



Nanomaterials

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Editorial

Engineered nanoparticles: understanding and managing potential risks

Nanoparticles may be small, but they are at the centre of a huge debate. Nanotechnology has great potential for industry and society, but we need more awareness of the potential impact of manufactured or engineered nanoparticles on human health and the environment to ensure that its products are safe. Although nanotechnology is new, it is expanding quickly and research is needed to understand its associated risks. This thematic issue outlines some of this research and indicates areas for future investigation.

The potential impacts of manufactured nanoparticles on health are of particular concern. The article "Are carbon nanotubes the 'new asbestos'?" examines the claims that nanotubes cause similar health problems as asbestos. "The effects of sunscreen nanoparticles on skin DNA" studies the possible damage that zinc oxide nanoparticles - a common component of sunscreens - cause to human skin cells. Still considering DNA, "Testing the toxicity of nanomaterials" observes the potentially damaging impacts of two commercially available nanomaterials. Whether existing regulations need to be revised to account for the specific effects of nanomaterials is currently under debate.

There are also concerns about the possible effects of nanomaterials on the environment. The article "Discovering how nanoparticles affect the environment" assesses previous research on the interaction of nanoparticles with fungi, bacteria and algae. It identifies five areas where more knowledge is needed to confirm the degree of risk. Focusing on risk assessment, the article "Assessing the ecotoxicological risks of nanoparticles" reviews a range of methods for describing and detecting nanoparticles in the environment. It suggests that, although no single method

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Engineered nanoparticles: understanding and managing potential risks (*continued*)

of risk assessment can be used for the diversity of nanoparticles, testing standards should be developed to allow data comparison from different assessments.

All the studies featured here raise the important issue of methodology in assessing risk. "Predicting the inflammatory potential of nanoparticles" tests a possible method of assessing the inflammatory effect on lungs without the need for animal testing. Its findings also indicate that some metal oxide nanoparticles are unlikely to cause extensive lung disease. "Inhaled nanoparticles can enter the bloodstream" examines evidence for the theory that nanoparticles can enter the lungs and move into fine blood vessels.

Managing exposure to nanoparticles is a key means of managing risk. Taking a life-cycle perspective, the article "How nanotubes could be released into the environment" investigates the different points in a product's life when nanotubes may be discharged into the environment. Specifically, it considers rechargeable batteries and synthetic textiles, two mass-produced products that may contain nanotubes in the future. "Managing exposure to nanoparticles in the workplace" applies a well-known health and safety framework to examine how to minimise risks associated with exposure to nanomaterials in the workplace.

The issues surrounding engineered nanomaterials are recognised as important by the European Commission. The nanotechnology action plan (2005-2009)¹ has provided strong support for research in this area. However, more research is needed, especially in the areas of food and exposure assessment. To allow nanotechnology to develop to its full potential, research into the risks of nanotechnology must continue alongside development of nanotechnology itself to inform future policy and maintain European industrial competitiveness.

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¹ See http://ec.europa.eu/nanotechnology/pdf/action_plan_brochure_en.pdf

Further information on nanotechnology is available from:
http://ec.europa.eu/nanotechnology/index_en.html



Are carbon nanotubes the 'new asbestos'?

The demand for carbon nanotubes is increasing because they have unusual properties, such as unique electrical properties. However, their needle-like shape is similar to asbestos, raising questions about their safety. A recent study conducted on mice indicates that a specific type of carbon nanotube does have asbestos-like effects, but further research is needed to assess whether this is also the case for humans.

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Theme(s): Chemicals, Environment and health

“Although the results do suggest a link between long carbon nanotubes and the cancer caused by asbestos, it remains unknown whether there will be sufficient exposure in the environment or workplace to actually cause it.”

The demand for carbon nanotubes is increasing because they have unusual properties, such as unique electrical properties. However, their needle-like shape is similar to asbestos, raising questions about their safety. A recent study conducted on mice indicates that a specific type of carbon nanotube does have asbestos-like effects, but further research is needed to assess whether this is also the case for humans.

