

Working with engineered nanomaterials

Towards developing safe work practices

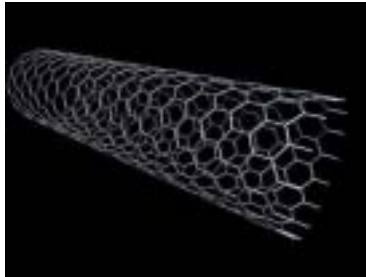
Andrew D. Maynard

**National Institute for Occupational Safety and Health
4676 Columbia Parkway, Cincinnati OH 45226**

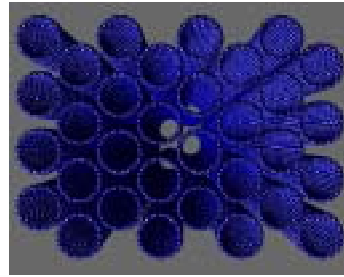
Nanotechnology

Science Fiction or Science Fact?

Imagine...



A material where strength is governed by atomic bonds...



... that can be woven into super-strong strands and ropes...



... and used to build an elevator to space!

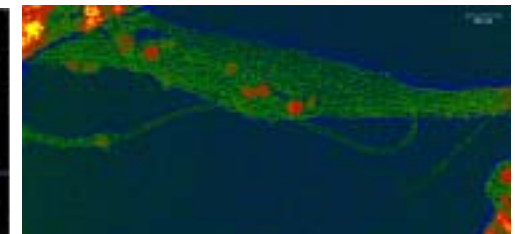
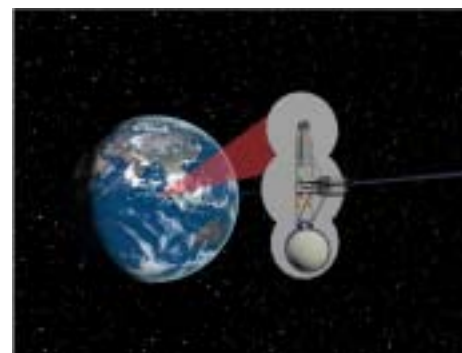
Nanotechnology is turning fiction to reality...



LIFTPORT GROUP
THE SPACE ELEVATOR COMPANIES™

Countdown to Lift: April 12, 2018

4891 days, 10 hours, 33 minutes, 42 seconds



Single Walled Carbon nanotubes

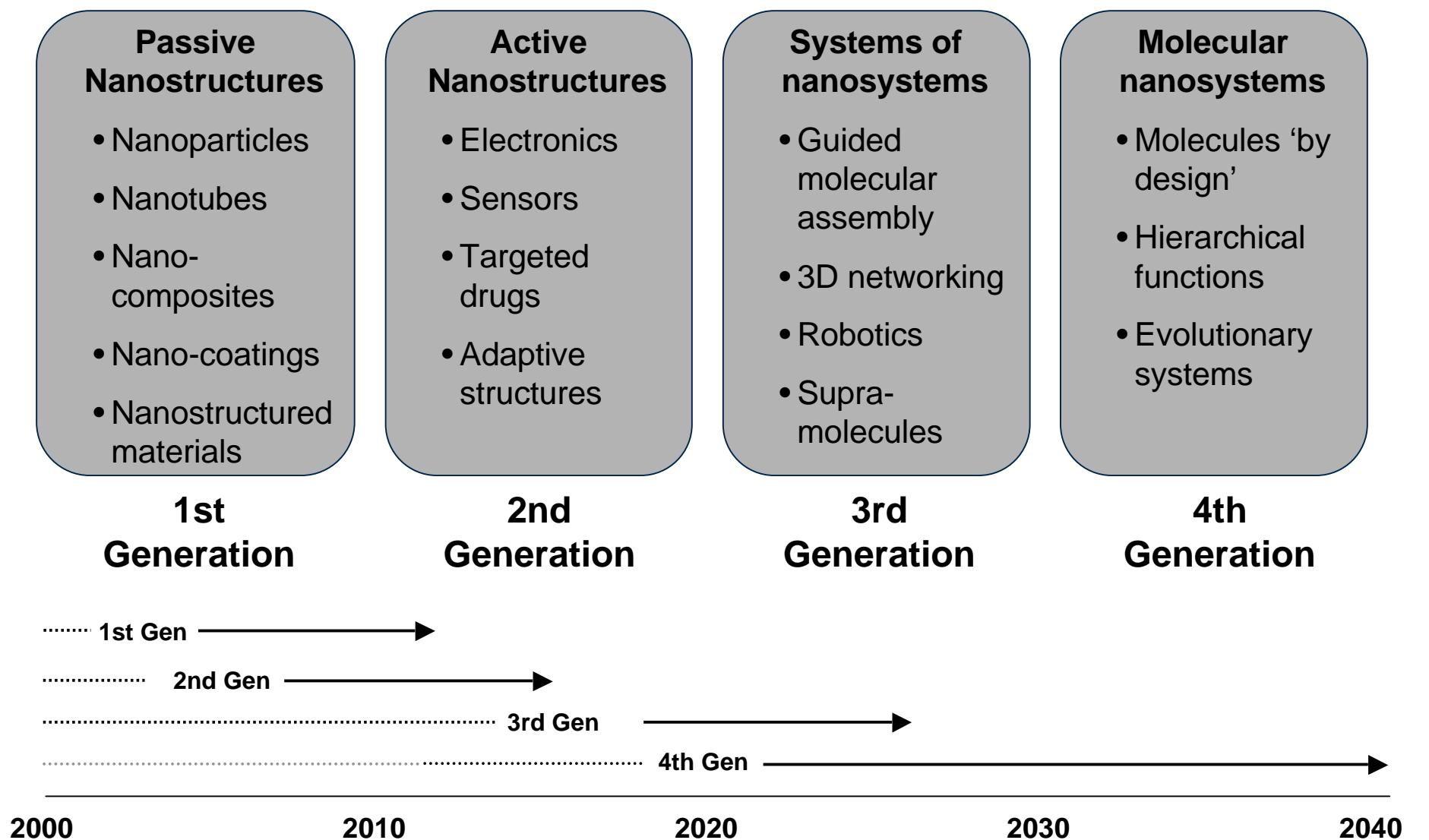
Nanotechnology, Environment, Health and Safety

The Challenge

Nanostructured materials and devices demonstrate new and unique properties and behavior

