Finalization of Multiyear Metals Environmental Exposure Data Collection Program (MEED) Anticipating the Challenges of the EU Zero Pollution Ambition and the Combined Exposure to Mixtures.

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Background

The **Zero Pollution Action Plan** and the **Chemicals Strategy for Sustainability** (CSS), key pillars of EU's **Zero Pollution Ambition** (ZPA) aim at "*reducing exposures to levels that are no longer expected to be harmful to health and the environment*" and addressing long-lasting challenges like combined toxicity through a Mixture Allocation Factor (MAF). These elements test the demonstration of risk control and safe use for chemicals and require, besides compliant effects datasets, good quality exposure data covering the EU now and in the future and a proper understanding of the effects of mixture toxicity. This constitute a scientific challenge for the metals industry, given their increasing use in Green Deal applications like EV batteries, solar cells, windmills and electronics and drove the sector to design a comprehensive "Environmental Exposure gathering Program" (MEED), including the collection of recent exposure and existing mixture toxicity data, the development of scientific concepts and selective test work to assess combined exposure to demonstrate progress towards the ZPA objectives aimed to demonstrate no significant impact on biodiversity.

Expected growth rate of metals in EU by 2050

% metal required in 2050 for clean energy technologies vs. 2020 overall use (SDS ambitious climate scenario).

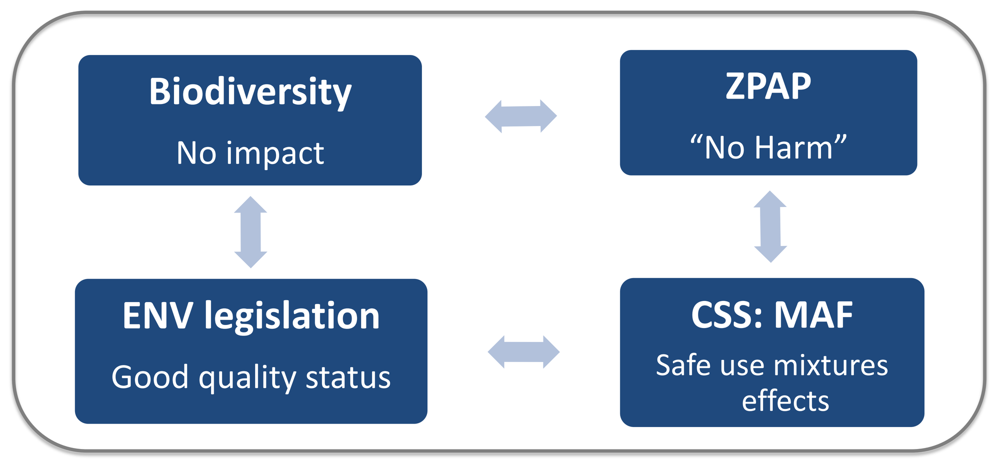
Li Lithium	2109%	Si Silicon	62%
Dy Dysprosium	433%	Tb Terbium	62%
Co Cobalt	403%	Cu Copper	51%
Te Tellurium	277%	Al Aluminium	43%
Sc Scandium	204%	Sn Tin	28%
Ni Nickel	168%	Ge Germanium	24%
Pr Praseodymium	110%	Mo Molybdenum	22%
Ga Gallium	77%	Pb Lead	22%
Nd Neodymium	66%	In Indium	17%
Pt Platinum	64%	Zn Zinc	14%
Ir Iridium	63%	Ag Silver	10%

- Aluminium, Copper, Zinc, Silicon → *Electricity distribution*
- Lithium, Nickel, Cobalt → *Batteries*
- Dysprosium, Neodymium, Praseodymium → *Permanent magnets*

