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Training Courses

Prof. Dr. Evren TUNCA

Transfer of Heavy Metal Pollution from Ecosystems to Humans





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Training Courses

Part 1: Defining the Problem and the Core Misconception

Part 2: The Biological Filter Mechanism (Why Does Decoupling Occur?)

Part 3: Implications for Human Health and the Math of Risk

Part 4: Analytical Traps and Proposed Solutions





Decoupling environmental contamination from human health risk through selective bioaccumulation: The role of analytical spectrum and physiological modulation

Evren Tunca^{a,*}, Özkan Uğurlu^a, Georgeta Tudor^b, Mehmet Aydın^a

^a Faculty of Marine Sciences, Ordu University, 52400, Fatsa, Ordu, Türkiye

^b National Institute for Research and Development in Environmental Protection, 294 Splaiul Independenței Blv, 060031, Bucharest, Romania

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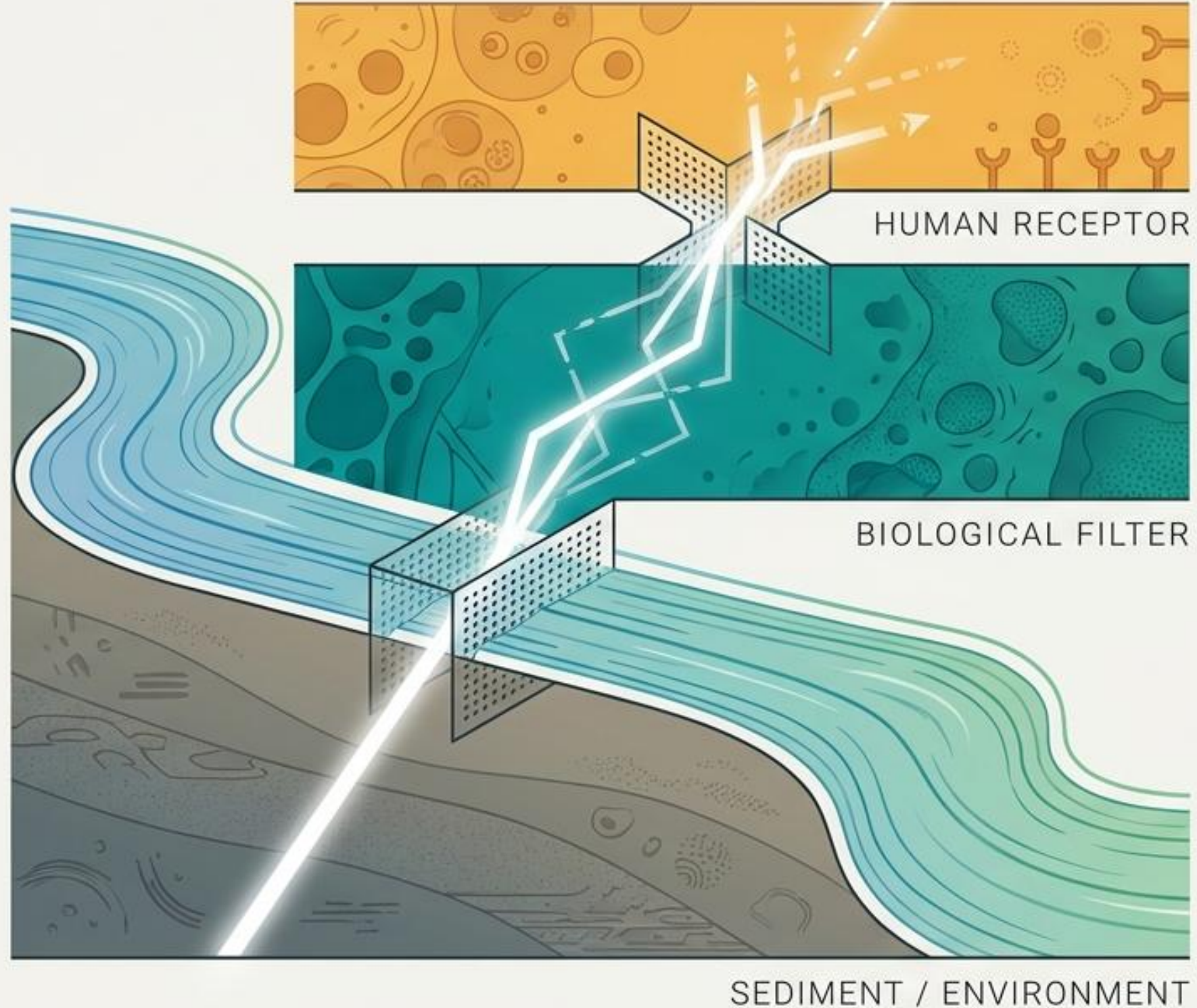
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ABSTRACT

This study discusses metal(loid) accumulation in the Kızılırmak Delta system (Samsun, Türkiye) using a multi-layered approach. Fifteen metal(loid)s, including As, Cd, Hg, Pb, Cr and Ni, were studied in 5 different lagoons, the Kızılırmak River, and the Black Sea as a whole. Environmental pollution, bioaccumulation, and human health risks were evaluated in an integrated manner. While contrasting hydrological seasons were chosen for water and sediment samples, we focused our biotic sampling on the wet season. Data were analyzed using sediment assessment indices such as the enrichment factor (EF) and the contamination factor (CF) (Layer 1), bioaccumulation indices such as BAF, BSAF, and MPI (Layer 2), along with non-carcinogenic (THQ, HI) and carcinogenic risk indices (CR, TCR) that are important for public health (Layer 3). Layer 3, while separated from Layer 1 by the hotspots it revealed, showed closer agreement with Layer 2. Furthermore, the lack of correlation between BAF and BSAF supported this decoupling.

The results of this study show that freshwater and saltwater habitats may influence tissue-specific accumulation patterns. Additionally, reducing the analytical spectrum from 15 metal(loid)s to commonly used subsets of 9 and 5 was found to alter tissue hierarchies, suggesting that MPI results are sensitive to the number and selection of elements. Ultimately, the metal(loid) risk in transitional systems is governed by selective biological transfer and analytical resolution, rather than solely by environmental load.



