

Nanotechnology and Occupational Health

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Concern over the Potential Impact of Nanotechnology



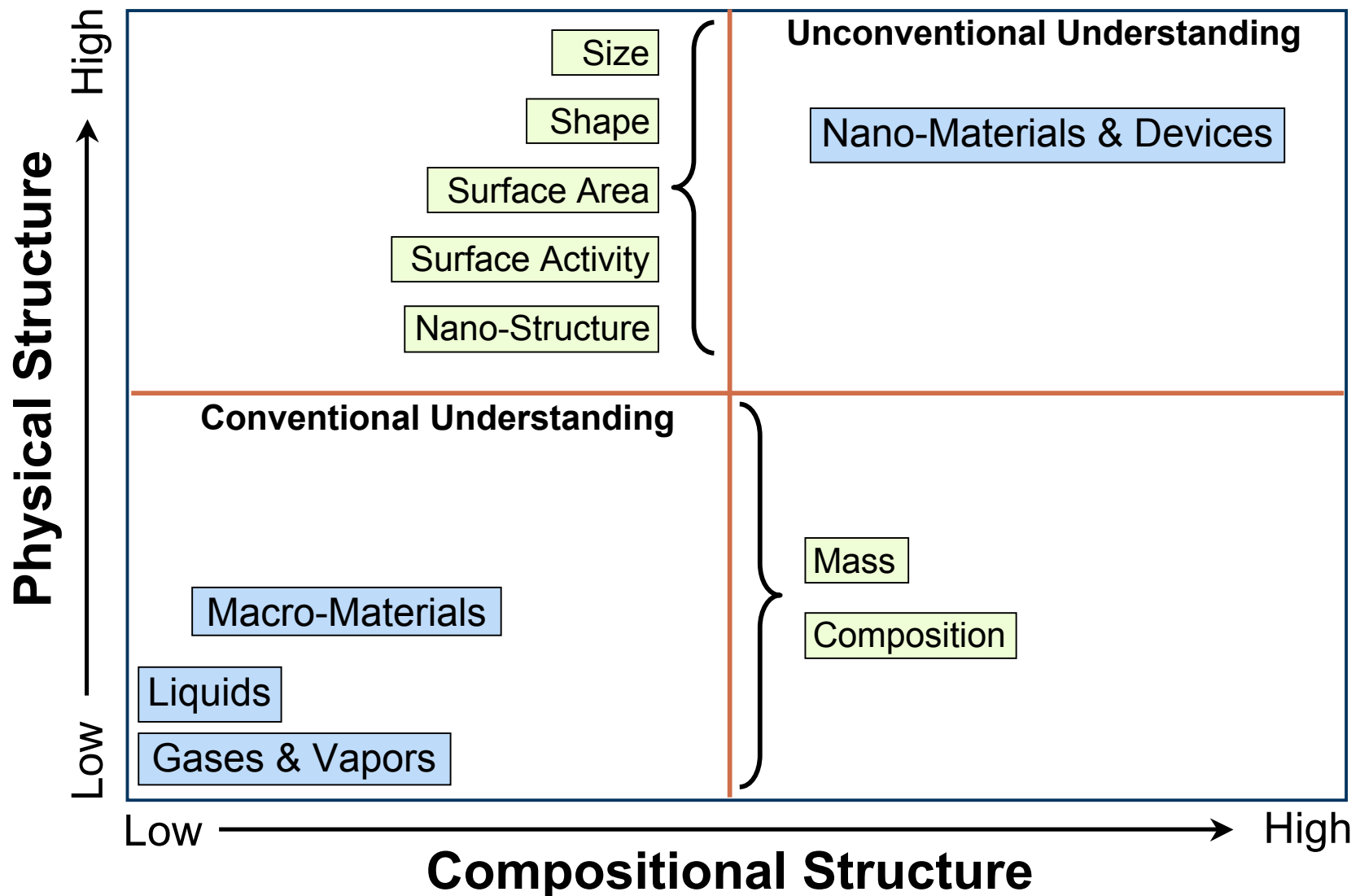
Environmental Health Perspectives 2004

Royal Society 2004

Potential Health Impact

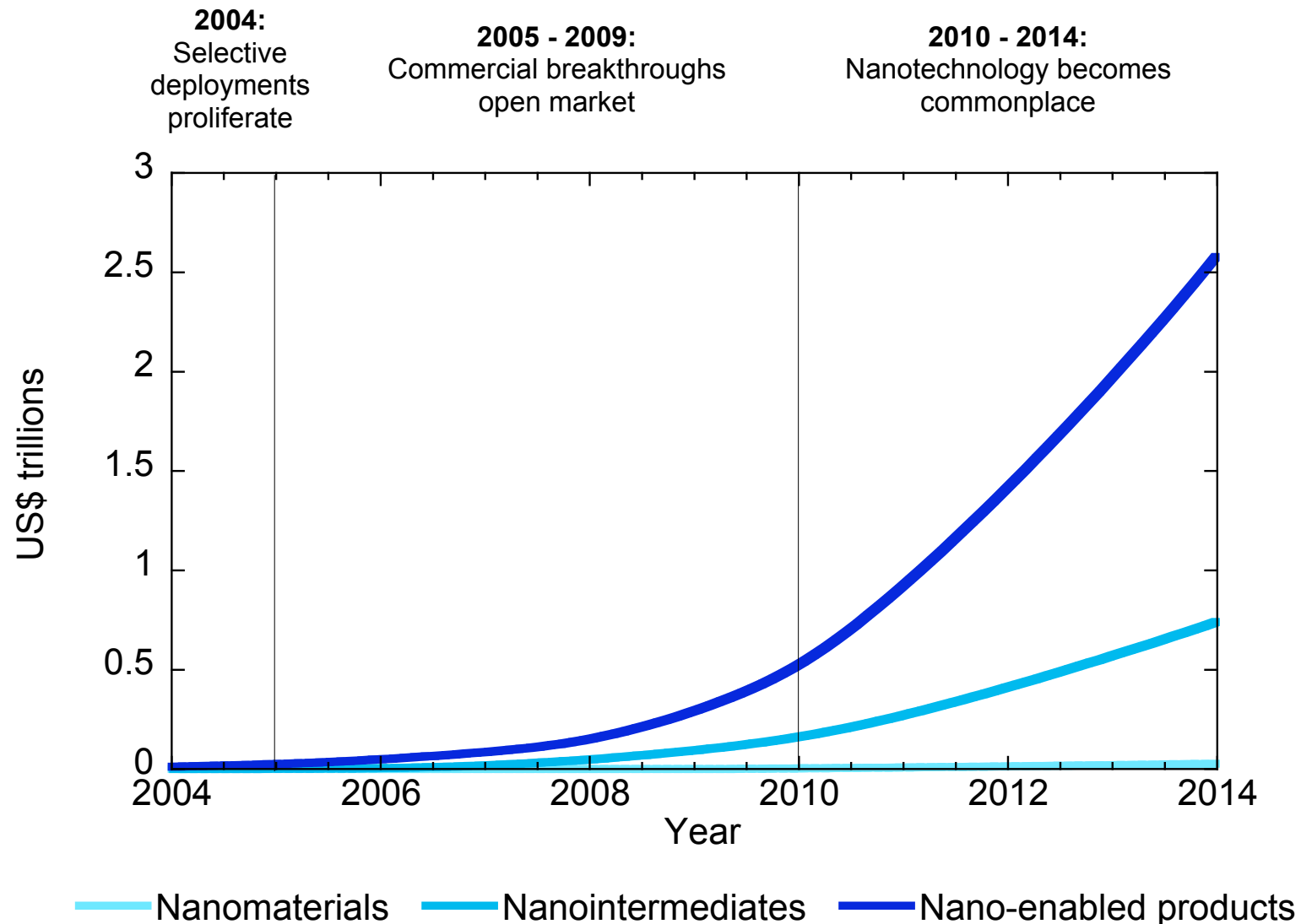
What makes 'nano' different?

Influence of structure on potential health impact



Nanotechnology

Global forecast of products sold incorporating nanotechnology



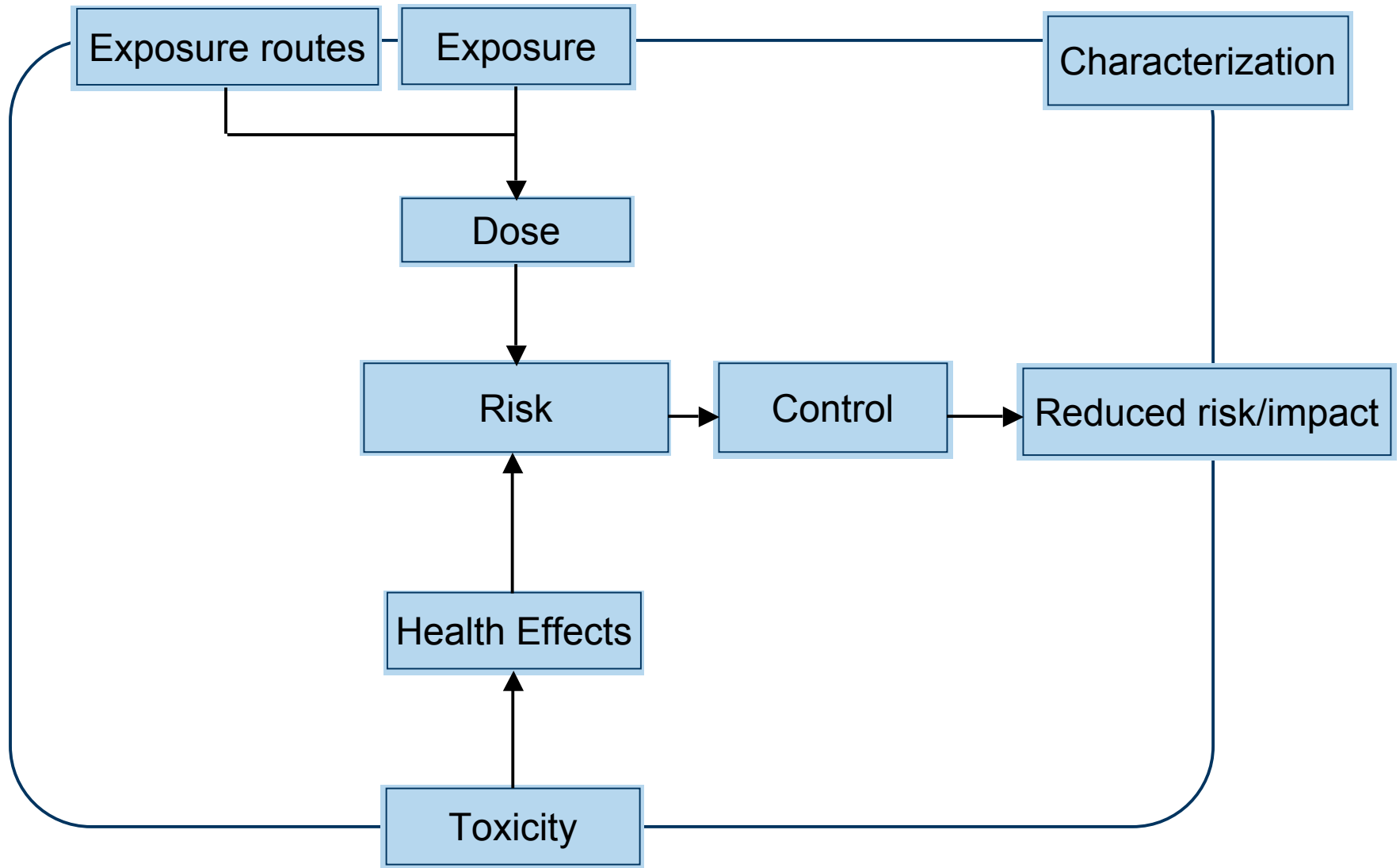
Source: 2004 Lux Research Report: "Sizing nanotechnology's value chain"

