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Composition and state of decay of soil organic matter in permafrost-affected soils of the Lena River Delta, Arctic Russia

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Permafrost-affected soils of the northern hemisphere are crucial for the global carbon cycle as major reservoirs for the storage of organic carbon (OC). Subject to ongoing climate change, Arctic soils face broad alterations due to enhanced warming with subsequent deepening of the active thermal layer, leading to changes of carbon stocks due to alleviated accessibility of organic matter (OM) by microorganisms. In order to unscramble the response of stored OM to ascending temperatures, it is essential to decipher the distribution of OM within these soils, of which chemical compounds it is compiled and how advanced its decomposition is.

Analyzed were soils from Samoylov Island in the Lena River Delta, a region characterized by a polar climate and thick continuous permafrost. Free and occluded particulate OM (fPOM and oPOM) were obtained by density fractionation and mineral soil fractions by wet sieving and sedimentation. Carbon and nitrogen contents of all fractions were determined by elemental analysis and soil OM fractions were objected to 13C nuclear magnetic resonance (13C NMR) spectroscopy.

Sand- and silt-sized particles dominated all samples, while clay-sized particles played a minor role. The portion of fPOM exceeded the portion of oPOM in most samples, independent of the depth layer. Most carbon and nitrogen is stored as particulate OM, while in some samples also clay-sized mineral associated OM contribute considerably to OC stocks despite the low amounts of clay-sized minerals. 13C NMR spectroscopy debunked that the dominating chemical shift region represents O/N alkyl carbon, implying that only less decomposed OM is present and that this dominance is largest in the fPOM and oPOM >20 μm fractions.

Different methods were applied to clarify these findings. The ratio of alkyl to O/N alkyl carbon (Baldock et al. 1997) confirmed that decomposition is most advanced in oPOM <20 μm fractions. Utilizing a method that considers the ratio of the chemical shift regions 70-75 and 52-57 (Bonanomi et al. 2013) showed corresponding results. The molecular mixing model (Baldock et al. 2004) showed a clear dominance of carbohydrates, hence not yet altered or decomposed OM in the POM >20 μm fractions and a slightly more balanced distribution of compounds in the oPOM <20 μm fractions with a higher percentage of lipids.

These results indicate that the major part of SOM stored throughout the profiles of these permafrost-affected soils is composed of organic compounds that represent a rather early stage of decomposition. Consequently, we assume that the fPOM and oPOM fractions >20 μm are at stake when soil thawing enhances as these fractions are labile, primarily protected by the low temperatures (regular freezing) and therefore possibly prone to microbial decay under warmer conditions. On the other hand, the chemical composition of oPOM fractions <20 μm can be regarded as more stable as a shift towards less labile organic compounds is traceable. With ongoing changes in water regime and temperature, it is assumable that soil OC in organo-mineral complexes may play a larger role for the sequestration of carbon in lowland permafrost-affected soils in the future.