Carbon nanotubes (CNT) are cylindrical carbon molecules, typically a few nanometres in diameter (1 nanometre = 1 millionth of a millimetre). They are very strong, conduct heat efficiently and have unique electrical properties that make them potentially useful in many fields such as optics, electronics and architecture. The demand for CNT is therefore expected to grow. However, there are concerns about their potential health hazards due to their superficial resemblance to asbestos. Exposure to asbestos causes a specific type of cancer called mesothelioma and there are concerns that CNT may also cause this cancer.

The research exposed mice to different types of asbestos, carbon nanoparticles and multi-walled carbon nanotubes (MWNT). MWNT consist of many nanotubes stacked inside each other. The mice were exposed to the substances in the lining of their abdominal cavity which is similar to the lining of the human chest cavity which is affected by asbestos and where mesothelioma normally arises. Indicators of the harmful effects usually caused by asbestos were monitored, such as inflammation and the production of scar-like structures or lesions.

The results revealed that only long multi-walled carbon nanotubes show asbestos-like behaviour. However, the authors point out that their test was specific for fibres and that nanocarbon in the form of particles could be harmful in ways that are not addressed in this study. This flags up the importance of choosing the correct method of evaluating toxicity.

The authors also point out some limitations in their study. Although the results do suggest a link between long CNT and the cancer caused by asbestos, it remains unknown whether there will be sufficient exposure in the environment or workplace to actually cause it. This indicates that there needs to be more in-depth research into exposure levels of long CNT before their use becomes more widespread.

Source: Poland, C.A., Duffin, R., Kinloch, I. *et al.* (2008). Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study. *Nature Nanotechnology*. 3: 423-428.



The effects of sunscreen nanoparticles on skin DNA

A new study indicates that zinc oxide nanoparticles have the potential to cause damage to DNA in human skin cells. These nanoparticles are used as UV filters in sunscreens in many parts of the world, although their use is not yet authorised in Europe (with the exception of one Member State).

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Theme(s): Chemicals, Environment and health

“The results revealed significant damage to DNA from zinc oxide nanoparticles at two of the higher concentrations (0.8 micrograms/ml and 5 micrograms/ml), after six hours of exposure.”

During the last two years, there has been a rapid growth in the use of nanotechnology, some of which has raised concerns about adverse health impacts. The EU's REACH regulation deals with the registration, evaluation, authorisation and restriction of chemical substances¹. Recently, the European Community produced a document that discussed the application of REACH to nanomaterials and identified a number of challenges in this area². A key question raised was how to evaluate a nanomaterial that might be a concern for human health or the environment.

Sunscreens, particularly those using zinc oxide, represent one of the most commonly used nanotechnology-based products. In its traditional form, zinc oxide remains white on the skin, but many sunscreens use its nano-form. Zinc oxide nanoparticles scatter less light so that the sunscreen appears clear. Despite its popularity, there is still a lack of information on possible interactions between zinc oxide nanoparticles and DNA in the skin.

The study exposed human cells from the epidermis (the top layer of skin) to various concentrations of zinc oxide nanoparticles. A number of responses and changes in the cells were monitored at different periods of time (between 3-48 hours) to evaluate the level of exposure to zinc oxide nanoparticles that might damage skin cells.

The results revealed significant damage to DNA from zinc oxide nanoparticles at two of the higher concentrations (0.8 micrograms/ml and 5 micrograms/ml), after six hours of exposure. The data also demonstrated that the nanoparticles caused oxidative stress in the cells, even at low concentrations (0.008 to 0.8 micrograms/ml). Oxidative stress produces 'free radicals' and have been implicated in skin cancer.

The authors believe these results are significant as the concentrations studied are much lower than those actually found in sunscreens (quantities vary, but can be around 160 milligrams/ml). They suggest that care should be taken with zinc oxide nanoparticles used in sunscreens as well as while handling them. They also suggest possible mechanisms by which the nanoparticles might cause the observed effects but state that further studies are needed to ascertain the exact mechanism.

