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Size-resolved aqueous distribution and solid phase partitioning of trace elements in soils from Elmvale, Ontario

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Soils act as natural geochemical filters that regulate the transport of trace elements (TEs) from atmospheric deposition to groundwater. In the Elmvale region of southern Ontario, previous work has shown that groundwater is strongly depleted in TEs relative to freshly fallen snow, indicating efficient attenuation during infiltration. Here we investigate the partitioning of TEs among soil phases and their distribution between truly dissolved (<300 Da) and colloidal fractions in soil waters. Metal-free lysimeters were installed at 0–15 cm and 15–30 cm depths across four nests and sampling was conducted during three campaigns from July to September 2023. All lysimeter components and sampling materials were subjected to acid cleaning procedures employed at the metal-free, ultraclean SWAMP laboratory. Sequential extraction of soils shows that Fe and Mn oxyhydroxides constitute the dominant sink for many elements, accounting for 40–90% of As, Cd, Co, Cu, Mn, Ni, Pb, U, V, Y, and Zn. Exchangeable ions and carbonate-associated phases were dominant for Ba, Cd and Sr, accounting for 20-50% of their total concentrations. Organic matter and sulfide minerals account for 15–40% of Cu, Mo, Ni, Pb, U, V, while the residual fraction contributes 10–30% for Ba, Cr, Pb, Sr, Tl, and V. Only minor proportions occur in the water-soluble pool. Size-resolved fractionation using AF4-UV-ICPMS shows that at pH 7–8, As, Ba, Li, Mn, Mo, and Sr occur predominantly in the <300 Da fraction. Copper, Cr, Ni and Th show substantial association with dissolved organic matter (0.5-2 kDa) whereas Al, Fe, Pb, U, Th, V, and Y occur mainly in small (5-20 kDa) and large (>600 kDa) inorganic colloids. These results demonstrate that integrating solid-phase partitioning with size-resolved aqueous distribution defines TE behavior during infiltration and provides a methodological framework for understanding natural filtration of water by soil.