LCA Metals Workshop

Integrating Emerging Metal Risk Assessment Technologies Into Life Cycle Impact Assessments

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Overview

- Issues Associated with LCIA
- Overview of LCIA
- Bringing in new science specific to metals

Issues On The Use Of Ecological And Health Data In LCAs

- LCA and Eco/health metrics are incompatible
- LCAs aggregate data in the LCIAs in ways that are incompatible with risk assessment
- Endpoint assessments and data expression are often different
- Assessing comparative risk is the big challenge

Issues On The Use Of Ecological And Health Data In LCAs

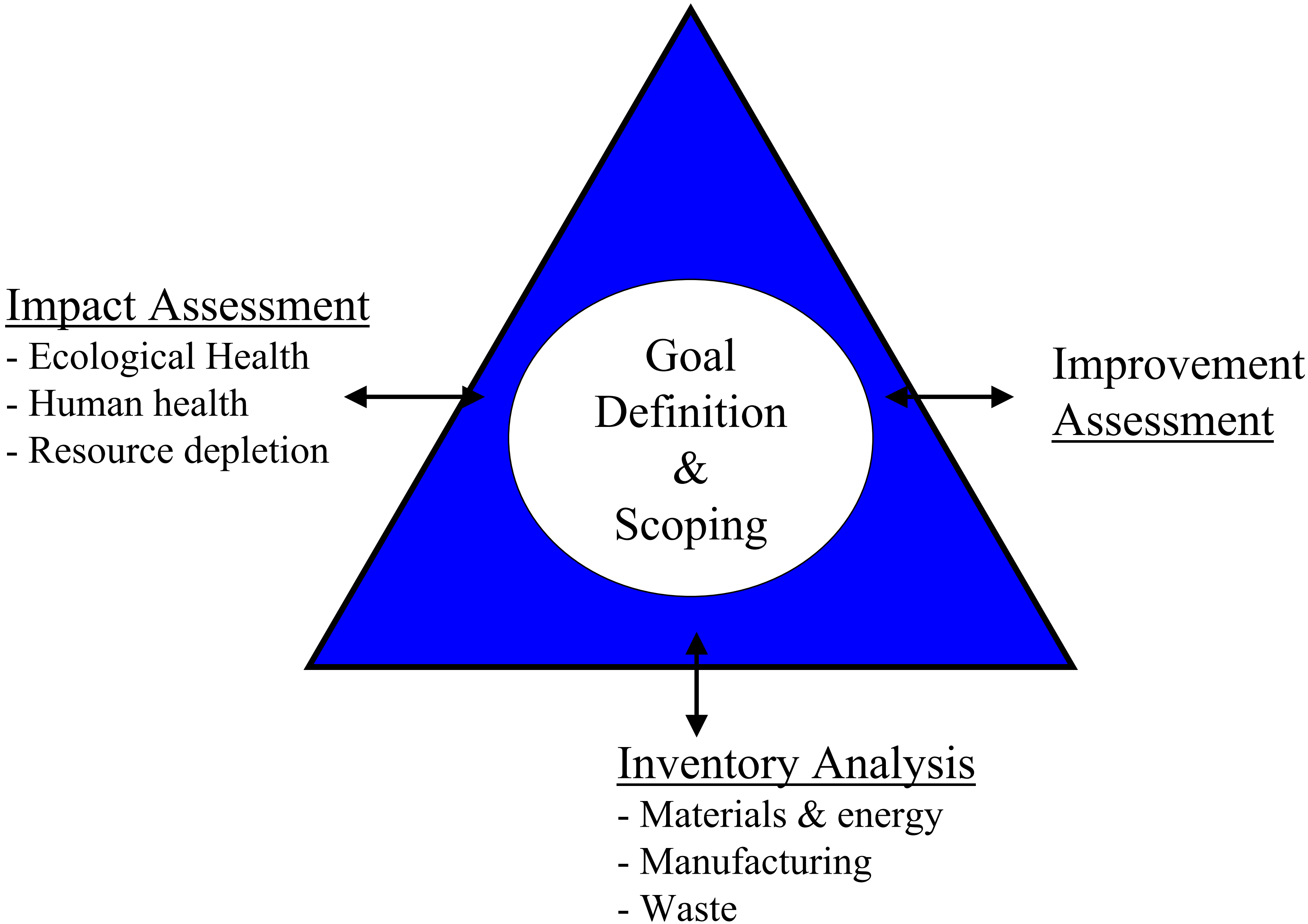
- Benefit assessment for essential trace elements (Cu, Zn, Se, Co) are not included in either risk assessments or LCAs
- Scoring systems frequently used in LCAs can misrepresent risks and benefits. Note - the risk process is one that evolved to avoid misrepresentation provided by "hazard" scoring.

Starting Point

"LCIAs are approximations and simplifications of aggregated loadings and resources used. Thus, in LCIA actual impacts are not measured, potential impacts are not predicted, risks are not estimated and there is no direct linkage to actual impacts."

