Nanotechnology and Occupational Health

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EPA June 13th 2005

NIOSH

Concern over the Potential Impact of Nanotechnology

ETC Group 2003

VDI (Germany) 2004

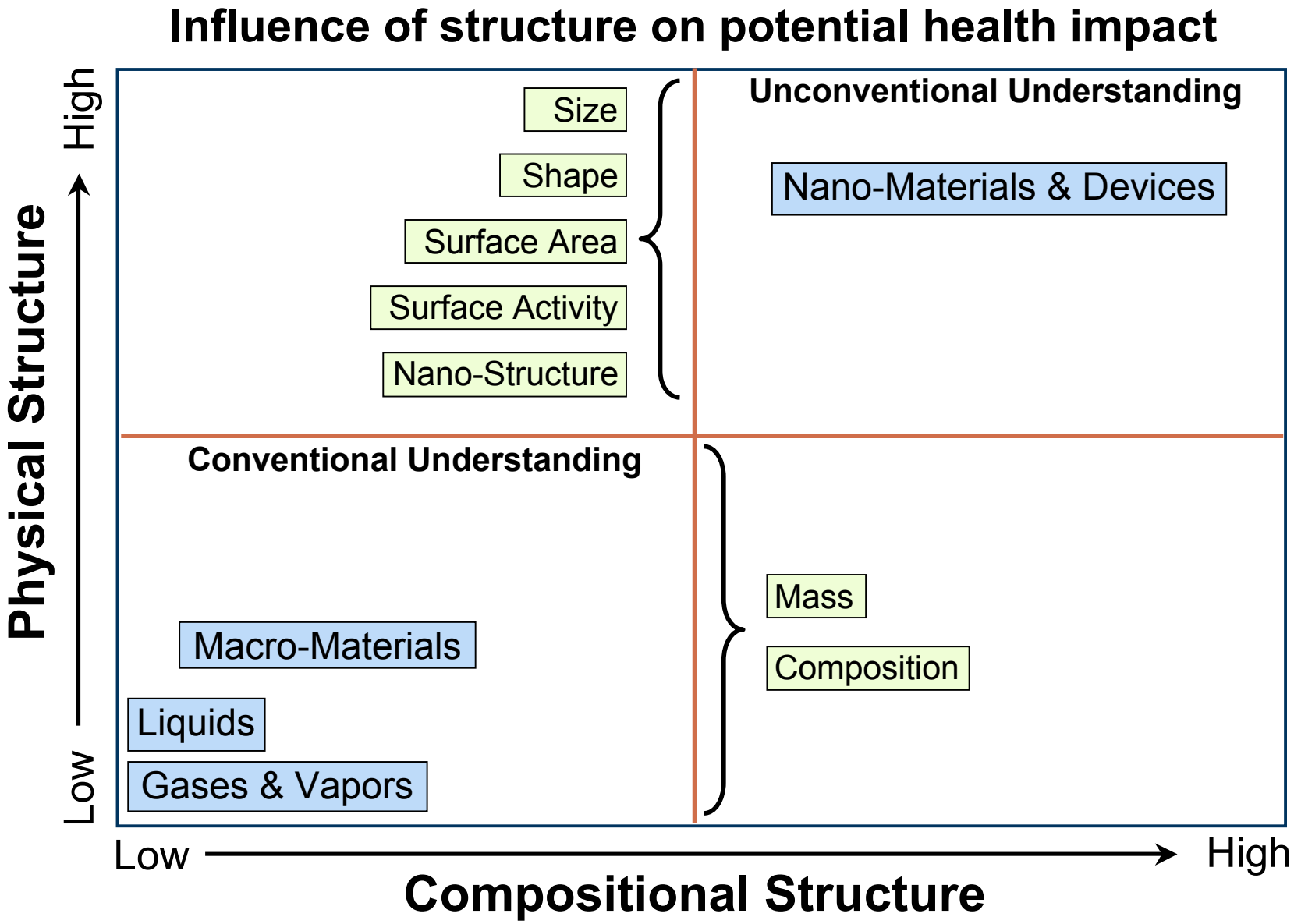
SwissRe 2004

Environmental Health Perspectives 2004

Royal Society 2004

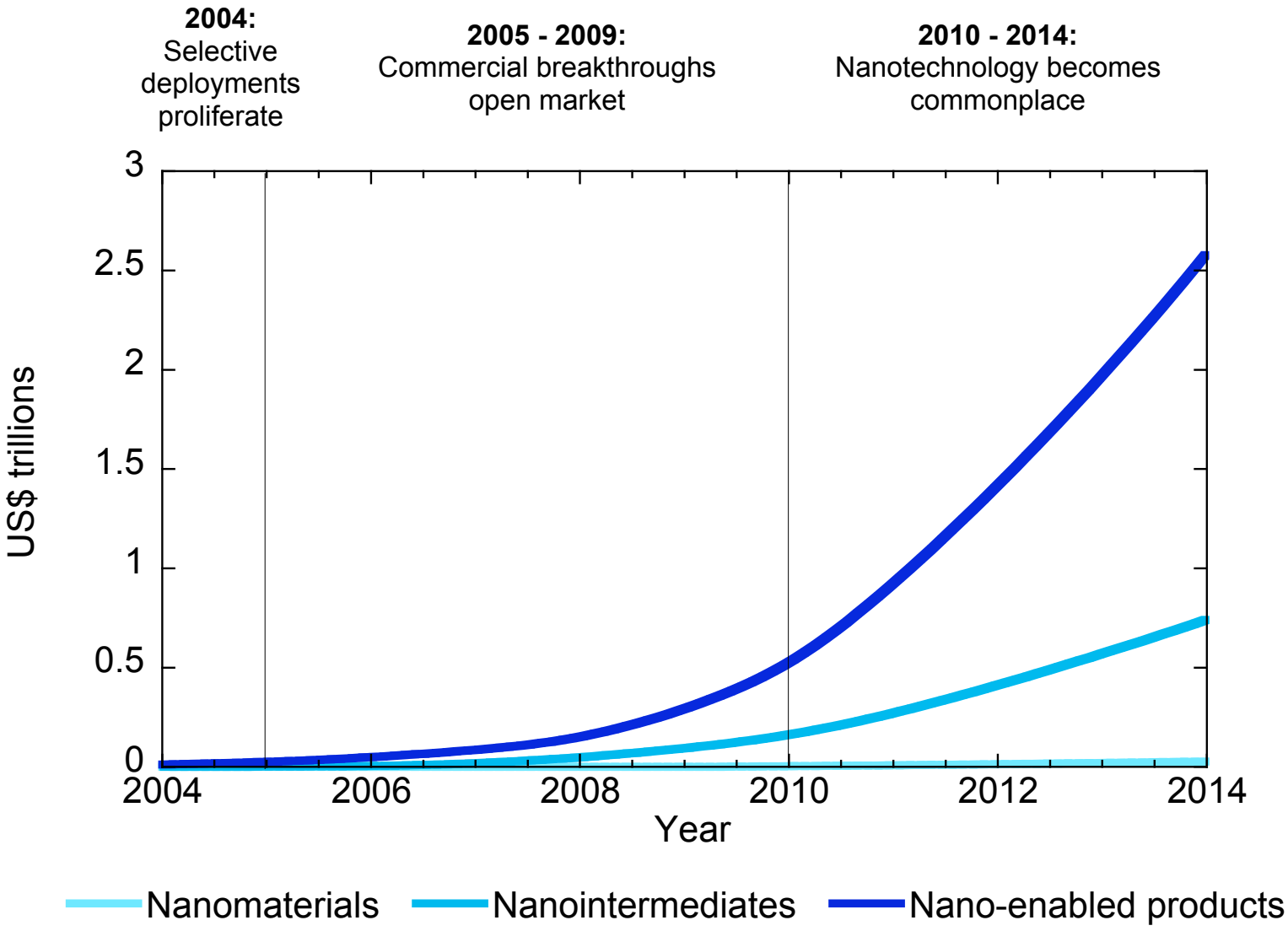
Potential Health Impact

What makes ‘nano’ different?



Nanotechnology

Global forecast of products sold incorporating nanotechnology



Source: 2004 Lux Research Report: “Sizing nanotechnology’s value chain”

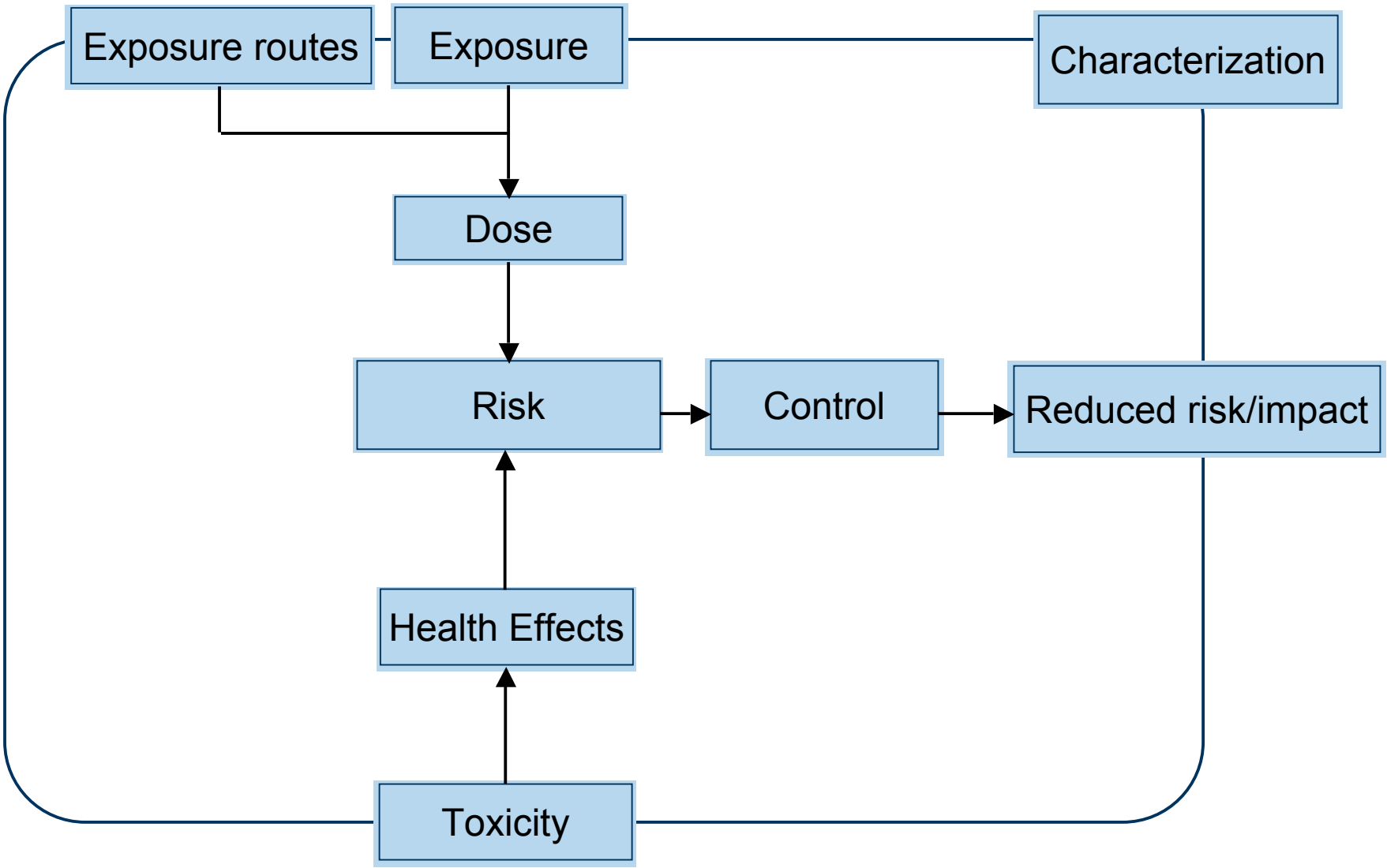
Defining the Issue

Nanotechnology and Occupational Health

- **Nanotechnology - The Motivation**
  - Purposely engineered nanostructured materials and devices demonstrate new, unique and non-scalable properties and behavior

- **Nanotechnology - The Challenge**
  - Does the nature of engineered nanostructured materials and devices present new safety and health risks?
  - How can the benefits of nanotechnology be realized while proactively minimizing the potential risk?

