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Decolorization of azo dye C.I. Direct Black 38 by Photocatalytic method using TiO_2 and optimizing of process

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Abstract

Dye wastewaters are considered as major pollutants to surface waters. The dye C.I. Direct Black 38 is one of the most important azo dyes used in dying industry and contaminated waters containing this harmful material are produced in large volumes. The purpose of this study is investigation removing of C.I. Direct Black 38 by photocatalytic method as one of advanced oxidation processes (AOPs) using TiO_2 as photocatalyst and determination of optimum values of effective parameters against color removing efficiency. Spectrophotometric results showed that photocatalytic process has decolorization ability of wastewaters containing C.I. Direct Black 38 in different dye concentrations. The operating conditions for 90% decolorization of C.I. Direct Black 38 were obtained for initial dye concentration of 50 ppm, hydrogen peroxide dosage of 26.56 mM, TiO_2 dosage of 0.75 g/l and pH of 5. TiO_2 can't be used in basic solution. The proper addition of hydrogen peroxide improved the decolorization, while the excess amount of hydrogen peroxide could quench the formation of hydroxyl radicals.

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Keywords: Decolorization, Direct Black 38, Photocatalytic, TiO_2, Optimization

1. Introduction

Dyes widely used in textiles, paper, rubber and plastics industries often create severe environmental pollutions in the form of colored wastewater discharged into environmental water bodies [1]. Over 700,000 tons of approximately 10,000 types of dyes and pigments are produced annually worldwide. From this amount, about 20% are discharged as industrial effluents during the textile dyeing and finishing processes

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without previous treatment [2, 3]. The colour and toxicity of dyes influence the quality of life by causing health problems besides influencing the efficiency of some water treatment techniques [4, 5].

Considering the volume and chemical composition of the effluent discharge, the textile dyeing and finishing industry is one of the major polluters among industrial sectors. Therefore, establishing removal technologies for dyes is an urgent problem. The commonly used methods for the treatment of wastewater such as: biological oxidation, physical-chemical, ozonation, chemical precipitation and electrocoagulation have been reported in recent years [6]. However, these processes are quite ineffective in colour removal of wastewater because azo dyes aren't biodegradable due to their aromatic structure, and physical-chemical treatments and other similar methods provide only a phase transfer of dyes and produce large quantities of sludge. Chemical oxidation aims at the mineralization of contaminants to carbon dioxide, water and inorganic components or, at least, their transformation into biodegradable or harmless products. During the last two decades, advanced oxidation process (AOPs) has been applied for the removal of organic pollutants [7, 8].

In the past decade, considerable attention has focused on using nanocrystalline TiO_2 as a photocatalyst for the degradation of organic pollutants. Several papers have discussed the fundamentals of the photocatalytic degradation process. The photocatalyst, titanium dioxide, is a wide band gap (3.2 eV) semiconductor, corresponding to radiation in the near-UV range. Upon the absorption of this UV energy, TiO_2 particles will form a paired electron (e^-) and hole (h+), in the conduction band and valence band. The positive hole is apparently able to oxidize a water molecule to hydroxyl radical. The hydroxyl radical, in turn, is a powerful oxidant. Moreover, the possible use of vis-light has recently drawn attention [9]. Some authors demonstrated how the photobleaching dyes could be achieved by sunlight irradiation using TiO_2 as photocatalyst [10]. In the present study the optimum conditions of experimental parameters for the removal of C.I. Direct Black 38 (DB38) have been determined which can be extensively used in textile, foodstuff and pharmaceutical industries.

2. Experimental

2.1. Materials

Azo dye C.I. Direct Black 38 was obtained from Sigma-Aldrich Chemical Co., and used without further purification. The structure of C.I. Direct Black 38 is shown in Fig. 1. Hydrogen peroxide solution (30% w/w), NaOH and H_2SO_4 were provided by Merck. Titanium dioxide (Degussa P25) with average primary particle size around 30 nm and purity above 97% was utilized as a photocatalyst.

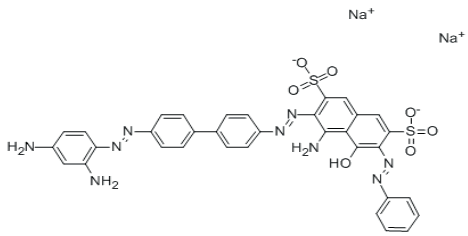

Fig.1. The structure of DB38.

2.2. Procedure

Concentration of dye solution was selected 50 ppm. The pH values of solutions were adjusted at desired level using dilute NaOH and H_2SO_4 and measured by using Metrohm 744 digital pH meter. The radiation