Risk management of carbon nanotubes

This information sheet provides occupational health and safety guidance relating to the manufacture and manipulation of Carbon Nanotubes (CNTs).

Background

CNTs are molecular scale manufactured 3 dimensional forms of carbon, falling into two general groups:

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

CNTs may be present as long, straight fibres or tangled bundles. CNTs can differ in terms of chemical composition; they may be pure carbon or contain metals or other materials, by design, through contamination or as a result of residual catalyst. 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.

Occupational exposure to CNTs can occur:

- during manufacture;
- through incorporation in other materials, e.g. polymer composites, medical applications and electronics; and
- generating nanoparticles in non-enclosed systems
- during research into their properties and uses.
- cleaning of dust collection systems used to capture nanoparticles
- as a result of incorrect disposal
- as a result of accidental spillage

Emerging data indicates that when CNTs are breathed in they can cause lung inflammation and fibrosis. The type of CNT, its physical form and presence of impurities and surface modifications may influence the severity of the response but at present there is not enough information to identify which factors are of greatest concern. It is also not clear if inhaled CNT have a role in the development of adverse health effects at other sites in the body. There is an increasing body of evidence to suggest that CNTs and other nanomaterials with a long, thin and straight shape (referred to as high aspect ratio nanomaterials or HARN) may be particularly hazardous. However, there are insufficient data to confirm the health consequences of long-term repeated exposure.

There is some evidence to suggest that CNTs may be able to provoke inflammatory reactions in the skin but more information is required to properly understand the conditions of exposure that are required to produce such effects.

In view of the evidence for lung damage and lack of information on the effects of long-term repeated exposure a high level of control is warranted for CNTs.

Legal duty

The occupational use of nanomaterials is regulated under the Control of Substances Hazardous to Health Regulations (COSHH) 2002 (as amended).

The principle of risk assessment is embedded in COSHH and applies even though all the necessary information on nanomaterials is not available.

Since there is uncertainty about the risks of being exposed to CNTs, the regulatory and safe response is to take a precautionary approach. The **toxicity of CNTs has not yet been fully investigated.** However it is clear that Safety Data Sheets for CNTs that are based on conventional graphite or graphene will **NOT** provide suitable adequate information to assess the risk from CNTs.

Furthermore as measuring potential airborne exposure levels of CNTs is not a simple task, it is therefore difficult to carry out a rigorous COSHH risk assessment. Having said this it is important that an assessment is done for all work involving CNTs and suitable and sufficient risk management measures put in place.

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

This guidance should help with these processes.

Supply of CNT materials

When supplying CNTs to other companies or university departments, health and safety information must be provided with the material. This information should include a warning that the material contains CNTs, with an indication of the CNT percentage or concentration. It is good practice to label the material ‘Caution: substance not yet fully tested’. It is also important to bring this guidance document to the attention of the person receiving the CNTs.

Risk management advice

CNTs are substances of high concern and unless, or until, sound evidence is available on the hazards from inhalation a precautionary approach should be taken to the risk management of all CNTs.

If the use of CNTs cannot be avoided then the implementation of a risk management programme in the workplaces where exposure to CNTs exists can help to minimise the potential for exposure to CNTs. Elements of such a programme should include the following:

- Assess the worker's job and tasks to determine the potential for exposure.
- Use appropriate work processes, systems and engineering controls, and provide suitable 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) fitted with a HEPA filter. When using other types of LEV, try to enclose the process as much as possible. Ductless HEPA filtered safety cabinets and recirculating HEPA filtered micro-biological safety cabinets can be used with small quantities (<1gram) of CNTs, as long as they are subject to rigorous maintenance and checks are carried out to ensure they are effective at all times. 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, monthly and annual LEV checks.
- Reduce the number of employees handling CNTs, and minimise the level and duration of exposure and the quantities used.
- 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 (e.g. gloves, non-woven coveralls). Use single use disposable gloves where possible. Glove material thickness is a major issue in determining diffusion of nanoparticles and therefore at least 2 layers of gloves are recommended to be worn while handling nanomaterials. If your risk assessment indicates latex is the safest choice then only use low protein powder free gloves. Provide protective clothing such as polyethylene textiles (e.g. Tyvek) which performs better and does not

retain dust or allow dust to penetrate – do not use wool, cotton or knitted material.
- Consider maintenance, filter replacement, storage and disposal in risk assessments for the control of exposure to CNTs.
- Use 'wet-wiping' wherever practicable for cleaning and avoid the use of vacuum cleaners. If vacuum cleaners are the only reasonably practical option they must be appropriately HEPA filtered and decontaminated before further use. Contaminated wet wipes should be double bagged and treated as hazardous waste.
- Emergency procedures should be in place to deal with spills, accidents and emergencies.
- Educate and train workers in the proper handling of nanomaterials (e.g. good work practices) and keep records of all training carried out.

Remember to check that all controls are effective and continue to work and that associated operating instructions are up to date, and continually reviewed, including those on how to use equipment.
HSE specialists are also available to provide advice, and can be contacted via Info line on 0845 345 0055.

Health surveillance

Ongoing research on the hazards of engineered nanoparticles is needed along with the continual reassessment of available data to determine whether specific medical screening is warranted for workers who are producing or using nanoparticles.

There is currently no legal requirement for heath surveillance for those working with CNTs. However, it is now considered best practice to keep a record of all those working with CNTs via the equivalent of a COSHH health record form, in a similar way to other substances of concern.

