Letters to the Editors

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Comment on mean residence time in flow systems

(Received 1 November 1983)

Dear Sirs,

Recently, Awasthi and Vasudeva [1] purported to show that the measured mean residence time for a flow system, $\bar{t}$, is not always equal to the quotient of the system's volume and the flow rate, V/Q. While the possibility that $\bar{t} < V/Q$ when the system has a stagnant (or "dead") zone has been extensively discussed in the literature, both physically and theoretically (see e.g. Levenspiel [2] and Rubinovitch and Mann [3]), the authors' suggestion that $\bar{t} > V/Q$ is new and is in contrast to a well-accepted result. Such a claim requires either a contrary theoretical argument or contrary experimental results. The latter must be obtained in exceptionally well-performed and controlled experiments to assure their reliability. The authors do not provide any theoretical argument for their surprising result but rather base their conclusions on results which were obtained using questionable experimental and computational procedures.

A necessary, though not sufficient, control on residence time experiments is confirmation that the material balance is satisfied. That is, that the amount of tracer in the effluent stream is identical to the amount of tracer injected, M. This is expressed by

$$M = Q \int_0^\infty c(t)\,dt.$$

It has been shown that even very slight discrepancies in the material balance can cause serious error in the measured values of $\bar{t}$ [4]. Unfortunately, the authors did not perform this test to assess the accuracy of their experimental and computational procedures.

Besides this major deficiency, there are several errors and questionable steps in the sample calculations given in the appendix. These also raise doubts about the validity of the results.

(1) The summations Σc and Σtc do not approximate the integrations $\int c\,dt$ and $\int tc\,dt$, respectively, unless the summations are multiplied by Δt. The inclusion of Δt is not important when the ratio of the two sums is used to calculate $\bar{t}$, but it is essential when the integrations of the tail of the tracer response curves is calculated by an analytical integral. The value of $\bar{t}$ in the appendix is incorrect since it was obtained by summing two incommensurable terms. The sum-terms should be multiplied by $\Delta t = 0.25$ min.

(2) The constant W in the exponential function, that was used to approximate the tail was calculated from two adjacent time points, reported to at most two significant figures. This is imprecise. In addition, the value of W given ($W = 0.1178$) does not follow from the numbers shown, which give $W = 0.5341$.

(3) The integral expression on the top of the right column on p. 319 is incorrect; the term $\exp(-Wt_1)$ multiplying the bracket should not appear there if the integration is performed correctly. Unfortunately, this term was used in calculating $\bar{t}$. The authors state that the tails contributed at most 5% to the integrations, but this will be up to 20% when the summations are reduced by a factor of 0.25.

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