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Dye removal using iron–polyphenol complex nanoparticles synthesized by plant leaves

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HIGHLIGHTS

- Iron–polyphenols complex nanoparticles (Fe–P NPs) were used as flocculant.
- The Fe–P NPs are more effective to remove dye than traditional flocculant $FeCl_3$.
- The Fe–P NPs can be applied in water treatment due to its low toxicity and cost.
- This article indicated that many plants can produce this type of Fe–P NPs.

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ABSTRACT

This paper examined the ability of iron–polyphenol complex nanoparticles (Fe–P NPs) synthesized by eucalyptus leaf extracts as a novel adsorptive flocculant to remove acid black 194 from aqueous solution. The influential parameters such as ratios of reagents, doses of Fe–P NPs, pH, temperatures and initial dye concentration were tested. The kinetics, experimental equilibrium and thermodynamic data for acid black 194 and Fe–P NPs systems were collected. The adsorption of dye on Fe–P NPs appears to be a physical process. This study confirms that removal of dye utilizing Fe–P NPs is more efficient than using traditional inorganic flocculant $FeCl_3$. The Fe–P NPs could be employed as inexpensive and low-toxic adsorptive flocculant for removing dye from water.

1. Introduction

A range of conventional treatment technologies for removing dye has been investigated, such as trickling filter, chemical coagulation and flocculation, chemical oxidation, carbon adsorption, and photodegradation, (Forgacs et al., 2004). Adsorption and flocculation can handle fairly large flow rates, producing a high-quality effluent that does not result in the formation of harmful substances such as chemical oxidation. The adsorption of dyes has been examined using various materials such as clay (Vimonses et al., 2010), fly ash (Wang et al., 2005a), activated carbon (Wang et al., 2005b), char (Mui et al., 2010), wheat straw (Oei et al., 2009), and others. Traditional coagulants and flocculants are inorganic salts (e.g., $Al_2(SO_4)_3 \cdot 18H_2O$, $FeSO_4 \cdot 7H_2O$, $FeCl_3 \cdot 6H_2O$) (Golob et al., 2005), inorganic polymer flocculants (e.g., polyferric sulphate) (Wang and Tang, 2001), synthetic organic polymer flocculants (e.g., polyacrylamide) (Wong et al., 2006) and natural polymeric flocculants (e.g., chitosan) (Renault et al., 2009). Coagulation and flocculation occur in successive stages and their objective is to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc (Gregory and O'Melia, 1989). However, there are drawbacks in flocculants and these are the large amounts of dye containing sludge, poor efficiency removing some dyes, and the high cost. In particular, synthetic organic polymer flocculants may cause damage to organism DNA (Takigami et al., 1998).

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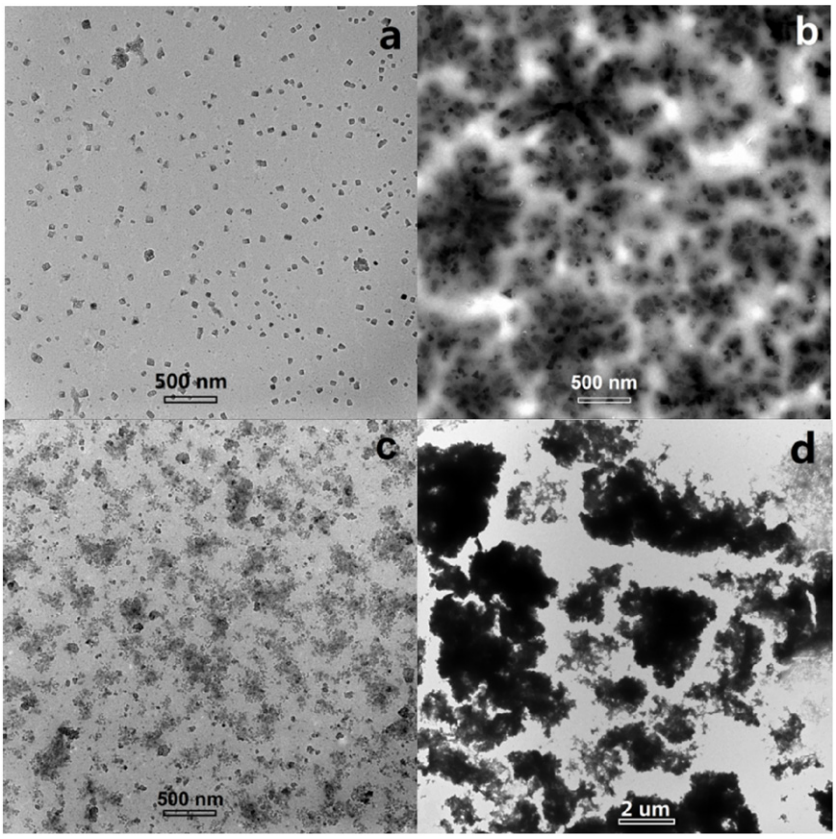

