

The rivers Vistula and Oder and the gadolinium microcontamination of the Baltic Sea

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Rare earth elements and yttrium (REY) are environmental contaminants due to their wide use in enabling technologies. Anthropogenic Gd from Gd-based contrast agents (GBCAs) used in medical diagnostics has become a worldwide concern. Contamination of coastal seawater with GBCAs has been documented for the North Sea and the outflow of the Baltic Sea. However, the source(s) of this anthropogenic Gd in the Baltic Sea are not yet known. Hence, our study explores the distribution of REY in the two largest Polish rivers, the Oder and the Vistula, along with some of their tributaries. The Oder and the Vistula rivers are by discharge the sixth and second largest rivers, respectively, entering the Baltic Sea. Therefore, they are responsible for a significant portion of the pollutant flux into the Baltic Sea and from there into the Kattegat and further north.

We report significant Gd contamination of all rivers studied as shown by large positive Gd anomalies (Gd_{SN}/Gd^*_{SN} : 4.92 to 44.6). These anomalies reveal the omnipresence of anthropogenic Gd which makes up >90% of the total Gd inventory in these rivers. Considering that the number of MRI scans is expected to increase further, better understanding of the behavior of anthropogenic Gd in the environment is a pressing issue. Ultrafiltration shows that this Gd is truly dissolved and not associated with nanoparticles and colloids. Hence, its physical speciation is in marked contrast to that of the highly particle-reactive geogenic REY. As the anthropogenic Gd is released from wastewater treatment plants, its presence in river, ground, tap and seawater strongly suggests a high probability of contamination with other waste water-derived substances such as pharmaceuticals, endocrine disruptors and hormones. This not only affects riverine ecosystems but also ground and drinking water quality, and has numerous ramifications for coastal seawater (e.g., ecosystems, aquacultures, etc.). A rough estimate of the annual flux suggests that the Oder and Vistula rivers alone account for the input of about 1 tonne of anthropogenic Gd per year into the Baltic Sea, suggesting that anthropogenic Gd levels in the Baltic Sea should be monitored to protect ecological integrity in the Baltic Sea.