Under the EU Cosmetics Directive³, zinc oxide is not registered for use as a UV filter in sunscreens in Europe, either in nano- or non-nano form (with the exception of Germany which has a provisional authorisation). However, the EU's Scientific Committee on Products Safety⁴ has delivered an opinion that zinc oxide (non-nano) is safe to use as a UV filter. This opinion is being implemented. The safety of zinc oxide in its nano-form as UV filter is currently being assessed by the Committee. Sunscreen manufacturers are required to submit data by the end of 2009 as part of this evaluation.

Source: Sharma, V., Shukla, R.K., Saxena, N. *et al.* (2009). DNA damaging potential of zinc oxide nanoparticles in human epidermal cells. *Toxicology Letters*. Doi: 10.1016/j.toxlet.2009.01.008.

¹ See http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm

² See <http://ec.europa.eu/environment/chemicals/reach/pdf/nanomaterials.pdf>

³ See http://ec.europa.eu/enterprise/cosmetics/html/consolidated_dir.htm

⁴ See http://ec.europa.eu/health/ph_risk/committees/04_sccp/04_sccp_en.htm



Testing the toxicity of nanomaterials

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Theme(s): Chemicals, Environment and health

When the properties of materials are not fully understood, as with nanomaterials, how can they be adequately tested? A new study has found that two commonly-manufactured nanomaterials can damage human DNA. This highlights the need to evaluate the risks they might pose and design appropriate safety tests.

“In manufactured goods, nanoparticles are usually permanently bound in a matrix, so they are not a risk via inhalation. However, if nanoparticles are free in the atmosphere, for example, during manufacture, studies like this suggest they could be hazardous.”

Materials that damage DNA can cause human cells to mutate, which can eventually lead to cancer. The new findings, although not the first to demonstrate the potential risks that nanomaterials pose, are evidence that precautionary measures need to be put in place to protect manufacturing workers, and possibly consumers, from these risks.

Nanotechnologies are attracting increasing investment from governments and businesses throughout the world. Their minuscule size gives them special properties, which are often quite different from the same material in larger sizes. These novel properties provide a vast array of new technological and medical possibilities.

For example, carbon nanotubes, which are cylinders of single sheets of carbon atoms, have been shown to be useful in hydrogen fuel cells because their huge surface area helps cause chemical reactions. Also, ‘nanomedicines’ allow more targeted therapy, where these tiny particles can be specifically sent to organs that are otherwise difficult to reach.

The research team investigated two nanomaterials already commercially available: carbon nanotubes and graphite nanofibres. Previous research has shown that carbon nanotubes can cause mesothelioma (a type of cancer) in mice, in a similar way to asbestos. The scientists treated cultured human lung cells with the nanotubes and nanofibres, and observed changes in the DNA.

Both the nanomaterials caused DNA damage in the cultured cells, and there was a direct link between the dose of carbon nanotubes and the amount of damage.

In manufactured goods, nanoparticles, such as carbon nanotubes, are usually permanently bound in a matrix, so they are not a risk via inhalation. However, if nanoparticles are free in the atmosphere, for example during manufacture, studies like this suggest they could be hazardous.

This study points to the need to introduce regulations to protect human health from the risks of inhaling nanoparticles. Legislators are exploring the extent to which current regulations cover risks of nanomaterials¹. In Europe, the application of the EU’s REACH legislation (Registration, evaluation, authorisation and restriction of chemicals) to nanomaterials is currently under discussion². Also, a 2009 report from the European Commission’s own scientific committee on emerging and newly identified health risks (SCENIHR) has recommended a ‘case by case approach for the risk assessment of nanomaterials’³.

