Editorial: Further rare earth elements environmental dissemination: Observation, analysis, and impacts

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Editorial: Further rare earth elements environmental dissemination: Observation, analysis, and impacts

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Editorial on the Research Topic
Further rare earth elements environmental dissemination: Observation, analysis, and impacts

Thanks to their unique properties, the so-called "rare Earth elements" (REEs) are present in daily life technological devices in all sectors, including the high-tech, automotive, energy storage, and agricultural sectors. Many new technologies have been developed to limit greenhouse gases (wind turbines and hybrid cars, etc.); these are known as greentech products, which are based on the use of these strategic elements, hitherto in negligible quantities in the environment (e.g., REE). As a result, their dissemination pathways and threats to the population are poorly understood. Therefore, the corresponding exposomes are particularly poorly characterized. REE are thus qualified as emerging pollutants, and disruptions in their (bio) geochemical cycles have already been highlighted (e.g., Kulaksız, and Bau, 2007). The disturbances are expected to increase, since the growing development of green technologies will be accompanied by an increase in their extraction (i.e., their recycling is non-existent at present, since it is less profitable than their extraction).

In the European Union (EU), they are currently not extracted, even if some deposits have been identified in Denmark, Finland, Greece, Norway, and Sweden, and some are even being developed by mining companies (EURARE, 2017). The EU is reliant on REEs imports from overseas, mainly from China (McLead, 2019), which comes with related potential socio-economic implications due to the external dependence on such strategic raw materials. Currently, the One Health effects of REEs mining (i.e., those caused by ore mine tailings and active/abandoned mines), their use, and the end-of-life of products containing REEs, such as the alteration of their biogeochemical cycles, are still unknown.

This special issue aims to showcase a variety of perspectives in how REEs can be present into the environment and how REE can potentially interact with living organisms including human beings (Brouziotis et al., 2022a). It introduces a comprehensive, even if not exhaustive, collection of original research articles in topics including cerium (Ce) anomaly as a potential tracer for paleo-oceanic redox conditions (Cao et al., 2022), the impact of steel-making activities (Hissler et al.), the methodological set-up for REEs identification in urine samples (Brouziotis et al.), the application of exposure-related effects to biological models focusing on photosynthetic organisms (Gjata et al.; Siciliano et al.), and an integrated environmental risk assessment on aquatic ecosystems (Lachaux et al.).

Brouziotis et al. provide a comprehensive review on the potential human health impact caused by direct and indirect exposure to REEs. Indirect exposure events occur mainly at the environmental and occupational levels, as well as in cases of contaminated food intake, while direct exposure is mainly related to gadolinium (Gd) as a magnetic resonance imaging contrast agent. The overview proves that REEs can alter the production of reactive oxygen species, potentially inducing DNA and cell damage, including cell death, and presenting higher toxicity to cancer cells.

Cao et al. investigate how cerium anomaly in marine sediment can be used to reconstruct the redox conditions in paleo-oceanic environments to understand the Earth's biogeochemical evolution *via* a thermodynamic-based oxidation model. The results suggest that cerium anomaly is not sensitive to changes in dissolved oxygen in oxic environments but is well-correlated with anoxic ones.

Hissler et al. present a study about how REEs and yttrium (Y) (REY) can impact riverine suspended matter and the related sediment, especially in the presence of past steel-making activities. Specific lanthanum (La)/Gd, La/lutetium (Lu), and Y/holmium (Ho) ratios identify the strong heritage of the iron used in the steel factory, which also includes REY enrichments (Ey>Yb>Sm>Ce>Tm). REY compositions also permit the interpretation of the evolution of sediment composition in parallel with the end of industrial activity in an area, where the sediment shifts from the waste origin to a pure natural one in cases of local soil erosion.

Brouziotis et al. highlight the importance of analyzing REEs in human urine samples in biomonitoring studies through inductively coupled plasma mass spectrometry methods. A simple dilution method was compared to microwave-assisted acid decomposition, confirming that both methods are effective (recovery close to 100%) for the determination of REEs levels in human urine.

Siciliano et al. investigate the potential effect of La, Ce, neodymium (Nd), samarium (Sm), europium (Eu), Gd, dysprosium (Dy), and erbium (Er) on the marine diatom *Phaeodactylum tricornutum* Bohlin, considering growth inhibition as the endpoint. The median effect concentrations (EC50) ranged between 0.98 and 13.21 mg/L, in which Gd and Sm were the most and least toxic, in that order. The comparison between the predicted no-effect concentrations and measured environmental concentrations shows a potential limited risk just for estuarine environments.

Gjata et al. present data about the cytological alteration caused by Ce and Nd to lentil (*Lens culinaris* Medik.) seedlings and onion bulbs (*Allium cepa* L.), including the growth rate, biomarkers of stress, and mitotic changes. The results indicate the presence of mitotic aberrations in the root tissues in both the biological models and elements, with levels of reactive oxygen species and malondialdehyde proportional to the exposure concentrations.

Lachaux et al. explore the potential mixture effect of Nd, Gd, and Yb in the presence of dissolved organic matter (DOM) targeting freshwater species such as microalgae, crustaceans, and fish. The results show that DOM can significantly reduce REEs bioaccumulation and toxicity and provide evidence for similar additive effects in all the investigated species, with the risk of REEs mainly limited to wastewater treatment plants and mining activities.

The guest editors would like to thank all the authors and reviewers for their work and devotion to the Research Topic and hope that it can inspire further research about how rare Earth elements target biogeochemical alterations and their effects on a One Health basis.

Author contributions

This editorial was drafted by GL and MD and revised by all co-authors.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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