Role of size, concentration, and natural organic matter on the fate, behavior, and toxicity of nanoparticle in aquatic environment

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Understanding the impact of engineered nanoparticles (ENPs) physicochemical properties such as size, surface coating and concentration; and environmental factors such as ionic strength, media composition and natural organic matter (NOM) on NP fate, behavior, and toxicity is crucial for ENP risk assessment. Thus, the overall aim of this dissertation is to evaluate the effects of ENP properties and water chemistry on the behavior, bioavailability, and toxicity of silver nanoparticles (AgNPs) and platinum nanoparticles (PtNPs).

The aggregation behavior of PtNPs was typical of Derjaguin, Landau, Verwey, and Overbeek (DLVO) type aggregation and the critical coagulation concentration of PtNPs was independent of particle size. PtNPs aggregate size increased with increases in NP concentration and with decreases in PtNP primary particle size in moderately hard water (MHW) and synthetic seawater. NOM enhanced the aggregation of 20 nm PtNPs (PtNP20) in MHW due to the bridging of NOM-coated PtNPs by divalent counterions but had no effect on the aggregation of 95 nm PtNPs (PtNP95). PtNP20 aggregate size increased with the increase in NOM elemental ratio of H to C and the relative abundance of lignin formulae. However, PtNP20 aggregate size decreased with the increase in NOM molecular weight, SUVA254, elemental ratio of O to C, and the relative abundance of condensed hydrocarbon and tannin. Whereas PtNPs did not undergo significant dissolution (i.e., < 15% after 24 h) in synthetic seawater regardless of the NP exposure concentration; AgNPs dissolved faster and to a greater extent with the decrease in NP concentration. This finding suggests that NP aggregation became less significant and NP dissolution became more dominant at lower concentrations.

PtNP influx rate constant (k_{uw}) in Lymnaea stagnalis decreased with decreases in PtNP size, possibly due to increased aggregation with the decrease in PtNP size. NOM did not have a significant impact on the bioavailability of PtNP20 but suppressed the bioavailability of PtNP95. The bioavailability of PtNP95 increased by 6-fold (from k_{uw}= 0.075±0.05 to 0.456±0.037 L g^{-1} D^{-1}) with the increase in NOM sulfur content. Reduced sulfur (S_{red}) content - in form of exocyclic and heterocyclic reduced sulfur- in the NOMs exhibited a strong positive correlation with k_{uw}, which was attributed to the higher affinity of reduced S to PtNPs relative to the oxidized S. A concentration dependent increase in Amphiascus tenuiremis mortality was observed in AgNPs and dissolved Ag exposures, at environmentally relevant sub-lethal concentrations (i.e., 20-75 µg L^{-1}). A sharp decline of 1.8-7 folds in the reproduction (i.e., fecundity) were observed in the AgNO3 exposure, whereas, fecundity was not impacted by the AgNPs exposure. Slower release of dissolved Ag from AgNPs and/or reduced Ag uptake in the nano form attributed these sharp contrasts in responses.

Overall, the results suggest that the NP’s physio-chemical properties, water chemistry, and NOM compositions are key factors that contribute to the behavior, transformation, bioavailability, and toxicity of metallic NPs in the aquatic environment. Hence, scientists, regulators, and policy makers should carefully consider NP colloidal stability, NP concentration, and NP-NOM interactions while assessing the risk of released NPs from consumer products.