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

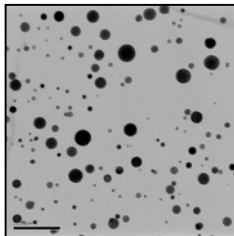


Setting Boundaries

Engineered nanomaterials which potentially present new challenges

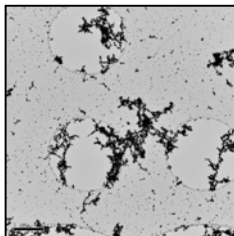
- **Criteria:**

- 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



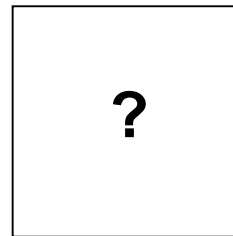
Comminution

Aerosols from grinding,
cutting, machining
nanomaterials



Degradation/Failure

Aerosols and suspensions
resulting from degradation
and failure of nanomaterials



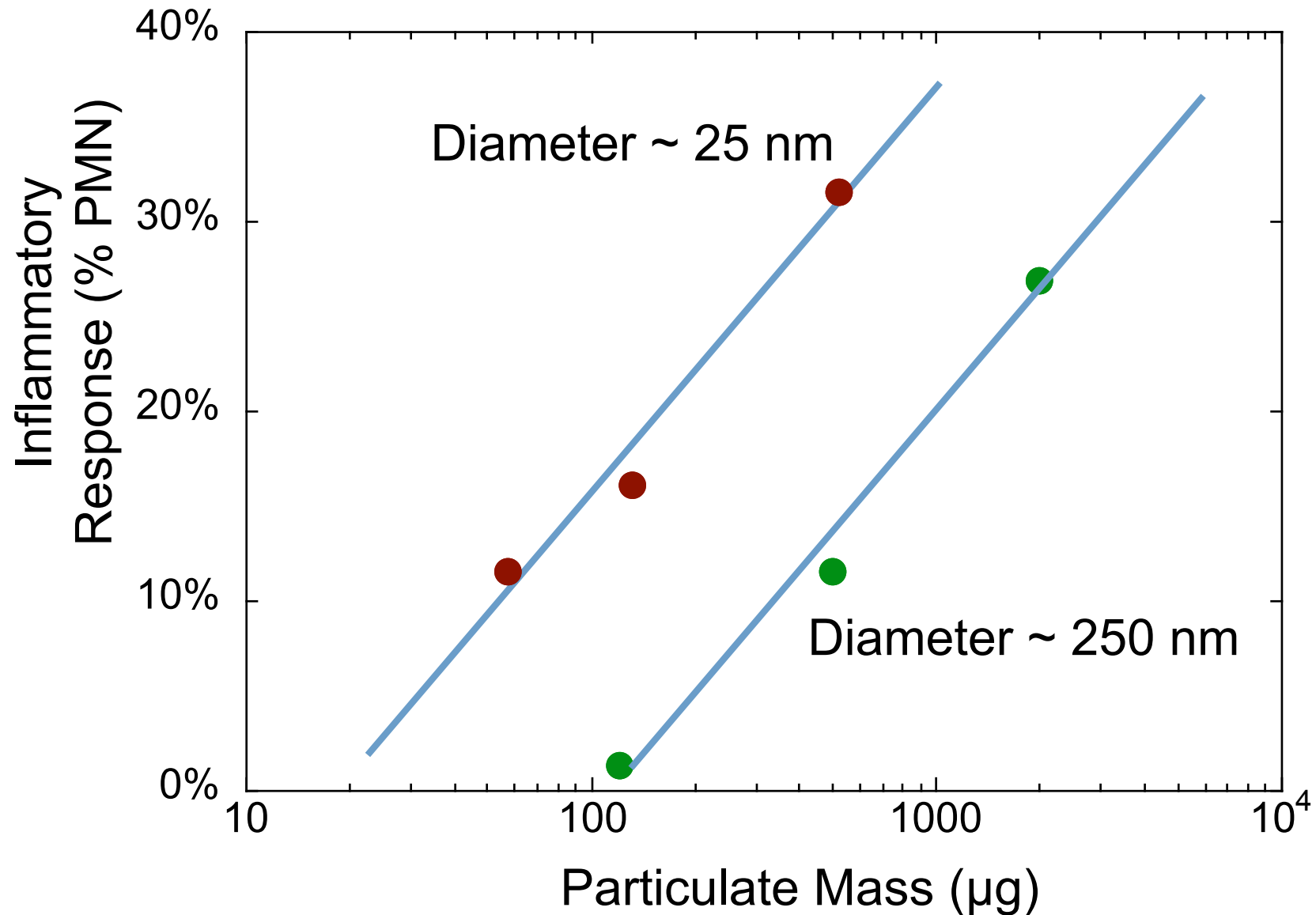
Unintentional use

Potential exposure from
unanticipated/unintentional
use

Hazard

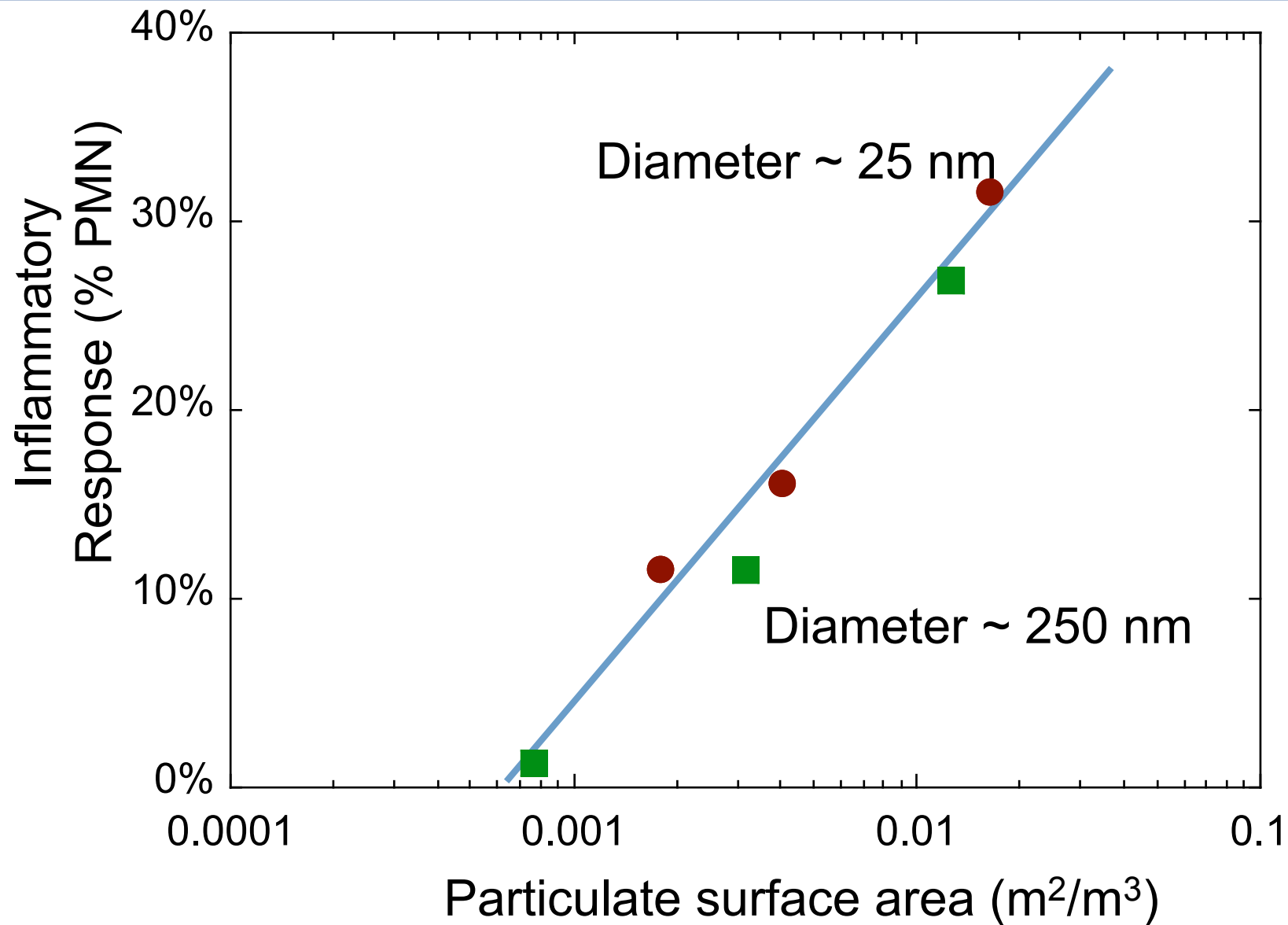
TiO₂ Instillation in Rats

Oberdörster et al. (2000)