Need for metals and emission challenges

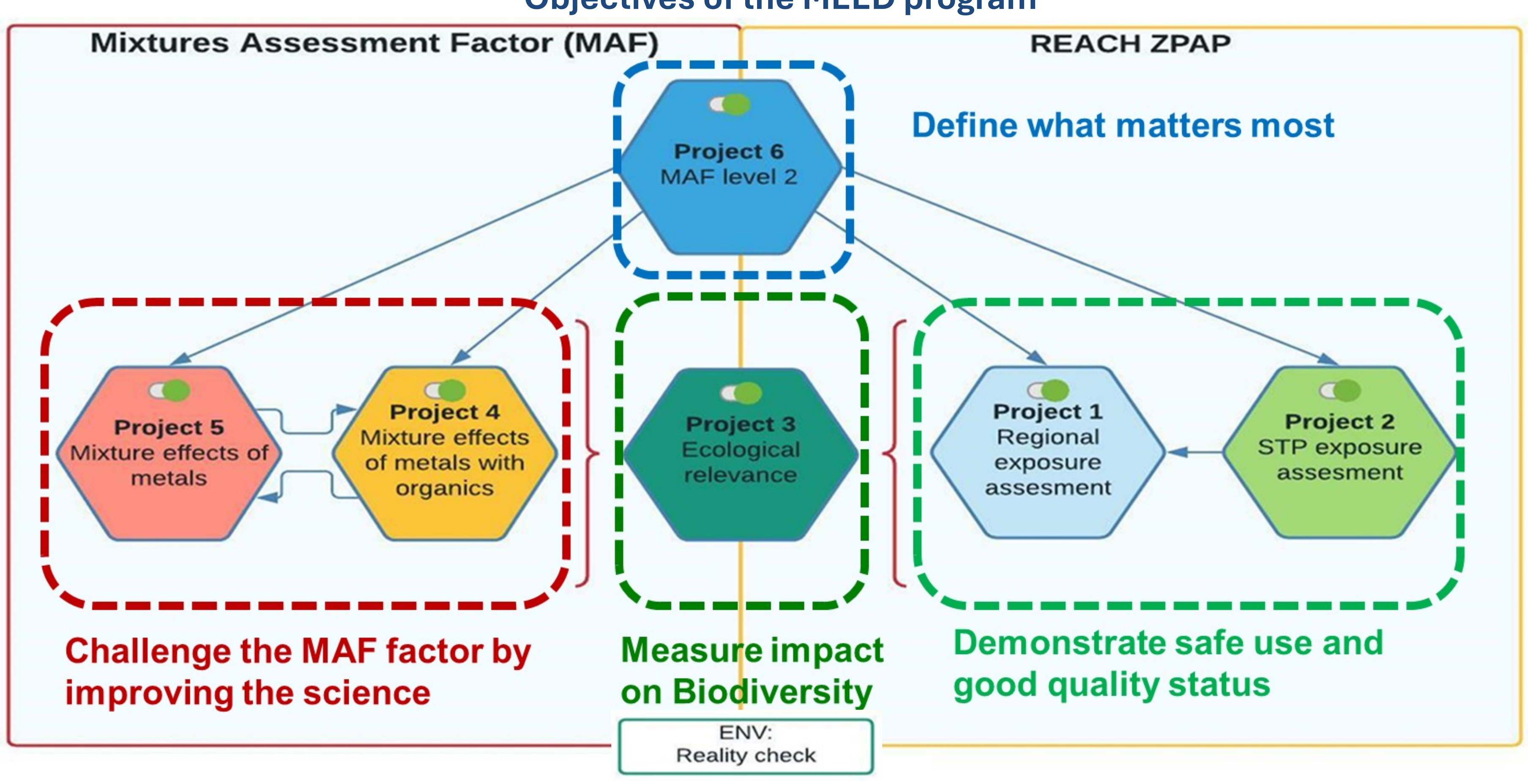
- ✓ The **EU's twin green and digital transitions**, coupled with the targets of the Critical Raw Materials Act, drives a sharp increase in metal uses and demand.
- ✓ The **required material** can be gained from longer lifecycles of substances in articles for a given function (e.g., mobility) and recycling, but also from primary production to fill the gap and ensure resilience.
- ✓ There are concerns that industrial activities linked to production and recycling could **increase emissions**, which might be contrary to the aims of the ZPA.
- ✓ In addition, exposure to **relevant metal mixtures** requires a better level of understanding

