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Conservative or reactive? Mechanistic chemical perspectives on organic matter stability

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Carbon fixation by terrestrial and marine primary production has a fundamental seasonal effect on the atmospheric carbon content and it profoundly contributes to long-term carbon storage in form of organic matter (OM) in soils, water, and sediments. The efficacy of this sequestration process strongly depends on the degree of OM persistence. Therefore, one of the key issues in dissolved and particulate OM research is to assess the stability of reservoirs and to quantify their contribution to global carbon fluxes. Incubation experiments are helpful to assess OM stability during the first, early diagenetic turnover induced by sunlight or microbes. However, net carbon fluxes within the global carbon cycle also act on much longer time scales, which are not amenable in experiments. It is therefore critical to improve our mechanistic understanding to be able to assess potential future changes in the organic matter cycle. This session contribution highlights some achievements and open questions in the field.

An improved mechanistic understanding of OM turnover particularly depends on the molecular characterization of biogeochemical processes and their kinetics: (i) in soils and sediments, aggregation/disaggregation of OM is primarily controlled by its molecular composition. Hence, the chemical composition determines the transfer of organic carbon from the large particulate to the small dissolved organic matter reservoir - an important substrate for microbial metabolism. (ii) In estuaries, dissolved organic carbon gradients usually suggest conservative behavior, whereas molecular-level studies reveal a substantial chemical modification of terrestrial DOM along the land-ocean interface. (iii) In the ocean, previous studies have shown that the recalcitrance of OM depends on bulk concentration and energy yield. However, ultrahigh resolution mass spectrometry in combination with radiocarbon analyses also emphasized that stability is tightly connected to molecular composition: Recalcitrant marine OM was particularly characterized by compounds with a higher degree of unsaturation, and lower content of dissolved organic nitrogen and sulfur. Both aspects combined suggest that aggregation processes are also likely to be critical for OM fluxes. Carboxyl-rich alicyclic molecules have been suggested to promote aggregation and thereby affect OM reactivity. One important challenge for the oncoming research in the field is to establish approaches which use semi-quantitative mechanistic understanding for the quantitative determination of long-term kinetics.