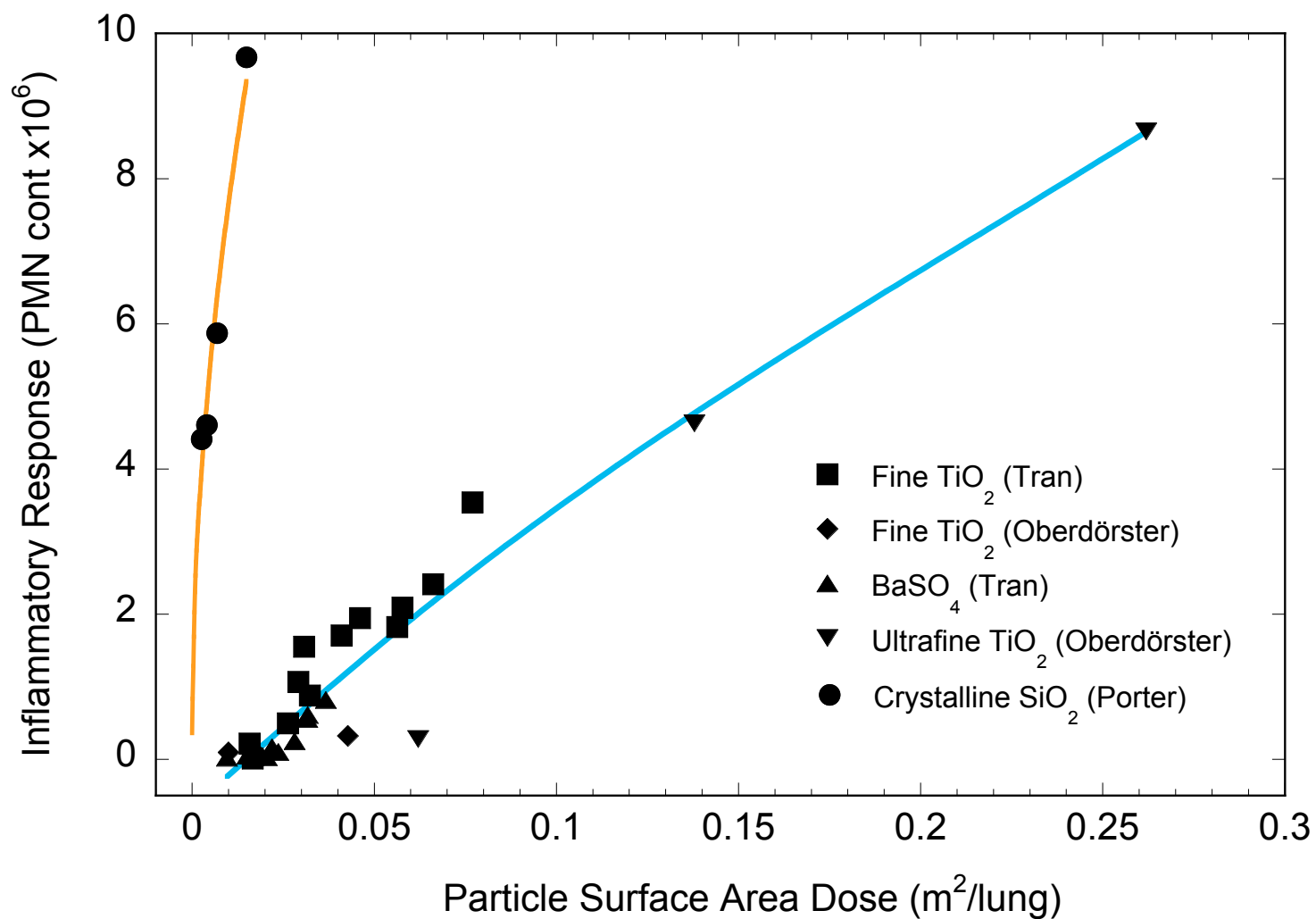
TiO₂ Instillation in Rats

Oberdörster et al. (2000)



Importance of Surface Chemistry

Comparison of insoluble materials with different biological activities

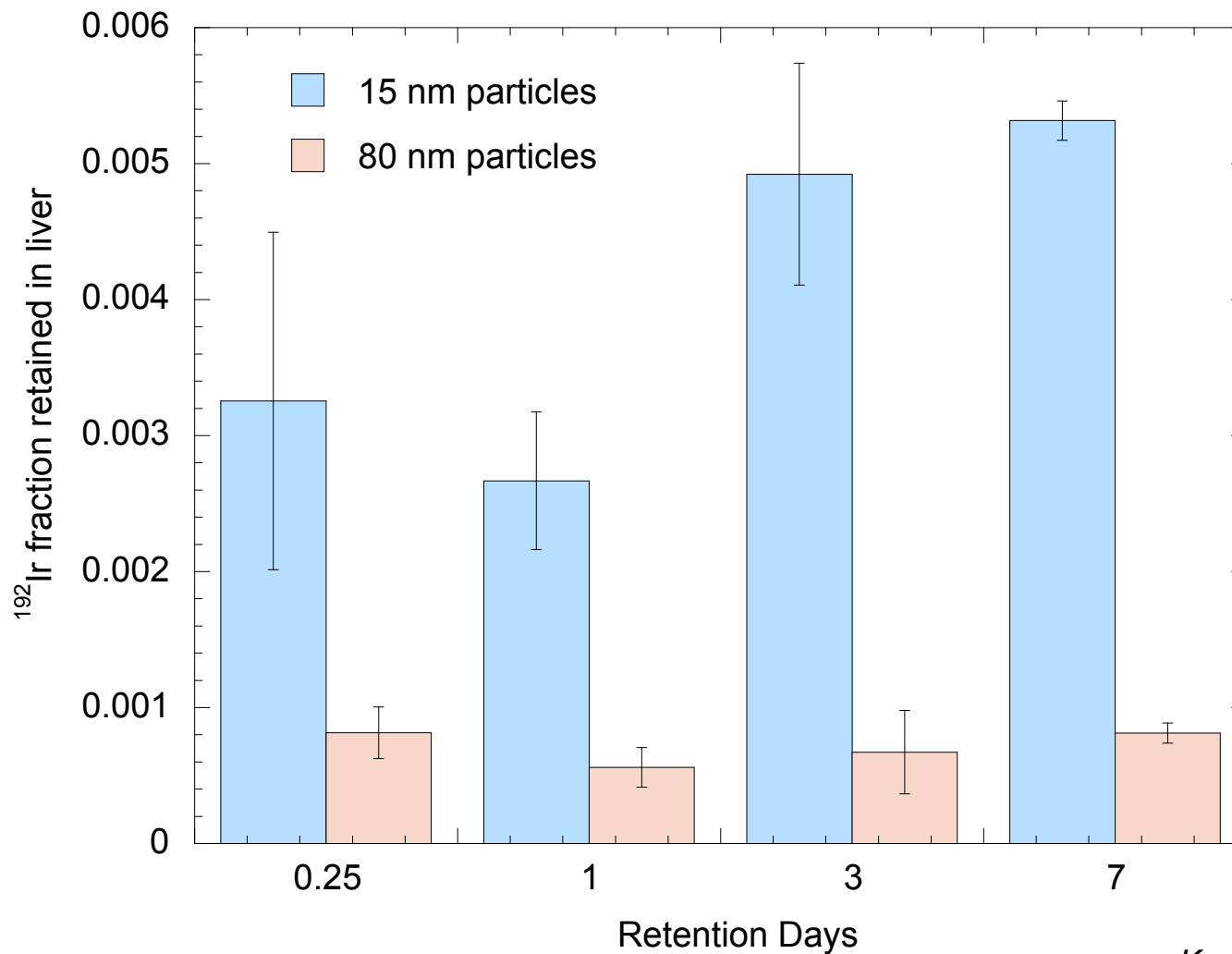


After Kuempel, in Maynard and Kuempel (2005)

Translocation Following Inhalation

Lungs to Liver

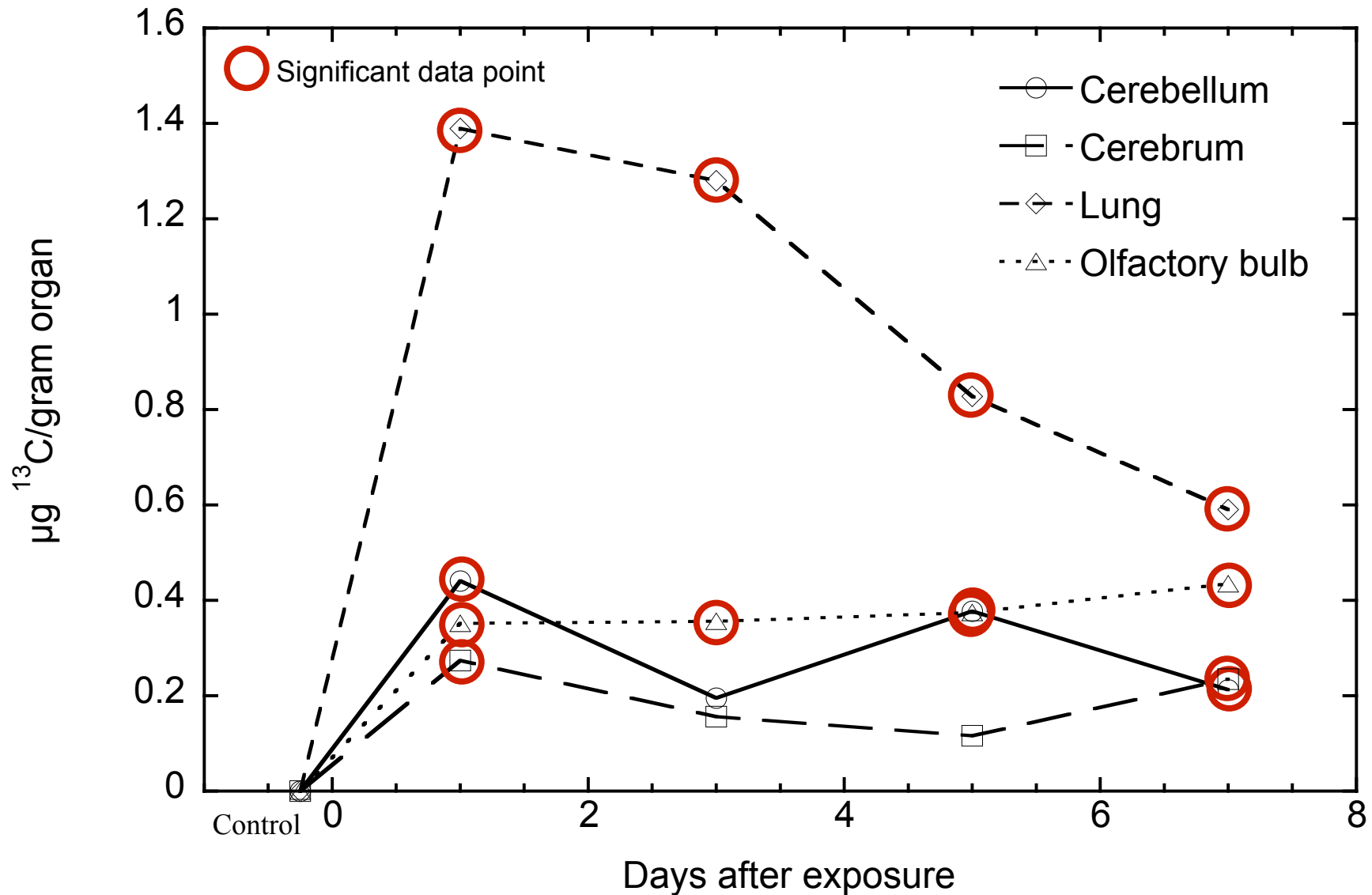
Fraction of inhaled insoluble ^{192}Ir translocating to liver in rats



