Bioavailability and Toxicogenomic Effects of Pristine and Aged Ag Nanoparticles to a Model Organism *Caenorhabditis elegans*

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Abstract

There has been rapid growth in nano-containing products currently available on the market. According to life-cycle analyses, many of these nanoparticles (NPs) will be entering the terrestrial environments through wastewater treatment (WWT) streams and eventually through application of biosolids to agricultural soils. Once the nanoparticles enter WWT and soils, they will inevitably undergo environmental transformations. Given the high amount of sulphur present in wastewater and sewage sludge, the predominant transformation product has been shown to be Ag_2S.

In this study we investigated the toxicity and genomic responses of both pristine and fully sulfidized PVP coated Ag nanoparticles (Ag NPs), as well as Ag ions, to a model soli organism *Caenorhabditis elegans*. Overall, aged Ag NPs were less toxic for all three endpoints studied (mortality, growth, and reproduction) than pristine Ag NPs due to their lower solubility and bioavailability. The bioavailability of Ag, examined using a synchrotron-based X-ray microprobe, showed that *C. elegans* took up little Ag from the aged Ag NPs. However, the animals were exposed to pristine and aged Ag NPs and Ag ions at the concentrations that caused the same level of mortality. This suggests that that tissue concentration required to elicit a given level of mortality is actually lower for sulfidized Ag NPs than for pristine Ag NPs. Alternatively, the mechanism of toxicity for sulfidized Ag NPs does not involve uptake of Ag.

To get an insight into toxicity mechanisms that might be caused by Ag NPs, we used exposures at EC_{30} for reproduction to examine and compare transcriptomic responses of *C. elegans* to both pristine and sulfidized Ag NPs as well as Ag ions. Only 3% of the differentially expressed genes were shared among all treatments emphasizing the uniqueness of the responses. The nematodes exposed to the sulfidized Ag NPs demonstrated very distinct transcriptomic responses when compared to those of pristine Ag NPs or Ag ions. Even though pristine Ag NP-exposed *C. elegans* also were characterized with distinct transcriptomic responses they shared more genes (12%) in common with ion-exposed nematodes than the animals exposed to the sulfidized particles (7%). Nematodes exposed to pristine and sulfidized Ag NPs shared only 7% of differentially expressed genes. The observed toxicities for both pristine and sulfidized Ag NPs were mainly particle-specific because the particle-free supernatants caused very little toxicity and because there were not that many genes shared between particles and ions. Taken together these results demonstrate that aging has very different effects on transcriptomic responses and hence, on toxicity and likely acts through different mechanisms than pristine Ag NPs.