Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACG33-P06 Room:Convention Hall Time:May 26 18:15-19:30

Seasonal variation in saline submarine groundwater discharge and associated nutrient fluxes into Obama Bay

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Submarine groundwater discharge (SGD) is now recognized as a major conveyor of dissolved materials from land to the sea. Nutrient loads carried by SGD are commonly calculated as the product of SGD rate and concentrations of coastal fresh groundwater with the assumption that chemical transport through the coastal aquifer is conservative. However, most of the discharging water is usually saline groundwater (recirculated seawater) except in some karstic, volcanic and glacial areas where it is composed principally of fresh meteoric water. Recent studies have shown that biogeochemical processes in the subterranean estuary would have an important effect on concentrations of the dissolved species. Therefore, it still remains unclear how to identify endmember concentrations in a subterranean estuary for calculating SGD-derived nutrient fluxes. In this study, to evaluate nutrient fluxes through the saline SGD and their seasonality, we conducted monthly observation from March to November 2014 in the shallow coast in Obama Bay using a Lee-type seepage meter for SGD rate and piezometers for nutrient endmembers in the subterranean estuary. Estimated SGD rates which mainly composed of recirculated seawater ranged from 0.01 cm d^{-1} to 3.86 cm d^{-1}. This seasonal variation was dominated by integrated precipitation for 30 days before observation date with time lags of 1.5-2.5 months, suggesting that the recharging water takes time to percolate through the unsaturated zone to the water table. Assuming that endmember of nutrients concentrations is derive from saline groundwater in 0.9 m beneath the bottom, fluxes of dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorous (DIP) and dissolved silica (DSi) were 1.9-479.7 μmol m^{-2} d^{-1}, 0.1-15.1 μmol m^{-2} d^{-1} and 7.4-1092.6 μmol m^{-2} d^{-1}, respectively. If we used nutrient concentrations in fresh groundwater, fluxes of DIN and DSi were overestimated while DIP was underestimated, because nutrient concentrations in fresh groundwater were enriched in DIN and DSi while depleted in DIP. These results show that biogeochemical processes in subterranean estuary affect crucial impact on nutrient loads carried by saline SGD.

Keywords: saline submarine groundwater discharge, nutrient flux, seasonal variation, subterranean estuary