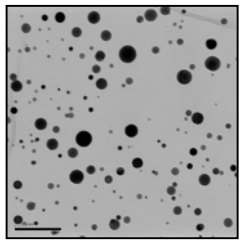
Addressing Occupational Impact



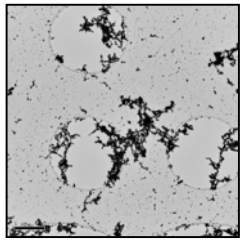
Setting Boundaries

Engineered nanomaterials which potentially present new challenges

- **Criteria:**
  - Nanomaterials capable of entering or interacting with the body
  - Nanomaterials which potentially exhibit nanostructure-dependent biological activity



Nanoparticles
Simple, complex, “smart”. Aerosols, powders, suspensions, slurries



Agglomerates
or aggregates of nanoparticles

Aerosolized suspensions
Including slurries and solutions of nanomaterials

www.osha.gov

Comminution
Aerosols from grinding, cutting, machining nanomaterials

www.picturearts.com

Degredation/Failure
Aerosols and suspensions resulting from degradation and failure of nanomaterials

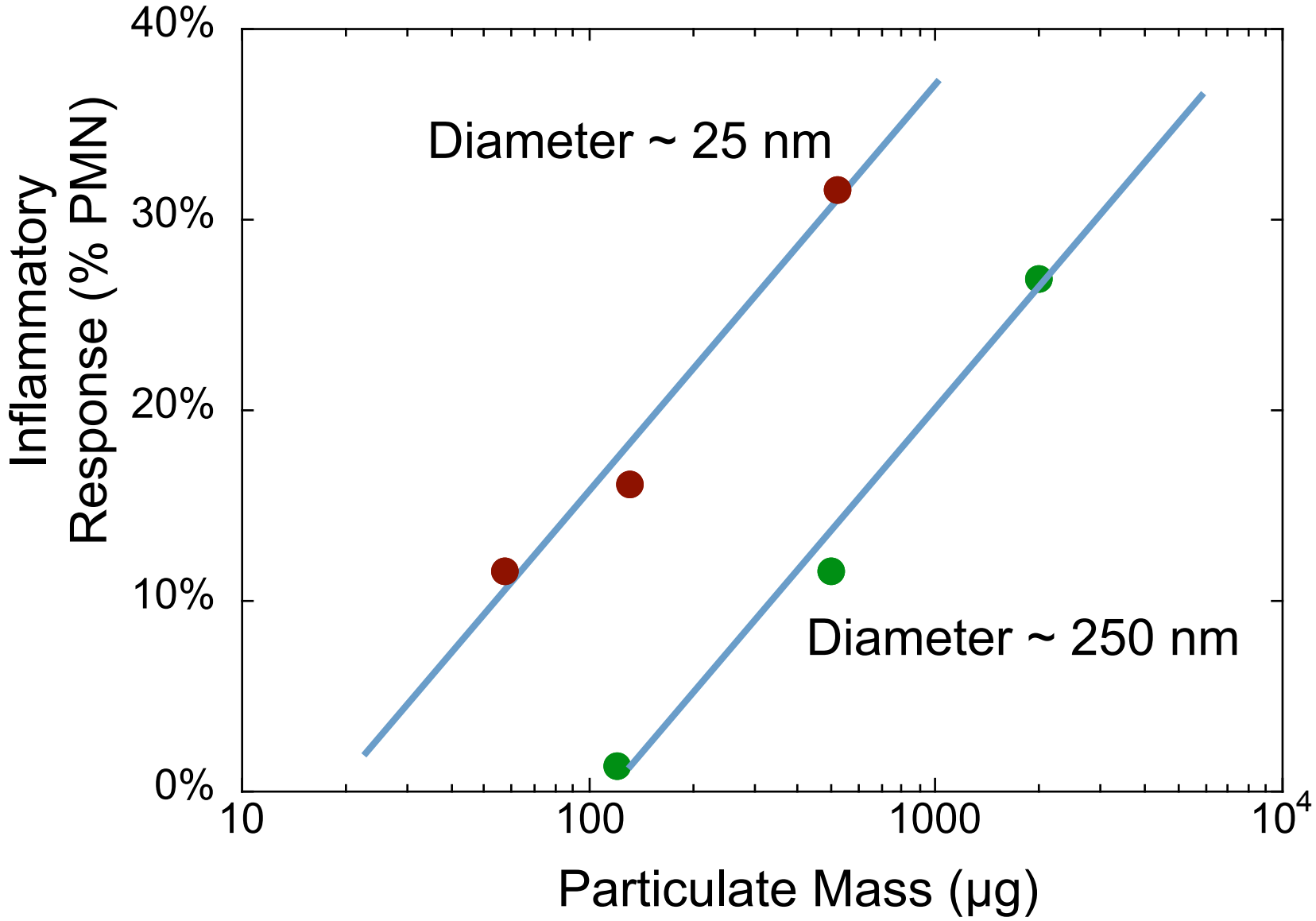
?

Unintentional use
Potential exposure from unanticipated/unintentional use

Hazard

TiO_2 Instillation in Rats

Oberdörster et al. (2000)



TiO_2 Instillation in Rats

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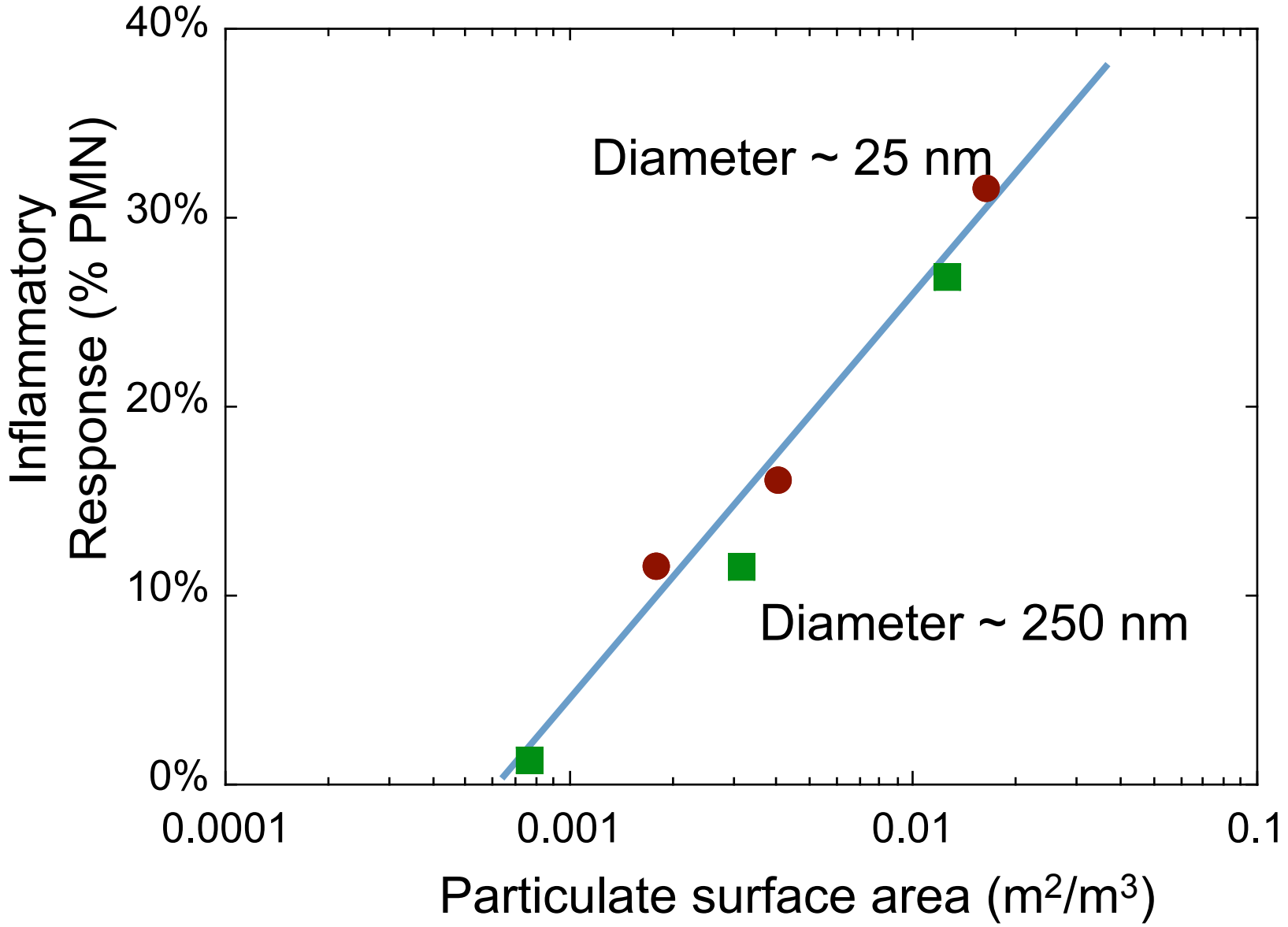
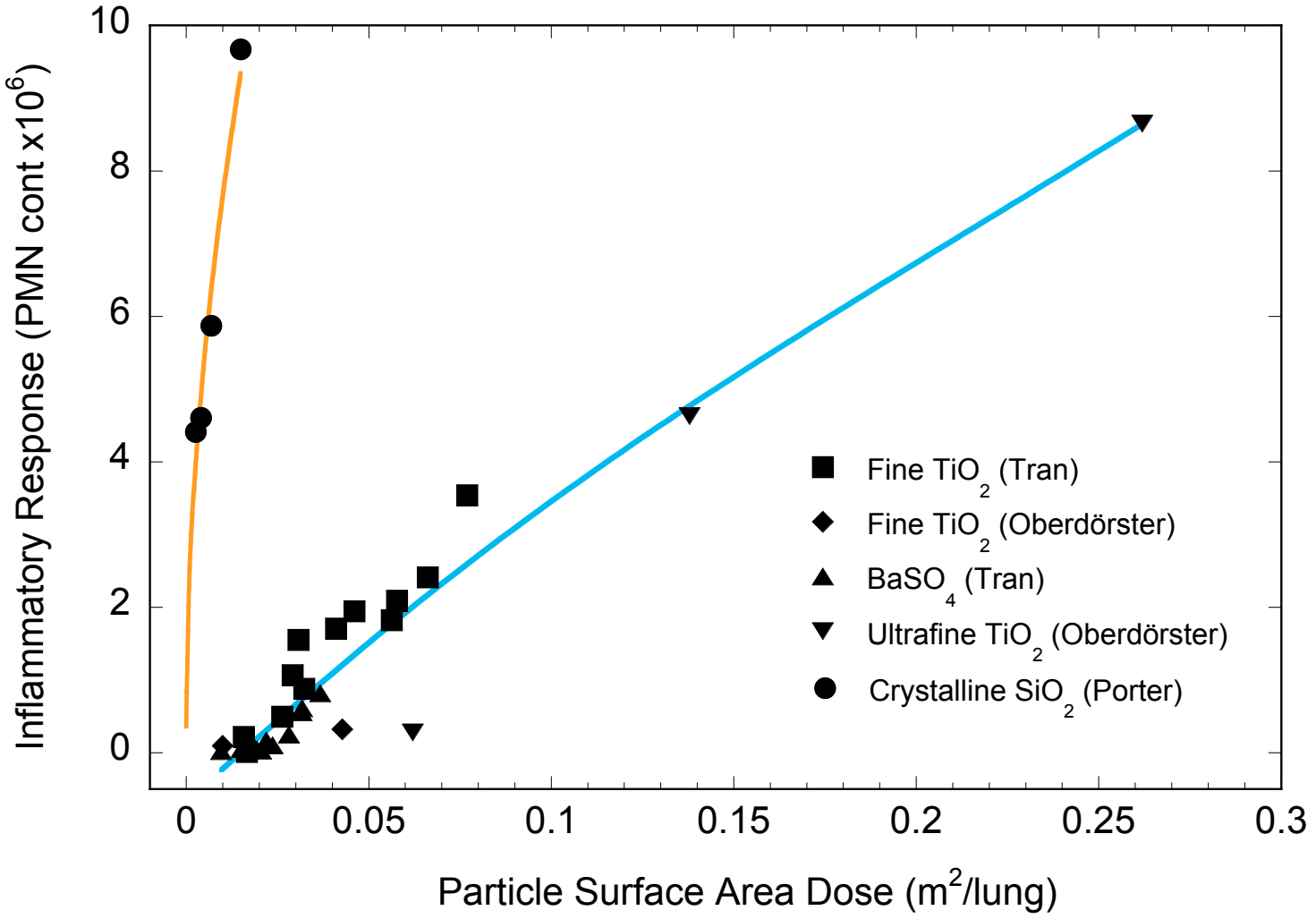


