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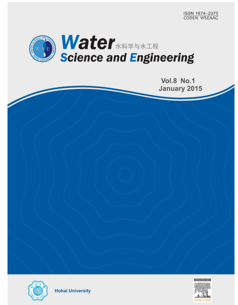

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Estimating submarine groundwater discharge and associated nutrient inputs into Daya Bay during spring using radium isotopes

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Abstract

Daya Bay, a semi-enclosed bay in the South China Sea, is well known for its aquaculture, agriculture, and tourism. In recent years, many environmental problems have emerged, such as the frequent (almost yearly) occurrence of harmful algal blooms and red tides. Therefore, investigations of submarine groundwater discharge (SGD) and associated nutrient inputs to this bay have important theoretical and practical significance to the protection of the ecological system. Such a study was conducted using short-lived radium isotopes ^{223}Ra and ^{224}Ra. The estimated SGD fluxes were 2.89×10^7 m^3/d and 3.05×10^7 m^3/d based on ^{223}Ra and ^{224}Ra, respectively. The average SGD flux was about 35 times greater than that of all the local rivers. The SGD-associated dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) fluxes ranged from 1.95×10^6 to 2.06×10^6 mol/d and from 5.72×10^4 to 6.04×10^4 mol/d, respectively. The average ratio of DIN to DIP fluxes in SGD was 34, much higher than that in local rivers (about 6.46), and about twice as large as the Redfield ratio (16). Our results indicate that SGD is a significant source of nutrients to the bay and may cause frequent occurrence of harmful algal blooms. This study provides baseline data for evaluating potential environmental effects due to urbanization and economic growth in this region.

Keywords: Submarine groundwater discharge (SGD); Radium isotopes; Radium mass balance model; SGD-associated nutrient fluxes; Daya Bay

1. Introduction

Coastal zones with increasingly dense human occupation are at the complex and dynamic interface between the land and the ocean. As an important process of land-ocean interaction and a component of the hydrological cycle, submarine groundwater discharge (SGD) has been widely recognized as a significant source of water (Wang et al., 2015) and an important pathway for dissolved material (e.g., nutrients, metals, and carbon) transport from land to the ocean (Taniguchi et al., 2002; Peterson et al., 2009; Knee et al., 2016; Moran et al., 2014). Owing to spatial and temporal variations, SGD is very difficult to measure and evaluate. Nonetheless, SGD and associated nutrient fluxes, in some regions, have been shown to rival those from local surface waters (Swarzenski et al., 2007; Hwang et al., 2010; Knee et al., 2016; Zhou and Boyd, 2015). Thus, SGD is very important to the marine geochemical cycle of elements such as nutrients and metals, and it can lead to various environmental problems in coastal zones (Moore, 1997; Moore, 2006; Beck et al., 2007; Wudtisin and Boyd, 2005). Numerous studies have shown that the nutrient inputs to coastal water through SGD may trigger harmful algal blooms, which have negative impacts on the marine environment and economy (Lee and Kim, 2007; Lee et al., 2009; Waska and Kim, 2011).

The definition of SGD, from Burnett et al. (2003), is flow of water on continental margins from the seabed to the coastal ocean, regardless of fluid composition or driving force. Driven by both terrestrial and marine forcing components, SGD comprises terrestrial fresh groundwater and circulated seawater. The composition of SGD, however, differs from simple mixing of terrestrial fresh groundwater and circulated seawater, since biogeochemical reactions in the aquifer modify its chemistry (Moore, 2010). The terrestrial driving force of SGD consists of the inland hydraulic gradients, which result from the difference in water level between terrestrial groundwater and

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