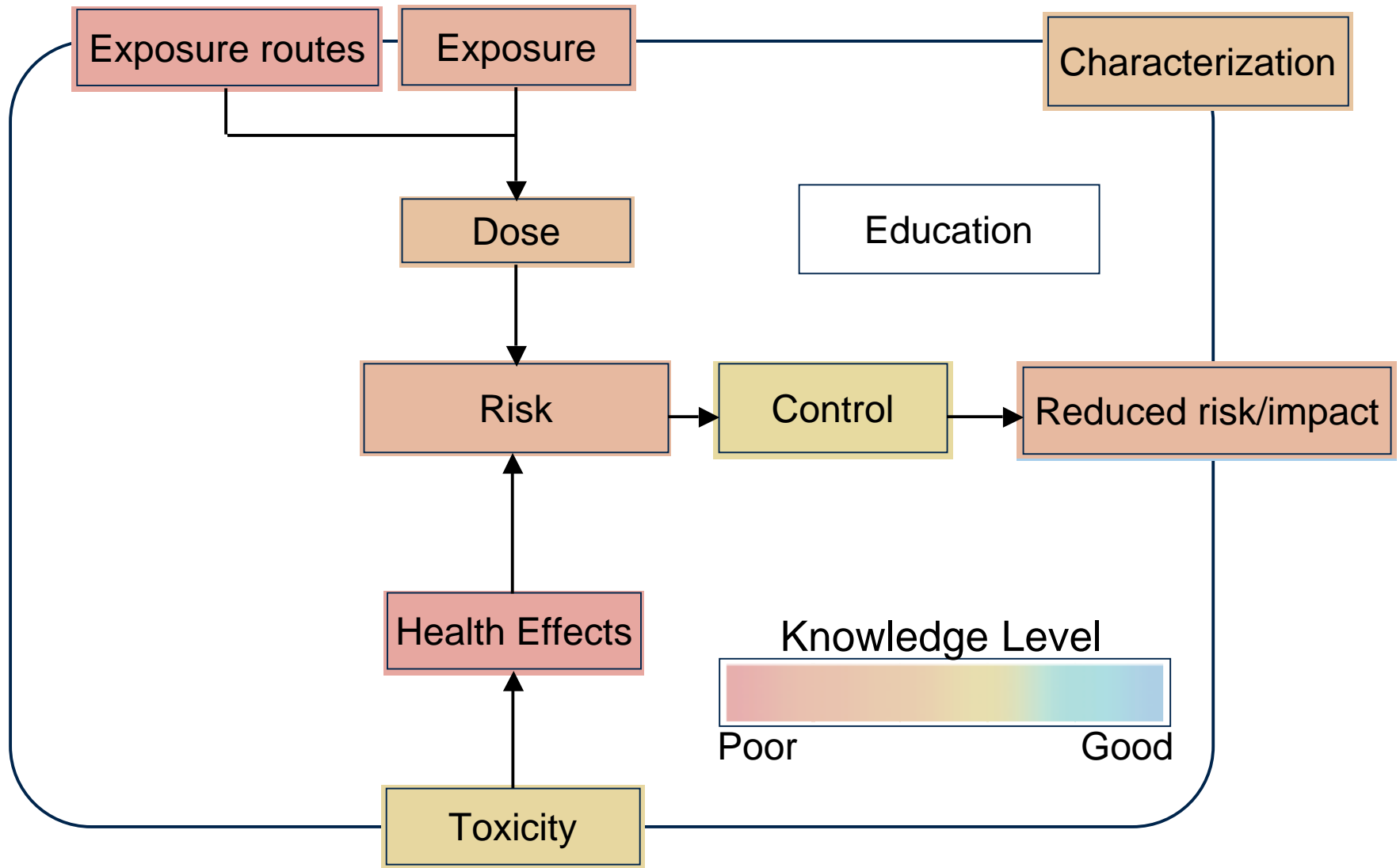
- **The Environmental, Health and Safety challenge:**
 - Do these properties lead to new and unique health risks ...?
 - ... or are current procedures, guidelines and regulations sufficiently robust to protect human health & the environment?
- **Consequences of inaction:**
 - Loss of public confidence
 - Potential acute and chronic health and environmental impact
 - Societal and economic benefits not realized

Nanotechnology development and implementation



Adapted from Roco, MC (2004) *AIChE J.* 50 (5)

Addressing occupational impact



Exposure Routes

- **Ingestion**
 - Virtually no information available at present
 - Possible exposure through food/surface contamination, or lung clearance
 - Will standard OH practices minimize exposure?
- **Dermal Penetration**
 - Very little information at present
 - Evidence that sub-micrometer particles can penetrate the outer layers of skin, but biological impact is unknown
- **Ocular exposure**
 - No information on nanoparticle exposures
 - Protective eyewear should reduce exposure
- **Inhalation**
 - Growing body of data for incidental and engineered nanoparticles
 - Indications that on a mass basis, insoluble nanoparticles are more toxic than larger particles with similar chemistry.

