SOIL AND PLANT HG DYNAMICS IN THE ARCTIC TUNDRA

[1]Christine Hedge, [1]D. Obrist, [1]Y. Agnan, [1]C. Moore, [2]H. Biester, [3]M. Jiskra, [4]D. Helmig

[1]Desert Research Institute, Division of Atmospheric Sciences, Reno, USA; [2]Technische Universität Braunschweig, Environmental Chemistry, Braunschweig, Germany; [3]Geosciences Environment Toulouse, CNRS, Toulouse, France; [4]University of Colorado Boulder, Institute of Arctic and Alpine Research, Boulder, USA

christine.hedge@dri.edu

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Introduction: Atmospheric mercury (Hg) can be transported over long distances to remote regions such as the Arctic where it can then deposit and cause detrimental effects to arctic wildlife and humans (AMAP 2009). Little information is known about Hg storage and pools in arctic upland tundra ecosystems, a large receptor area for atmospheric deposition and a major source of Hg to the Arctic Ocean (Fisher et al., 2012). This research aims to improve the understanding of terrestrial Hg cycling in the arctic tundra, a major biome that covers 4% of global land surface area (Bailey, 2014). We focus on determination of tundra vegetation and soil Hg concentrations and pools and their potential origin and fate using geochemical tracers. We further aim to characterize spatial variability in distribution patterns at different scales, both within local upland and wetland transects and regionally using large tundra transects. We further assess depth patterns of soil Hg, including concentrations in permafrost soil layers.

Methods: The primary research site is at Toolik Field Station (68° 38' N) in northern Alaska, with additional samples collected along a 200 km transect from the station to the Arctic Ocean. Further sites are located in Denali National Park and Noatak National Preserve in central Alaska. Soil and vegetation samples collected in summer of 2014 and 2015 were analyzed for total Hg concentration, pH, soil texture, bulk density, soil moisture content, organic and total carbon, nitrogen, along with major and trace elements. Select samples were also age-dated using carbon-14 analysis and analyzed for organic methyl-Hg. Hg pool sizes were estimated by scaling up Hg soil concentrations using soil bulk density measurements. Contributions of exogenic and lithogenic Hg were estimated using reference concentrations of conservative elements (Al, Ti, Zr) in bedrock as described in Guedron et al., (2006).

Results: Results from Toolik station show total Hg concentrations in tundra vegetation averaging 112±15 $\mu g\ kg^{-1}$, 151±7 $\mu g\ kg^{-1}$ in organic soils, and 98±6 $\mu g\ kg^{-1}$ in mineral soils. At Denali National Park, concentrations averaged 40±0 $\mu g\ kg^{-1}$ (vegetation), and 98±8 $\mu g\ kg^{-1}$ (organic soils). Compared to Hg levels found at many temperate sites (e.g., Obrist et al., 2012), vegetation Hg levels were higher in arctic vegetation which is attributable to a high representation of lichen and mosses with higher Hg concentrations. Mineral soil Hg concentrations in the arctic tundra were 2-3 times higher than those at temperate sites. Vertical concentration patterns were relatively constant, in contrast to temperate sites showing strong declines with depth. These results indicate incorporation of atmospheric Hg deposition into deeper soil horizons. Permafrost soil Hg concentrations, on the other hand, were much lower (average 40±0 $ug\ kg^{-1}$). Mass calculations show that Hg mass in the upper 40 cm of the soil profile (200-500 $g\ ha^{-1}$) was primarily stored in mineral soil layers (over 90%). Hg mass showed substantial spatial variability, particularly along an upland-wetland gradient where wetland Hg pools were much lower due to an absence of mineral soil layer in the top 40 cm. Methyl-Hg were low in soils (on average below 3% of total Hg) and below detection limit (0.1 $ng\ g^{-1}$) in permafrost soils.

Principle component analyses including major and trace elements showed that soil Hg was correlated to organic matter, although much weaker than in temperate sites. However, soil Hg was independent of geogenic soil elements indicating that soil Hg was not of lithogenic origin but from atmospheric sources. Carbon-14 dating showed over 7,000 years old organic carbon in mineral soils of the active layer. We found that highest concentrations of soil Hg were observed in the oldest dated layers, suggesting that high concentrations were possibly caused by a long legacy of atmospheric deposition and retention in soils.

Conclusion: Results of this study show substantial Hg levels in tundra plants and soils, exceeding levels often observed at temperate sites closer to pollution impacts, and providing further evidence of Hg influence in upland areas of remote ecosystems. Given the potential impact of global change on tundra soils, including thawing of permafrost and increased occurrence of wildfires, the terrestrial tundra Hg dynamics needs to be understood to constrain potential impacts of Hg runoff to the Arctic Ocean.

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