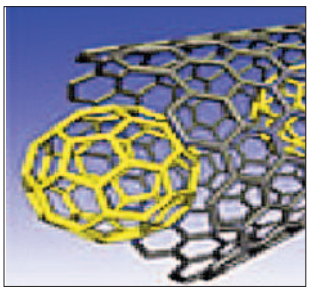
Risk management of carbon nanotubes



This information sheet is specifically about the manufacture and manipulation of carbon nanotubes and has been prepared in response to emerging evidence about the toxicology of these materials. However, the risk management principles detailed here are equally applicable to other nanodimensioned bio-persistent fibres with a similar aspect ratio.

Background

Carbon nanotubes (CNTs) are molecular-scale manufactured forms of carbon. There are two general groups:

- single-walled (SWCNTs); and
- multi-walled (MWCNTs).

CNTs can differ in terms of chemical composition. They may be pure carbon or contain metals or other materials. They can be sixty times stronger than steel, yet six times lighter. CNTs have chemical, physical and bioactive characteristics of considerable research and commercial interest.

There has been much discussion about the similarities between CNTs and asbestos within the scientific and regulatory community. This is because **some** CNTs are:

- similar in shape to asbestos fibres; and
- similar in their ability to persist in the lungs of laboratory animals.

Exposure to asbestos can have serious effects on the health of those exposed, including lung fibrosis, lung cancer and mesothelioma. The fundamental question is whether or not, if inhaled, CNTs are also capable of causing these health effects.

Exposure to CNTs can occur:

- during manufacture;
- through incorporation in other materials, eg polymer composites, medical applications and electronics; and
- during research into their properties and uses.

New evidence (2008)

The University of Edinburgh recently published new research in *Nature Nanotechnology*.[1] The research found that long, straight MWCNTs with a high aspect ratio produced a marked inflammatory reaction and the formation of granulomas when injected into the abdominal cavity of mice. Granulomas are small nodules of cells that form around foreign bodies that cannot easily be cleared. The reaction was similar to that seen when asbestos fibres with a high aspect ratio are injected into the abdominal cavity of mice. When short asbestos fibres, nanoparticulate carbon black and short or tangled MWCNTs were injected there was little or no inflammation. This suggests that the inflammatory response seen in this study may be due to the long, thin shape of the fibres. Long-thin fibre shape is thought to be an important factor in the development of asbestos-related diseases. While this research does not prove that CNTs will cause the same diseases as asbestos, it does raise the level of concern.

This finding applies only to long and thin carbon nanotubes (and possibly other nanomaterials that are long and thin). It does not apply to other nanoparticles that have different shapes.

Legal duty

People who create risk through work activities have a legal duty to understand those risks, and make sure they are kept as low as reasonably practicable. The principles of risk assessment are well established and apply even though all the necessary information on nanoparticles is not yet available. Although there is uncertainty about the risks of exposure to CNTs, the regulatory response is to take a precautionary approach. An assessment under the Control of Substances Hazardous to Health Regulations 2002 (as amended) should be carried out for all work involving CNTs and suitable and sufficient risk management measures put in place. This guidance will help with this process. Failing to carry out a suitable and sufficient risk assessment may lead to enforcement action by HSE.

It is also particularly important that everyone potentially exposed to CNTs receives a high standard of information, instruction and training, particularly on controlling exposure and maintaining that control.

Supply of CNT materials

When supplying CNTs to other companies or university departments, always provide health and safety information with the material. This information should include a warning that the material contents are CNTs, with an indication of the CNT percentage or concentration. It is good practice to label the material ‘Caution: substance not yet fully tested’.

Risk management advice

HSE views CNTs as being substances of very high concern. Although the recent findings only apply to some CNTs, we think a precautionary approach should be taken to the risk management of **all** CNTs, unless sound documented evidence is available on the hazards from breathing in CNTs. If their use cannot be avoided, HSE expects a high level of control to be used. This should include:

