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Biodegradation of ethyl benzene and xylene contaminated air in an up flow mixed culture biofilter

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A B S T R A C T

Biofiltration of ethylbenzene - xylene mixture was performed in a continuous biofilter employing mixed microbial culture in the total inlet loading rate range of 25.0–408.0 g m^{-3} h^{-1}. The maximum elimination capacities attained for ethylbenzene and toluene were 85.63 and 63.2 g m^{-3} h^{-1} respectively. The elimination capacities were evaluated at different loading rates and found to very in a linear pattern. The effect of biofilter bed height on the removal efficiency was studied and the contribution of the lowest part was more than the upper sections due to different biomass growth patterns. The actual yield coefficient with respect to carbon dioxide production was found to be 4.07 and the correlation was given by CPR = 4.076 EC + 9.027. Heat release was observed during the experimental studies confirming the exothermic nature of biodegradation. Biomass growth profile showed better biofilm formation in the lower and middle section of the column.

1. Introduction

Volatile Organic Compounds (VOCs) released from industrial sources include ethylbenzene and xylene as two main components which are members of the BTEX group comprising of benzene, toluene, ethylbenzene and *p*, *m* and *o*-xylene. Due to improper handling, leakages from storage tanks and incompetent disposal methods, these compounds gain entry into the atmosphere (Rene et al., 2012; Chang et al., 2015). This group accounts for nearly 57% (*w/w*) of the gasoline related pollutants and 80% of the total VOC in petrochemical plants (Gallastegui et al., 2011). BTEX, classified as mono aromatic compounds, are used in the industrial production of plastics, synthetic fibers, polymers and pesticides. Also, they are released due to anthropogenic emission during combustion processes and automobile exhaust. These compounds when released into air cause ozone layer depletion, global warming and greenhouse effect (Mohammad et al., 2007). Human exposure to these compounds lead to damages to nervous, digestive, kidney and respiratory system under long term exposure (El-Naas et al., 2014). In order to prevent the living organisms from the detrimental effects, there is a strong legislation to control their emissions into the natural environment. Single and binary VOCs adsorptions using sulfuric acid treated activated carbon have been reported (Pak et al., 2016). Compared to the conventional physico-chemical methods for air pollution control like catalytic oxidation, incineration and adsorption, biological methods are found to be effective, efficient and eco-friendly technologies (Chen et al., 2010; Lee et al., 2009; Rene et al., 2009). The physico-chemical methods suffer from disadvantages like high operating and maintenance costs, increased energy requirements and production of toxic byproducts (Mudliar et al., 2010). BTEX compounds are susceptible to microbial degradation under aerobic conditions. Dissolved oxygen is required for the occurrence of degradation through ring activation and cleavage of aromatic nucleus (Andreoni and Gianfreda, 2007). Attacking the side chains and oxidizing the aromatic ring are the two possible mechanisms for the degradation of volatile organics. Biological methods involve the use of both bacteria and fungi either together in mixed culture systems or any one of the pure microbial strains for biodegradation. Several bioreactor configurations like biofilter, bio scrubber and bio trickling filter have been developed for various air pollution control applications. Biodegradation of BTEX compounds was studied in a fungal

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biofilter and a maximum capacity of 244.2 g BTEX m^{-3} h^{-1} was achieved (Rene et al., 2012). Studies on advanced oxidation of BTEX isomers using *Trametes versicolor* were conducted and an average of 71% degradation was reported (Aranda et al., 2010). Different biofilter media like wood charcoal (Singh et al., 2010), press mud (Saravanan and Rajamohan, 2009), corn stack (Saravanan et al., 2013) and *Macadamia ternifolia* nutshells (Volckaert et al., 2013) have been tried in various biofilter applications. Thermophilic biofiltration of sulfur dioxide using desulfurization bacteria was studied (Zhang et al., 2016) Biofiltration of benzene has been investigated using the same biofilter employed in this study (Rajamohan et al., 2015). Even though many studies were conducted in either of the VOCs used in this study, the treatment of ethylbenzene – xylene mixture contributed to the novelty in this research. The present investigation is focused on the feasibility studies on the biofiltration of air contaminated with ethylbenzene and xylene using a date palm tree bark based biofilter. The influence of operating variables, namely inlet pollutant concentration and flow rate, represented by the inlet loading rate was studied and the removal efficiency was estimated. The axial removal pattern of the pollutant was studied by monitoring the concentrations at different sections. The temperature was monitored throughout the experimental period and the gas production rate was recorded at the exit of the biofilter and correlated to the total elimination capacity. The biomass was estimated at different sections of the biofilter during the different phases of study.

2. Materials and methods

2.1. Microbial culture and filter media

This study employs a naturally available cheap plant based material, Date palm tree barks, produced from the tree *Phoenix dactylifera*, found commonly in the Arabian gulf, as the biofilter media. The biofilter was inoculated using a mixed microbial culture which was collected from the activated sludge system of the municipal sewage treatment plant located nearby. The inoculum was cultured in an aerated batch reactor and diluted as explained elsewhere (Saravanan and Rajamohan, 2009).

