Direct evidence for relatively fast cycling of lignin and its high temperature sensitivity

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Climate projection requires an accurate understanding for the decomposition of soil organic carbon (SOC) and its response to warming. However, the wide array of organic molecules in the soil exhibits distinct chemical structures and kinetic properties, making it difficult to unravel the conundrum of SOC stability and response to warming.

An emergent view considers that environmental constraints rather than chemical structure alone control SOC turnover and its sensitivity to warming, but this view has not been tested on long-term (> centennial) scales in natural systems.

In a study published in *Ecology Letters*, researchers from the Institute of Botany of the Chinese Academy of Sciences (IBCAS) assessed the turnover time and long-term responses of various SOC components (including lignin, lipids and black carbon, which collectively account for ~50% of SOC) to temperature variations in soil profiles across a 3,300-km natural grassland transect, by using a novel ecosystem-level approach and the emergent compound-specific radiocarbon analysis.

With 225 measurements of ^{14}C on individual SOC molecular species, the researchers provided the first direct evidence for the relatively rapid turnover of lignin phenols compared with slower-cycling molecular components of SOC (i.e., long-chain lipids and black carbon). This finding suggested that the primary macromolecular structure of lignin does not necessarily confer resistance to decomposition, challenging the validity of carbon cycling models that parameterize SOC pools of differing lability based on lignin contents or lignin-to-nitrogen ratios.

Furthermore, the researchers found that lignin turnover is mainly regulated by temperature and exhibits high temperature sensitivity (Q_{10}) in contrast to the slow-cycling components whose turnover is strongly modulated by mineral association. By compiling published ^{14}C data on physical (density) fractions from globally distributed soils, they confirmed that slow-cycling (heavy, mineral-associated) carbon has lower Q_{10} than fast-cycling (i.e., light) fractions.

This study provides direct molecular-level evidence that mineral association largely governs SOC turnover and attenuates its response to temperature increase. "Our results suggest that global warming may greatly accelerate the decomposition of lignin which is a major component of organic matter in carbon-rich terrestrial environments, such as peatlands and forest organic layers," said Dr. Feng Xiaojuan, corresponding author of the study.

More information: Juan Jia et al, Molecular ^{14}C evidence for contrasting turnover and temperature sensitivity of soil organic matter components, *Ecology Letters* (2023). DOI: 10.1111/ele.14204

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