Biodegradation of BTEX in a fungal biofilter: Influence of operational parameters, effect of shock-loads and substrate stratification

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The effect of relative humidity (RH: 30% to >95%) of a gas-phase mixture composed of benzene, toluene, ethylbenzene and para-, meta- and ortho-xylenes (BTEX), inlet concentrations (0.2–12.6 g m⁻³), and empty bed residence times (EBRTs) (48–144 s) was tested in a fungi-dominant biofilter. A maximum elimination capacity (ECmax) of 244.2 gBTEX m⁻³ h⁻¹ was achieved at a total inlet loading rate (ILR) of 371.2 gBTEX m⁻³ h⁻¹ (RH: 65%). The transient-state response was tested by increasing the ILR, in two steps, from ~50 to 850 g m⁻³ h⁻¹ and from ~50 to 320 g m⁻³ h⁻¹, at a constant EBRT of 41.7 s. Increasing the ILR reduced the total BTEX removal efficiency (RE) from >97% to 35%, and from >90% to 60% during medium and high shock-load, respectively. When subjected to short (4 d) and long-term (7 d) shut-down periods, the biofilter was able to recover high ECmax of, respectively, 200 and 72 gBTEX m⁻³ h⁻¹ after resuming operation.

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1. Introduction

Benzene, toluene, ethylbenzene, para, meta, and ortho-xylenes, collectively called BTEX, are important industrial chemicals and are well-known volatile organic compounds (VOCs) of environmental and health concern. Due to improper handling and disposal practices, and the negligence or failure of some process industries to adopt suitable VOC elimination techniques, these compounds can frequently be released into the ambient atmosphere.

Biofilters allow the treatment of low concentrations of contaminants, at high gas-flow rates. In a biofilter, the attached microorganisms convert the gas-phase pollutant(s) into end-products such as carbon dioxide, water, biomass and salts. Recent studies have even successfully evaluated the possibility of converting some volatile pollutants to useful products such as biofuels (Abubakar et al., 2011). The extent to which biological wastewater treatment can occur in a biofilter is affected by several factors: physical and chemical properties of the pollutant(s), degree of biodegradability of the pollutant(s), pollutant loading rate, microbial physiology and ecology, and other suitable environmental conditions such as temperature, relative humidity (RH), and pH (Kennes and Veiga, 2001; Jorio et al., 2009). Literature reports on the removal of BTEX compounds in fungi-inoculated or fungi-dominant biofilters are sparse, though a few authors have investigated the removal of BTX or BTEX compounds, as mixtures, in liquid systems using fungi (Oh et al., 1994; Prenafeta-Boldu et al., 2002). One of the main advantages of favouring the growth of fungi rather than bacteria for the removal of hydrophobic pollutants in biofilters is their ability to degrade these compounds under a broad range of process conditions (Kennes and Veiga, 2004).

Most of the reported studies on the biofiltration of BTEX (B, T, E, p-X, m-X and o-X compounds) were carried out at steady-state. The transient-state behavior of waste-gas treatment systems to sudden variations in operating conditions, during shock-loads or shut-down and re-start operation, has started to receive attention and there are several recent studies that have reported transient behavior with a single pollutant. In field applications, the occurrence of transient conditions, either in the form of an unexpected pollutant shock-load, or complete reactor shut-down, can be either regular or frequent (Seignez et al., 2004; Moe and Li, 2005). Such transient operations would lead to instability of the biomass, perturbation between steady-states and would eventually affect the dynamics of pollutant removal and reaction kinetics in the waste-gas treatment system. Substrate starvation is also a type of shock-load where no external substrate is fed to the microbial population, thus depriving them of the essential carbon and energy source. Pollutant starvation can be expected in process industries under the following conditions: overnight or weekend closures, plant maintenance, equipment malfunctioning, and regular change in process operation (Nabatilan et al., 2010). Re-acclimation times after starvation for a biofilter can vary widely depending on the starvation period, pollutant characteristics, microbial activity, packing material, and reactor configuration, among others. A prior

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