Space elevators, tennis racquets, and mesothelioma

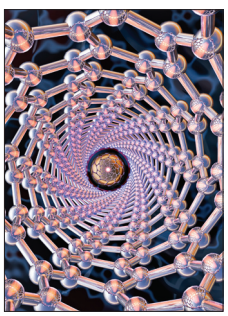
On May 20, 2008, research published in *Nature Nanotechnology* showed carbon nanotubes cause an asbestos-like pathogenicity in the abdominal mesothelium of mice. The rapid commercialisation—predicted to reach US$2 billion by 2014—of this particular nanotechnology is being done under an assumption that the chemical does not pose any hazards to human health. However, this latest study, along with other data, suggests otherwise.

Carbon nanotubes are cylindrical molecules with nanometre diameters, and with lengths varying from micrometres to millimetres. Notably, they are stronger than diamond, are very lightweight, and have extraordinary electrical and thermal conductivity. These characteristics have given rise to a burgeoning manufacturing industry in which carbon nanotubes are being used in electronics, optics, drug-delivery devices, protective clothing, strengthening of sports equipment, and in research into genetically modified crops and space exploration. However, production and disposal of carbon nanotubes on an industrial scale potentially exposes many workers to prolonged inhalational contact. This exposure creates two hazards: first, the shape and dimensions of the carbon fibres are similar to the carcinogenic forms of asbestos, and second, iron from the manufacturing process is retained in the nanofibres—a situation comparable to that in commercially available asbestos—leading to an additional carcinogenic risk in which iron accelerates the generation of oxygen-free radicals in the pleural lining of the lungs.

The study in *Nature Nanotechnology* is the third report this year to highlight the biological effects of carbon nanotubes. Together with papers published in specialised toxicology and material sciences journals, the data show nanotubes can cause an inflammatory response and granuloma formation in the peritoneum along with frustrated phagocytosis, which can cause chronic stimulation and production of inflammatory mediators. Furthermore, carbon nanotubes are biopersistent, induce mesothelioma in mice, and affect cultured mesothelioma cells in a similar way to asbestos. Although these studies are not conclusive, taken together, the findings highlight the possibility that carbon nanotubes might be carcinogenic to human beings.

More risk research is still needed to establish exactly what type of carbon fibres pose the greatest risk, the extent of exposure needed to elicit a carcinogenic effect, and, moreover, whether mesothelioma, or other lung diseases, are possible outcomes in human beings after particle inhalation. But, until such knowledge has caught up with the technological advances, it would be wise to invoke the Precautionary Principle to ensure health and safety measures are sufficiently rigorous to decrease the possibility of health risks to industry workers. Safety measures, such as modified industrial processes, changes to working practices, and adaptations to personal protective clothing and respiratory equipment, have been suggested. These actions would prevent a repetition of the pitiful response seen in the 20th century to evidence linking asbestos with various lung diseases. Mistakes that have left an appalling legacy: 5000 deaths per year from asbestos-related mesothelioma in the UK by 2020; 1 million deaths worldwide by 2035; and economic consequences of epic proportions—at least £471 million in health-care expenditure in the UK in 2000, and estimated litigation costs of US$200–300 billion in the USA. Such consequences must be avoided during the implementation of carbon nanotechnologies.

Nanotechnologies are being assimilated quickly into the re-engineering of existing products and into new technologies, even though our physical and chemical knowledge of these molecules exceeds our biological understanding of their effects. In 1946, a company doctor at a leading asbestos company commented, "…humanitarian motives may decide the public conscience not to wait for scientific proof before insisting on more stringent safeguards against dust inhalation". A remark that was as insightful then as it is now. Industrialists, regulators, and health and safety executives involved in oversight of nanotechnologies would be well advised to recall this thought and to not dismiss it with the ease of their predecessors. ■ *The Lancet Oncology*



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For more on the **biological effects of carbon nanotubes** see *Nature Nanotechnol* published online May 20, 2008; DOI:10.1038/nnano.2008.111; *J Toxicol Sci* 2008; **33:** 105–16; and *J Mater Sci: Mater Med* 2008; **19:** 1523–27