Volume 3 • Number 2 • 2008

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NanoTox: Hysteria or scientific studies?

A recent paper published in *Nature Nanotechnology* (Poland et al 2008) has been receiving a lot of attention. The paper details a study in which carbon nanotubes were injected into the mesothelial lining of the chest cavity of mice and concludes that multiwalled carbon nanotubes longer than 15 microns cause asbestos-like, length-dependent, pathogenic behavior (including inflammation and the formation of lesions known as granulomas). As one can ascertain by the alarming title of this article, it has been sending shivers down every scientist's back who works with carbon nanotubes for various medical and nonmedical applications.

However, as needed as such studies are to understand the toxicity of nanomaterials (a field often now called "NanoTox"), is the "not-needed" hysteria that can result from such studies (and titles from such studies as perceived by the general public who would not read the actual study). Specifically, the field of NanoTox must always keep in mind that not all nanomaterials are created equal. While it doesn't take much to explain the difference between iron oxide nanoparticles and carbon nanotubes, it may be unknown to some that, even within the family of carbon nanotube materials, extreme diversity exists. There are multiwalled compared to single walled carbon nanotubes. There are functionalized and nonfunctionalized carbon nanotubes. There are purified and unpurified carbon nanotubes. All have extremely different properties tailored for different applications.

Scientists conducting such studies must also keep in mind the final form of the nanomaterials in the eventual product. As is well known, conventional materials display much different toxicities depending on material availability. If a toxic material is embedded in an implant (such as in the widely implanted Ti6Al4V) and, thus, such materials will never be released into the body, clearly it is not as much of a concern as if that material is exposed and ready to enter the body. In terms of the *Nature Nanotechnology* study, it is important to mention that only a small fraction of final products are based on exposed particulate carbon nanotubes as was studied; thus, one has to wonder how pertinent studies evaluating the toxicity of particulate carbon nanotubes are. This is even more true since most of the medical applications of carbon nanotubes involve their growth from other materials (such as from anodized materials) or direct incorporation into polymers under closed environments.

Equally as important to keep in mind for the NanoTox research area, are impurities. As in the paper published in *Nature Nanotechnology*, it is important to emphasize that one of the toxic carbon nanotubes had 37.3 micrograms/gram of an impurity (iron); significantly higher than any of the other carbon nanotubes tested. Just like in conventional materials, impurities in nanomaterials are just that: impurities and undesirable. Many of the carbon nanotubes now intended for medical applications possess fully reacted catalysts and, thus, do not have this extremely highly level of impurities present. (Even the second type of carbon nanotubes found to be toxic in the *Nature Nantechnology* study, contained upwards of 0.8 micrograms/gram of vanadium, whereas all other carbon nanotubes, even the two found not toxic, did not contain any vanadium.)

Lastly, the animal model used in NanoTox studies must accurately mimic the nanoparticle route of entry. As the authors of the *Nature Nanotechnoloy* paper attest,

their paper intended to correlate inhalation of asbestos to carbon nanotubes, yet, their study did not employ inhalation what-so-ever.

So as a plea to the scientific community, before creating hysteria for nanomaterial toxicity, please conduct these important studies thoroughly and with great scientific rigor before making broad claims.

References

Poland CA, Duffin R, Kinloch I, et al. 2008. Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study. *Nature Nanotechnology*, available on line, May 20, pp. 1–6.