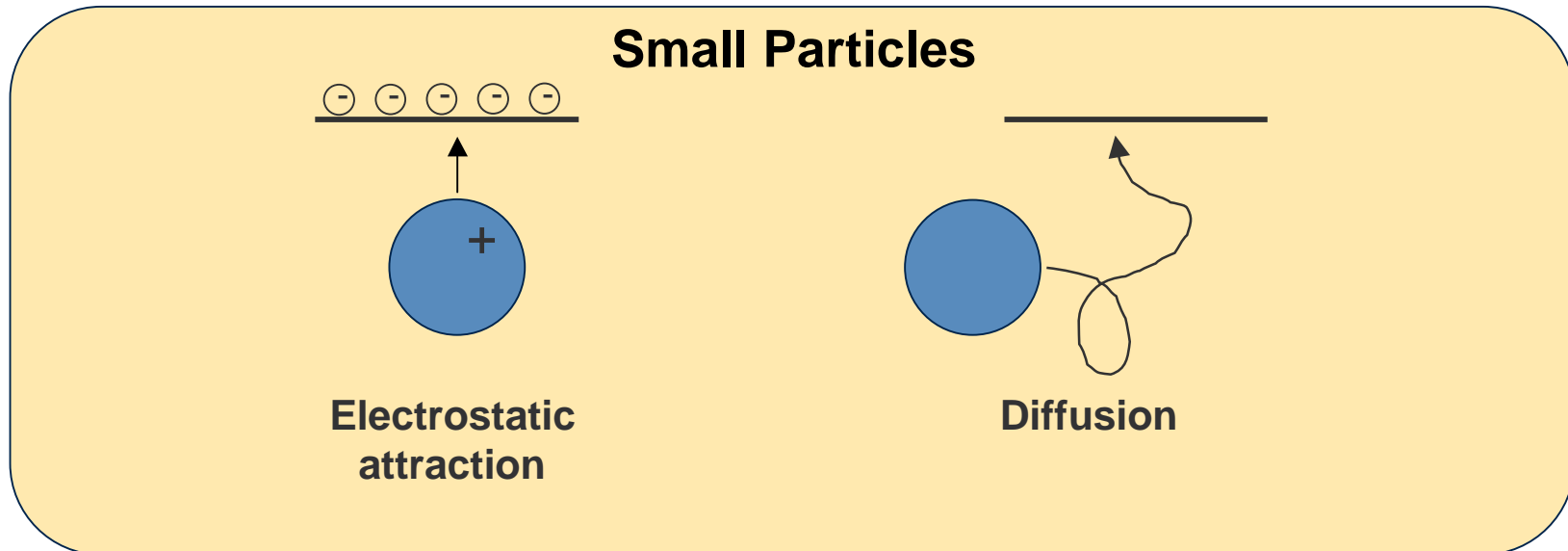
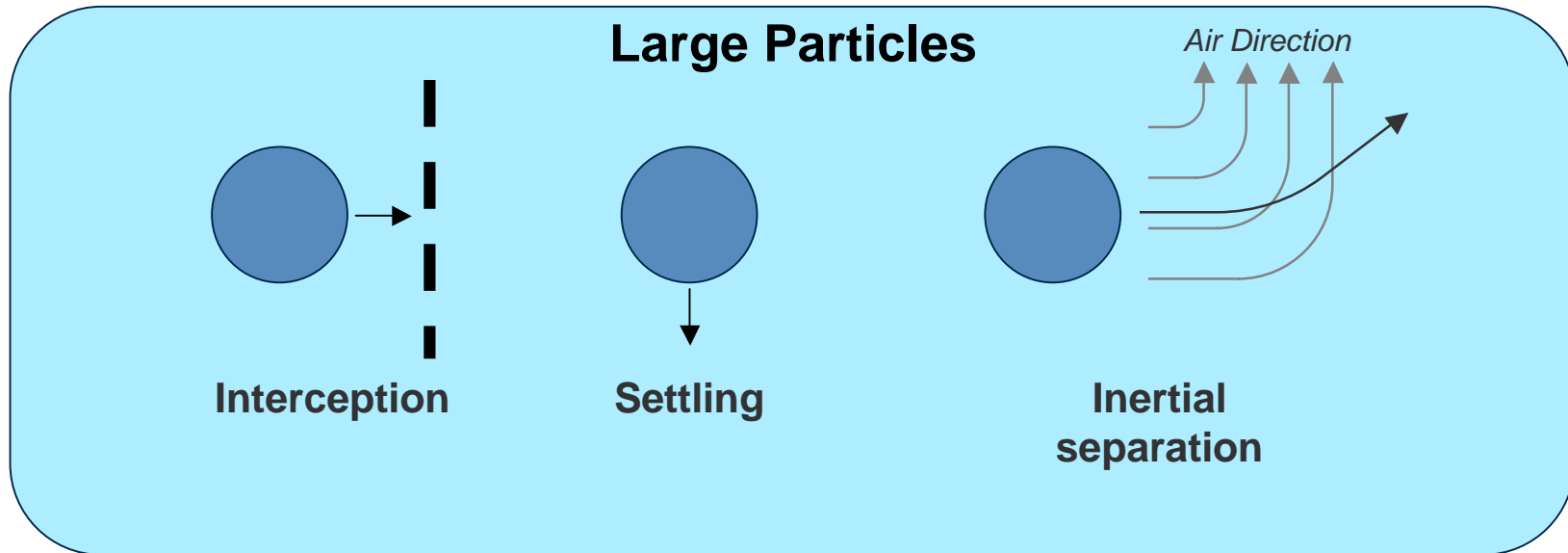
Airborne nanomaterials

Managing inhalation exposure - current knowledge

- **Lung dose**
- **Exposure measurement**
- **Filter efficiency**
- **Engineering controls**
- **Exposure management systems**

Airborne Particle Behavior

5 key mechanisms



Nanoparticles and nanostructured particles

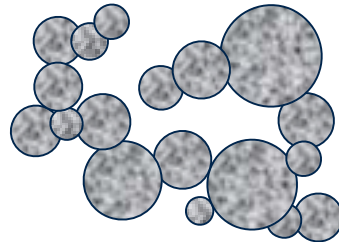
The significance of particle size

10 nm
↔



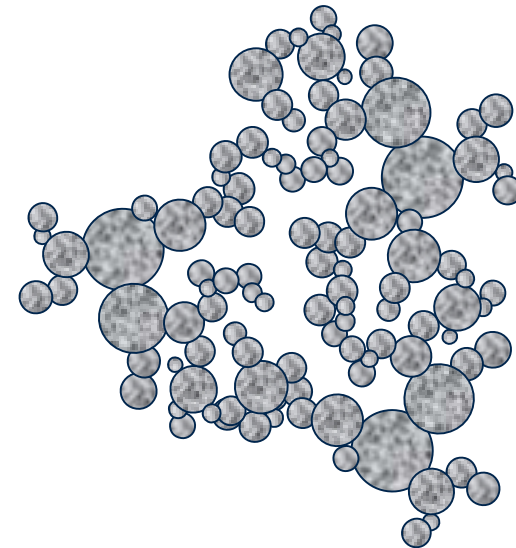
Deposition throughout
the respiratory system
Penetration beyond the
respiratory system

1 μm
↔



Penetration to the deep lung
Comparable surface
area/activity to discrete
particles

