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Letter to the Editor

Comments on "Particle surface characteristics may play an important role in phytotoxicity of alumina nanoparticles" by Yang, L., Watts, D.J., Toxicology Letters, 2005, 158, 122–132.

Keywords: Alumina; Aluminum; Nanoparticle; Phytotoxicity

An article published recently in *Toxicology Letters* (Yang and Watts, 2005) received significant national and international media attention (UPI, 2005). This article was used in the media to claim that nanoparticles exert a negative impact on plants. This media coverage reflects the increasing public attention to biological effects of nanoscale particles, as well as the growing number of scientific publications reporting both positive (for example, nanoscale titanium oxide improved growth of spinach seeds, see Zheng et al., 2005) and negative (Holsapple et al., 2005) effects. However, effects due to the chemical nature, in contrast to unique features of nanoparticles such as quantum effects and ability to translocate, are not always distinguished despite the importance of these issues for understanding the mechanisms of biological activity/inactivity of nanoscale materials. Yang and Watts (2005) failed to make this distinction and, therefore, reached some unsupported conclusions.

The paper describes results of phytotoxicity studies of nanoscale alumina powder coated with phenanthrene, and uncoated. This research showed that uncoated alumina particles caused inhibition of plant root elongation, a phytotoxicity measure. This inhibition was reduced upon increased loading of phenanthrene to the surface of the particles, as well as upon addition of dimethyl sulfoxide which reportedly has strong affinity to surface aluminol species. No changes in root elongation were reported upon treatment with an unspecified dose of submicrometer-size alumina particles of unidentified origin. This research has three important limitations.

(1) The authors do not describe previous studies demonstrating phytotoxicity of aluminum and the reduction in phytotoxicity upon treatment with chelating agents. Instead, they dedicate the Introduction to assessment of animal toxicity studies with other nanoscale particles. They leave the reader new to this topic unaware that aluminum toxicity in plants has been well documented including inhibition of root growth (Sparling and Lowe, 1996; Schaedle et al., 1989; Gensemer and Playle, 1999; Rengel, 2004). It has long been suggested that increased solubility of alumina soil compounds with acidic precipitation is responsible for the die-back of trees in Europe and North America (Ulrich et al., 1980). Furthermore, the effects of chelating agents on the toxicity of aluminum have been thoroughly described (Sauvant et al., 1999, 2000). Depending on the cell culture, chelating agents caused increased or decreased toxicity (Sauvant et al., 1999). Plants use ameliorative effects of aqueous silicon species for protection against alumina toxicity (Hodson and Evans, 1995; Cocker et al., 1998; Hodson and Sangster, 1999). The protective role of silicon was related to the formation of very stable alumosilicates.

(2) The authors do not discuss the increased solubility of nanoscale alumina and do not characterize the

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concentration of aqueous aluminum species. The solubility of alumina must be considered since aqueous aluminum species are known phytotoxic agents. Dissolution of minerals including alumina is proportional to mineral surface area (Lasaga, 1981). Since the surface area of particles is inversely proportional to particle diameter per given mass, then dissolution of alumina can be expected to increase with decrease in particle size. This in turn would lead to an increased concentration of aqueous aluminum species available to inhibit root growth. Thus, the increased toxicity of nanoscale alumina compared to microscale alumina for the same mass dose can be expected. In an earlier toxicological study, it was shown that for ciliated protozoa the IC_{50} values were found to be between 10 and 15 μg Al/ml for soluble aluminum salts and 495 μg Al/ml for fine particles of alumina (Sauvant et al., 2000). Since Yang and Watts (2005) failed to quantify exposures and response to aqueous aluminum species, their paper contributes little to the understanding of mechanisms of increased phytotoxicity. Concentration of aqueous aluminum species could be determined with a number of analytical methods such as inductively coupled argon plasma in tandem with atomic emission spectroscopy or flame atomic absorption spectrophotometry (NIOSH, 1994).

(3) Despite the lack of measurement of plant exposure to aluminum present in solution, the authors concluded that phytotoxicity of alumina nanoparticles is not related to alumina as a chemical. This contradicts previous reports of alumina toxicity (Sparling and Lowe, 1996; Schaedle et al., 1989; Gensemer and Playle, 1999; Rengel, 2004), including microscale alumina (Sauvant et al., 2000), and reports of enhanced plant growth following treatment with nanoscale titania (Zheng et al., 2005). Since the authors failed to quantify plant exposure to submicrometer-size alumina particles, there is insufficient evidence to support their conclusions.

These limitations necessitate care in the interpretation of these research findings. The toxicology of nanoscale particles is a very broad area potentially encompassing an enormous variety of materials. There are still many unresolved issues and challenges concerning the biological effects of nanoscale particles (EPA, 2005; Holsapple et al., 2005). In order to conduct research activities most effectively, it is of paramount importance to quantify exposures and to conduct thorough physical and chemical characterization of test materials as recommended (Oberdörster et al., 2005). Attention to appropriate experimental design and interpretation will be needed to provide a defensible scientific understanding of the biological effects of nanoscale particles.

Disclaimer

The findings and conclusions in this report are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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