Importance of Surface Chemistry

Comparison of insoluble materials with different biological activities

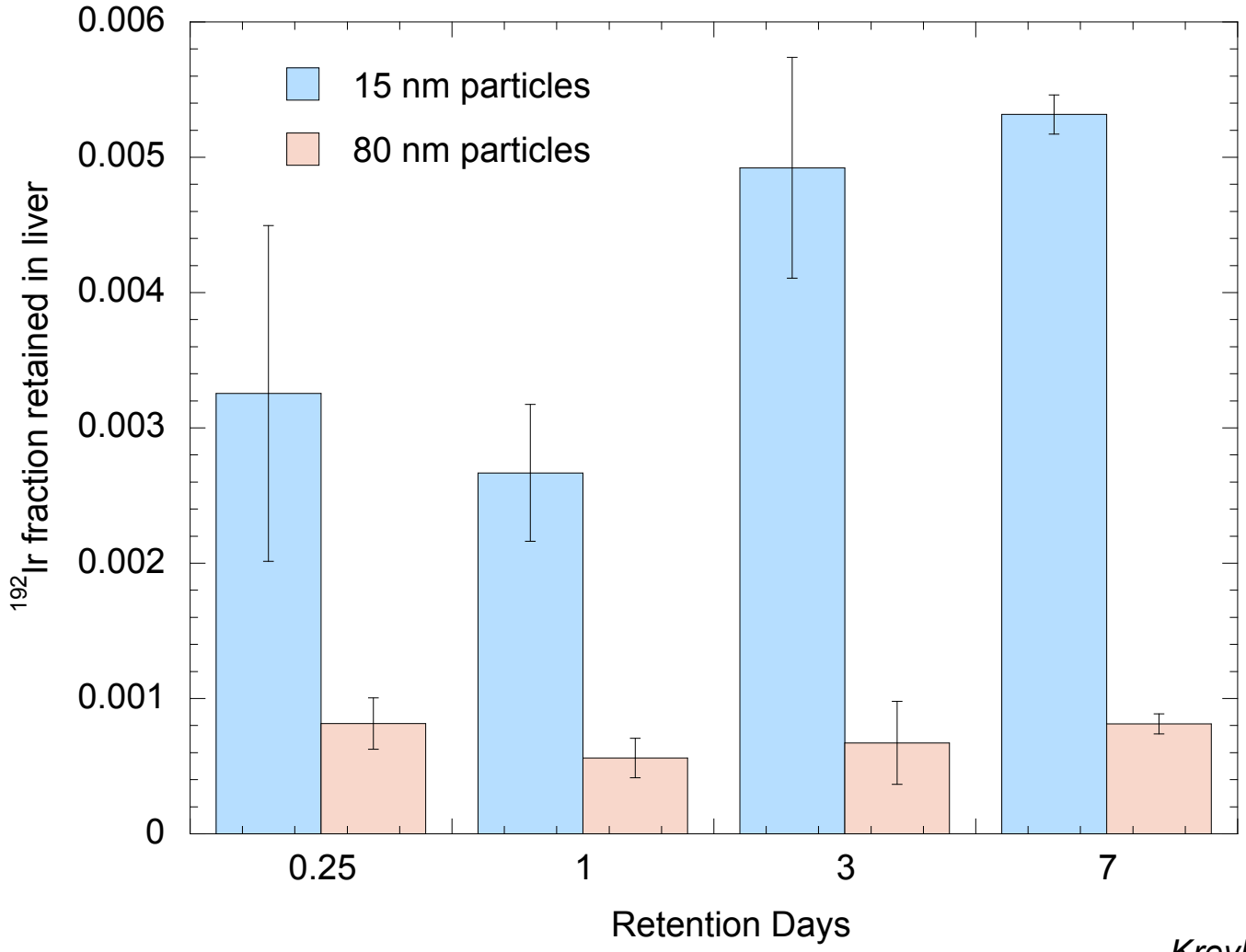


After Kuempel, in Maynard and Kuempel (2005)

Translocation Following Inhalation

Lungs to Liver

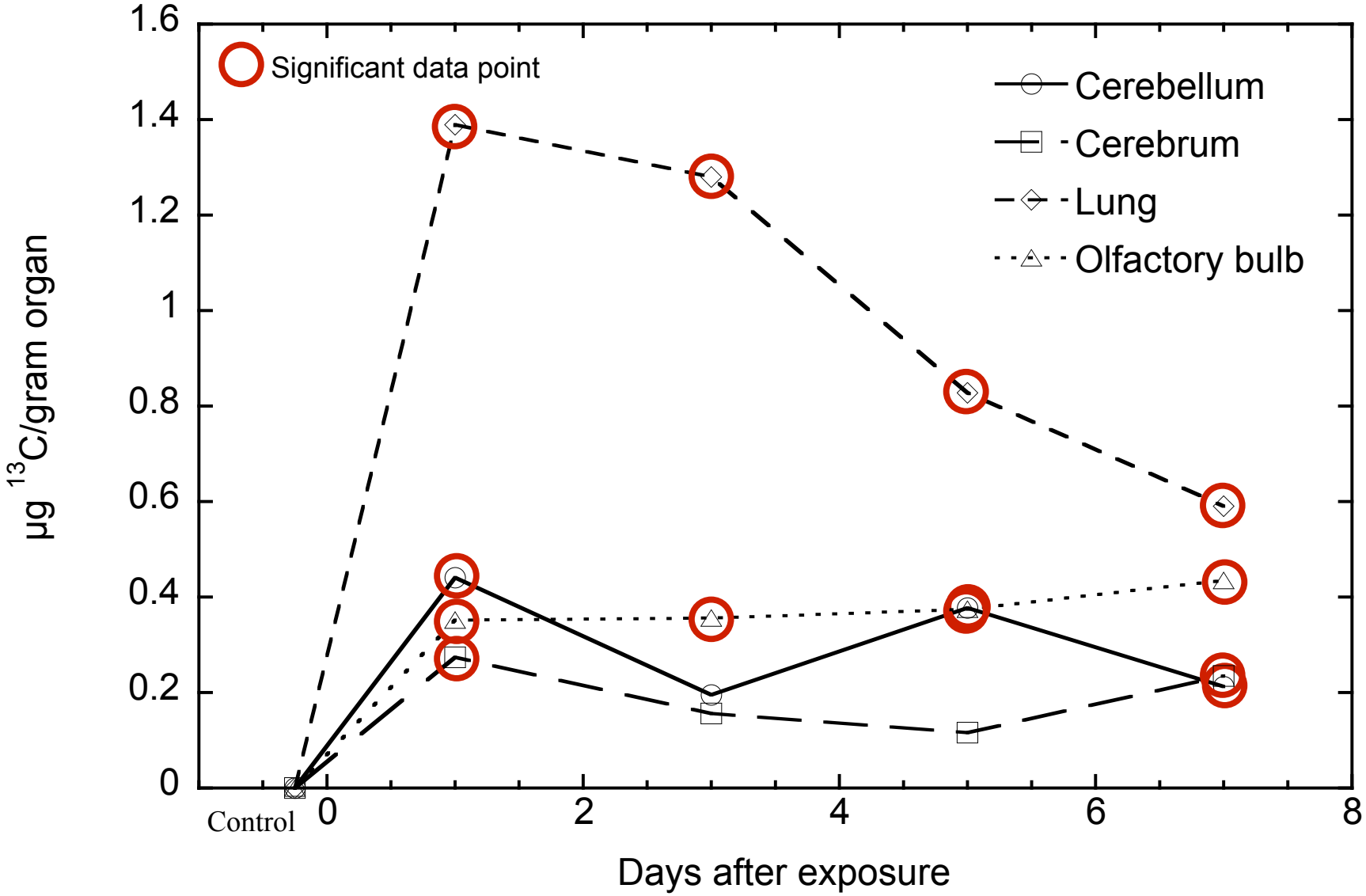
Fraction of inhaled insoluble ^{192}Ir translocating to liver in rats



Kreyling et al. (2002)

Translocation Following Inhalation

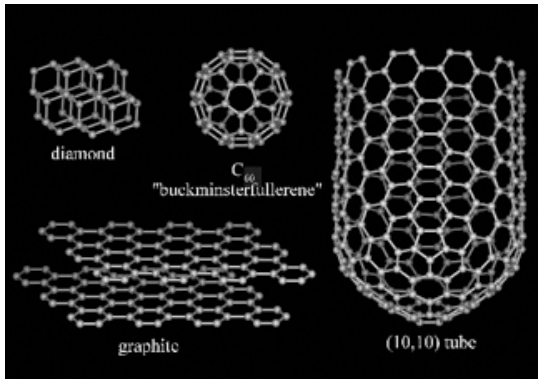
Upper airways to brain - ^{13}C labeled 36 nm diameter particles



Oberdörster et al. 2004

Particle Shape?

Single Walled Carbon Nanotubes



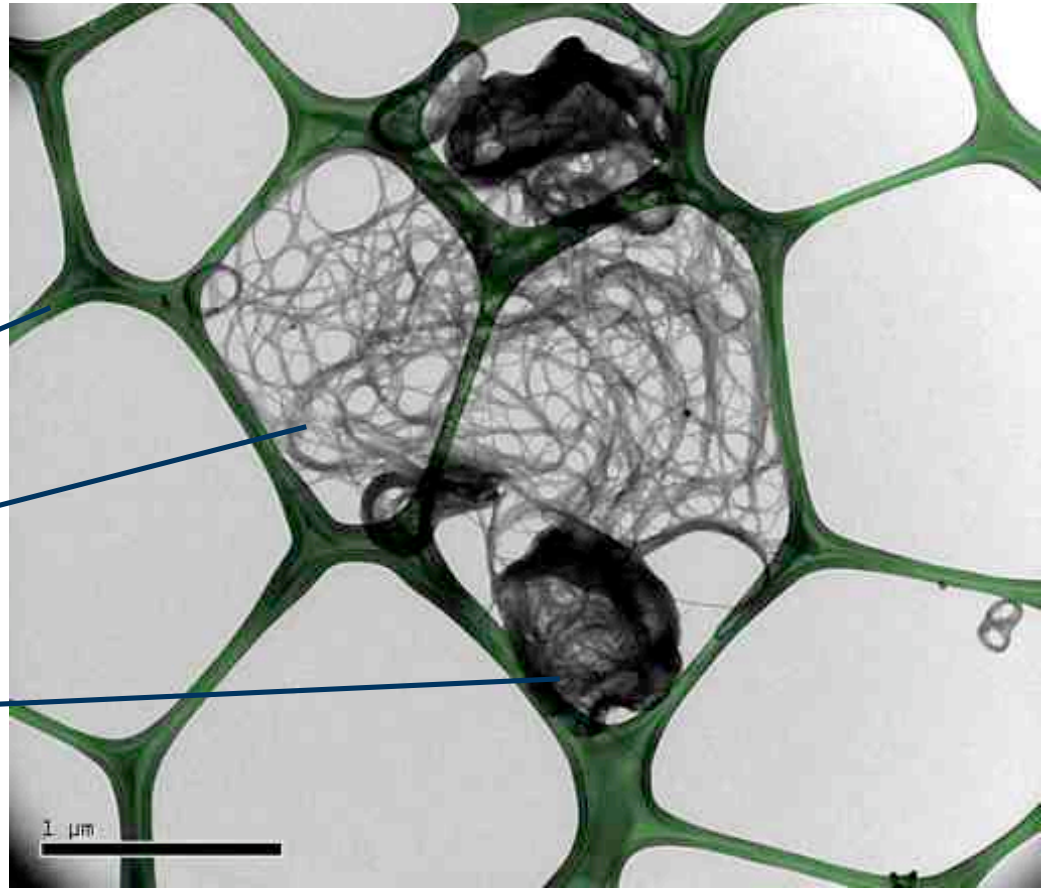
Allotropes of carbon

Transmission Electron Microscope image of purified single walled carbon nanotube particles