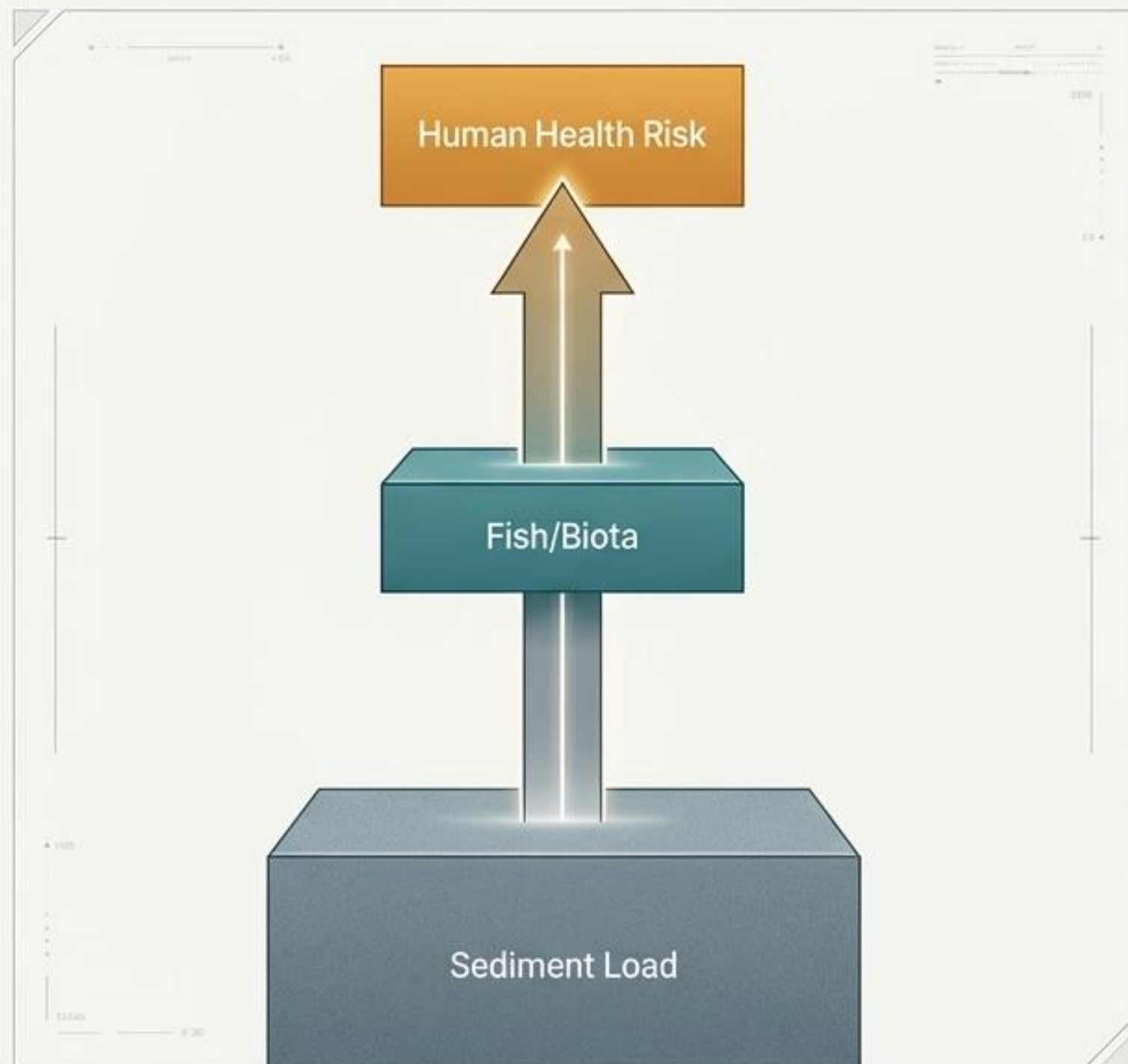
The Decoupling Phenomenon

Why Environmental Pollution Hotspots Are Not Human Health Hotspots.

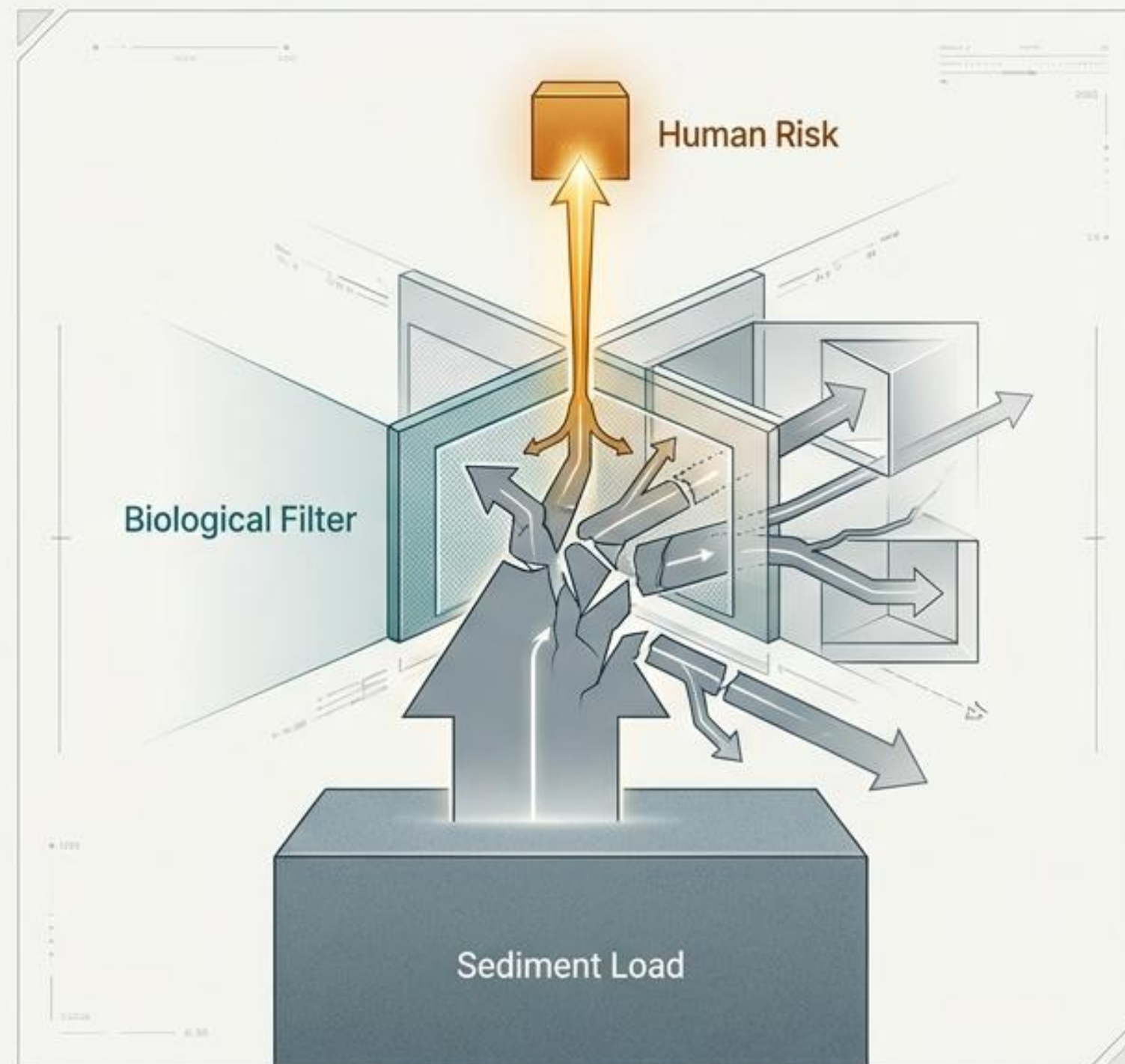
An integrated analysis of selective bioaccumulation and physiological modulation in the Kızılırmak Delta.

