SUMMARY

Wastewater discharges from textile dyehouses are complex, variable, and highly coloured, generally containing dyes at concentrations of 10 to 200 mg/M, depending on the dyeing proces in operation. Although dilution of the effluent can, and does occur, colour is discernible at concentrations as low as 1 mg/M. Dilution of dyehouse effluent therefore tends to compound the treatment problem, by increasing the volume of coloured effluent.

Conventional treatment processes presently in use at waste water treatment works do not usually achieve satisfactory colour removal, resulting in coloured effluent being discharged from the treatment works. Consequently, downstream use of the treated water is limited, and the highly visible nature of the pollution source often gives rise to public concern.

Solutions to treatment problems are being sought through exploration of chemical, physical and biological treatment options. Chemical treatment processes such as the use of Fentons Reagent, and physical treatment such as the removal of dyes by filtration (reverse osmosis, crossflow microfiltration) are successful in removing colour. However, by-products such as possible dye intermediates (Fentons reagent) or dye concentrates (filtration) are alternative pollution sources which must be treated or disposed of.

Research into specialised biological treatment of dye-containing wastewater has shown potential for a complete treatment system ie. mineralisation of organic dye compounds, to inorganic constituents such as carbon dioxide, methane, and water.

Degradation of simple azo dyes by aerobic microorganisms has been reported in the literature, however, factors such as the restricted substrate specificity and highly bred nature of the bacteria, has rendered these processes impractical for large-scale waste treatment. In contrast to the substrate specificity demonstrated by aerobic dye-degrading microorganisms, anaerobic populations show potential for non-specific colour removal, although the nature of the decolourisation process, and the ability of anaerobic populations to mineralise intermediary dye metabolites, is uncertain.

Anaerobic treatment of dyes was chosen as the target of this research, and was investigated in two phases : (i) the ability of anaerobic microorganisms (enriched from digester sludge) to decolourise a reactive red dye viz. Procion Red HE-7B, and (ii) the ability,if any, of this anaerobic population to degrade/mineralise any dye metabolites originating from decolourisation of Procion Red HE-7B.

Research to date has been conducted in the form of batch studies in anaerobic serum bottles. Factors such as the order of decolourisation, and subsidiary rate limiting factors, have been addressed in the initial studies. The order of decolourisation of Procion Red HE-7B has been found to be first-order with respect to dye concentration, however, the decolourisation of Procion Red HE-7B does not appear to be a result of a catabolic pathway, and for this reason it is possible that the rate of decolourisation is pseudo-first order ie. factors other than dye concentration are indirectly responsible for the shape of the decolourisation curve. The literature favours the theory that decolourisation of azo dyes by anaerobic microorganisms is the result of dye reduction by reduced flavin nucleotides in the electron transport chain. To test this theory, competitive electron acceptors, such as nitrate and sulphate, are added to the assay bottles. To date only nitrate addition has been completed, and has been found to effectively inhibit decolourisation. This collaborates the above hypothesis, as nitrate is more favourable thermodynamically, and is therefore reduced preferentially in the electron transport chain.

Possible rate-limiting factors for decolourisation of Procion Red HE-7B, are as diverse as cell permeability, redox potential of the dye, and nature and concentration of an additional carbon source. The latter has been investigated by addition of glucose (non-limiting concentration) to the bottles in which decolourisation takes place. This has been found to result in an approximate 15-fold increase in decolourisation of Procion Red HE-7B. Alternate cabon rich sources that may be applicable in a wastewater treament system are currently being investigated. Microorganisms are being acclimated to utilise the carbon sources present in cotton scouring effluents, and preliminary results indicate the

ability of these microorganisms to decolourise Procion Red HE-7B at a rate comparable to that in the standard assay bottles.

Phase II ie. the mineralisation of resultant dye metabolites, will be investigated via Biochemical Methane Potential (BMP) tests, and through identification of dye metabolites, with the aim of determining the fate of these metabolites.

In addition, toxicity trials are to be conducted to assess the concentration of dye (and metabolites) that

ABSTRACT

Decolourisation of a reactive azo dye, Procion Red HE-7B was studied using serum bottle assays. Inoculum for the assays was obtained from laboratory digesters in which anaerobic digester sludge was incubated with Procion Red HE-7B for 4 months.

A standard set of operating conditions were developed to study the anaerobic decolourisation of Procion Red HE-7B. The rate of decolourisation in the standard assay system was determined to be first-order with respect to dye concentration, but was inversely proportional to the initial dye concentration in the system. This was not in agreement with first-order kinetics and was attributed to microbial inhibition, either due to increasing concentrations of Procion Red HE-7B and/or metabolites. These results were compared with those in literature and probable rate-limiting factors for decolourisation were identified as the rate of permeation of Procion Red HE-7B into the microbial cells, and the presence of supplemental carbon and/or additional electron acceptors.

Dye permeation was investigated using permeabilised biomass. Increased permeation of the dye into the microbial cells was found to inhibit decolourisation, suggesting that decolourisation occurred extracellularly. The rate of Procion Red HE-7B decolourisation was measured in the presence and absence of a supplemental carbon source (glucose 1 g/M) and was found to be limited in the absence of glucose. The addition of nitrate (as a competitive electron acceptor) to the assay system inhibited decolourisation for a period of time proportional to the concentration of nitrate in the system. In contrast the addition of sulphate to the system was shown to have no marked effect. It was proposed that nitrate reduction was preferential to Procion red HE-7B reduction which, in turn, was preferential to sulphate reduction. The role of system redox potential in the anaerobic decolourisation of Procion Red HE-7B was therefore investigated. It was found that a strictly anaerobic system was conducive to decolourisation.

The chemical reaction responsible for decolourisation was investigated using ultraviolet scanning. Decolourisation was found to be caused by reduction of the azo bonds and subsequent destruction of the dye chromophore. The fate of the ensuing metabolites was investigated with respect to their mineralisation potential in the anaerobic system, however, neither acclimated nor unacclimated biomass showed any capacity for mineralisation of Procion Red HE-7B.

The toxicity of Procion Red HE-7B to the anaerobic biomass was investigated by means of an anaerobic toxicity assay. Total gas production was monitored and maximum rate ratios were calculated to determine the level of inhibition. Acclimated biomass did not show significant inhibition at any of the test concentrations, however, unacclimated biomass was significantly inhibited at the higher dye concentrations.

Abiotic decolourisation of Procion Red HE-7B in the standard assay system was found to be caused by adsorption of the dye to the biomass (approximately 17 %) and decolourisation by the mineral salts medium (approximately 35 %). Adsorption isotherms developed for Procion Red HE-7B with anaerobic digester sludge as the adsorbent conformed to Freundlich and Langmuir isotherms.

A treatment process was investigated using organic-rich textile scouring effluents as carbon sources during decolourisation of Procion Red HE-7B. This system showed potential for decolourisation of the dye and for the reduction of the organic carbon in the scouring effluent.