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Impact of the City of Vienna on Temporal Concentration Patterns of Rare Earth Elements

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Due to the consumption of rare earth elements (REE) in the high-tech industry and its use in the medical sector REE such as Gadolinium (Gd) have emerged as contaminants in aquatic environments. A broader application of medical services and a rising need for high-tech products led to an increased release of REE into the environment. Positive anomalies of specific REE have been observed in numerous rivers and surface waters in Europe, Asia, Australia, North and South America; in recent years, contamination with anthropogenically used REE have been reported for coastal seawater, groundwater and tap water of metropolitan areas. Less, however, is known about the temporal concentration patterns of anthropogenically influenced concentrations of REE in rivers downstream of large cities. For this study concentration patterns of REE were measured in the river Danube upstream and downstream of the City of Vienna. The mass flow of Gd determined by the measured Gd concentrations was compared to calculations with data from health insurances companies.

Results show a pronounced pattern for anthropogenic gadolinium (Gd_{anth}). In the river Danube downstream of Vienna, on a daily basis the lowest concentrations were observed at 11 AM before steadily increasing until 7 PM. In the course of one week, lowest concentrations were measured on Sunday and Monday; the concentration steadily increased from Monday until Thursday before decreasing again until Sunday. Upstream of Vienna, no temporal concentration pattern could be observed. The influence of the city of Vienna on the concentration patterns of Gd_{anth} in the river can be clearly seen. Based on the measured average concentrations the mass flow of Gd_{anth} and the impact of Vienna on the river Danube were determined. 1928 g d^{-1} of Gd_{anth} are transported in the Danube upstream of Vienna; downstream of Vienna 2508 g d^{-1} are transported. Beside the measured Gd concentrations, calculations based on the number of magnetic resonance imaging (MRI) applications (with Gd used as contrast agent) performed in Vienna in the month of the sampling were done. The calculated input for the City of Vienna and for the whole Metropolitan Area, is matching well with the determinations from the measured concentrations.

This study provides essential information about the concentration patterns of REE in the river Danube affected by the metropolitan area of Vienna in a high temporal resolution. Further we could prove that calculations of the additional mass flow of Gd_{anth} in rivers flowing through metropolitan areas of highly developed countries by using the number of MRI applications conducted in the city is a reasonable and valid way to estimate local concentration ranges in rivers.