Barnthouse et al 1998 (SETAC)

Life Cycle Assessment



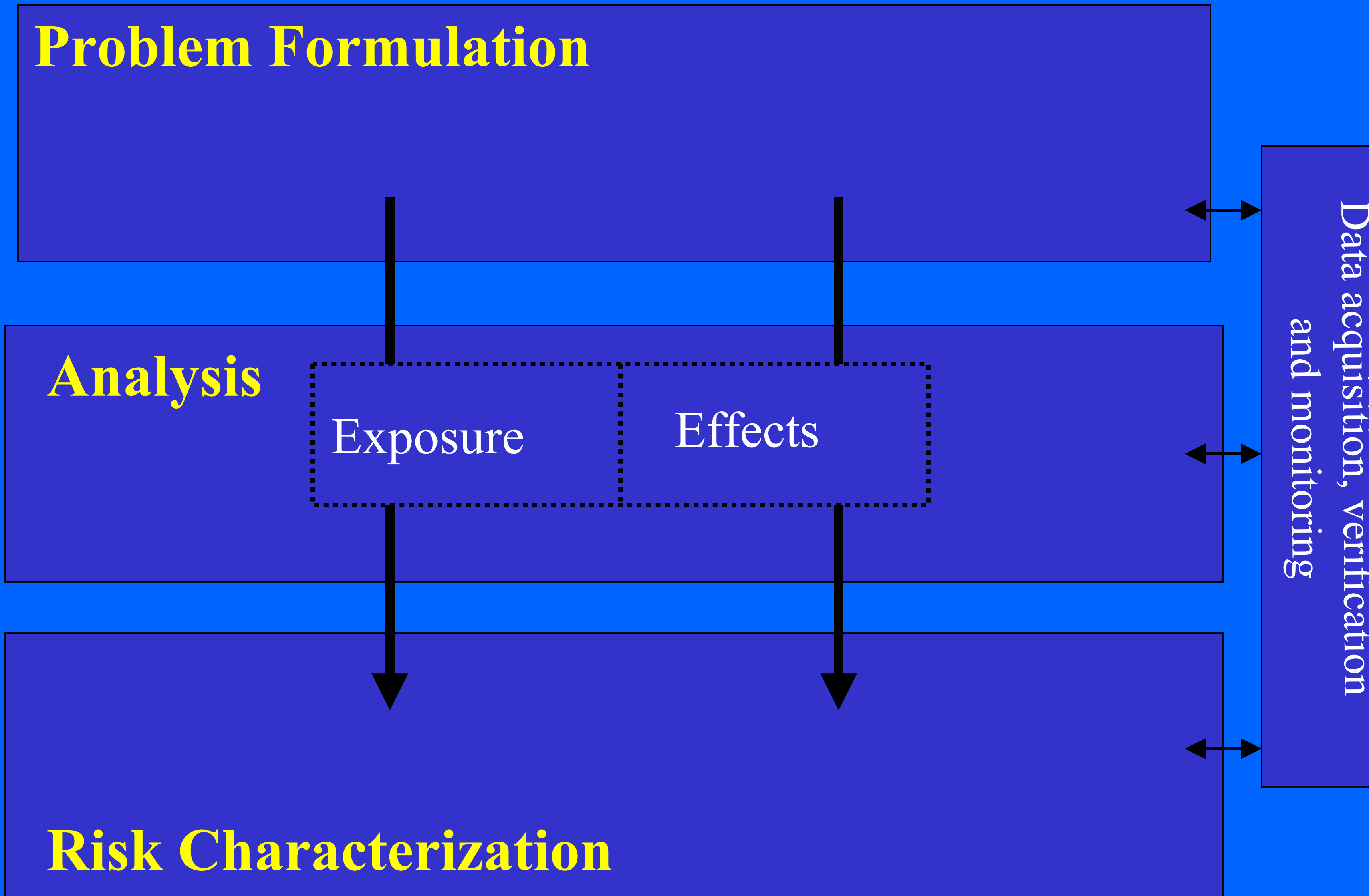
Major Obstacles Limiting Use of LCA

(UNEP/SETAC Life Cycle Initiative)

1. Lack of peer reviewed international databases for LCIs

2. Insufficient scientific knowledge from multidisciplinary fields into widely recognized LCIA methods

Ecological Risk Assessment Framework*



* USEPA Ecological Risk Assessment Framework (EPA, 1992)