2.2. Experimental set-up and performance evaluation

The configuration of the date palm tree bark biofilter used in this study was the same as described as follows. The biofilter reactor employed an acrylic column which has column diameter of 5 cm, height of 100 cm, with a H: D ratio of 20:1. The working volume of the biofilter was 1962 cm^3. A 10 cm headspace for collection of the treated gas and nutrient feed addition and a 10 cm bottom space for leachate collection were provided. The schematic of the experimental set-up was shown in Fig. 1. The column consisted of four individual modules, each of 25 cm height and can be dismantled whenever required for maintenance. The packing media was loaded in the column section-wise in a random manner and a perforated plate was provided at the bottom of the each section permitting only air flow through it. In order to collect gas samples and parameter monitoring, two sampling ports at the tail end of each section from the direction of flow of air were provided. The nutrient media, which was autoclaved at 120 °C for 20 min, was added at periodic intervals from the top of the column using a nutrient distribution system, which utilizes a peristaltic pump to pump the nutrient solution from the storage tank. The composition of the nutrient media was presented in an earlier study (Saravanan and Rajamohan, 2009). During the start-up phase, nutrient media addition was continuously performed. The ethylbenzene–xylene (EB-X) stream was generated using compressed air. The air stream was divided into two streams, namely primary and secondary streams. The primary air stream was passed into the storage tanks containing ethyl benzene (99% purity) and xylene (99% purity) and then passed through the humidifier to maintain sufficient relative humidity. The primary air stream loaded with VOC was mixed with the secondary air stream in the mixing

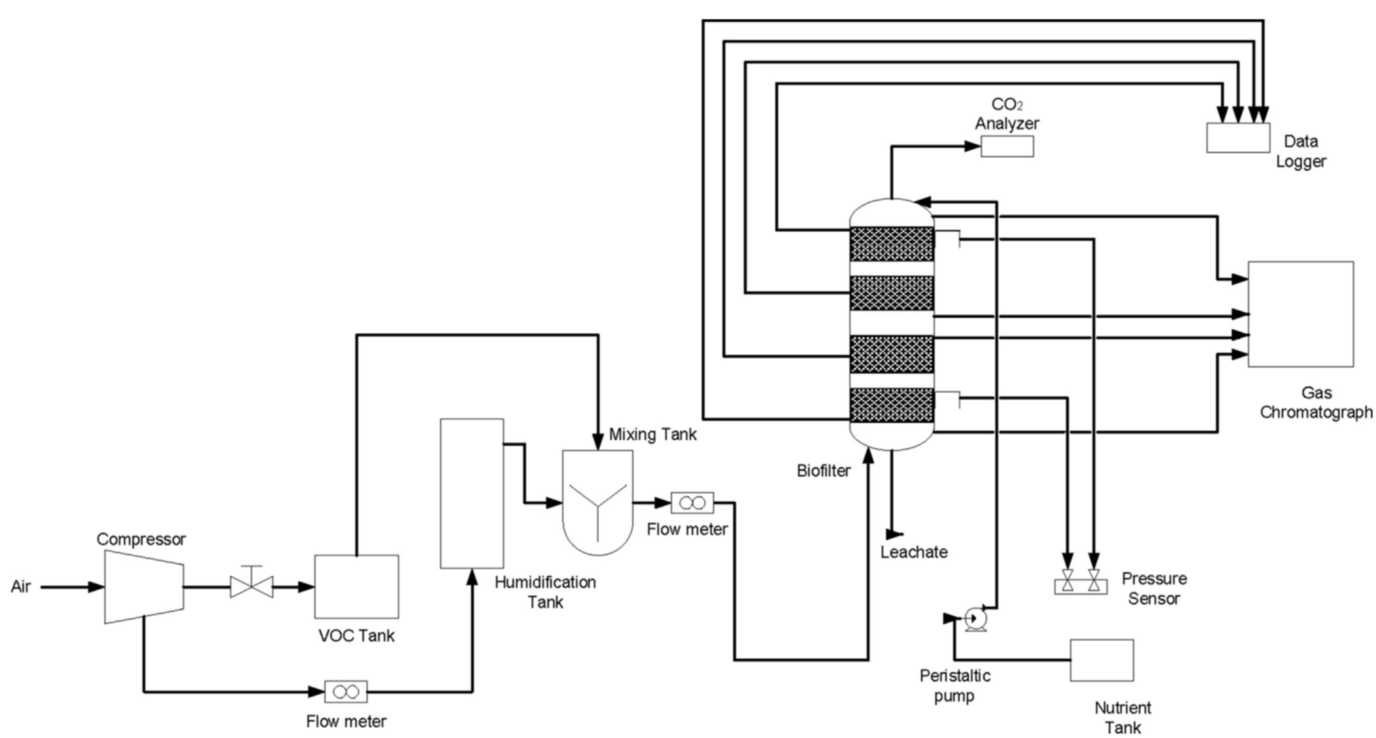

Fig. 1. Experimental set up of biofilter reactor assembly.

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