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INTRODUCTION TO NANOTECHNOLOGIES AND NANOMATERIALS

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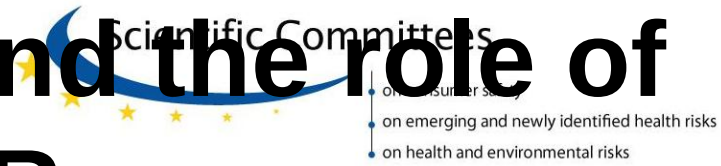
Nanotechnologies and the role of SCENIHR



To provide opinions on:

multidisciplinary issues requiring a comprehensive assessment of the risks to consumer safety or public health and related issues.

To include:

* new technologies eg nanotechnologies
* medical devices
* interactions of risk factors

Nanotechnologies:The challenge

How to harness the undoubted potential benefits of the products of the nanotechnologies (nanomaterials /nano-objects) without unacceptable risks to human health and to the environment.

Topics to be addressed

1. Background
2. Applications of nanotechnologies
3. Physico-chemical and biological properties of particular interest
4. Definitions and methodology
5. Conclusions and next steps

1. Background

Nano forms humans can be exposed to

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- Naturally occurring *eg soil erosion, sea spray*

- By products of human activity *eg combustion of fuels, metal processing, cooking.*

- **Engineered/manufactured** *ie deliberately produced*

QUESTIONS

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Should the nanotechnologies be treated as a single coherent category or not?

In view of the extensive exposure to nanoparticles etc over many centuries should engineered nanomaterials be considered as novel or not?

Differing views

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Importance

- The largest engineering innovation since the industrial revolution (Springston J 2008)
- Nanotechnologies can contribute in an exceptional manner to a large increase in substitution of hazardous substances (BMU 2008)