Carbon support film

Open structured particles

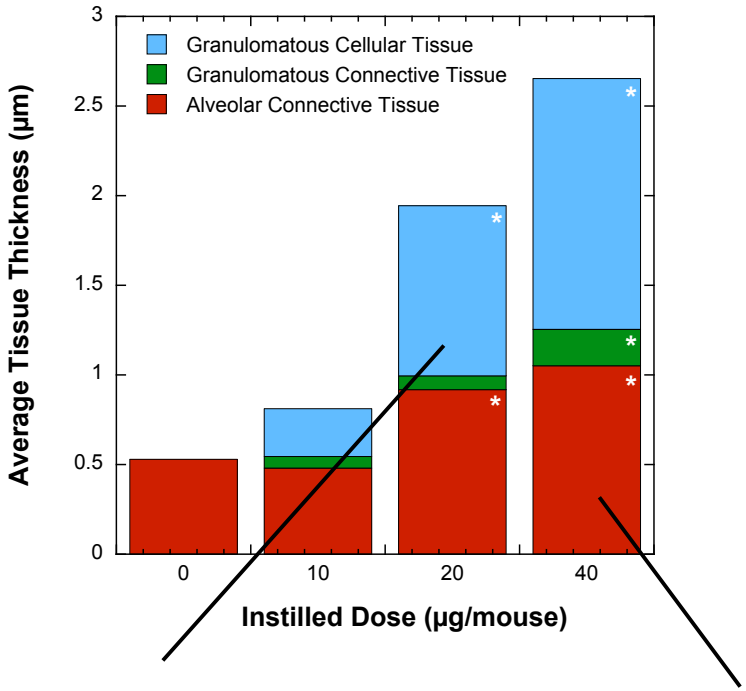
Closed structured particles

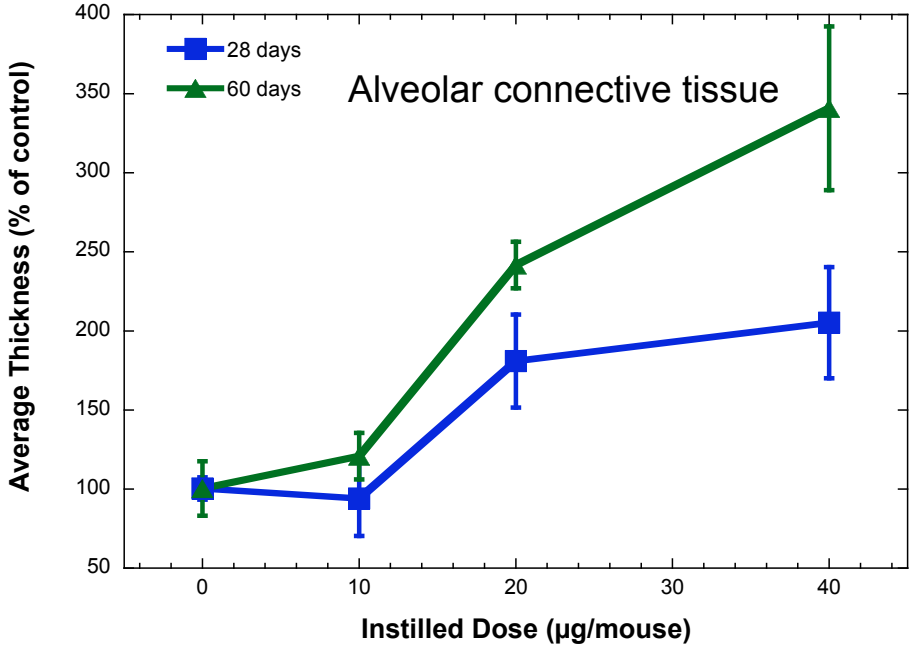


Ku, Evans, Ramsey and Maynard

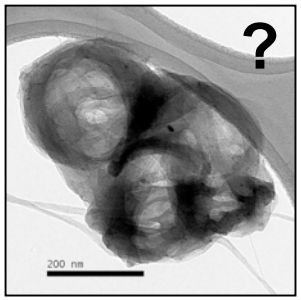
Pulmonary Response to Single Walled Carbon Nanotubes

Pharyngeal aspiration in mice

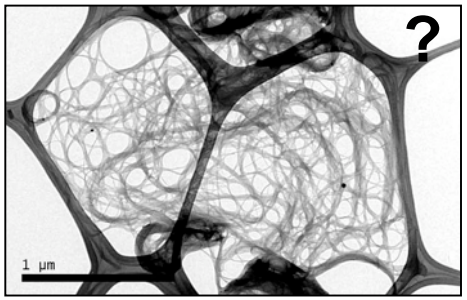




Histopathology:
Proximal region of lung
Visible SWCNT clumps



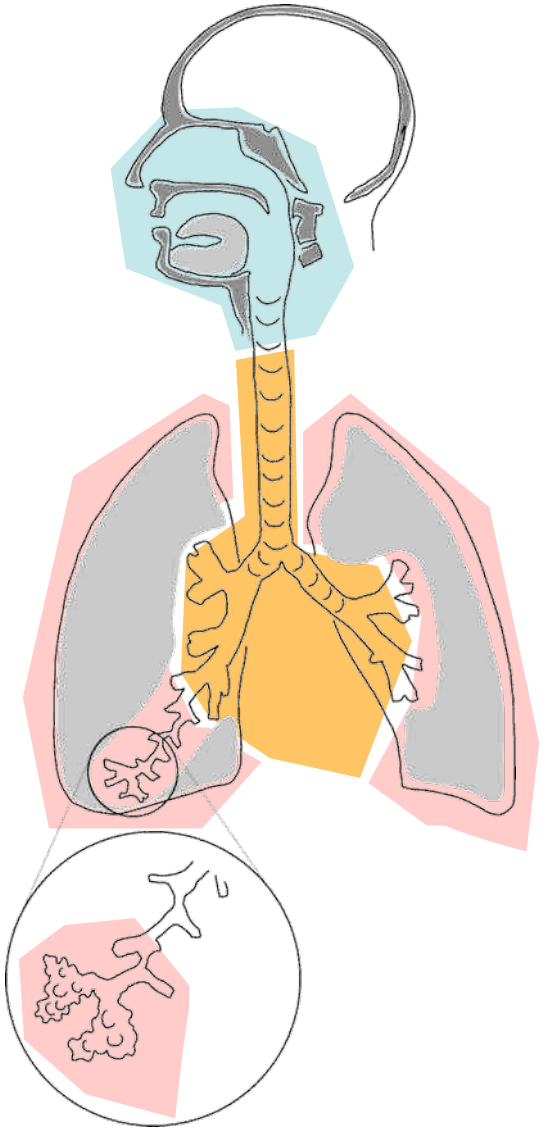
Histopathology:
Distal region of lung
No SWCNT visible

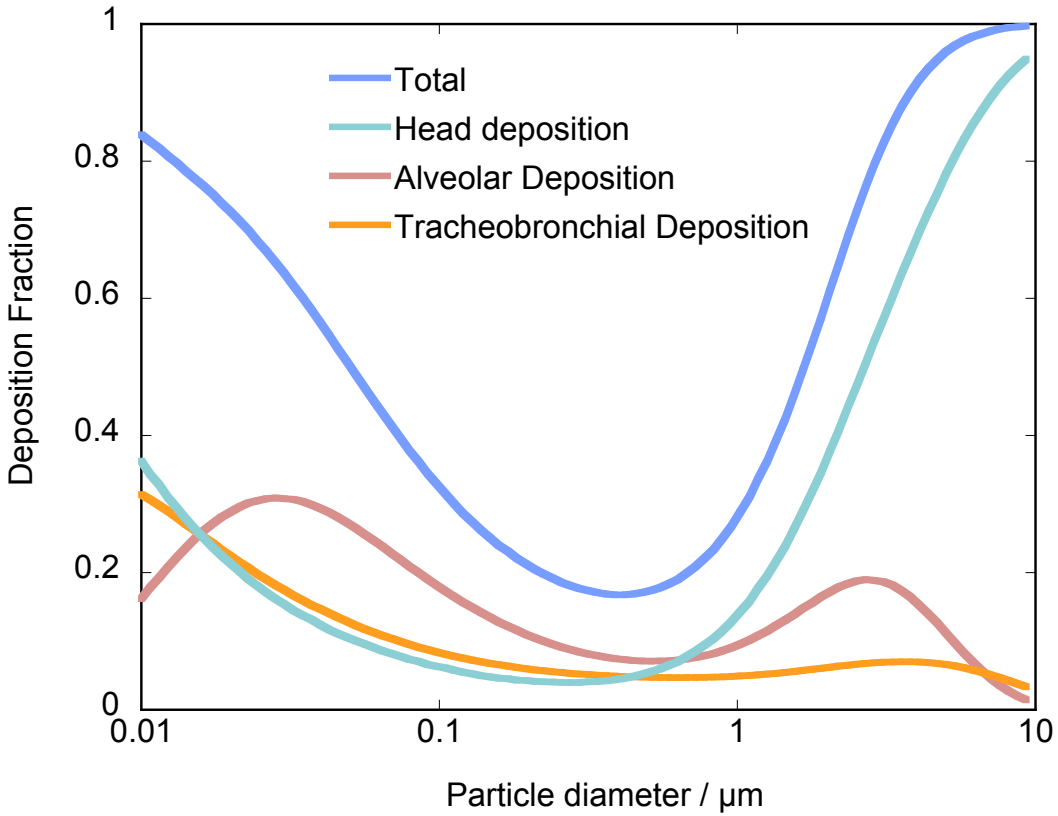


Shvedova *et al. (2005) In Press*

Exposure

Particle Deposition in the Lungs



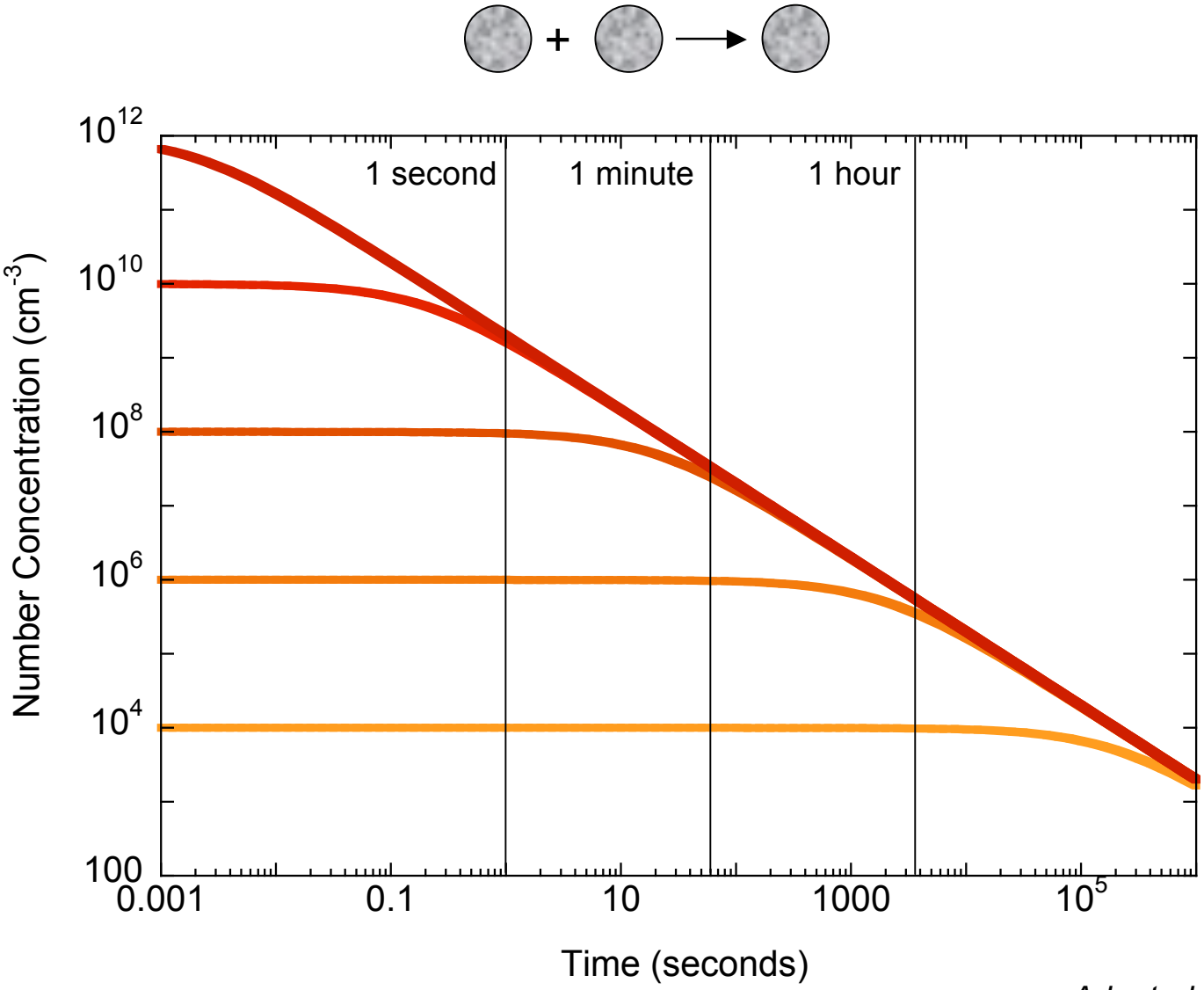


Modeled lung deposition. Mouth and nose breathing, person at rest.

