

Organic matter composition in organic-mineral soil particles

P. Leinweber

Institute for Soil Science, University of Rostock, Justus-von-Liebig-Weg 6, D-18051 Rostock, Germany

The intimate association of organic and mineral soil constituents to form organic-mineral complexes is one of the most important soil characteristics as it affects almost all physical, chemical and biological, soil properties. Therefore, the composition and functions of soil organic matter (SOM) in organic-mineral soil particles are subject to intensive research. According to pre-treatment and isolation techniques we can distinguish investigations of (1) particle-size, (2) density and (3) aggregate fractions. Methodical approaches applied were (1) wet-chemical analyses (contents of carbohydrates, lignin decomposition products, N-containing compounds, lipids), (2) non-invasive spectroscopy (solid-state ^{13}C -NMR), and (3) combinations of pyrolysis with gas-chromatography/mass spectrometry (GC/MS) and field-ionization mass spectrometry (FI-MS). This contribution gives the state of knowledge about organic matter composition in soil fractions of different size, density and spatial arrangement (aggregates).

Extraction, hydrolysis and wet-chemical analyses

The proportions of carbohydrates hydrolyzable in 12 M H_2SO_4 increase from sand to clay. Wider hexose to pentose ratios indicate that portions of carbohydrates enriched in clay derive from microbial decomposition products. Various characteristics of phenolic lignin oxidation products show reduced proportions and increased degree of decomposition and side-chain oxidation of lignin with decreasing particle size. The contents of N-containing compounds increase in this direction so that organic matter in clay fractions has the closest C/N ratios. The proportions of N-fractions always followed the order of nonidentified N > amino acid-N > NH_3 -N > amino sugar-N. Amino acid patterns are relatively constant across size fractions. Lipids appear to be relatively enriched in clay although only a few systematic studies have been carried out.

Solid-state ^{13}C -NMR spectroscopy

Figure 1 shows increasing abundance of alkyl-C and decreases in O-alkyl- and aromatic C with decreasing

particle-size. Carboxyl C does not vary systematically with fraction size. Limitations in acquisition and interpretation of solid-state ^{13}C -NMR spectra of particle-size fractions arise from the influence of paramagnetic metal cations. More favourable is the application of ^{13}C -NMR to specific light density fractions.

Analytical pyrolysis

Between 35–95% of C and 60–100% of N can be volatilized from organic-mineral particles. The assignment of marker signals to important SOM compound classes showed increasing proportions of phenols, lignin monomers, carbohydrates and N-containing compounds with decreasing particle size. We identified 37 N-containing molecules in the pyrolysates of hydrolysis residues from clay. These indicated that the fraction of wet-chemically nonidentified N is composed of proteinaceous materials bound by pedogenic oxides and alkylated N-heterocycles in stable humic substances (Leinweber and Schulten, 1998). The organic matter in Vertisols, a soil group with exceptionally large contents of swelling clays, contained more peptides and heterocyclic N than in other major soil groups. This is considered as further evidence for the strong influence of mineral matrix on SOM composition. Investigations of light and heavy density fractions showed that organic-mineral bonds increase the thermal stability of distinct compound classes, e.g. alkylaromatics (Schulten and Leinweber, 1998). The spatial arrangement of organic-mineral soil particles results in aggregate fractions of different size, composition, stability and SOM turnover rates. Monreal *et al.*, 1997) observed that microaggregates < 50 μm contained old organic matter with slow turnover rates. The FI-mass spectra of < 50 μm aggregates pointed to the depletion of pyrolyzable plant and microbial components which are concentrated in macroaggregates.

Conclusions and outlook

This survey describes the state of the art of novel analytical approaches in the investigation of organic-

mineral soil fractions. Hitherto, their composition and basic functions can be described on the basis of wet-chemical and spectroscopic data. A breakthrough for a deeper understanding of organic-mineral and organic-organic reactions on the molecular level can be expected if well established wet-chemical, sophisticated spectroscopic, novel submicroscopic techniques and molecular modelling organic-mineral particles and surface reactions are applied in an integrative approach (Schulten *et al.*, 1998).

References

- Leinweber, P. and Schulten, H.-R. (1998) *Soil Sci. Soc. Am. J.*, **62**, 383–93.
- Monreal, G.C., Schulten, H.-R. and Kodama, H. (1997) *Can. J. Soil Sci.*, **77**, 379–88.
- Schulten, H.-R. and Leinweber, P. (1998) *Europ. J. Soil Sci.* (submitted).
- Schulten, H.-R., Leinweber, P. and Schnitzer, M. (1998) In: *Structure and Surface Reactions of Soil Particles* (eds. P.M. Huang, N. Senesi and J. Buffle). pp. 282–324. J. Wiley and Sons Ltd.

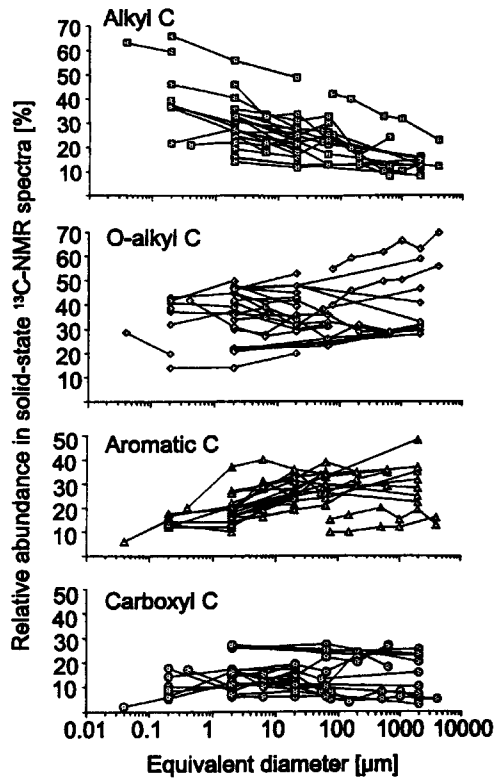


FIG. 1. Relative abundance of C-species in ¹³C-NMR spectra.