Quantifying the signature of the industrial revolution from Pb, Cd and Zn isotopes in the Susquehanna Shale Hills Critical Zone Observatory

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Anthropogenic forcings have dominated metal cycling in many environments. During the period of the industrial revolution, mining and smelting of ores and combustion of fossil fuels released non-negligible amounts of potentially toxic metals such as Pb, Cd, Mn, and Zn into the environment. The extent and fate of these metal depositions in soils during that period however, have not been adequately evaluated. Here, we combine Pb, Cd, and Zn sotopes to trace the sources of metal pollutants in a small temperate watershed (Shale Hills) in Pennsylvania. Previous work has shown that Mn additions to soils in central PA were likely caused by early iron production, as well as coal burning and steel making upwind. Pb and Cd concentrations in the soils from this watershed are best explained as atmospheric additions. Pb isotope results further reveal that the extensive use of local coals during iron production in the early 19th century in Pennsylvania was most likely the anthropogenic Pb source for the surface soils at Shale Hills.

Furthermore, Cd and Zn in such iron furnaces are expected to have low boiling points (<1000 °C) that could easily lead to repetitive evaporation and condensation. These processes could generate systematic mass-dependent isotope fractionations between coal burning products and the naturally occurring sulfide minerals in the coals. Cd and Zn isotopes can be used as novel tracers of materials that have been affected by industrial high temperature processes, distinguishing them from natural sources. Our ongoing Cd and Zn isotope measurements in the same soil profiles thus hold significant promise for tracing anthropogenic sources of these highly toxic metals in the environment. Our study highlights the importance of using multiple isotope systems to identify historical point sources and the use of such isotopes to quantify industrial inputs to metal contamination to top-soils.