Environmental Aspects of Nanotechnology
Case study: Carbon nanotubes and uncertainty – Part I

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Nanotechnology is a broad area of scientific research and development. According to the US National Nanotechnology Initiative, one of the largest funders of nanotechnology research in the world, 'Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometer, where unique phenomena enable novel applications.'

One class of nanoparticles are carbon nanotubes, believed to be the strongest known material on a weight-by-weight basis. Carbon nanotubes look like a sheet of graphite, rolled up into a long tube with carbon atoms arranged in hexagons and pentagons. They have diameters of a few nanometres, and can be up to 1 mm long. They are flexible, have metallic or semi-metallic behaviour and high electrical conductivity. For these reasons, they are believed to have many potential commercial applications. They may play an important role in manufacturing car and spacecraft bodies, and also in lightweight bullet-proof fabrics. They can be functionalised with many chemical groups and thus have potential medical applications.

At the moment, however, production of carbon nanotubes is limited by practical difficulties in making pure samples and their cost. About 500 tons of carbon nanotubes were produced globally in 2008, while Japanese companies alone are planning to produce thousands of tons annually within five years.

Another limitation with carbon nanotubes is their potential biological and environmental toxicity. The long, thin fibrous nanotubes raise concerns that they might have asbestos-like toxicity. Poland et al. (2008) injected carbon nanotubes into mice which developed inflammation and lesions, similar to those leading to mesothelioma, the hallmark cancer caused by asbestos. Zhao et al. (2008) injected carbon nanotubes into mice with faulty immune systems and found no negative effects. However, the carbon nanotubes accumulated in their livers and spleens, causing no apparent damage, but raising questions about their distribution throughout the body and long-term accumulation. Carbon nanotubes are highly fat-soluble compounds. Other studies following radioactively-labelled carbon nanotubes have found no accumulation in the liver, spleen and lungs of mice.

You are preparing to launch a major research initiative at your university involving carbon nanotubes. How would you address human and environmental toxicity in:

a. Your application for funding for your Carbon Nanotube Research Centre.

b. The protocols you will put in place for researchers handling carbon nanotubes.

c. Prepared comments requested by a local newspaper for an article about the Centre.

Case study: Carbon nanotubes and uncertainty – Part II

The precautionary principle

The precautionary principle is one approach to dealing with questions of risk which involve much scientific uncertainty. The principle has been incorporated into many environmental conventions. The European Commission's Code of Conduct for Responsible Nanosciences and Nanotechnologies (N&N) Research states:

> N&N research activities should be conducted in accordance with the precautionary principle, anticipating potential environmental, health and safety impacts of N&N outcomes and taking due precautions, proportional to the level of protection, while encouraging progress for the benefit of society and the environment.
> ftp://ftp.cordis.europa.eu/pub/fp7/docs/nanocode-recommendation.pdf

Applying the precautionary principle has been challenging because of its numerous definitions and lack of clarity about how it should be practically implemented. However, some key features common to its formulations are that it calls for approaches which involve:

- Focusing on situations of scientific uncertainty where important information is unknown.
- Aiming to prevent serious and/or irreversible harm to the environment and health.
- Setting appropriate goals in light of what is known about potential risks and benefits.
- Shifting the burden of proof onto those who seek to develop or market products or processes with significant risks.
- Applying the 'polluter pays' principle when damage does occur.
- Identifying alternative means of achieving goals that carry reduced risk of harm.
- Involving all stake-holders in the decision-making process.

(from *Nanoethics: big ethical issues with small technology*; Continuum, 2009)

In what ways would the above criteria help in the design of best practice policies for researchers in your new Carbon Nanotube Research Centre?

Your Centre has received £20 million in start-up funding with a potential to increase this by £100 million provided high-impact outcomes are produced within three years. Would these funding arrangements raise any ethical concerns?