70f Biofiltration of Chlorinated Volatile Organic Compounds: Laboratory-Scale and Pilot-Scale Studies

Walter Den, Varadarajan Ravindran, and Massoud Pirbazari

The effects of co-metabolism and substrate inhibition among mixtures of volatile organic compounds (VOCs) in gas-phase biofiltration processes are important because most industrial emissions contain a variety of compounds. In this context, co-metabolism and substrate inhibition associated with chlorinated VOCs in biofilters have not been elucidated. Gaining insights into these aspects is significant in the optimization of biofilters for treatment of industrial emissions containing mixtures of both easily biodegradable and recalcitrant compounds.

The focus of this study is to evaluate the potential effects of co-metabolism and substrate inhibition in gas-phase biofilters treating VOCs, including two model chlorinated compounds commonly found in waste emission from microelectronic industry, namely trichloroethylene (TCE) and dichloromethane (DCM). The presence of chlorinated compounds among VOC mixtures creates a challenge to biofilter performance since biodegradation of these xenobiotic compounds requires pathways normally not associated with heterotrophic bacteria. Consequently, most chlorinated compounds of environmental concern exhibit recalcitrance and cannot serve as sole carbon and energy sources for heterotrophic bacteria under aerobic conditions. Nevertheless, these chlorinated compounds might be co-metabolized in the presence of a more easily biodegradable non-chlorinated hydrocarbon serving as the primary carbon and energy source. This research involves biofilter experiments for treatment of synthetic VOC mixtures containing DCM and methanol, as well as TCE, toluene and acetone. The study includes pilot-scale investigations for the biofiltration of chlorinated VOCs emitted from a semiconductor manufacturing facility in Taiwan. These laboratory-scale and pilot-scale scale investigations were employed to investigate the potential stimulatory (co-metabolism) or antagonistic (inhibition) effects in the presence of co-substrate(s) to the removal of the target contaminants.

Laboratory-scale biofiltration studies were conducted for treating a mixture of DCM and methanol vapors under different operating conditions. These studies showed that DCM was removed equally well with or without methanol, indicating that neither co-metabolism nor inhibition was a significant factor in biodegradation of DCM with methanol as co-substrate. The biofilter packed with activated carbon (adsorbing medium) and inoculated with acclimatized mixed consortium achieved significantly higher DCM removal efficiency and mineralization rate than that packed with anthracite (non-adsorbing medium). A pilot-scale biofiltration study was conducted for treating emissions from a semiconductor facility contaminated with TCE, acetone and toluene. These investigations showed that that the biofilter packed with activated carbon and inoculated with acclimatized mixed cultures was capable of achieving TCE removal efficiencies of 60% to 80%. It was observed that the presence of toluene in the gas stream promoted co-metabolism to enhance TCE biodegradation, a result confirmed in bench-scale biofilter feasibility studies using the similar microbial culture for TCE degradation. However, the pilot-scale studies demonstrated that the presence of acetone suppressed the removals of both TCE and toluene in the biofilter, attributable to competitive inhibition. In essence, the study highlighted the effects of co-metabolism and substrate inhibition in the biofiltration of chlorinated VOCs with non-chlorinated hydrocarbons. The presentation will include biodegradation mechanisms for DCM and TCE with reference to co-metabolism and substrate inhibition.