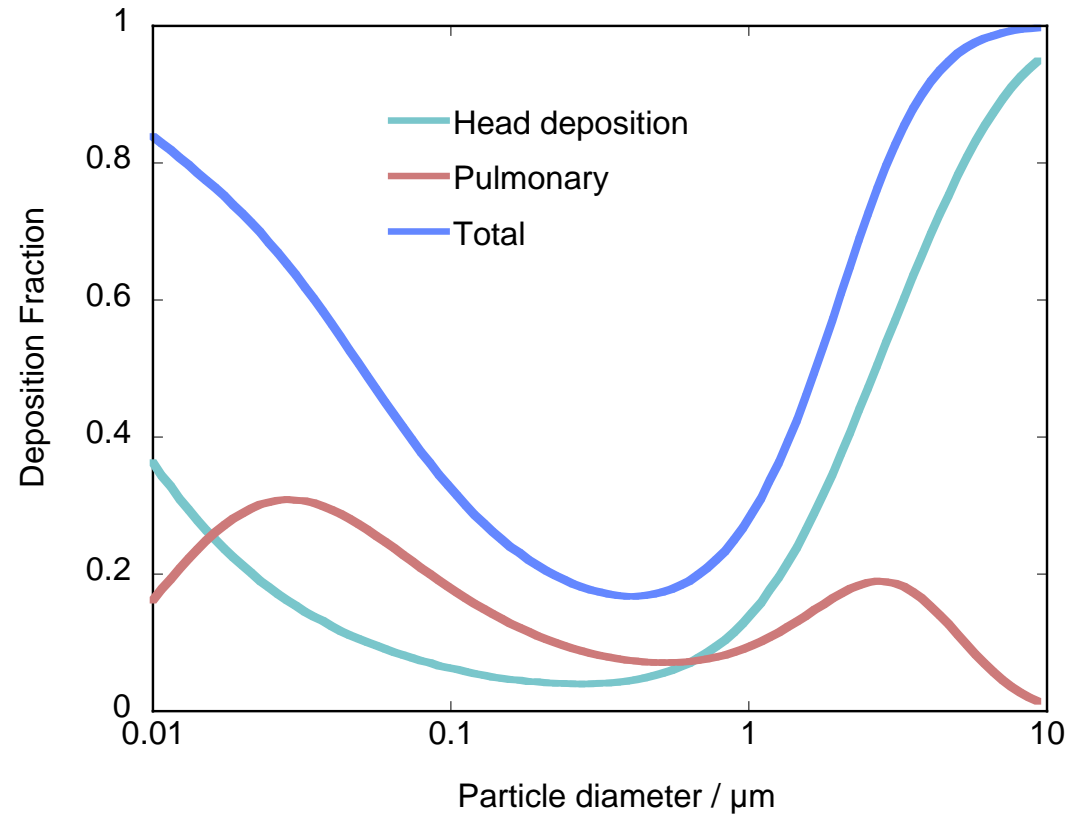
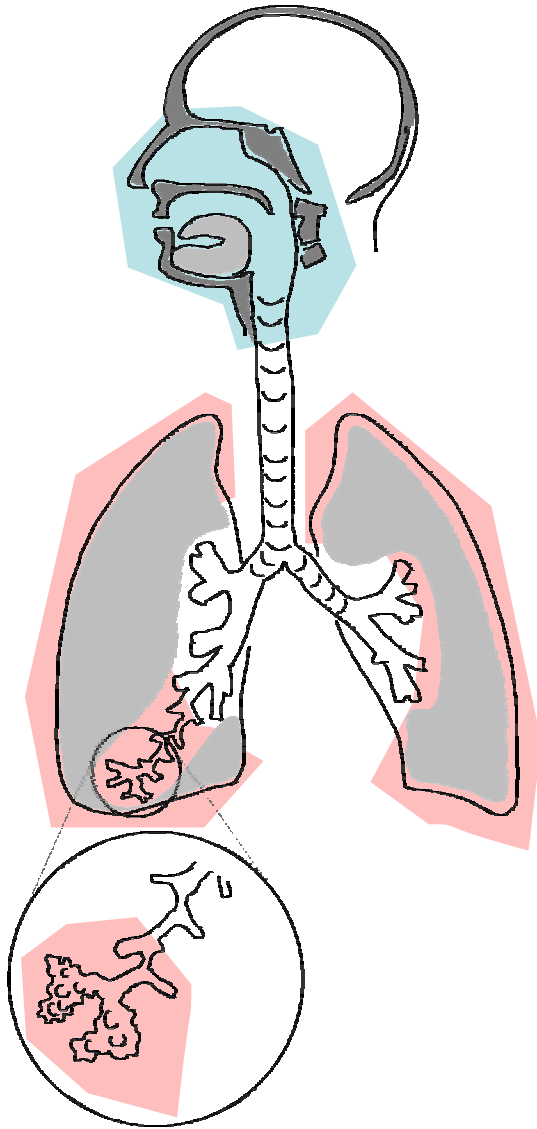
10 μm
↔



Comparable surface
area/activity to discrete particles
Possible dissociation to smaller
particles

**Particle size is important, but so is
particle nanostructure**

Do nanoparticles deposit in the lungs?



Deposition models - LUDEP, ICRP

Monitoring nanoscale aerosol exposures

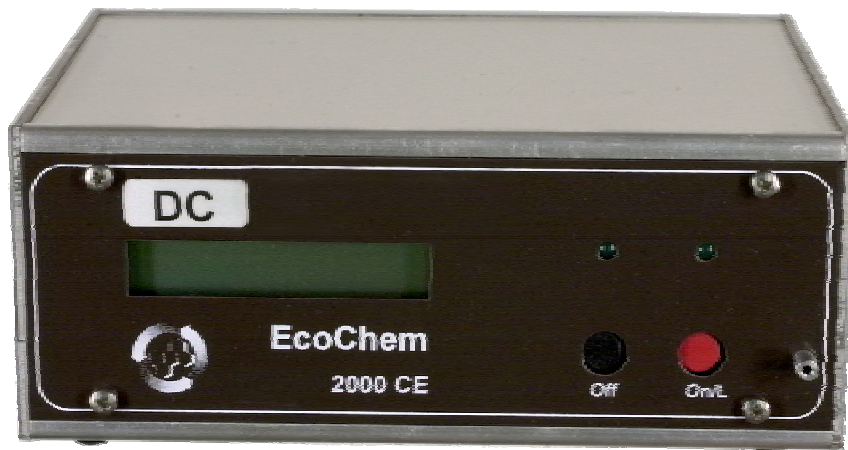
Options

- Adapt current mass-based approaches
 - Continuity with the past
 - Sensitivity and relevance issues
- Measure size distribution
 - Provides a lot of information
 - Impractical in many instances
- Monitor number concentration
 - Relatively simple
 - Difficult to differentiate between process-related and background aerosols
 - Relevance?
- Monitor aerosol surface area concentration
 - Relevant for some materials
 - Is this achievable?

