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Biochemical, microbiological and sensing approaches to assess the environmental impact of engineered nanoparticles on soil ecosystems

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Among the several pollutants released into environments in the last centuries by human activities, recent developments in nanotechnology and use of engineered nanoparticles (ENPs) in the production of novel materials employed for industrial and environmental applications, as well as the release of ENPs as by-products of human activities, have been increasing the concentrations of ENPs in environments. Such nanomaterials are inorganic, organic or a mixture of them. The presence of ENPs in environments is raising concerns about their potential impacts on living organisms. Nanomaterials released through human activities can easily reach soil through different ways. Then, organisms living in soil contaminated with ENPs might be significantly affected in their features. However, information on how ENPs affect soil microbial communities under field conditions is scarce. Furthermore, natural compounds, such as soil organic matter components (e.g. humic and fulvic acids), could possibly alter, under field conditions, both the toxic effects of ENPs, as presumed through tests carried out in artificial media, and the resistance and resilience of soil microbial communities. Soil microorganisms play an important role in ecosystem processes, such as nutrients cycling and soil organic matter decomposition. Hence, any factor affecting global biomass, composition and activity of microbial communities in soil would necessarily affect soil quality. Then, such parameters might represent sensitive (biological) indicators of soil response to environmental stresses (e.g., organic pollutants, heavy metals, anti-microbial agents, hormones, etc.).

In the last years, we investigated the possibility to use sensors and sensing systems in monitoring microbial metabolic activities and soil quality, as well as the presence and degradation of organic pollutants in soil ecosystems. We used different sensing approaches from electronic noses (E-noses) to multi-parametric hybrid sensing probes in both laboratory and field experiments. The sensing systems were demonstrated to be effective for the specific purposes tested in different experimental contexts.

Here we tested the capacity of a sensing system (typically an E-nose) in risk assessment of ENPs for microbial communities in soil ecosystems. Specifically, we investigated the short-term effect of some ENPs (MWCNTs and TiO_2) on the metabolic activity and biomass of microorganisms to provide us with insights on how these nanomaterials may alter key ecosystem functions. Three doses of each nanomaterial were individually applied to two soil types undergoing different managements, which were then incubated for 30 days. The atmosphere of the differently treated soil ecosystems was analysed periodically with a specifically designed E-nose. In parallel sets of experiments, similar soil ecosystems were analysed in biochemical and microbiological parameters, since microbial populations are commonly considered as the component of soil most sensitive and responsive to environmental modifications, and is often used to assess soil quality and health. Specifically, microbial biomass, modifications in the microbiological community of nitrifiers, the catabolic potential of soil microbial communities in the ecosystems and nutrient cycling capacity were measured. The results obtained through E-nose measurements were compared and integrated with findings obtained through the other soil methodologies and are here discussed.