LCA
Goal Definition / Scoping

Inventory Analysis
- Materials & energy
- Manufacturing/use
- Waste

Impact Assessment
- Classification
- Characterization
- Evaluation

Improvement Analysis

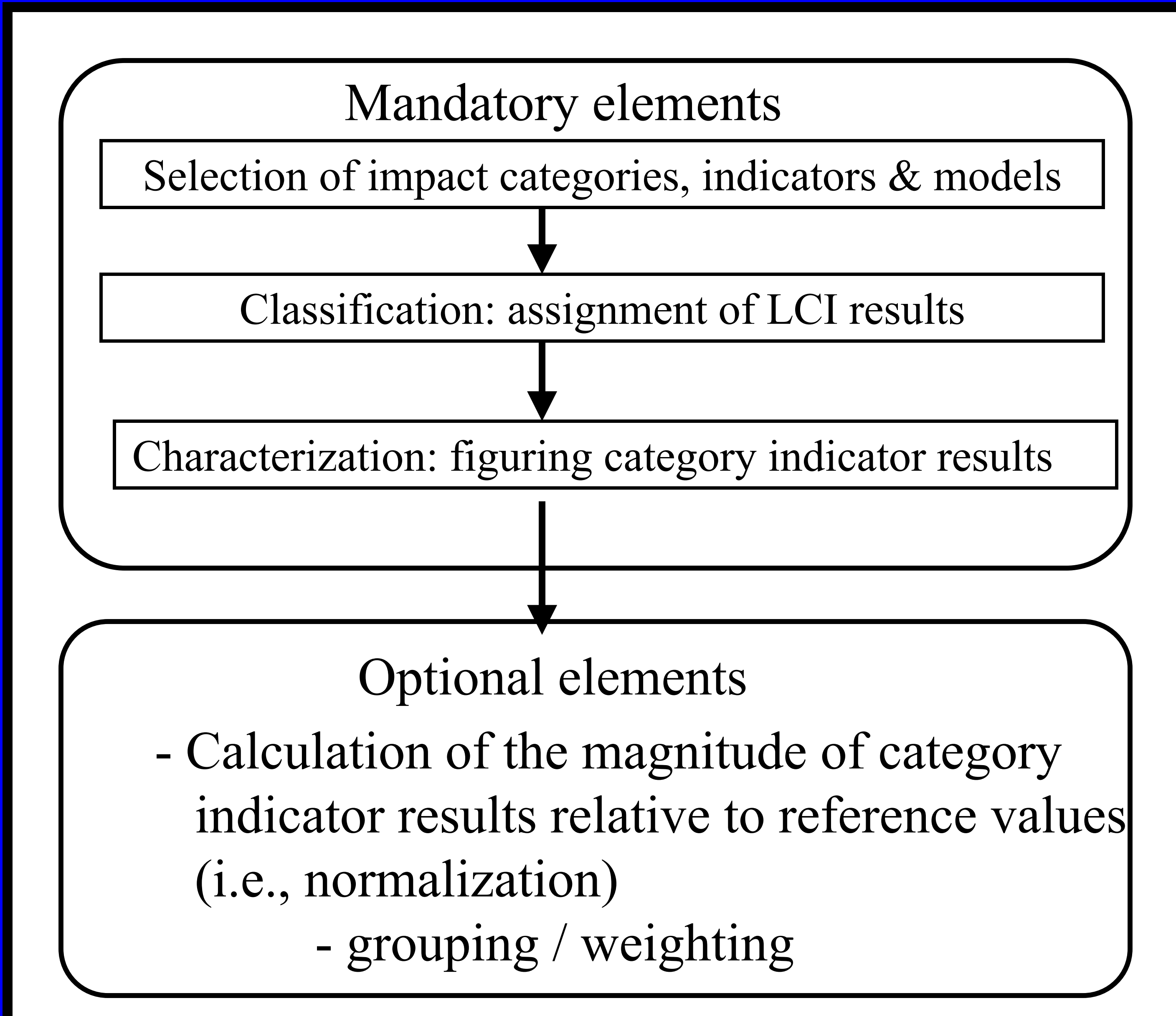
Risk Assessment
Problem Formulation

Effects Assessment
- Dose response
- Effects distribution

Exposure Assessment
- Mass loading
- Concentration distribution

Risk Characterization

Life Cycle Impact Assessment Elements



LCIA Categories

	Environment	Human Health	Resources
Global warming	●		
Acidification	●	●	
Ozone Depletion	●	●	
Photochemical smog	●	●	
Human toxicity		●	
Ecological toxicity	●		
Eutrophication	●	●	
Solid waste	●		
Resource depletion			●
Land disruption	●		●
Biodiversity reduction	●		●

Risk Calculation

“Classical Engineering” Risk

p Occurrence x Consequence = Risk

0.10 (probability of dam failure) x $100 M (damage)

= $10 M

Risk Calculation

Engineering Risk

p Occurrence x Consequence = Risk

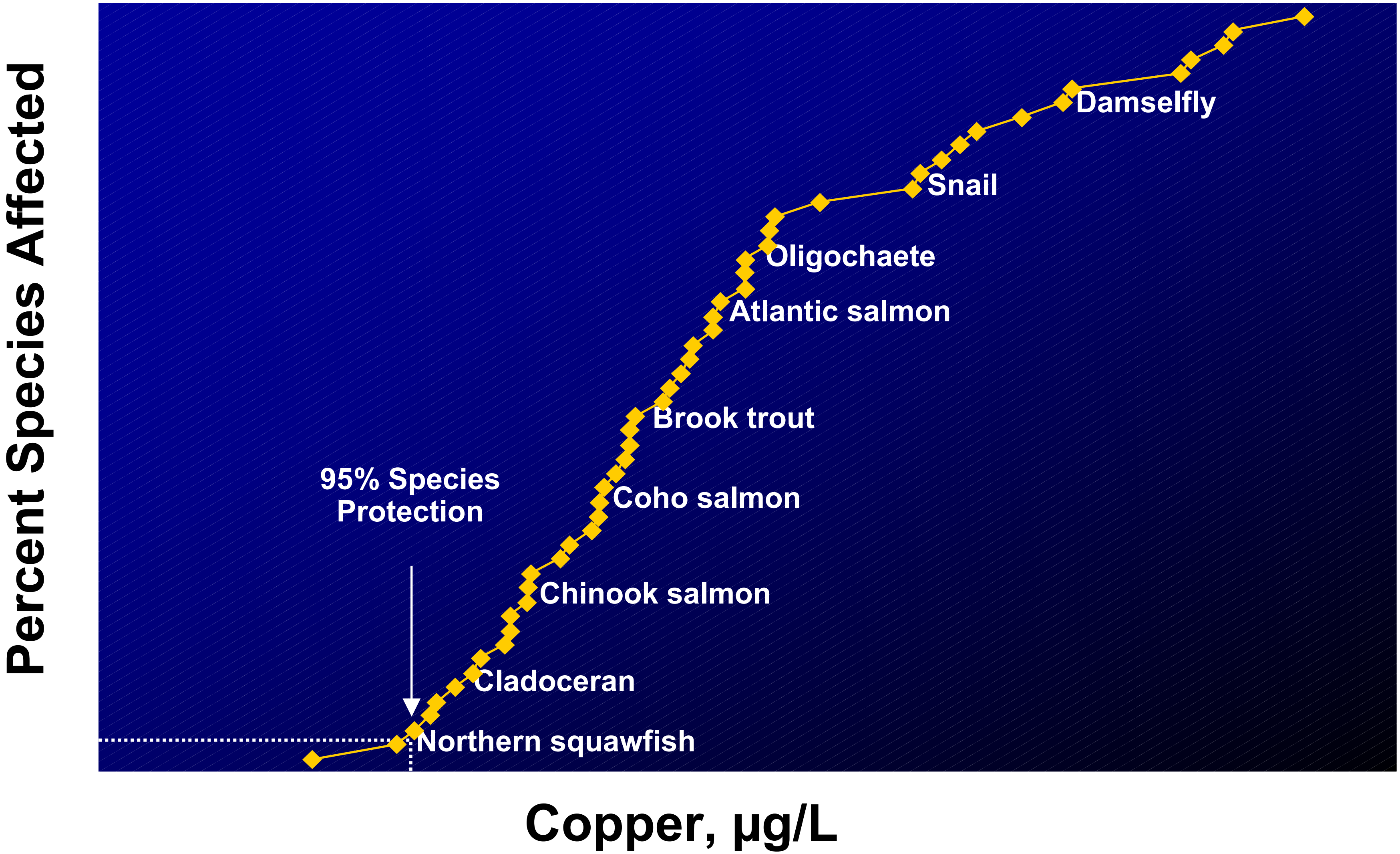
0.10 (probability of dam failure) x $100 M (damage)

