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Position specific labeling: a new tool to trace the fate of C in soil

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Understanding and managing organic C in soil is one of the most important issues not only in the scope of climate change and C sequestration, but also for maintenance of soil fertility and ecosystem sustainability. To trace C in soil, 13C and 14C labeling were applied since 1946. In the first studies the labeled plant residues were used, later – after the 70ties the individual organic substances such as sugars, amino acids, carboxylic acids etc. as well as dimers and polymers of these monomers were applied. The application of the 13C and 14C labeling allowed huge progress in understanding the sources, transformation, translocation, sequestration and losses of C in/from soil. This progress would be not possible without the labeling and not based on the natural abundance of 13C or 14C.

Nearly all previous studies used uniformly labeled organic substances i.e. all C atoms in the molecules were labeled with 13C or 14C. However, this classical approach did not allow to conclude whether the labeled substances were involved in any processes as initial substances, or whether they were transformed to metabolites, and the metabolites and not the initial substances were investigated.

Here we introduce and overview the unique feature of isotope applications – position-specific labeling – to trace the fate of individual C atoms in the molecules and consequently to reflect the specifics of functional groups in the transformations in soil. We show the advantages of position-specific 13C and 14C labeling to investigate sorption, microbial uptake and utilization, decomposition as well as plant uptake of representatives of sugars, amino acids and carboxylic acids. The position-specific labeling allowed always to clarify differences between the fate of initial substance and its metabolites. Such metabolite tracing allowed to evaluate contribution of individual functional groups of one substance to various processes in soil. Furthermore, we coupled position-specific 13C labeling with compound specific 13C analysis of phospholipid fatty acids to trace utilization of individual C atoms of glucose by various microbial groups.

To reflect the differences between the fate of individual C atoms independent on the concentration and pools of the substances in soil, we introduced a divergence index. The divergence index reflects the convergence or divergence of pathways of C from different molecule positions during microbial utilization and stabilization, and consequently during humification in soil.