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Carbon Nanotubes: Canary In The Mine?

Friday, Jun 20, 2008 --- This month, scientists at the University of Edinburgh Centre for Inflammatory Research, the Woodrow Wilson International Center for Scholars, and other locations released results from a study linking carbon nanotube (CNT) exposure in mice to the development of cell pathologies associated with asbestos exposure.

The widely-publicized research specifically found that exposing the mesothelial lining of the body cavity of mice to long-fibered CNTs results in asbestos-like pathogenic behavior, including the formation of cell lesions of the type which are known precursers to mesothelioma development in humans.[1]

Suggesting a connection between CNTs, the rising star of the thriving nanotechnology industry, and the human health questions associated with asbestos is a surefire way to gain the public eye, but the study did not answer the critical question of whether CNT exposure can cause cancer in humans.

The study was focused on mice, not people, and it was a short term exposure study, not an evaluation of longer-term exposures that cause asbestos-related diseases. The study did not involve inhalation, the route of exposure that is known to cause the most common asbestos-related diseases. The study did not even address whether CNTs would be able to reach the cells where mesotheliomas develop.

While the study raises more questions than it answers, it nonetheless emphasizes the importance of conducting vigorous research into the human health ramifications of nanotechnology alongside investigations of the technologies' new industrial applications.

By evoking the specter of asbestos-like problems, the study brings to the forefront the need to design and implement adequate protection for the health of nano-exposed workers, users and consumers.

Carbon Nanotubes: Nanotechnology Stars

Carbon nanotubes are among the myriad nano-scaled substances currently the focus of a worldwide blizzard of scientific research. A nano-scaled material is one of extremely small size – one to 100 nanometers in length is the usual measure – with characteristics often dramatically different from those of its macro-scaled chemical counterparts.

These characteristics open the door in many cases to exciting applications.

Nanosilver, for example, is already being used in novel ways ranging from a clothes washer additive said to require less water for effective cleaning to the promotion of rapid healing in burn wounds through long lasting antimicrobial action.

But the undisputed "poster particle" of the nano revolution is the CNT. Its characteristic cylindrical shape and ability to be formed with a single or multiple (2 to 50) walls concentrically stacked along a common long axis gives CNTs properties highly desirable in many industrial products.

Indeed, the study authors note that the "global market for CNTs is predicted to grow to between $1 billion to $2 billion by 2014."[2]

CNTs' characteristic long, thin particles are also evocative of the needle-like shape of some asbestos fibers. This resemblance gives rise to questions about potential health risks like those associated with asbestos: asbestosis, lung cancer, and mesothelioma.

Potential Pathogenicity Of Needle-Like Structure

Prior studies have shown that injection of long-fibered asbestos into the peritoneal cavity of mice causes mesothelioma, a cancer of the cell layer lining internal surfaces of the pleural and peritoneal cavities and associated organs.

Building on that foundation, the present research explored the effects of injected long-fibered CNTs on the mesothelium.

Researchers prepared samples of both long and short fibered amosite asbestos and multi-walled CNTs, including two with a substantial proportion of fibers longer than 20 • m and 2 consisting of "short" (low aspect ratio) CNTs arranged in tangled aggregates. A nano-particulate carbon black sample was also used as a non-fibrous control.

The scientists then injected 50 • g doses of the samples into the peritoneal cavities of mice, which were systematically washed out at 24 hours and 7 days following exposure in order to test the cells and molecules then present in the peritoneal cavity.[3]

From the recovered material, the researchers assessed the protein levels and cell populations to evaluate inflammatory and pathogenic responses to the different substances.[4] Inflammation is a normal response to pathogenic material, and is typified by production of polymorphonuclear leukocyte (PMN) and proteins.

Cell lesions and foreign body giant cells are also typical findings in cases of indigestible or non-degradable materials that macrophages cannot eliminate.

Pathogenic Behaviors In CNT-Exposed Cells

The data analyzed by the researchers shows that pathogenic behavior, in a pattern to which asbestos and other pathogenic fibers conform, is associated with long-fibered CNTs exposure.

Thus, the samples containing long fibers of both asbestos and CNTs yielded inflammation markers: significant PMN, protein exudation; lesions of aggregated fiber-containing cells on the diaphragm's peritoneal side; and foreign body giant cells.

Equally significant, samples without detectable long fibers failed to cause any significant inflammation at 24 hours or giant cell formation at 7 days. The non-particulate carbon black sample also did not evidence peritoneal inflammation.

This finding suggested to the researchers that it was the fibrous shape, rather than the simple graphene chemistry, that had the dominant effects on the mesothelium.[5]

Questions Abound

The authors underscore the study's limited focus: exploring the theory that CNTs' needle-like structure is associated with the development of the observed cell pathologies.

While the lack of peritoneal inflammation in the study's non-fibrous carbon black sample supports the theory, the authors acknowledge the need for further confirmatory work and additional research to eliminate other factors, such as particle size and relative length, as potentially involved in cell pathology development.[6]

The researchers also acknowledge many of the questions that remain unanswered by this study, such as whether the inflammatory responses found in the mice cells at issue would have proceeded to develop into mesothelioma, along the pattern typical of injected asbestos particles, and whether inhaled CNTs (as distinct from the injected materials used in the study) would be able to reach the mesothelium in sufficient numbers to cause mesothelioma.[7]

Additional studies will be required to explore these and other issues related to the question whether human uses of CNTs hold human health risks.

What Does It Mean For CNTs?

In these early years of the 21st Century, the seemingly limitless technological uses for which CNTs seem well-suited are dazzling. Research into the promising innovations and applications enabled by CNTs and other nano materials should certainly continue. The present study's reminder of experience with asbestos, last century's industrial star, does not counsel otherwise.

Rather, this study underscores the importance of undertaking vigorous concomitant research to fully explore potential health effects from exposure to CNTs.

All of those engaged in work involving the use of nano materials should keep abreast of the literature to ensure that material handling and other relevant techniques are up to date.

And, for every step in nano-related research, development, manufacture and sale, effective health-protective measures should be proactively designed and implemented for researchers, workers, users and consumers.

--By Antony Klapper, Margaret L. Sanner and Jesse Ash, Reed Smith LLP

Antony Klapper, Margaret Sanner and Jesse Ash are product liability litigators and members of Reed Smith's Nanotechnology Team. Please contact them directly to learn more about the firm's comprehensive nanotechnology services.

[1] Craig A. Poland, Rodger Duffin, Ian Kinloch, Andrew Maynard, William A.H. Wallace, Anthony Seaton, Vicki Stone, Simon Brown, William MacNee, & Ken Donaldson, “Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study,” Nature Nanotechnology, 1 (May 20, 2008), advance online publication at www.nature.com/naturenanotechnology.

[2] Id., 1.

[3] Id., 2.

[4] Id., 2-3.

[5] Id., 4.

[6] Id., 5. The study authors explain that their prior research shows that intraperitoneal injection of long-fibered asbestos resulted in an exaggerated inflammatory response and found little such response from exposure to short amosite fibers; they acknowledge that these findings are not necessarily associated with CNTs.

[7] Id., 5.

