Radium isotopes as a tracer of sediment-water column exchange in the North Sea

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Sediment-water column exchange plays an important role in coastal biogeochemistry. We utilize short-lived Radium isotopes to understand and quantify the dominant processes governing sediment-water column exchange throughout the North Sea. Our comprehensive survey, conducted in September 2011, represents the first of its kind conducted in the North Sea, and to the best of our knowledge, in any other region. Two main sources regulate surface Ra distributions: minor coastal input from rivers and shallow mudflats, and underlying sediments as the dominant source. Porewaters show 100-fold larger activities than the water column. Large Ra enrichments were observed in the overlying water column following sediment incubations, allowing us to quantify benthic Ra fluxes. Sediment characteristics such as porosity, mean grain size, and turbulence at the sediment-water interface, are dominant factors contributing to variability of Ra efflux. Ra inventory and mass-balance approaches consistently yield high benthic Ra effluxes in the Southern North Sea, driven by strong tidal and wind mixing, which in turn cause high sediment irrigation rates. Our results exceed incubation-based Ra flux estimates, and the majority of previously reported Ra flux estimates for other regions. Ra-based estimates of benthic alkalinity fluxes compare well to observed values and the high rates of Ra efflux imply a potentially significant exchange of other products of sedimentary reactions, including oxygen, carbon and nutrient species. Passive tracer simulations lend strong support to the Ra source attribution and imply seasonal variation in the surface water Ra distribution depending on stratification conditions.