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Research article

Effect of extended and daily short-term starvation/shut-down events on the performance of a biofilter treating toluene vapors

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A B S T R A C T

Industrial emissions of Volatile Organic Compounds are usually discontinuous. To assess the impact of interruptions in pollutant supply on the performance of biological treatment systems, two identical biofilters previously operated under continuous toluene loadings were subjected for 110 days to extended (12, 24, 36, 48, 60, 72, 84 and 96 h) and for a week to daily (8 h on, 16 h off) toluene starvation/shutdown events. One biofilter was operated under complete shutdowns (both air and toluene supply were interrupted), while the other maintained the air supply under toluene starvation. The biofilter operated under complete shutdowns was able to withstand both the extended and daily pollutant interruptions, while starvation periods >24 h severely impacted the performance of the other biofilter, with a removal efficiency decrease from 97.7 ± 0.1% to 45.4 ± 6.7% at the end of the extended starvation periods. This deterioration was likely due to a reduction in liquid lixiviation (from a total volume of 2380 mL to 1800 mL) mediated by the countercurrent airflow during the starvation periods. The presence of air under toluene starvation also favored the accumulation of inactive biomass, thus increasing the pressure drop from 337 to 700 mm $H_2O.m^{-1}$, while decreasing the wash out of acidic by-products with a significantly higher pH of leachates (Student paired *t*-test <0.05). This study confirmed the need to prevent the accumulation of inhibitory compounds produced during process perturbation in order to increase biofiltration robustness. Process operation with sufficient drainage in the packing material and the absence of countercurrent airflow are highly recommended during toluene deprivation periods.

1. Introduction

Toluene is a volatile organic compound (VOC) primarily emitted to the troposphere by anthropogenic sources. It is a ubiquitous contaminant whose emissions must be strictly controlled. Among the different end-of-the-pipe technologies available to control these emissions, biofiltration is a cost-effective and environmentally friendly alternative (Muñoz et al., 2015) nowadays considered as best available technology for the removal of VOCs from off-gases in the chemical industry (Sempere et al., 2008). Biofiltration is based on the circulation of the contaminated air stream through a packed bed colonized by an active biofilm. While the air circulates across the packing material, the contaminants are absorbed into the biofilm, where they are biologically converted to innocuous compounds such as carbon dioxide, water and additional biomass. Nevertheless, biological treatment technologies are still perceived as very sensitive to fluctuations in operating conditions and their detractors have often pointed out the lack of robustness as the main drawback of biotechnologies (Lebrero et al., 2010).

Fluctuations in the composition and flowrate of the polluted air stream are very common in industry as a result of routine manufacturing practices (Kim et al., 2005; Sempere et al., 2008; Álvarez-Hornos et al., 2012; Zamir et al., 2014). A major challenge in biofilter reliability is the capacity of biofiltration to respond to such transient loadings, and particularly to withstand periods without contaminants. Indeed, a temporary interruption of pollutant supply can negatively affect microbial activity, causing microbial decay and lysis (Zhu et al., 2015). When deprived of contaminants, microorganisms can initially maintain themselves

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by saprophytic activity, consuming alternative carbon sources such as cellular debris material, products of cell lysis, extracellular polymeric substances, residual metabolites, intracellular storage products, or even organic packing material (Métris et al., 2001; Chen et al., 2015).

In this context, previous studies have already indicated that biological technologies can efficiently treat discontinuous VOC emissions with periodic weekend and/or night interruptions (Moe and Qi, 2005; Álvarez-Hornos et al., 2008; Zamir et al., 2011, 2014). In some of these studies, a control biofilter under continuous feeding mode was carried out for comparative purposes (Álvarez-Hornos et al., 2008; Qi and Moe, 2006). Unfortunately, discontinuous feeding assays have not often been implemented under the same conditions as the continuous control (Álvarez-Hornos et al., 2012; Zamir et al., 2014). Likewise, process robustness was also evaluated in biotrickling filters during their start-up phase (without well-established biofilms), where biofilms are more sensitive to process fluctuations. Therefore, the results obtained in these experiments might not be representative of performance under long-term operation (Cox and Deshusses, 2002). Finally, many robustness studies have been carried out in biofilters operated well below their maximum capabilities, which can imply a lower sensitivity to transient conditions and thus revealed an unrealistic impact of the starvation periods (Woertz et al., 2001; Moe and Qi, 2005; Rene et al., 2005). This is central since most industrial facilities cannot be overdimensioned and are typically operated under critical loadings (the highest load at which pollutant removal efficiency is nearly complete), where the impact on process robustness can be very relevant. Therefore, there is a need for representative evaluations of the robustness of biofilters against the multiple pollutant supply interruptions faced by industrial facilities.