Aerosol surface-area measurement

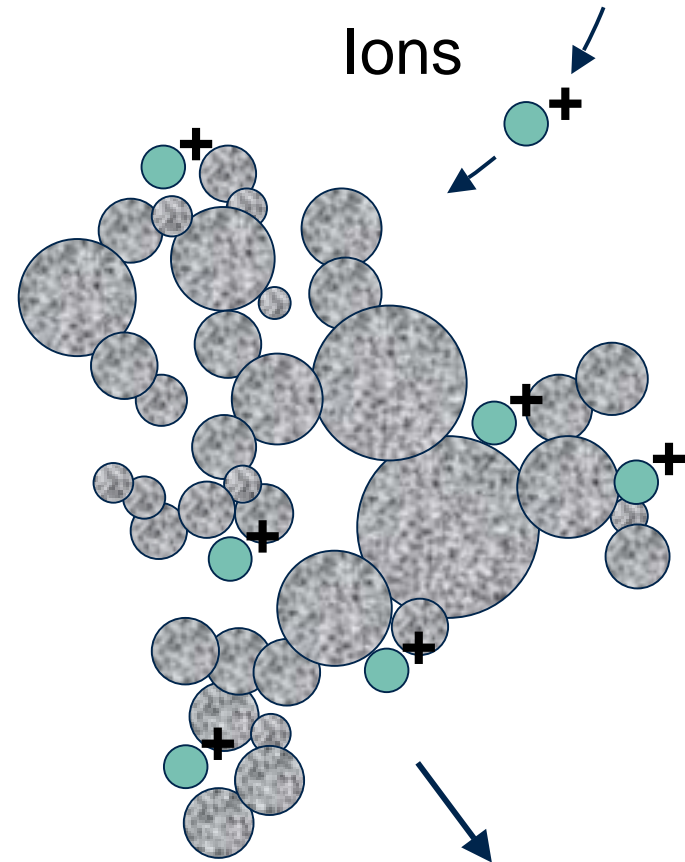
Using attachment rate

Charge on Aerosol \propto Surface Area



DC2000 CE Diffusion Charger

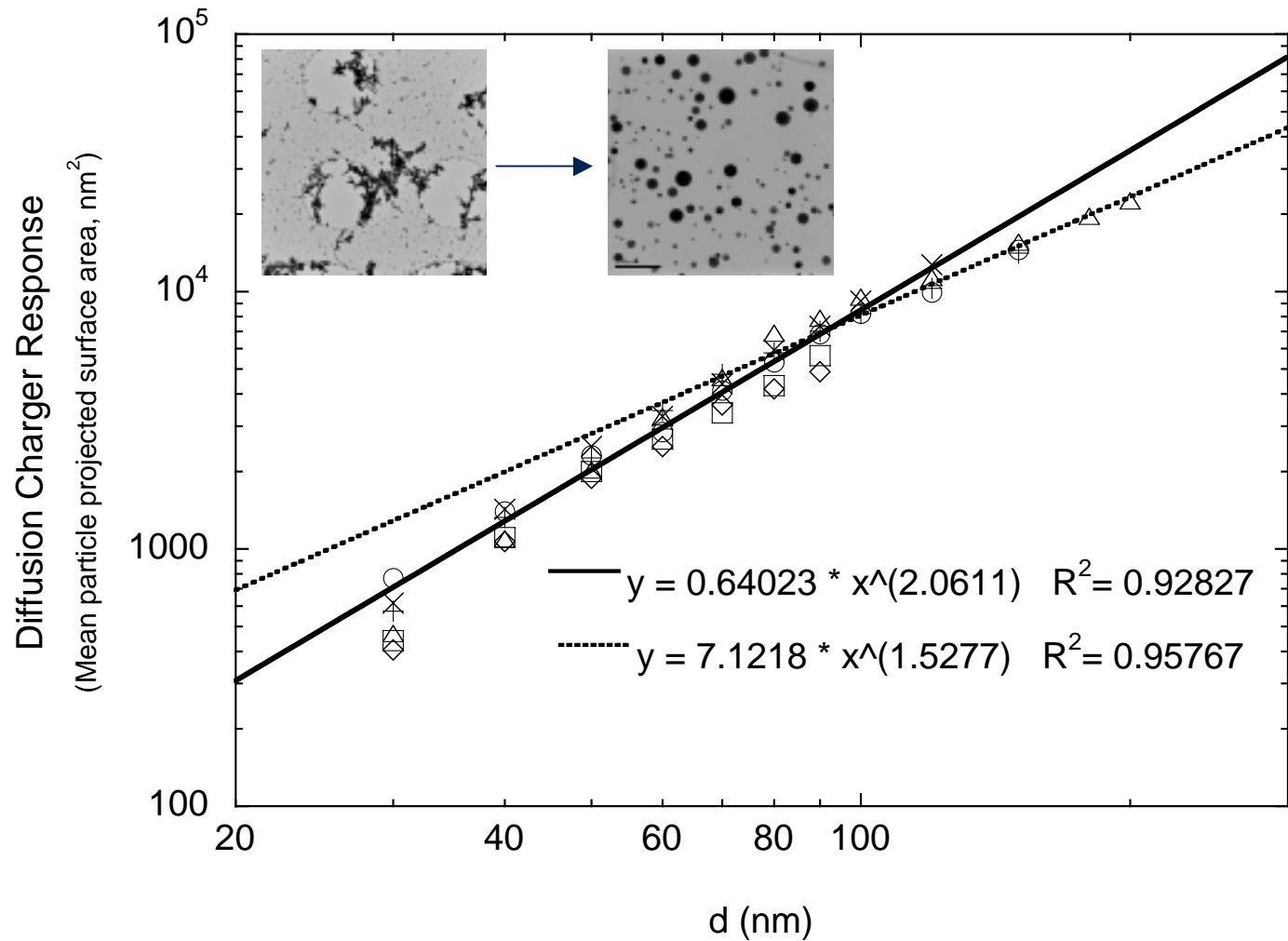
EcoChem



