Treatment of exhausted reactive dyebath effluent using anaerobic digestion: Laboratory and full-scale trials

CM Carliell, SJ Barclay and CA Buckley*

Pollution Research Group, Department of Chemical Engineering, University of Natal, Private Bag X10, Dalbridge 4014, South Africa

Abstract

Reactive dyes are difficult to remove from textile waste water due to their solubility and they pass through conventional aerobic biological sewage treatment systems and enter the receiving water body. Investigations into the use of anaerobic digestion to decolourise reactive azo dyes have been successful on a laboratory scale and the investigation was extended to full-scale trials. Exhausted reactive dyebath effluent (3 *kl/d)* was discharged into a primary digester (1.34Ml) on weekdays for a 151-d period. On average, 48 *kl/d* of sludge was fed to the experimental and control digesters. The overflow was monitored for colour, sodium and sulphide concentrations. A laboratory digester was also set up to simulate the full-scale conditions but was operated at twice the exhausted dyebath loading recipe. No visual difference in colour was noted between the overflow of the primary or laboratory digester and the control digester, but elevated levels of sodium and sulphide were obtained due to the high concentration of sodium sulphate used in the reactive dyeing process. The laboratory digester became unstable at sulphide concentrations of 400 *mg/l.* However, the sulphide concentrations in the primary digester never increased such that it threatened digester stability.

Introduction

Waste water from textile finishing industries is complex and highly coloured. Colouration of the liquid effluent results from wastage and washing during dyeing and printing processes, with the degree of colouration being dependent on the colour/shade dyed and the type of dye used. Water insoluble dyes (e.g. disperse and vat dyes) generally exhibit good exhaustion properties (i.e. most of the dye bonds to the fibre) and can be removed from the effluent by physical means such as flocculation. When this effluent is discharged to a conventional sewage treatment works most of the colour is removed by adsorption to the biomass (Shaul et al., 1986; 1988). However, since the introduction of water soluble dyes, e.g. reactive dyes, conventional biological treatment processes are no longer able to achieve adequate colour removal.

Reactive dyes are coloured molecules capable of forming a covalent bond between the dye molecule and the fibre, and they are used to dye cellulosic fibres. The reactive systems of these dyes react with ionised hydroxyl groups on the cellulose substrate. However, hydroxyl ions present in the dyebath due to the alkaline dyeing conditions compete with the cellulose substrate, resulting in a percentage of hydrolysed dyes which can no longer react with the fibre. Thus between 10 and 50% of the initial dye load will be present in the dyebath effluent (ENDS Report, 1993), giving rise to highly coloured effluent which is difficult to treat due to the water-soluble nature of the hydrolysed dyes.

Unless additional treatment steps are implemented, water-soluble dyes pass through a sewage treatment works and give rise to colouration of the receiving water body. Although anaerobic treatment has traditionally only been used to treat the solids fraction of the waste at a sewage treatment works, recent studies have resulted in this process being adapted to the successful high-rate treatment of liquid industrial wastes. Moreover, the literature indicates the potential of anaerobic systems for the non-specific decolourisation of water soluble azo dyes (Brown and Laboureur, 1983). Since azo dyes account for over 50% of all textile dyestuffs produced and are the most common chromophore of reactive textile dyes (Waring and Hallas, 1990), an anaerobic treatment system was proposed as a viable option for the decolourisation of textile effluents from reactive dyeing. Initial laboratory investigations were undertaken using a target reactive dye (C.I. Reactive Red 141), the results of which are documented in Carliell et al. (1995).

The target compound in the treatment system (azo dye) is not biodegraded by the micro-organisms, instead the dye acts as an oxidising agent for the reduced flavin nucleotides of the microbial electron transport chain and is reduced and decolourised concurrently with re-oxidation of the reduced flavin nucleotides (Gingell and Walker, 1971). Therefore, a source of reduction equivalents, resulting from the degradation of a suitable carbon source, is essential to ensure decolourisation and maintain the anaerobic population in the treatment system. In other words, a labile carbon source (other than the dyes) is required for decolourisation to take place. The carbon source requirement was fulfilled by glucose in the laboratory systems (Carliell et al., 1995); however, this is clearly not suitable for large-scale applications. It was decided to investigate the possibility of combining textile effluent decolourisation with the chemical oxygen demand (COD) removal operation of an existing anaerobic digester. This is shown in Fig. 1. The primary and secondary sludge are the carbon sources for anaerobic digestion. The carbon is converted to methane and carbon dioxide, during which process electrons are released. These electrons cascade down the electron transport chain (as indicated in the box in Fig. 1) to a final electron acceptor such as nitrate, sulphate or an azo reactive dye. The electrons react with the dye by reducing the azo bonds and thus causing decolourisaton.

The results reported in this paper are from a 5-month trial in which concentrated reactive dyebath effluent was added daily (weekdays only) to an operating anaerobic sewage sludge digester at the Umbilo Sewage Purification Works (USPW) in Pinetown (KwaZulu-Natal). The objectives of the trial were to ensure that the addition of the textile effluent did not increase the colouration of the digester effluent and did not adversely affect the daily operation of the digester.

* To whom all correspondence should be addressed.
8 (031) 260-3357; fax (031) 260-1118; e-mail buckley@che.und.ac.za
Received 15 August 1995; accepted in revised form 19 April 1996.