= $10 M

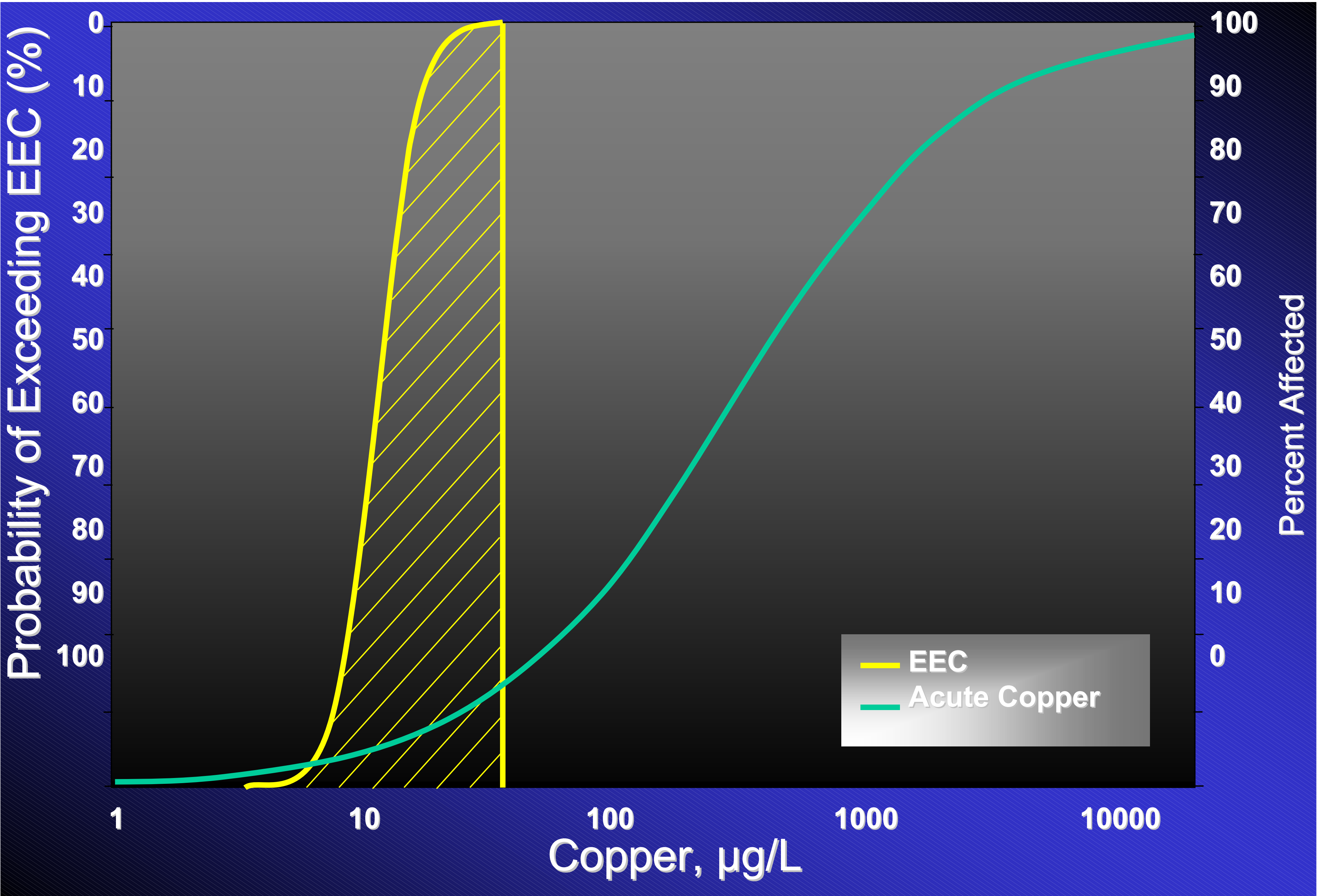
Ecological Risk

$\sum$ p of exposure exceedences x $\sum$ p effects = risk

Graphical Representation of Acute Toxicity for Copper



Integration of Exposure and Effects: Copper



Risk Calculation Table

Copper µg/L	EEC %	Taxa Affected %	Risk %
0-3	1.5	0	0
4-6	10.7	2.5	0.27
7-9	31.2	10.2	3.2
10-12	36.4	21.4	7.8
13-15	16.9	33.9	5.7
16-18	3.1	45.6	1.4
19-21	0.23	56.4	0.13
		Expected Risk:	**19%**

Risk Calculation

p Occurrence x Consequence = Risk

1.0	X	$100 M	= $100 M

(exposure set as 1.0)

Soluble Metal Salt	Aquatic Acute (ug/L)	Aquatic Chronic (ug/L)
Iron	----	1000
Arsenic	340	150
Zinc	120	120
Aluminum	750	87
Chromium III	570	74
Nickel	470	52
Cobalt	706	42
Chromium VI	16	11
Copper	13	9
Selenium	20	5
Lead	65	2.5
Cadmium	4.3	2.2
Mercury	1.4	0.77
Silver	3.4	0.1

LCIA Methods

- CML – Centre of Environmental Science (Leiden)
- EDIP – Env. Development of Industrial products
- CST – Critical Surface Time
- USES-LCA

LCIA

- Use of equivalency factors is central to the development of LCIA indicators – they convert inventory parameters into units that can be aggregated
- LCIA requires comparative evaluation and aggregation of emissions, disturbances, impacts
- Stressor aggregation invariable contains "apples-and-oranges comparisons," e.g., greenhouse gases versus aquatic effects
- Determination of the comparative detriment of one environmental insult to another is not primarily a question of measurement, but judgment. [Hertwick and Hammitt (2001)]

LCIA - Requirements

- Grouping of cause and effect chains should be based on similarities in the chains.