Electrometer

Aerosol surface-area measurement

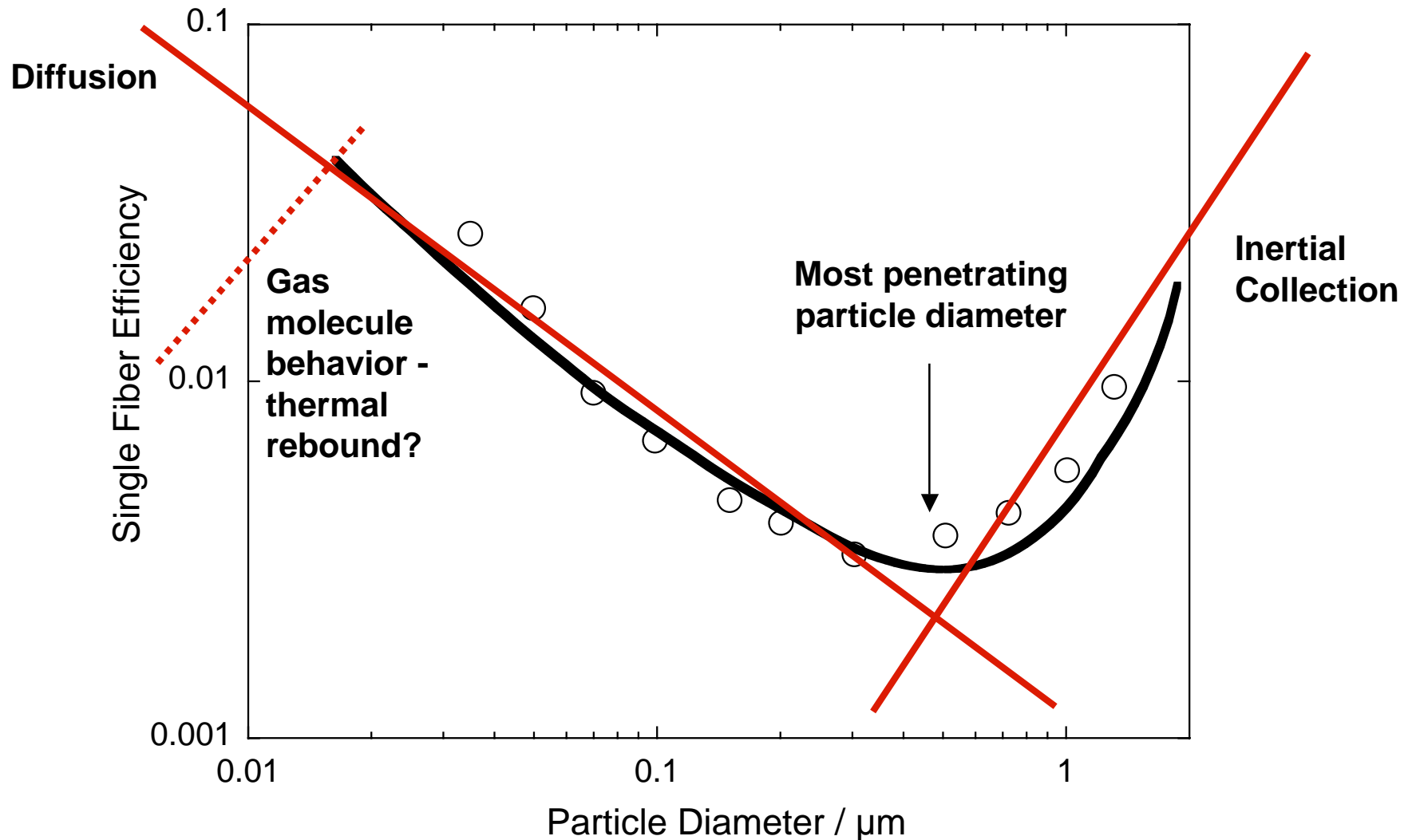
Diffusion Charger Response



Ku and Maynard (2004)

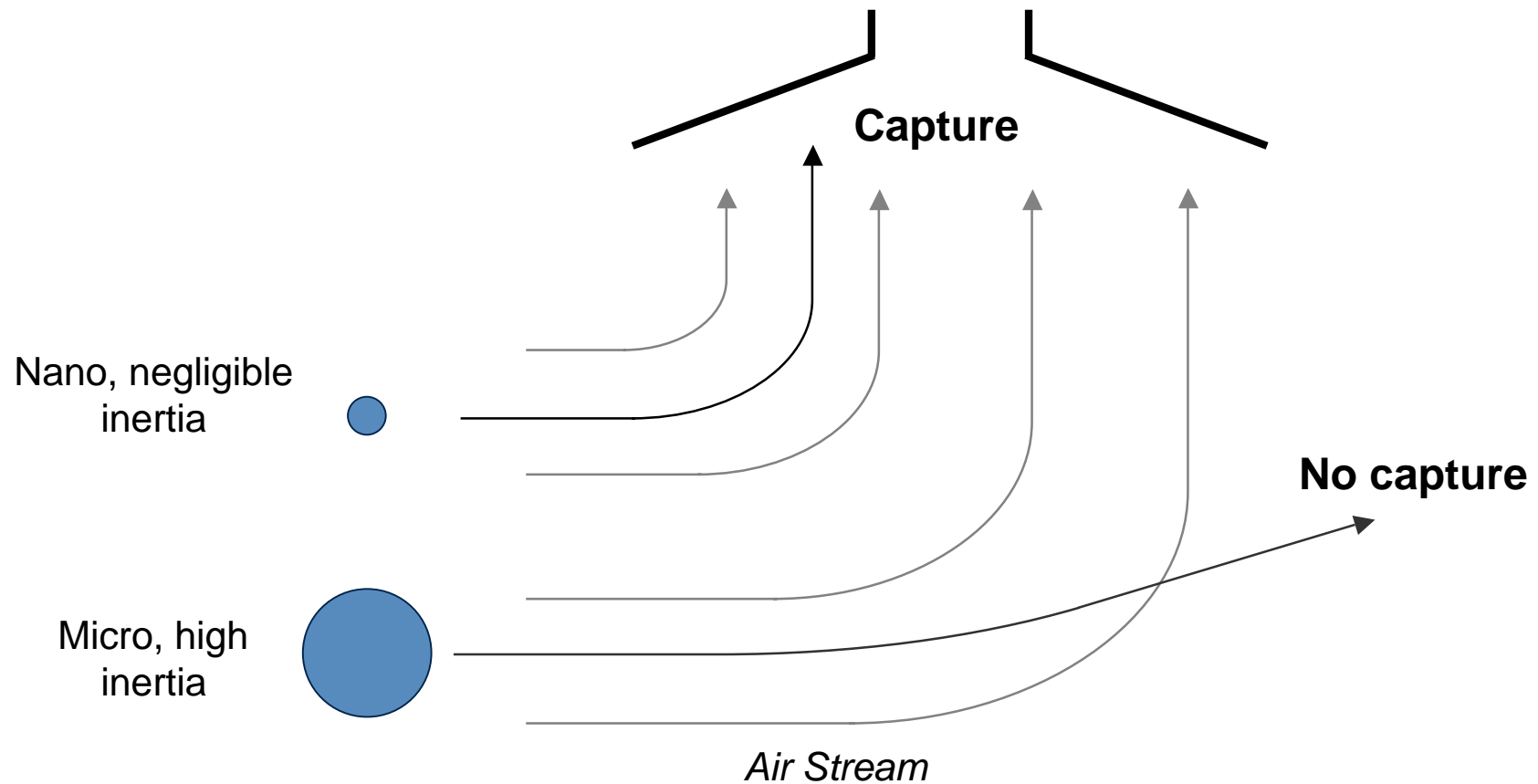
Are filters effective for airborne nanoparticles?

