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Recycling of extracellular metabolites exceeds biomass de-novo synthesis

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In the past decades it was assumed that the C for microbial biomass formation is derived directly from degraded plant-derived organic matter (OM). Microbial necromass was largely discussed as a rather slow-cycling pool contributing to the long-term stable OM in soils. Awareness of the importance of the recycling of cell compounds from "the dead neighbor", i.e. microbial necromass recycling, just recently emerged during long term incubation experiments with frequent disturbances: An ongoing C turnover within a substance class but with variation of the molecular speciation of the isotopically labelled metabolites over several years indicated that C in soils is continuously recycled and that this recycling plays a fundamental role in microbial biomass formation.

We aimed at proofing this relevance of necromass recycling in two experiments under steady state and disturbed conditions: The death of 50% of microbial community was induced by toxin application followed by a rapid recovery of the microbial population. We used position-specific ^{13}C labelling to trace metabolic pathways of de-novo synthesis of phospholipid fatty acids during the recovery phase. Instead of de-novo synthesis, the microbial recovery was accompanied by an intensive metabolite recycling especially of rather complex, "expensive" metabolite pools, e.g. alkyl chains. Consequently, recycling of necromass OM compounds is a key explanation for the rapid recovery of microbial populations in soils after exposure to toxicants.

Assessing the role and rate of recycling under steady state conditions can only be done by biomolecules that display another molecular speciation in the living cells, than they show in non-living soil OM. This prerequisite is fulfilled by the alkyl chains of phospholipids that are present as phospholipid in the membranes of living cells but get cleaved off rapidly from the phosphate and head group after cell death. Consequently, alkyl chains are the dominant OM necromass compounds in soils functioning as a precursor for the microbial phospholipids. Applying position-specifically ^{13}C labeled alkyl chains, we quantified that 75% of the newly incorporated alkyl chains into microbial membranes are derived from intact metabolite recycling under steady state conditions. This preference for recycling rather than for de-novo synthesis of the phospholipid alkyl chains was a rather general observation for bacterial and fungal microbial groups.

Thus, necromass OM recycling is a key process not only for recovery of microbial populations after disturbance but also under steady state conditions. This result challenges future research: 1) In microbial ecology, it has to be considered that biomass "formation" in soil is not necessarily linked to the uptake of a newly added C source, but cells can survive and even grow on their dead neighbors with potentially low incorporation of new plant-derived C. 2) Our definition of "stable", "stabilized" or "persistent" C in soils have to be reconsidered, as continuously recycling C compounds, likely those, which are "metabolically expensive", can have high mean residence times in soil by continuous cycling . Our data call for intensive focus of C (re)cycling studies focused on necromass C reutilization as a largely ignored key process of the soil C cycle.