The Linear Flow of Pollution is a Myth

Single-matrix assessments operate on a flawed assumption. The ecosystem actively buffers, redirects, and amplifies specific elements.



The Linear Assumption: Mass-based environmental loads directly dictate human risks.



The Decoupling Phenomenon: Non-linear divergence caused by selective biological transfer.

Defining the Problem and the Core Misconception

The Three Strata of Ecotoxicological Assessment

LAYER 3: THE RECEPTOR

Human Health Risk

Metrics: THQ, HI, CR, TCR



Insight: Layer 3 (Human Risk) is shaped entirely by the biological filtering of Layer 2, largely ignoring the raw environmental loads of Layer 1.

LAYER 2: THE FILTER

Biota (Algae, Mollusks, Fish)

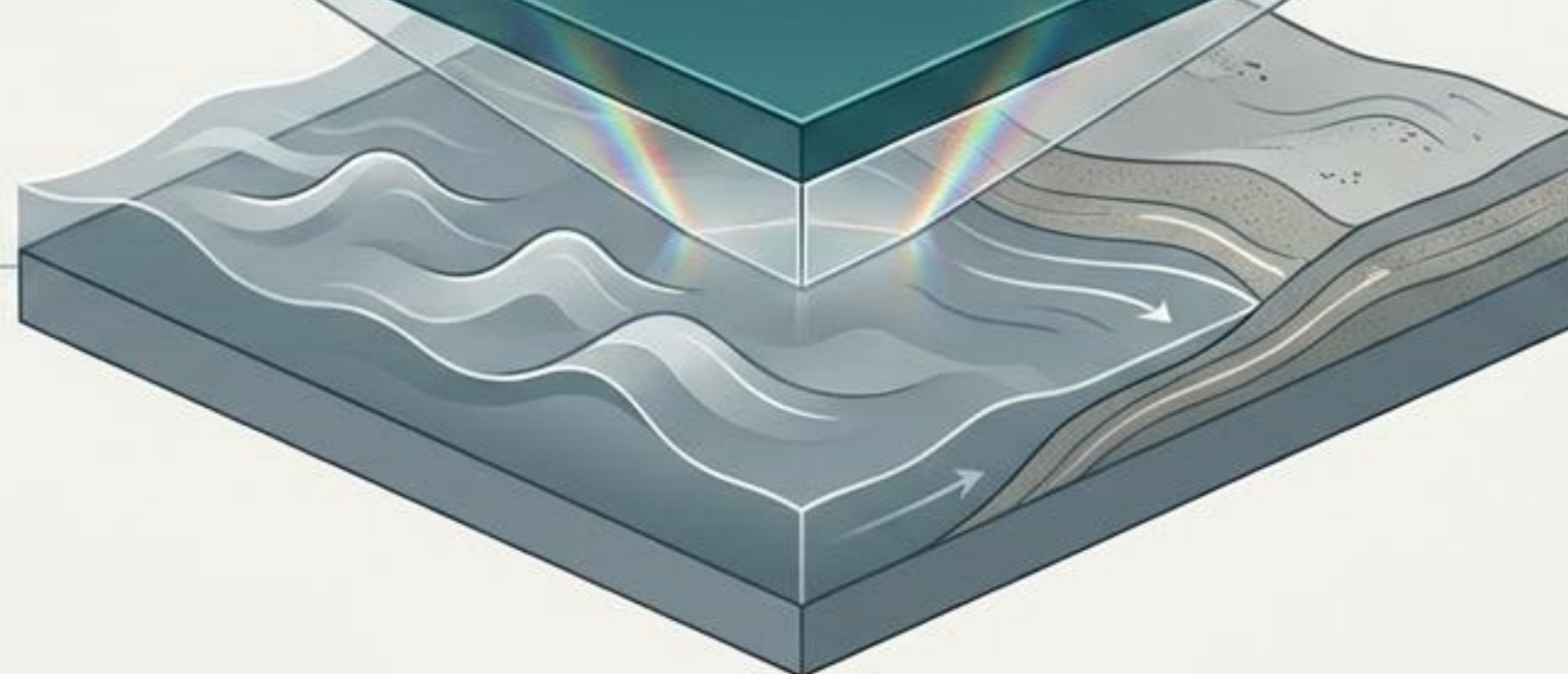
Metrics: BAF, BSAF, MPI



LAYER 1: THE SOURCE

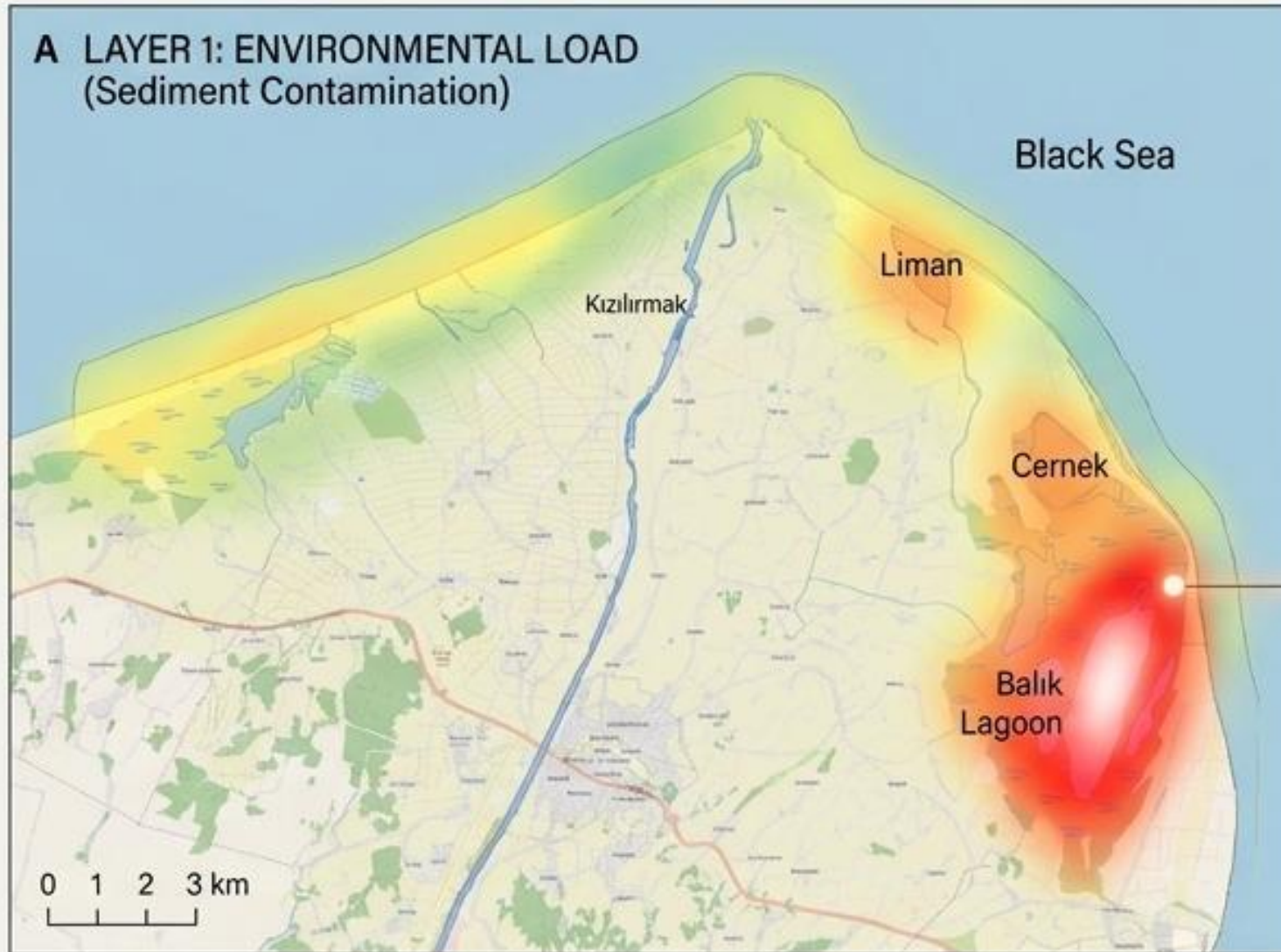
Water & Sediment

Metrics: CF, EF, Igeo

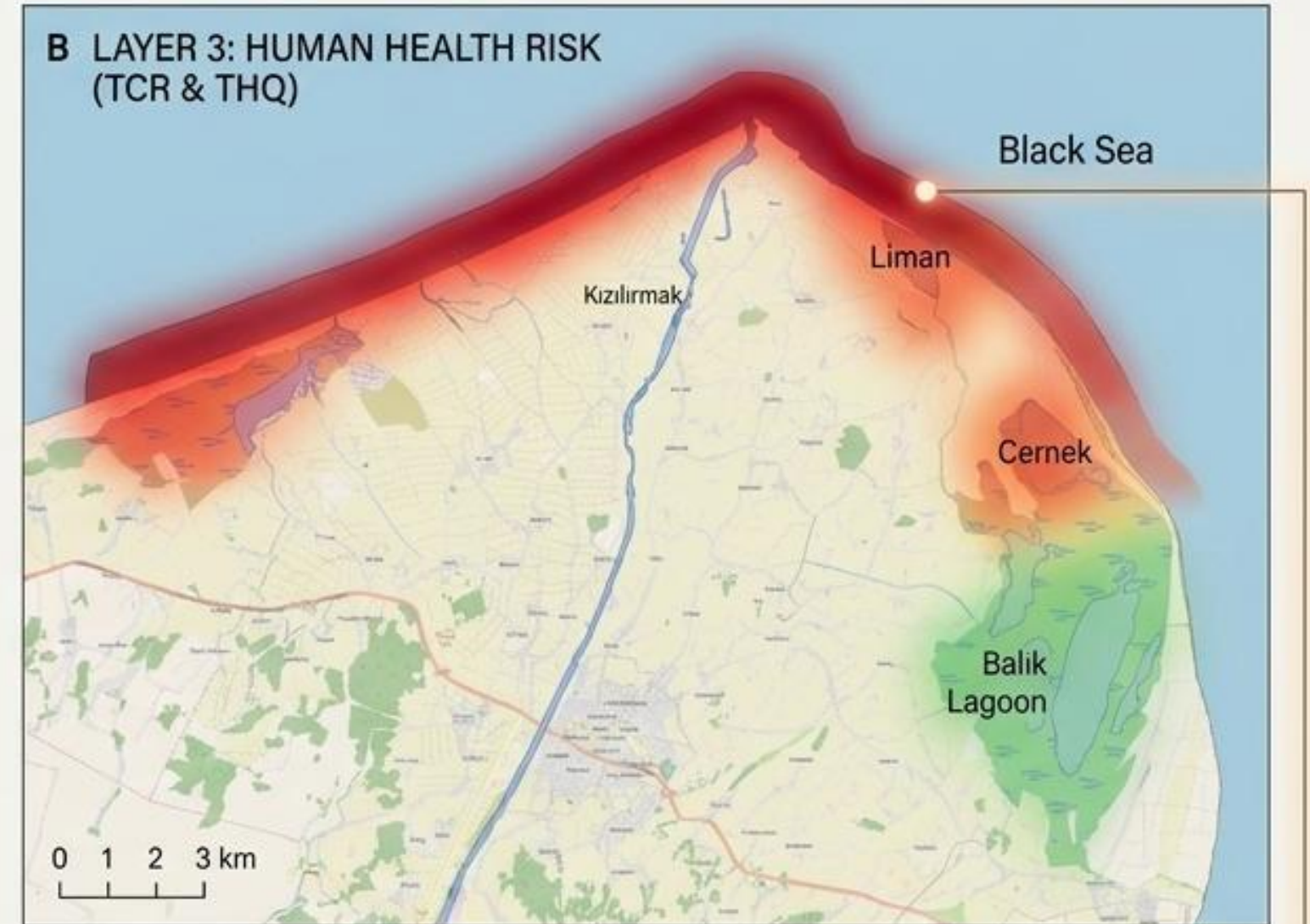


The Spatial Mismatch: The Illusion of the Hotspot

Sediment chemistry cannot predict human exposure. Statistical modeling shows sediment pollution indices exhibit weak inverse relationships with human health risk.



Balık Lagoon: Ranks #1 in Sediment Contamination, but Ranks #3 in Human Risk (High Pb, $PLI > 1$).



Black Sea: Ranks #3 in Sediment Contamination, but Ranks #1 in Human Risk ($TCR > 10^{-4}$).

The Decoupling Matrix

The ultimate proof of spatial mismatch. Risk hierarchies are completely upended from environment to human.

