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Modelling and computational fluid dynamic behaviour of a biofilter treating benzene

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HIGHLIGHTS

- Biological method have been applied for removal of contaminated air steam containing benzene.
- Benzene is widely used as a solvent, mainly in paints industries, denatured alcohol and rubber.
- In biofiltration, microbial metabolism of VOCs consists adsorption, diffusion and biodegradation.
- Performance of the biofilter is in terms of the elimination capacity using 3-D mesh techniques.
- The kinetic behaviours, and benzene concentration are analysed by CDR model and CFD technique.

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ABSTRACT

Biofiltration of an air stream containing benzene has been studied in a laboratory biofilter packed with a mixture of compost, sugar cane bagasse and GAC. In this study, the overall performance of a biofilter has been evaluated in terms of its elimination capacity by using 3-D mesh techniques. The overall results indicate that the agreement between experimental data and estimated model predictions is excellent for benzene. The benzene concentration profiles along the depth of biofilter have also been determined using a convection–diffusion reactor (CDR) model and computational fluid dynamic (CFD) technique. At low flow rates and low concentrations of benzene, the concentration profile throughout the biofilter shows good agreement with CDR model and it becomes more curved and resembles typical decay. Combined analysis of experimental results with CDR model and the CFD shows that the profile of benzene at low concentration becomes more curved and then linear at high concentration. The benzene profiles obtained by CFD are within 5% accuracy of experimental results. The CDR and CFD models are found to be able to predict concentration profiles preciously with depth under the experimental conditions.

1. Introduction

Benzene is one of five compounds by the clean air act as a 'toxic air pollutant'. The total benzene emission on the national level in the United States is estimated to be 513 times per year in 2002 (Hassan and Sorial, 2009). Benzene, toluene, ethylbenzene and xylene are mostly present in gasoline and this group accounts for up to 59% (w/w) of gasoline pollutants. Benzene is a potent carcinogen while toluene, ethyl benzene and *p*-xylene are highly toxic and mutagen (Gallastegui et al., 2011). Benzene is widely used as a solvent, mainly in industrial paints, paint removers, adhesives, degreasing agents, denatured alcohol, rubber, cements, arts and crafts supplies etc., (Young et al., 1978). Due to its carcinogenic health effects, benzene has been classified by the Environmental Protection Agency (EPA) as a Group A, known human carcinogen of medium carcinogenic hazard (Lanyona et al., 2005). EPA has set a goal to lower the concentration of benzene to 0.62% in gasoline by the year 2011 (Hassan and Sorial, 2009; Hassan and Sorial, 2010). From the Priority List of Hazardous Substances Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, 2007), benzene is ranked sixth amongst the 275 substances identified to pose the most significant potential threat to human health. The long-term exposure of benzene can cause anaemia, excessive bleeding, deterioration of the immune system and leukaemia (Robledo-Ortiz et al., 2011). Because of its confirmed carcinogenic properties (ATSDR, 1997; Shim et al., 2002), the standard set by USEPA 2002 for benzene in drinking water is 5 μg L^{-1}. While OSHA set an

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