Fig. 1. (a) TEM image of Fe–P NPs synthesized at 1:2 ratio of plant extract and $FeCl_3$ solution in volume; (b) TEM image of Fe–P NPs synthesized at 7:1 ratio of plant extract and $FeCl_3$ solution in volume; (c) TEM image of Fe–P NPs synthesized at 1:7 ratio of plant extract and $FeCl_3$ solution in volume; (d) Dye flocs formed by Fe–P NPs.

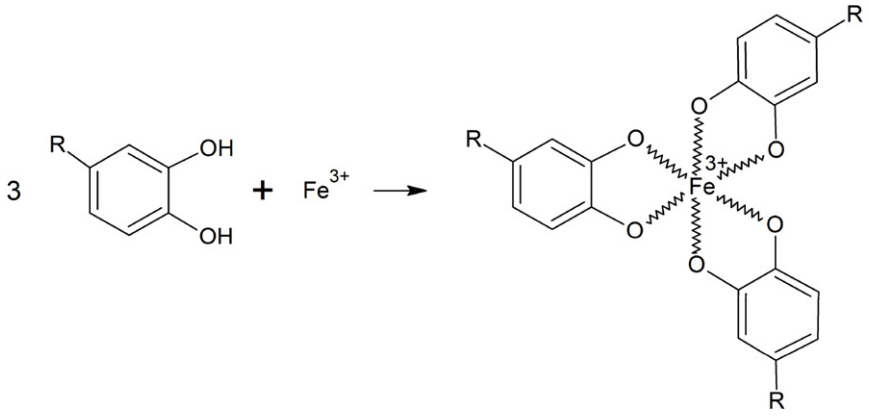

Fig. 2. Proposed chemical structure of Fe–P NPs.

This study reports on a novel option for dye removal using an environmental friendly adsorptive flocculant synthesized by eucalyptus leaf extract, which is more efficient than traditional flocculant $FeCl_3$. Eucalyptus leaves contain mainly gallic acid, ellagic acid, hydrolyzable tannins, leucoanthocyanins, and flavonol glycosides (Hingston, 1963) with plenty of –OH groups worked as effective metal chelators to form iron–polyphenol complex nanoparticles (Fe–P NPs). In recent study (Wang, 2013), the morphology of Fe–P NPs has been characterized using transmission electron microscope (TEM), and the structure of Fe–P NP has been investigated with X–ray absorption spectroscopy (XAS). The results have shown that the Fe–P NPs are amorphous materials with sizes generally in the 60 nm range (Fig. 1(a)), and with a ferric ion located in nanoparticles chelated by plant polyphenols (Fig. 2). The iron–polyphenol nanoflocculant is able to remove acid black 194 from aqueous solution more efficiently than $FeCl_3$. Since the adsorption hypothesis can convincingly explain dye removal in equilibrium sorption studies, and Fe–P NPs can help dye to form approximately 1 mm-sized flocs, this process can be termed as an adsorptive flocculation.

A variety of additional plant sources of polyphenols has also been used in other studies to synthesize analogous iron complex nanomaterial including rosemary, tea, camphor, lavender, melaleuca and diosma successfully. It is assumed that many plant species can yield this kind of nanomaterial with $FeCl_3$, which enable the plant-based adsorptive flocculants for water treatment to be produced in a cheap, easy and sustainable way globally.