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Geochemistry of submarine groundwater discharge: an important source of nutrients and its impact on the coastal marine environment

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The discharge of freshwater from the seafloor of the continental shelf has been recognized as an important, direct transport pathway both for water and other materials between the groundwater system of the adjacent land and the marine environment. This submarine groundwater discharge (SGD) is possibly more important than its contribution to the water balance alone would suggest, because the concentration of dissolved material is greater than that of river water, and much of the riverine dissolved material is removed by colloids and/or up taken by phytoplankton in the estuary region. The purpose of this study is to clarify, by using geochemical techniques, the circulation of SGD including its discharge mechanisms, spatio-temporal variability, and impact on the coastal marine ecosystem. Conclusions are based on a case study of the Toyama Bay in central Japan.

The sampling technique enables collection of a large amount of SGD water within a depth range 5 m to 33 m without contamination from the surrounding seawater. Based on hydrogen and oxygen isotope compositions, the SGD samples are found to originate from nearby mountain precipitation within the altitude range 800 m to 1200 m. From geographic/geological conditions and tritium data, it is deduced that the SGD flowed through a buried ancient river bed and emerged from the sea floor 10 to 20 years after having entered the underground mountain aquifer. The newly developed flow rate meter (SGD-Flux Chamber) was developed and measurements were carried out from April to December, 2003 in the SGD area, 150–200 m seaward of the coastline in water depths of 8 m and 22 m. The average fluxes were 0.84-1.27 L/min/m^2 at 8 m and 0.50-0.81 L/min/m^2 at 22 m. On tidal time scales, the SGD flux increases with the dropping of the tide level with a time lag of 2 hours. There are indications the flux is controlled by changes in landward groundwater potential pressure, sea level at the SGD area, and the geotechnical condition of submarine sediment. Since the flux of SGD is spatially very inhomogeneous, we developed a method for calculating the SGD flow rate by using sediment temperature over a wide area, based on the high sediment temperature-SGD flow rate correlation (R^2=0.94). The sediment temperatures, at 256 stations over an area of 1024 km^2 were measured; the SGD flux was estimated to be.7×10^5 L/day. The maximum SGD flux measured was estimated to be 25% of the riverine flux using a box model; the SDG accounts for up to 50% (dissolved PO_4) and 50% to 100% (dissolved NO_2+NO_3) of the nutrient budget relative to the river flux. However, in early summer, nutrients are especially low in middle water depths (5 to 40 m in depth) because of seawater stratification, only near SGD areas, relatively high chlorophyll concentrations were observed in this depth range, implying nutrient delivery by SDG. It is clear that SGD plays an important role in the nutrient budget of Toyama Bay.