Distribution of metals in soil profile in association with carbon

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Many elements in soil, such as Pb and Hg, are strongly adsorbed to soil organic matter (SOM), and thus their distribution in a soil profile may be controlled, at least in part, by carbon processes, e.g., SOM respiration and transport. As a result, many such elements show a decrease in concentration with soil depth, reflecting loss of available bonding sites when carbon concentration decreases. To understand the fate of these elements in soil, particularly toxic ones such as Hg, it is important to study how carbon cycles in soil affect their mobilization and transport.

A carbon cycle model that simulates both carbon density (g/cm^3) and C-13 to C-12 ratio ($\delta^{13}C$) variations is modified to include another element. The model assumes continuous distribution in carbon quality or turnover times, and a vertical advection velocity of carbon transport. It generates a steady state distribution of carbon density and $\delta^{13}C$ with depth. The second element enters the soil either from atmospheric deposition or from chemical weathering primarily near the surface, producing a characteristic element to carbon ratio at the surface of the mineral soil. This element then follows carbon through decomposition and transport processes. Particularly, with each cycle of SOM through soil microbial biomass, a fraction of carbon is lost as CO_2 and so may be a fraction of the element; the remaining fractions of carbon and the element are incorporated into the microbial biomass and then returned to the SOM pool upon fatality of soil microbes.

The model predicts that the logarithm of the element to carbon ratio is linearly related to $\delta^{13}C$ along the soil depth, both of which are linearly related to the logarithm of carbon density. We tested these relationships for four elements: Hg, As, Fe and Pb, measured from soils of a mixed forest at Bartlett Experimental Forest. All four element/C vs. $\delta^{13}C$ relationships are highly significant ($p<0.0001$) with r^2 values ranging from 0.70 to 0.83 ($n=27$). The physical mechanism behind these linear relationships and their respective slopes and intercepts may differ from one element to another. For Hg, for example, the slope suggests that the Hg distribution is likely in a transient state in response to increased Hg deposition after industrial revolution.

The model is useful for studying how heavy metal vs. carbon relationships are affected by a range of processes or geochemical factors such as pH, Eh, land use change or other disturbances, as well as hydrological conditions.