Kreyling et al. (2002)

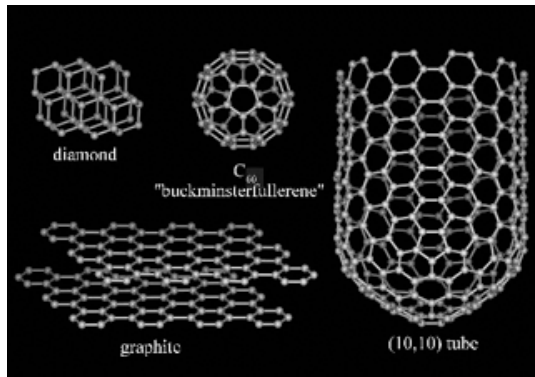
Translocation Following Inhalation

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



Particle Shape?

Single Walled Carbon Nanotubes



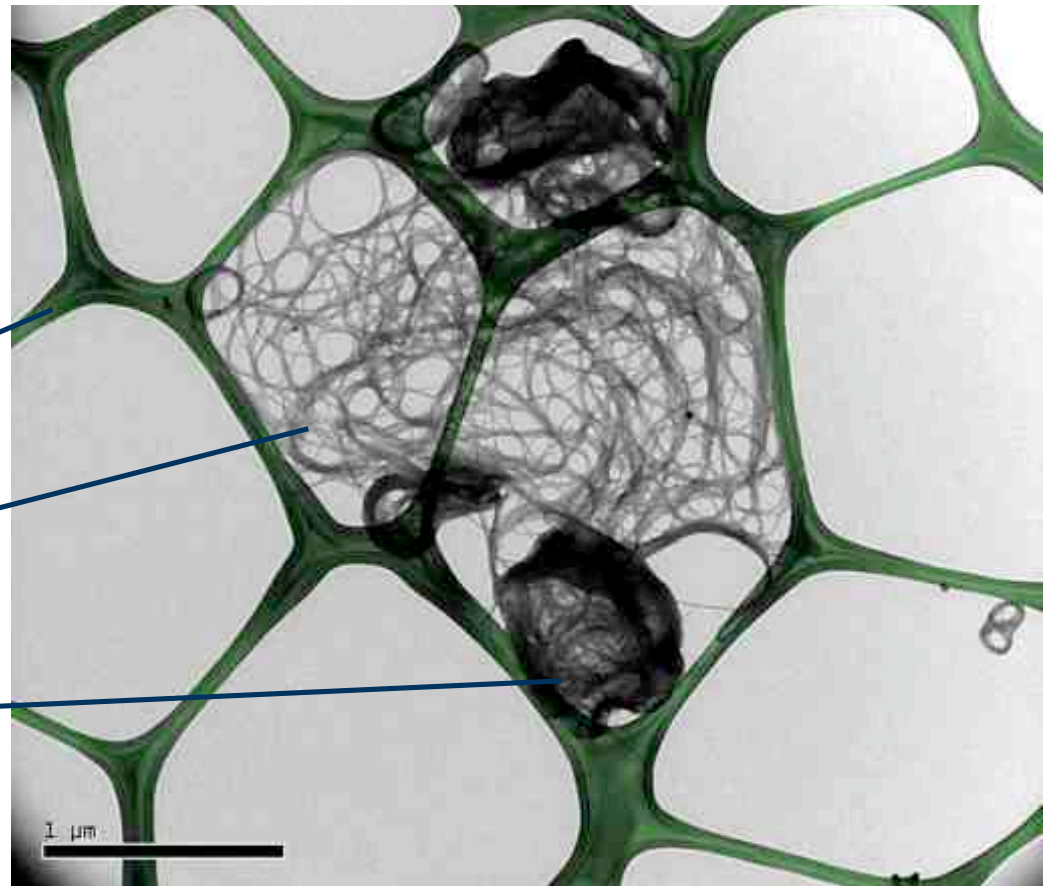
Allotropes of carbon

Carbon support film

Open structured particles

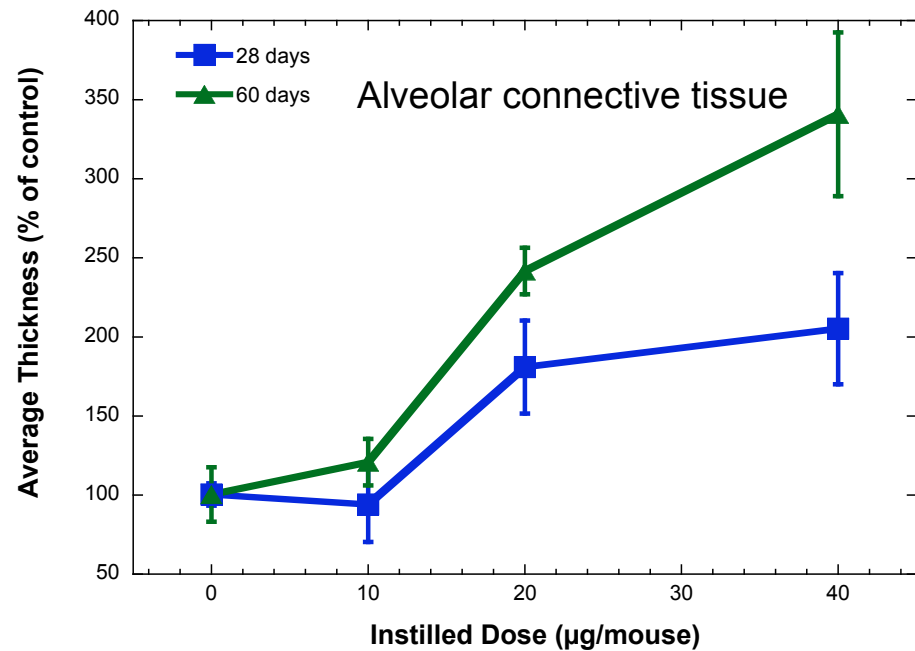
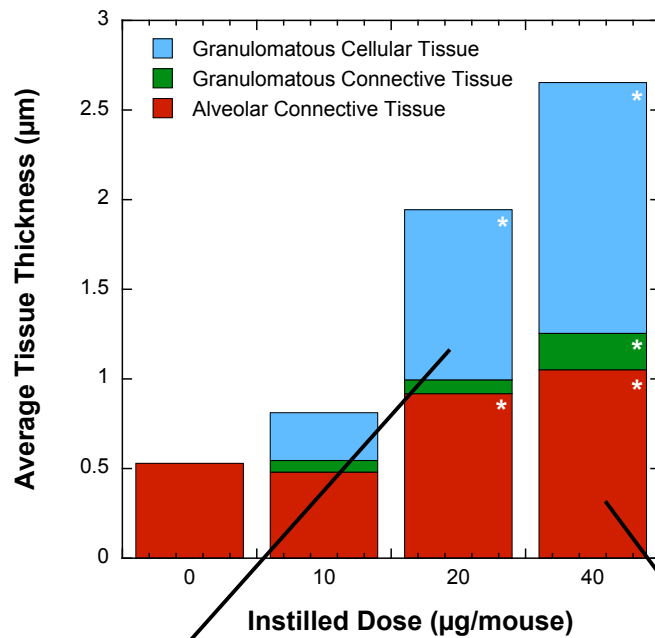
Closed structured particles

Transmission Electron Microscope image of purified single walled carbon nanotube particles

