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3E3) A Treatability Study of Low Concentration of VOCs using A New Biotrickling Filter

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1. Introduction

Industrial finishers have taken the necessary steps to reduce or control emissions of volatile organic compounds (VOCs) from their plants because the surface coating industry is facing increasingly stringent regulations on VOC emissions. In addition, based on the general data of VOC volume and mass emission rates(1), the estimated daily average emission concentrations are in the range between 0.0137 and 0.0093 g/m^3 which are quite low for the biotreatment. These low concentration levels guide the necessary and proper biodegradation mechanisms to be studied.

Although a variety of the emission control system are currently available in the market, biological reduction of the paint VOC emissions is an emerging technology (Kinney et al., 2002; Webster et al., 2002)which is becoming more popular amongst industries facing increasingly stringent environmental regulation (Leson and Winer, 1991; Devinny et al., 1999). Also most of VOCs are microbially metabolized and the degradation pathway have been verified (BBD, University of Minnesota, 2002).

The full-scale biotrickling filter appears to be the most cost effective reactor. Treatment in the airlift reactor was estimated to be twice as expensive and catalytic oxidation 5 times as expensive (Zuber et al., 1997). Therefore, biological waste air treatment offers economical alternatives to conventional techniques for waste air treatment. Biological treatment of contaminated air, in particular in biofilters has become in many instances the method of choice for the control of low concentrations of odors, volatile organic compounds, or hazardous air pollutants (HAP) in large air streams.

The most widely used bioreactors for air pollution control are biofilters and biotrickling filters (Leson and Winer, 1991; Devinny et al., 1999). While biofilters have been widely implemented at the industrial scale, biotrickling filtration is still in development. Biotrickling filters have shown in several instances to be superior to biofilters (Mpanias and Baltzis, 1998; Fortin and Deshusses, 1999). Biotrickling filters are potentionally well suited for the treatment of low concentrations of VOCs such as Benzene, Toluene, Methyl Ethyl Ketone, or chlorinated hydrocarbons including Methylchloride and Vinyl Chloride, because the existence of the free water phase allows controlling the pH and leaching the chloride ions formed during biodegradation of these compounds (Revah et al., 1995; Mpanias and Baltzis, 1998; Zuber et al., 1997). The current limitations and the potential performance of the proposed new biological reactors for air pollution control are discussed as follows.

The performance of vapor-phase bioreactors is usually expressed as the elimination capacity (EC) or removal efficiency (RE) defined in Equations 1 and 2, as a function of the inlet and outlet gas concentrations (Cg,in, Cg,out), the air flow rate (Q) and the bed volume (V). The elimination capacity represents the amount of pollutant degraded per unit of reactor bed volume and time; it is often reported as a function of the pollutant loading L (Equation 3). A typical elimination capacity

vs. load characteristic for a vapor-phase bioreactor is shown in Figure 1.

$$EC = \frac{(Cg, in - Cg, out)Q}{V} \quad (1), \quad RE = \frac{(C_{g,in} - C_{g,out})100}{C_{g,in}} \quad (2), \quad L = \frac{C_{g,in}\,Q}{V} \quad (3)$$

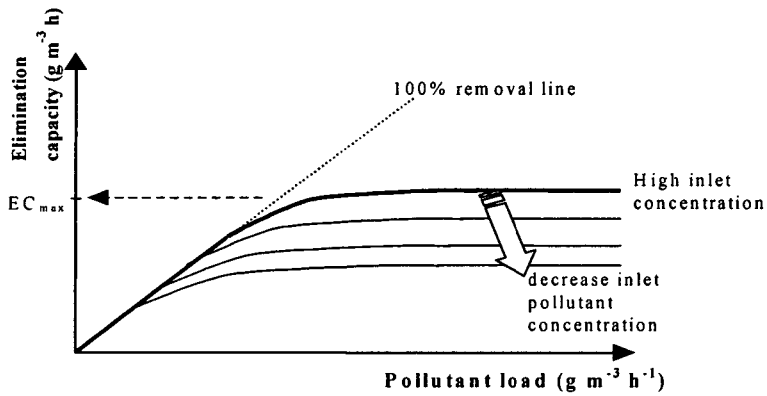

Fig. 1. A typical elimination capacity vs. load characteristic for a vapor-phase bioreactor

Since one of the principal factors controlling biodegradation processes is biodegradability, research which examines the biodegradability of contaminants in waste matrices, the potential for toxic effects of various intermediate metabolites during biodegradation of wastes, and interactions between waste chemicals and organisms in their environment is urgently needed. The emphasis in this research project should be on the biodegradability of contaminants and the behavior of mixtures of chemicals. Laboratory studies must eventually demonstrate applicability to field studies.

