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A Comparative Study of Homogeneous and Heterogeneous Photo-Fenton Process for Textile Wastewater Treatment

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Abstract

In this study, the COD removal and Dye removal efficiencies of homogeneous and heterogeneous photo-Fenton process are compared for the treatment of synthetic textile wastewater. The effect of parameters like pH, catalyst dosage, H_2O_2 dosage and U V power are evaluated using Taguchi's experimental design. In heterogeneous photo-Fenton process copper modified iron oxide is used as the catalyst. The heterogeneous process showed the highest removal efficiencies under optimum condition with COD removal of 62% and Dye removal of 85%.For homogeneous photo-Fenton process COD removal and Dye removal are 47% and 82% respectively.

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Keywords: Textile wastewater; Homogeneous photo-Fenton process; Heterogeneous photo- Fenton process; Taguchi's experimental design

1. Introduction

Textile industry is one among the various industries having very diverse sector and has a very complicated industrial chain. The major impacts caused by textile industries include pollutants discharge, water consumption and energy consumption. The discharged wastewater is the main environmental problem caused by the textile industry. The major processes in textile industries are sizing, weaving, desizing, scouring, bleaching, mercerizing, fulling, dyeing and finishing. Dyeing and finishing processes contribute the major portion of pollution [1].

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Various chemicals and dyes of complex structures are used for the different processes in the textile industries. The presence of textile dyes in water bodies affects the photosynthetic activity, aesthetic appearance, makes water unfit for drinking and for the use of domestic and irrigation purposes [2].

Various physico-chemical processes are used for the dye contaminated effluent treatment. But, these processes are ineffective due to their various disadvantages like high cost, high sludge and difficulty in handling. Advanced oxidation processes (AOPs) is a most promising alternative which overcomes these disadvantages. Advanced oxidation processes deals with the generation of hydroxyl radicals. The hydroxyl radical oxidizes organic contaminants into carbon dioxide and water rapidly and as a result it can effectively degrade the pollutants. The most important AOP is the Fenton's system, which consist of the reaction between H_2O_2 and Fe^{2+} in an acidic solution to produce free *OH.

The Fenton process that takes place in presence of U V light or visible light is called the Photo-Fenton process. In this method *OH is released by the molecular fragmentation of water molecule to oxidize the organic compounds. Photo-Fenton process in presence of U V light is found to be an effective method for wastewater treatment.

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + *OH + OH^- \quad (1)$$

$$Fe^{2+} + H_2O_2 \rightarrow Fe(OH)^{2+} + *OH \quad (2)$$

$$Fe(OH)^{2+} + h\nu \rightarrow Fe^{2+} + *OH \quad (3)$$

Eq.1 represents the Fenton reaction. In this equation Fe^{2+} reacts with hydrogen peroxide and produces Fe^{3+} and *OH. The reaction also produces iron aqua complex, $Fe(H_2O)_5(OH)^{2+}$ represented as $Fe(OH)^{2+}$(Eq.2). It is the new important source of *OH. The reaction of $Fe(OH)^{2+}$ with UV light regenerates Fe^{2+} and *OH(Eq.3). Thus compared to Fenton process, photo-Fenton process requires less Fe^{2+} concentration. A cyclic mechanism takes place when this UV regenerated Fe^{2+} reacts with the H_2O_2 in the solution [3].

The photo-Fenton process can be both homogeneous and heterogeneous. The type of interaction between the Fenton's reagent and the compounds to be degraded is mainly considered in the homogeneous process. But the major disadvantages of this process are sludge generation due to post treatment process, limited pH range, high iron discharge to environment and difficulty in iron ion recovery [4].

These disadvantages made heterogeneous process superior to homogeneous process. In heterogeneous phase, the physical steps in addition to chemical changes take place on the surface of the catalyst at the active sites where mass transfer limited adsorption of reactant molecules occurs. At the end of the reaction, the product molecules are desorbed and leave the active sites available for a new set of reactant molecules to attach to the surface and react. The main advantages of heterogeneous process are less iron production, environment friendly, easy separation of catalyst from the solution.

In this study comparison of homogeneous photo-Fenton process and heterogeneous photo-Fenton process using photo-Fenton process is conducted. The optimum process parameters are found out using Taguchi method. Taguchi's method is used to find out the most significant factor in the process. An orthogonal array is used to find out the factors. The main advantage of this method is the lesser number of experiments. An orthogonal array means the design is balanced so that factor levels are weighted equally. Because of this, each factor can be evaluated independently of all the other factors, so the effect of one factor does not influence the estimation of another factor. The analysis of variance (ANOVA) is also used to find out the significant factors [5, 6].

2. Materials and methods

2.1. Characteristics of textile wastewater

Collection of real textile wastewater was done at different intervals from Augustan Textile colours Ltd. Palakkad. The collected samples were stored at an appropriate temperature (4°C) and they were analyzed to find out the characteristics. Table 1 gives the average values of the characteristics of untreated textile wastewater.

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