



Strong organic-mineral interactions promote rapid accumulation of organic matter in young soils derived from calcareous wastes of soda production

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Accumulation of organic matter is the most evident process during initial stages of soil genesis. To study the mechanisms of organic matter accretion in young soils in greater detail we took advantage of a time series of soils that developed in homogeneous calcareous wastes resulting from the industrial production of soda at Bernburg (Saxony-Anhalt/Germany). The four sites selected derive from lagooned $\text{CaO} \cdot \text{H}_2\text{O}$ and CaCO_3 and were under natural succession for 15, 19, 57, and 70 years. The soils are weakly to strongly alkaline with pH values ranging from 8 to 11.

Soil samples were taken from various pits at 0–4, 4–10, 10–20, and 20–30 cm depth and analyzed for mineral composition (X-ray diffraction), organic and inorganic carbon. Organic matter pools were determined using density fraction with Na polytungstate. Free particulate organic matter not attached to the soil mineral matrix was separated by flotation using a solution of a density (d) of 1.6 g cm^{-3} . Particulate organic matter ($d < 1.6 \text{ g cm}^{-3}$) occluded within aggregates $< 2 \text{ mm}$ was separated after ultrasonic dispersion at 50 J ml^{-1} . Fractions of organic matter intimately associated with mineral particles (mineral-associated organic matter) were separated using a solution with $d = 2.2 \text{ g cm}^{-3}$. Organic matter fractions were analyzed for organic and inorganic carbon and for chemical composition, using CuO oxidation and solid-state nuclear magnetic resonance spectroscopy (NMR).

At all study sites, rapid accumulation of organic C took place. In the topsoils (0–4 cm), the concentrations of organic C ranged from 1.8–3.1% at the 19-year site to

4.1–8.8% at the 70-year site. Even at 20–30 cm depth, concentrations of organic C were between 0.1–0.5%. The amounts of organic matter occluded within minerals increased with time, however, occluded organic matter comprised only a small fraction of organic carbon in the soils. The dominant portion of organic carbon was due to mineral-associated matter in the density fraction 1.6–2.2 g cm⁻³. According to CuO and NMR analyses, the most evident difference between organic matter in that fraction as compared with free and occluded particulate organic matter was the larger content of carboxyl groups, indicating partial microbial oxidation. Only small concentrations of organic carbon were found in the density fraction >2.2 g cm⁻³.

Elemental analyses and X-ray diffraction revealed calcite to be the dominant mineral in all soils, progressively increasing with age. In the oldest profiles, calcium carbonate comprised up to 82% of the soil material. In all soils, the density fraction >2.2 g cm⁻³ consisted almost exclusively of calcite while the density fraction 1.6–2.2 g cm⁻³ mainly contained ettringite, thaumasite, hydrocalumite, and hydrotalcite. Layered double hydroxides such as hydrocalumite and hydrotalcite are characterized by a high point of zero charge which means they are positively charged even under the alkaline conditions in the studied soils and thus well suited to adsorb large quantities of acidic organic compounds.

The results suggest that the rapid accumulation of organic matter is because of the attachment of partly oxidized organic matter to reactive mineral resulting in stabilization against further decomposition.