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Submarine groundwater discharge solute fluxes to the coastal French Mediterranean Sea determined using Ra isotopes: A comparison between karst and permeable sand shorelines

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Submarine groundwater discharge (SGD) into the coastal oceans is increasingly recognized as an important source of chemical species (nutrients, trace elements or contaminants) to the ocean. Therefore, these fluxes impact the coastal geochemical cycles and they need to be considered in oceanic budgets. Two different processes are at play when considering groundwater discharge into the sea: i) circulation of seawater through permeable coastal sediments and ii) direct input of terrestrial groundwater into the coastal region when the aquifer is connected to the sea. Both processes constitute vectors for various chemical species. Here, we investigated several coastal regions located along the Gulf of Lions in the western Mediterranean Sea, including i) coastal zones dominated by permeable sands where seawater circulates through (La Franqui beach) and ii) karstic coastlines where terrestrial groundwater discharges into the sea (Côte Bleue; Calanques de Marseille-Cassis). In this study, radium isotopes (223Ra, 224Ra, 228Ra) were used to derive solute fluxes (water, nutrients, trace metals) associated with terrestrial groundwater discharge and/or seawater circulation through permeable sediments. We used either i) offshore transects of Ra isotopes to derive horizontal eddy diffusivity coefficients that were subsequently combined with surface water nutrient gradients (N, DSi, trace elements) or ii) Ra mass balances in order to determine the net fluxes from SGD. Temporal variability in solute fluxes was considered in some cases by conducting field work at different periods of the year. Chemical fluxes derived for each type of coastline (coastal karstic systems vs permeable sands) were compared with each other. We used these data to evaluate the relative significance of both processes involved in groundwater discharge (ie. terrestrial groundwater discharge vs seawater circulation) at the scale of the Gulf of Lions. Finally, these fluxes were compared to the Rhône river solute fluxes, the latter being the largest surface water input into the western Mediterranean Sea.