Spatially differentiated comparative toxicity potentials of metals in global coastal seawater

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Short Abstract:

The comparative toxicity potential (CTP) of a chemical, used in Life Cycle Assessment (LCA), represents an estimate of the potential ecotoxic impact caused by a unit emission of the chemical through environmental exposure. The fate of metals in the environment and the exposure to the toxic species of a metal is influenced by water residence time and metal speciation, governed by aquatic environmental conditions, in particular salinity, pH, and DOC concentration. This study developed CTPs for the metals Cadmium, Cobalt, Copper (II), Nickel, Lead and Zinc spatially explicit for 64 Large Marine Ecosystems (LMEs) - independent seas that together comprise the coastal seawater in the world. The waters of the LMEs show a large variation in residence time and temperature, but more modest variations in DOC, POC, SPM concentration, pH and salinity.

The CTP is the product of the Fate Factor (FF, representing the residence time of total metal in the seawater compartment), Bioavailability Factor (BF, the fraction of truly dissolved metal within total metal) and Effect Factor (EF, indicating the ecotoxicity of the truly dissolved metal). For each LME, the specific water chemistry was applied to derive two CTPs - one for direct emission to seawater ($CTP_{sw\text{-}sw}$) and one for emission to freshwater followed by transportation to seawater ($CTP_{fw\text{-}sw}$), incorporating metal removal in both freshwater and estuary. The multimedia fate model of USEtox, metal speciation model WHAM 7.0 and Free Ion Activity Model (FIAM) were used in the derivation of FF, BF and EF respectively.

Results showed a strong dependence on residence time, but also other coastal water parameters were of importance. Metals thus showed lower CTPs in LMEs with short water residence time and high organic matter concentration. In contrast, the highest CTPs were observed in LMEs with long water residence time and lower organic matter concentration. The metal ecotoxicity ranking given by the CTPs also differed between the LMEs. CTPs ranked Cd the highest in most LMEs. CTPs of each metal varied up to ca. 2-3 orders of magnitude across LMEs, mainly driven by differences in water residence time. The results indicate the relevance of taking emission location into consideration when assessing metal CTP in coastal seawater for LCA.