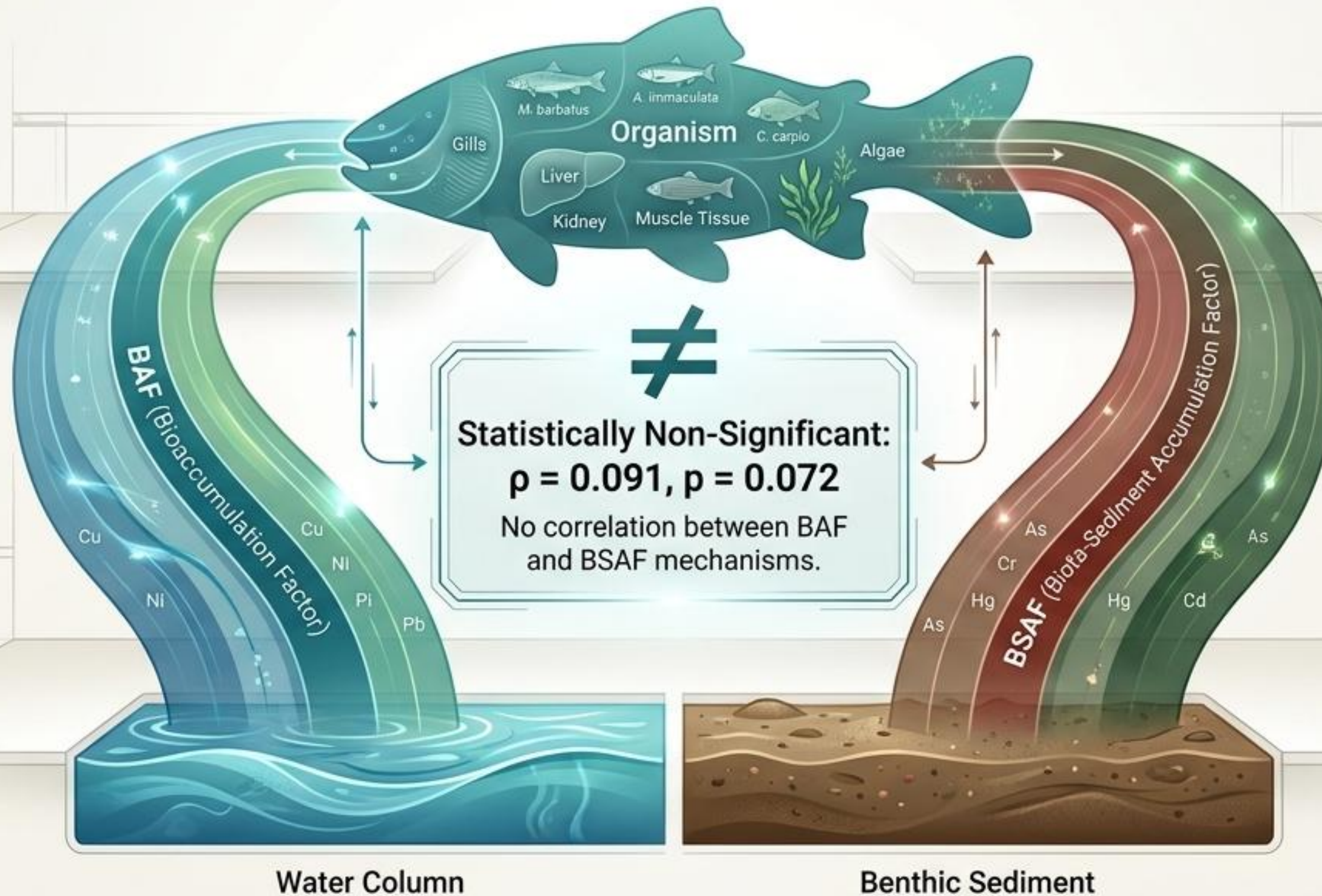
	Balık Lagoon	Kızılırmak River	Black Sea
Layer 1 (Sediment Load)	Highest [↑↑]	Moderate [→]	Lowest [↓]
Layer 2 (Biota Burden)	Moderate [→]	High [↑]	Extreme [↑↑]
Layer 3 (Human Risk)	Lowest [↓↓]	High [↑]	Extreme [↑↑]

Environmental loads are redistributed during biological transition, inverting the geographical risk map.

The Biological Filter Mechanism

Diverging Pathways: Water vs. Sediment Uptake

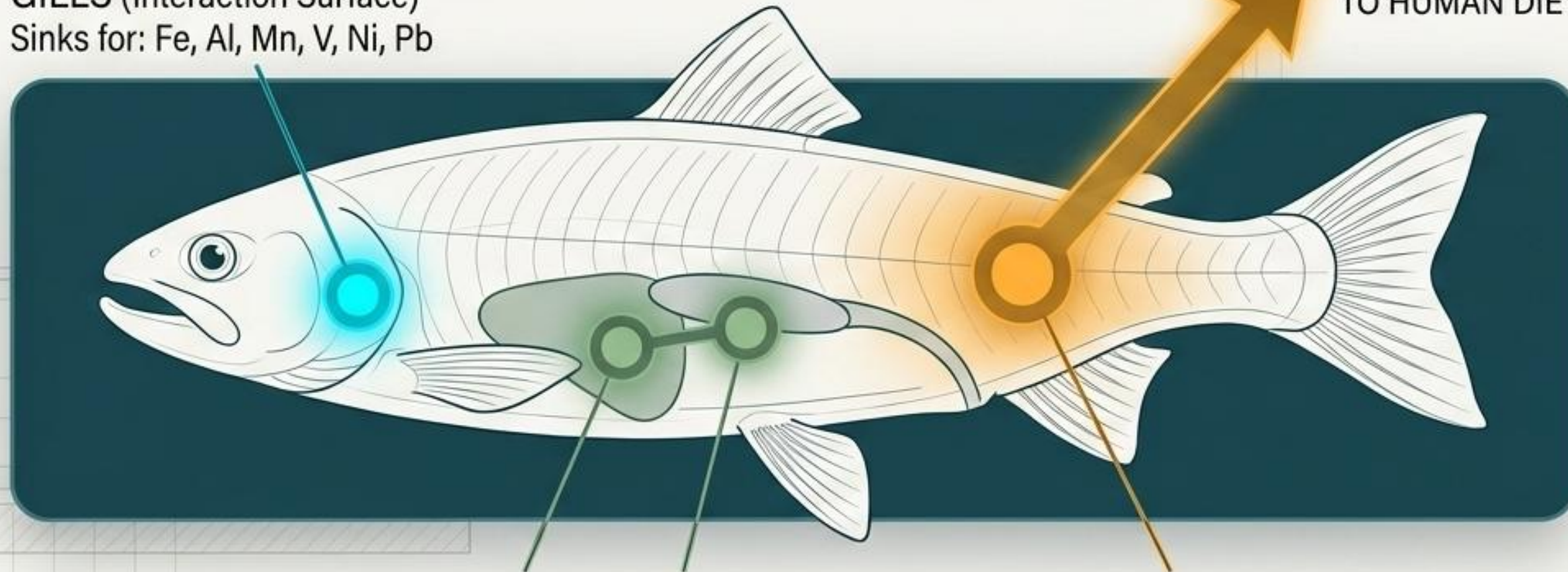
Mechanistic decoupling begins immediately at the organism's surface. There is no correlation between an element's accumulation from water and its accumulation from sediment. They are distinct pipelines.