Waste

- The Environment Agency[1] advises that CNT waste material should be classified and coded as 'hazardous waste'.
- Based on current information, high temperature incineration at a hazardous waste incinerator is the preferred disposal method.
- Other technologies may be suitable if it can be demonstrated that they render the wastes safe.
- CNT waste should be double wrapped in sealed polythene bags.
- Specialist waste contractors should be employed if the above conditions cannot be met.
- The disposal facility should provide adequate documentation of the disposal conditions and incineration temperature.

http://www.environment-agency.gov.uk/netregs/businesses/chemicals/112767.aspx

Appendix -

Local exhaust ventilation (LEV):
Conventional ducted fume cupboards fitted with HEPA filtration and ducted microbiological safety cabinets may be used for CNTs, see below.

Fume cupboards
A fume cupboard is an enclosure designed to contain and exhaust vapours and gaseous contaminants generated inside it. A fume cupboard is a key engineering control device, therefore the selection of the appropriate fume cupboard design and the adherence to safe work practices are crucial to user safety.

For use with CNTs the fume cupboard exhaust air should be HEPA filtered, and wherever reasonably practicable vent to a safe place outside.

It is important that a fume cupboard complies with BS EN 14175-4:2004 and the fume cupboard does not lose containment during normal use. In most circumstances velocity measurements and smoke test will show whether the fume cupboard is effective. Smoke tests can be used to investigate a number of problems, such as:

- irregular air-flow and eddy characteristics resulting in air movement out of the cupboard,
- the possible negative effects of equipment on airflow ,
- the possible negative effect of heat sources within the cupboard on airflow
- leakage from the cupboard or ducting.

However, if there is any doubt about the integrity of the fume cupboard then it may be necessary to carry out a containment test as in BS EN 14175-4:2004.

Installation of fume cupboards must be only be undertaken by those with knowledge of British Standard BS EN 14175-5: 2004 ‘Fume cupboards, recommendations for installation and maintenance’ In particular fume cupboards must not be sited;

- On heavy pedestrian traffic routes
- Adjacent to doors
- Adjacent to opening windows

As the above can cause air turbulence and wake affects that can affect the cupboards containment

- At the open end of a u-shaped laboratory bay, since a fire or explosion within the cupboard, may trap workers in the bay.

Microbiological safety cabinets

Ducted microbiological safety cabinets 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.
*** It should be noted that a Class II cabinet is not suitable for handling large quantities of CNTs because it re-circulates up to 70% of its air.**

Ductless recirculating HEPA filtered safety cabinets and recirculating microbiological safety cabinets

Safety cabinets and microbiological safety cabinets which recirculate air from the cabinets interior, thorough a HEPA filter, back into the laboratory can be used for small quantities of CNTs in the absence of hazardous vapours or gases.

If using a recirculating safety cabinet or recirculating microbiological safety cabinet the following must be considered;
Cupboard must conform to British Standard BS 7989:2001.3

- The filter must be HEPA; charcoal filters alone must not be used[†].
- The cupboard should have a filter saturated warning/alarm
- The cupboard must have a low airflow warning/alarm
- How is a saturated filter to be safely changed?
- How is the contaminated filter to be safely disposed of? (incineration)
- Ensure that the filter integrity test is performed`.
- Subjected to thorough examination and testing at a periods not greater than fourteen months, and more frequently if the assessment identifies higher risk, every 6 months would be good practice.

Charcoal filters are designed to absorb vapours and fumes, for which they have a finite capacity. When the capacity is exceeded, contaminate is returned to the workplace. Charcoal filters alone are not designed for filtering solid materials and for these reasons the use of such systems should be avoided

Users should take steps to ensure that the standard of supervision, training, system of work and record keeping is up to date. The safety cabinet should be set aside for use with CNTs or chemically similar materials because some other chemicals may affect the effectiveness and integrity of the fitted filter.

NB: HEPA filtered recirculating cabinets do NOT absorb or capture fumes, gases or vapours, for which external venting to a safe place would be required in addition to the HEPA filter.

HEPA filter recirculating fume cupboards or cabinets can be used to control any potentially airborne 'dusty' hazardous substance as long as it is subjected to a rigorous risk assessment **BUT** should only be considered where external venting to a 'safe place' is not reasonably practicable.

References

1. BS EN 14175-4:2004 Fume cupboards: Onsite methods British Standards Institution

2. BS EN 14175-5:2004 Fume cupboards, recommendations for installation and maintenance

3. BS 7989:2001 Specification for recirculatory filtration fume cupboards British Standards Institution

4. ISO/TR 12885:2008(E) Nanotechnologies – Health and Safety practices in occupational settings relevant to nanotechnologies

Further information

HSE priced and free publications are available by mail order from HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA Tel: 01787 881165 Fax: 01787 313995Website: www.hsebooks.co.uk (HSE priced publications are also available from bookshops and free leaflets can be downloaded from HSE's website:www.hse.gov.uk.

For information about health and safety ring HSE's Info line Tel: 0845 345 0055Fax: 0845 408 9566 Text phone: 0845 408 9577 email: hse.infoline@natbrit.com or write to HSE Information Services, Caerphilly Business Park, Caerphilly CF83 3GG.

British Standards can be obtained in PDF or hard copy formats from the BSI online shop: www.bsigroup.com/Shop or by contacting BSI Customer Services for hardcopies only Tel: 020 8996 9001 email: cservices@bsigroup.com.

[1] http://www.environment-agency.gov.uk/business/topics/waste/default.aspx

This guidance is issued by the Health and Safety Executive. Following the guidance's 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.