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Submarine Groundwater Discharge and the Related Inorganic Nitrogen Transportation in the Pearl River Delta Front Estuary, China

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Submarine groundwater discharge (SGD) is an important pathway for water and material transportation from continents to oceans. Large-river delta-front estuaries (LDE) have been identified to be important interfaces between continents and oceans in terms of water and material fluxes which have a worldwide impact on marine biogeochemistry. However, there are limited studies discussing about SGD at the LDE globally. The Pearl River (PR) in Southern China is the 14^{th} largest river of the world in terms of annual water discharge. Meanwhile, there is naturally occurring abnormally high ammonium groundwater that widely distributed in the PRD quaternary aquifer. The Pearl River Delta (PRD) is located within the Guangdong-Hong Kong-Macao Greater Bay Area, where inorganic nitrogen pollution in the nearshore seawater is a serious environmental problem. This study aims to estimate the SGD and the related inorganic nitrogen transportation of the entire PRD front estuary, and to understand the ecologic environment impacts of SGD and the related naturally occurring abnormally high ammonium groundwater of this area. Two cruises were carried out in the PRD front estuary during July 30 to August 10 2017 (wet season) and March 15 to 21, 2018 (dry season). At the same time, groundwater samples in the PRD were collected. Over 150 seawater samples from 60 sampling stations in the sea were collected. Radioactive radium isotopes (^{223}Ra, ^{224}Ra, ^{226}Ra and ^{228}Ra) were measured to trace SGD. The results demonstrated that SGD is a ubiquitous phenomenon of the entire PRD front estuary, and the spatial distribution of radium activity is generally consistent with that of the total inorganic nitrogen, suggesting SGD is one of the most important pathways for inorganic nitrogen input within the study area. On the basis of a short lived radium (^{223}Ra and ^{224}Ra) mass balance model, total SGD of the PRD front estuary is $0.9(0.6\text{-}3.5)\times10^{12}$ m^3/yr, which is equal to 273(192-1040)% of the annual discharge of the PR. SGD related inorganic nitrogen transportation is about $1.3(0.9\text{-}4.9)\times10^{10}$ kg/d, which is 20%(14%-74%) higher than that transported by the PR. SGD of this area has also been found to have significant influence on the hypoxia developed in the lower reach of the estuary and the subaqueous area of the delta in summer, and nitrification is one of the important processes consuming dissolved oxygen in the seawater.