

# Treatment of a textile dye in the anaerobic baffled reactor

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## Abstract

Synthetic organic colourants, the majority of which are recalcitrant in nature, are used in many different manufacturing processes. The dyes are released into the environment in industrial effluents and are highly visible even at low concentrations (< 1 mg/l). Decolorisation of the dye CI Reactive Red 141 was investigated in a laboratory-scale anaerobic baffled reactor (ABR). The results of the physical decolorisation tests suggested significant decolorisation due to adsorption to the biomass; however, it is possible that the dye chromophores were reduced due to the low redox potential environment within the test bottles. No dye breakthrough, due to adsorption saturation, was observed during operation of the reactor. COD reduction was consistently > 90 %. Colour reduction averaged 86 %. The biomass showed acclimation to the dye, with increased methanogenic activity with each increase in dye concentration. The reactor operation was stable, even with increases in the dye concentration. This investigation has shown that successful treatment of a highly coloured wastewater is possible in the ABR.

**Keywords:** Anaerobic baffled reactor, textile dyes, CI Red 141

## Introduction

The successful application of anaerobic technology to the treatment of industrial wastewaters depends on the development of high-rate bioreactors, which achieve a high reaction rate per unit reactor volume by retaining the biomass in the reactor for long periods of time (solids retention time – SRT), independent of the hydraulic retention time (HRT). While there have been many high-rate designs developed, the ABR has many advantages compared to these, such as:

- better resilience to hydraulic and organic shock loads,
- longer biomass retention times, lower sludge yields, and
- the ability to partially separate the various phases of anaerobic catabolism (Barber and Stuckey, 1999).

The ABR is a high-rate reactor that contains between 3 and 8 compartments in which the liquid flow is alternately upwards and downwards between compartment partitions (for a review see Barber and Stuckey, 1999). During upflow, the waste flows through an anaerobic sludge blanket and is thus in contact with the active biomass but, because of the design, most of the biomass is retained within the reactor.

Dye wastewaters enter the environment from dye manufacturers and dye consumers, e.g. textile, leather and food industries (Cooper, 1995), usually in the form of a dispersion or a true solution (Seshadri et al., 1994), and often in the presence of other organic compounds. Dyes are normally present in dyehouse effluent at concentrations of 10 to 50 mg/l (Laing, 1991). CI Reactive Red 141, or Evercion Red HE7B, is an azo reactive dye (Fig. 1) with a molecular mass of 1 634 Da. The dye is representative of a dye class known to be problematic with treatment in a conventional wastewater treatment system; reactive dyes are hydrophilic, there-

fore, they have little affinity to adsorb to biomass and generally pass through activated sludge systems (Bell, 1998). The red hue is known to give rise to aesthetic problems at relatively low concentrations. Previous investigations have determined the reaction kinetics of CI Reactive Red 141 (Carliell, 1993; Carliell et al., 1994; Carliell et al., 1995; Carliell et al., 1996; Bell, 1998).

It was hypothesised that anaerobic digestion, in the ABR, could reduce the COD and colour of a CI Reactive Red 141 waste stream at a low (20 h) hydraulic retention time (HRT). The objectives of this investigation were to determine whether adsorption to the anaerobic biomass played a significant role in the decolorisation of the waste stream, to assess the feasibility of the ABR for treatment of a CI Reactive Red 141 waste stream; including reduction of COD and decolorisation, evaluate any impact on reactor performance with increasing dye concentrations, and to determine whether the anaerobic biomass became acclimated to the dye, thereby improving degradation and decolorisation, with time.

## Materials and methods

A batch control run (data not shown) investigated the difference in degradation potential of both un-hydrolysed and hydrolysed dyes. Four azo dyes were hydrolysed, to imitate their form in a wastewater stream, by raising the pH to 11 with 0.2 M NaOH and heating at 80°C for 2 h. There was a negligible difference in the results, thus un-hydrolysed dyes were used for the remainder of the study.

**Physical decolorisation:** Two tests were conducted to determine the extent of adsorption of CI Reactive Red 141 to the digester sludge since this could contribute to the decolorisation potential in the ABR. The test conditions are outlined in Table 1.

In Test 1, mixed anaerobic digester sludge collected from the Umbilo Sewage Works (Pinetown, South Africa) was inactivated by autoclaving at 121°C for 80 min. Once the sludge had cooled, aliquots were transferred into a series of serum bottles. The CI Reactive Red 141 dye stock solution was diluted to the required concentration (2 g/l). In Test 2, sodium azide, which is an inhibitor

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