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Recycling of textile dye using double network polymer from sodium alginate and superabsorbent polymer

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ABSTRACT

Double network polymers (DNP) of different compositions were photosynthesized using sodium alginate (NaAlg) and superabsorbent polymer (SAP). They were characterized by FT-IR, thermal stability (TG), morphology by scanning electron microscopy (SEM), and its mechanical properties were also evaluated for their dye adsorption–desorption characteristics via adsorption isotherms at different temperature and pH values. The spectrophotometric determination of adsorbed dye indicated that the maximum dye uptake in column mode was 439 mg/g. The nearly identical visible absorption spectra of the fabrics dyed with virgin and recovered dyes indicated that the recovered dye retained its structural stability during column recovery and the dyed fabrics possess good color fastness properties. Dye adsorption kinetic and de-sorption mechanism were found to be pseudo-first-order and non-Fickian, respectively. The adsorption showed best fit for Langmuir adsorption isotherm. The changes in the thermodynamic parameters namely Gibbs free energy (ΔG°), entropy (ΔS°) and enthalpy (ΔH°) for the dye-adsorbent systems inferred that the adsorption process was spontaneous and exothermic.

1. Introduction

Industrial effluents are discharged into land and water from industries such as dying, paper, plastic, leather, food and mineral processing (Orthman, Zhu, & Lu, 2003) without proper treatment leading to complex environmental pollution and health problems. Textile dying process generates huge quantity of toxic effluents which contains unabsorbed residual dyes and salts that spoils the environment enormously. Low biochemical oxygen demand and high chemical oxygen demand (Nasr, Abo El-Ola, Ramadan, & Hashem, 2006) are the characteristics of dye effluent. Many synthetic organic dyes from effluent are highly toxic and endanger the aquatic life and environment (Kadirvelu, Brasquet, & Cloiree, 2000). The reactive dyes may be mutagenic and carcinogenic (Rajeswari, Namasivayam, & Kadirvelu, 2001) and can cause severe damage to the liver, digestive and the central nervous system of human beings and affect agricultural cultivation and underground water. Hence there is an urgent necessity to remove dyes from the effluent before being discharged into land and water using appropriate physico-chemical methods. Among them the adsorption technology which employs activated carbon (Nasr et al., 2006), natural clays (Tahir & Rauf, 2006), modified clays (Baskaralingam, Pulikesi, Ramamurthi, & Sivanesan, 2006), fly ash (Dhodapkar, Rao, Pande, & Kaul, 2006), etc. as adsorbents is generally considered to be a cost effective method to bring down the concentration of unabsorbed dyes in dye effluent (Tsai, Chang, Ing, & Chang, 2004). In recent years SAPs (Paulino et al., 2006) are progressively being used to remove the colors, toxic and heavy metal substances and other pollutants from waste water through adsorption mechanism which involves mass transfer from the liquid phase to the adsorbent and subsequent binding via physico-chemical interaction (Wang & Liu, 2013; Zheng, Huang, & Wang, 2011).

SAPs are physico-chemically crosslinked three-dimensional networks of hydrophilic polymer chains with properties between liquids and solids. These polymers can imbibe and retain large amount of water and water soluble substances without dissolving and losing their structural integrity (Guilherme et al., 2005). Due to these properties, they are finding widespread applications (Dhanapal, Vijayakumar, & Subramanian, 2013) in bioengineering, biomedicine, agriculture, water purification, separation process, effluent treatment, etc. For constant use, the mechanical strength of these polymers must be good enough to withstand varies shearing forces. But unfortunately these polymers are not having enough mechanical properties for the continuous applications. It has been

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reported (Guilherme et al., 2005) that the mechanical properties of SAPs can be improved by double network formation through physico-chemical crosslinking in the presence of another pre-formed polymer (Gong, Katsuyama, Kurokawa, & Osada, 2003). In this laboratory SAPs are synthesized for water conservation in agricultural applications and effluent water treatment, but their mechanical properties are not good for broader applications. Hence an attempt is made to widen its application by improving its mechanical properties by double network formation taking NaAlg as the second pre-formed polymer. The primary choice of NaAlg for double network formation is due to the attractive combination of availability, price, and its performance in effluent water treatment. Besides these it possesses good water solubility, non-toxicity, biodegradability and biocompatibility (Nakajima et al., 2009).

DNPs were reported (Marandi, Sharifnia, & Hosseinzadeh, 2006) to be good candidate matrix for the removal of dye from the textile effluent. This was done by photo crosslinking of SAP and $CaSO_4$ induced ionic crosslinked NaAlg using 254 nm radiations. NaAlg, a natural ionic hydrophilic linear polysaccharide containing β-D-mannuronic acid and α-L-guluronic acid with —OH and —COO⁻ groups is commonly used in the synthesis of tough hydrogels for different applications (Guilherme et al., 2005). The sugar residues in NaAlg can either be arranged in blocks or they can be randomly distributed. Moreover, NaAlg grafted/crosslinked SAP was shown to be an excellent adsorbent for the removal of colored materials and toxic heavy metal ions from industrial effluent (Kobaslija & McQuade, 2006), Hence the present investigation involves the synthesis of a potential DNP by photo crosslinking of NaAlg on reported SAP (Dhanapal et al., 2013) and its subsequent evaluation as an adsorbent to remove the dyes from the textile dye effluent.