Source: Lindberg, H.K., Falck, G. C-M., Suhonen, S. *et al.* (2009). Genotoxicity of nanomaterials: DNA damage and micronuclei induced by carbon nanotubes and graphite nanofibres in human bronchial epithelial cells in vitro. *Toxicology Letters*. DOI:10.1016/j.toxlet.2008.11.019.

¹ See: http://ec.europa.eu/nanotechnology/pdf/comm_2008_0366_en.pdf

² See: <http://ec.europa.eu/environment/chemicals/reach/pdf/nanomaterials.pdf>

³ See: http://ec.europa.eu/health/ph_risk/committees/04_scenihr/midday2_en.htm



Discovering how nanoparticles affect the environment

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Theme(s): Biodiversity, Chemicals

“Airborne engineered nanoparticles can accumulate on leaves, where they may be able to penetrate cells. Experiments have revealed that fungi can incorporate engineered nanoparticles from soil, via their roots.”

Although nanotechnology remains at an early stage of development, engineered nanoparticles are already interacting with fungi, bacteria and algae in natural ecosystems. A recent paper identifies gaps in our knowledge about this interaction which require intensive attention.

Engineered nanoparticles (ENPs) are of a more regular shape and composition than those formed naturally (e.g. by volcanoes) or by combustion engines, the main source of atmospheric nanoparticles. Annual production of ENPs is expected to reach one hundred thousand tonnes and be worth more than \$1trillion (about 800 billion Euros) within 5 years. Despite this rapid proliferation, the study indicates five key properties of ENPs which remain unknown:

- **At which concentrations do ENPs become problematic in terrestrial, aquatic and atmospheric environments?** Environmental nanoparticle quantities and concentrations are unknown, as are the concentrations at which ENPs actually become toxic to organisms.
- **Which physical and chemical characteristics of ENPs determine their behaviour?** The high surface area to volume ratio of ENPs increases their reactivity and chances of binding to other molecules or ENPs, but their behaviour will change according to their surroundings. For some uses, ENPs are treated to prevent them from clustering with other particles, which can cause them to settle in sediments and reduce their availability to organisms. However, some ENPs are deliberately treated to maintain their separated status, for example, in uses such as environmental remediation of water or land.
- **How do ENPs enter cells?** Some small molecules can pass through the cell walls of fungi, algae and bacteria. Airborne ENPs can accumulate on leaves, where they may be able to penetrate cells. Experiments have revealed that fungi can incorporate ENPs from soil, via their roots.
- **Which properties of ENPs cause toxic effects?** The increased reactivity of ENPs may affect photosynthesis and respiration. Studies have revealed relationships between high concentrations of some ENPs and reduced plant growth, or increased permeability of bacterial cells. Indirect toxic effects due to ENP accumulations include increased cell weight (affecting algae's ability to float) and reduced fertility of seaweeds. They may also prevent photosynthesis by reducing nutrient absorption. The toxicity of other pollutants may also be affected.
- **Do ENPs accumulate in the food chain?** ENPs have been observed to remain within bacterial cells for long periods and so may accumulate in larger organisms. Various environments may cause several different toxic behaviours at different levels of the food chain.

Although possible positive effects of ENPs are discussed, the authors expect negative effects on algae, bacteria and fungi. European Commission communications on nanotechnology¹ recognise knowledge gaps and the need for continued scientific investigation of health and environmental risks. Current expectations are that regulation can be achieved under existing legislation, but implementation will have to continually adapt to new information arising from research.

Source: Navarro, E., Baun, A., Behra, R., *et al.* (2008). Environmental behaviour and ecotoxicity of engineered nanoparticles to algae, plants and fungi. *Ecotoxicology*. 17:372-386..

¹ http://ec.europa.eu/nanotechnology/index_en.html



Assessing the ecotoxicological risks of nanoparticles

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Themes: Chemicals, Risk Assessment

“The sheer range and diversity of engineered nanoparticles, means that no single method can be used for detecting and quantifying such particles.”