In fact, biofilter performance is limited because biodegradation is mediated by essentially resting organisms. The process culture probably uses the pollutant essentially for maintenance purposes as discussed by Cherry and Thompson (1997).

Under these circumstances, it is not surprising to find that bioreactors such as biotrickling filters or bioscrubbers relying partially on cell growth are more effective and achieve higher specific biodegradation rates (Zuber et al., 1997; Kirchner et al., 1989; VDI, 1996; DeHollander et al., 1998; Kozliak et al., 2000).

2. Experiment and Results

Activated sludges can be introduced into the biotrickling filter from the separated system under control of the sludge retention time and keep the microorganism population in the reactor. The biomass activity can also be controlled by retention time. In this study, the performance was investigated at three different levels of the sludge retention time with continuous supply of activated sludge. Analyses of the gas phase and the liquid purge and determination of the biomass accumulation rate allowed the calculation of carbon mass balances and the determination of the influence of biomass age on reactor performance.

A hybrid system composed of a biotrickling filter and an activated sludge was investigated under conditions of three differnt sludge retention times, and thus performances of the hybrid reactor were considered to be directly comparable. A detailed description of the equipment as well as operational conditions has been given in Table 1 and Figure 2. Activated sludge was recirculated from a reactor of activated sludge over the filter bed at a superficial velocity of

7.9 m/h and fresh mineral medium and phosphate buffer was continuously supplied to the activated sludge reactor at a rate (of 273 mL/h) according to the set sludge retention times. Paint VOCs was supplied to air stream at concentration of 1 and 2 g/m^3 by a metering pump.

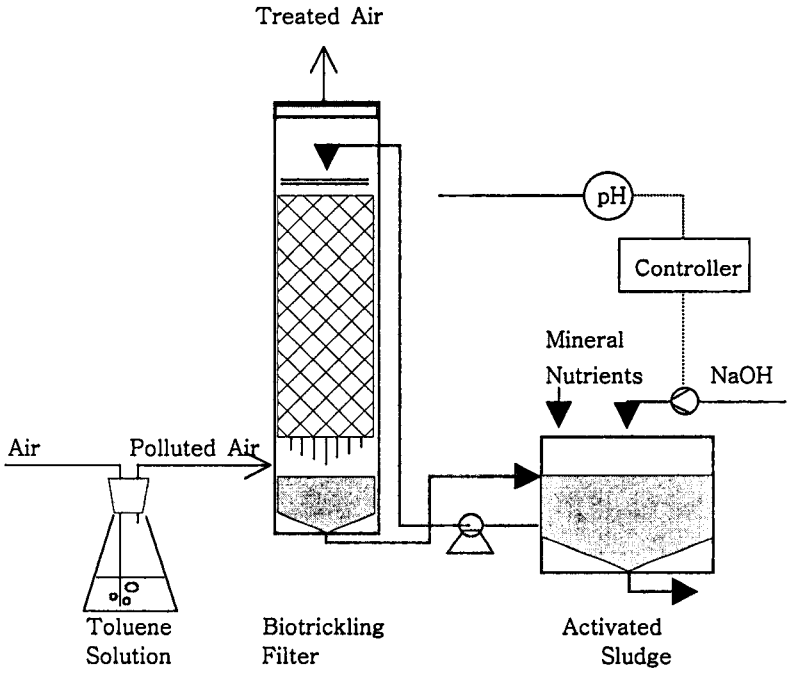

Fig. 2. Schematic of the experimental set-up of the hybride process of biotrickling filter and activated sludge.