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Bioavailable Carbon and the Relative Degradation State of Organic Matter in Active Layer and Permafrost Soils

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The decomposability of soil organic matter (SOM) in permafrost regions is a key uncertainty in efforts to predict carbon release from thawing permafrost. The cold and often wet environment is the dominant factor limiting decomposer activity, and SOM is often preserved in a relatively undecomposed or less humified state and can be poorly associated with soil minerals. Thus, the impacts of soil warming and permafrost thaw are likely to depend at least initially on the past history of SOM degradation before its stabilization in permafrost. The Argonne National Laboratory TES SFA is investigating the utility of soil fractionation approaches for assessing the relative degradation state of SOM and the amount of readily bioavailable soil organic carbon (SOC) in the active layer and upper permafrost of tundra soils in arctic Alaska. To assess the relative degradation state of SOM, we used particle size fractionation to isolate fibric (coarse) from more degraded (fine) particulate organic matter (POM) and separated mineral-associated organic matter into silt- and clay-sized fractions. To assess readily bioavailable SOC, we quantified salt (0.5 M K_2SO_4) extractable organic matter (SEOM), which correlates well with carbon mineralization rates in short-term soil incubations. In general, bulk SOC concentrations in permafrost were lower than in comparable active layers. Averaged across all soil layers, 60% of bulk SOC was found in POM. Even in mineral soils, about 40% of bulk SOC was in POM pools. Thus, overall, the organic matter in both active layer and permafrost soils was relatively undecomposed compared to typical temperate soils. In organic soils, SOM was more degraded in permafrost than in comparable active layers. But in mineral soils, this relationship was reversed; SOM was more degraded in the active layer than permafrost. For cryoturbated soils, the presence/absence of permafrost had no effect on degradation state. SEOM pool size was directly related to the quantity of POM carbon on a mass basis, but SEOM averaged only 1.2% of bulk SOC. However, the quality of the SEOM pool was more strongly related to the size of the organomineral pool (clay-sized fraction). Finally, analyses using this dataset showed that mid infrared spectra of bulk soils can be calibrated to predict the measured SOM fractions, which could facilitate widespread, high-throughput estimates of the size of the readily bioavailable carbon pool and organic matter degradation state for permafrost-region soils.