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Saturation of clay surfaces by organic matter: consequences on physical, chemical and microbiological properties

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Abstract:
Clay minerals are considered to protect organic matter (OM) from degradation by microorganisms and therefore to contribute to carbon sequestration in soils (Kleber et al. 2021). Recent studies showed contradictory results on the limit of mineral-associated organic carbon in agricultural soils (Georgiou et al., 2022; Begill et al., 2023; Cotrufo et al., 2023), suggesting that fine-scale processes are not yet well understood. This study aimed to determine the maximal capacity of different types of clay minerals to stabilize OM and evaluate the consequences on physical, chemical and microbiological properties. To this aim, we conducted a laboratory experiment using 3 types of clays differing in their specific exchange surfaces: kaolinite (30 m²/g), montmorillonite (250 m²/g) and sepiolite (600 m²/g). Each microcosm (100 ml) consisted of the same 10 g ratio of sand (80%) and each type of clay (20%) mixed with different amounts (1, 5, 10, 25 or 50%) of green waste compost (GWC) in order to test the saturation of mineral surfaces. After 6 months of incubation, during which CO_2 emission was monitored weekly, we measured the water holding capacity, chemical parameters like pH and cation exchange capacity (CEC), and the microbial biomass by qPCR. Interactions between clay minerals and OM were also observed with the scanning electron microscope (SEM). As expected, mesocosms respiration measurements showed the lowest CO_2 release in sepiolite treatments, compared to montmorillonite, kaolinite and the control without clays. The large specific surface of sepiolite inevitably impacted microbial growth. The effect of clays on the OM mineralization was observed up to 5%, 10% and 25% of GWC in the mix, respectively with kaolinite, montmorillonite and sepiolite, suggesting that above these amounts of OM, mineral surfaces were saturated. SEM analyses revealed that without clay minerals, OM matter remained as particulates (POM), whereas in the treatments with kaolinite, montmorillonite and sepiolite addition the mineral-associated OM (MAOM) were visible. Results showed the highest water retention in sepiolite treatments and with increased doses of compost, kaolinite and montmorillonite treatments remained on the same level. CEC and pH also varied significantly after the incubation, suggesting changes in physicochemical properties due to OM stabilization and interaction with clays. The microbial biomass, either bacteria or fungi, followed the amount of CO_2 released, suggesting that the accessibility of OM by microorganisms was limited by clay minerals, depending on their nature and saturation capacity. Ongoing Rock-Eval pyrolysis will help to characterize the chemical composition of the organo-mineral complex in order to determine if the physical protection of OM is associated with chemical change. Microbial community structures assessed by means of amplicon next-generation sequencing (NGS) will also inform on microbial qualitative change according to OM stabilization.

Annex :

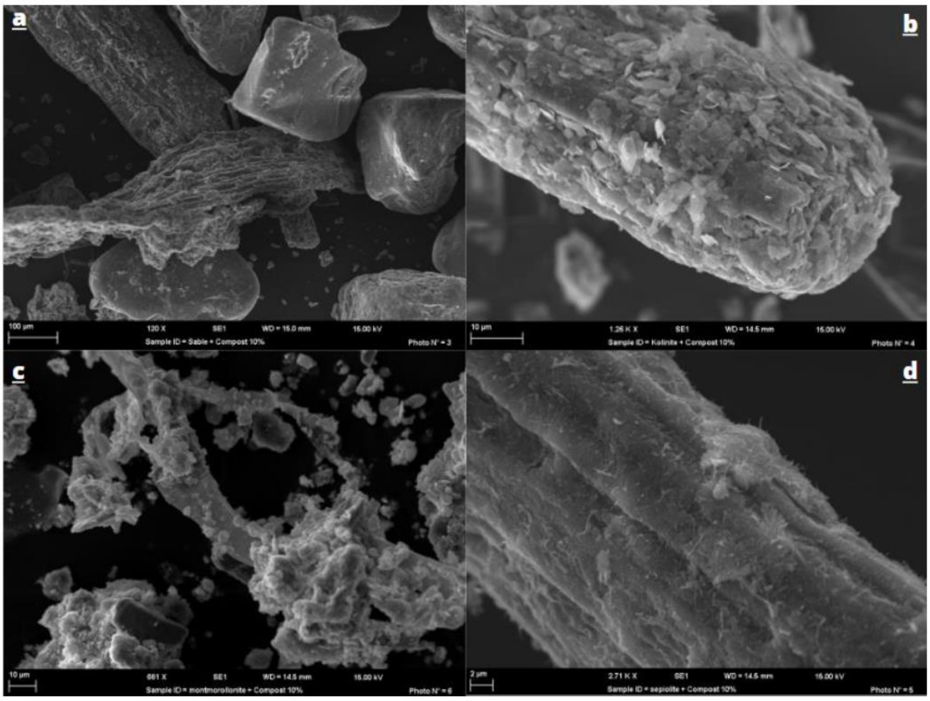

Figure 1: Scanning electron microscopy (SEM): sand (a), kaolinite (b), montmorillonite (c) and sepiolite (d) with 10% compost after 6 months of incubation.