폐가스 처리를 위한 바이오필터 모델링

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Boifilter modeling for waste air treatment

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INTRODUCTION

Some of the previous works involving biofilter modeling describe the steady states or can be applied to a narrow range of operating conditions. Others describe the transient performance of a biofilter with more complicated model parameters than those for steady states.

In this paper various models of a biofilter that have been worked on by previous investigators are classified in accordance with their model-components and are discussed on their inherent characteristics including mathematical interpretation and applicability that result from their respectively differentiated classification of methods in biofilter modeling. Subsequently inherent characteristics among various models are compared and evaluated in order to propose which one shall be the best model that has easy and trustable applicability with relatively small number of model parameters.

HIERARCHY OF MODELS

1) Ottengraf

Ottengraf (1986) and Ottengraf *et al.* (1986) made the following assumptions in developing a theoretical model describing the elimination of carbon sources in the filter bed.

1) The mass transfer resistance in the gas-phase is negligible, compared to that in the liquid phase.
2) The biofilm thickness (*l*) is much smaller than the diameter of packing particles (*i.e.*, medium) so that the biofilm may be treated as a planar surface.
3) Substrate transport through the biofilm is made by diffusion.
4) No limitation occurs except for the substrate.
5) The interface between gas phase and liquid phase is in the equilibrium.
6) The Michaelis-Menten kinetics or relationship of Monod is assumed for substrate utilization in the biofilter.

7) The net growth of biomass in the biofilm is controlled to be "zero" so that one may apply constant kinetic constants.
8) The biomass is uniformly distributed in the biofilter.
9) The biofilter is treated as a plug flow reactor.

The steady-state concentration profile of the pollutants in the biolayer (Eq. 1) was derived and the treated outlet concentration of waste gas streams through a biofilter was analytically solved. (Eq. 2) Thus two mass balances over biofilm and gas phase are described in their model as bellows.

$$D\frac{d^2C_l}{dx^2} - r_A = 0 \quad \text{(Biofilm)} \quad \text{(Eq. 1)}$$

$$-u\frac{dC_g}{dh} = Na \quad \text{(Gas phase)} \qquad \text{(Eq. 2)}$$

2) Lim(1, 2, 3)

In Lim's works (Lim(1), 1999; Lim(2, 3), 2001) the effect of adsorption property of the medium on the biofilter capacity of eliminating organic components in waste gas streams is theoretically discussed and is included in a biofilter model. Considering the effect of adsorption capacity of the medium, on the biofilter capacity of eliminating organic components in waste gas streams, the general steady-state solutions in the situations of reaction limiting as well as diffusion limiting are derived for the case of excess adsorption capacity and is compared with the steady-state solutions of Ottengraf (1986) and Ottengraf *et al.* (1986) where the medium is saturated with pollutants and is lost its ability to adsorb them. (Lim(1)(1999), Lim(2)(2001))

In formulating the model for a biofilter the following assumptions are added to those by Ottengraf (1986) and Ottengraf *et al.* (1986):

1) No catalytic reaction except for adsorption and desorption on the surface of the medium (*i.e.*, beneath the biofilm) exists upon the adsorption of the organic particles.
2) The dissolved organic particles are assumed to adsorb on the surface of the medium irreversibly and the number of vacant adsorption sites of the medium is assumed to be in excess so that the rate of adsorption may not be limited by the number of vacant adsorption sites.

However in most cases vacant adsorption sites become occupied and the rate of adsorption is limited as the adsorption continuously proceeds. Thus the transient behaviour of the biofilter is controlled by adsorption (Hodge and Devinny, 1994, 1995) or` sorption with negligible adsorption (Deshusses *et al.*, 1995). The former was recently modeled by Lim (Lim(3), 2001) so that the unsteady state-governing equations for mass balance are solved analytically in order to be easily interpreted and to be applied to the industrial unsteady state-operations of a biofilter. Among the additional assumptions made for the case of excess adsorption capacity assumption 2 should be replaced by “2) The dissolved organic particles are assumed to adsorb on the surface of the medium reversibly and the rate of adsorption is limited by the number of remaining vacant adsorption sites.”

