Deciphering the Ages of Saline Water in the Baltic Sea by Anthropogenic Radiotracers

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Figure 1. Simulated input function of reprocessing-derived ^{129}I/^{236}U ratio in the Baltic inflowing water (Arkona Basin: 54.93 ºN, 13.54 ºE; depth=45m). The ^{129}I discharge data are from HELCOM/OSPAR discharge database, and The ^{236}U discharge data are reconstructed by Castrillejo et al. (2020).

The slow water renewal of the Baltic Sea endows a strong "memory effect" retaining excessive pollutants and nutrients for decades. Deciphering the water ages of the Baltic Sea is of particular importance to understand the hydrodynamics of the Baltic Sea and the associated impacts on pollutant/nutrient dynamics. Even though the circulation timescale of the Baltic Sea has been resolved by 3D ocean model (Meier, 2007), the estimated water ages have never been directly verified due to the lack of suitable age tracers.

In this work, we estimated the ages of saline water in the Baltic Sea using two long-lived anthropogenic radionuclides ^{129}I and ^{236}U released from two European nuclear reprocessing plants. Based on a 47-year hindcast simulation (1971-2017) with a 3D ocean model HBM, a monotonically increasing input function was established for the reprocessing-derived ^{129}I/^{236}U ratio in the Baltic inflowing saline waters (**Figure 1**). The ages of saline water in the major sub-basins of the Baltic Sea were thereby constrained according to the observations of ^{129}I and reactor-derived ^{236}U in 2015-2019 (Qiao et al., 2021; Lin et al., 2022).

In general, the distributions of reprocessing-derived ^{129}I/^{236}U ratios and tracer ages show a highly stratified structure in the Baltic Sea (**Figure 2**). In the southern and central Baltic Sea, the surface water are about 10 years older than the bottom water, suggesting that the upwelling and dilution of saline water are rather slow processes in the central Baltic Sea. This work not only provides the first observation-based results for the water ages in the Baltic Sea, but also demonstrates the great power of anthropogenic ^{129}I and ^{236}U as oceanic tracers on investigating hydrodynamic processes of the Baltic Sea.

Figure 2. Distributions of reprocessing-derived ^{129}I/^{236}U ratio (A) and estimated ages of saline water (B) in a transect from the Arkona Basin to Gulf of Finland in 2015-2019. The reprocessing-derived ^{129}I/^{236}U ratio ($R_{RP}^{129/236}$) is derived from the measured concentrations of ^{129}I, ^{236}U, and ^{233}U (c_{I-129}, c_{U-236}, and c_{U-233}; atoms/L) using the following equation: $R_{RP}^{129/236} = c_{I-129}/(c_{U-236} - \frac{c_{U-233}}{0.014})$.

References

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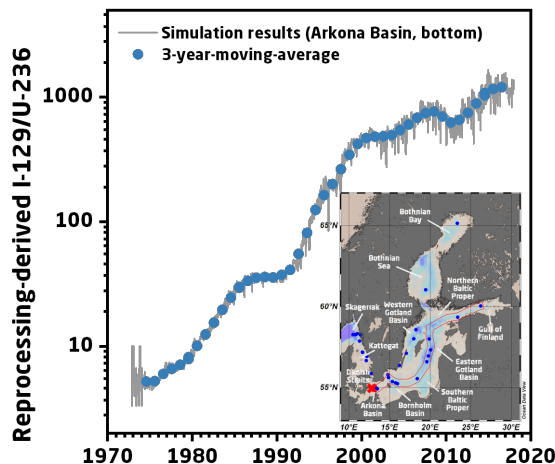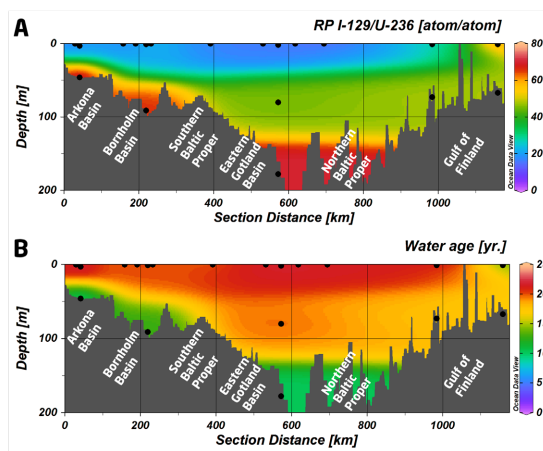Lin, M., et al. Anthropogenic ^{236}U and ^{233}U in the Baltic Sea: Distributions, source terms, and budgets. *Water Research*, 2022, 210: 117987.