Unraveling the Complex Environmental Fate of Engineered Nanomaterials through Synchrotron X-ray Spectroscopy

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Engineered nanomaterials (ENMs) have entered commerce, and therefore are entering the environment. The environmental implications and health effects of these novel materials are still being assessed. Environmental transformations of these materials are one key factor affecting their fate and impacts. Synchrotron X-ray spectroscopy methods are the only methods avalable to track ENM transformations in complex environemntal and biological media.

We have used a combination of X-ray absorption spectroscopy, micro-X-ray fluorescence, and X-ray scattering methods to elucidate the key transformation processes like sulfidation and phosphorylation for the most common ENMs including Ag^0, CuO, and ZnO. These transformations occur in complex media like wastewater treatment plant biosoilds and freshwater wetland sediments. We have also used these tools to better unerstand the ENM properties affecting the uptake and translocation in aqautic and terrestrial plants.

Results indiate that CuO and Ag^0 ENMs sulfidize quickly (<1 week) in wetland sediemnts and in WWTP biosolids. Despite sulfidation, these materials remain bioavailable to plants due to the ability of plants to take up the sulfidized ENMs directly. Surface charge greatly affects the ability of 4nm CeO_2 NPs to translocate in plants, and controls the locations in the plants where the ENMs target. This suggests that coating charge can be used to target selected regions within the plant vasculature. Importantly, both CuS and ZnS formed in sediments and biosolids are highly labile depending on environmental conditions, resulting in bioavialable metals.

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