The Organ Map: Physiological Sinks

Elements do not distribute evenly. They are partitioned based on metabolic activity and protein affinity. Because humans consume the muscle, Hg bypasses ecological detox centers directly into the human diet.

GILLS (Interaction Surface)
Sinks for: Fe, Al, Mn, V, Ni, Pb



DIRECT PATHWAY
TO HUMAN DIET

LIVER & KIDNEY (Detox Centers)
Sinks for: Cd, Mo, Sb (Kidney)
and Cu (Liver)

MUSCLE (Human Pathway)
Exclusive Sink for: Mercury (Hg)
A. derjugini muscle Hg BAF reached an extreme **10,331**.

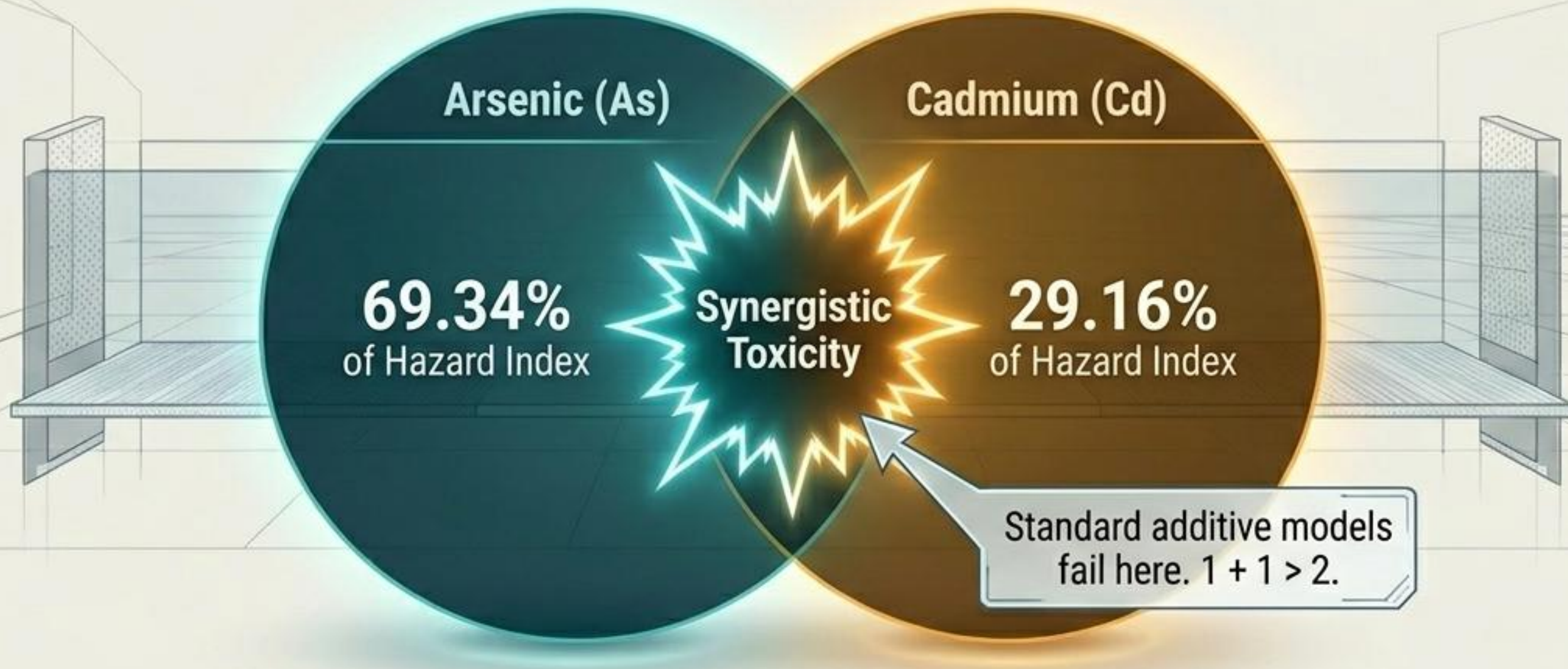
The Taxonomic Funnel: Trophic Level Dictates Burden

Metal Pollution Index (MPI) scores reveal a strict hierarchy. Bivalves act as massive sinks, effectively trapping environmental loads before they reach higher trophic levels.



The Hidden Multiplier: Synergistic Threats

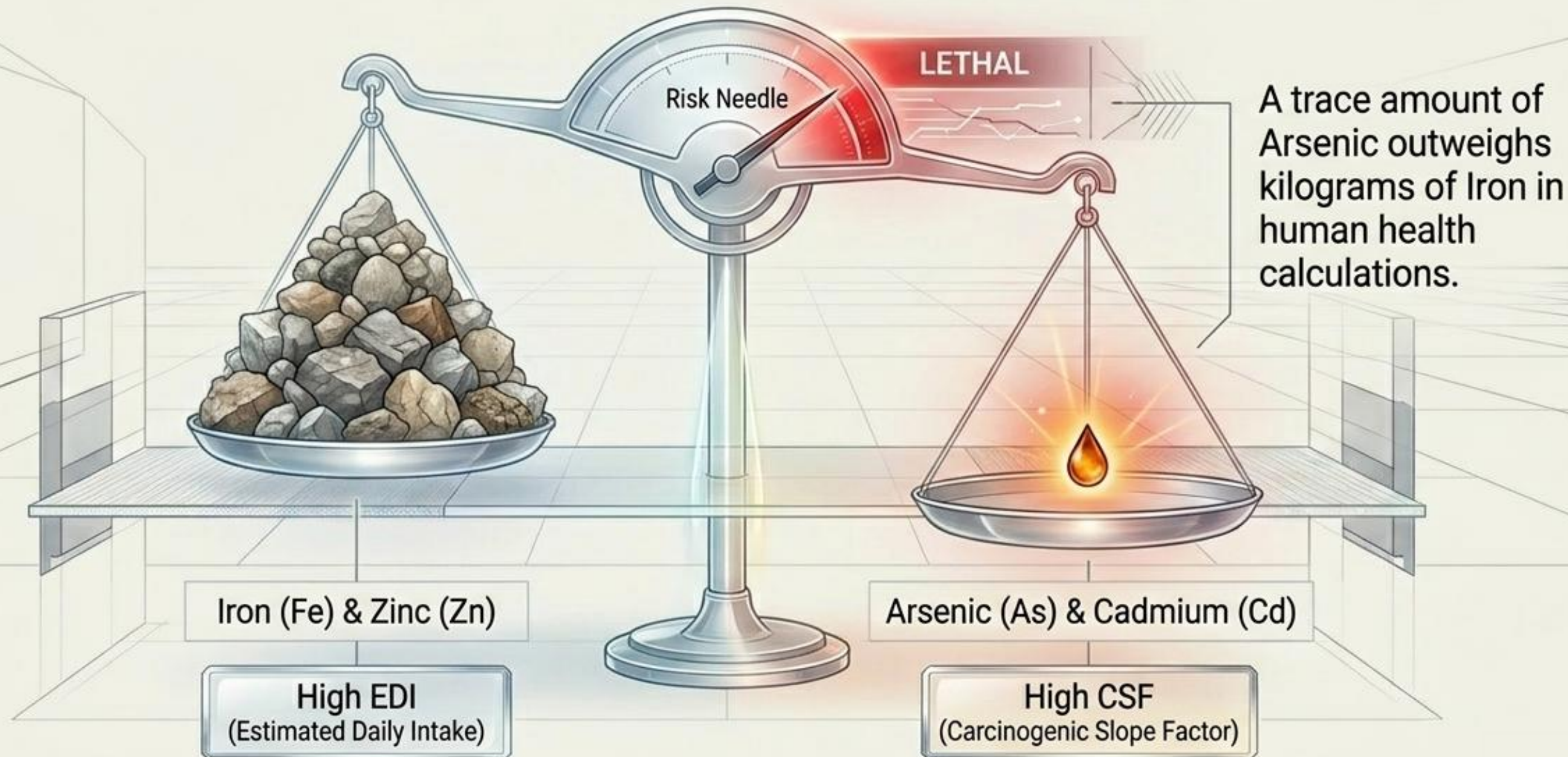
Standard models rely on simple addition. However, the co-occurrence of elevated Arsenic and Cadmium presents a known synergistic interaction, meaning current screening levels underestimate real-world danger.