Single Fiber Efficiency - Theory and Experiment



Lee and Liu (1982). Theory: Dawson (1969)

Are engineering controls effective for airborne nanoparticles?



Based on the inertial behavior of airborne particles

Working with Engineered Nanomaterials

Control banding - concept

Parameters

Hazard Group

Dustiness

Amount Used

Control Approach

1. General Ventilation
2. Engineering Control
3. Containment
4. Specialist Advice



Amount Used	Low Dustiness	Medium Dustiness	High Dustiness
Hazard Group A			
Small	1	1	1
Medium	1	1	2
Large	1	2	2
Hazard Group B			
Small	1	1	1
Medium	1	2	2
Large	1	3	3
Hazard Group C			
Small	1	1	2
Medium	2	3	3
Large	2	4	4
Hazard Group D			
Small	2	2	3
Medium	3	4	4
Large	3	4	4
Hazard Group E			
For all hazard group E substances, choose control approach 4			

www.ilo.org

Working with Engineered Nanomaterials

Can Expert Control Banding be used?

		Exposure Index				
		A	B	C	D	E
Impact Index	A	Light Blue	Light Blue	Light Blue	Yellow	Yellow
	B	Light Blue	Light Blue	Light Blue	Yellow	Brown
	C	Light Blue	Light Blue	Yellow	Brown	Red
	D	Yellow	Yellow	Brown	Red	Red
	E	Red	Red	Red	Red	Red

CONCEPTUAL

Exposure Index

- 'Dustiness'
- Amount Used

Impact Index

- Bulk hazard
- Surface Area
- Surface Activity
- Shape
- Size

Control Approach

- General Ventilation
- Engineering Control
- Containment
- Specialist Advice



Working with Engineered Nanomaterials

NIOSH Communications

- Nanotechnology topic page
- Strategies for working with engineered nanomaterials
- Fact Sheet
 - Raise awareness on nanotechnology and occupational health
- Frequently Asked Questions (and answers)
 - A resource for developing occupational hygiene strategies
- Current Intelligence Bulletin
 - Engineered nanomaterials
- Summary document to accompany the CIB

CDC | CDC Home | CDC Search | CDC Health Topics A-Z

NIOSH National Institute for Occupational Safety and Health

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NIOSH Safety and Health Topic:
Nanotechnology

Background

The past decade has seen intense interest in developing technologies based on the unique behavior of nanometer-scale (nanoscale) structures, devices and systems, leading to the rapidly expanding and highly diverse field of nanotechnology.

Nanotechnology is somewhat loosely defined, although in general terms it covers engineered structures, devices and systems that have a length scale of 1 – 100 nanometers¹. At these length scales, materials begin to exhibit unique properties that affect physical, chemical and biological behavior. Researching, developing and utilizing these properties is at the heart of the new technology.

Although many nanotechnologies are still in the pre-competitive stage, nanoscale materials are increasingly being used in optoelectronics, electronics, magnetic, medical imaging, drug delivery, catalysis, catalytic and materials applications. Between 1997 and 2003, world-wide government investments in the field rose from \$432 million a year to just under \$3 billion a year, and the global impact of nanotechnology-related products is predicted to exceed \$1 trillion by 2015². In the US, an estimated 2 million workers are currently exposed to nanometer-diameter particles on a regular basis. (Based on year 2000 national industry-specific occupational employment estimates by the US Department of Labour³, it has been estimated that an additional 2 million workers will be required globally within nanotechnology-related industries in order to meet predicted demand for products over the next decade⁴.)

First International Symposium on Nanotechnology and Occupational Health

In October, the First International Symposium on Nanotechnology and Occupational Health will be co-sponsored by NIOSH and the United Kingdom Health and Safety Executive. This symposium, to be held in the Bilton town of Buxton, will bring researchers, decision makers, occupational health professionals and other stakeholders together to discuss what is known and what we still need to discover about the occupational impact of nanotechnology. A series of workshops at the end of the symposium will consider how best to address the key information gaps that exist in order to protect workers. Further details of the meeting can be found at <http://www.cdc.gov/niosh/topics/nanotech>.

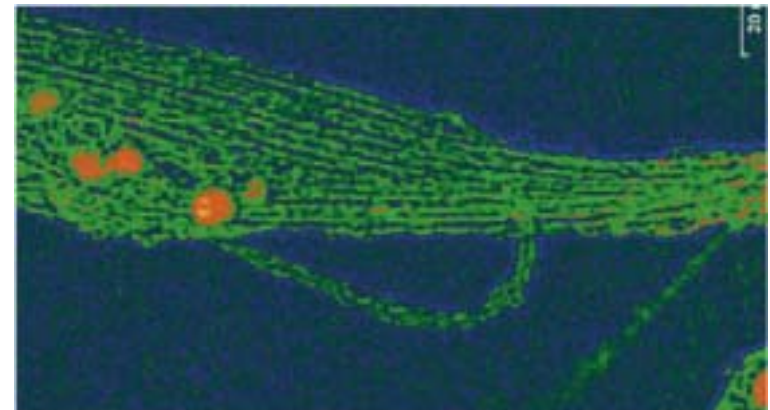
Nanotechnology

Scanning Electron Microscope image of a compact bundle of carbon nanotubes. Each rope is formed from aligned single walled carbon nanotubes. Research is being carried out to understand the physical nature and toxicity of inhaled carbon nanotube particles.

On This Page...
[Background](#)
[Occupational Health Risks](#)

Occupational health risks associated with manufacturing and using nanomaterials are not yet clearly understood.

www.cdc.gov/niosh/topics/nanotech



Nanotechnology
& Occupational Safety
and Health

Working with Engineered Nanomaterials

FAQs - draft outline, December 2004. Publication date: Soon!

