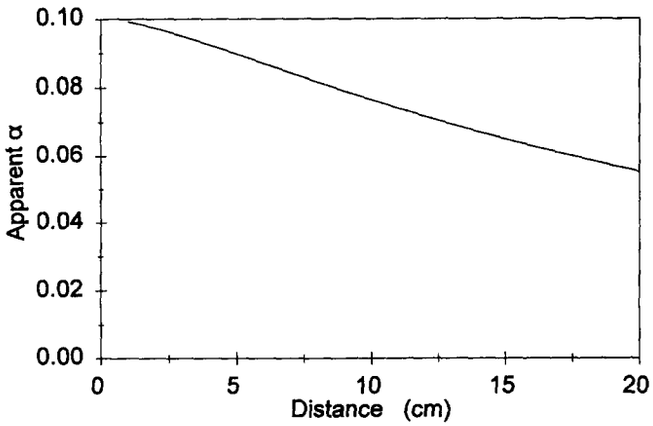

FIG. 4. Apparent Sticking Coefficient as a Function of Travel Distance in a 20-cm-long Column (Assumes $D = 10^{-1}$ cm^2 s^{-1} and Parameters Used in Fig. 3)

since α is the only adjustable parameter in the filtration equation. The sticking coefficient is included in filter coefficient, λ, defined as

$$\lambda = \frac{3(1 - \theta)\alpha\eta}{2d_c} \tag{33}$$

where η is calculated using the RT model ($\eta = 0.0168$ for these column conditions). For plug flow conditions ($D = 0$), the breakthrough fraction is $C/C_o = 0.065$ and increases in proportion to chemical dispersion. For $D < 10^{-4}$ cm^2 s^{-1}, the error in α is <0.12%. A $D = 10^{-2}$ cm^2 s^{-1} would produce $C/C_o = 0.072$ resulting in an error in α of 9.7%.

While dispersion could play a more important role in transport over longer distances than those used in laboratory columns, if colloids are to be transported over appreciable distances they must have extremely low sticking coefficients, on the order of $<10^{-3}$ (Gross and Logan 1995). Under these conditions the removal rates will be low enough to achieve large transport distances (that is, not all the particles will be removed, or "reacted away," before they can be transported). Lower sticking coefficients will result in a decrease in λ and β, producing no appreciable impact of dispersion on transport.

The type of dispersion modeled by this dispersion-advection transport equation should not be confused with other types of dispersion that arise from different mechanisms. For example, slow desorption of colloids from surfaces can result in delayed breakthrough times and particle dispersion, but a desorption term is not included in (23). Desorption produces a different type of dispersion than that described by (23). Desorption spreads out the plume by delaying breakthrough, but it does not result in faster forward longitudinal dispersion or allow particles to undergo less reaction during their transport through the column.

The subject of particle dispersion in packed beds is quite important and may still be more of a factor in bacterial transport than implied by calculations using (23). For example, bacterial transport through porous media can result in sticking coefficients that vary with transport distances (Albinger et al. 1994; Martin et al. 1996). Heterogeneity in bacterial (even within a monoclonal population) or collector surfaces can explain some of these observations (Albinger et al. 1994; Johnson et al. 1995) but so can dispersion. If dispersion coefficients are on the order of 10^{-1} cm^2 s^{-1}, particle sticking coefficients calculated with a plug flow assumption could make it appear as if α had decreased when, in actuality, it would be dispersion that was producing this apparent decrease in α (Fig. 4). These calculations and observations indicate that particle dispersion in porous media, particularly dispersion produced by particles that undergo many unsuccessful collisions and reversible adsorption, needs to be more fully investigated in order to mathematically describe colloid transport in porous media.

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VOCs IN FIXED FILM PROCESS. II: MODEL STUDIES[a]

Discussion by Reza Iranpour,[4] Member, ASCE

The authors present in this paper an analysis of data obtained with the equipment used in the companion (Parker et al. 1996) paper 1, performing a nonlinear regression to estimate K_v and K_b, the constants for volatilization and biodegradation, respectively. The quality of the data analysis makes this paper less successful than the first part. The authors acknowledge that, "the standard errors associated with the values of K_b and K_v for the trickling filter were equivalent to the estimated values," but proceed as if the uncertainties were much smaller, concluding, for example, that estimates for K_b for bromoform of 8.1 and 0.6 in experiments 1 and 5 are significantly different from each other. However, these values have standard errors of 15.7 and 10.4, respectively, so that according to conventional statistical theory neither is significantly different from 0.0 and the difference between them is not significant.

Since many of the rate coefficients derived from the trickling filter data are not significantly different from 0.0 in experiments 1 and 5, according to the standard error estimates, the standard errors are more favorable in experiments 2–4,

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experiments 1 and 5 must have produced raw data with very high scatter. Further consideration of these differences might have been more informative than dismissing the entire subject with a remark about the effect of correlation between K_v and K_b.

These concerns about the quality of parameter estimation for mathematical models of the fates of volatile organic compounds (VOCs) are prompted in part by current efforts to use such models for planning wastewater treatment plant operation and modification, despite the frequently poor accuracy of the outputs these models (ASCE 1995; Melcker et al. 1994; Monteith et al. 1995). For example, figures from Melcer et al. (1994) [reproduced as Fig. 2 in Straub (1995)] show that the TOXCHEM model predicted concentrations of 1,1,1 trichloroethane and 1,4 dichlorobenzene in the range of 0.5–1 ug/L, under conditions where the actual concentrations of these VOCs in the effluent from a treatment plant were in the 1–3 ug/L range, and varied much more than the prediction. As the TOXCHEM model is the work of the authors of this paper, it may be presumed to include methods similar to those discussed here, and hence doubtful features of the work in this paper may help clarify the discrepancies observed in Melcer et al. (1994).

It is clear that a high degree of accuracy cannot be expected, because of the inherent uncertainties of the subject. A model parameter like biofilm thickness is merely an average of variations over many square meters of surface, and small errors in estimating some of these parameters are magnified in the final result. Moreover, it is possible that some of the variability is attributable to features of the system that are not considered in the model, such as the effect on biodegradation of oxygen availability and other substrates. However, extensive tests like those reported in this paper are necessary steps toward the development of models with predictive power adequate to the ambitions of wastewater engineers.

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Closure by Wayne J. Parker,[5] Hugh D. Monteith,[6] and Henryk Melcer[7]

The considerable uncertainty associated with the parameter estimates is regrettable. However, whenever one is conducting research on the technical scale it is difficult to eliminate variability in the data. It should be noted that this is the first known study that has attempted to estimate biodegradation and mass transfer rate coefficients for VOCs in large-scale fixed film wastewater treatment processes. However, it is believed that the statistical techniques that were employed to analyze the data were appropriate and that the conclusions drawn from the analysis were not excessive.

Comparisons of the techniques used in this study to those of Melcer (1994) are irrelevant to this paper since different models were employed and the studies were unconnected. It is unfortunate that the discussors have referenced an internal document (Straub 1995) to support their arguments since this is not readily available to the writers or the general public.

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