

Tracing anthropogenic Gd from the Baltic Sea and North Sea in Norwegian fjords

ANNA-LENA ZOCHER¹, TOMASZ M. CIESIELSKI^{2,3},
STEFANIA PIARULLI⁴, JULIA FARKAS⁴ AND MICHAEL
BAU⁵

¹School of Science, Constructor University Bremen gGmbH

²Norwegian University of Science and Technology

³The University Centre in Svalbard (UNIS)

⁴SINTEF Ocean

⁵School of Science, Constructor University Bremen

The occurrence of anthropogenic rare earth elements and yttrium (REY) in the environment receives increasing attention due to their potential impact on ecosystems and entrance into the food chain. Since the first evidence of anthropogenic Gd in river water in 1996 [1], anthropogenic Gd enrichments, which can be easily identified as positive anomalies in shale-normalised ($_{SN}$) REY patterns, have been observed in many waters worldwide. This contamination originates from the use of Gd in Gd-based contrast agents for magnetic resonance imaging. Despite its ubiquity, not much is known about anthropogenic Gd in the Baltic Sea and its outflow.

We here present dissolved REY data for water samples from the coasts of Sweden, Denmark and Norway. Samples from the Baltic Sea outflow were collected over a period of one year and show for the first time that anthropogenic Gd is permanently present in these waters. Moreover, these findings reveal that anthropogenic Gd is transported from the Baltic Sea into the Skagerrak towards the Norwegian coast. This is corroborated by REY data for coastal waters from southern Norway and for the Trondheimfjord in central Norway. Independent of the location, deeper samples from the fjords always show lower REY concentrations than shallow water samples. The REY $_{SN}$ patterns of most Norwegian fjord and bay waters show typical seawater-like signatures but are less fractionated between light and middle REY. Only shallow water samples taken close to estuaries are characterised by different REY $_{SN}$ patterns, whose flat shape reflects the incoming river water that is rich in nanoparticles and colloids. In accordance with the observations in the Baltic Sea outflow, a few samples collected in southern Norway clearly show anthropogenic positive Gd $_{SN}$ anomalies. This signal is most likely not caused by local inputs but primarily originates from the Baltic Sea and additional input from the southern North Sea [2]. In the Trondheimfjord further to the north, the Gd/Tb ratio is also elevated relative to North Atlantic water, however, the anomalous Gd enrichment is less pronounced.

[1] Bau & Dulski (1996), *Earth Planet. Sci. Lett.* 143, 245–255.

[2] Kraemer et al. (2024), *Mar. Pollut. Bull.* 207, 116794.