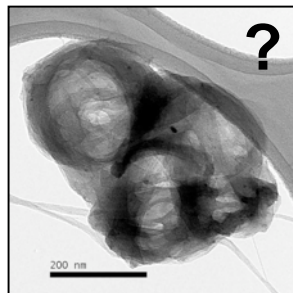


Pulmonary Response to Single Walled Carbon Nanotubes

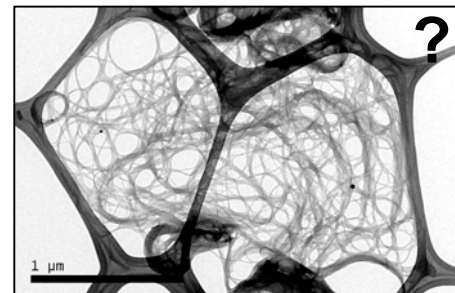
Pharyngeal aspiration in mice



Histopathology:
Proximal region of lung
Visible SWCNT clumps



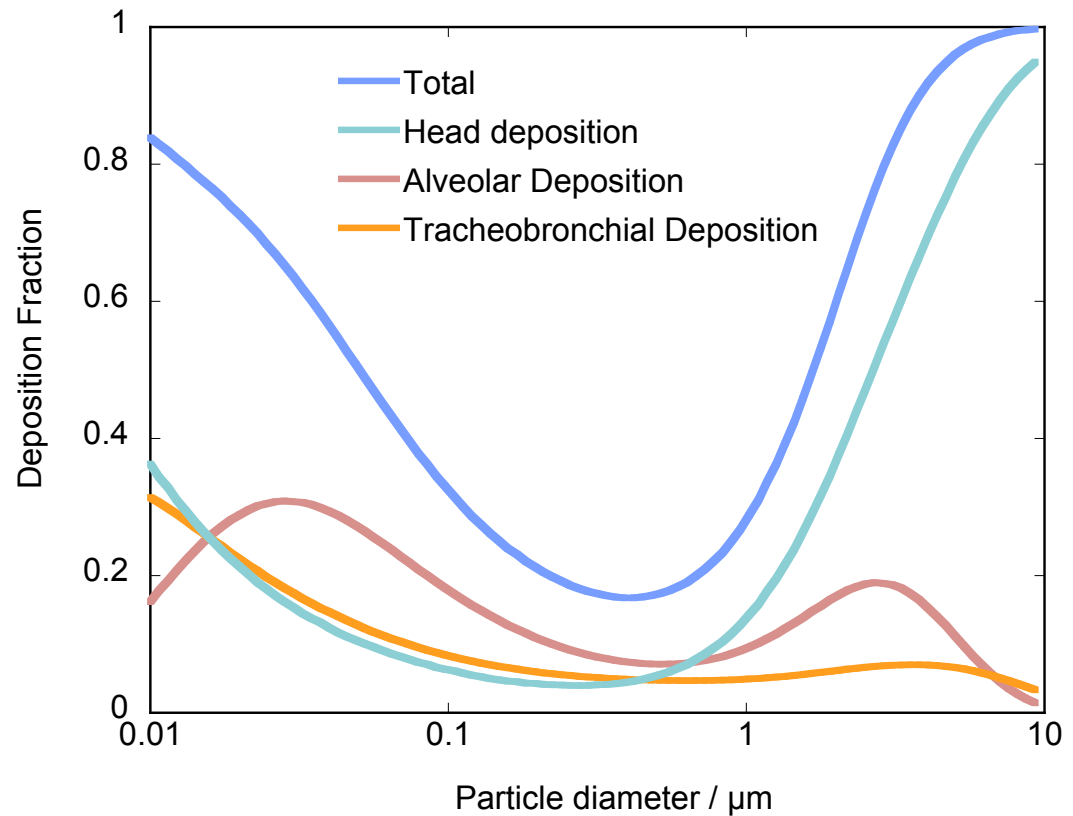
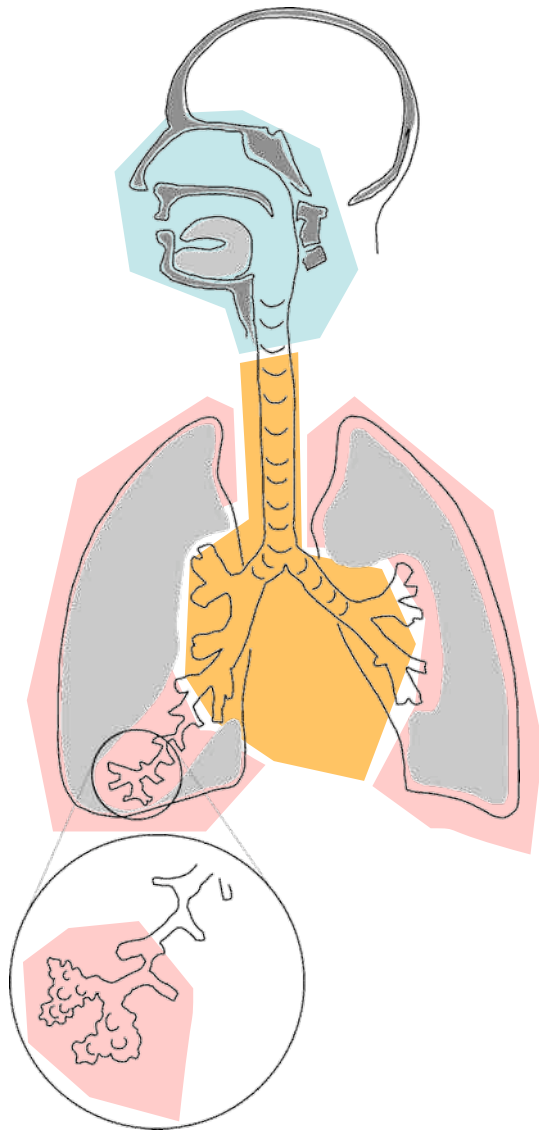
Histopathology:
Distal region of lung
No SWCNT visible



Shvedova *et al.* (2005) *In Press*

Exposure

Particle Deposition in the Lungs

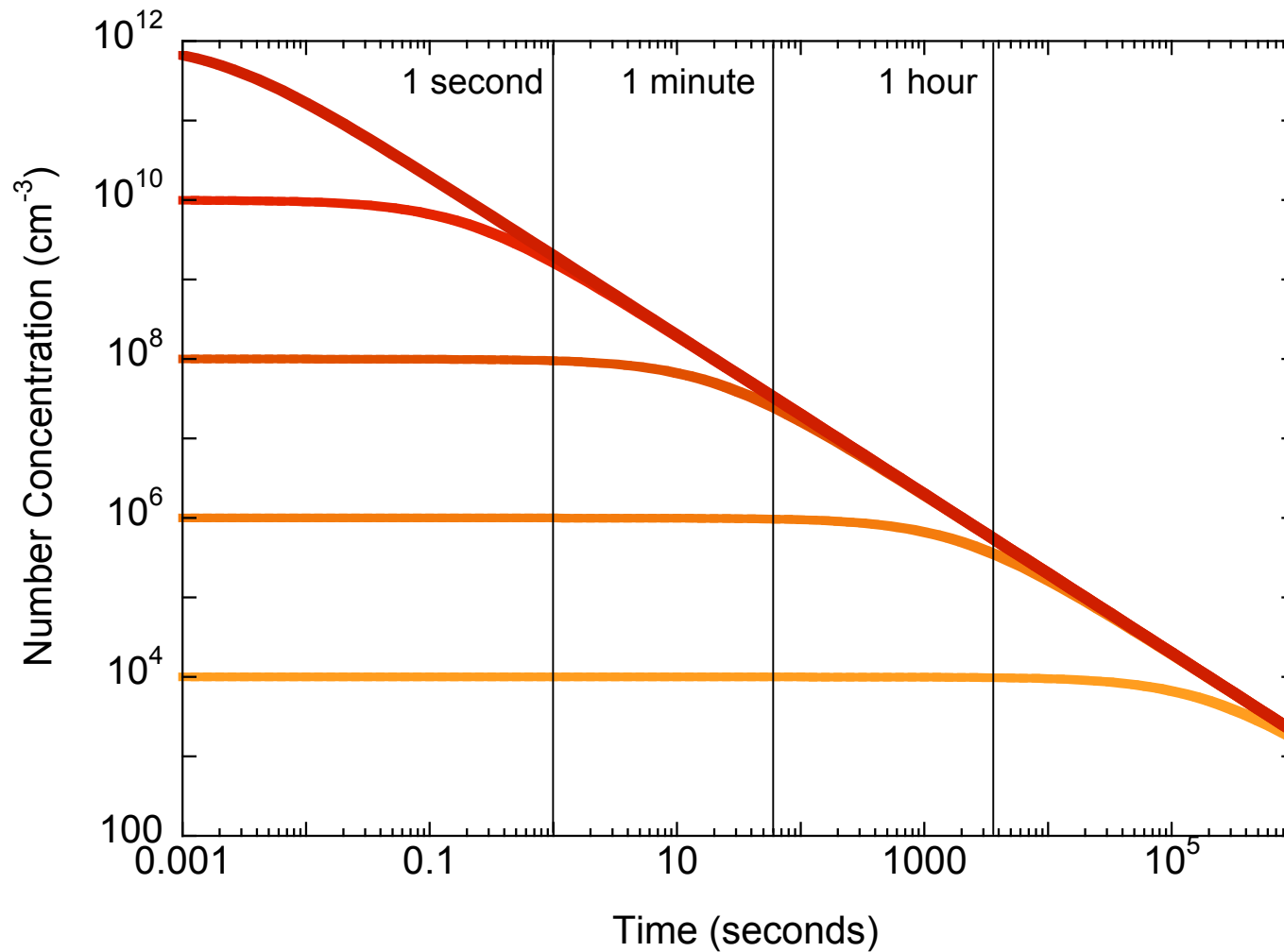


Modeled lung deposition. Mouth and nose breathing, person at rest.

Source: Multiple Pathway Deposition Model (MDEP), CIIT

Airborne nanomaterials transformation

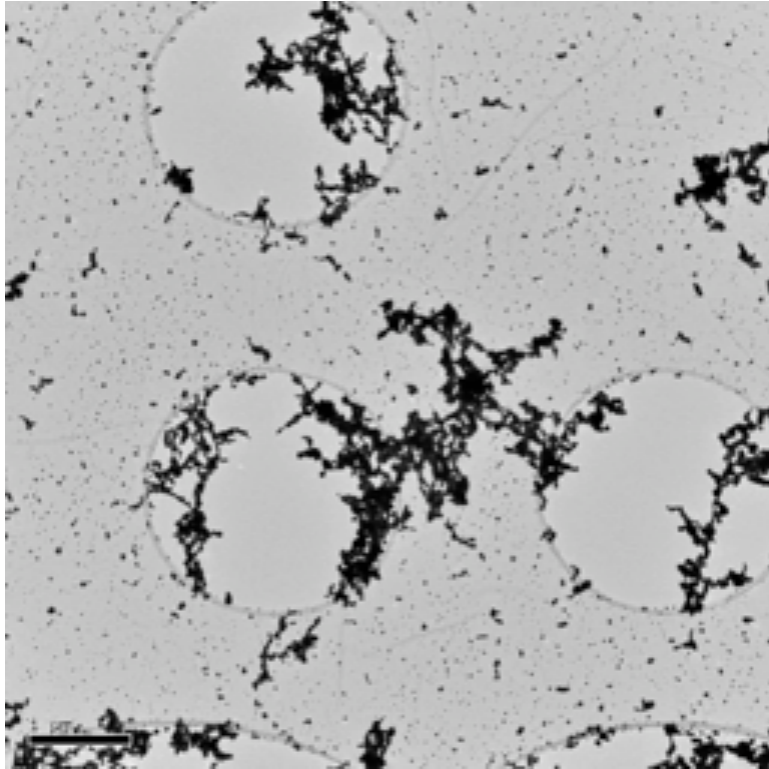
Monodisperse coagulation



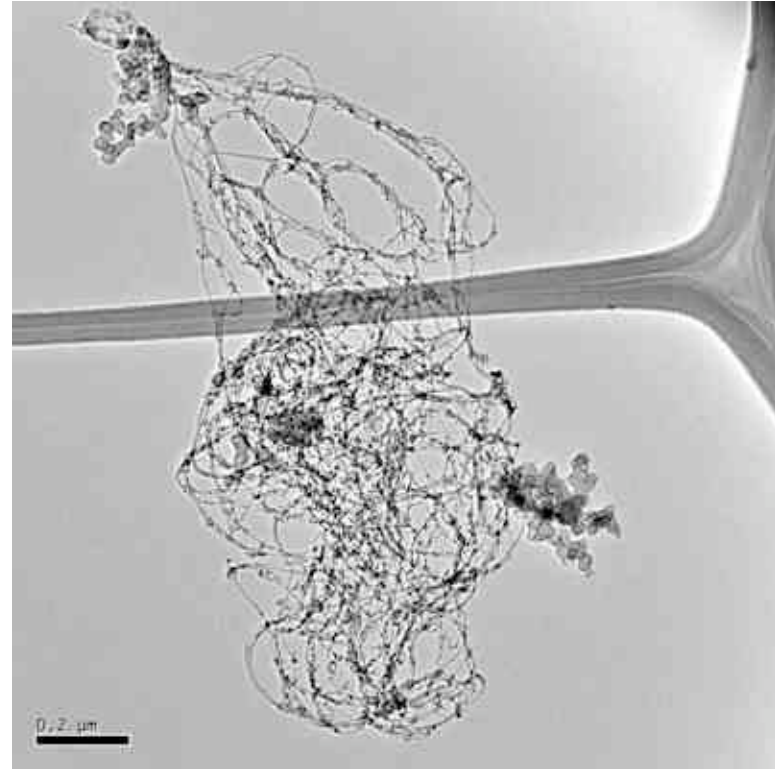
Adapted from Hinds (1999)

Agglomeration

How does it affect particle biological activity?