Anticipated regulatory protection objectives



Structure and Methods

Objectives of the MEED program



Overall structure of the MEED program

Define what matters most (Project 6):
- Define I-PCS **"Inorganic-Priority Contributing Substances"** (P6) to provide focus and efficiency

Update regional exposure levels (Projects 1 & 2):
- Map **today's metal concentrations** and combined risks across the EU, trends & predicted future concentrations due to volume increase (P1) for as many metals as possible
- Improve the assessments of **consumer and professional releases**, given a weak link (P2)

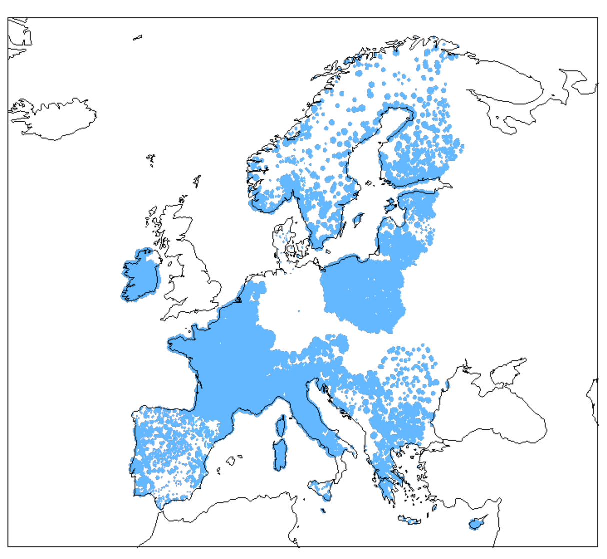
Assess impact mixture effects (Projects 4 & 5):
- Review of **existing knowledge** on metal-metal mixtures and metal-organic mixture interactions
- **Design smart testing program** to fill I-PCS mixture gaps
- Perform testing on *Dapnia* and Algae (*Raphidocelis subcapitata*) on metal and metal-organic mixtures in field realistic combinations

Measure potential impact on Biodiversity (Project 3):
- Provide toolbox to assess impact on biodiversity
- Run **pilot trials** to develop efficient assessment

Develop scientific robust tools to refine default mixture risk assessments:
- Science based tiered alternative approaches to be applied in environmental Risk Assessment
- Applicable for different regulatory schemes

Results and Proposals

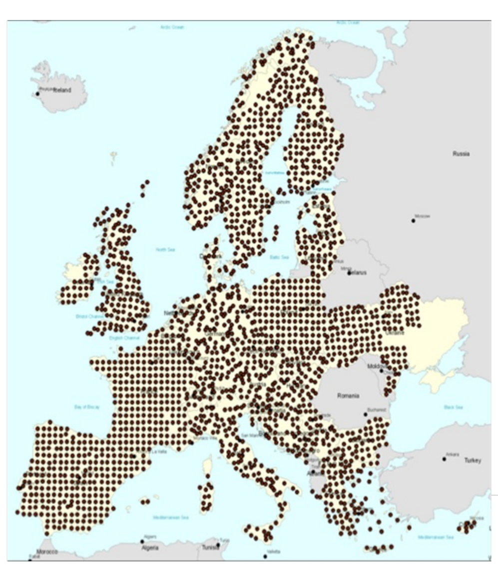
P 1: Regional exposure update



Spatial distribution of metal samples in **Water**base

Inorganic	Before data processing	After data processing
Ag	20 954	5 595
As	189 824	163 341
Ba	35 274	33 917
B	48 674	40 102
Cd	278 072	233 094
Co	45 785	30 033
Cr	222 037	185 970
Cu	245 462	184 935
Hg	212 579	178 944
Li	1 783	489
Mn	95 172	71 170
Mo	25 465	25 342
Ni	275 291	240 689
Pb	280 208	241 503
Sb	30 551	30 145
Se	49 235	37 156
Ti	14 749	14 267
V	55 094	49 220
Zn	210 488	145 225