Source: Multiple Pathway Deposition Model (MDEP), CIIT

Airborne nanomaterials transformation

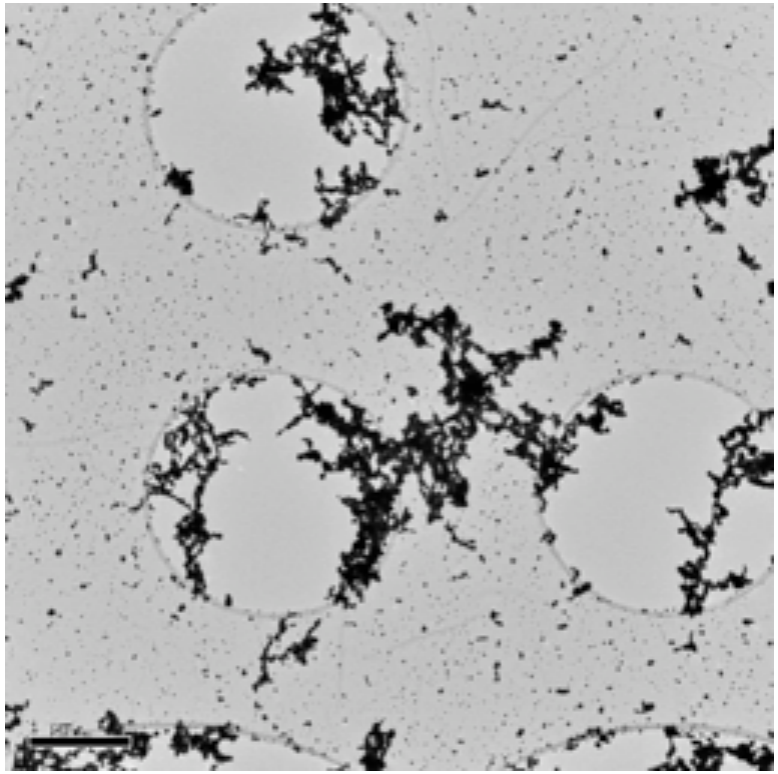
Monodisperse coagulation



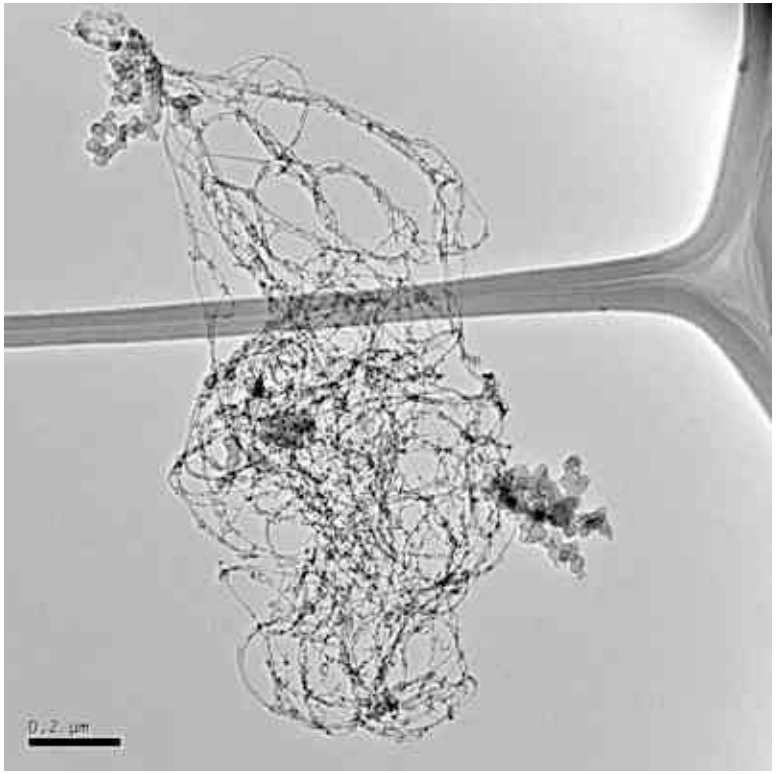
Adapted from Hinds (1999)

Agglomeration

How does it affect particle biological activity?



Agglomerated silver particles

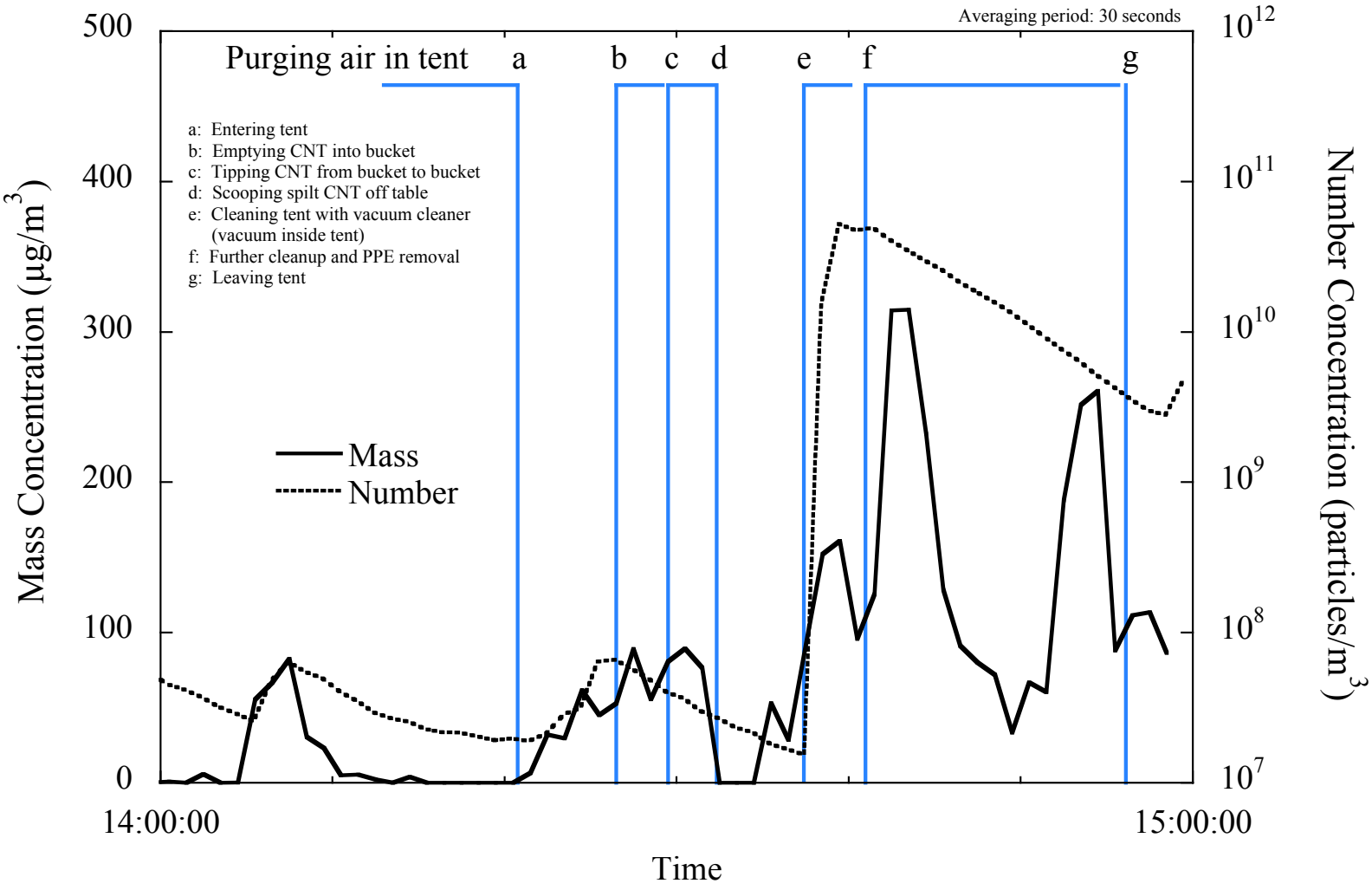


“Agglomerated” single walled carbon nanotubes

Handling nanotube material

Raw single walled nanotube material

Aerosol release in the field

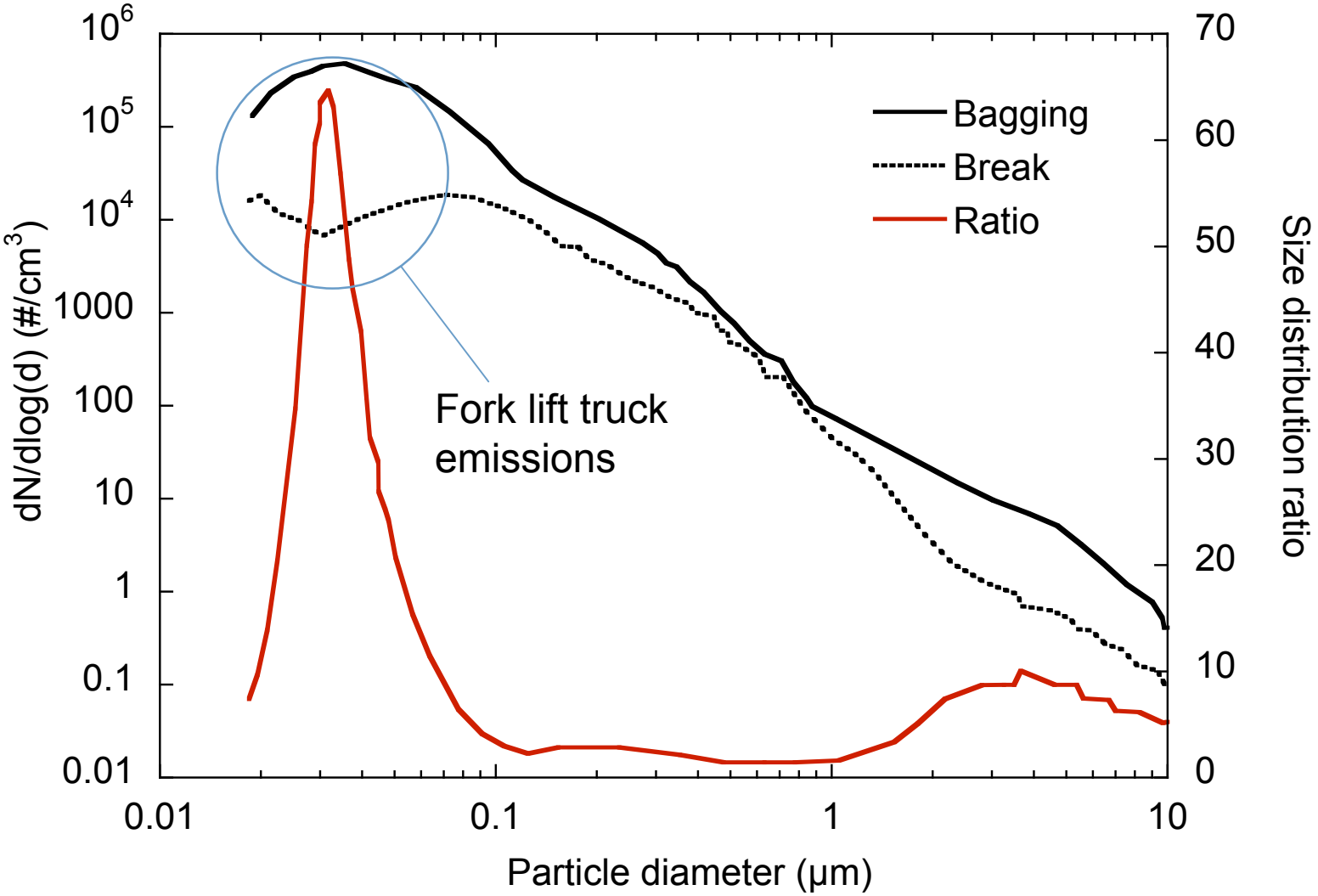


Monitoring aerosol number and mass concentration while handling raw material

Estimated airborne concentrations: 0.7 - 52.7 µg/m^3

Airborne nanomaterials exposure

Carbon black production - bag filling areas



Kuhlbusch *et al.* (2004)

Characterization

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?

