

DISPERSION AND MOBILITY OF TECHNOLOGY-CRITICAL ELEMENTS IN THE AQUATIC ENVIRONMENT AND SEDIMENTS OF THE FLANDERS SCHELDT ESTUARY

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Introduction

In assessing the necessary input factors for an envisioned sustainable economy, a list of metals is considered essential. The so-called technology-critical elements (TCEs) consist of gallium, germanium, indium, tellurium, niobium, tantalum, tellurium and thallium, besides the Platinum Group Elements and rare-earth elements (Cobelo-García et al., 2015). Their use in technologic applications rapidly led to a dispersion in the aquatic and terrestrial environment. Elevated levels of Platinum Group Elements for example have been detected in urban areas all over Europe (Rauch et al., 2005).

Concerns about the effects of TCE exposure on human are rising. The acute toxicity of Nb³⁺ and Tl³⁺ was shown earlier (Haley et al., 1962; Ralph and Twiss, 2002). While intrinsically less toxic, Ga³⁺ and In³⁺ are able to bind human serum transferrin and concentrate in tissues (Castronovo and Wagner, 1971). Information on the exposure is however incomplete to fully comprehend the associated risks (Fillela et al., 2014). This study monitored, on the one hand, the dispersion of TCEs in the Scheldt estuary and near industrial sites in Flanders, and on the other hand determined the mobility and availability of the elements through leaching.

Methods

Water (n = 30) and sediment (n = 90) samples were collected along the Belgian part of the Scheldt estuary. In total, 10 locations between Kastel and Doel were considered and sampled in triplicate. The sediment samples were taken at the depth of 0-5 cm, 5-15 cm and 15-80 cm.

In addition, soil samples (n = 30) in the vicinity of 2 industrial metal processing sites were taken, namely at Olen (51°10' N, 4°52' E) and Balen (51°11' N, 5°13' E). Prevalent wind directions were taken into account to monitor different locations and corresponding degrees of dispersion on that axis. To study the mobility of the selected elements, successive rhizon extracts were taken from each soil and sediment as well.

Water samples were filtered through cellulose microfilters of 0.45 µm pore size. Soil and sediment samples were dried, grinded and sieved over 1 mm, before 0.5 g was weighted and digested with Aqua Regia upon heating. All solutions were consecutively analyzed for niobium, tantalum, indium and thallium concentrations by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS).

Results and Discussion

The presence of niobium, tantalum, indium and thallium was demonstrated in the studied terrestrial environment (Table 1). The obtained values contribute to the mapping of technology-critical elements, since very little is known on reference concentrations in literature, especially for niobium and tantalum. We observed significant concentrations for niobium and tantalum in the soil and sediments of the Scheldt estuary. The low relative standard deviation of 4.7 % and 10.4 % for Nb over the different locations indicates a homogenous distribution in the top soil and sediments respectively. Indium, on the other hand, is marked by enrichments in the soil at locations near industrial sites, clearly indicating point sources. This

anthropologic proliferation of indium, mainly through atmospheric deposition, was demonstrated earlier by Tessier et al. (2014). The high soil concentrations of thallium, meanwhile, could imply a potential risk, given its extremely high toxicity. Rhizon extracts however revealed that the element is immobile and less than 0.1 % was leached after 3 days.

Table 1. Presence of technology-critical elements niobium, tantalum, indium and thallium in the soil between 0 and 5 cm, sediments, ground- and surface waters. Observations for the surface waters sampled in the Scheldt estuary were all below the limit of detection of the direct spectrometric method.

Element concentrations	Niobium	Tantalum	Indium	Thallium
Soil ($\mu\text{g kg}^{-1}$)	245 \pm 11	45 \pm 25	69 \pm 74	963 \pm 32
Sediment ($\mu\text{g kg}^{-1}$)	569 \pm 59	39 \pm 10	38 \pm 1	28 \pm 2
			0.05 – 0.22 ^b	0.69 ^d
			0.06 – 0.73 ^b	0.58 ^d
Groundwater ($\mu\text{g L}^{-1}$)			9.3 ^c	506-770 ^d
			20.1 ^b	
Surface water ($\mu\text{g L}^{-1}$)	< 0.4	< 0.2	< 0.03	< 0.88
	0.0004 – 0.0007 ^a	0.0001 ^a	0.0000 - 0.0004 ^b	

^a Firdaus et al. (2008), ^b Tessier et al. (2014), ^c Chen (2006), ^d Liqin et al. (2012)

References

- Chen, H. (2006). Gallium, Indium, and Arsenic Pollution of Groundwater from a Semiconductor Manufacturing Area of Taiwan. *Bulletin of Environmental Contamination and Toxicology*, 77(2), 289-296.
- Cobelo-García, A.; Filella, M.; Croot, P.; Frazzoli, C.; Du Laing, G.; Ospina-Alvarez, N.; Rauch, S.; Salaun, P.; Schäfer, J.; Zimmermann, S. (2015). COST action TD1407: network on technology-critical elements (NOTICE) – from environmental processes to human health threats. *Environ. Sci. Pollut. Res.*, 22(19), 15188-15194.
- Filella, M.; Magnenat, D.-J.; Bensimon, M. (2014). Direct determination of niobium at the low nanogram level in mineral waters and freshwaters. *Anal Methods*, 6, 8090-8093.
- Firdaus, M. L.; Norisuye, K.; Nakagawa, Y.; Nakatsuka, S.; Sohrin, Y. (2008). Dissolved and labile particulate Zr, Hf, Nb, Ta, Mo and W in the western North Pacific Ocean. *Journal of Oceanography*, 64(2), 247-257.
- Liqin, D.; Song, J.; Li, X.; Yuan, H.; Li, N.; Xu, Y. (2012). Thallium concentrations and sources in the surface sediments of Bohai Bay. *Marine Environmental Research*, 73, 25-31.
- Rauch, S.; Hemond, H.F.; Barbante, C.; Owari, M.; Morrison, G.M. (2005). Importance of automobile exhaust catalyst emissions for the deposition of platinum, palladium, and rhodium in the northern hemisphere. *Environ Sci Technol*, 39, 8156-8162.
- Tessier, A.; Gobeil, C.; Laforte, L. (2014). Reaction rates, depositional history and sources of indium in sediments from Appalachian and Canadian Shield lakes. *Geochimica Et Cosmochimica Acta*, 137, 48-63.