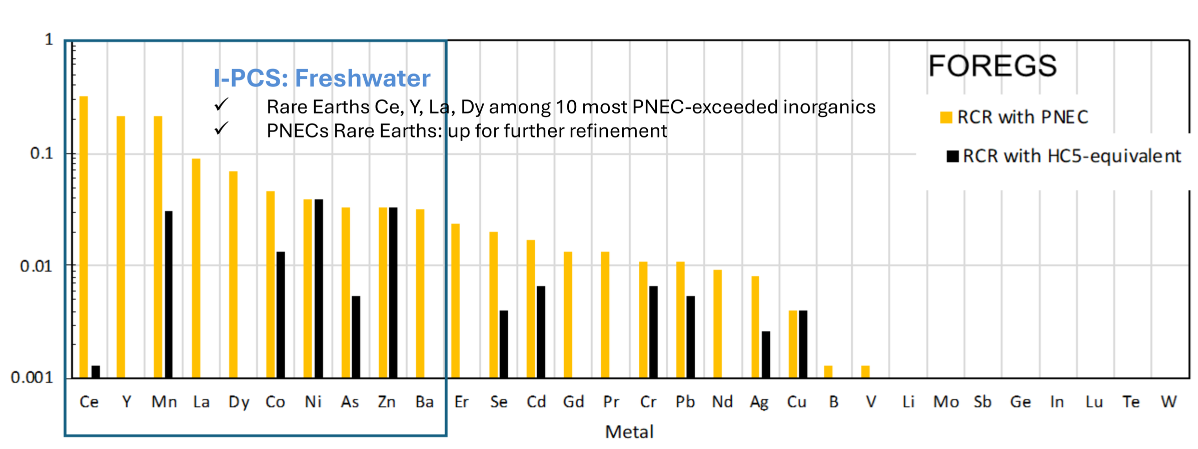
Metal samples in Waterbase



Spatial distribution **soil** samples GEMAS

Interpretation: Existing monitoring datasets are extensive, even after data quality checks. But monitoring techniques can be improved (e.g. LOD for Ag) and data are still lacking on some key *critical metals* for the twin transition (e.g., Li, Rare Earths).

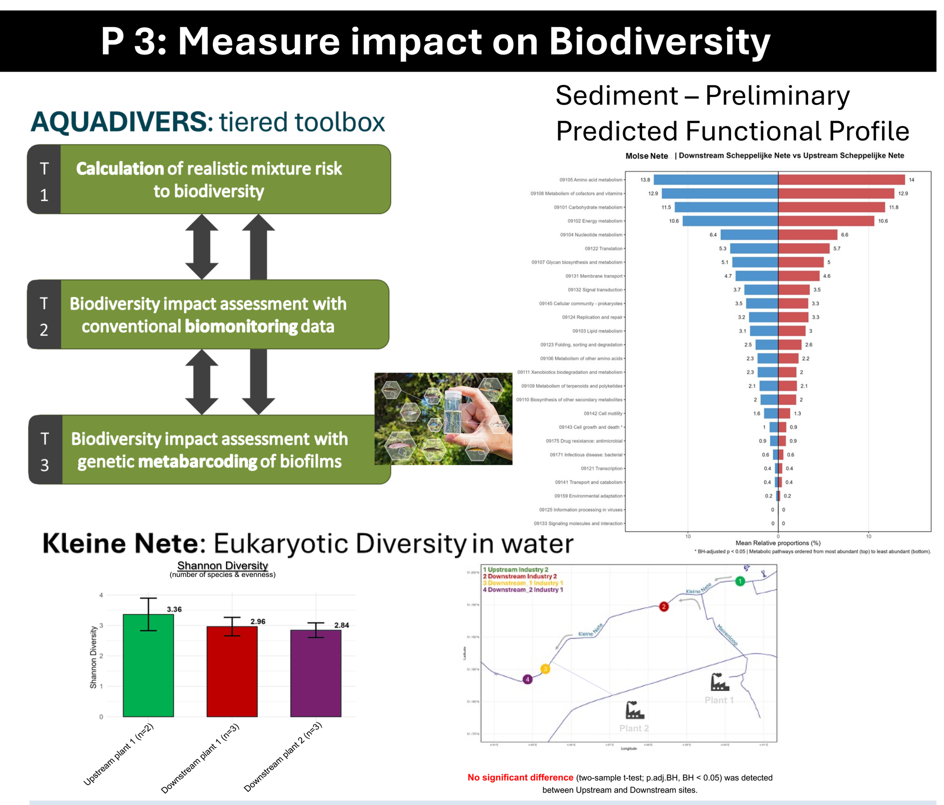
P 6: Inorganic Priority Chemical Substances (I-PCS)



