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Decolourisation of textile indigo dye by DC electric current

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Abstract

The electrochemical technology has been employed for the treatment of soils and liquid medium contaminated with aromatic pollutants as indigo textile dye. In liquid medium, 76% of colour removal was obtained in 87 h, and the addition of NaCl (10 g/l) reduced the treatment time up to 45 min. In soils, two alternative methods were developed: a direct electrochemical treatment and the extraction of dye from the soil followed by electrochemical decolourisation of the liquid collected. In the latter process, 50% ethanol in water solution was selected as the best extracting agent. This extracting solution (indigo concentration of 0.5 g/l) was further decolourised electrochemically in the presence of NaCl (10g/l) for 24 h, ending in a colour removal of 70%. Using the direct electrochemical treatment, a regular decolourisation profile along the whole cell was attained. The decolourisation degree was 76% and was reached after 16 days of treatment and an electric power consumption of 61 W · h.

Keywords: Indigo, Decolourisation; Electrochemical degradation; Soil remediation

1. Introduction

Large amounts (around 10^6 tons) of chemically different dyes are produced annually world-wide. They are used extensively in the dye and printing industries, and 5–10% of the dyestuffs are lost in the industrial effluents. Decolourisation of industrial textile wastewater can be obtained by ozonisation (50–60% of colour reduction), flocculation–filtration (up to 80% of colour removal), by alkalinisation with calcium hydrosulphite and biological treatment.

The indigo dye is extensively used in textile industries and is considered a recalcitrant substance. The treatment of wastewater containing dyes (such as indigo dye) and its decolourisation involves serious problems such as: a wide range of pH intervals, salt concentrations and complex chemical structures.

As an alternative, an electrochemical process for degrading and decolourising wastewater containing indigo dye is proposed. The electric current induces redox reactions upon the electrode surface resulting in the destruction of the organic compounds. Several researchers (Comninellis and Pulgarin, 1991; Cañi-

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zares et al., 1999; Torres et al., 2003) investigated the electrochemical degradation of soluble organic contaminants such as benzene, toluene and phenols. They found that electrochemical oxidation is a promising, versatile alternative with a high potential to replace or improve existing processes.

There are few reports that used the electrochemical technology to degrade wastewater with high dye concentration. Among them, Ciorba et al. (2001) applied the electrochemical treatment to simulated dye wastewater. They reported that the decolourisation efficiency depended on dye nature. Gutierrez et al. (2002) demonstrated that the electrochemical oxidation is a very effective technique for wastewater processing. Moreover, they proposed several mathematical models to describe the behaviour of the decolourisation of dyes, being verified to four reactive dyes.

These promising results permit to consider the electrochemical technology as an alternative to wastewater processing. However, its efficiency has not been evaluated in soils contaminated by these wastes. Some studies demonstrated a good correlation between degradation of aromatic pollutants and decolourisation of dyes as a simple method to assess the efficiency of the degrading process (Field et al., 1993; Novotný et al., 2001).

In order to look for an adequate technique to permit the remediation of soils of recalcitrant substances at low economic cost, two methods have been tested in soils contaminated with textile indigo dye:

(1) *Indirect method*: Extraction of pollutant compounds from the soil and the subsequent electrochemical decolourisation of the liquid collected.
(2) *Direct method*: In situ direct electrochemical treatment. In this method the pollutant compounds are degraded by active oxidisers electrogenerated at the electrodes.

The aim of this work is to test the feasibility of the electrochemical treatment by the degradation of recalcitrant substances such as a model dye in soil (direct method) and in liquid medium (indirect method). Thus, in order to evaluate this alternative technique, the ability of decolourisation a typical dye as indigo by electrochemical treatment has been investigated.

2. Materials and methods

2.1. Experimental equipment

2.1.1. Liquid decolourisation

Experiments were carried out in a reaction cell with a rectangular body with a working volume of 1 l. Current or potential was imposed (HP Power supply 3662 A), and monitored by means of a multimeter (Fluke 75). Graphite electrodes were fixed in caps, which can be mounted on the ends of the cell body and magnetic stirring was maintained in order to avoid the concentration gradients. In order to investigate the influence of electric current, experiments with different potentials were carried out. Synthetic liquid indigo–blue with the chemical structure shown in Fig. 1 was selected as a model carbonyl type. The initial concentration of indigo dye was 0.5 g/l.

2.1.2. Soil remediation

Two alternative methods were tested in this work: a direct electrochemical treatment and the extraction of dye from the soil and the subsequent electrochemical decolourisation of the liquid were collected.

A sand matrix (porosity: 40%) was artificially contaminated by mixing 1.2 kg of soil and 0.5 l of indigo dye at a concentration of 3.19 g/l. The mixture was kept at room temperature for 3 days.

Direct electrochemical treatment: Experiments were carried out in a reaction cell (Fig. 2a) with a working volume of 1 l, filled with the contaminated soil at 29% of moisture. The initial dye concentration in the soil was 1.132 g of indigo/kg of dry soil. Constant potential was imposed (HP Power supply 3662 A), and monitored by means of a multimeter (Fluke 75). Graphite electrodes were mounted on the ends of the cell body and fixed in caps. This system allowed the application of an electric field along the entire soil sample. The voltage drop was kept in 30 V

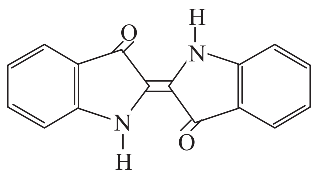

Fig. 1. Chemical structure of textile Indigo.