

Utilization of short-lived ^{222}Rn and ^{224}Ra for evaluating SGD rates in shallow coasts of the Seto Inland Sea

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Submarine groundwater discharge (SGD) is now recognized as an important pathway of water, nutrients and metals between terrestrial area and coastal seas. It is well known that SGD is ubiquitous phenomenon compare to river discharge. Additionally, SGD is defined as constitution of fresh groundwater derived terrestrial area (FSGD) and saline groundwater derived seawater (RSGD). In order to evaluate terrestrial water budgets as water resources and nutrients dynamics in coastal seas, it is important to identify the ratio of FSGD and RSGD, and quantify both fluxes. Seepage meter is one of the approach for quantifying SGD and can evaluate reliable FSGD and RSGD. However, this method has disadvantage to expand the scale from local to regional. On the other hand, geochemical tracers showed integrated SGD signals, and thus they have been used to evaluate SGD in a variety of scale. Generally, ^{222}Rn ($t_{1/2}=3.84$ d) enriched in fresh and saline groundwater relative to surface water. Ra isotopes are enriched specifically in saline groundwater. Therefore, an estimate of SGD rates by ^{222}Rn activity indicates total flux of SGD (FSGD+RSGD), while that by Ra isotopes would express the flux of RSGD. Combining approach of these short-lived isotopes, ^{222}Rn and ^{224}Ra , can provide the fluxes of FSGD and RSGD. In this study, to evaluate SGD rates by ^{222}Rn and ^{224}Ra , we have conducted simultaneous time-series measurements of short-lived ^{222}Rn and ^{224}Ra activities at two different SGD rates sites from 6 –7 July 2017 in the central part to the Seto Inland Sea, Japan. Moreover, at both sites, we also quantify SGD, FSGD and RSGD rates using the seepage meter to verify the SGD rates estimated by ^{222}Rn and ^{224}Ra . Measured SGD rates by seepage meter at one site were 99.8 ± 39.3 cm d⁻¹, and at the other site were 4.9 ± 6.5 cm d⁻¹. The ratio of FSGD and RSGD in SGD by ^{222}Rn and ^{224}Ra (31.6% and 68.4%, respectively) showed similar value to these by seepage meter (11.7% and 88.3%, respectively) at the site with high SGD rates. At low SGD rates site, SGD rates by ^{222}Ra (mean \pm SD= 118.7 ± 73.2 cm d⁻¹) showed considerably high value against SGD rates measured by seepage meter (mean \pm SD= 4.9 ± 6.5 cm d⁻¹), and the ratio of FSGD and RSGD in SGD by ^{222}Rn and ^{224}Ra (89.9% and 10.1%, respectively) showed different values from those by seepage meter (14.4% and 85.6%, respectively). Since an average of ^{222}Rn activity in seawater at low SGD rates site (mean \pm SD= 2.1 ± 0.8 dpm L⁻¹) was lower than offshore seawater (3.3 dpm L⁻¹), overestimates of ^{222}Rn -derived SGD may be due to lower ^{222}Rn activity in seawater relative to in offshore seawater. These results suggested that coupling of ^{222}Rn and ^{224}Ra is convenient approach to quantify FSGD and RSGD in regional scale, except for circumstances showing lower geochemical tracers activities in seawater of study area relative to in offshore seawater.

Keywords: Submarine groundwater discharge, Ra isotopes, Rn-222, Seto Inland Sea, Coastal seas