Metals in the ocean: an adapted LCA fate and exposure model

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Research motive:

remarkable phenomenon:
LCA toxicity characterization factors for metals tend to be extremely large.

cause:
very long environmental residence times of metals, especially in ocean compartment (where metals end up)

main research question:
Are these extreme characterization factors for metals justifiable?

fate model used: SimpleBox (Mackay type multimedia model, RIVM, The Netherlands)

Modelling aspects accounted for:

1. Multimedia fate modelling
riverine input: 90% or more of suspended matter load is deposited in or near estuaries

▹ *90% of adsorbed metals in rivers do not reach ocean water compartment*

2. Dimensions of oceanic environmental system
most important exposure zone: upper mixed layer (approx 100 m)

▹ *residence time in exposure zone much lower than in original upper 1000 m*

3. Fate within ocean compartment: sedimentation
- key process in metal removal from environmental system
- metal-specific residence times in upper mixed layer available with respect to
  - sedimentation
  - upward vertical mixing

▹ *much more precise estimates of residence times of metals in oceanic upper mixed layer*

4. Biological availability in saline waters
specific processes with respect to metals, especially in saline waters:
- non-ideal effects: activity
- speciation

non-ideal effects: activity:
caused by electrostatic forces between ions

▹ *concentrations in marine waters should be corrected into activities*

NB: not to be adapted if test organisms were marine: already accounted for if test medium was saline!

speciation:
metal ions, complexed by ligands, tend to be far less biological available: Free Ion Activity Model

▹ *biological availability of metals largely depends on relative proportion of free ions in sea water*

RELATIVE PROPORTION OF FREE IONS IN SEA WATER

metal	% free ions in sea water	% free ions in test medium
Cadmium	0.8	71
Chromium	0.0011	91
Copper	12	76
Lead	5	40
Mercury	7.90E-14	1.55E-2
Nickel	68	77
Zinc	0.9	80

Results:
Despite all adaptations in fate and exposure modelling, immense differences (around 4 orders of magnitude for aquatic ecotoxicity) remain to exist between characterization factors for metals and organics.

Conclusion:
The discrepancy between LCA characterization factors on the one hand and perceived harmfulness of metals in the ocean on the other may be caused not only by imperfections in fate and exposure modelling, but above all by choices, made in the eventual effect analysis. LCA effect modelling in general, and the fact that the assessment is based purely on induced environmental amounts, regardless of concentrations, seem to be good candidates for a next critical review.