- A requirement is that all stressors within an impact category fit the same “characterization method,” e.g., both SO_2 and NO_3 cause acidification and the mechanism of action is the same.

Integrating “New” Science Into Risk Assessments and Life Cycle Impact Assessments

Assessment Tools For Metals

Can They Be Used To Assess Hazard?

Persistence — Half –life; Precipitation; Mineral formation; Unit World Model

Bioavailability — Sorption to: Suspended solids, DOC, ligands; WHAM Model

Bioaccumulation — Tissue increase; Biomagnification; Trophic transfer; Sediment BSAFs; Sulfide binding

Toxicity — Acute/chronic; Solubility; Transformation; Biotic Ligand Model

Speciation — Speciation models; pH effects; Ion conc.; MINEQL

Tools

Aquatic Toxicity

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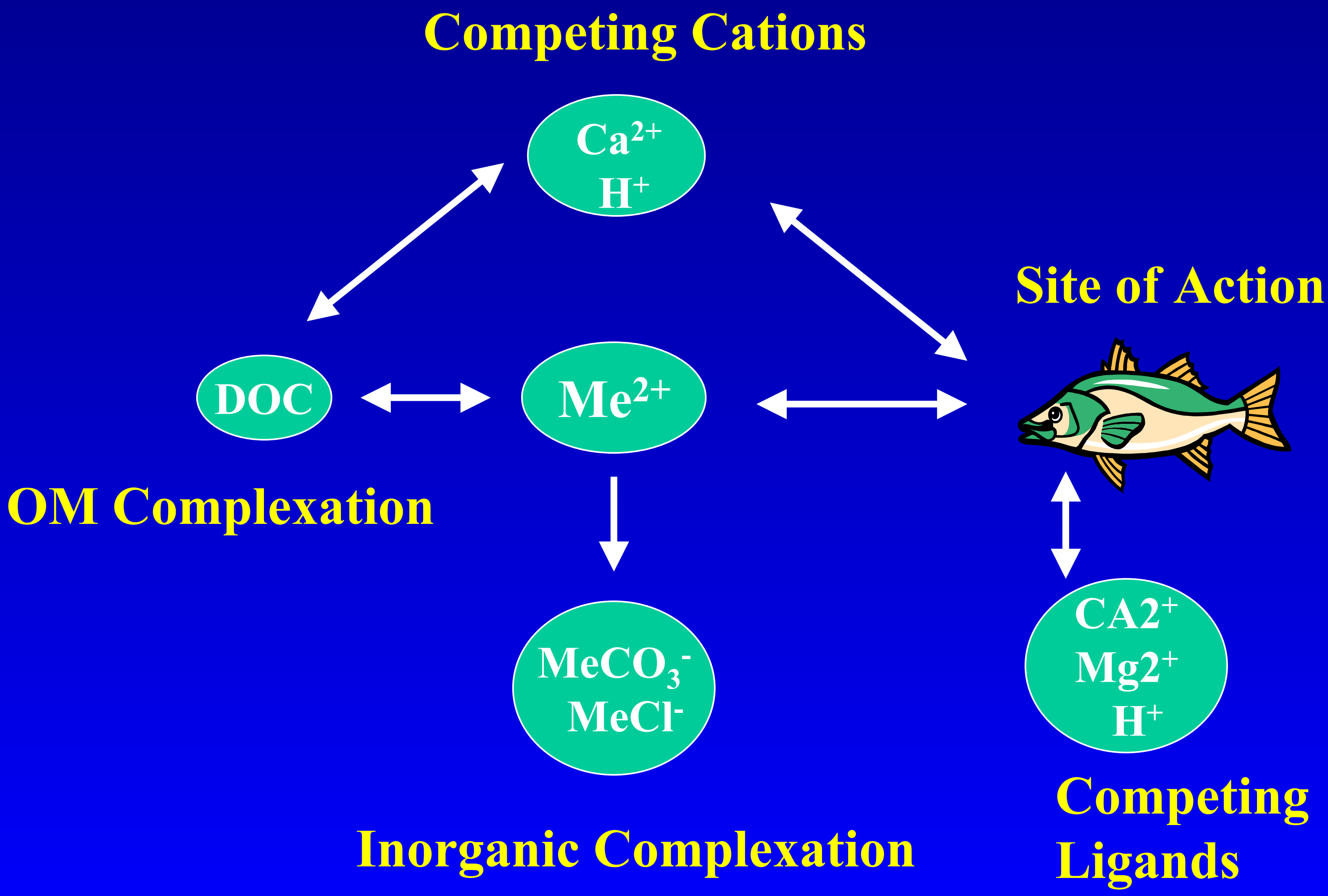
Biotic Ligand Model