Agglomerated silver particles



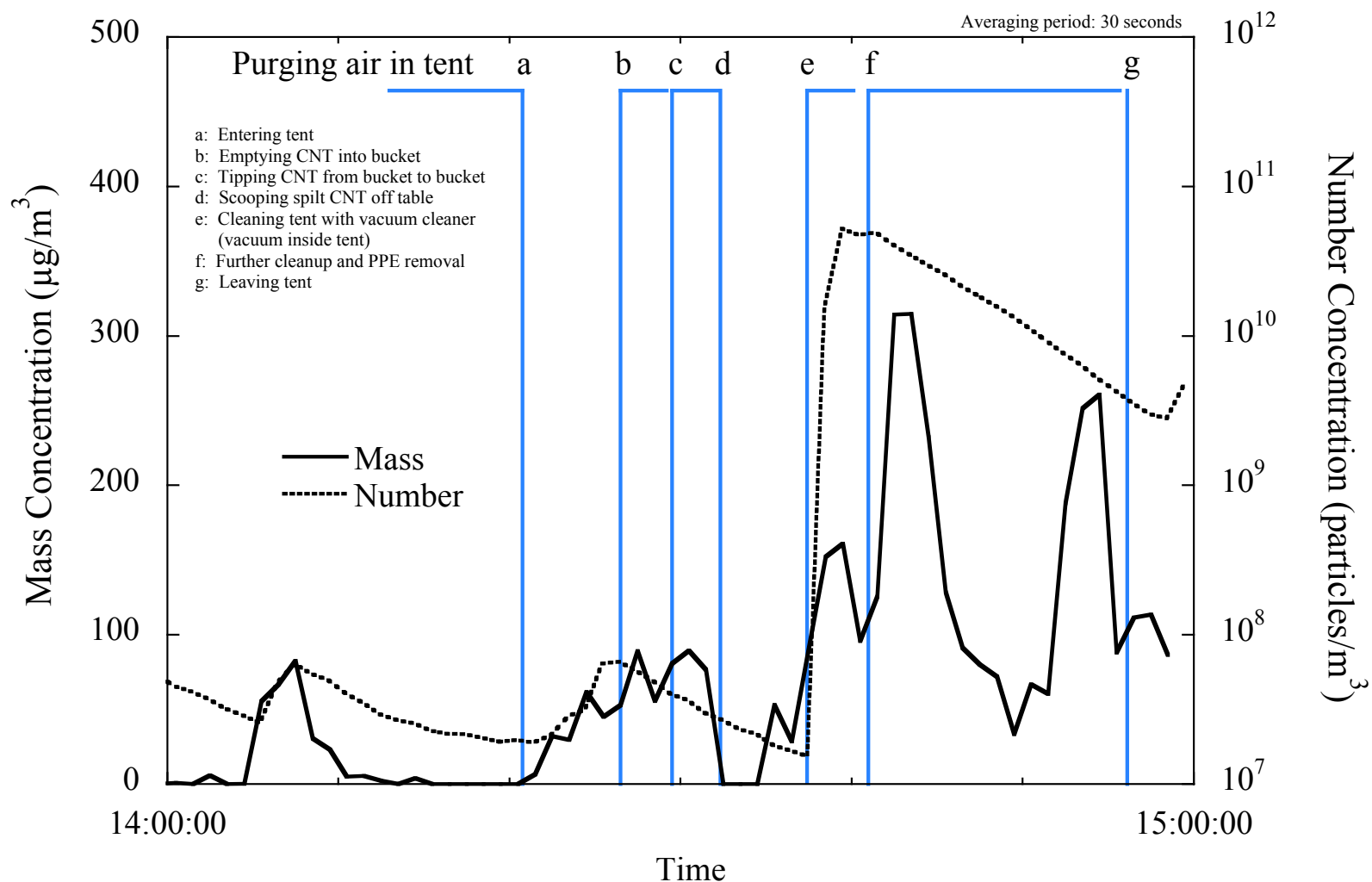
“Agglomerated” single walled carbon nanotubes