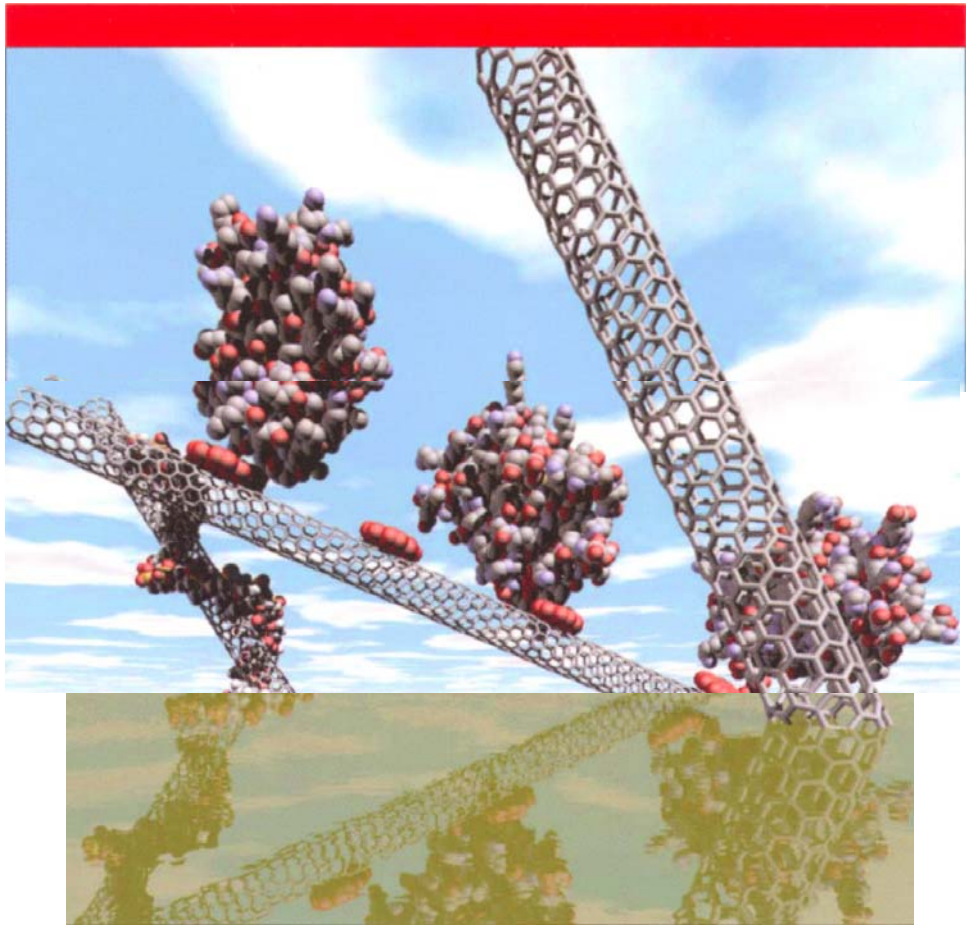
Risk to health

- Political action (should be taken) based upon experiences and early scientific warnings even when there is no scientific evidence to prove a causal link (Throne-Holst H 2008)

Structures of engineered nanomaterials

- Particles
- Rods, fibres and tubes
- Sheets
- Composites
- Embedded in non-nanostructures.

Nanotubes and nanoclusters



Carbon nanotube assembly

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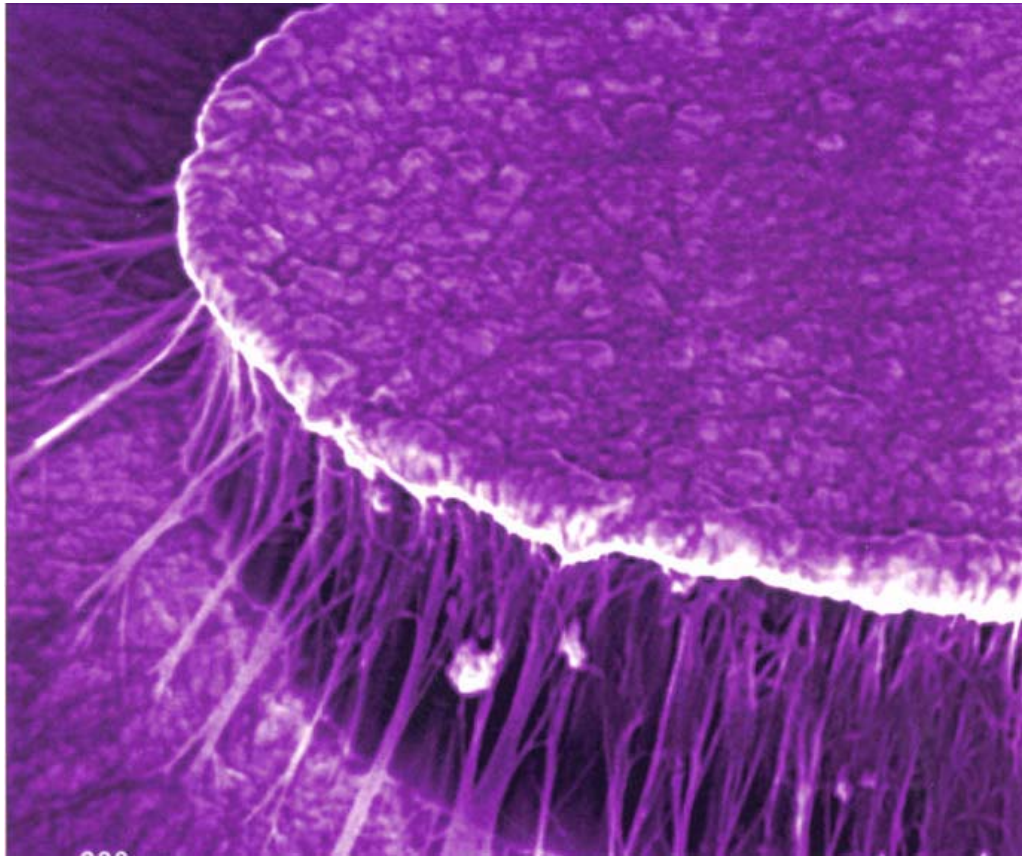

2 Applications of nanotechnologies

Percentage of nano-products by product type worldwide 2009

60%. Cosmetics and personal care products

10%. Food and nutritional supplements, food packaging, agrochemicals, veterinary medicines

10%. Paints and coatings, catalysts and lubricants, security printing, textiles and sport, medical and health care

10%. Water decontamination, construction materials, electronics, fuel cells and batteries,, weapons and explosives, paper manufacture.

Total >1000 products.