Category	Criterion	I-PCS selection
Usually risk drivers in mixtures	Contributing to the 90th percentile of the Hazard Index (HI) in >50% of the mixtures	As, Ba, **Ce**, Co, Cu, **Dy**, Mn, Ni, Se, **Y**, Zn
Sometimes risk drivers in mixture	Contributing to the 90th percentile to HI in ≥10-50% of the mixtures	Ag, Cd, Cr, **Er**, **Gd**, **La**, Pb, V
Usually not risk drivers in mixtures	None of the above	B, Ge In, Li, **Lu**, Mo, **Nd**, **Pr**, Sb, Te, **W**, Zr

Interpretation: I-PCS contributing most to (mixture) risks: Ag, As, Ba, Cd, Ce, Co, Cr, Cu, Dy, Er, Gd, Hg, La, Mn, Ni, Pb, Se, V, Y, Zn

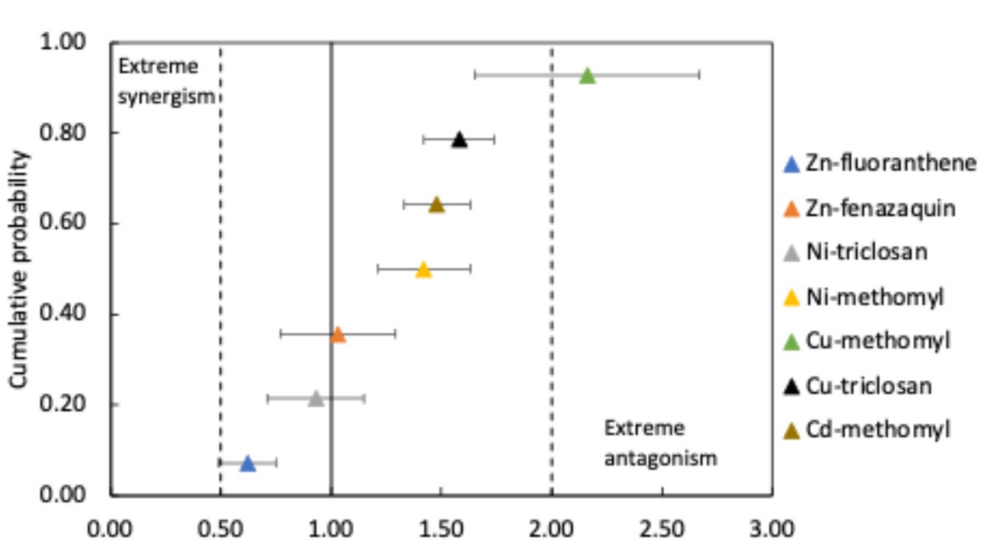
P 3: Measure impact on Biodiversity



Outcome: AQUADIVERS **toolbox** works. **Metabarcoding** of eukaryotes in water and prokaryotes in sediments can detect subtle responses in biological conditions.