A new study highlights the need for more research aimed at understanding the effects of nanoparticles on the environment. Efforts should focus on developing more sensitive analytical methods for characterising and detecting nanoparticles, say the researchers.

The study discusses engineered nanoparticles (ENPs), a diverse class of nanoscale particles that do not occur in nature, including nanotubes, metal oxides and quantum dots (a type of semiconductor, used in solar cells and transistors, among other applications). Although certain industrial uses of ENPs are covered under existing regulation, there are currently no specific regulations designed for these materials, in the EU or elsewhere. This is due to a lack of information on the behaviour of ENPs in environmental systems. For example, how do nanoparticles undergo degradation or accumulate in the environment? Are they hazardous to aquatic organisms?

In addressing this problem, the researchers, based in the UK and Sweden, consider a range of different methods for characterising and detecting ENPs in environmental systems. Since ecotoxicity depends on a number of different properties, including size, shape and structure, it is important to understand the exact properties of nanoparticles under scrutiny. Crucially, changes to any of these properties can change the environmental behaviour of nanoparticles and this must be taken into account when assessing the risk associated with each type of ENP.

The sheer range and diversity of ENPs, means that no single method can be used for detecting and quantifying such particles. For instance, microscope-based approaches might be suitable for detecting ENPs in water, while combinations of fractionation (separation) methods with sophisticated analytical techniques, such as mass spectrometry, will need to be employed for systems including sludge, soils and sediments.

The researchers call for environmental testing standards to be agreed that will allow for better comparison and interpretation of data from different studies. This science is in its infancy and requires the cooperation of researchers from many different fields, as well as collaboration between industry and academia. They also highlight the need for transparency when publishing applied methods for the analysis of nanoparticles.

In 2005, the European Commission adopted its Nanosciences and Nanotechnologies action plan to “boost support” for research into the potential impact of engineered nanoparticles on human health and the environment¹. This action plan is scheduled to end in 2009. However, continued efforts to ensure that effects on the environment are properly understood are clearly needed.

Source: Tiede, K., Hassellöv, M., Breitbarth, E. *et al.* (2009). Considerations for Environmental Fate and Ecotoxicity Testing to Support Environmental Risk Assessments for Engineered Nanoparticles. *Journal of Chromatography A*. 1216: 503-509.

¹ European Commission. (2005). Nanosciences and Nanotechnologies: An Action Plan for Europe 2005-2009. See: http://ec.europa.eu/nanotechnology/policies_en.html



Predicting the inflammatory potential of nanoparticles

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Theme(s): Chemicals, Environment and health

New methods to screen nanoparticles for potential toxicity to humans are needed to test the growing number of engineered nanoparticles being developed. A battery of simple tests has been developed that can be used to investigate the potential of nanoparticles to cause lung inflammation and also avoids the need for animal testing.

“Tests could be used to predict the inflammatory potential of metal oxides, though single tests alone were not sufficient. This suggests that *in vitro* tests could be developed for use in screening metal oxide nanoparticles for potential toxicity.”

Despite the many benefits of using nanomaterials, concerns have been raised about the effects of these particles on human health. Of particular concern is the potential of some of these particles to cause inflammation in the lungs if they are inhaled. Inflammation is the immune system's response to irritants. The researchers therefore wanted to determine the most efficient way of testing nanoparticles of metal oxides for their potential to cause inflammation of the lungs without using live animals.

Until now, researchers have largely relied on animal tests to test whether nanoparticles could cause inflammation. This new research explored the potential of a range of simple *in vitro* tests (not conducted in a living organism, i.e. a 'test tube' test) to replace animals as a means of screening nanoparticles for toxicity. The researchers compared the set of tests with findings in rats, to determine whether the *in vitro* tests produced similar findings.

In this study, rats were exposed to a panel of metal oxides which are used extensively in industry, to determine the inflammatory response of the lungs to each of the nanoparticles. In addition, four separate tests were conducted on tissue cultures exposed to the different nanoparticles. The results of these tests were compared with the actual inflammatory response detected in the rat lungs.

