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Biofiltration of benzo[α]pyrene, toluene and formaldehyde in air by a consortium of *Rhodococcus erythropolis* and *Fusarium solani*: Effect of inlet loads, gas flow and temperature

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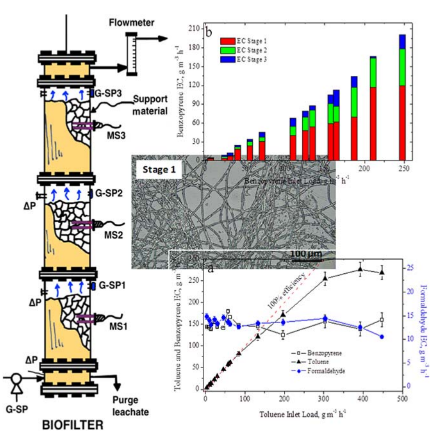
GRAPHICAL ABSTRACT



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ABSTRACT

Volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) are air contaminants with serious effects on human health. They include compounds with very different physicochemical properties, ranging from low to high volatility and low to high hydrophobicity. The objective of this research is to assess the feasibility of the simultaneous abatement of formaldehyde, a soluble and slightly polar VOC, toluene a hydrophobic and volatile VOC and benzo[α]pyrene (BaP), a representative PAH in a biofiltration reactor inoculated with the fungi *Fusarium solani* and the bacteria *Rhodococcus erythropolis*. Results obtained at an extended range of inlet loads: 3.7 to 447.7, 9.0 to 273.1 and 6.9 to 247.4 $g\,m^{-3}\,h^{-1}$ of toluene, formaldehyde and BaP, respectively, show that the elimination capacity and removal efficiencies of the contaminants were largely independent of each other. Moreover, the system can accommodate a fivefold increase in inlet gas flow maintaining removal efficiencies close to 60% for all the contaminants tested when the inlet loads of contaminants were kept constant. The most dramatic decrease in elimination capacity and removal efficiency in the system was obtained by changing the temperature of the system, where a decrease from 25 °C to 17 °C reduced the formaldehyde removal efficiency from 67% to 43%. BaP and toluene removal efficiencies were less affected by the decrease in

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system's temperature. This study shows the high flexibility of a biofiltration system inoculated with *F. solani* and *R. erythropolis* for the abatement of toluene, formaldehyde and BaP.

1. Introduction

Air pollution is a health concern worldwide. The Global Burden of Disease 2015 report [1], a study where the health impacts of air pollution were quantified for 188 countries during the period 1990–2015, reveals that in 2015 there were 4.2 million deaths attributable to outdoor fine particulate matter. Furthermore, indoor exposure to household air pollution from the use of biomass and other solid fuels for cooking and heating was responsible for another 2.8 million deaths. Particulate material is often accompanied by volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) [2]. VOCs comprise an important group of chemicals that evaporate easily at room temperature and are commonly present in indoor and outdoor air [3]. VOCs are emitted from industrial and residential sources, being formaldehyde and toluene the VOCs most known to the public. Toluene is present in many consumer products, including household aerosols, paints, varnishes, adhesives, and glues, and is also associated with incomplete combustion and evaporation of fuels, stationary sources such as industrial surface coating and solvent use, gas stations, power plants and refineries [4]. As for formaldehyde, its sources include combustion processes as well [5], but can also be found in construction materials such as particleboard, fiberboard, and plywood [6]. On the other hand, PAHs are a large group of chemicals with two or more fused aromatic rings in linear, angular or clustered arrangements [7]. PAHs are characterized by chemical stability, low volatility and low solubility in water [8]. The presence of PAHs in indoor and outdoor environments is mainly due to the incomplete combustion of wood and other fuels used for residential heating, tobacco smoke and cooking gases [9]. In Chile, the use of wood for residential heating in the central and south regions creates episodes of contamination during winter time characterized by high concentrations of particulate material, VOCs and PAHs [9]. In particular, benzo[α]pyrene (BaP), has been used as a marker for carcinogenic levels of PAHs in environmental studies [10].