Handling nanotube material



Raw single walled nanotube material

Aerosol release in the field

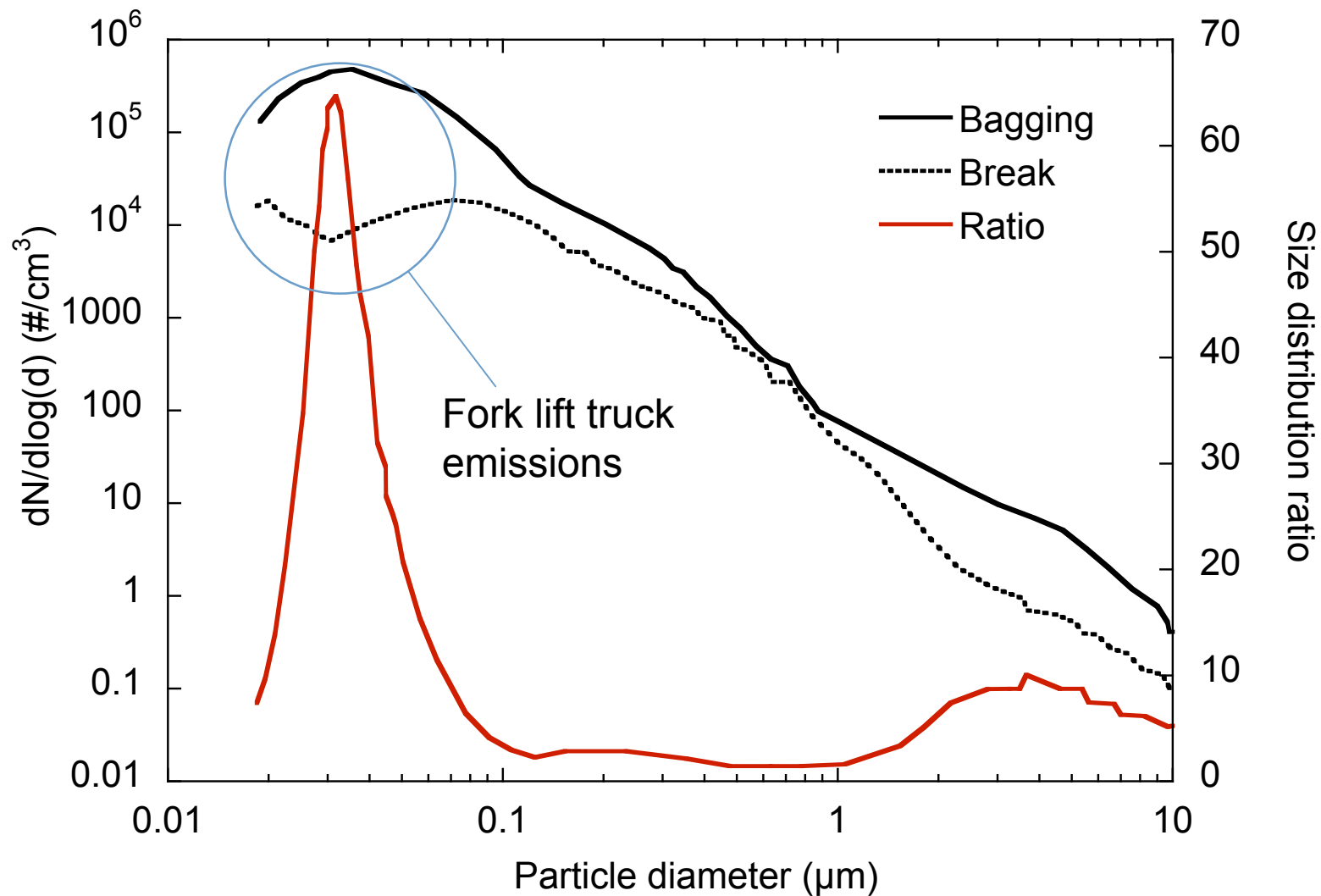


Monitoring aerosol number and mass concentration while handling raw material

Estimated airborne concentrations: $0.7 - 52.7 \mu\text{g}/\text{m}^3$

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

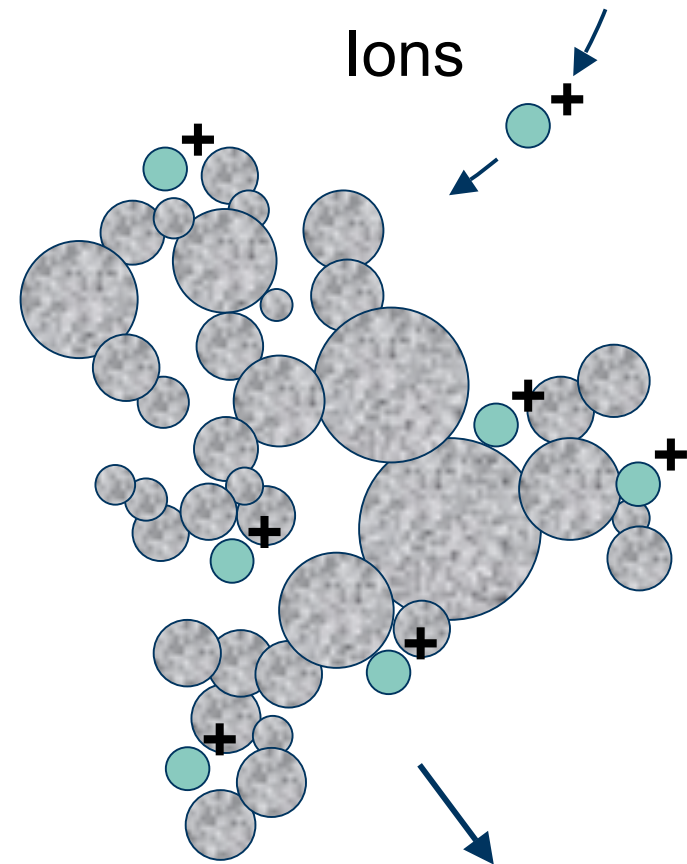
Using attachment rate

Charge on Aerosol \propto Surface Area



DC2000 CE Diffusion Charger

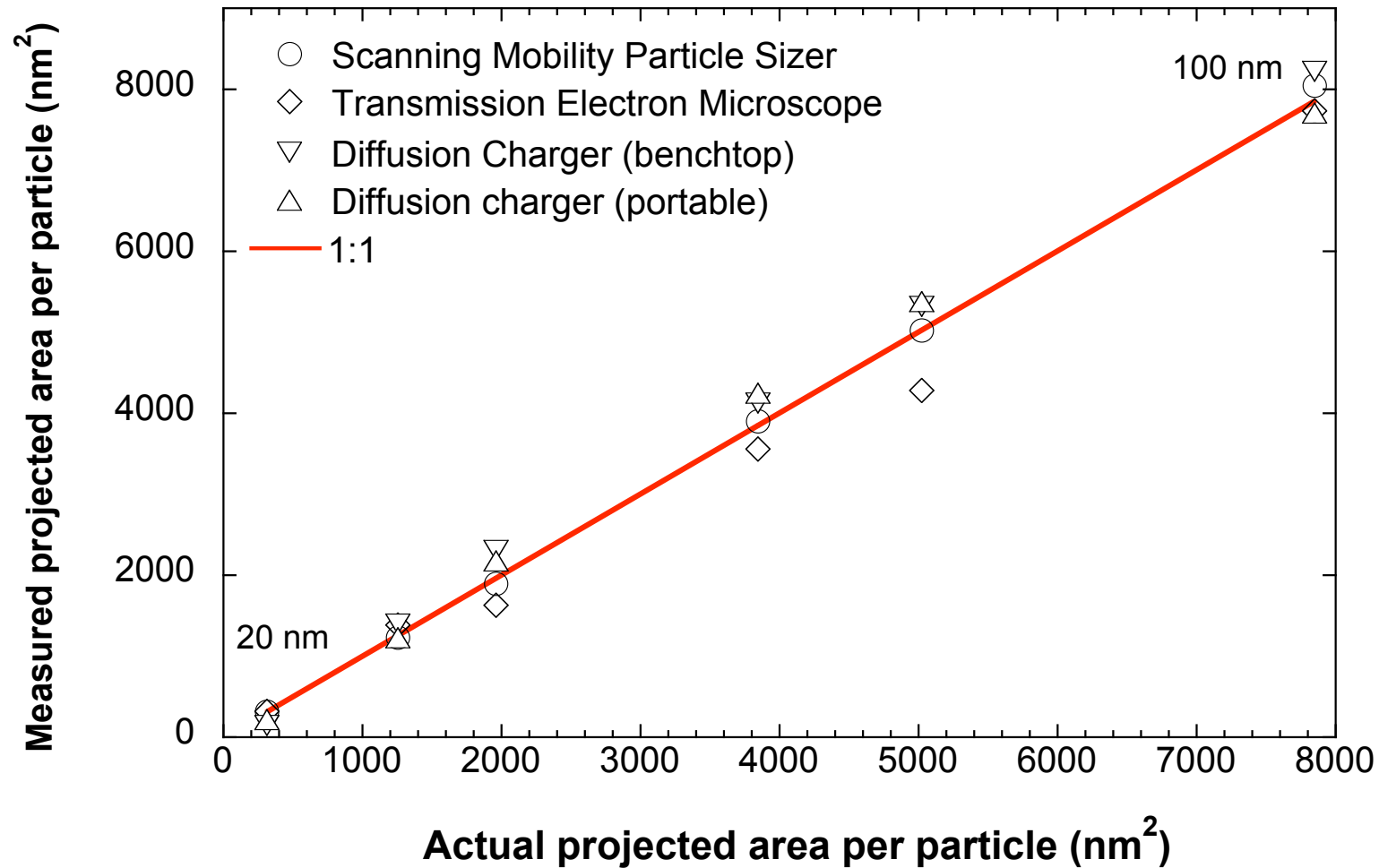
EcoChem



Electrometer

Comparison of Surface-Area Measurement Methods

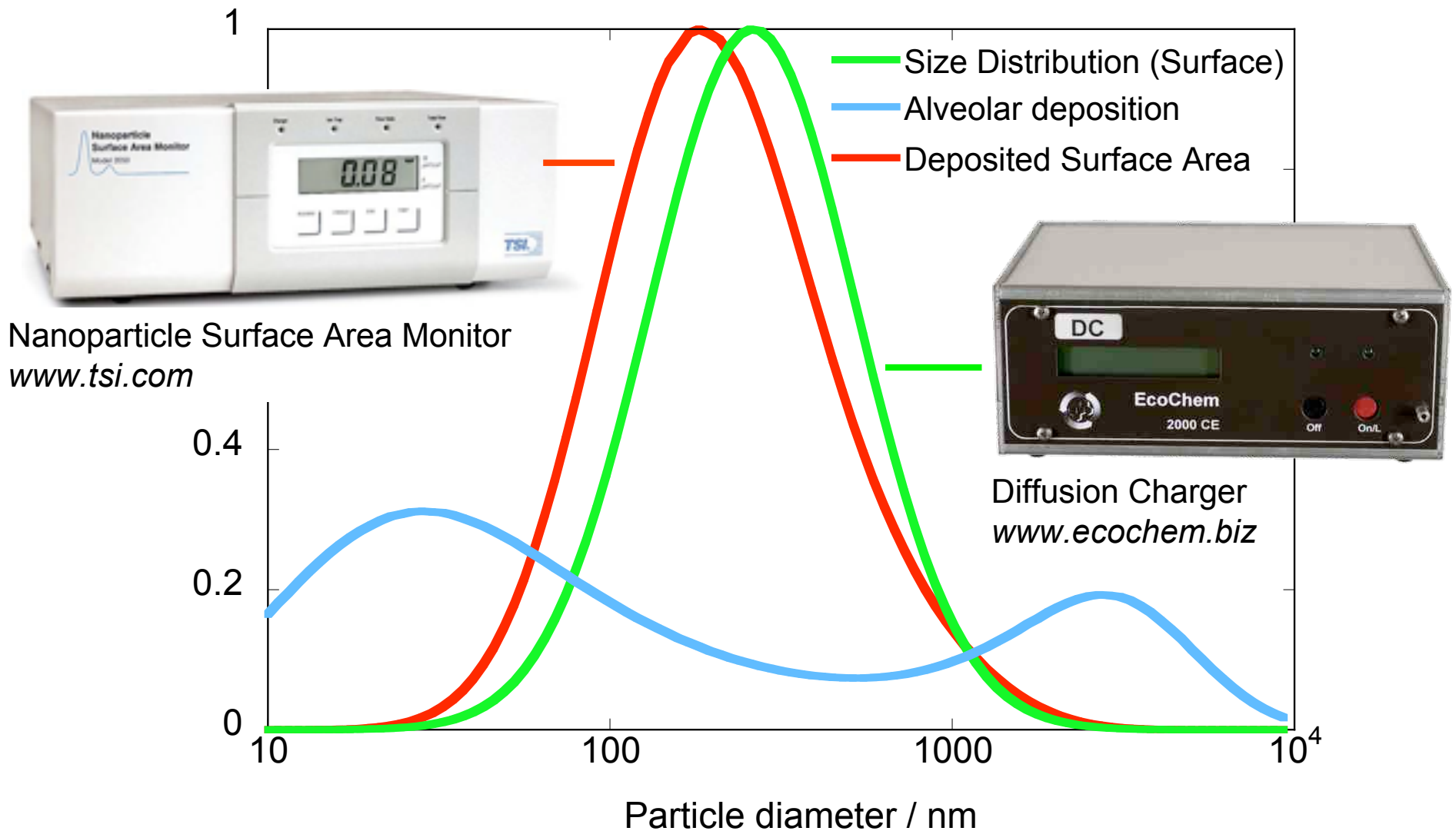
Monodisperse particles < 100 nm, fractal-like



