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Geochemical behavior of beryllium-9 in the Changjiang estuary: the importance of benthic fluxes

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Knowledge of exchange processes between the particulate and the dissolved phases for trace metals and their fluxes from rivers to estuaries to oceans is key to quantifying their marine geochemical budgets. Beryllium (Be) is a particle-reactive element still much overlooked in ocean elemental budgets, despite the ratio of its cosmogenic (^{10}Be) to stable (^{9}Be) counterpart being a tracer of past continental weathering and ocean circulation. We investigated the role of estuaries in moderating riverine ^{9}Be flux into the global ocean. We present a detailed profile of ^{9}Be concentrations along the entire salinity gradient in the Changjiang (Yangtze River) estuary for both surface and bottom waters as well as ^{9}Be carried by the corresponding suspended particulate matter (SPM). Concentrations of dissolved ^{9}Be exhibit a so-far undocumented behavior in the Changjiang estuary. Upon entering the estuary, dissolved ^{9}Be is initially removed at low salinity due to salt-induced colloidal flocculation. At mid-salinity (both in surface and bottom waters), ^{9}Be is released back into the dissolved phase. At high salinity where water is stratified, dissolved ^{9}Be is scavenged from surface waters but is released into bottom waters. In combination with hydro-physicochemical data (i.e. SPM concentration, pH, dissolved oxygen, and dissolved inorganic phosphorus), we suggest the removal of ^{9}Be from surface waters of the stratified zone is likely associated with organic matter scavenging facilitated by phytoplankton blooms. Benthic processes including porewater diffusion and expulsion or submarine groundwater discharge are responsible for the release of ^{9}Be. We find that hypoxia conditions in bottom waters may enhance the benthic flux of ^{9}Be. This benthic-sourced ^{9}Be may contribute to surface waters when water is vertically mixed or in zones of upwelling. Therefore, when exploring the mechanisms that modulate the riverine input of dissolved ^{9}Be to the oceans, considering only surface dissolved ^{9}Be data from shallow estuaries does not suffice. Rather, to calculate the ^{9}Be flux to the oceans, the contribution of the benthic flux also needs to be accounted for.