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Synthesis and characterization of polypyrrole, polyaniline nanoparticles and their nanocomposite for removal of azo dyes; sunset yellow and Congo red

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A B S T R A C T

Polypyrrole, polyaniline nanoparticles and their nanocomposites were prepared using microemulsion polymerization method. For the synthesis of polypyrrole and polyaniline nanoparticles sodium dodecyl sulfate as a surfactant for two reasons was used; to the creation of a micro reactor vessel and to improve the physical properties of polymers such as stability, solubility in organic solvents, conductivity, and processability. These nanoparticles were dedoped through 20% NaOH solution. The removal of sunset yellow and congo red dyes was carried out using both doped and dedoped species and nanocomposites at room temperature and under ultrasound irradiation. Also, the effect of adsorbent dosage, initial pH, effects of contact time on adsorption and ultrasonic power as experimental parameters on the removal of the sunset yellow and congo red dyes was investigated. It was found that all of the premade species including multiwall carbon nanotubes, carboxylate-multiwall carbon nanotubes, polypyrrole, polyaniline, polypyrrole/multiwall carbon nanotubes and polyaniline/multiwall carbon nanotubes can be used for removal of anionic dyes such as sunset yellow and congo red from water solutions. The highest removal efficiency for sunset yellow dye (~99%) was achieved at 0.007 g of polypyrrole/multiwall carbon nanotubes nanocomposite, at $pH = 2$, at ambient temperature and at ultrasonic irradiation power 500 W and for congo red dye the highest removal efficiency (~98%) was achieved at 0.01 g of polypyrrole/multiwall carbon nanotubes nanocomposite, at $pH = 2$, at ambient temperature and at ultrasonic irradiation power 500 W. The polypyrrole/multiwall carbon nanotubes and the polyaniline/multiwall carbon nanotubes adsorbents, the recovery achieved more than 80% with the proportion of 55:45 from acetone: H_2O. The strong adsorption capacity of polypyrrole/multi-walled carbon nanotubes and the polyaniline/multiwall carbon nanotubes nanocomposites prepared with ammonium per sulfate as initiator can be attributed to the π-π electron donor-acceptor interaction and electrostatic attraction. The nanoadsorbents multiwall carbon nanotubes, carboxylate-multi-walled carbon, polypyrrole/multiwall carbon nanotubes and the polyaniline/multiwall carbon nanotubes produced with ammonium per sulfate as initiator was used to removing azo dyes from H_2O through efficient microscale filtration and can be scaled up for commercial and industrial applications.

1. Introduction

Several studies indicate artificial food dyes caused behavioral and hyperactivity issues in children (Mohammad and Mohammad, 2013; Santhy and Selvapathy, 2006; Panswad and Luangdilok, 2000). (see Table 1)

Sunset yellow dye (SY dye, Yellow 6 or E110) is a petroleum-derived orange azo dye (Santhy and Selvapathy, 2006; Dotto et al., 2011). It is a mono-azodisulfonated hydroxyl dye (Fig. 1) and it commonly used in food products e.g. juices, soft drinks, candies, jellies, and snacks, in order to give them a yellow-orange coloring (Gonçalves et al., 2015) (see Fig. 2).

Side effects reported for SY dye includes gastric upset, hives, runny nose, allergies, hyperactivity and occurrence of tumors in animals, mood swings, and headache (Tanaka, 1996; Williams et al., 1978; Worm et al., 2001).

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Table 1
Compare of adsorption capacity q with the similar reported adsorption capacity for removing CR and SY dyes.

Entry	adsorbent	Dye	Time (min)	pH	Temperature (k)	q (mg/g)	Ref.
1	F-MWCNT	CR	60	6.5	298	148.0	Gupta et al., 2012
2	activated carbon	CR	40	2	308	6.7	Namasivayam and Kavitha, 2002
3	Leucaena leucocephala seed pods	CR	120	5		10.8	Shrivastava, 2012
4	Composites of GO–MWCNT	CR	350	5	303	66.7	Ansari et al., 2017
5	Lady Finger Stem	CR	40	8	298	15.9	Abbas et al., 2012
		SY	30	2	298	24.6	
6	Chitosan hydrogel beads impregnated with CNT	CR	360	5	303	450.0	Chatterjee et al., 2010
7	activated ipomoea carnea	CR	50	6	333	70.0	Pandian et al., 2015
8	chitin	CR	180	7	348	139.0	Zúñiga-Zamora et al., 2015
9	PPy/mw nanocomposite	SY	5	2	298	212.1	This work
		CR	5	2	298	147.0	

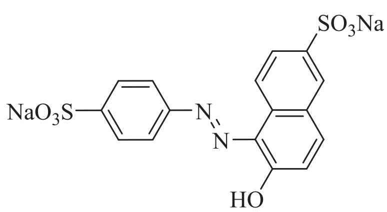

Fig. 1. The molecular structure of SY dye.