2. Experimental

2.1. Materials

Acrylic acid (AA, Himedia, Mumbai) and potassium persulphate (KPS, NICE, Cochin) were used after purification by vacuum distillation (700 mm Hg) and recrystallization with double distilled water, respectively. NaAlg, calcium sulphate ($CaSO_4$), trimethylolpropane triacrylate (TMPTA) (Himedia, Mumbai), N-isopropyl acrylamide (NIPAAm, Aldrich), acetone, methanol, isopropanol, potassium hydroxide (Rankem, New Delhi), sodium chloride (NaCl), sodium carbonate (Na_2CO_3) (Merck), reactive blue 4 (RB 4) (Sigma–Aldrich, molecular weight = 637.43, color index no = 61205, λ_{max} = 595 nm) were used as received, and the chemical structure of RB 4 is shown in Fig. 1(a).

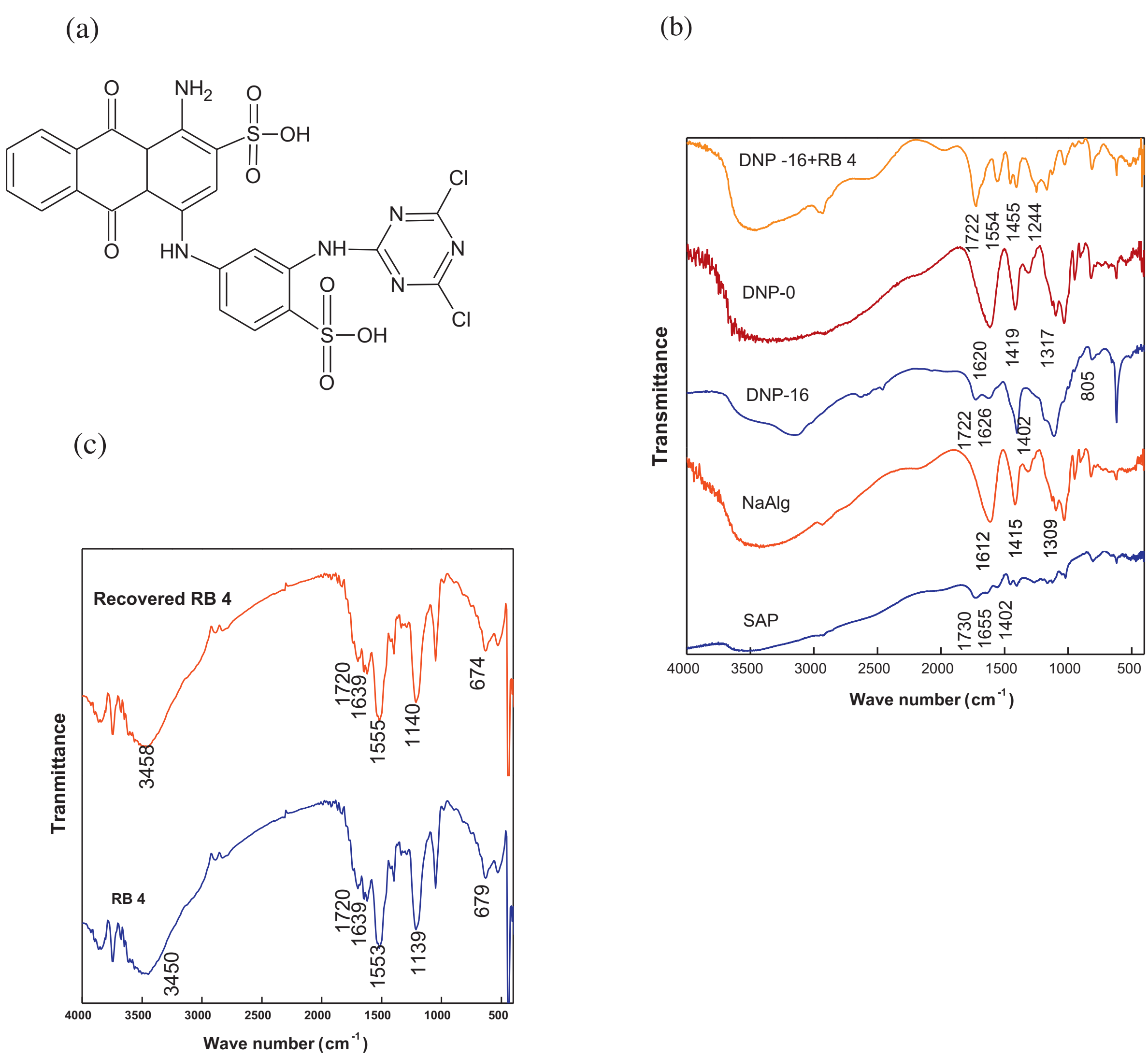

Fig. 1. Chemical structure of RB 4 (a), FT-IR spectra of SAP (b), NaAlg (b), DNP-16 (b), DNP-0, DNP-16 + RB 4 (b) and virgin and recovered RB 4 (c).