Metals and Aquatic Life: Counting the Trees and Not Seeing the Forest (Newsletter)*

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Dissolved metals such as copper, cadmium, and zinc can be toxic to aquatic life, particularly fish. The current tool used to estimate site-specific water quality criteria for a metal is the biotic ligand model (BLM). The BLM intends to quantify how water chemistry affects speciation and biological availability of metals in aquatic ecosystems. This is important because bioavailability and bioreactivity of metals control their potential for acute or chronic harm. A BLM incorporates aquatic chemistry, fish physiology, and ecotoxicology but not ecology.

The biotic ligand model includes numeric submodels that also require assumptions or estimates of missing values, rate constants, and coefficients that have not been measured in natural aquatic ecosystems or are so variable that an estimate is used in the model.

The toxicological values come from static (sometimes flow-through) survival assays in a laboratory. The limitation of laboratory bioassays is that contaminant exposures and resultant ecological impacts in natural environments are significantly more complicated. Natural ecosystems involve mixtures of exacerbating and mitigating chemical influences and complex physical, chemical and biological community structures. Extrapolation of laboratory-derived results to an actual water body is a significant source of uncertainty in predicting ecological effects of metal contamination.

There are several important assumptions inherent in the use of available versions of the BLM, including:

- The model considers only one metal and one organism at a time. No metal mixtures or multiple aquatic organisms can be modeled at the same time.

- The model considers only dissolved equilibria. It does not consider mineral precipitation or other interactions between dissolved and particulate phases (e.g., adsorption).

- The calculations assume that the system is at chemical equilibrium, i.e., kinetic reactions are not important.

- The equilibrium constants among a given metal, major cations, hydrogen ions, and biotic binding sites are the same for all organisms. The median lethal

activity values (LA50) do not change with solution composition or account for variations in the sensitivity of organisms to a given metal.

- The BLM is calibrated for only specific ranges of element concentrations.

While water quality criteria are supposed to be site specific, the definition of 'site' is not defined by the EPA. The proposed Oregon BLM implementation could define ecoregions or physiographic provinces as sites. Regulation on such a large scale is ineffective.

Thirty years ago numeric models were common in ecology and environmental science because not everyone had access to a computer, statistical software, or the knowledge to select appropriate statistical models and interpret results using established ecological theory. Today, robust statistical software for all environmental data are freely available and run on all computer platforms. Many of the statistical models most appropriate for environmental chemistry were developed by geochemical statisticians.

Clean Water Act Section 303(c)(2)(B) requires states to adopt water quality criteria for toxic pollutants that are listed in Section 307(a)(1) where the discharge or presence of these toxics could reasonably be expected to interfere with the designated uses adopted by the state. States must establish numeric values based on one of the following: (1) §304(a) guidance; (2) §304(a) guidance modified to reflect site-specific conditions; or (3) other scientifically defensible methods (40CFR §131.11(b)). In addition, states can establish narrative criteria where numeric criteria cannot be determined or to supplement numeric criteria.

Option 3 allows states to use technically sound and legally defensible statistical analysis of aquatic biotic communities (fish when present, benthic macroinvertebrates everywhere). By quantifying the range of inherent variability of community function (energy processing and nutrient cycling) changes likely caused by anthropogenic activities can be identified. Supplementing the numeric results with narrative criteria makes clear to everyone whether water quality standards for a specific designated beneficial use at a specific site have been impaired by human activities. With climate change occurring more rapidly than in past centuries, a decade-long drought continuing in the western US, and a desire to demonstrate sustainability it is critical that natural variability be distinguished from anthropogenic effects. Statistical analyses can do this objectively while BLMs cannot.

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