



Contribution ID: 73

Type: Talk

Elevated mercury and major ion concentrations in snowmelt runoff from a small Arctic Alaska watershed

Thursday, January 11, 2018 12:10 PM (20 minutes)

Mercury is deposited to polar snow and ice surfaces during springtime atmospheric mercury depletion events (AMDEs). AMDEs require sunlight, frozen surfaces, and a reactive bromine source such as sea ice or halogen-rich snow. During these events gaseous elemental mercury (Hg⁰; GEM) is oxidized to reactive gaseous mercury (Hg^{II}; RGM) which can associate with particles to form particulate Hg (PHg). Hg concentrations above 1,000 ng/L have been measured in polar snow and ice, following AMDEs, far greater than that found in lower latitude snow. RGM can be photochemically reduced back to GEM and emitted to the atmosphere or retained by the snowpack and released in spring when snow melts. The majority of polar surface runoff, including AMDE-sourced Hg, occurs during this spring freshet, but the fate of the Hg in the snow is complex, with the Hg depositing in lakes, exporting to the ocean, sorbing to vegetation or soil, or accumulating in soil by microbes.

In this study we tracked the fate of snowpack Hg in meltwater percolating through snowpack and snowmelt runoff near Utqiagvik (formerly Barrow), Alaska. We worked in a small (2.5 ha) watershed near the Arctic Ocean coast where active AMDE chemistry and elevated Hg in snow and ice have been reported. In late winter prior to snowmelt (April) and during snowmelt runoff (May and June) in 2008 and 2009 we made over 10,000 snow depth measurements and 36 snow water equivalent (SWE) measurements in the watershed to calculate the end of winter SWE and Hg load. Gaseous elemental Hg in air and local meteorology were also measured. Snowpack, meltwater, and stream channel water were collected and analyzed for total Hg and major ion concentrations and stable oxygen and hydrogen isotopes. We calculated total snowpack and runoff water Hg fluxes.

Results show a snowmelt “ionic pulse” of Hg and major ions during both melt seasons with the total dissolved Hg in meltwater in 2008 at 14.3 mg/ha and 8.1 mg/ha in 2009. These values are 5 to 7 times higher than reported from other Arctic watersheds. Record low summer 2007 precipitation may have led to 50% higher major ion and Hg concentrations during the 2008 melt compared to 2009. We calculated that 78% of snowpack Hg was exported with snowmelt runoff in 2008 and 41% in 2009. From these results we estimate roughly 25% of snowmelt Hg is attributable to AMDEs. We argue a projected warmer future Arctic with more ice sea ice leads, will provide greater halogen sources for AMDEs in the future, and this may increase Hg deposition, reduce Hg re-emission due to higher snow pack halogen concentrations and, ultimately, increase snowpack and meltwater Hg concentrations.

Significance statement

A springtime pulse of mercury and major ions in a high Arctic watershed; links between mercury runoff and watershed snow and melt water hydrology; potential impacts on these processes by a projected warmer future Arctic

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Track Classification: Fundamentals of the Cryosphere