P 4: metal-metal and metal organic interactions

Example: metals-organics mixture effects on Daphnia

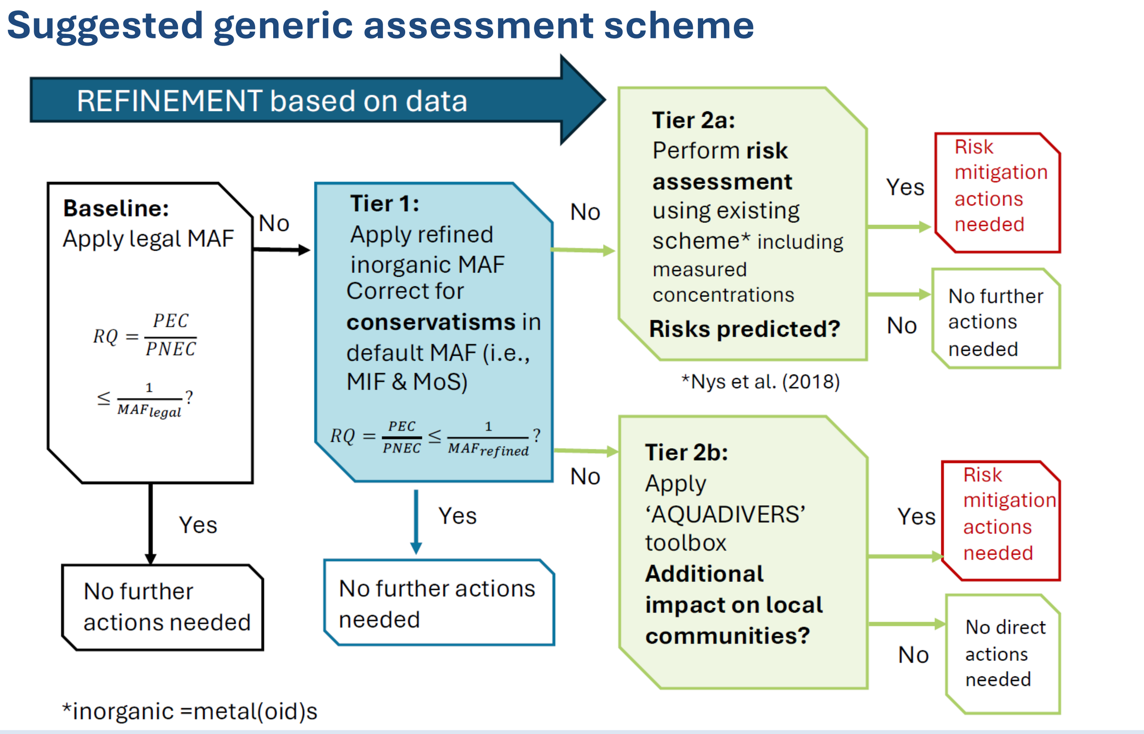


Daphnia magna

Mixture Interaction Factor (MIF) is *the degree of conservatism that* ***CA*** (standard regulatory mixture model) provides relative to observed mixture effects at low effect levels (i.e., 10% mixture effect). MIF < 1 = synergism; MIF > 1 = antagonism
MIF>1 indicates that CA overestimates metal mixture effects