Only two nanoparticles, nickel oxide and alumina 2, showed significant inflammation of the lungs in the rats. The inflammatory potential of nickel oxide had been anticipated but not that for alumina 2. Three types of alumina nanoparticles had been tested, from different sources and of different sizes. As only one of the three (alumina 2) had the potential to cause lung inflammation, the researchers suggest that testing one variant of a nanoparticle might not give a representative result for all the variants of that nanomaterial.

Overall, the research found that the tests could be used to predict the inflammatory potential of metal oxides, though single tests alone were not sufficient. This suggests that *in vitro* tests could be developed for use in screening metal oxide nanoparticles for potential toxicity, allowing particles to be identified that might need further testing.

The results also suggest the nanoparticles tested have low toxicity. This indicates there is little potential to cause lung disease in people working with these materials. While inflammation is an indicator of irritation, it does not necessarily indicate or cause disease.

The researchers suggest it would be unlikely that these tests could be extended to different shapes of nanoparticles – such as fibrous types. Nevertheless, this research could be extended to design models to predict the toxicity of untested nanoparticles from the chemical and structural characteristics of the particles.

Source: Lu, S., Duffin, R., Poland, C. *et al.* (2009). Efficacy of Simple Short-Term *in vitro* Assays for Predicting the Potential of Metal Oxide Nanoparticles to Cause Pulmonary Inflammation. *Environmental Health Perspectives*. 117(2): 241-247.



Inhaled nanoparticles can enter the bloodstream

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Themes: Chemicals, Environment and health

Studies have found that populations who live in areas with polluted air, containing high levels of combustion-derived nanoparticles (fine particulate matter), are more likely to suffer from respiratory and cardiovascular diseases. This has raised concerns that nanoparticles are to blame and that engineered nanoparticles of a similar size could behave in the same way.

“Whilst it is reasonable to suggest that translocation does happen, the extent of this and its importance for human health is not fully understood.”

Studies have found that populations who live in areas with polluted air, containing high levels of combustion-derived nanoparticles (fine particulate matter), are more likely to suffer from respiratory and cardiovascular diseases. This has raised concerns that nanoparticles are to blame and that engineered nanoparticles of a similar size could behave in the same way.

It is important, therefore, to understand how nanoparticles interact with the body, including what happens to nanoparticles in the lungs, and whether they enter the bloodstream or various cells of the body. This information could help us understand how nanoparticles pose a health risk. A new study considers all forms of nanoparticles (defined here as smaller than 100 nanometres in diameter), both engineered and combustion-derived.

The research suggests that when nanoparticles are inhaled, they can enter the deepest part of the lungs and come into contact with the 140 square metres of folded surface present in the lungs. There is then the potential for the nanoparticles to translocate, or move through the cells lining the lungs, and cross into the fine blood vessels of the lungs. From here they could circulate throughout the body.

Previous studies have demonstrated that a small fraction of nanoparticles can translocate from the lungs to the blood stream and be transported to other parts of the body. This was seen, for example, in studies on the effect of titanium dioxide nanoparticles on rats. Whilst it is reasonable to suggest that translocation does happen, the extent of this and its importance for human health is not fully understood.

There are a number of ways by which nanoparticles can enter cells lining the lung cavities. Further studies are needed to understand these entry methods in relation to the composition and surface properties of the nanoparticles and to functioning of cells in the lungs.

The researchers have suggested that the following areas of investigation are required to understand exactly how nanoparticles interact with the body and whether they could cause any health problems:

- Do nanoparticles need to translocate to the circulation of blood to cause adverse cardiovascular health problems?
- What happens if nanoparticles accumulate in the body?
- What happens to nanoparticles that translocate in the body?
- What are the different mechanisms by which nanoparticles enter the different cells of the body and what factors affect cell uptake of nanoparticles?

Studies addressing these questions could advance the understanding of how exposure to nanoparticles affects human health.