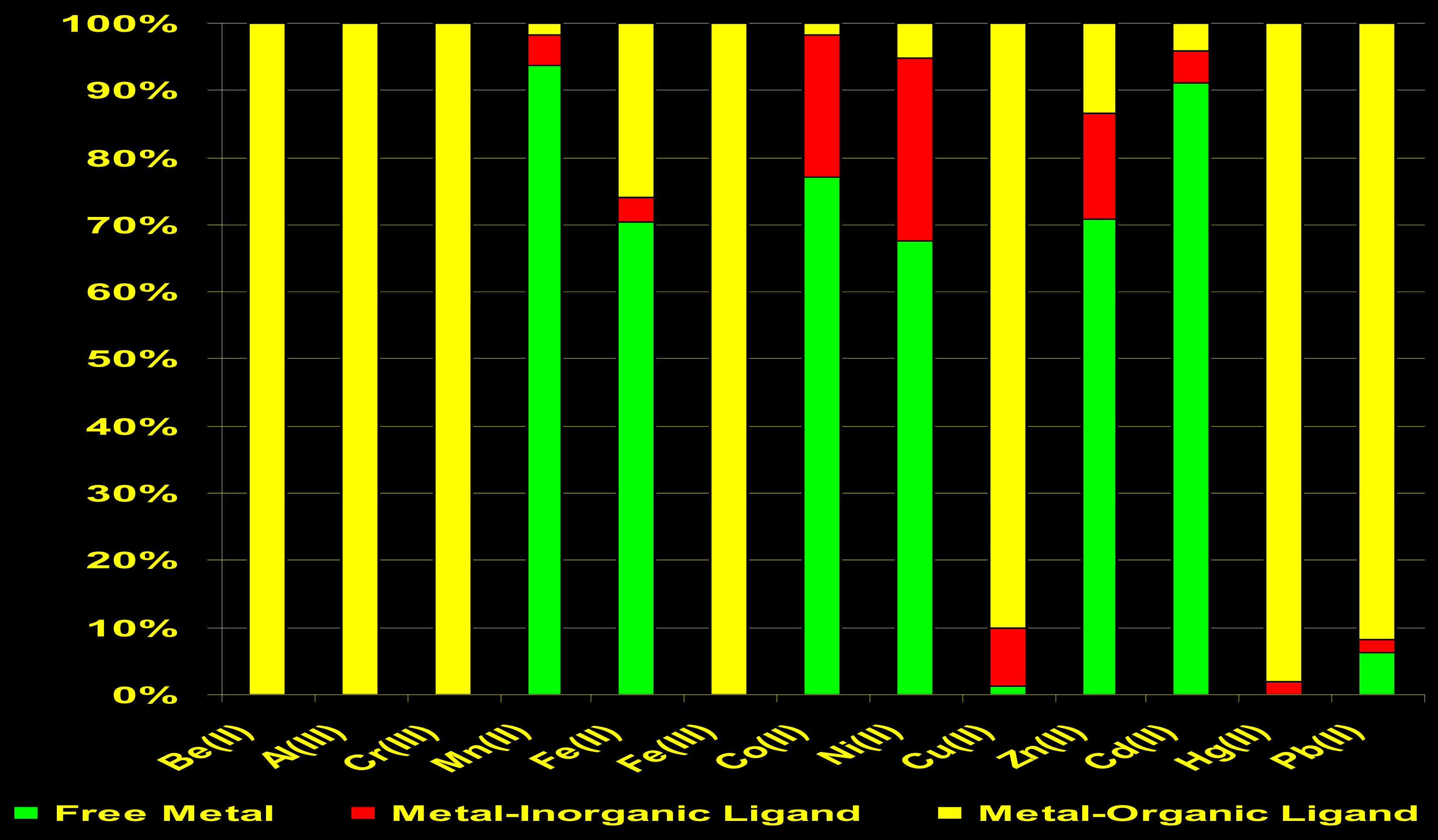


Biotic Ligand Model

- BLM provides a more accurate measurement of toxicity than waterborne metal concentration
- Variables eliminated
  - Ionic composition
  - Ionic strength
  - pH
  - DOC
  - POC

Persistence
- Metal Fate -

Metal Speciation in Freshwater @ pH 6 (WHAM Simulation)



