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The response of recalcitrant soil organic matter to climate change; insights from speleothems

D. Rudzka and F. McDermott

UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland.(dominika.rudzka@ucd.ie ; frank.mcdermott@ucd.ie)

The mass of carbon stored in soil organic matter (SOM) (1115-2200 Pg) exceeds that of the atmosphere (750 Pg) and vegetation (570 Pg). Enhanced rates of decomposition of SOM due to increased global temperatures cause higher CO2 emission to the atmosphere, constituting a positive feedback. The magnitude of this feedback remains poorly quantified due to different decomposition rates and temperature sensitivities of individual SOM compounds. Soil contains carbon pools that range from easily degradable, active (labile) pools with typically high 14C activity, to passive old carbon (recalcitrant) pools with low 14C activity. The latter dominate (c.90%) the total SOM in most soils. Due to its molecular attributes it is characterized by low decomposition rates and can therefore be stored in soils for hundreds to thousands of years. Also, the recalcitrant pool has a higher activation energy (e.g. tanin: 70 kJ per mol.) compared with the labile pool (e.g. glucose 30 kJ per mol.), which, according to Arrhenius kinetics, reflects the higher temperature sensitivity of the recalcitrant pool. Chemical reaction kinetics dictate that recalcitrant SOM decomposition will accelerate in a warmer climate, but recent published tests (e.g. laboratory and field soil-warming experiments) are controversial due to poorly quantified soil compound properties and the limited duration of warming experiments. To investigate this issue we decided to examine the 'effective' response of SOM to temperature increases by using the radiocarbon signal derived from soil and recorded in speleothems. Stalagmites deposited during a major warming event associated with the last deglaciation were used to avoid the problems associated with the short-term nature of laboratory warming experiments. The transition from the Younger Dryas (YD) to the Holocene (c. 11,600 years ago) is used here as an example of a rapid warming event. The new methodology involves combining radiocarbon data with U-series dated stalagmites. Temporal changes in the initial 14C activity of U-series dated stalagmites deposited during the last deglaciation reflect changes in the local carbon cycle in the overlying soils due to warming. If recalcitrant soil carbon has higher temperature sensitivity than labile carbon, as suggested by kinetic modelling, we predict a increase in the initial 14C activity of organic carbon incorporated into stalagmites during the YD. Results from stalagmite GAR-01 from N. Spain show that the initial 14C activity anomaly during the YD is twice that of the atmosphere. This anomaly is interpreted as a change in the balance in the rate of decomposition of different carbon pools. During the cold event (YD), recycling of recalcitrant carbon appears to have slowed down relative to the preceding warmer episode (Bølling/Allerød), and the subsequent warmer early Holocene. This result is consistent with the hypothesis that recalcitrant carbon is more temperature sensitive.