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Kinetic Characterization by Respirometry of Volatile Organic Compound-Degrading Biofilms from Gas-Phase Biological Filters

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Supporting Information

ABSTRACT: A novel heterogeneous respirometer for in situ assessment of the biological activity and mass transport phenomena of biofilm developed on packing materials of gas-phase biological filters is presented. The flexible respirometer configuration allows reproducing the operational features of biofilters and biotrickling filters to obtain reliable diagnoses of the bioreactor performance. A batch-operating mode was chosen for the biological assessment in which dynamic concentrations of oxygen, pollutant, and carbon dioxide were online recorded and used to calibrate a mathematical model that considers the principal phenomena occurring in the respirometer. The maximum elimination capacity of two different packing materials colonized by sulfide-oxidizing bacteria and toluene-oxidizing fungal populations was estimated and compared with previously reported values. Additionally the rate controlling phenomena were analyzed using the biofilm effectiveness factor. The experimental system can be easily applied to pilot- and industrial-scale gas-phase biological filters when the kinetic expression of pollutant degradation is available.

1. INTRODUCTION

Mitigating the noxious effects of air pollution is essential in promoting sustainable development. Anthropogenic volatile organic compounds (VOCs) emissions are severely affecting public health and ecosystems and some of these can further increase global warming.[1] In addition to known physicochemical methods, biological air treatment systems have been used to eliminate low concentrations of gaseous pollutants under ambient conditions. One of these biological techniques is biofiltration which consists in passing a polluted gas stream through a packed bed colonized by microorganisms, which transform the absorbed pollutants to new microorganisms and nontoxic substances.[2]

High performance of gas-phase biological filters, comprising both biofilters (BF) and biotrickling filters (BTF) may be reached with adequate control of nutrients and operation parameters of the process, although, in practice, performance may be difficult to maintain for long periods of time.[2] Optimum gas-phase biological filters operation is difficult to attain because of the limited knowledge of the interactions (chemical, biological, and mass transport) occurring in the biological filter beds, besides the reduced number of variables that can be reliably measured in real-time. Mathematical modeling can be a useful tool to analyze the phenomena by simple equations[2] expressed in terms of readily measured variables. However, simplifying the equations in a model must be supported by experimental evidence, which allows an identification of the key phenomena and provides consistent parameters to be included in the model. The use of a differential gas-phase biological filter operated as a closed-loop has shown to be a useful technique to evaluate the biological activity[3] and to characterize mass transport in gas-phase biological filters[4,5] by preserving typical biofiltration conditions such as flow regimes. This procedure referred to as heterogeneous respirometry might be deployed and adapted to evaluate biofilm and mass transport features in colonized packing samples by monitoring oxygen uptake rates.

Heterogeneous respirometry has advantages over the respiration measurement in free cells suspensions since preservation of biofilm morphology leads to a more realistic kinetics and mass transport examination. Drawbacks would be related to the heterogeneous colonization degree often encountered in pilot or full-scale gas-phase biological filter packed beds, which would imply an extensive sampling and thorough respirometric assays in order to obtain representative results.

Heterogeneous respirometry should be carefully controlled to deal with these drawbacks and obtain reliable data. In this

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