Despite the abundance of evidence linking the exposure to VOCs and PAHs in indoor air with various health effects, only a few reports evaluating the existing abatement technologies are currently available. Biological treatment techniques for VOC have gained popularity in view of the several advantages they offer in comparison to traditional physical and chemical removal methods. Biological waste air treatment processes are not only more cost effective than conventional techniques, such as incineration or adsorption, but are also environment-friendly [11,12]. Several studies have demonstrated that biotrickling filters can effectively treat formaldehyde [13,14], where the layer of flowing water surrounding the biofilm promotes the solubilization of the hydrophilic formaldehyde molecules. On the other hand, when treating hydrophobic air pollutants, such formaldehyde and toluene, switching to a biofiltration system where flow is not continuous may more effectively remove the gaseous contaminants from air [15–18]. Biofiltration of certain mixtures such as benzene, toluene, ethylbenzene and xylene (BTEX) or benzene, hexane and toluene [19] have been extensively studied since they mimic the composition of gasoline vapors. However, there are no recent reports on the simultaneous biofiltration of formaldehyde and toluene, although they constitute an interesting challenge since their hydrophobicity and miscibility in water greatly differ. Likewise, BaP degradation, has been extensively studied using bioremediation catalyzed by fungi, bacteria and a consortium of both for soil treatment [8,20–22]. Nonetheless, there are no previous studies on the removal of BaP from air using biofiltration systems. To overcome the mass transfer limitations when hydrophobic VOCs are treated, several alternatives have been proposed. Fazaelipoor et al. [23] used a two phase biofilter where the biofilm is covered by a layer of an organic solvent that is immiscible in water. The simulation of the latter

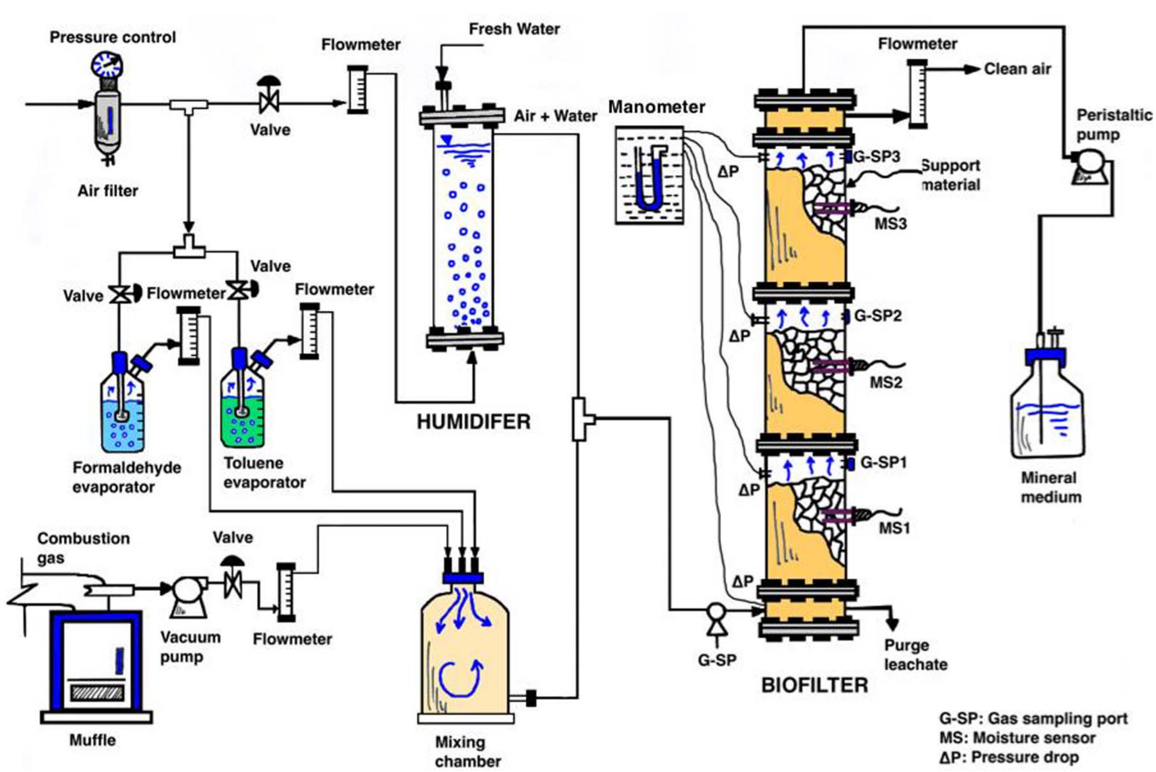

Fig. 1. Schematic of the laboratory-scale experimental biofilter.