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Assessing Human Imprints on Trace Element Fluxes in the Great Lakes

F. Jacob Pinter, Colton Bentley, and Bas Vriens
Department of Geological Sciences and Geological Engineering, Queen's University

The extraction and use of rare earth elements, platinum group elements and other trace metals is growing exponentially around the world. The occurrence of these trace elements in anthropogenic waste streams is increasing correspondingly. Yet, conclusive data on trace element concentrations in urban runoff and wastewater is scarce as these elements are typically not part of governmental surveillance programs and barely environmentally regulated. The human imprints on natural trace element fluxes and their potential environmental impacts therefore remain poorly quantified. We are working to quantify natural and anthropogenic trace element fluxes in the Great Lakes basin. The Great Lakes basin provides a globally unique setting to investigate human imprints on large-scale elemental cycling because it houses >60 million people, contains >20% of the world's freshwater, and is divided into serially connected sub-basins that facilitate environmental system analyses at various scales.

First, we established baseline estimates of current (natural) trace element fluxes in the Great Lakes by aggregating hydrometric and water quality data in simplified black-box mass-balances and dynamic reactor models. These models were informed by >100,000 hydrometric and >50,000 water quality measurements collected across the Great Lakes between 1980-2020 and were calibrated to existing long-term water level and water chemistry records. The bulk of the incorporated data stems from Canadian and US federal and provincial and state monitoring programs, including publicly available datasets from NOAA, EPA, ECCC, Ontario and Michigan state, municipalities, and local conservation authorities. Mass-balance could be achieved up to 94% for conservative elements (Cl, Na), while our dynamic models reveal significantly different source/sink behavior across the upper and lower lakes for more reactive elements. We are currently expanding our models with new ultra-trace level analyses of recent freshwater samples from cruise expeditions, major tributary rivers, and precipitation, as well as sediment records.

Second, we considered municipal and industrial wastewater as a proxy for human activity. We collected and analyzed wastewater effluent and digested sludge samples from >40 US and Canadian wastewater treatment facilities (WWTF) and estimated, for >20 trace elements, average discharge rates into the Great Lakes basin. We compared average wastewater-effluent loads with large-scale natural biogeochemical fluxes in the Great Lakes, allowing us to rank the analyzed trace elements as well as individual lakes and tributaries by their apparent human imprint. Our results show anomalously high loading rates for select rare earth elements and precious metals in several tributary systems. Geospatial attributes of the sampled sewersheds (demographics, land use, industrial activity) serve as independent variables in our ongoing effort to source-track these anomalous loads and establish human imprints on catchment tributaries further upstream.