Source: www.nanotechproject.org/inventories/consumer

Some specific uses of metal based nanoparticles

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Environment

- Clean up of oil contaminated land using nano iron

Consumer exposure

- Nano silver coated socks to reduce odour and risk of bacterial infection
- More effective sun block agents using nano titanium oxide.

NB Total industry (all applications) estimated at $3.1 trillion by 2015

3. Physicochemical and biological properties

Physicochemical properties of nanomaterials

- Size, shape and quantity
- Other important properties:

  -surface properties including reactivity

  -stability in relevant media

  -solubility

  -agglomeration

Size and related aspects

- Reduction in size leads to a large increase in overall surface area and potentially reactivity
- At sizes below about 30nm quantum effects become increasingly important. This can lead to a major change in properties
- Size distribution must be taken into account
- Shape and flexibility may have an important influence on properties
- Internal structure should be considered
- Is number of particles the most important metric?

Other important properties

Agglomeration

↑↓

Nanomaterial---->Nanoparticle/fibre----> Solubilisation

/ \

/ \

v v

Chemical reaction(s) /stability

Surface adsorption of/onto other substances

Relevant biological properties

- Ability to penetrate cell membranes
- Resistance to degradation (persistence)
- Generation of active oxygen species
- Inflammatory responses not due to active oxygen formation
- Binding to proteins causing conformational changes
- Interactions with nucleic acids eg DNA

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4. Definitions and supporting methodology

Definitions and their applications

a) Purpose of the definition eg legal, insurance cover, health risk based etc?
b) How precautionary should it be?
c) How to allow for variations in the products/nanomaterial? *eg particle size distribution*
d) What is included that is not relevant and what is excluded that might be important?

Definitions currently favoured

i) Nanoscale: *1-100nm or 1-300nm*

ii) Nanoparticles: *Three dimensions in the nanoscale*

iii) Nanorods, nanotubes and nanofibres: *Two dimensions in the nanoscale*

Nanoscale definition what to include and exclude?

Exclude?

- Natural products such as globular proteins
- Other molecules

Include?

-Graphene

-Fullerenes

-Agglomerates (based on internal structure)

What should we measure?

Nanomaterial --->Particle/rod/fibre/tube

↓ ↓ ↓

Degradation/ surface or other ↓

solubilisation modification ↓

↓ ↓ ↓

Lung/gut/skin

↓ ↓ ↓

Binding to proteins and other molecules

↓ ↓ ↓

Persistence--> Clearance ← **Interactions with essential cell molecules eg receptors**

Analytical methods

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Different media require different methods. Very few standard methods are available and none of these can be applied universally.

Size

-Scanning electron microscopy (doesn't measure any organic coating around the particle)

-Dynamic light scattering

Composition

-Mass spectrometry

-Atomic absorption (metals)

Hazard assessment methods

i) Existing in vivo tests appear to be adequate for the assessment of most, if not all, major effects.

ii) A number of in vitro tests may need to be modified to allow for uptake factors

iii) Some additional methods may be needed to assess specific endpoints.

5. Conclusions and suggested actions

SCENIHR conclusions 2010

i) The full life cycle must be considered
ii) A number of physicochemical and biological properties may change when a bulk material is converted to a nano-form.
iii) The definition of size is universally applicable but size distribution must also be described
iv) There is no scientific justification for a specific upper and lower size limit from a health safety and environment perspective.
v) There is no single methodology suitable for routine use.

Next steps?

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- Use of existing data *Eg improved access, learning from past mistakes*
- Identifying and filling critical scientific data gaps. *Eg Measurement technology, studies on uptake by organisms and cells, protein interactions*
- Development of a valid classification system

  At present the data is insufficient for generalisations so a case by case basis is needed
- Cultural changes *Eg integration of design and development with safety considerations, active stakeholder dialogue*

Prediction of nanotechnologies?

Walt Disney (circa 1970):

‘It’s a small, small world’

Stages in the development of nanotechnologies

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Phase 1.

Passive nanostructures eg nanocoatings, nanocomposites, nanoparticles

Phase 2

Active nanostructures eg biosensors, targeted medicinal agents, electronics

Phase 3

Systems involving combinations of active nanomaterials eg Robotics, 3D networks, supramolecules

Phase 4 ?

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Thank you for your attention