Reference: *A. immaculata* in the Black Sea ecosystem.

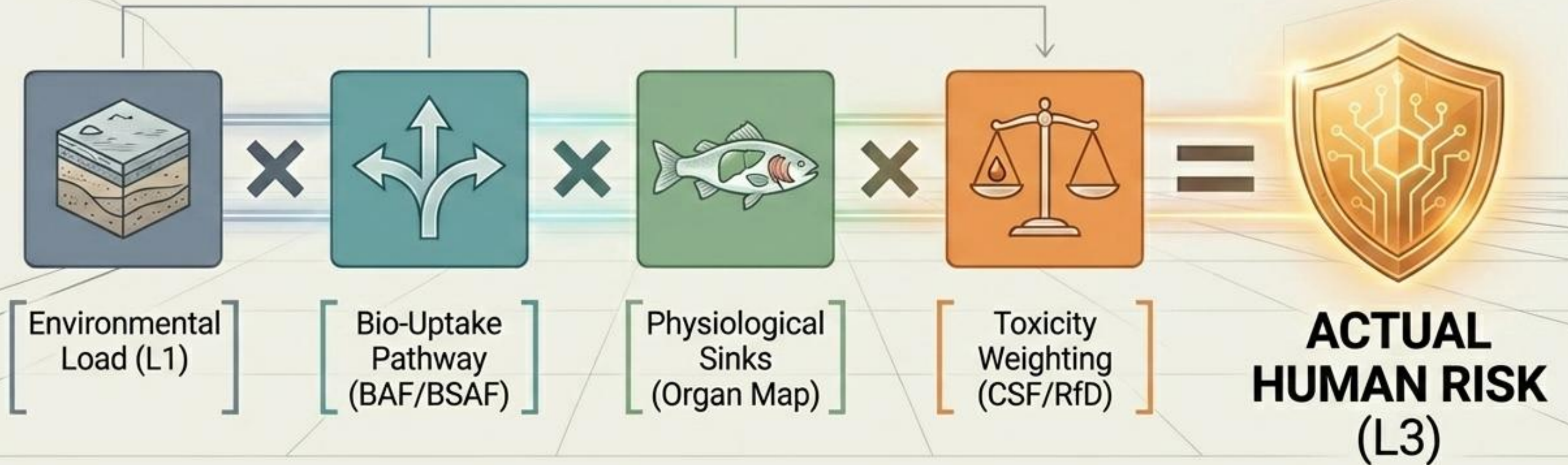
The Math of Risk: Toxicity Multipliers

Human risk is mathematically driven by specific elements with immense toxicity multipliers, rather than absolute environmental abundance.



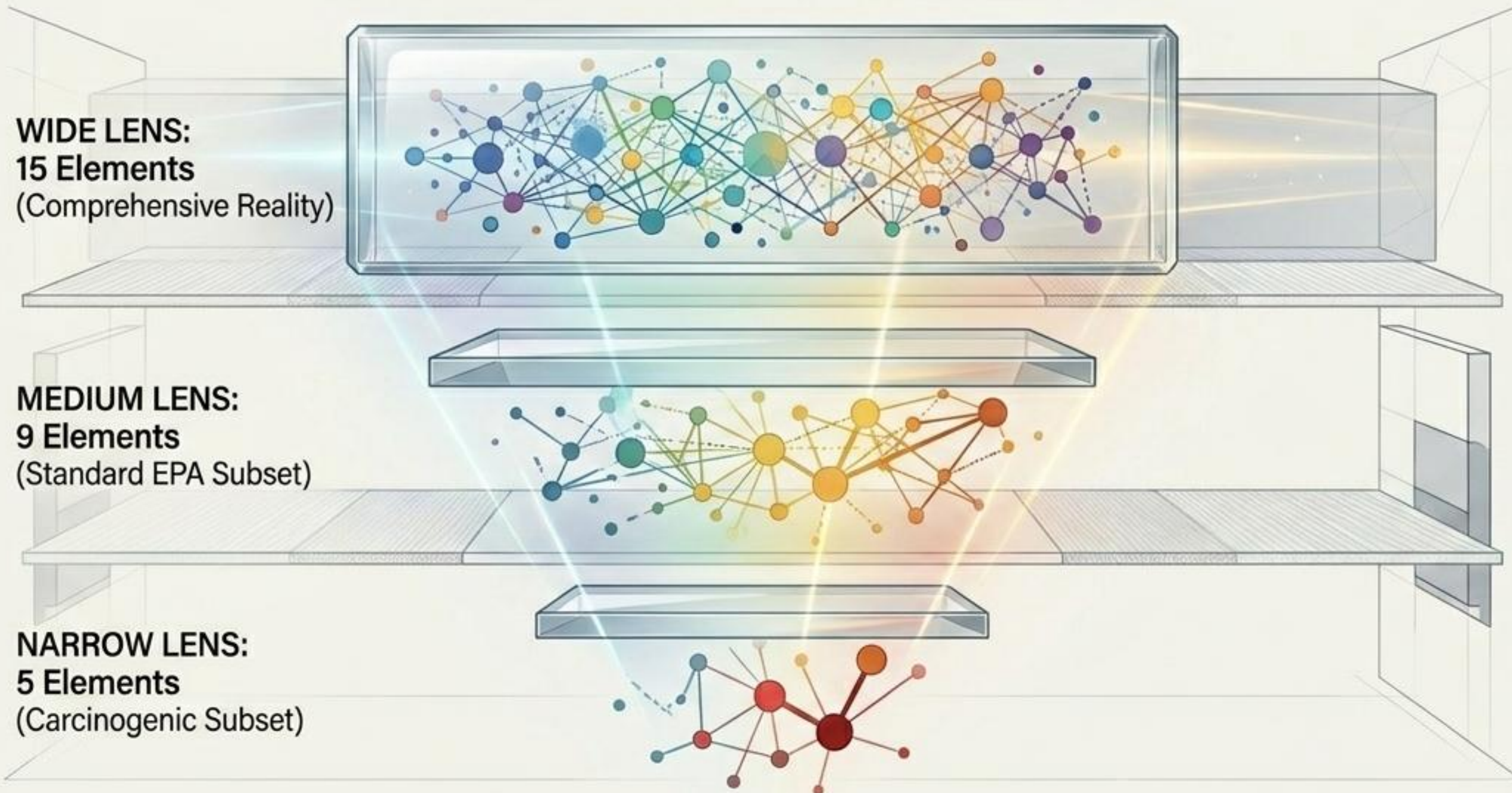
The Decoupling Blueprint: The Equation of Risk