RESULTS AND DISCUSSION

In Lim’s model general steady-state solutions in various limiting situations are derived analytically for the case of excess adsorption capacity and compared with those of Ottengraf (1986) and Ottengraf *et al.* (1986) as one of their special operating conditions. (Lim(1), 1999; Lim(2), 2001) Thus, as a special case, when the value of α that indicates the ratio of adsorption constant and effective diffusivity multiplied by interfacial surface area per unit volume, becomes zero the boundary condition of Lim’s model reduces into that of Ottengraf (1986) and Ottengraf *et al.* (1986) so that the media lose the adsorption ability. In spite of its simplicity Lim’s model predictions (Fig. 2) are more comparable to Hodge and Devinny’s (1995) experimental data than their predictions. (not shown)

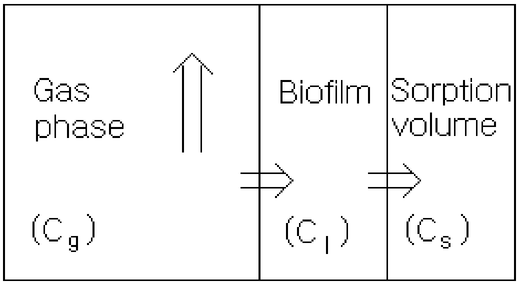

Fig. 1 Schematic diagram of a biofilter-model where a biofilm is treated as a planar surface

CONCLUSION

The model of Lim may be applied to unsteady-state operations of a biofilter with the possible minimum number of model parameters and with the required time scale that industry calls for. Since his model does not require a numerical solution but an algebraic solution to describe the concentration of organic pollutants in waste-air-streams along the height of a biofilter even under unsteady-state conditions, it satisfies the condition of simplicity that is one of the important model requirements. In spite of its simplicity Lim’s model predictions are quite excellent to fit Hodge and Devinny’s experimental data.

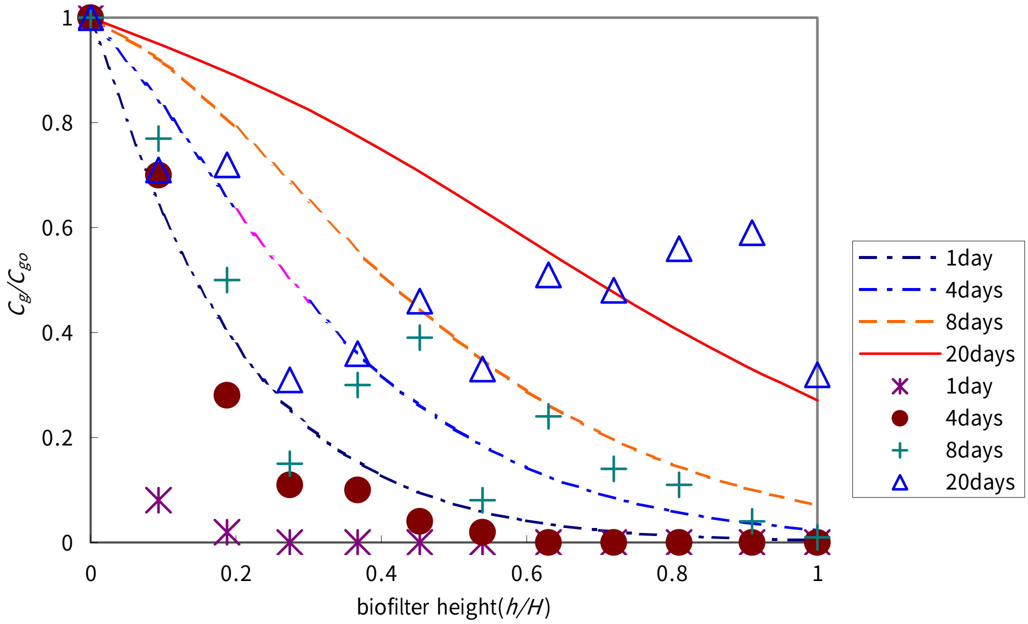

Fig. 2 Model predictions of the distribution of C_g/C_{go} along the height of a biofilter at various given experimental times

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