Assessing Bioavailability:Free Metal Ion Concentration Computed Using WHAM

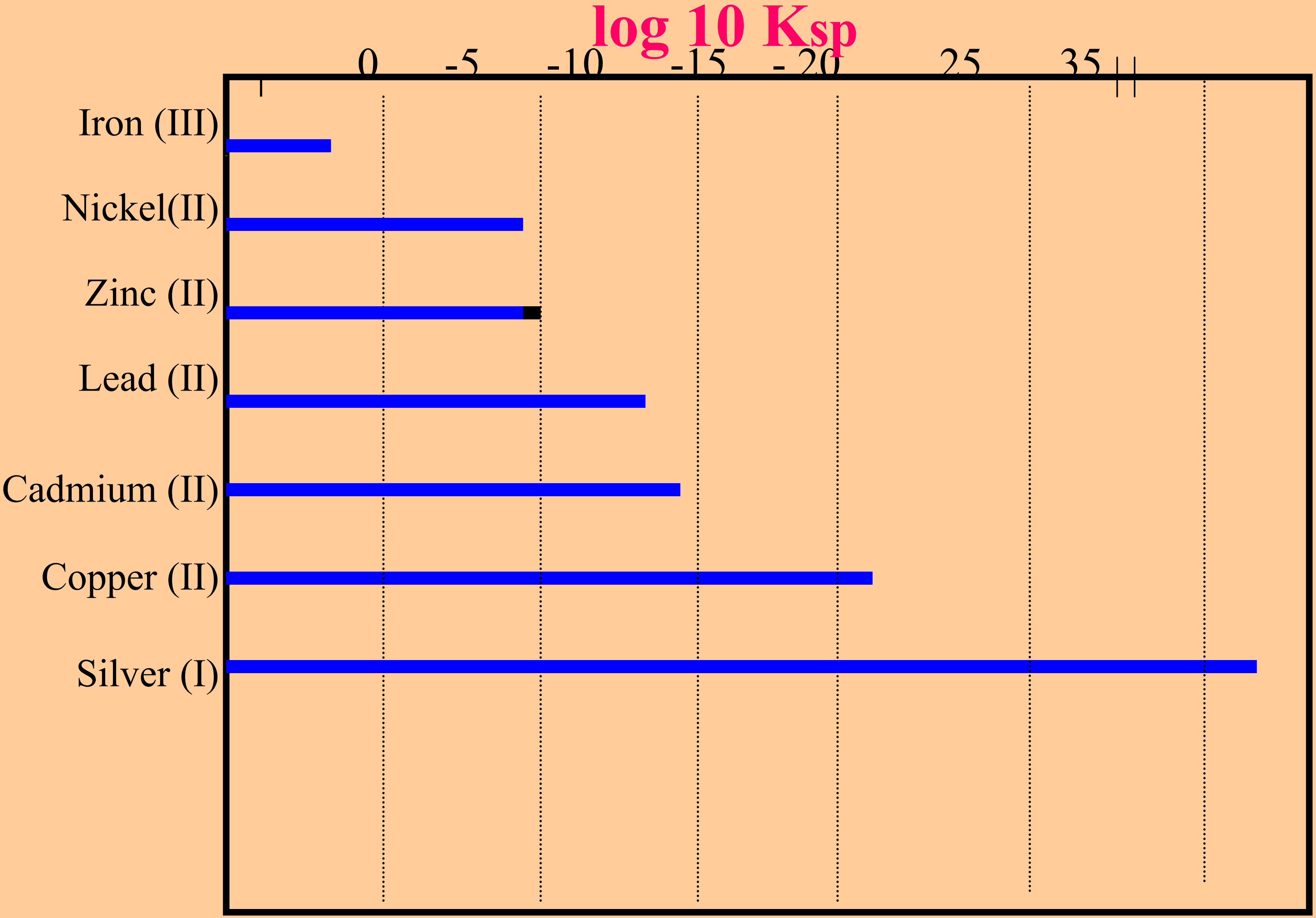
Metal	Free Metal Ion (Fraction) – pH 6.0
Manganese	0.94
Cadmium	0.91
Cobalt	0.77
Nickel	0.68
Z inc	0.71
Iron (II)	0.70
Lead	0.06
Copper	0.01
Beryllium	3.4×10^{-4}
Aluminum	7.9×10^{-5}
Chromium (III)	9.0×10^{-8}
Mercury	1.6×10^{-9}

Assessing Bioavailability: Persistence Index-Water

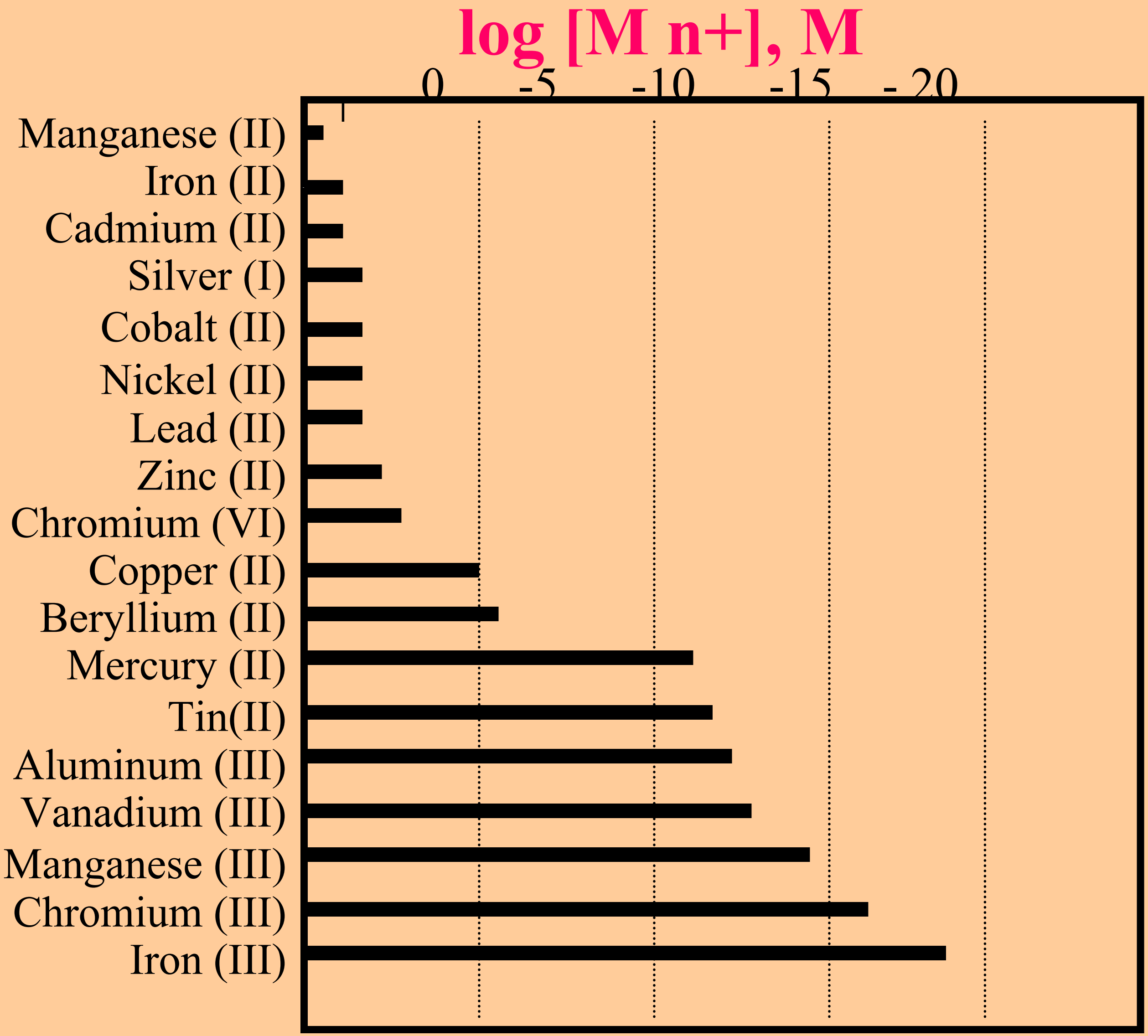
Metal	Persistence Index – Water
Manganese	9.4
Iron (II)	7.0
Cadmium	4.6
Cobalt	3.9
Nickel	3.4
Z inc	2.8
Lead	0.12
Copper	0.03
Aluminum	7.9×10^{-5}
Chromium	2.3×10^{-7}
Mercury	1.8×10^{-9}
Iron (III)	2.7×10^{-11}

