20b Carbon Nanotubes: Assessing Potential Human and Ecological Uptake

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Nanotechnology generally centers around the fact that materials exhibit novel properties and functions at the nanometer scale, properties and functions that cannot be observed and discriminated at any other scale. At the same time, nanomaterials may well involve new environmental and health risks that cannot be readily observed, discriminated, or predicted by traditional approaches and assessment techniques based on our current knowledge platforms of materials behavior (Masciangioli and Zhang 2003). A rigorous mechanistic characterization and quantification of such effects thus constitutes a pressing research need.

Carbon nanotubes represent one of the highlights to emerge from nanotechnology research and development to date. First discovered by Sumio Iijima in 1991 (Iijima 1991), these materials have attracted significant research attention over the past decade due to their potential for breakthroughs in a broad range of applications. Carbon nanotube research has been driven to date by potential applications, and extensive information regarding the relevant electrical, thermal and mechanical properties of these materials has been forthcoming. On the other hand, the potential health and environmental impacts have not been similarly characterized, and the risks they pose to the welfare of humankind and the environment are not well understood (Colvin 2003).

The lack of research on the environmental transport and potential uptake of carbon nanotubes is largely attributable to the fact that methods to quantify such materials in complex environmental or biological samples are not currently available. While optical counting, light transmittance, and elemental carbon analysis can be used to measure carbon nanotubes in relatively pure samples, background particulate matter or carbonaceous materials confound measurements that employ these methods. Other common analytical approaches such as liquid chromatography are hindered by the polydisperse nature of carbon nanotubes; e.g., regardless of the synthesis procedure employed, nanotubes vary widely in length and diameters, which results in an array or agglomeration of signals. While it may be possible, albeit laborious, to integrate over the entire frequency range to estimate the total carbon nanotube concentration, this approach may become infeasible in the presence of other chemicals or organic matter.

Similarly, near-infrared fluorospectroscopy has been used to detect carbon nanotubes in cells (Cherukuri et al. 2004), but quantitative analyses using this method also require the summation over multiple signals. Further drawbacks of this approach include its inability to detect metallic carbon nanotubes, the need for the nanotubes to be fully dispersed, and the potential for sonication time to influence absorption readings (Heller et al. 2005). Several researchers have used fluorescent tracers chemically bonded to carbon nanotubes to trace their movement in cells (e.g., Prakash et al. 2003), but these bonds alter the physical and chemical properties of the nanotubes, which will likely change their uptake potential.

In the work reported here, a novel method we have developed to synthesize labeled carbon nanotubes allows precise quantification of both as-produced and functionalized carbon nanotubes in environmental and biological media. These nanotubes have a very high purity as determined using a suite of analytical techniques including thermal gravimetric analysis and transmission electron microscopy. In the work described here, these labeled carbon nanotubes were used to assess the potential uptake of carbon nanotubes by common ecological receptors and humans.

The ecological receptors include the aquatic worms (Lumbriculus variegatus) and the earthworms (Eisenia foetida), representative organisms for the sediment and terrestrial environments respectively. The potential uptake of carbon nanotubes by humans through oral ingestion was assessed using monolayers of Caco-2 cells, cells from a human liver carcinoma cell line. These cells have been widely used to assess uptake across the small intestine often the limiting step in the uptake of foreign chemicals. The implications of these findings will also be discussed.

References Cherukuri, P., S. M. Bachilo, S. H. Litovsky and R. B. Weisman (2004). "Near-infrared fluorescence microscopy of single-walled carbon nanotubes in phagocytic cells." Journal of the American Chemical Society 126(48): 15638-15639. Colvin, V. L. (2003). "The potential environmental impact of engineered nanomaterials." Nature Biotechnology 21(10): 1166-1170. Heller, D. A., P. W. Barone and M. S. Strano (2005). "Sonication-induced changes in chiral distribution: A complication in the use of single-walled carbon nanotube fluorescence for determining species distribution." Carbon 43(3): 651-653. Iijima, S. (1991). "Helical Microtubules of Graphitic Carbon." Nature 354(6348): 56-58. Masciangioli, T. and W. X. Zhang (2003). "Environmental technologies at the nanoscale." Environmental Science & Technology 37(5): 102A-108A. Prakash, R., S. Washburn, R. Superfine, R. E. Cheney and M. R. Falvo (2003). "Visualization of individual carbon nanotubes with fluorescence microscopy using conventional fluorophores." Applied Physics Letters 83(6): 1219-1221.