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Investigations of incorporation of elements into ice in Lake St. Clair, SE Michigan, during extreme weather conditions: an analogy for chemical cycling in the Arctic Ocean

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Coastal Arctic sea ice is instrumental in the transport of coastal sediments and sediment-laden chemical species to the shelf, slope and open Arctic Ocean. The mechanisms of incorporation of suspended sedimentary particles in frazil ice is poorly understood. During a once-in-a-lifetime extreme weather condition in southeastern Michigan (15-20 cm of snowfall over ~48 hrs; temperatures -17 to -8°C high; -17 to -25°C low; Jan. 29 – 1 Feb. 2019), Lake St. Clair (1,114 km^2, mean depth: 3.3 m) reached 100% surface ice coverage. Twenty-four lake ice samples were collected during snow events between January and March 2019 to investigate the mechanism of incorporation of radionuclide-laden sediment into lake ice. Ice samples were brought to the shore-based laboratory where sediment and melt water were separated. The sediments were wet-sieved into four fractions (< 32, 32-45, 45-63 and >63 mm); Total and fractionated sediment masses were determined gravimetrically. The sediments were analyzed for ^{7}Be, ^{210}Pb, ^{137}Cs and ^{226}Ra by gamma spectrometry. The melt water was preconcentrated using $Fe(OH)_3$ precipitation and analyzed for ^{7}Be and ^{210}Pb. Po-210 analysis was conducted by alpha spectrometry. Specific activities of ^{210}Pb, ^{210}Po and ^{7}Be in ice-rafted sediments varied by up to three orders of magnitude higher than that found in lake surface sediments (factors of 510, 156, 1970, respectively) and in melt water (compared to the natural background levels in the lake) varied by factors of 440, 167 and 152, respectively. The excess $^{210}Po/^{210}Pb$ and $^{7}Be/^{210}Pb$ activity ratio (AR) ranged from 0.10 to 0.61 and 1.1 to 7.9, respectively. From the measured $^{210}Po/^{210}Pb$ AR and fluxes of ^{7}Be and ^{210}Pb in precipitation in conjunction with the ratio in surface sediment, the fractions of ^{210}Pb derived from the atmosphere and bottom sediment are quantified. This suggests enrichment of these nuclides in ice-rafted sediment occurs on a short timescale (< 1 day). The mechanisms responsible for enrichment of ^{210}Pb and ^{7}Be in ice-rafted sediments in this lake is congruent with sea-ice in the Arctic. Thus, atmospherically delivered pollutants may be highly concentrated in lake ice reaching toxic levels during storm events.

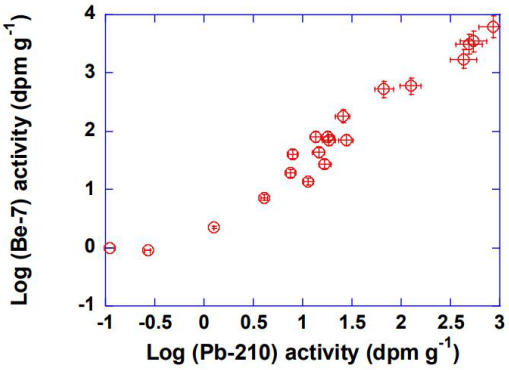

Figure 1: Log (Be-7) activity vs Log (Pb-210) activity in ice-rafted sediments collected from Lake St. Clair, SE Michigan during January – March 2019