sorption rate was observed. This result revealed that adsorption of RR 198 was fast at first (until 45 min) and the equilibrium was achieved after 60 min of contact time. Taking into account these results, a contact time of 60 min was chosen for further experiments.

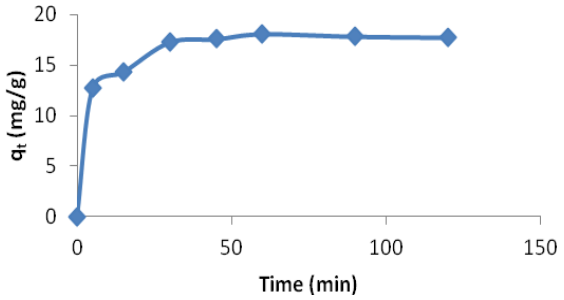

Figure 5: The effect of contact time on the removal efficiency with: PAni/AC (the initial concentration, *p*H, volume of solution and amount of adsorbent was 20 mg/L, 3, 100 mL and 0.1 g, respectively).

Conclusion

In this research, polyaniline/AC composite was prepared by coating the activated carbon substrate with aniline using the chemical oxidative polymerization method and its ability in the removal of RR 198 from aqueous solution was investigated. The results indicate that the PAni/AC composite has a considerable potential for the removal of RR 198 from aqueous solution. Optimum conditions for RR 198 removal were found to be *p*H 3, adsorbent dosage of 1 g/L and equilibrium time 60 minute.

Experimental

Materials and equipment:

All chemicals used were analytical reagents grade and prepared in distilled water**.** Aniline was obtained from Merck and distilled before use. Reactive red 198 (Reactive red RB) was purchased from Dystar (Figure **6** & Table **1**). This dye shows an intense absorption peak in the visible region at 515 nm. This wavelength corresponds to the maximum absorption peak of the Reactive red 198 (λ_{max}=515). Other equipment were UV–Vis spectrophotometer (Jenway model 6505), *p*H meter (Jenway model 3510), Scanning electronic microscope (LEO 440i, Leo Electron Microscopy, Cambridge, England), and shaker bath equipped with thermostat (SDL–D403/1-3) operated at 100 rpm.

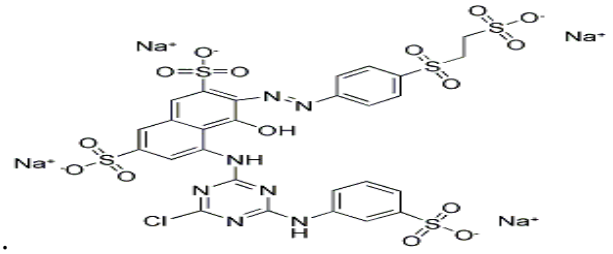

Figure 6: The chemical structure of RR 198

Table 1: Characteristics of RR 198

name	CAS number	C.I. number
Reactive red 198	145017-98-7	18221
Formula	Molecular weight	λ_{max}
$C_{27}H_{18}ClN_7Na_4O_{15}S_5$	968.21g/mol	515

Preparation of activated carbon:

Rice husk used was obtained from a nearby rice mill of Babol, Mazandaran, Iran. It was washed repeatedly with double-distilled water to remove dust and soluble impurities, and this was followed by drying at 343 K for 3 h. The dried rice husk was then suspended in sulphuric acid (H_2SO_4) solution and the treated rice husk was then dried at 343 K for 6 h. After drying, the adsorbent was stored in sealed glass containers. The same adsorbent was used in all the experiments.

Preparation of PAni/AC composite:

For the preparation of PAni/AC composite, 1 g KIO_3 was added to 100 mL of sulphuric acid (1 M) and then uniform solution was obtained by using magnetic mixer. After 20 min, 1 g of activated carbon was added to solution and after 30 min, 1 mL fresh distilled aniline monomer was added to stirred solution. The reaction was carried out for 5 h at room temperature. Consequently, the product was filtered and then washed with deionized water and acetone to separate the impurities and finally dried at temperature about 60 $^{\circ}$C in oven for 24 h.

Batch adsorption experiment:

Batch experiments were conducted to investigate the parametric effects of adsorbent dose, adsorption time and *p*H for RR198 adsorption on the PAni/AC composite. RR198 samples were prepared by dissolving a known quantity in distilled water and used as a stock solution and diluted to the required initial concentration. 100 mL of RR198 solution of known concentration (C_o) was taken in a 250 mL conical flask with a required amount of adsorbent and was shacked for different time duration in a shaker at different *p*H and temperature. The solution was centrifuged. The *p*H of the solution was adjusted by using either 0.1 N NaOH or 0.1 N H_2SO_4.

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