BIOLOGICAL ANOXIC TECHNOLOGY FOR THE TREATMENT OF VOC EMISSIONS FROM THE PETROCHEMICAL INDUSTRY

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Petrochemical industrial facilities are nowadays identified as major emission hotspots of volatile organic compounds (VOCs) worldwide. Some petrochemical VOC emissions are characterized by their O_2-free and hazardous nature, and explosion risk when O_2 is present (Bloch and Wurst 2010). Explosion risks in bulk storage tanks are normally controlled by headspace inertization with N_2 or CO_2, to avoid the presence of O_2 (Yanisko et al. 2011). To ensure a complete sweep of O_2 in the headspace, periodical purge of the inert VOC-laden headspace must be done and therefore, bulk fuel/solvent storage facilities are major VOC emission sources. These O_2-free VOC emissions are usually treated by means of catalytic incineration or simple gas flaring; however, it is important to stress that these technologies can exhibit prohibitive operating costs and/or are not environmentally friendly.

Among the available technologies for VOC abatement, biological methods constitute the most sustainable and cost-effective technology, exhibiting the lowest operating costs and environmental impacts (Estrada et al. 2012, Lopez et al., *in press*). However, the O_2-free nature and the explosion risks associated with the presence of O_2 strongly limit the use of conventional aerobic biological techniques for the direct treatment of VOC emissions from the petrochemical industry. Nevertheless, VOC biodegradation can also be achieved in the absence of O_2. Several studies showed that VOCs such as benzene, toluene, ethylbenzene, xylene and even methane can be successfully removed under anoxic denitrifying conditions (Phelps and Young 1999; Shim et al. 2005; Raghoebarsing et al. 2006). These previous studies, focused on treating pollutants in aqueous phase in closed systems and batch mode, confirmed the feasibility of using denitrification as a core metabolic process for VOC degradation.

In our laboratory, an innovative biofiltration technology based on the anoxic biodegradation of VOCs was developed. In contrast to traditional aerobic biofiltration, anoxic biofiltration does not require conventional O_2 supply to mineralize VOCs and therefore, the VOCs contained in O_2-free streams can be directly removed, avoiding the use of expensive physical/chemical or non-environmental friendly technologies without explosion risks. On the other hand, since the final gaseous products of denitrification are N_2 and CO_2, the VOC-free gas at the outlet of the anoxic system can be re-used for inertization purposes, leading to important savings in the overall operating costs of the petrochemical plant.

Process description and performance

For the proof of concept, toluene was used as model VOC and the anoxic biofiltration system was implemented in a biotrickling filter. The general equation for toluene removal under anoxic conditions without biomass formation is:

$C_7H_8 + 8NO_3^- + 12H+ 4N_2 + 7CO_2 + 10H_2O$

A diagram of the biotrickling filter set-up is shown in Figure 1 and the removal efficiency (RE) of the system as a function of the toluene load, including the metabolites produced by the microorganisms, is depicted in Figure 2.

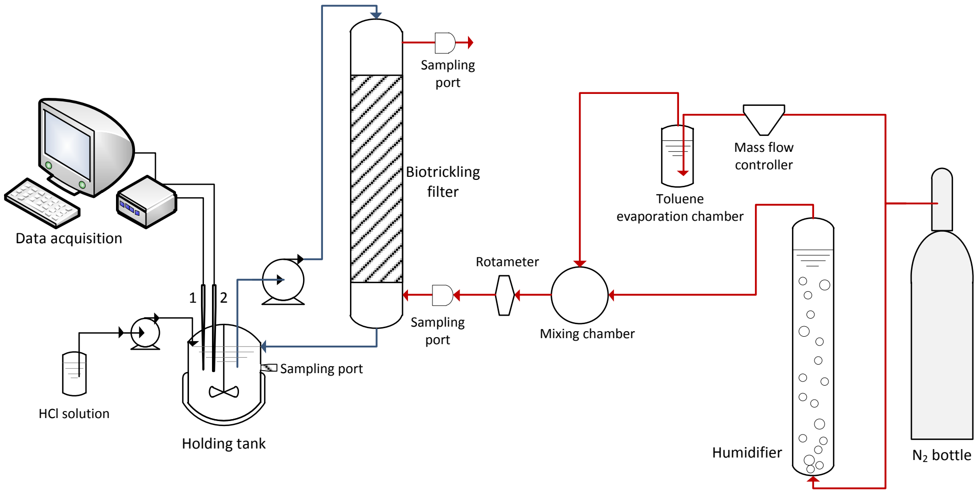

Figure 1. Schematic representation of the experimental set-up, where 1 and 2 are the pH and temperature probes, respectively.

