EDITORIAL

REVISITING SIGNIFICANT FIGURES

We all know that the quantities of 40, 40.0, and 40.00 are the same, but their meanings are different. Unfortunately, for a variety of reasons, some engineers and scientists often neglect the significance of significant figures. Glancing over the papers published in this journal last year (1996), one sees a flow rate of 5.431 m^3/s, carbonaceous biochemical oxygen demand (CBOD) of 20.36 mg/L, water content of 55.87%, a residual sum of squares of 1.422, an exponential coefficient of 0.08647, powdered activated carbon (PAC) cost of $6.30/kg, chemical cost of $2,293.94/yr, a recycling rate of 22.20%, a boiling point of 87.20°C, an acetic acid removal rate of 0.1964 mg/min per g granular activated carbon (GAC), total organic carbon (TOC) of 0.158 mg/L, a PAC dosage of 2.070 mg/L, and a biochemical oxygen loading (BOD) loading of 40,638 lb/d. Should we use so many significant figures?

The answer is an emphatic "no." Reported numbers, which provide quantitative information about the subject areas, should not reflect more accurate and precise quantities than they actually are. These numbers are obtained from measurements (e.g., flow rate), analysis [e.g., chemical oxygen demand (COD)], calculation, literature data (e.g., diffusivity), current information (e.g., cost), model prediction, and statistical analysis, among others. Because of measurement errors, one cannot accurately measure the flow rate as precisely as 163.62 mL/min in the laboratory setting or a flow rate of 25.63 mgd in a wastewater plant, because of meter calibration and compounded recording and transmission errors. If the detection level of some parameter is 0.05 mg/L, the reported value of 0.058 mg/L does not reflect reality, especially considering the uncertainty of sample representation, procedures, and reagents used; calibration accuracy; and quantification level. For those of us in the wastewater field, the reported average BOD value of 145.67 mg/L is unrealistic. In the elemental analysis of a solid waste, the reported 36.65% of C composition is not justified, if the accuracy is only within 0.3%.

Those values determined from multiplication, division, addition, and subtraction cannot be more precise than the initial quantities. A case in point is a pollutant loading (lb/d) obtained by multiplying 25 mgd and a BOD concentration of 125 mg/L with a conversion factor of 8.34. The answer is neither 2,606 nor 2,610 lb/d; rather, it should be reported as 2,600 lb/d. After all, 8.34 is a round-off conversion number, and two significant figures in 25 mgd should prevail in the final answer. In the conversion to SI units for publication, the ASCE authors' guide clearly points out that converted quantities should not imply a degree of accuracy greater than that of the original value. By the same token, in empirical modeling and/or regression analysis, the precision of the predicted values of a dependent variable governs the significant figures of various coefficients used. Thus, it is unnecessary to use a coefficient value of 1.2587 for the prediction of influent BOD. In air quality monitoring, the detection level of coliform in air is 4 cfm/m^3, thus the use of so many significant figures in the regression equation of $28.5838 - 0.0308X$ is questionable. In statistical analysis, the significant figures of mean values reported should not be more (or less) than those of the standard deviation. Thus, the reported volatile solids content of $83.0 \pm 8.42\%$ is unwarranted. In risk analysis or empirical modeling, it is unnecessary to calculate the compound molecular weight based on the atomic weight of C = 12.01, especially considering the uncertainty of other parameters.

On the other hand, the thermal efficiency of some toxic compounds and disinfection efficiency of *Cryptosporidium* are often four to six orders of magnitude; thus the reported efficiences may be in the 99.99–99.9999% range. The density of sludge should be determined and reported to a more precise degree. For example, specific gravities of 1.02 and 1.01 would result in 100% difference in settling velocity calculations when one considers $(\rho_s - \rho)$; for comparison 1.015 and 1.011 only results in a 25% difference.

Inconsistent use of significant figures is a common problem in papers: within the same column of a table, from column to column in a table, and between text and tables. It is certainly possible that the numbers in text description have been rounded off. Nonetheless, consistency is essential.

It is time to report numbers as they reflect reality; no more, no less. Authors, reviewers, editors, and copy editors all should pay attention to these seemingly trivial, yet important, significant figures. Incidentally, why not use scientific notation for some large numbers (e.g., population) and small numbers (e.g., diffusivity)?

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