Tracking the footprints of new technologies: critical raw materials accumulation in north sea marine mammals

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The rapid advancement of technology, shifts in industrial practices, and the on-going global energy transition, have likely altered the distribution of trace elements in the North Sea, with potential implication for its ecosystem. Critical raw materials (CRMs)—elements that are economically indispensable and associated with high supply risks—play a pivotal role in the development of emerging technologies, including renewable energy, e-mobility, and defense systems[1]. However, the increasing demand for CRMs raises concerns regarding their potential impacts on marine ecosystems, particularly on trophic interactions within food webs. Marine mammals, such as harbour porpoises (*Phocoena phocoena*) and harbour seals (*Phoca vitulina*), are well-established bioindicators of trace element contamination due to their extended lifespans, high trophic positions, and reliance on coastal habitats[2]. This study investigates CRM accumulation patterns in these species, the tissues exhibiting the highest CRM concentration, and assesses temporal changes in CRM levels in harbour porpoises between two periods: 1999–2001 and 2019–2024.

The concentrations of 33 CRMs—including Li, Be, Al, Ti, V, Ge, As, Sr, Nb, Sb, Ta, Bi, Pt, In, Mn, Co, Ni, Cu, and the rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Y, Tb, Dy, Ho, Er, Yb, Lu, Sc)—as well as additional trace elements (Zn, Se, Mo, Cr, Cd, Sn, Ba, Tl, Pb, U), were quantified in the liver (n=55) and muscle (n=52) tissues of harbour porpoises and harbour seals from the southern North Sea. Analyses were performed using inductively coupled plasma–mass spectrometry (ICP-MS, Agilent 7900). The finding reveal that the liver accumulates higher CRM levels than the muscle in both species. For harbour porpoises, elevated concentrations of As, Bi, Cd, Ce, Co, Cu, Mn, Mo, Nd, Pb, Se, Sn, Sr, V, and Zn were observed in the liver. Similarly, harbour seals exhibited higher hepatic concentrations of Al, As, Cd, Co, Cr, Cu, Dy, Er, Eu, Gd, La, Mn, Mo, Pb, Se, Sr, V, Y, and Zn. Temporal analysis of harbour porpoise liver samples revealed substantial increases in Al, Nb, and Sb concentrations over time, although no consistent temporal trend was detected for rare earth elements (REEs). Notably, heavier REEs were absent in harbour porpoises, while harbour seals accumulated all REEs at higher levels, indicating their greater sensitivity to REE contamination. These results suggest that while both species are effective bioindicators of CRM contamination, harbour seals may provide more reliable insights into REE dynamics in the North Sea ecosystem. The observed temporal trends underscore the importance of monitoring CRMs to understand their ecological and environmental implications.

References

[1] Study on the Critical Raw Materials for the EU 2023 – Final Report
[2] Das, K., Siebert, U., Fontaine, M., Jauniaux, T., Holsbeek, L., & Bouquegneau, J. (2004b). Ecological and pathological factors related to trace metal concentrations in harbour porpoises Phocoena phocoena from the North Sea and adjacent areas. Marine Ecology Progress Series, 281, 283–295

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