This work aimed at evaluating the impact of daily short-term and extended starvation/shutdown periods on the performance of biofilters operated with well-established biofilms under critical loading using toluene as a representative VOC. Additionally, the influence of biofilter aeration during the starvation period was also assessed. Most preceding studies only tested a very limited number of feeding interruptions, with somewhat arbitrary durations ranging from 8 h to 8 months (Marek et al., 2000; Elmrini et al., 2001).

2. Materials and methods

2.1. Biofilter set-ups

Two identical glass biofilters (namely A and B), which were previously operated in parallel for the treatment of toluene, were subjected to different toluene feeding interruptions (Fig. 1). The biofilters were operated at the Instituto Potosino de Investigación Científica y Tecnológica (San Luis Potosí, Mexico) under laboratory conditions for 129 days with statistically similar results in terms of elimination capacities, carbon dioxide and biomass productions,

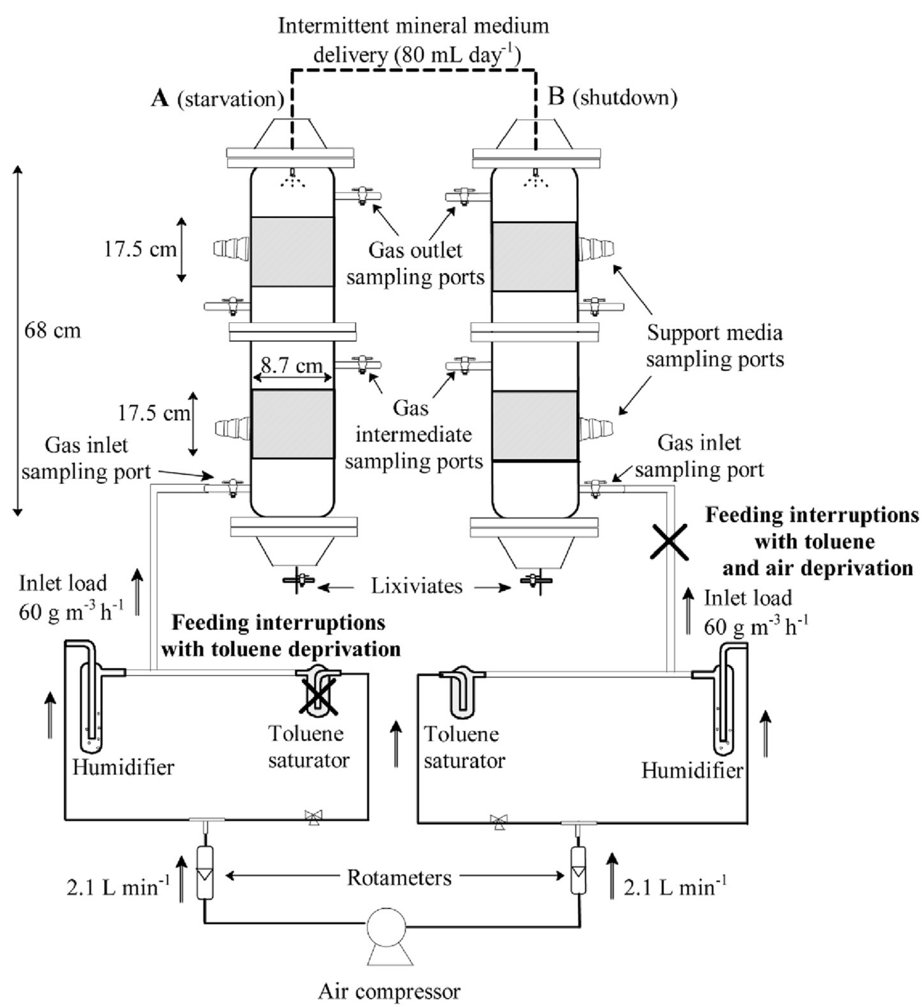

Fig. 1. Schematic diagram of the biofilter set-ups.