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ScienceDirect
Marine Chemistry 109 (2008) 279–291
MARINE CHEMISTRY
www.elsevier.com/locate/marchem

Submarine groundwater discharge to Great South Bay, NY, estimated using Ra isotopes

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Received 16 March 2007; received in revised form 2 July 2007; accepted 31 July 2007
Available online 15 August 2007

Abstract

There is increasing evidence that submarine groundwater discharge (SGD) in many areas represents a major source of dissolved chemical constituents to the coastal ocean. In Great South Bay, NY, previous studies have shown that the discharge of nutrients with SGD may cause harmful algal blooms. This study estimates SGD to Great South Bay during August 2006 by performing a mass balance for each of the dissolved Ra isotopes (^{224}Ra, ^{223}Ra, ^{228}Ra, ^{226}Ra). The budget indicates a major unknown source (between 30 and 60% of the total input) of Ra to the bay. This imbalance can be resolved by a flux of Ra-enriched groundwater on the order of $3.5–4.5 \times 10^9$ L d^{-1}, depending on the Ra isotope. The Ra-estimated SGD rates compare well with those previously estimated by models of flow that decreases exponentially away from shore. Compared to previous reports of fresh groundwater discharge to the bay, the Ra-estimated discharge must comprise approximately 90% recirculated seawater. The good agreement between Ra- and model-estimated flow rates indicates that the primary SGD endmember may be best sampled at shallow depths in the sediments a short distance bayward of the low tide line.

Keywords: Ground water; Radium isotopes; Estuarine chemistry; Submarine groundwater discharge; SGD; New York; Great South Bay

1. Introduction

The importance of submarine groundwater discharge (SGD) in chemical fluxes to the coastal ocean is well established (Johannes, 1980; Capone and Bautista, 1985; Oberdorfer et al., 1990; Krest et al., 2000; Crotwell and Moore, 2003; Charette and Buesseler, 2004; Kim et al., 2005; Hwang et al., 2005a), although it remains uncertain how best to measure its magnitude (Zektzer et al., 1973; Buddemeier, 1996; Burnett et al., 2001; Shaw, 2001; Beck et al., 2007a). In addition, with increasing ability to identify this discharge, the impact of SGD-associated chemical fluxes on ecological processes in coastal ecosystems is also beginning to be understood (Johannes, 1980; LaRoche et al., 1997; Rutkowski et al., 1999; Gobler and Sañudo-Wilhelmy, 2001; Boudreau et al., 2001; Gobler and Boneillo, 2003; Hwang et al., 2005b; Lee and Kim, 2007). The ecological significance of SGD has been particularly well documented in Long Island, NY, with nutrient discharge associated with SGD implicated in the initiation and proliferation of harmful algal blooms over the past few decades (LaRoche et al., 1997; Gobler and Sañudo-Wilhelmy, 2001; Gobler and Boneillo, 2003; Taylor et al., 2006).

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doi:10.1016/j.marchem.2007.07.011

An important consideration is that SGD comprises both fresh (meteoric) groundwater and recirculated seawater (Burnett et al., 2006), yet most of the previous studies in Great South Bay have considered only the former portion. Each of these components has unique geochemical characteristics, and both tend to be variable on differing temporal and spatial scales (Michael et al., 2005; Robinson et al., 2006). There is significant spatial variability of SGD in Great South Bay; discharge rates measured by seepage meters are typically highest near shore, and decline bayward (Bokuniewicz and Zeitlin, 1980; Zeitlin, 1980; Seplow, 1991; Bokuniewicz et al., 2004). However, discharge does not always follow this pattern, and sites of locally increased discharge have been occasionally but consistently observed (Bokuniewicz and Zeitlin, 1980; Bokuniewicz et al., 2004). A seepage meter can only cover a limited area of the seabed, and a large scale study requires many deployments that can be time consuming and inefficient. Therefore, a number of methods based on the use of geochemical tracers such as Rn and Ra, have been developed for indirect quantification of SGD (e.g. Moore, 1996; Burnett and Dulaiova, 2003), and to provide an assessment of SGD that integrates over a larger area. Ra is perhaps the tracer examined most thoroughly, and has been utilized extensively over the past decade in numerous coastal settings (Charette et al., submitted for publication, and references therein). In the present study, we construct a mass balance for Ra in Great South Bay. Using the flux-by-difference approach, we estimate the average rate of SGD into the entire bay.

1.1. Site description

Great South Bay is the largest of several shallow embayments along the southern Long Island coast. Great South Bay is approximately 35–40 km in length, and ~9 km across at its widest point (Bokuniewicz and Zeitlin, 1980; Wong, 1993). The bay covers a surface area of about 235 km^2 (Wong, 1993), and has an average depth of 1.2 m, although it may reach depths of up to 4 m (Wilson et al., 1991). The tidal range in the bay is generally less than about 0.25 m (Bokuniewicz and Zeitlin, 1980). The bay exchanges water with the

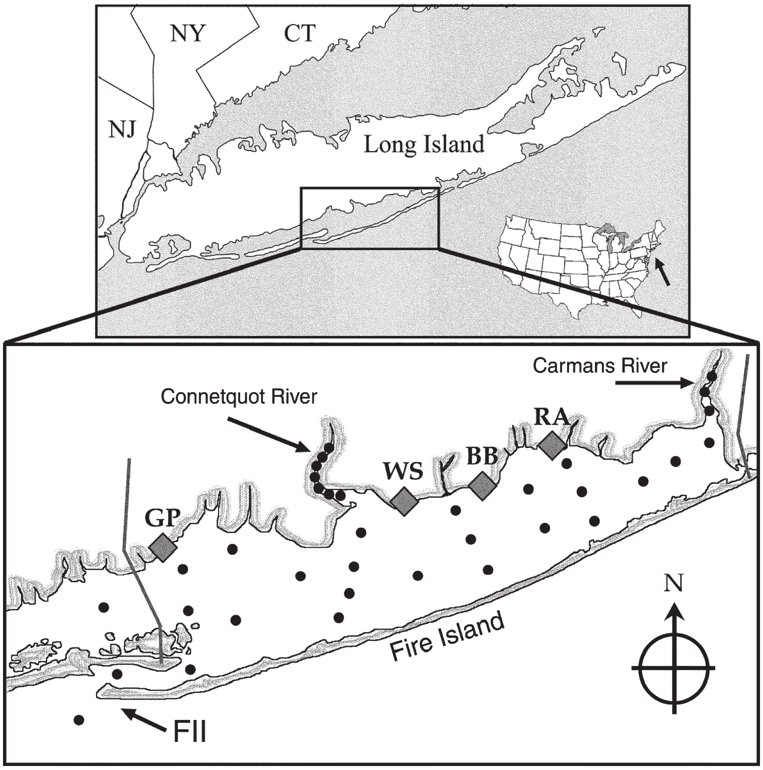

Fig. 1. Great South Bay, NY. Sampling stations are indicated by solid circle symbols. Fire Island Inlet (FII) is indicated, as are the Connetquot and Carmans River locations. Groundwater sampling sites are marked with gray diamonds; site IDs are: GP — Gardiners Park, WS — West Sayville, BB — Bayport Beach, RA — Roe Avenue. The sharp gray lines at the east and west borders of the Bay show locations of the Smith Point and Jones Beach causeways, respectively.