Reliability of Deterministic Models for Predicting Water Quality Impacts of Alterations in Pollutant Loads

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A deterministic environmental quality model is typically a series of differential equations that incorporate selected parameters, estimated or theoretical mathematical relationships, and measured, estimated, or presumed coefficients to describe the behavior of stressors and relationships among stressors, conditions, and environmental characteristics. A typical goal for their use is the quantification of how a particular modeled system, such as a waterbody, responds to changes in the stressor parameters considered, such as toxic chemicals. By necessity, the differential equations of the model often significantly over-simplify the behavior of, and relationships among, modeled parameters, and are ill-equipped to handle more subjective and relative aspects of water quality. Normally the differential equations and coefficients are calibrated, or "tuned," to an existing database for the system; that is, equations and coefficients are adjusted to cause the model output to match the existing database. Then, the reliability of the model is "evaluated" by examining how well the output of the tuned model matches a different, but typically similar, data set. If the agreement is deemed to be "reasonable," the model is said to be "reliable."

Deterministic models have been developed to relate the input of aquatic plant nutrients (nitrogen and phosphorus) to a waterbody and the resulting nutrient concentrations in the waterbody, and to the amount of planktonic algae as measured by planktonic algal chlorophyll. The tuned models are then used to predict how significant alterations in the driving-force loads, such nutrient loads, will impact planktonic algae biomass in the waterbody. Based on the output of these calculated results many million of dollars are spent by nutrient dischargers to implement nutrient control. Greater caution should be exercised in using such models in this manner, to recognize that the models may have limited predictive capability under altered load situations.

Too often, the impacts of the limitations of model design, evaluation, and application on model output/results, are not sufficiently recognized or incorporated into decision-making; it is far-more expedient to consider model output to be fact. One common and fundamental deficiency in deterministic water quality models is the nature and extent of monitoring of the impacts of altering the loads of the contaminant of concern that is incorporated into the model. Models that have been tuned to one set of data may have little or no applicability to another system, even one considered to be similar. Model evaluation or "verification" may not incorporate the nature or extent of the perturbation under consideration in the application of the model, leading to a false sense of applicability of the model. Without proper, independent verification, the true reliability and versatility of the model is not properly evaluated. It is sometimes claimed that these types of deficiencies are not of concern because the model output is being used for "screening" or "preliminary" assessments. While such reasoning may be acceptable if the modeling results were consistently conservative in their assessment, they are not; they are simply unreliable.

Furthermore, various types of management and priority decisions are, in fact, made as a result of screening or preliminary assessments. Having unreliable information is as bad as, or sometimes worse than, having no information at al.

Many “water quality models” fail to incorporate an assessment of the sensitivity of the modeling output to changes in input parameters. Modelers should include an error analysis and report the results when presenting the results of the modeling effort. All deterministic models should include information on how the results of the model depend on changes in model input parameters as well as changes in reaction coefficients.

A key component of any modeling should be follow-up monitoring after changes in input, or other alterations, have been made to the subject waterbody, to define the realized change in water quality characteristics that have resulted from the alteration. The results of the follow-up monitoring should then be used to provide true model evaluation, i.e., to document and quantify how well the model performed in predicting the impact of altering the input/loads on waterbody’s water quality, without additional fine-tuning to achieve a match to the data. Such information can and should be used to improve future modeling for that or similar situations. Any modeling effort that does not provide adequate funding and follow-up monitoring and model review should be considered deficient.