Mercury isotopes record historical penguin population and climate changes in Ross Sea, Antarctica

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Seabirds such as penguin are known to transport contaminants and nutrients from ocean to land in forms of guano. Therefore, elements and their isotope compositions in coastal sediments that are affected by guano are potential tracers of historical changes in seabird activity and ocean climate. Here we present a ~700-year sequence of Hg stable isotope compositions in a guano-affected sediment profile from a coastal area of Ross Sea, Antarctica. Mercury isotopes can be powerful tracers of Hg sources and transformations as they display both mass dependent fractionation and mass independent fractionation (reported here in capital delta notation).

We find that the variation of Hg concentration and Hg isotopes are both consistent with traditional proxies such as total organic carbon (TOC), total nitrogen (TN) and phosphorous (P). We observe an abrupt decrease in Δ^{199}Hg at ~1650 AD to present, which coincides with similar shifts in traditional proxies and is linked with a drop of penguin population. The change in Δ^{199}Hg is accompanied by a shift in Δ^{199}Hg/Δ^{201}Hg from 1.35 to 0.99, indicating that the source of Hg in the sediment shifted from guano-imported oceanic methylmercury that has undergone photodegradation to terrestrial or atmospheric Hg (non-methylated) that was affected by photoreduction. We also found a gradual increase of Δ^{199}Hg but constant Δ^{199}Hg/Δ^{201}Hg (1.35) between ~1400 and 1650 AD, the onset of Little Ice Age (LIA, ~1350 to 1850 AD), implying that the degree of photodegradation of oceanic methylmercury was increasing during this time period. We propose that climate change during LIA promoted stronger katabatic winds across the Ross Ice Shelf resulting in more polynya, which affected the extent of photodegradation of methylmercury. Our results indicate that Hg cycle in the maritime Antarctic is strongly associated with penguin activity and climate changes, making Hg isotope composition a novel tracer of marine ecology and paleoclimate.