Free Metal Ion (Fraction) @ pH 6.0 x ($1/Kd \times 10^5$)

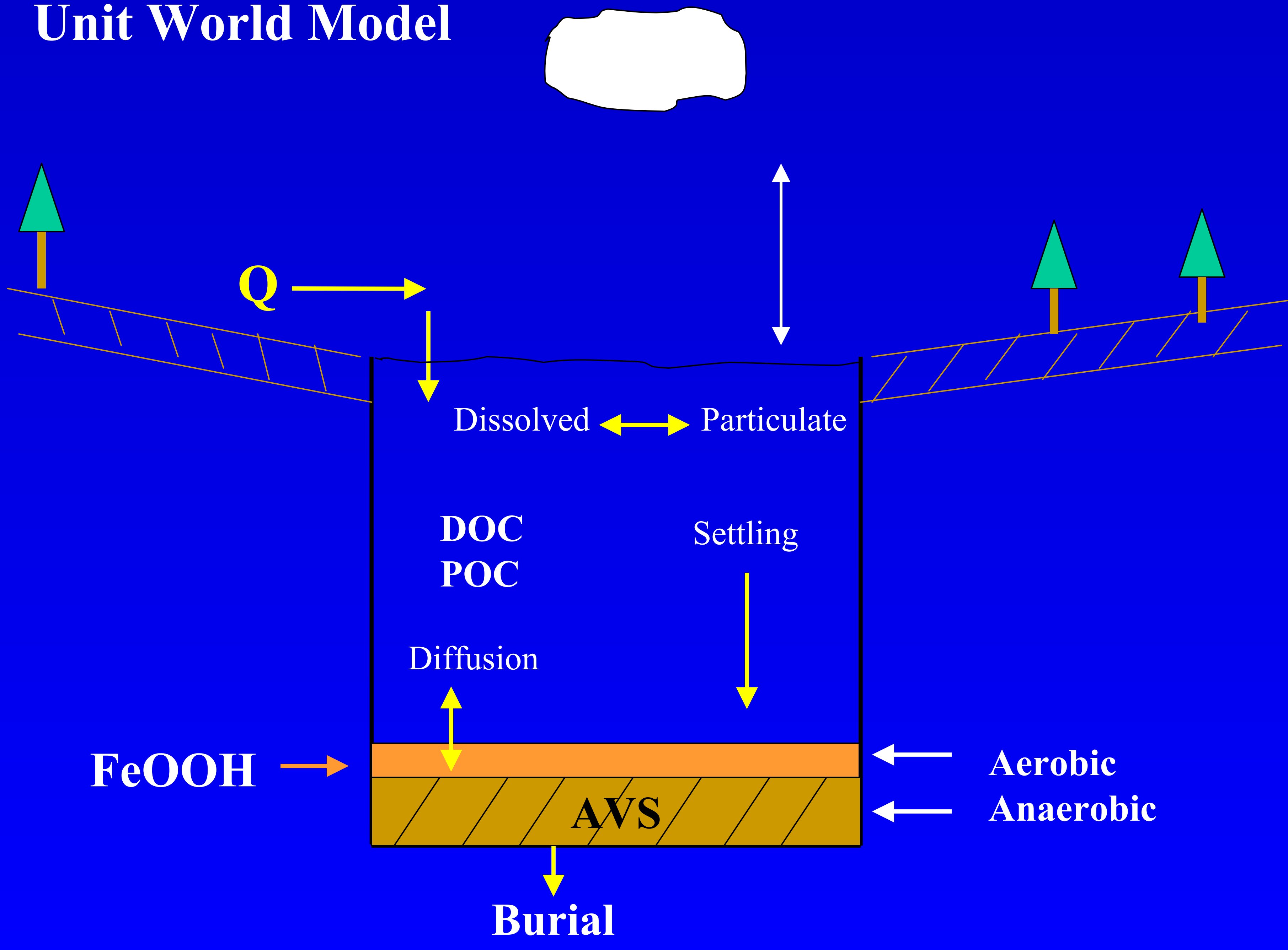
Solubility of Metal Sulfides



Solubility of Metal Hydroxides in Pure Water (pH = 7)



Unit World Model



Conclusions

- Directions that might permit some consideration of ecological and health endpoints in LCA:
  - Address the eco and health risks and benefits semi-quantitatively in LCAs
  - Avoid the use of aggregate scoring systems in favor of chemical-specific (and region-specific) semi-quantitative risk-benefit assessments
  - For now, address health and eco endpoints in adjunct analyses, separate from but attached to the LCA, and fold the results of both into the LCA conclusions
  - Engage in research to improve our ability to integrate ecological and health risk and benefit into LCAs. .. mostly an issue of metrics.

Conclusions

- A key question is whether LCA/LCIAs should aim to quantify effects or should they calculate relative hazard scores?
  - The former calculates “true” risk
  - The latter makes it possible to compare contributions of different substances to an impact category such as aquatic toxicity


The End