- 1 AIMS AND SCOPE OF THE FAQ
- 2 DESCRIPTIONS AND DEFINITIONS
- 3 EXPOSURE TO NANOMATERIALS.
 - 3.1 Potential Health Risk
 - 3.2 Exposure to nanomaterials
 - 3.3 Exposure routes
 - 3.4 Nanoparticle behavior in the body
 - 3.5 Toxicity and potential health risk associated with nanomaterials
 - 3.6 Toxicity and potential health risk associated with carbon nanotubes
- 4 WORKING WITH ENGINEERED NANOMATERIALS
 - 4.1 Exposure standards and regulation
 - 4.2 Measurement and characterization
 - 4.3 Controlling exposure to nanomaterials
 - 4.4 Use of personal protective equipment with nanomaterials
 - 4.5 Good working practices
- 5 POTENTIAL APPLICATION OF NANOTECHNOLOGY TO OCCUPATIONAL SAFETY AND HEALTH
- 6 GENERAL INFORMATION

Working with Engineered Nanomaterials

Useful questions to ask

- What is the potential for human exposure (inhalation, skin, ingestion, eye contact etc.)?
- What is known about the magnitude of potential exposures?
- What is known about the health risk associated with the nanomaterial?
- What are the health hazards associated with the bulk material(s)?
- What material attributes may affect the hazard?
 - Particle size?
 - Surface Structure?
 - Surface Chemistry?
 - Particle shape?
- Can available information be used to estimate appropriate exposure limits?
- How should exposures most appropriately be measured ?
- What measures can be taken to reduce exposures?

Fostering partnerships and dialogue

The screenshot shows a web browser window with the URL http://events.cce.umn.edu/events/section_detail.aspx?sect_key=177245&cluster_cd=WS20. The page is titled "Continuing Professional Education ENGINEERING" and features the University of Minnesota logo. The main content area is for the "Second International Symposium on Nanotechnology & Occupational Health". It lists the dates as Monday, October 3, 2005 (Tutorials) and Tuesday-Thursday, October 4-6, 2005 (Conference). The location is the Rabelson Hotel Metrodome, 615 Washington Ave SE, Minneapolis, MN 55414. The event ID is 177265, and the registration status is "Registration Pending". The page also includes a "Mark your calendars" section with key dates for abstract submission and brochure mailing. Logos for the University of Minnesota, OVP&R, and NIOSH are displayed. Contact information for Heather Carr is provided at the bottom.

Second International Symposium on Nanotechnology & Occupational Health

Monday, October 3, 2005: Tutorials
Tuesday-Thursday, October 4-6, 2005: Conference

In addition to invited plenary lectures, platform and poster sessions will be held for those with relevant new work to report.

Event ID: 177265
Event Dates: 10/3/2005 - 10/6/2005
Registration Costs: TBD
Registration Status: Registration Pending

Number of meetings: 4
Hotel Lobby Check-in: Rabelson Hotel Metrodome
615 Washington Ave SE, Minneapolis, MN 55414

Mark your calendars:

- Call for abstracts will be mailed January 15, 2005.
- Abstracts will be due March 15, 2005.
- Conference brochure will be mailed in July, 2005.

Organized by the University of Minnesota and the National Institute for Occupational Safety and Health.

UNIVERSITY OF MINNESOTA
Research OVP&R Excellence
Office of the Vice President for Research
NIOSH
National Institute for Occupational Safety and Health

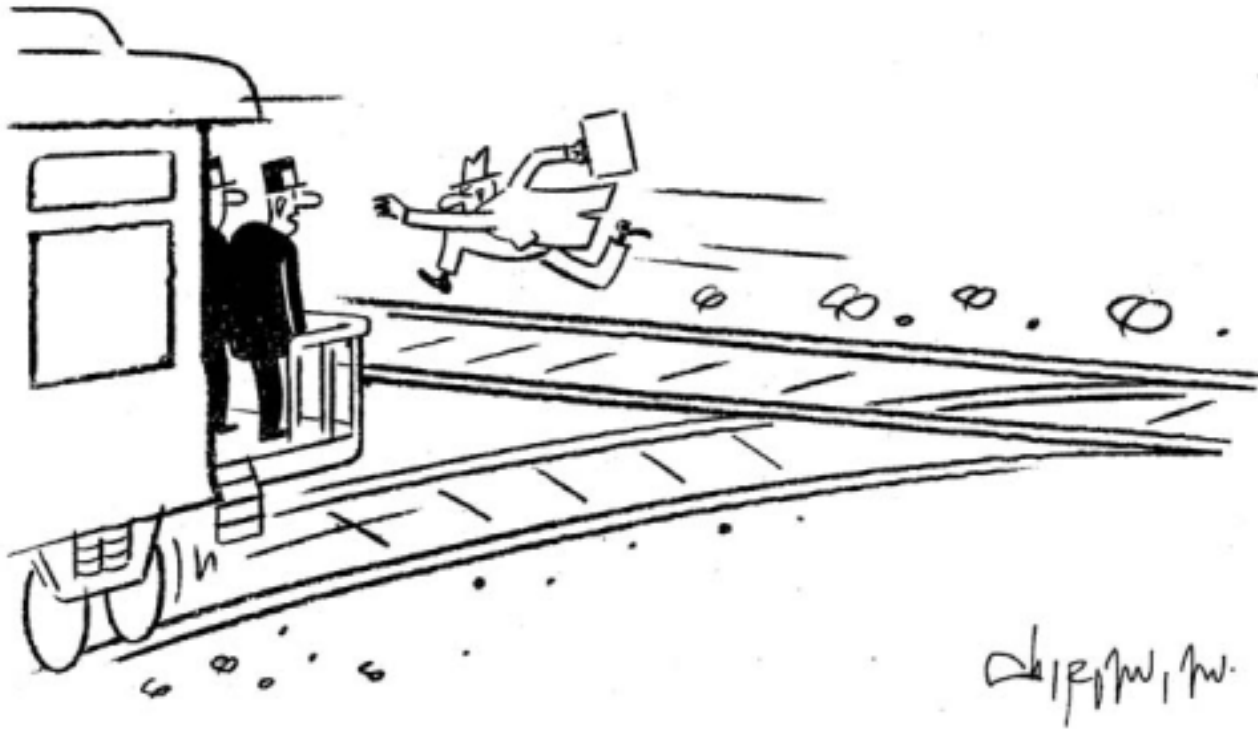
Contact:
Heather Carr
ccarr@cce.umn.edu
(612) 625-5267

Second International Symposium on Nanotechnology and Occupational Health

- Sponsored by NIOSH
- Supported by NORA Emerging technologies team
- Hosted by the University of Minnesota
- October 3 - 6 2005, Minnesota
- Multi-stakeholder meeting
- www.cce.umn.edu/nanotechnology

Controlling technology impact

The accepted model?



"For 2 minutes there I thought he was going to make it."

...with nanotechnology, we still have the chance to make a difference before the train leaves the station