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Stabilization of microbial biomass in soils: Implications for SOM formation and xenobiotics degradation

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Soil organic matter (SOM) plays an important role in soils. It is the carbon source and the habitat of many soil microorganisms, its quality and quantity thus affect soil microbial activity. Therefore, the amount and composition of SOM determines soil quality, but SOM formation and stabilization are not yet sufficiently understood. Recently, microbial biomass residues could be identified as a significant source of SOM. We incubated 13C-labelled bacterial cells for 224 days in an agricultural soil and traced the fate of the 13C label of bacterial biomass in soil by isotopic analysis. The data were combined to a mass balance, and the biomass residues were visualized by scanning electron microscopy (SEM). A high percentage of the biomass-derived carbon (in particular from proteins) remained in soil, mainly in the non-living part of SOM, after extended incubation. The SEM micrographs only rarely showed intact cells. Instead, organic patchy fragments of 200-500 nm size were abundant. These fragments were associated with all stages of cell envelope decay and fragmentation, indicating specific disintegration processes of cell walls. Similar fragments developed on initially clean and sterile in situ microcosms during exposure in groundwater, thus providing clear evidence for their microbial origin. Microbial cell envelope fragments thus contribute significantly to SOM formation. A significant contribution of cell envelope fragments to SOM formation provides a simple explanation for the development of the small, nano-scale patchy organic materials observed in soil electron micrographs. It also suggests that microstructures of microbial cells and of small plant debris provide the molecular architecture of SOM attached to particle surfaces. This origin and macromolecular architecture of SOM is consistent with most observations on SOM, e.g. the abundance of microbial-derived biomarkers, the low C/N ratio, the water repellency and the stabilization of microbial biomass. The specific molecular architecture controls carbon mineralization and balance. The process is also involved in the fate of environmental contaminants in soil. This has been demonstrated by studies on the biodegradation of isotope labeled 2,4-D, MCPA and ibuprofen in soil where we quantified the contribution of microbial biomass residues to nonextractable residues (NER) in soil. The high amount of label found in biomolecules (fatty acids, amino acids) indicated that virtually all of the NER was made up by microbial biomass residues. We therefore conclude that stabilization of cell wall residues plays an important role in both SOM formation and pollutant degradation in soil.