Treatment of substituted phenol mixtures in single phase and two-phase solid–liquid partitioning bioreactors

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Abstract

The biological treatment of phenolics is constrained by the inherent cytotoxicity of these compounds. One method to alleviate such toxicity is to add a sequestering phase to absorb, and subsequently release, the substrate(s) to the micro-organisms; such a system is termed a Two Phase Partitioning Bioreactor. Here we have compared the performance of a TPPB, relative to single phase operation, in which a small volume (5%, v/v) of beads of the polymer Hytrel 8206 was used to treat aqueous mixtures of 2,4-dimethylphenol and 4-nitrophenol. Hytrel 8206 was selected from a range of polymers that were tested for their partition coefficients (PCs) for the target molecules, with the more hydrophobic compound (2,4-dimethylphenol) having a higher PC value (201) than 4-nitrophenol (143). Significantly increased removal rates for both substrates were demonstrated in TPPB mode relative to single phase operation. Additionally, the differential release of the compounds to the aqueous phase and their distinct PC values changed the kinetic pattern of the biotreatment system, smoothing out the cellular oxygen demand. Release of the substrates by the polymer over 60 operating cycles was virtually complete (>97%) demonstrating the reusability and robustness of the use of polymers in overcoming cytotoxicity of phenolic substrates.

1. Introduction

Phenols, and substituted phenols, are important contaminants in wastewater that are of significant environmental concern because of their toxicity to many life forms; for example the EC50 (determined on activated sludge respiration inhibition) because of their toxicity to many life forms; for example the EC50 (determined on activated sludge respiration inhibition) of 4-nitrophenol and 2,4-dimethylphenol are 64 and 190 mg/L, respectively [1]. Effluents containing these compounds, present in discharges from a number of industrial activities (e.g. coal conversion processes, coke ovens, petroleum refineries and petrochemical industries, resin and fibreglass manufacturing and herbicide production), must be treated but the ability to eliminate these compounds via biotreatment methods is hampered by their inherent toxicity, which causes inhibition to the microbes responsible for their elimination [2].

An effective means of reducing or eliminating substrate toxicity, while still treating high concentrations of inhibitory compounds, is via the use of Two Phase Partitioning Bioreactors (TPPBs), which consist of a cell-containing aqueous phase, and a sequestering/partitioning phase that reduces aqueous concentrations of toxic substrates via equilibrium partitioning, and releases them to the cells based on metabolic demand. TPPBs have been successfully applied in the removal of xenobiotic compounds from air, water and soil [3–6]. We have demonstrated the enhanced biotreatment of phenol and of 4-nitrophenol (4NP) in TPPBs using immiscible organic solvents [7,8] and commercial polymer beads [9], with the latter approach allowing the use of mixed microbial consortia because of the non-bioavailability and biocompatibility of polymeric materials (e.g. plastics).

Since industrial wastewater is likely to contain mixtures of contaminants it is critical that strategies being developed for commercial application are able to demonstrate effective treatment of such mixtures, and are able to address the kinds of interactions that can occur with multiple toxic substrates. Such substrate interactions can be extremely complex, and can include enhancement, inhibition, and cometabolism as was shown for a mixture of benzene, toluene, ethylbenzene and xylene [10]. In the case of mixtures of substituted phenols, numerous such interactions have also been observed in batch experiments. For example, when cells were grown on a mixture of 4-chlorophenol, 4-nitrophenol and phenol, 4-chlorophenol degradation was delayed until 4-nitrophenol was almost completely depleted [11]. In a dual-substrate system of phenol and 4-chlorophenol, 4-chlorophenol was found to intensely inhibit phenol biodegradation [12]. Alexieva et al. [13] showed