Nanoscale Interactions between Engineered Nanomaterials and Black Carbon (Biochar) in Soil

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Joseph J. Pignatello,[1] Jason C. White[1], Minori Uchimiya[2]
[1]The Connecticut Agricultural Experiment Station, [2]USDA-ARS, New Orleans, LA

Project Objectives- An understanding of the interactions between engineered nanomaterials (NMs) and soil constituents, and a comprehension of how these interactions may affect biological uptake and toxicity is currently lacking. Black carbon (BC) is a natural constituent of soils due to fire history, and can be present at up to several percent by weight through the emerging practice of applying manufactured charcoal (biochar) to improve soil fertility. The structure of BC is nanoporous and hydrophobic, properties that may favor its heteroaggregation with engineered NMs. However, published reports on BC-NM interactions are completely absent. We have selected four NMs likely to be found in agricultural soils: zero-valent silver (n-Ag^0), cerium oxide (n-CeO_2), multiwalled carbon nanotubes (MWCNTs, ^{14}C-labelled), and n-C_{60} fullerene. The objectives are [1]:

1. Quantify and characterize the binding and binding reversibility of NMs to macroscopic BC particles in aqueous suspensions as a function of solution composition and BC surface and pore characteristics (including the effects of weathering) with the goal of establishing a mechanistic model for these interactions. This objective will include a determination of the effect of BC addition on the retention of NMs in soil columns.
2. Determine the impact of BC nanostructure and weathering on the biological effects and accumulation of engineered nanomaterials in plant and earthworm bioassays in soil. The effect of biochar on plant/worm biomass, transpiration, photosynthetic potential, reactive oxygen species production, and particle accumulation will be determined. An essential goal of this objective is to determine the correlation between bioavailability and physical availability as assessed in Objective 1.

NANO HIGHLIGHT-

The nanoporous and hydrophobic properties of biochar portend interactions with engineered nanoparticles. At neutral pH, n-CeO_2 does not adhere to biochar. However, n-CeO_2 dispersion in water is promoted by biochar, possibly due to a surfactant-like effect resulting from the dissolved organic matter associated with biochar. Biochar amendment to soil at levels up to 5% had little effect on the accumulation CeO_2 NPs by soybean. However, nanoparticle ceria added to soil significantly decreases pigment content (chlorophyll a,b and carotenoids) by the plant. Fullerenes strongly attach to biochar particles, possibly by pore penetration. Biochars, especially those made at low heat treatment temperature, decrease the size of n-C_{60} aggregates. Likely because of the release of soluble organic matter. The results of this study will serve agriculture by providing a mechanistic foundation for the fate and bioavailability of NMs in soil as a function of biochar presence that will aid in the development of accurate nanotoxicity risk assessment.

References

[1] For further information about this project, contact Joseph.Pignatello@ct.gov