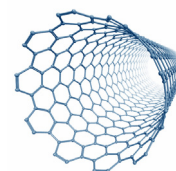




Epoxy Resins and Carbon Nanotubes

Helping Business with Risk, Regulation and Responsibility



Background

SAFENANO has contributed to a lifecycle analysis study of CNT-containing epoxy resins, to identify critical stages where there may be potential for the release of CNTs, and to give a qualitative assessment on the subsequent exposure inhalation risk posed.

The lifecycle study has identified the following groups that could be at risk exposure inhalation to CNTs :

- production personnel involved with **powder handling** and **processing** of CNTs, including **maintenance** and **cleaning**.
- personnel involved with **machining / fabrication** of hardened composites.
- personnel working at **recycling** facilities.

Risk, Regulation & Responsibility

The use of carbon nanotubes (CNTs) will continue to grow in the polymer composite sector as manufacturers continue to seek to exploit the enhanced mechanical, electrical and thermal properties that these nanomaterials impart.

A clear barrier to growth is the significant risk presented to business from :

- uncertainty that remains regarding the potential **toxicity** of these innovative raw materials.
- uncertainty regarding current **regulation** on nanomaterials coupled with the problem that many CNTs are supplied with MSDS data corresponding to graphite.
- results from recent studies^{1,2} which have indicated that some CNTs may manifest **asbestos-like** pathogenic effects through inhalation exposure.

Regulators in the United States³ and Europe⁴ continue to introduce further measures to regulate CNTs. Manufacturers and importers must therefore exercise appropriate duty of care measures and prepare for further regulatory compliance.

Who can help?

SAFENANO is a recognised **leader** in the **characterisation, exposure assessment** and **toxicology** of **particles**. We can help you identify, understand and address the potential risks from manufactured nanomaterials to your employees, your customers and the environment. Using a best practice approach SAFENANO can provide you with a basis for responsible stewardship to help meet your duty of care responsibilities.

1 – Poland, C et al. "Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study"; Nature Nanotechnol, vol, 3, no.7, pp. 423-428.

