Evaluating submarine groundwater discharge as a source of nutrients to the Mediterranean Sea using ^{228}Ra

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The Mediterranean Sea (MS) is considered one of the most oligotrophic seas in the world, where inputs of external nutrients are particularly relevant to sustain primary productivity. Despite its potential importance, the role of Submarine Groundwater Discharge (SGD) as a source of dissolved compounds to the MS has been largely ignored. Here, we used a ^{228}Ra mass balance for the upper MS to estimate the magnitude of SGD to this basin, as well as its associated nutrient inputs.

Radium isotopes have been widely applied as tracers of SGD, mainly because they are highly enriched in SGD relative to seawater and behave conservatively once released into the sea. We used ^{228}Ra because its half-life ($T_{1/2}$ = 5.75 yr) is considerably lower than the residence time of the MS waters (~100 yr), hence its radioactive decay is the primary sink of ^{228}Ra in the MS, which allows accurately constraining its removal rate. By evaluating all the sink (radioactive decay, advection to deep waters, particle scavenging and outputs through the straits of Gibraltar and Dardanelles) and source (rivers, atmospheric dust, sediments, advection from DW, and inputs from the straits) terms, we estimated the ^{228}Ra supplied by SGD as the difference between its inputs and outputs. By characterizing the ^{228}Ra concentration in the SGD fluids, we estimated that the total SGD contributes up to $(0.3 – 4.8)\cdot 10^{12}$ $m^3\cdot yr^{-1}$ to the MS, which appears to be equal or larger by a factor of 16 than the riverine discharge. SGD is also a major source of dissolved inorganic nutrients to the MS, with median annual fluxes of $190\cdot10^9$, $0.7\cdot10^9$ and $110\cdot10^9$ mol for dissolved inorganic nitrogen, phosphorous and silica, respectively, which are comparable to riverine and atmospheric inputs. This demonstrates the profound implications that SGD may pose in the biogeochemical cycles of the MS. Inputs of other dissolved compounds (e.g. iron, carbon) via SGD could also be significant and should be investigated.