Column studies for biosorption of dyes from aqueous solutions on immobilised *Aspergillus niger* fungal biomass

Yuzhu Fu and T Viraraghavan*
Faculty of Engineering, University of Regina, Regina, Saskatchewan, Canada S4S 0A2

Abstract

Biosorption is becoming a promising alternative to replace or supplement the present dye removal processes from dye wastewaters. Based on the results of batch studies on biosorption of the dyes on powdered fungal biomass, *Aspergillus niger*, an immobilised fungal biomass was used in column studies for removal of four dyes, Acid Blue 29, Basic Blue 9, Congo Red and Disperse Red 1 from aqueous solutions. For each dye, the effectively pretreated powdered fungal biomass was immobilised in a polysulphone matrix in the form of spherical beads. In column studies, adsorption and elution tests were conducted for each dye and the regeneration and reuse for Acid Blue 29 were carried out. The breakthrough data from column studies could be described by the Thomas model. Results of t-tests indicated that the Thomas model constants were statistically significant at 95% confidence level for Acid Blue 29 and Basic Blue 9, but not for Congo Red and Disperse Red 1. The beads had adsorption capacities of 64.7 mg/g for Acid Blue 29, 8.3 mg/g for Basic Blue 9, 1.1 mg/g for Congo Red, and 0.1 mg/g for Disperse Red 1, respectively. In the elution tests, Acid Blue 29 and Basic Blue 9 were easily desorbed from the beads, but Congo Red and Disperse Red 1 were minimally desorbed. The beads in the column retained a high adsorption capacity (91%) for Acid Blue 29 in the second cycle, which suggested that the system using *A. niger* biomass can be developed for the removal of certain dyes.

Key words: *Aspergillus niger*, immobilisation, Acid Blue 29, Basic Blue 9, Congo Red, Disperse Red 1.

Introduction

Dye wastewaters discharged from textile and dyestuff industries have to be treated due to their impact on water bodies, and growing public concern over their toxicity and carcinogenicity in particular. Dyes usually have synthetic origins and complex aromatic molecular structures (Banat et al., 1996). According to their dissociation in an aqueous solution, dyes can be classified as follows (Mishra and Tripathy, 1993):

- Anionic: acid, direct and reactive dyes
- Cationic: basic dyes
- Nonionic: disperse dyes.

Dyes such as acid, basic and direct are all water-soluble (Reife, 1990) but disperse dyes have low solubilities and colloidal dispersion properties; thus they are agglomerations (Reife and Freeman, 1996). Many different and complicated molecular structures of dyes make dye wastewaters difficult to be treated by conventional biological and physico-chemical processes. Therefore, innovative treatment technologies need to be investigated.

Biosorption has been studied since 1980s for removing heavy metals, dyes and other organic pollutants by various microorganisms from wastewater. Among these microorganisms, fungal biomass can be produced cheaply and obtained as a waste from various industrial fermentation processes (Kapoor and Viraraghavan, 1995). Decolorisation of dye wastewater by fungal metabolic activities is the subject of many studies (Benito et al., 1997; Knapp et al., 1995; Miranda et al., 1996; Polman and Breckenridge, 1996; Vasdev et al., 1995). Compared with live fungal cells, dead fungal biomass possesses various advantages such as absence of nutrient needs and ease of regeneration (Gadd, 1990). Dried, non-living and physically or chemically pretreated fungal biomass would be an attractive biosorbent for removing dyes from dye wastewaters. However, there are only limited studies on dye removal by dead fungal biomass (Fu and Viraraghavan, 1999; 2000; Gallagher et al., 1997; Polman and Breckenridge, 1996; Zhou and Banks, 1993; Mou et al., 1991). These fungi, which can biosorb diverse dyes, include *Aspergillus niger*, *Rhizopus arrhizus* and *Rhizopus oryzae*.

In batch studies, the dead fungal biomass is normally used in the powdered form, which is convenient and can be separated from a mixture of dye solution and fungal biomass by filters with a fine pore size without difficulty. However, the fungal biomass powder is composed of small particles with low density, low mechanical strength and low rigidity. These properties will cause difficulties in separation of the biomass in practice (Tsezos, 1990). Alternatively, immobilisation of the powdered dead fungal biomass into a solid matrix can overcome this difficulty. It can maintain the native properties of the biomass and has the advantages of improved strength and handling capacity, reduced blockage and head-loss in a column operation and better regeneration characteristics (Tobin et al., 1993; Brierley, 1990; Tsezos, 1990).

Two kinds of fungal biomass, live and dead, are used in immobilisation. Banks and Parkinson (1992) immobilised living fungal cells, *Rhizopus arrhizus* within the reticulated foam biomass support particles and used these immobilsed cells in columns to remove humic acid from the raw water. In the immobilisation of dead fungal biomass for heavy metals removal, various materials can be used as the solid matrix. These are polysulphone, alginate, polyacrylamide, epoxy resin and polyvinyl formal (Kapoor and Viraraghavan, 1998; Spinti et al., 1995; Ferguson et al., 1989; Tobin et al., 1993; Tsezos and Deutschmann, 1990). Polysulphone is an amorphous, rigid, heat-resistant and chemically stable thermoplastic material which is a good immobilising agent (Kapoor and Viraraghavan, 1998). So far no study of dead fungal biomass

* To whom all correspondence should be addressed.
☎ (306) 585-4734; fax: (306) 585-4855; e-mail: t.viraraghavan@uregina.ca
Received 26 January 2001; accepted in revised form 9 July 2003.