Source: Mühlfeld, C., Gehr, P., Rothen-Rutishauser, B. (2008). Translocation and cellular entering mechanisms of nanoparticles in the respiratory tract. *Swiss Medical Weekly*. 138(27-28): 387-391.



How nanotubes could be released into the environment

Carbon nanotubes (CNT) are a group of nanoparticles with remarkable physical and chemical properties. They are a promising material for a wide range of future technologies, including sports equipment, textiles and rechargeable batteries. However, questions have been raised about their safety. It is therefore important to understand how they could be unintentionally released into the environment in order to implement precautionary measures.

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Theme(s): Chemicals, Risk Assessment, Environment and health, Waste

“Responsible product development is necessary in order to ensure the safety of workers and consumers, and should be implemented at an early stage in the innovation process of nanotechnology.”

CNT consist of tiny hollow carbon cylinders, a few nanometres in diameter. They have a unique shape and do not degrade easily as they are mechanically and chemically resistant. Nanoparticles are biologically more active than larger particles due to their large surface area. Animal tests suggest they may be toxic to the lungs and cause cardiopulmonary diseases (disorders of the heart and lungs).

The prospective widespread use of synthetic CNT in industrial applications and consumer products has provoked concern that they could pose environmental and health risks. A recent study investigated possible ways in which CNT can be released from products leading to exposure of humans. Taking a lifecycle perspective, the researchers assessed two classes of mass produced products that may contain CNT in future. These were rechargeable batteries (to be used in mobile phones, for instance) and synthetic textiles (likely to be used in expensive, fashionable sportswear).

Although the researchers found that CNT are unlikely to be released from batteries during normal use, they could be emitted during the production, recycling and disposal stages of their life-cycle. Improper processing can cause CNT to be released into the air as dust. Battery recycling and recycling of metal from waste incineration residues in particular could cause occupational exposure to CNT. Incinerating batteries together with household waste would probably not degrade the CNT in the batteries. Environmental exposure could also occur if batteries are disposed of in landfills or dumpsites.

Release of nanotubes from textiles during use cannot be ruled out. Wear- and-tear could release CNT and lead to human exposure as garments are worn close to the body. CNT could also be released during recycling and disposal of used textiles. Used textiles are not subject to hazardous waste management. They are either exported overseas as second hand clothes or disposed of as household waste. While the fate of old textiles in developing countries is uncertain, the researchers assume that they may be disposed of in these regions through open burning. This would cause emissions of CNT since only incineration above 850°C eliminates CNT. Only modern waste incinerators operated properly could reach the required temperatures to degrade CNT.

Both case studies demonstrate that CNT can be released at various stages during the life cycles of products, and in an uncontrolled manner. Until, or unless, the adverse health effects of CNT can be ruled out, human exposure represents a risk.

The researchers adopt the precautionary principle and conclude that release of CNT from products should be avoided. Responsible product development is necessary in order to ensure the safety of workers and consumers, and should be implemented at an early stage in the innovation process of nanotechnology. Product designers should ensure that CNT are integrated into the product in a way which prevents release throughout the product's life cycle.

Source: Köhler, A., Som, C., Helland, A., Gottschalk, F. (2008). Studying the potential release of carbon nanotubes throughout the application life cycle. *Journal of Cleaner Production*. 16 (8-9):927-937.



Managing exposure to nanoparticles in the workplace

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Themes: Chemicals, Environment and health

“Little is known about the consequences of exposure to nanomaterials in the workplace, but it is vital that risk management strategies are in place to minimise potential harm.”

It is estimated that approximately 2 million workers will be employed in nanotechnology industries worldwide in the next fifteen years¹. A new study reviews an existing framework of occupational risk management and describes possible methods for controlling exposure to nanomaterials in workplaces.

The manufacture and use of nanomaterials is increasing. Although this is creating more jobs, those working in these industries are likely to experience the earliest and greatest exposures. Little is known about the consequences of exposure to nanomaterials in the workplace, but it is vital that risk management strategies are in place to minimise potential harm.

