

Stabilization of lignin in soils - lessons from compound specific ¹³C analysis in long-term field experiments

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Recently, compound specific isotope analysis of lignin-specific biomarkers has shattered the paradigm that the recalcitrant structure of lignin results in long-term stability of lignin in soil. Data from decadal field experiments with natural carbon isotopic labeling (C3-C4 vegetation change) indicate that there is both a stable and a labile lignin pool in soils. As for soil organic carbon in general, interactions with the mineral phase have been suggested to be involved in the stabilization of lignin in soils. In order to reveal where the stable lignin is mainly found, we combined for the first time density and aggregate size fractionation with compound-specific isotope analysis of lignin in the fractions. In a next step, we tried to link the variations in lignin stability between fractions to properties of individual fractions (surface area, type of minerals). The soil had been naturally ¹³C-labelled by 18 years of maize cropping. We identified old lignin deriving from the time before maize cropping by compound-specific isotope analysis of lignin-derived phenolic biomarkers and compared its distribution within the soil to the initial distribution in an archived soil sample. A large proportion of lignin was found in the coarse heavy fraction, suggesting inclusion into macroaggregates. However, isotope data clearly indicated that lignin in this fraction was less stable in the long-term than lignin in light fractions. Our study therefore provides first evidence that at least two different mechanisms operate to stabilize lignin in soils, and also gives us a clue as to their relative efficiency: (1) Some lignin-containing cell structures (e.g. thick cell walls) seem to be indeed recalcitrant enough to persist for decades even under intensive cropping. Due to intensive cropping before the isotopic labeling started, the light fractions are already enriched in these recalcitrant structures, and therefore show very little degradation during the observation period. (2) Macroaggregates, by contrast, may preserve some labile lignin, and the decomposition rate of this labile lignin would then be controlled by the aggregate turnover rate. However, such a temporary inclusion within macroaggregates does not seem to protect lignin as efficiently as the recalcitrant structures found in the light fraction.