- Use appropriate work processes, systems and engineering controls, and provide suitable work equipment and materials to minimise the likelihood of release. This means processes that minimise the amount of CNTs produced, or production of CNTs in a form that reduces the chance of them becoming airborne. Where possible, use equipment that fully encloses the process.
- Control exposure at source by carrying out all tasks, including packaging for disposal, in a ducted fume cupboard with a HEPA filter, or by using other suitable effective local exhaust ventilation (LEV) with a HEPA filter. When using other types of LEV, try to enclose the process as much as possible. HSE considers ductless fume cupboards and recirculating biological or safety cabinets unsuitable for use with CNTs, because these methods do not control exposure so that risks are reduced as low as reasonably practicable. See the Appendix for more information.
- Make sure the LEV achieves and maintains adequate control of exposure at all times. The system requires regular maintenance, periodic monitoring to ensure controls are working and thorough examination and testing once a year (legally you are allowed 14 months between tests). Make sure employees are trained in how to check and use the LEV. Keep records of all the daily, weekly and monthly LEV checks.
- Reduce the number of employees exposed, and minimise:
  - the level and duration of exposure;
  - the quantities used;
  - CNT handling.
- If possible, keep the material wet or damp to reduce the risk of it becoming airborne.
- Provide respiratory protective equipment (RPE). This is for emergencies, and only for use in addition to other control measures. All employees who use RPE must be trained and have had face fit testing. HSE recommends RPE with an assigned protection factor (APF) of 40 or higher.
- Provide personal protective equipment (eg gloves, coveralls). Use single use disposable gloves where possible. If you must use latex, provide low protein powder-free gloves. Provide protective clothing that does not retain dust – do not use wool, cotton or knitted material.
- Consider cleaning, maintenance, filter replacement, storage and disposal in risk assessments for the control of exposure to CNTs. Emergency procedures should be in place to deal with spills, accidents and emergencies.

Remember to check that all controls, including how to use equipment, are effective and continue to work and that associated operating instructions are up to date. Make sure people who use CNTs are properly informed, trained and supervised. Keep records of all training carried out.

HSE specialists are also available to provide advice, you can contact us via our Infoline on 0845 345 0055.

Waste

The Environment Agency advises that this type of waste carbon nanotube material should be classified and coded as hazardous waste. Based on current information, they consider high temperature incineration at a hazardous waste incinerator as the preferred disposal method. Other technologies may be suitable if you can demonstrate that they render the wastes safe. CNT waste should be double-wrapped in sealed polythene bags. Pyrolysis above 500^{o}C will oxidise CNTs completely. The disposal facility should provide adequate documentation of the disposal conditions and incineration temperature.

Appendix

Local exhaust ventilation (LEV): Fume cupboards and microbiological safety cabinets

Conventional ducted fume cupboards and microbiological safety cabinets

Conventional ducted fume cupboards and microbiological safety cabinets may be used for CNTs. A fume cupboard is an enclosure designed to contain and exhaust contaminants generated inside it. A fume cupboard is a safety device, and selection of the proper fume cupboard design and safe work practices are key to user safety.

It is important that a fume cupboard complies with BS EN 14175-4:2003[2] and on-site containment tests should be carried out to ensure effective containment. The robustness test only has to be carried out on the fume cupboards used for CNTs. The test only needs to be done once to make sure the fume cupboard contains under the condition described in the standard. The fume cupboard exhaust air should be HEPA filtered, before venting to a safe place outside.

Microbiological safety cabinets of all classes can be used. The Class II and III microbiological safety cabinets, unlike the Class I type, provide protection for both the user and the material in the cabinet's working environment. All these cabinets exhaust air through a HEPA filter.

Ductless fume cupboards and recirculating microbiological or safety cabinets

Because of the uncertainty about the risks of exposure to CNTs, the precautionary, good practice approach is not use recirculating fume cupboards or cabinets. These types of unit rely on effective filtration. They draw laboratory air over the work, through a dust filter, a carbon filter (and/or a HEPA filter) and return the cleaned air to the laboratory. They are designed to reduce the airborne concentrations of certain aerosols or vapours to acceptable levels. They are **not** designed to handle toxic substances.

Re-circulating fume cupboards should conform to BS 7989:2001.[3] These devices are not recommended for highly toxic chemicals, regular use of toxic and/or flammable solvents in large quantities or for CNTs. The main concern is that the filters have finite capacity. If the capacity is exceeded, hazardous concentrations of the contaminant will break through and return to the workplace.

Ductless fume cupboards and recirculating biological or safety cabinets usually exhaust 30% of the air through the exhaust HEPA filter in the top of the cabinet back into the room, with 70% going into the cabinet via another HEPA filter. Because of the uncertainty about the risks of exposure to CNTs, the precautionary, good practice approach is not to use recirculating fume cupboards or cabinets. Fume cupboards must be connected to externally vented ducting and have a HEPA exhaust filter, with an anti-blowback device between the cabinet and ducting.

References

1 *Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study* www.nature.com/nnano/journal/vaop/ncurrent/abs/nnano.2008.111.html
2 BS EN 14175-4:2004 *Fume cupboards: On-site methods* British Standards Institution
3 BS 7989:2001 *Specification for recirculatory filtration fume cupboards* British Standards Institution

Further information

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This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

A web version of this information sheet can be found at: www.hse.gov.uk/pubns/web38.pdf.