LETTERS TO THE EDITOR

TO THE EDITOR

The recent paper by Hales, Wolf, and Dana (1973) concerning the calculation of the amount of gaseous pollutants washed out by precipitation falling through a plume is very interesting. However, it appears that some guidelines are needed to indicate which equation should be used at a given downwind distance from the emission source to calculate the concentration of the pollutant gas in the rain drop at ground level, $C(a, 0)$; that is, either the exact form of the equation [Equation (11)] or the asymptotic form [Equation (14)]. It appears from our calculations that the exact form of the equation provides good results near the emission source (up to a few kilometers downwind). When the downwind distance exceeds a few kilometers, the co-error function in the exact form rapidly approaches zero causing calculation difficulties. The asymptotic approximation is useful for moderate downwind distances but provides unrealistic results with small downwind distances of less than approximately one kilometer.

LITERATURE CITED

Hales, J. M., M. A. Wolf, and M. T. Dana, "A Linear Model for Predicting the Washout of Pollutant Gases from Industrial Plumes," *AIChE J.*, 19, 292 (1973).

Timothy V. Larson
and Michael J. Pilat
Department of Civil Engineering
University of Washington
Seattle, Washington 98195

REPLY

The comments by Larson and Pilat point out an aspect of our derivation which we encountered but did not discuss explicitly in our paper. During early computations using our Equation (11) we encountered the same difficulties that they mention and this led us to derive the asymptotic expression (14) which approaches (11) under conditions where the noted computational problems occur.

The practical inadequacy of Equation (11) arises whenever the error-function arguments

$$(-\sigma_z^2\zeta - h)/(\sigma_z\sqrt{2})$$

and

$$(-\sigma_z^2\zeta + h)/(\sigma_z\sqrt{2})$$

become large. This behavior can occur under a variety of physical circumstances but tends to become more pronounced at greater downwind distances from the source (as noted by Larson and Pilat), owing to the increase with distance of the vertical plume-spread parameter σ_z.

So far as a criterion for when to shift from Equation (11) to Equation (14) is concerned, we suggest the use of (14) whenever

$$\frac{-\sigma_z^2\zeta - h}{\sigma_z\sqrt{2}} > 3 \qquad (1)$$

The truncation-error term in Equation (14) indicates that this should result in a fractional error conservatively estimated at $(3)^{-4}$, which is well within any practical limits for use of the equations. Furthermore, typical error-function estimation routines provide none of the observed problems when arguments are below 3.

An additional aspect of the problem is caused by the two error-function arguments, with the possibility of the one involving $+h$ becoming much larger than the one involving $-h$ under appropriate circumstances. This does not lead to computational difficulties with Equation (11), however, since the term containing the $+h$ becomes negligibly small compared to its $-h$ counterpart under such conditions.

We appreciate the constructive comments by Mr. Larson and Professor Pilat and hope that this reply will enable more practical utilization of our work.

Jeremy M. Hales
Marvin A. Wolf
and M. Terry Dana
Battelle, Pacific Northwest
Laboratories
Richland, Washington 99352

TO THE EDITOR: DIFFUSION IN HIGH VISCOSITY LIQUIDS

The recent paper by Hiss and Cussler (1973) on diffusion in high viscosity liquids is related in several ways to some work I published last year on the same subject (Lusis, 1972). In particular, I found that for diffusion in viscous liquids where no molecular complexes are formed due to hydrogen bonding, the diffusivity is approximately inversely proportional to the solvent viscosity raised to the 0.6 power (compare with the 2/3 value proposed by Hiss and Cussler). Furthermore, an analysis of the available experimental data showed that if the Le Bas molar volume of the solute is greater than about 80 cc/g mole, then the diffusivity can be estimated, with an error usually less than 30%, from the very simple equation

$$D = 7.5 \times 10^{-14}\left(\frac{T}{\mu^{0.6}}\right) \qquad (1)$$

where D is in m^2s^{-1}, μ in kg $m^{-1}s^{-1}$, and T in °K. Since Equation (1) can be applied to the experimental data of Hiss and Cussler, it is interesting to make a comparison of the predicted and observed diffusivities for hexane and naphthalene in various viscous solvents. This has been done in Table 1. As can be seen from this table, the predicted and observed values usually agree to within 30 or 40%. This agreement is quite satisfactory considering the extreme simplicity of Equation (1) and the fact that for many highly viscous liquid mixtures no other method presently exists for estimating the diffusivity.

LITERATURE CITED

Hiss, T. G., and E. L. Cussler, "Diffusion in High Viscosity Liquids," *AIChE J.*, 19, 698 (1973).

Lusis, M. A., "Predicting Diffusivities in Viscous Liquids," *Chem. Ind. Developments* (Bombay), 48 (Jan. 1972).

M. A. Lusis
Department of Chemical
Engineering
University of Toronto
Toronto 5, Canada

Table 1. Comparison of Predicted and Observed Diffusivities

Solvent, see Hiss and Cussler (1973)	$\mu \times 10^3$ (kg m^{-1} s^{-1})	$D \times 10^{10}$ (m^2 s^{-1}) at 25°C Predicted, Equation (1)	Observed Hexane solute	Observed Naphthalene solute
Trimethylpentane	0.484	22	26.0	24.0
S-3	3.09	7.2	6.67	5.23
S-6	7.66	4.2	3.32	3.20
S-20	29.4	1.9	1.54	1.25
S-200	394	0.39	0.334	0.233
S-2000	5,198	0.083	0.0518	0.0361