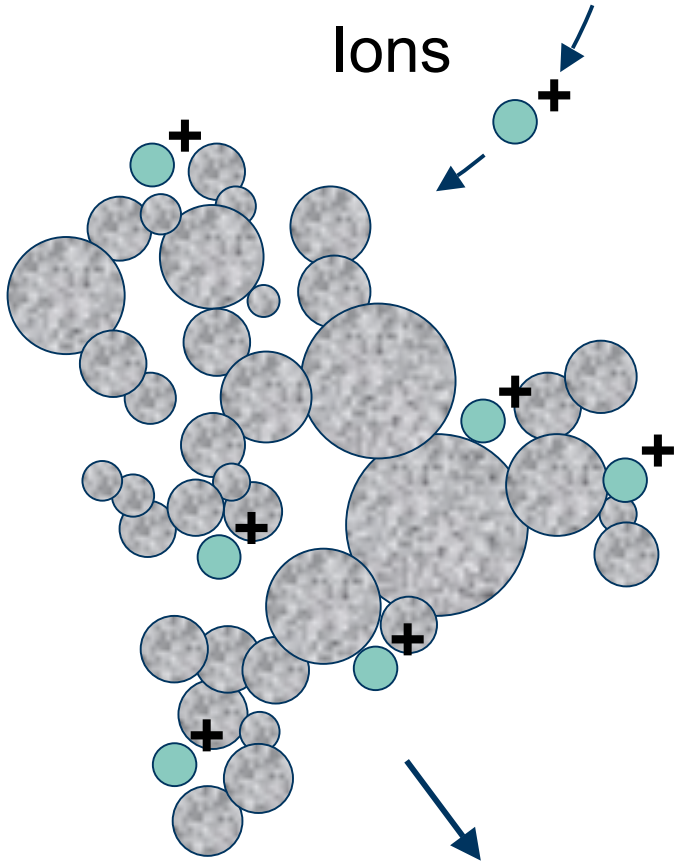
Aerosol Surface-Area Measurement

Using attachment rate

Charge on Aerosol $\propto$ **Surface Area**

DC2000 CE Diffusion Charger

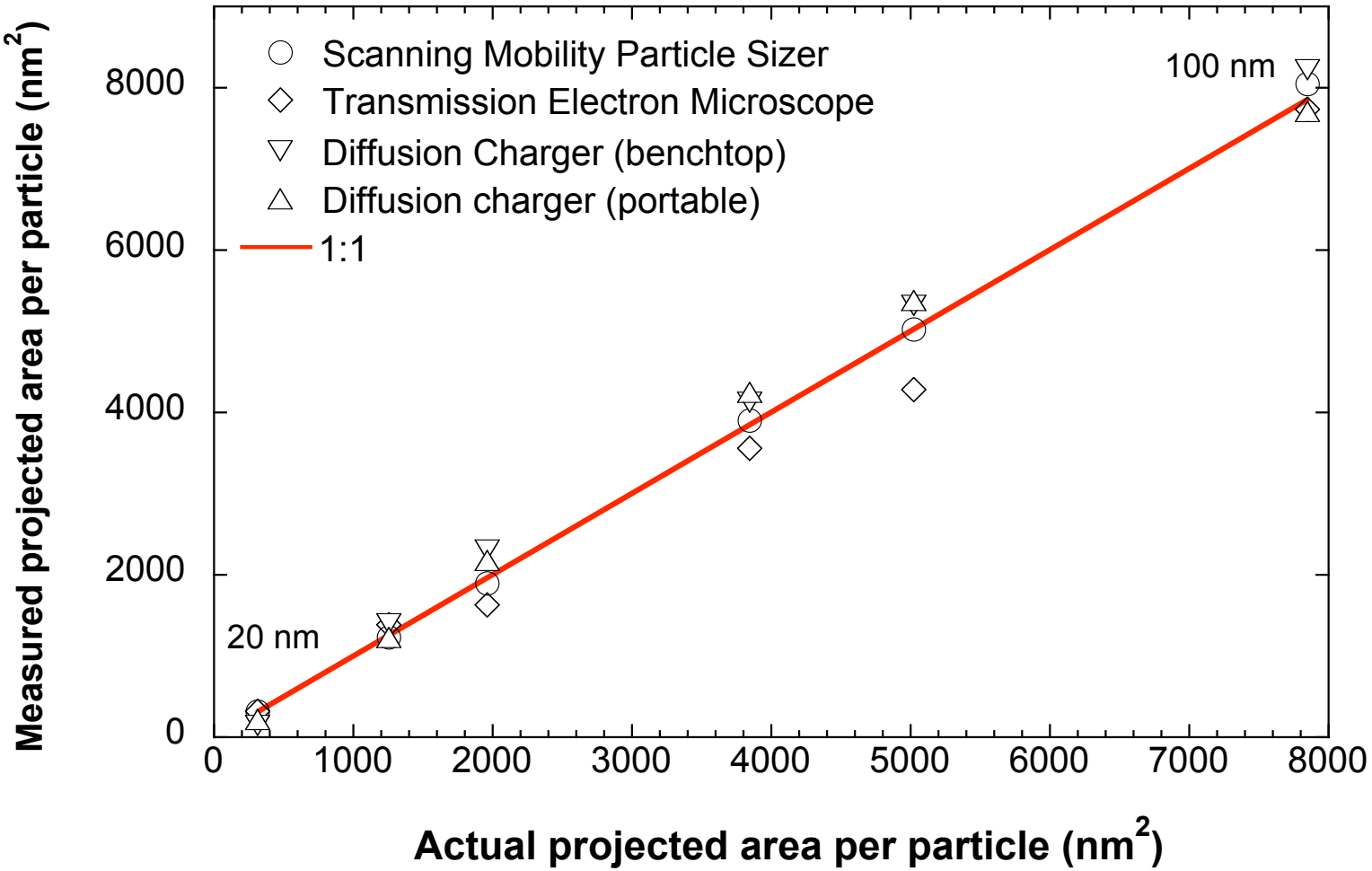
EcoChem



www.ecochem.biz

Comparison of Surface-Area Measurement Methods

Monodisperse particles < 100 nm, fractal-like



Ku and Maynard, J. Aerosol Sci (in press)

Emerging Measurement Technologies

Surface Area

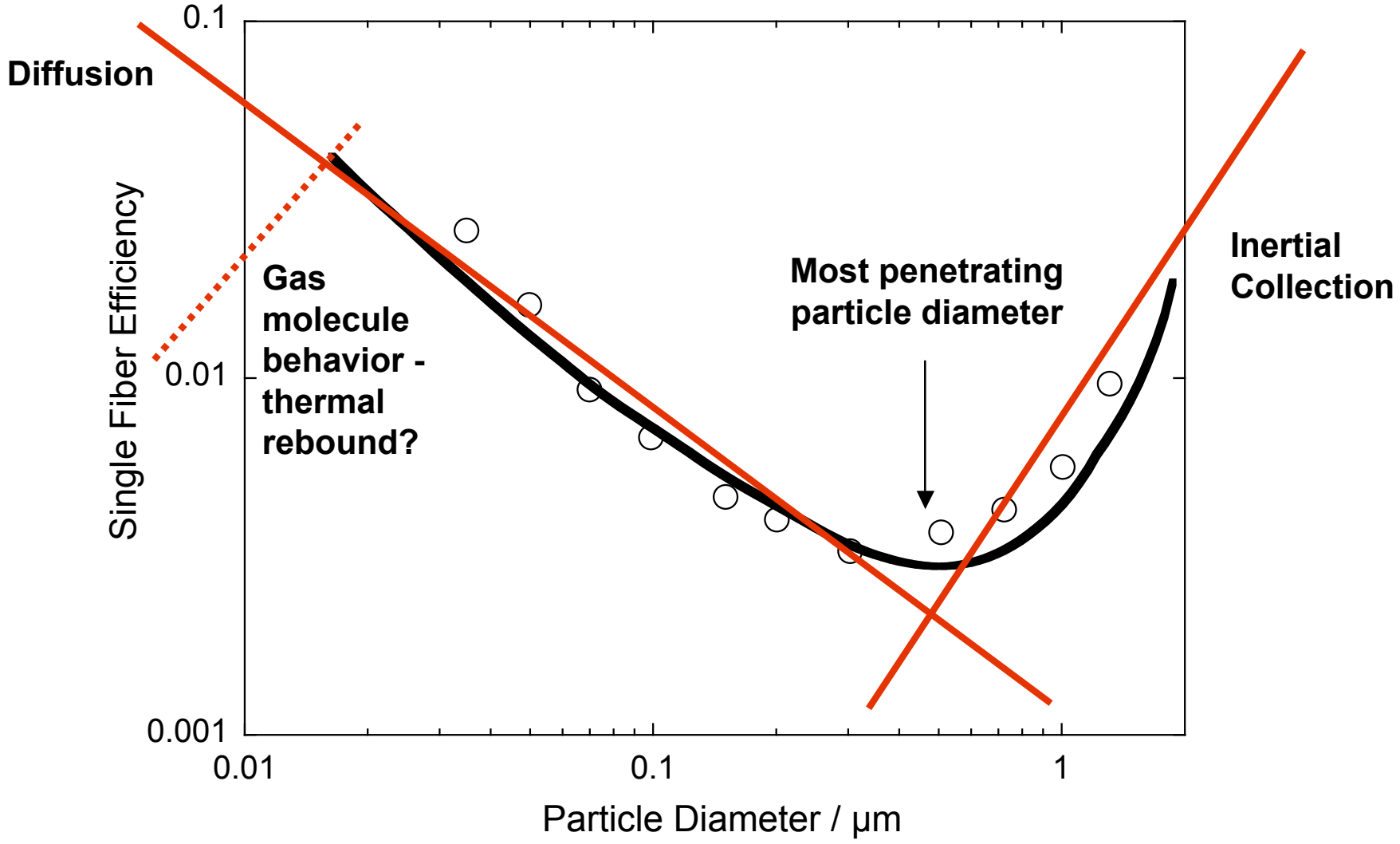
Nanoparticle Surface Area Monitor
www.tsi.com

Diffusion Charger
www.ecochem.biz

Control

Exposure Control

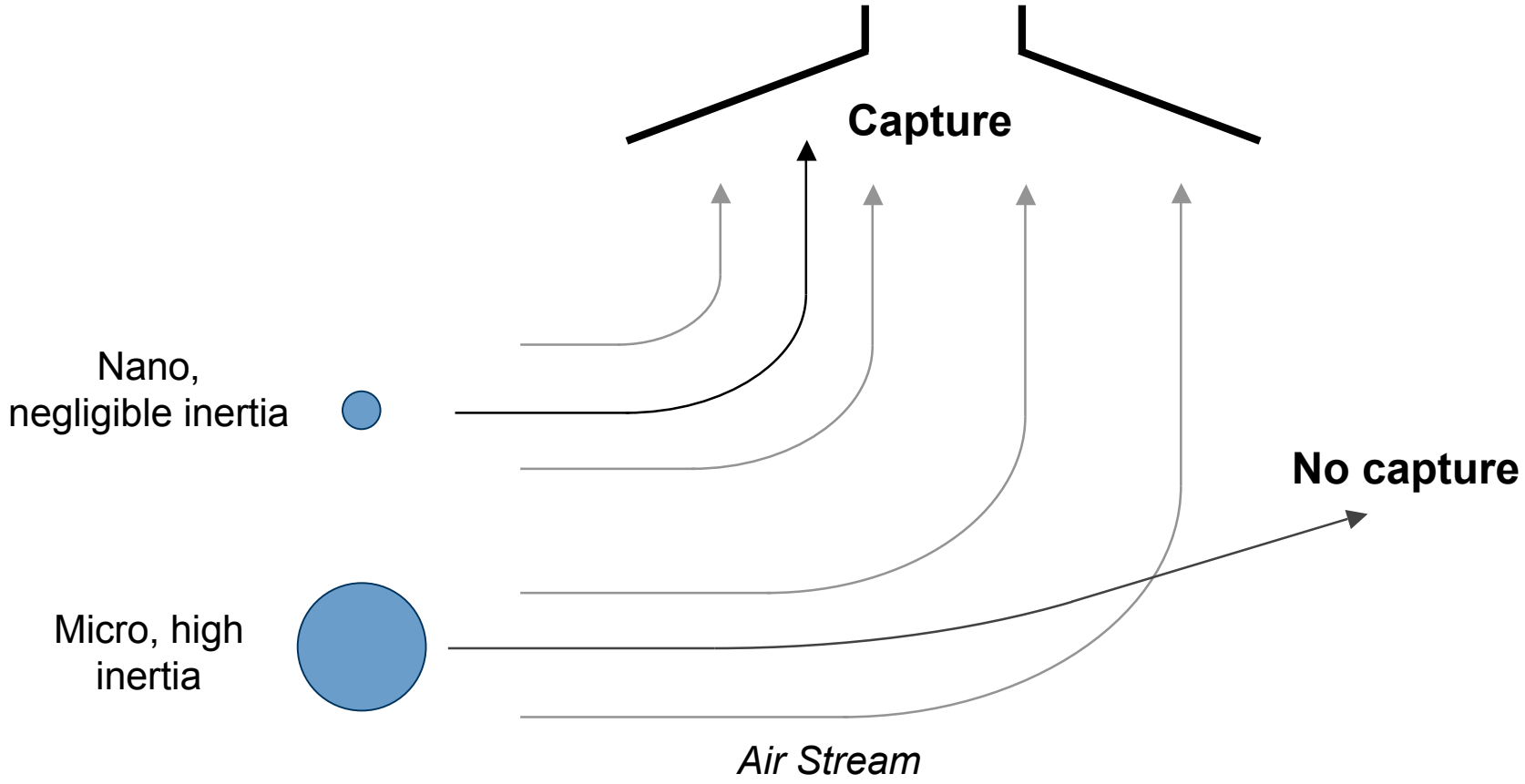
Filter Efficiency - Theory and Experiment



