Submarine groundwater discharge: a hidden pathway of Fukushima derived cesium to the ocean off Japan

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The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) experienced multiple reactor meltdowns in March 2011 followed by the releases of radionuclides to the marine environment, in particular of cesium-137 (^{137}Cs).

The highest ^{137}Cs activities measured outside the FDNPP site (as high as 23,000 ± 460 Bq m^{-3}) over the past five years were not found in the ocean, rivers or potable groundwater, but in saline groundwater beneath sand beaches over tens of kilometers away from the FDNPP. Cs levels in the beach surf zones were in excess of offshore seawater Cs and displayed a tidal variability, which is one line of evidence that beach groundwater is a source of Cs to the ocean. High Cs level were also measured in beach sand cores. The Cs inventory in beach sand (4.8 ± 0.6 × 10^5 Bq m^{-2}) was one order of magnitude higher than the largest inventory recorded in marine sediments, and within a factor of four of terrestrial soil cores inventories, indicative of a large reservoir of Cs contaminated solids.

Following a serie of adsorption/desorption experiments, we hypothesized that highly radioactive seawater intrusion in 2011 driven partly by waves and tides, led to the storage of Cs by adsorption onto beach sands. Similar fluid exchange and subsequent desorption of Cs from sand remobilizes slowly Cs into groundwater, and ultimately, into the ocean.

Parallel measurements of radium isotopes were conducted to provide regional estimates of the release of Cs via submarine groundwater discharge along the coast of Japan. This ocean source (0.6 TBq y^{-1}) is of similar magnitude of the ongoing releases of Cs from the FDNPP site, as well as the riverine input of dissolved Cs. This process may also impact other radionuclides as evidenced by elevated iodine-129 that were found in this beach groundwater.