Congo red dye (CR dye) is an anionic diazo dye and has been used in biology, biochemistry and textile industry. It is toxic to many organisms and suspected to cause carcinogen and mutagen. However, it has been prohibited in many countries because of health concerns. But, it is still widely used in several countries.

Synthetic dyes, e.g. CR and SY dyes are complicated as a result of its symmetric aromatic structure, providing the dyes thermal, physicochemical, and optical stability, and resistance to biodegradation and photodegradation (Rajabi et al., 2015; Mohammadi et al., 2016). Therefore, there is an urgent requirement for development of innovative, but low-cost processes, by which dye molecules can be removed. Adsorption technique is quite popular due to simplicity and high efficiency, as well as the availability of a wide range of adsorbents (Rajabi et al., 2016; Rajabi et al., 2015).

Various physical and chemical methods are applied to the removal of dyes which can be categorized into biodegradable methods, nondestructive methods, and oxidative processes (Liangguo et al., 2015). Recently, the heterogeneous photocatalysis using UV-radiation and quantum dots (QDs) method for the treatment of water polluted with the organic substances was reported (Rajabi et al., 2013, 2016; Shamsipur and Rajabi, 2014). Although widely applied in research and practical applications, these methods still have limitations. In developing countries, most of these technologies, due to their initial operation costs are too high to be widely used. Synthetic methods for most of the previously reported adsorbents for removal of CR and SY dyes were lack of high adsorption capacity, long effective adsorbent life, low reactivity, minimized side reactions, reduced coke deposition and long absorbent time. Adsorption technique has been found to be an efficient and economically inexpensive process for removing dyes (Nitayaphat and Jintakosol, 2015). Consequently, efforts are still needed to carry out an investigation for new promising adsorbents (Isa et al., 2007; Doulia et al., 2017).

Application of conductive polymers is an alternative coating agent that can eliminate the previous disadvantages and improve selectivity. Polypyrrole (PPy) and polyaniline (PANI) have extremely become popular for coating on the surface of nano materials (Sathishkumar et al., 2012; Yong et al., 2008; Zhang et al., 2009; Aftab et al., 2010; Khomenko et al., 2005; Philip et al., 2004; Ruihan et al., 2012).

Carbon nanotubes (CNTs) are the strongest and stiffest materials yet discovered in terms of tensile strength and elastic modulus respectively. This bond strength results from the covalent sp^2 bonds formed amongst the individual carbon atoms. The strength and elasticity of carbon nanotubes make them of promising use in monitoring other nanoscale structures, which recommends they will have a significant role in nanotechnology engineering, medicine, gene, drug delivery areas, field emission, energy storage, molecular electronics, and atomic force microscopy (AFM). Polymer compositions packed with carbon nanotubes are advanced materials that are drawing much attention because of their unique structures and mechanical properties (Abbasi 2017).

In continuing to our previous studies (Mahmoodi and Ghavidast, 2014; Mahmoodi et al., 2015; Nabid et al., 2013) in this work, PPy and PANI nanoparticles alone and in other efforts coated on the MWCNTs were synthesized chemically and applied for removal of the artificial SY and CR dyes from aqueous solutions. The premade composites after separation and purification were applied for removal of the artificial SY and CR dyes from aqueous solutions. Also, the effect of adsorption time, adsorbent dosage and pH were evaluated. This allows absorption to happen quickly and

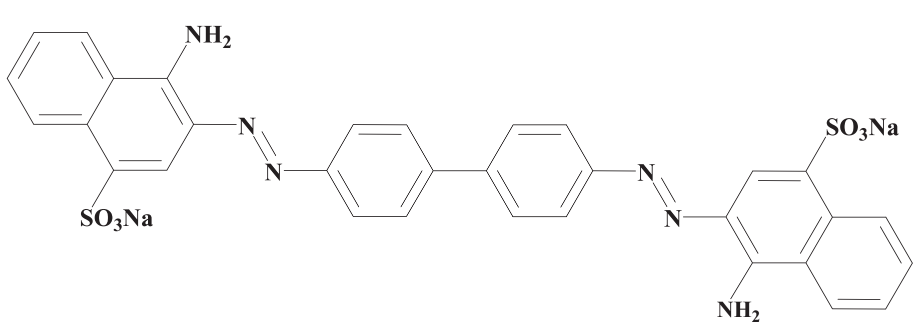

Fig. 2. The molecular structure of CR dye.