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

Exposure Control

Exhaust Ventilation



Based on the inertial behavior of airborne particles

Exposure Management

Control banding - concept

Parameters

- Hazard Group
- Dustiness
- Amount Used

Control Approach

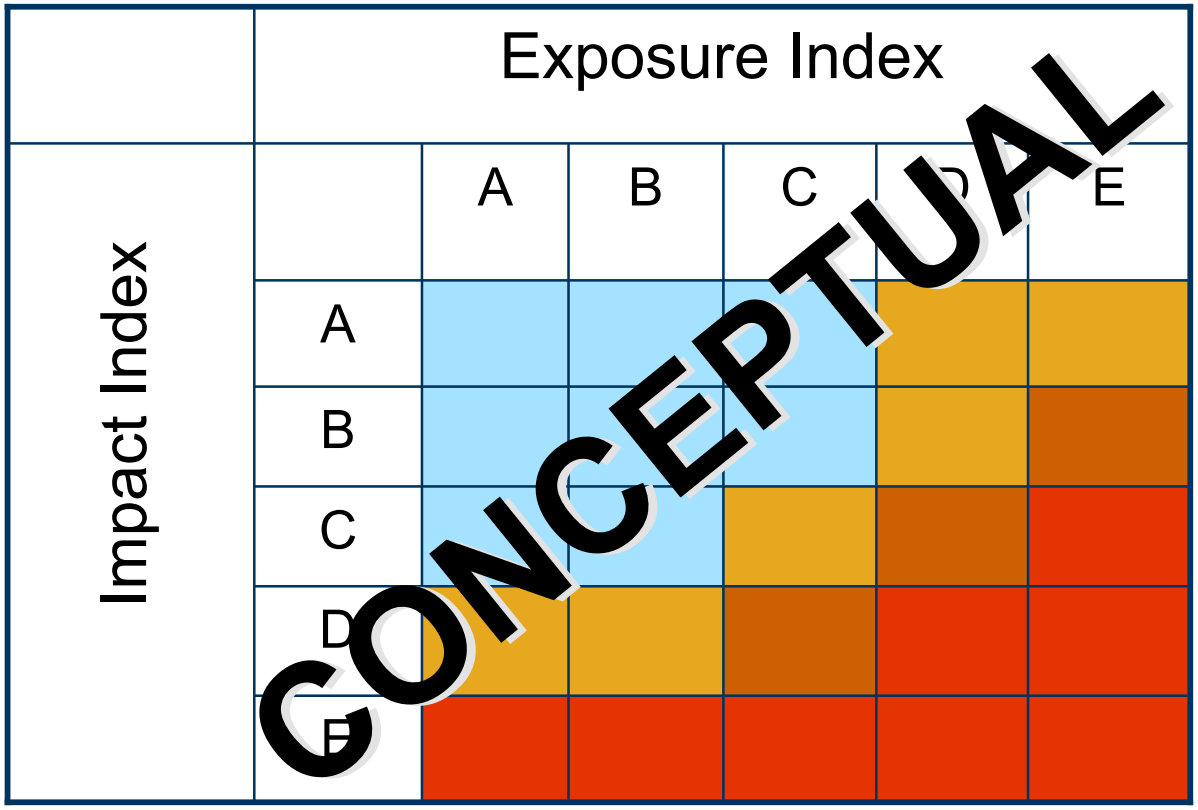
1. General Ventilation
2. Engineering Control
3. Containment
4. Specialist Advice

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

Exposure Management

Can Expert Control Banding be used?



Exposure Index

- 'Dustiness'
- Amount Used

Impact Index

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

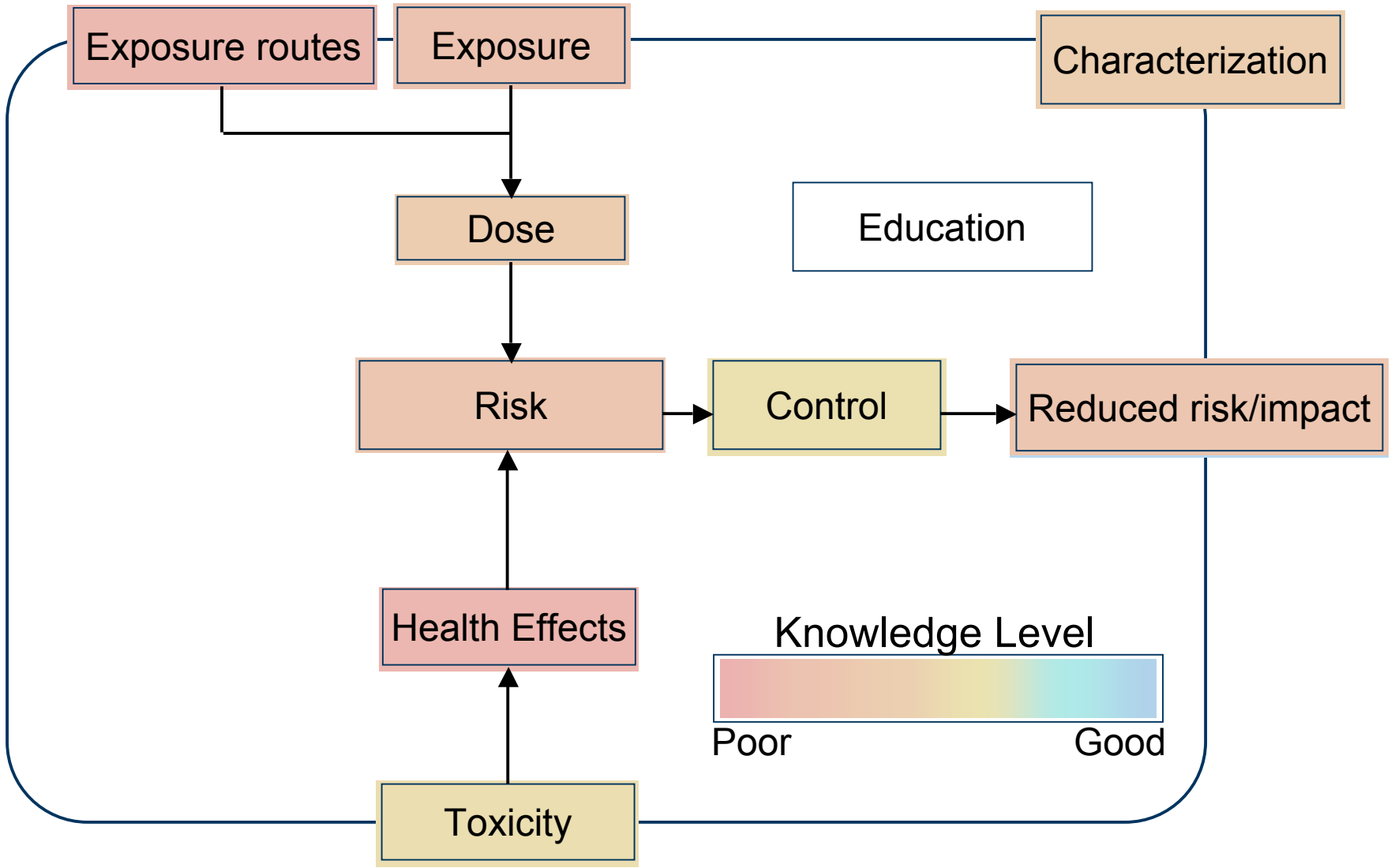
Control Approach

- General Ventilation
- Engineering Control
- Containment
- Specialist Advice

Responsible nanotechnology in the workplace

Research Gaps Analysis

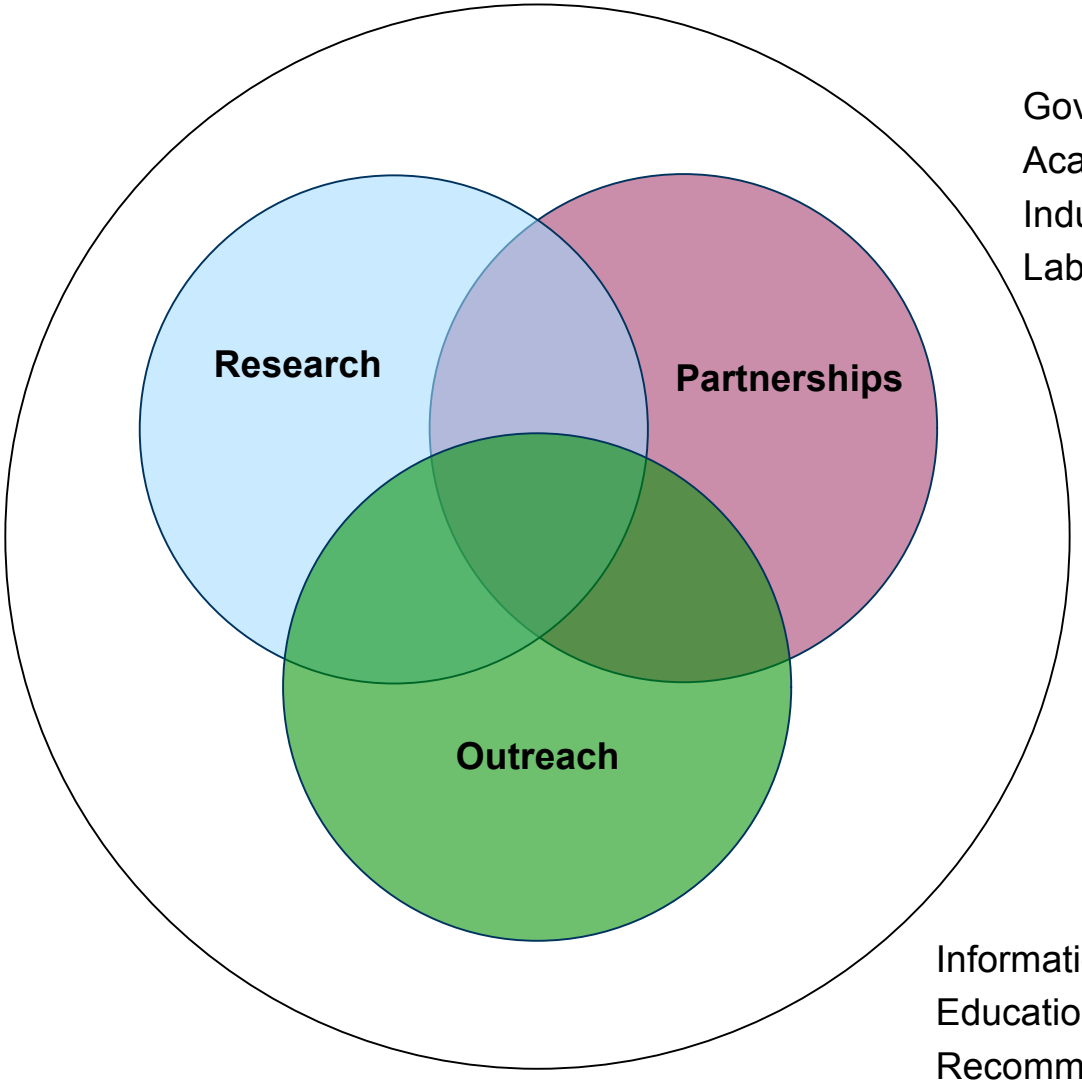
Qualitative



The NIOSH Nanotechnology Initiative

Addressing the implications and applications of nanotechnology in the workplace

Toxicity
Health Effects
Exposure
Measurement
Control
Surveillance
Risk Assessment
Risk Management