The study considers a well-known conceptual framework of company health and safety for possible application to the management of nanomaterials. It identifies the primary concerns for exposure as inhalation and skin contact during the manufacture and use of nanomaterials. It also lists possible jobs and operations that have a greater potential exposure after the manufacture of nanomaterial containing products, such as machining, sanding or drilling materials containing nanoparticles.

As part of this framework, recommendations were made for controlling exposure to nanomaterials. However, control may need to be more rigorous for nanoparticles than for larger particles because they have greater potential toxic effect for a given weight. This is currently being discussed at an EU level in terms of how the REACH regulation could take this into account².

The first suggested method of control is to eliminate or substitute nanomaterials. However, since nanomaterials are produced for their unique properties, a more feasible approach might be to coat the particle with a less hazardous material or change its form. Another approach would be to isolate or contain the nanoparticles until they are bound in a product, or use ventilation systems to capture airborne particles that might be released.

Administrative controls are also possible, for example, limiting the time a worker is exposed to nanoparticles. Personal protective equipment such as respirators, gloves and protective clothing can also be used. Additionally, monitoring the environment and the workers helps ensure that controls are effective in preventing harmful exposure.

Source: Schulte, P., Geraci, C., Zumwalde, R. et al. (2008). Occupational Risk Management of Engineered Nanoparticles. *Journal of Occupational and Environmental Hygiene*. 5: 4, 239-249.

¹ See <http://www.nano.gov/html/res/faqs.html>

² See <http://ec.europa.eu/environment/chemicals/reach/pdf/nanomaterials.pdf>



A selection of articles on Nanotechnology from the *Science for Environment Policy* News Alert

Action needed on testing and regulation of nanomaterials (18/12/08)

A recent report from the Royal Commission on Environmental Pollution (UK) has presented a detailed assessment of the current state of knowledge about the effect of new materials on the environment, focusing on nanotechnology. The authors recommend that more testing is urgently needed and that existing regulations should be amended to control the development of nanomaterials, given the state of uncertainty about their long-term effects on human health and the environment.

Wastewater treatment fails to remove all nanoparticles (13/11/08)

Nanomaterials are being used increasingly in the manufacturing industry, but questions remain about the best way to efficiently remove these nanoparticles from industrial wastewater processes or sewage treatment plants. Recent research suggests that some nanoparticles escape from treatment plants and are discharged into water.

Do nanoparticles affect the health of the soil ecosystem? (16/10/08)

New research reveals that many microorganisms, including bacteria and protozoa, show little sensitivity to fullerene nanoparticles applied to soil samples. However, fast-growing bacteria decreased in number and the genetic diversity of bacteria and protozoa altered slightly. This could affect the bottom of the food chain, which may have long-term implications for the overall health of the soil ecosystem.

Nanomaterials can move up the food chain (17/7/08)

The potential environmental risks of nanomaterials, including their impact on aquatic organisms, have been a central argument for regulating the nanotechnology sector. New research suggests that engineered nanomaterials can be transferred from single celled organisms in the lowest levels of the food chain, to higher, multi-celled organisms.

Soaking up oil spills with nanowires (17/7/08)

Oil spills and other industrial chemical leaks can cause havoc in ecosystems, killing marine and aquatic wildlife and polluting drinking water supplies. New research has developed a way of cleaning up spills using a super-absorbent material, which selectively draws up oil and other organic pollutants, leaving clean water behind.

Nanoparticles affect pollutant toxicity (06/3/08)

Nanoscience and nanotechnology are relatively new, but already nanoparticles made from C60 (Buckminster fullerenes) are finding potential applications in consumer products ranging from car lubricants to cosmetics and medicines. New research suggests that nanoparticles, when released into water systems, may interact with other common pollutants in aquatic environments with important consequences for their toxicity to plant and animal life.

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