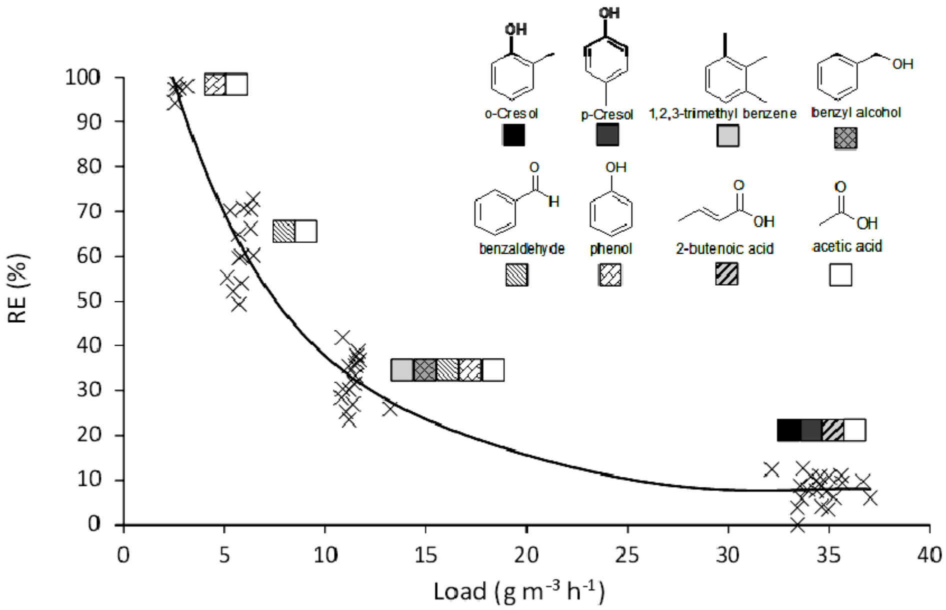

Figure 2. Metabolites produced and RE trend as a function of the toluene load.

Main conclusions and challenges

So far, a robust biological anoxic technology for the treatment of petrochemical VOC emissions was developed capable of achieving RE of 98%. However, research effort on mass transfer and microbiological aspects are still needed. The mass transfer of more realistic VOC mixtures and the design of specialized microbial consortia for the removal of such complex VOC mixtures are the main objectives pursued in our laboratory.

More information available at:

http://etuva.blogspot.com.es/

Relevant publications

López JC, Quijano G, Souza TSO, Estrada JM, Lebrero R, Muñoz R (in press) Biotechnologies for greenhouse gases (CH_4, N_2O, CO_2) abatement: state-of-the-art and challenges. Applied Microbiology and Biotechnology.

Bloch KP, Wurst DM (2010) Process safety management lessons learned from a petroleum refinery spent caustic tank explosion. Process Safety Progress 29:332-339.

Estrada JM, Rodriguez E, Quijano G, Muñoz R (2012) Influence of gaseous VOC concentration on the diversity and biodegradation performance of microbial communities. Bioprocess and Biosystems Engineering 35:1477-1488.

Phelps CD, Young LY (1999) Anaerobic biodegradation of BTEX and gasoline in various aquatic sediments. Biodegradation 10:15-25.

Raghoebarsing AA, Pol A, van de Pas-Schoonen KT, Smolders AJP, Ettwig KF, Rijpstra WIC, Schouten S, Damste JSS, Op den Camp HJM, Jetten MSM, Strous M (2006) A microbial consortium couples anaerobic methane oxidation to denitrification. Nature 440:918-921.

Shim H, Hwang B, Lee SS, Kong SH (2005) Kinetics of BTEX biodegradation by a coculture of *Pseudomonas putida* and *Pseudomonas fluorescens* under hypoxic conditions. Biodegradation 16:319-327.

Yanisko P, Zheng S, Dumoit J, Carlson B (2011) Nitrogen: a security blanket for the chemical industry. Chemical Engineering Progress, November: 50-55.