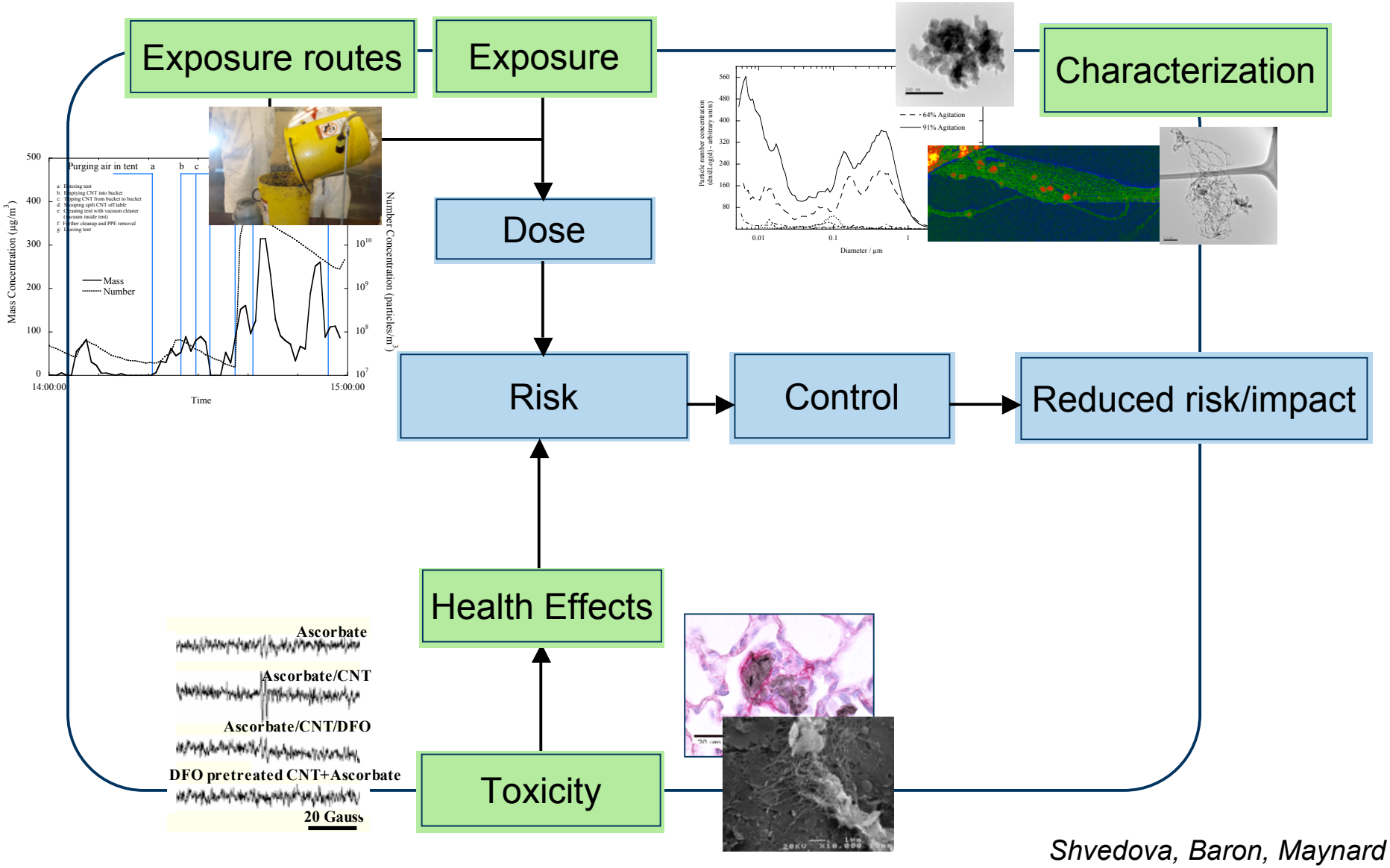
Government
Academia
Industry
Labor

Information
Education
Recommendations

NIOSH

Research (Example)

Working with Single Walled Carbon Nanotubes

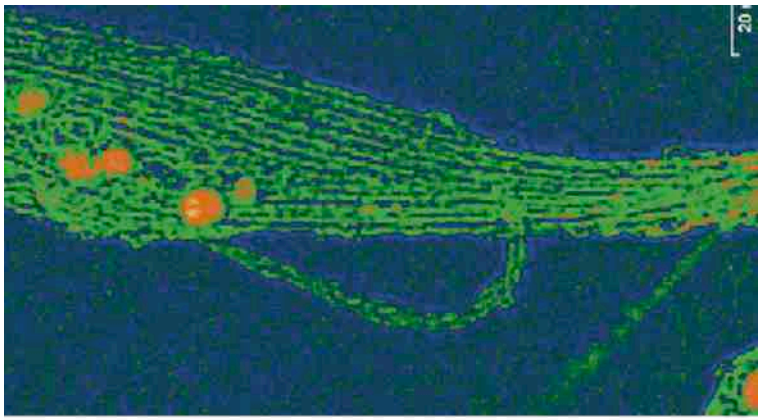


Shvedova, Baron, Maynard

NIOSH Resources

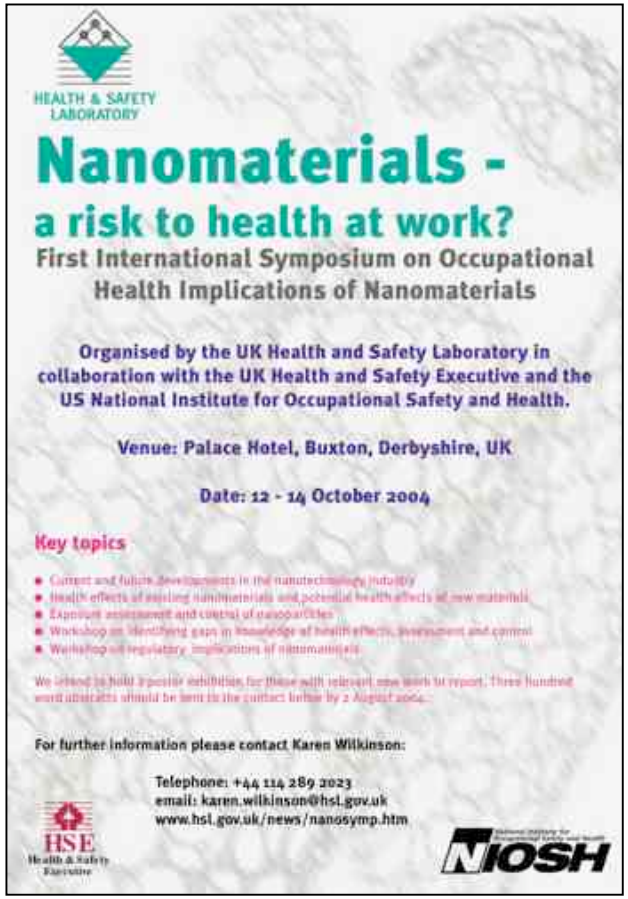
- **Nanotechnology topic page**
- **Strategies for working with engineered nanomaterials**
  - Raising awareness on nanotechnology and occupational health
    - Fact Sheet published Oct 2004
  - Addressing technical issues
    - Frequently Asked Questions on nanotechnology and occupational health
  - Making preliminary recommendations
    - Current Intelligence Bulletin (CIB) on Engineered nanomaterials. Anticipated 2005
  - Good working practices
    - Summary of the CIB. Anticipated 2005

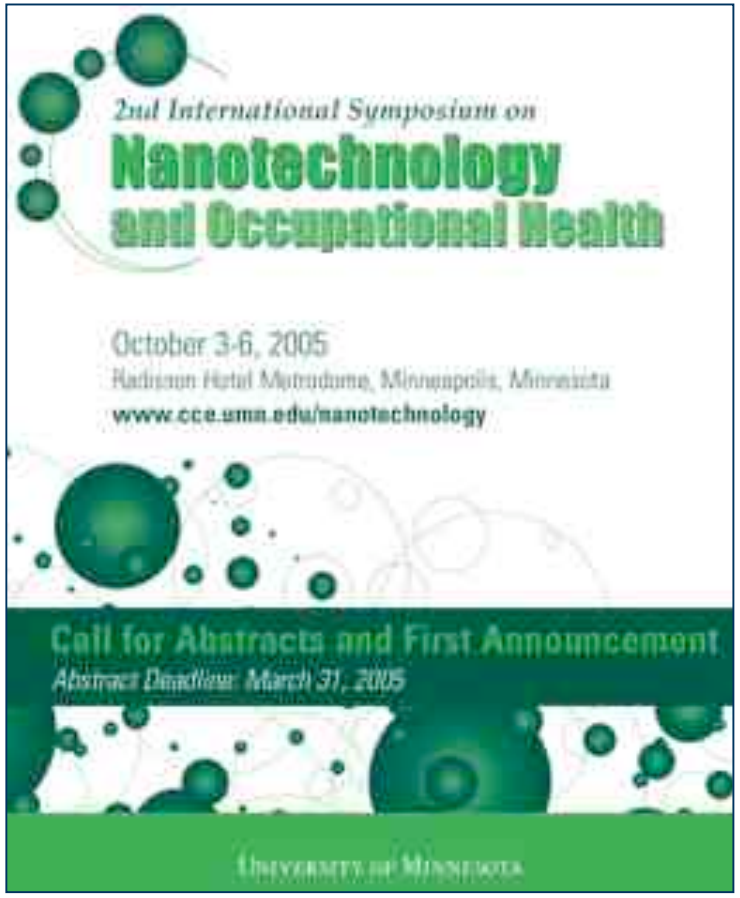
www.cdc.gov/niosh/topics/nanotech

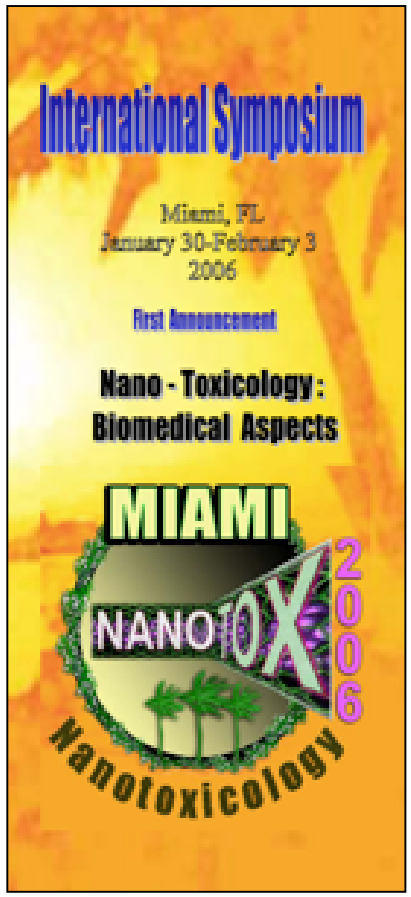


Nanotechnology & Occupational Safety and Health

Working in partnership







2004 (UK) **2005 (USA)** **2006 (USA)**

www.cdc.gov/niosh/topics/nanotech

Woodrow Wilson Center

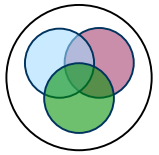
Project on Emerging Nanotechnologies

"[bringing] together leaders from industry, government, research, and other sectors to take a long-term view of what is known and unknown about potential health and environmental challenges posed by emerging nanotechnologies, and to develop recommendations to manage them."

Director:	David Rejeski
Deputy Director:	Julia Moore
Scientific Advisor:	Andrew Maynard

wwics.si.edu

Summary



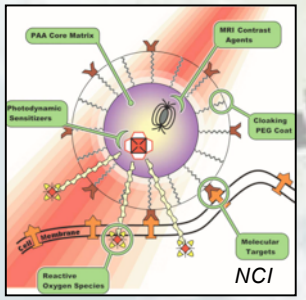
- Occupational safety and health is a key component of "responsible nanotechnology"
- Nanotechnology challenges conventional approaches to addressing occupational safety and health risk
- "Nano is ***now***"
- The number of workers potentially exposed to engineered nanomaterials will dramatically increase over the next decade
- The challenge: developing information and governance/oversight models that proactively address potential risk

Looking to the Future

Moving beyond the health impact of ‘simple’ nanomaterials

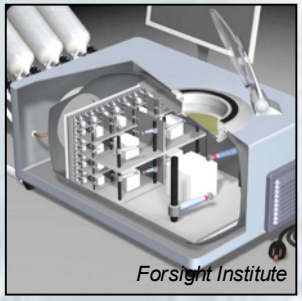
Safety

“Unconventional” and unanticipated behavior



Complex nanoparticles and nano-devices

Moving beyond simple response mechanisms



Convergence

Revolutionary health & safety challenges

Conceptual Space Elevator, Liftport Group