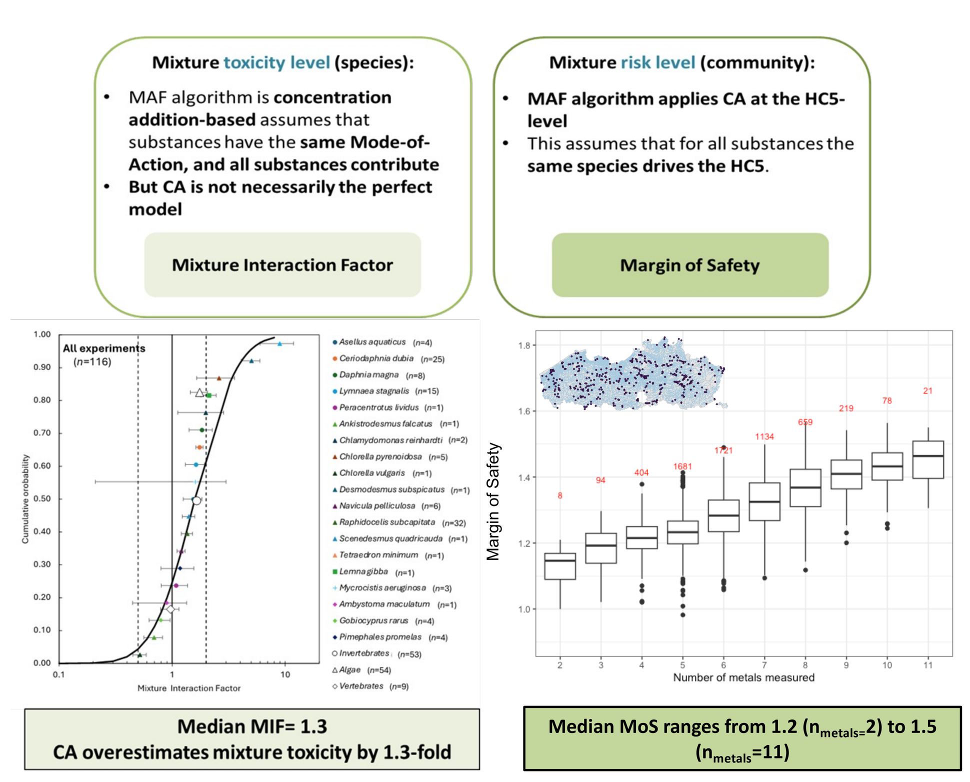
Defining alternative concepts to assess mixture toxicity under regulatory schemes (e.g. MAF)

Suggested generic assessment scheme



MEED allows to apply an alternative **science-based approach** assessing the impact of combined exposure at regional and local level.

TIER 2 assessment based on MEED outcome



Median MIF= 1.3
CA overestimates mixture toxicity by 1.3-fold

Median MoS ranges from 1.2 (n_{metals}=2) to 1.5 (n_{metals}=11)

More detail on MEED projects can be found on Maastricht SETAC Presentations: V. de Almeida Moreiro (poster): 1.10.P-We013, C. Nys (platform): 3.12.B.T.-02, M. Gallin (poster): 3.12.P-Mo186, M. Smith (platform): 3.12.B.T.-01, L. De Donno (poster): 3.12.P-Mo185

Conclusions

- ✓ **Metal volumes** (manufactured, used & recycled) increase due to the twin transition, questioning impacts of emission on combined environmental effects as well as on biodiversity
- ✓ **MEED** collected up-to-date aquatic, soil and sediment regional exposure datasets for the EU, to anticipate the EU-ZPA and environmental legislations to deal with mixtures effects.
- ✓ The monitoring data were collected for a long series of metals (>20), concluding extensive data sets being available but **data on key metals** for the twin transition like Li and Rare Earths **were limited or lacking**. It allowed identifying how **EU monitoring programs can be improved** to collect meaningful environmental data (e.g. LOD)
- ✓ Assessing the **combined metal toxicity for EU monitoring points** allowed to define "*Inorganic priority chemical substances*" (IPCS) that act as main risks drivers for mixture toxicity
- ✓ The **Mixture Interaction Factor (MIF) concept** allows to quantify the level of conservatism provided by the Concentration Addition model
- ✓ Literature on metal-metal mixtures and metal-organic mixtures was **updated, reappraised and complemented with extensive testing for lacking combinations** at environmental relevant conditions. It **demonstrated** that MIFs for metals and metal-organic mixtures are around a median MIF of 1.3, leaning more towards antagonistic than synergistic action.
- ✓ A pilot using the **AQUADIVERS toolbox demonstrated how to** assess the impact of unknown mixtures in environmental conditions using modelling, biomonitoring & metabarcoding
- ✓ The combined work of MEED allows to design **a tiered approach** based on available mixture toxicity evidence as **an alternative to the MAF concept** for different regulatory uses
- ✓ The **outcomes** of the **MEED program will be published** and made available for research on mixtures and regulatory compliance demonstration

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