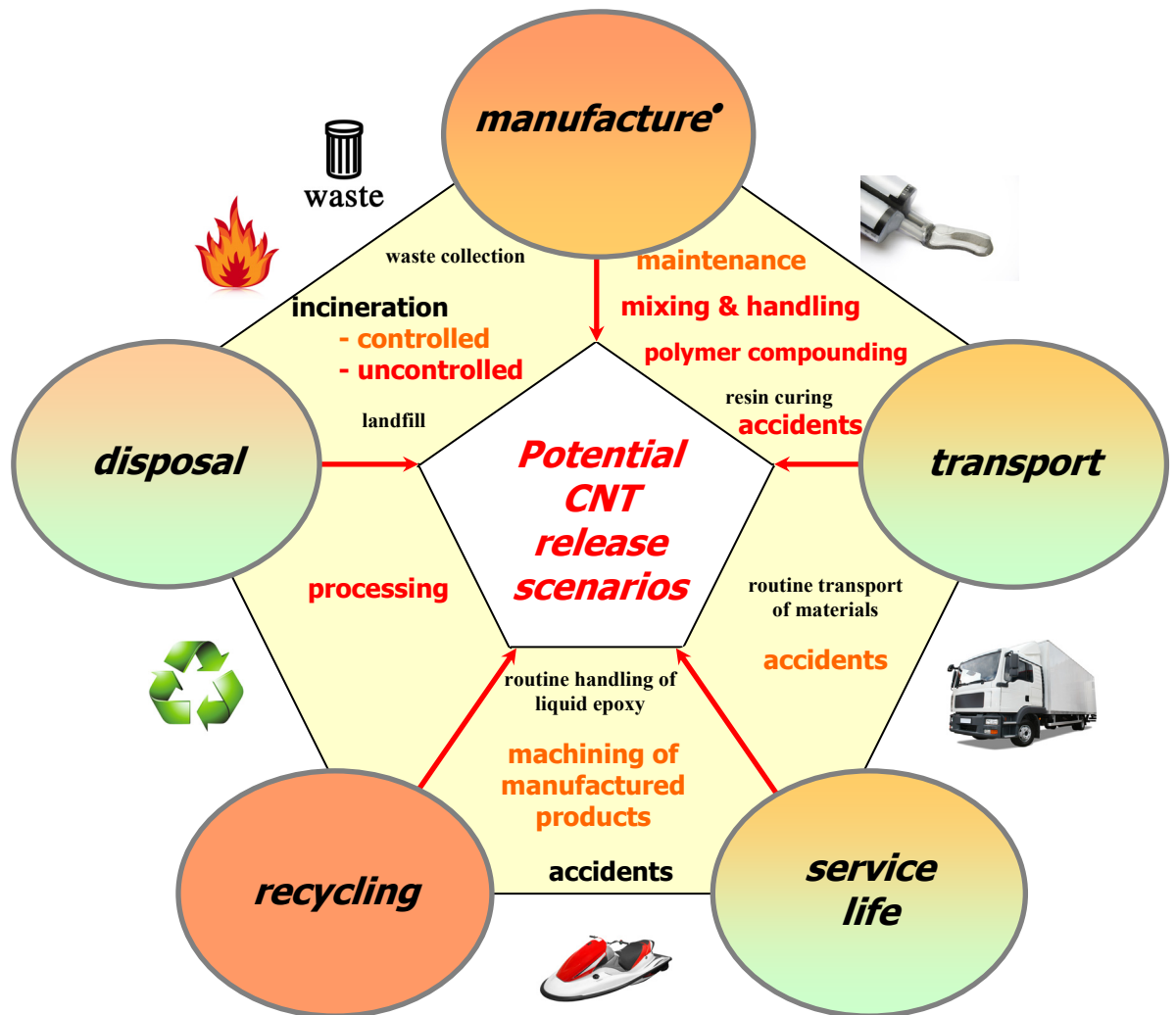
2 – Porter DW et al. "Mouse pulmonary dose- and time course-responses induced by exposure to multi-walled carbon nanotubes"; *Toxicology*. 2010 Mar 10;269(2-3):136-47.

3 – Unites States EPA - "Toxic Substances Control Act Inventory Status of Carbon Nanotubes"; FR Doc E8-26026.

4 – European Commission - Removal of exemption status of carbon and graphite from REACH Amended Annex IV and V.

Lifecycle Analysis of Epoxy Resins and Nanocomposites

The lifecycle analysis below provides information to help identify potential for inhalation exposure to carbon nanotubes used in epoxy resins, allowing you to evaluate the potential risks to your business.



- Analysis of the manufacturing stage assumes that the carbon nanotube material has been manufactured and supplied by a third party as a raw material i.e. the potential exposure inhalation risk resulting from the primary manufacture of carbon nanotubes has not been considered in the above LCA. However, detailed information on the commercial scale production of CNTs and associated release scenarios and exposure inhalation risks are documented in the full report.

The full report "**NANOLIFECYCLE – A Lifecycle Assessment Study of the Route and Extent of Human Exposure via Inhalation for Commercially Available Products and Applications Containing Carbon Nanotubes**" is available on the SAFENANO website, www.SAFENANO.org

