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Foreword to the Special Issue on 'Technology Critical Elements'

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Technology critical elements (TCEs) are a set of chemical elements often incorporated in high-tech applications and products. TCEs comprise the rare earth elements (REEs), the platinum group elements (PGEs), and others such as Ga, Ge, In, Nb, Sb, Ta, Te, and Tl (Gunn 2014). The rapidly increasing rate of production and use of TCEs has raised interest in their environmental and (eco)toxicological implications (Cobelo-García et al. 2015). This issue of *Environmental Chemistry* brings together articles that focus on the analysis, sources, fate and impact of various TCEs in the environment.

TCEs are generally present in the environment at ultra-trace concentrations. Therefore, highly selective and sensitive analytical techniques are needed to assess the extent to which their use in new technologies may influence their environmental impact. Unfortunately, the analytical tools available for measuring many of the TCEs have more limitations than generally thought (Cobelo-García and Filella 2017; Filella and Rodushkin 2018) and the development of adapted methods is necessary. In this issue, voltammetric-based methods are described for Pt (Pađan et al. 2020) and Te (Biver and Filella 2020), two of the most problematic TCEs from the analytical point of view.

Identifying TCE sources is a necessary first step in the evaluation of the impact of new technologies and requires a good understanding of TCE geochemistry. Environmental sources of TCEs are numerous and not necessarily directly linked to the mining and current uses of TCEs. For instance, coal burning and base metals mining and smelting have been identified as the potential main sources of some elements (Filella and Rodríguez-Murillo 2017). The difficulties involved in source identification are nicely exemplified by the study of Ruiz Cánovas et al. (2020) on the mobility of some TCEs (REEs, Sc, Y, Ga and Tl) in acid mine drainage from a sulfide underground mine in south-west Spain. That study shows that, contrary to what would be expected, TCE concentrations were controlled by the intensity of chemical weathering inside the mined zone rather than by the precipitation of secondary minerals. Abdou et al. (2020) attributed spatial distribution of dissolved and particulate Pt in a harbour to different Pt sources such as hospitals, domestic and industrial wastewater, atmospheric deposition and road runoff. They further suggested the use of Pt as a tracer of anthropogenic inputs in coastal systems.

The transport and fate of TCEs in the different environmental compartments depend on their interactions with other components present such as inorganic and organic ligands, mineral particles and microorganisms. Existing data on subsurface porous media (e.g. soil and aquifers) are reviewed in detail by Kouhail et al. (2020). Results from laboratory and field experiments show an enhanced transport of REEs and In in the presence of natural organic matter (NOM), with other mechanisms (e.g. colloid-assisted transport, REE sorption and dissolution) also playing a role in TCE mobility. The use of the binding of REEs by NOM to fingerprint the origin of various NOM types has been developed by Catrouillet et al. (2020). Tipping and Filella (2020) used linear free energy relationships to estimate the equilibrium constants needed to incorporate Ga, In, Sb^{III} and Bi in *WHAM7* and then used these constants to model the chemical speciation of each TCE element in surface waters.

Magdas et al. (2020) explore the potential use of REEs as tracers; in this case, as markers for geographical discrimination as a function of food matrix. The efficiency of the REEs' profiling is most effective for unprocessed food matrices (e.g. vegetables, fruits and meat) while the highest discrimination potential is provided by light REEs.

As shown in Rahmawati et al. (2020), knowledge of the solution chemistry of TCEs is needed for the development of remediation and recycling methods. In that study, the extraction of In from waste using a subcritical water extraction with organic acids was compared with conventional methods employing concentrated mineral acids.

Mechanisms and effects of TCE exposure are also discussed in this Special Issue. Vedeanu et al. (2020) co-exposed rats to low doses of Ru^{III} and Ag by oral administration for 28 days and found that the only observed impacts were an increase in red cell distribution width values (female rats) and a decrease of Ag urinary excretion and of Ag concentration in kidneys (male rats). The potentially harmful effects of Sb to organisms are studied in two biological models: the Sb^{V} pro-inflammatory response in macrophages (Canto et al. 2020) and the effect of Sb^{III} on cell integrity, expression of profibrotic factors and reactive oxygen species (ROS) in mouse cortical collecting duct cells (Roldán et al. 2020).

Bioremediation and methods of exposure assessment are explored for REEs and Tl. Preferential accumulation of light over heavy REEs was observed by Grosjean et al. (2020) when studying exposure to REEs in 49 different hardy fern species for phytoremediation purposes. The different responses observed in different ferns could lead to the use of a particular fern according to the area to be remediated. Mijošek et al. (2020) found that trends of spatial and temporal Tl variability were mostly comparable in the intestines of all salmonid and cyprinid fish species studied. This observation confirms the use of total and cytosolic Tl as a useful biological tool in fish exposure assessment.

We hope that these studies will provide a valuable base for further research on these elements. We thank the authors and referees for their contributions to this Special Issue.

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Conflicts of interest

The authors declare no conflicts of interest.

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