

Key factors affecting trace element uptake and toxicity in aquatic organisms

Peter G.C. Campbell

INRS Eau, Terre et Environnement, Université du Québec, 490 de la Couronne,

Québec, Canada G1K 9A9 (campbell@ete.inrs.ca)

In the area of trace metal nutrition and toxicology, much qualitative evidence exists to the effect that the total aqueous concentration of a metal is not a good predictor of its "bioavailability", i.e. that the metal's speciation will greatly affect its availability to (aquatic) organisms. Indeed, a convincing body of experimental evidence has accumulated to support the idea that the biological response elicited by a dissolved metal is usually a function of the free-metal ion concentration, $M^{Z+}(H_2O)_n$. It follows that the complexation of a metal with one or more ligands in solution should lead to a decrease in its bioavailability; this general principle underpins the so-called Free-Ion Model, as well as its more recent derivative, the Biotic Ligand Model (BLM). However, virtually all the experimental evidence in support of the BLM has been obtained in the laboratory in synthetic solutions in the presence of simple inorganic or organic ligands. Natural systems contain additional metal-binding ligands, notably natural dissolved organic matter (DOM), metastable reduced sulphur species (thiols, polysulphides, thiosulphate) and various low molecular weight metabolites. The extension of the BLM to such systems is currently hampered by our relative ignorance of how these diverse ligands affect metal bioavailability. Using silver and cadmium as representative non-essential metals, we have tested the applicability of the BLM in systems that contain some of these natural ligands and thus have a composition that is close to that of natural waters.

A number of key assumptions underlie the BLM, some obvious and others rather more subtle. The aim of this presentation is to examine some of these assumptions and explore the limits of the BLM. The following points will be considered in the platform presentation and in the subsequent workshop:

- Is metal internalization always slow relative to the other steps involved in metal uptake (i.e., is the organism surface in equilibrium with metal species in the exposure solution)?
- Does metal internalization necessarily occur via cation transport (or do other mechanisms exist for metal entry into cells)?

- Must internalization occur for toxicity to appear (or can surface-bound metal exert deleterious effects)?
- How do pH changes affect metal uptake and toxicity?
- How does natural organic matter affect metal uptake and toxicity?

Experiments with algae will be described, demonstrating anomalously high metal toxicity in the presence of common low molecular weight metabolites (citrate and alanine), or in the presence of an assimilable anion (thiosulphate). The demonstration that natural organic matter (DOM) tends to accumulate at biological surfaces, particularly at low pH values, raises a number of intriguing questions about the ambient chemical environment close to the cell surface - the consequences of this accumulation on metal-cell interactions will be discussed.

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