Environmental contamination does not equal human risk.
Ecological loads are redistributed and amplified.



The Twist: The Analytical Spectrum Trap

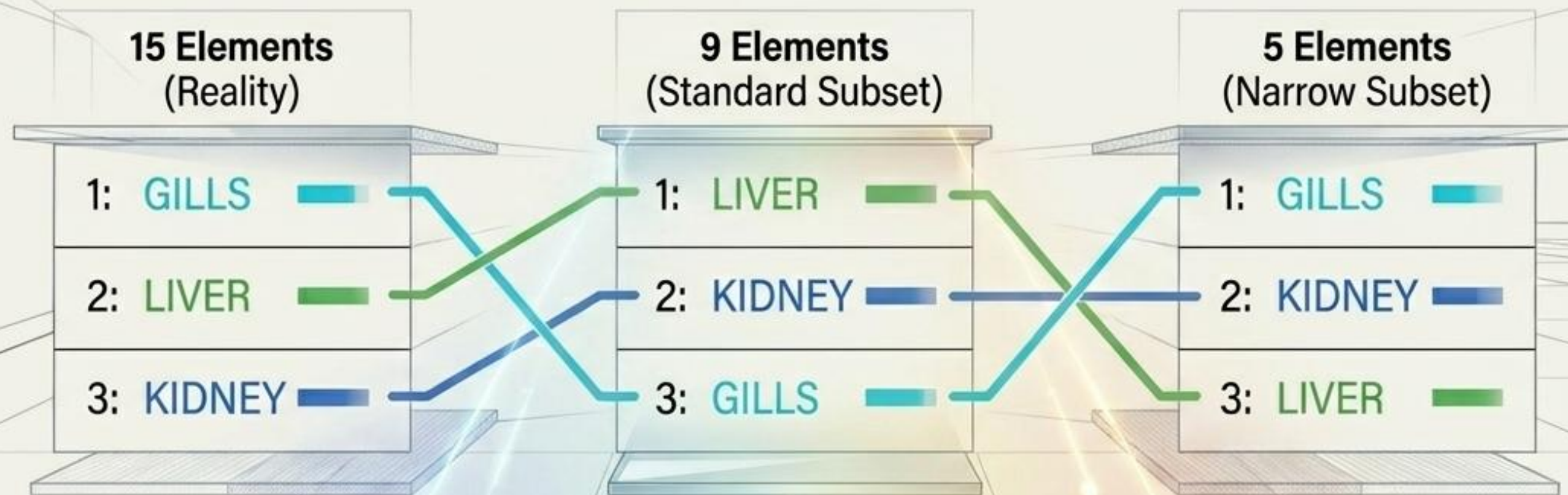
Does the number of elements we test change what we believe is true? Narrowed analytical spectra fundamentally distort perceived tissue hierarchies and risk profiles.



Narrowed Lenses Create False Realities

Reducing the analytical spectrum causes critical localized shifts, completely inverting the accumulation hierarchy in target species.

Target Species: *M. barbatus* (Marine)



Global correlations remain high ($p > 0.90$), creating a false sense of security while local realities invert.

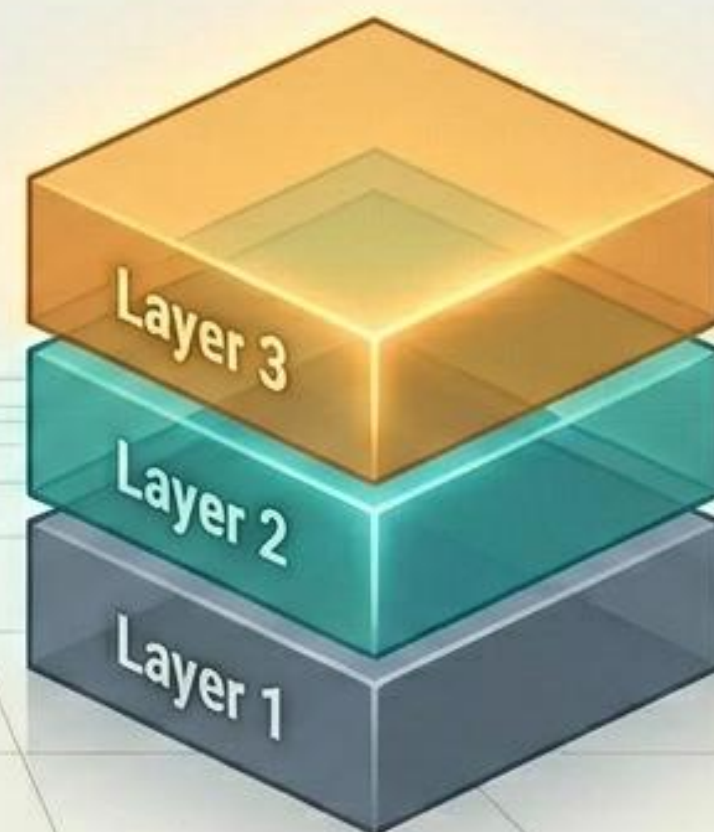
A New Mandate for Environmental Management

Metal(loid) loads in dynamic ecosystems cannot be reliably managed through single-matrix assessments. We must accurately map the path from environmental load to public health risk.



Single-Matrix Blindspots.

- Misdirects resources
- Misdiagnoses actual danger



Integrated Multi-Matrix Diagnostics.

- Captures biological filters
- Reflects true human exposure
- Prevents hotspot illusions



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Conclusion

- **Decoupling between sediment and health risk**
- **Lack of correlation between BAF and BSAF**
- **Questioning the reliability of the MPI index**





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