Lifecycle Analysis of Epoxy Resins and Nanocomposites

Lifecycle Stage	Potential Release Scenarios
Manufacture	Initial Handling / Mixing Potential inhalation exposure risk to CNTs exists during bulk handling activities involving CNTs (spraying, handling, mixing etc).
	Potential inhalation is possible under conditions where exposure to powder dust is conceivable.
	Polymer Compounding Transfer of CNT containing materials to moulding machines, mixers, extruders etc may generate particulate emissions. Further compounding, machining, finishing, grinding may also be anticipated to generate particulate emissions of CNTs and CNT composites.
	Accidents Accidents may generate particulate emissions of CNTs, CNT composites or their aggregates. This could lead to secondary sources of aerosolisable CNT containing material from dried spilled or residual material. Exposure of CNT concentrates to strong oxidising agents, strong Lewis or mineral acids and strong bases may lead to vigorous reactions and potential CNT release.
	Equipment Maintenance and Waste Disposal of any CNT containing waste generated (CNT that is not incorporated into epoxy or in a dispersion) or particulate emissions released during equipment maintenance may present an inhalation exposure risk.
	Resin Curing CNT release is not anticipated under normal circumstances. Run away cure reactions may char and decompose the resin system, generating vapours which may contain CNT particulates.
Transport	Accidental Exposure to High Temperature or Chemicals These are the principal factors to consider. Such situations may have the potential to release measurable CNTs when large quantities of the resin or nanocomposite are involved.
	Routine Transport Release and inhalation exposure is not anticipated under normal circumstances.
Service life	Processing Further processing (compounding, machining, grinding) may generate particulate emissions, although the potential for CNT release will depend on the strength of the binding within the polymer matrix. Machining tasks have previously demonstrated the release potential of CNTs. Inhalation exposure to CNTs will be influenced by the nature of the materials being handled, dustiness of the process and the containment and particulate control measures in place (e.g. LEV).
	Routine Handling of Liquid Epoxy Liquid-based epoxy resins are available to consumers in a range of sizes (millilitres to several kilograms). Once opened to the atmosphere the epoxy resin quickly begins to harden and is no longer usable. CNTs are not anticipated to be released under normal handling conditions.
Recycling	Recycling (grinding, chopping, milling, re-compounding, chemical treatment) may generate particulate emissions containing CNTs or CNT composites. Manual processes have potential for release into occupational settings and exposure to the workforce. Inhalation exposure will be influenced by the nature and quantity of the materials being handled.
Disposal	Uncontrolled Incineration Uncontrolled incineration (e.g. uncontrolled fires) is unlikely to destroy the CNT and may therefore present a risk of potential exposure.
	Controlled Incineration Incineration conditions (>850°C) are likely to destroy CNT materials except where the composite is fire resistant. Under reductive conditions, SWCNT may reform into MWCNT at around 2200°C. Therefore cylindrical cells, which enter the slag, may contain some CNTs.
	Landfill Disposal of unused pre-hardened epoxy resin in liquid form may be expected by consumers for small volumes and may present a potential source of CNT containing material. However, the epoxy is supplied in a robust container and if broken down would allow air to act on and harden the epoxy. The likelihood of significant quantities of CNT containing liquid epoxy existing in the environment and subsequent inhalation exposure risk to humans is considered low.

Potential Risk : - low - medium - high

Multidisciplinary expertise ...

Our expertise covers occupational hygiene and health, laboratory services, toxicology, ecotoxicology, review of existing data or knowledge and training provision. We offer first class client care from start to finish, using an approach that ensures each customer has access to our multidisciplinary scientific team via a single point of contact.

As recognised leaders in the field, our authoritative reports are guaranteed to be independent, and can be trusted by you, your employees, insurers and investors

Our approach is professional, with an emphasis on delivering multidisciplinary solutions tailored to your needs

Our services span six interconnecting areas :



The SAFENANO Team ...

In addition to its extensive in-house expertise through the IOM, **SAFENANO** has access to a multidisciplinary consortium of internationally recognised researchers through SnIRC – the Safety of Nanoparticles Interdisciplinary Research Centre. SNIRC was formed in 2004 to address nanoparticle risk issues, and is based on long-standing collaborations between the IOM, Edinburgh, Aberdeen and Edinburgh Napier Universities and the Central Science Laboratory (CSL).

The combined expertise of the IOM and SnIRC provides **SAFENANO** clients with a

unique and extensive wealth of experience in particle toxicology, exposure, ecotoxicological and human studies/epidemiology.

Members of the **SAFENANO** team are actively involved in advising government agencies such as DEFRA and NIOSH on the potential risks of nanotechnology to health, and management of these risks.

SAFENANO has also been heavily involved in the writing of landmark reports and papers such as BSI PD 6699-2 " **Good practice guide to safe handling and disposal of nanoparticles** " the Nature paper " **Safe handling of Nanotechnology** " and the DEFRA report " **EMERGNANO** ".



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