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

Emerging Measurement Technologies

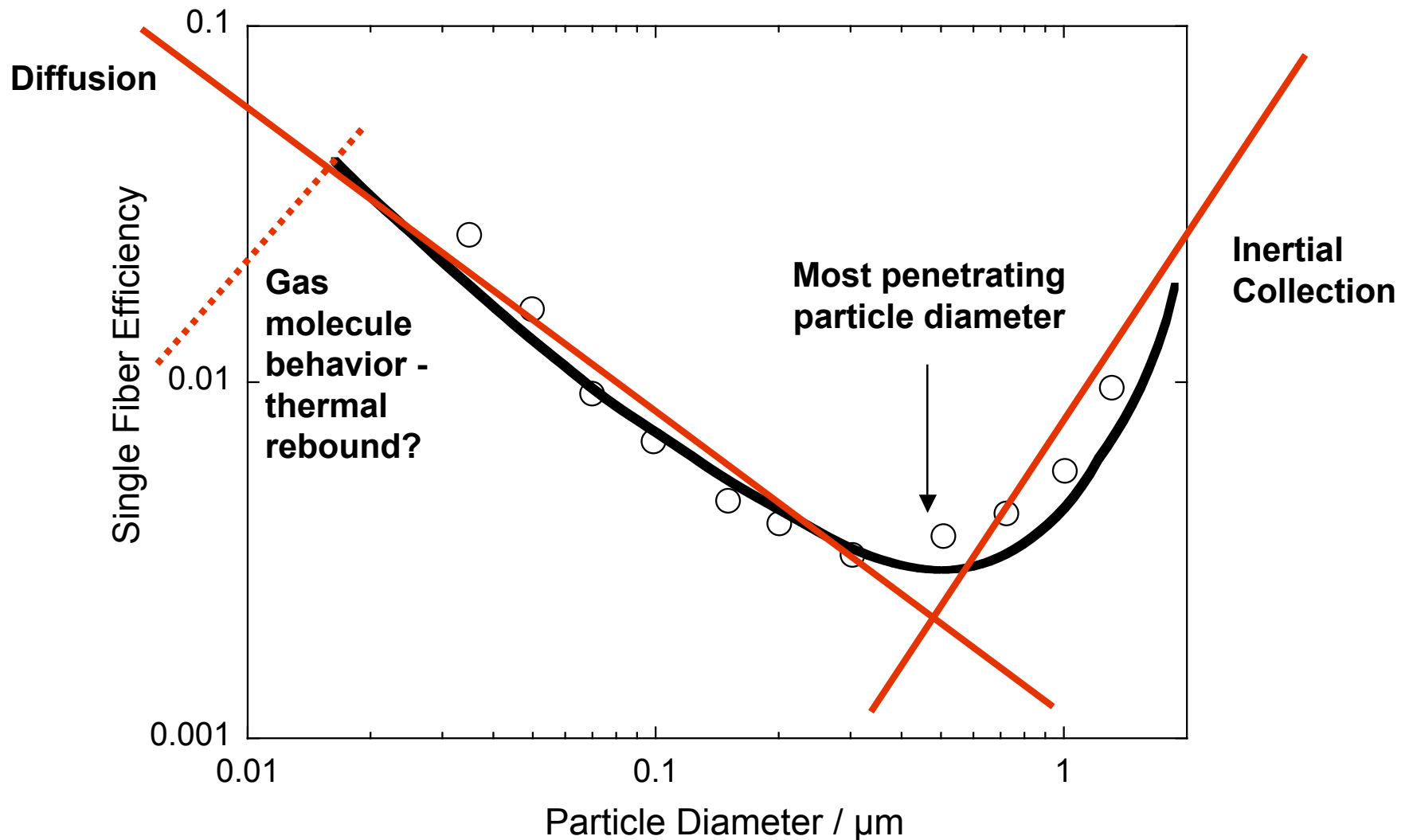
Surface Area



Control

Exposure Control

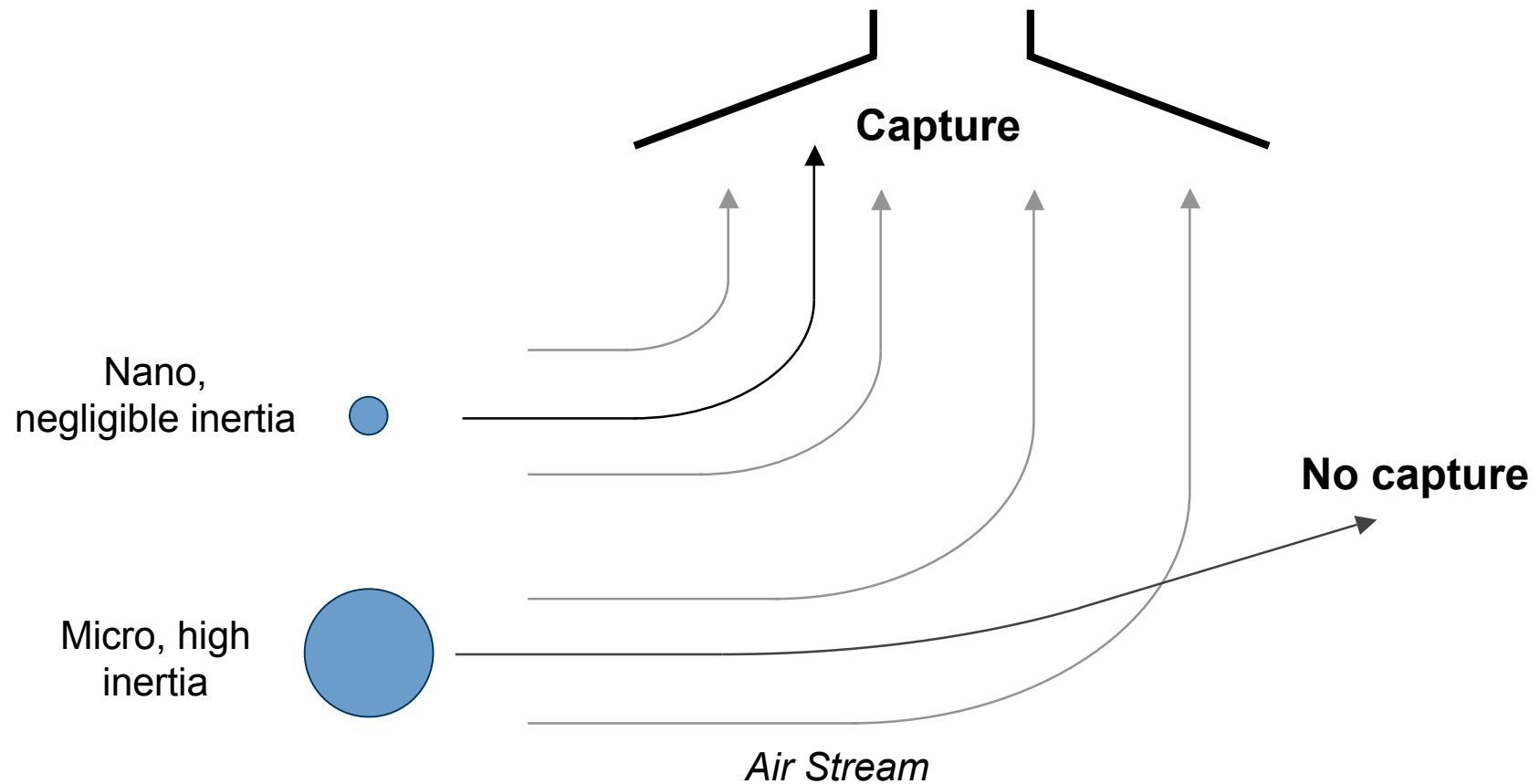
Filter Efficiency - Theory and Experiment



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				
		A	B	C	D	E
Impact Index	A	Light Blue	Light Blue	Yellow	Yellow	Yellow
	B	Light Blue	Light Blue	Yellow	Orange	Orange
	C	Light Blue	Yellow	Orange	Orange	Red
	D	Yellow	Orange	Orange	Red	Red
	E	Orange	Red	Red	Red	Red

CONCEPTUAL

Exposure Index

- 'Dustiness'
- Amount Used

Impact Index

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

Control Approach

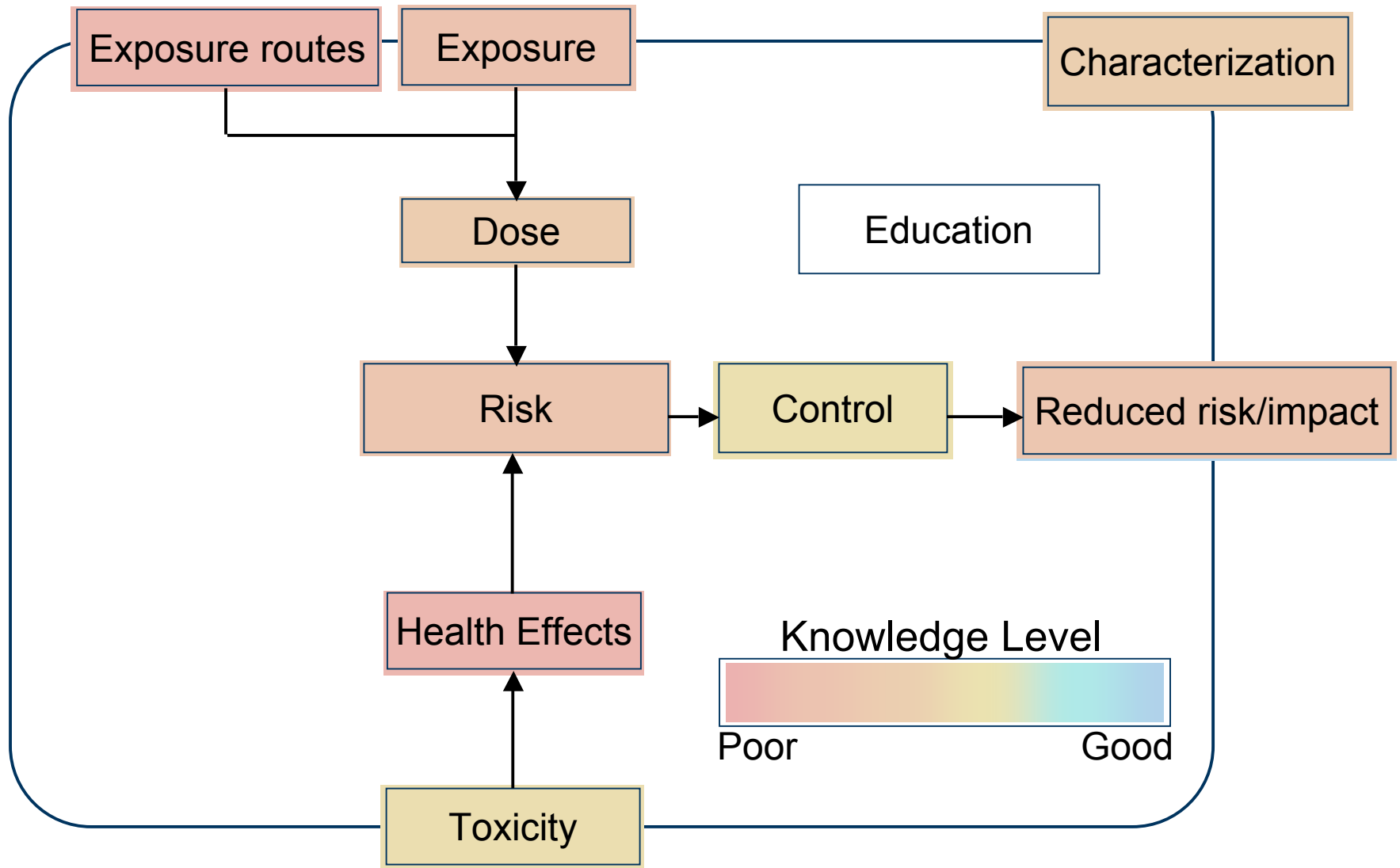
- General Ventilation
- Engineering Control
- Containment
- Specialist Advice



Responsible nanotechnology in the workplace

Research Gaps Analysis

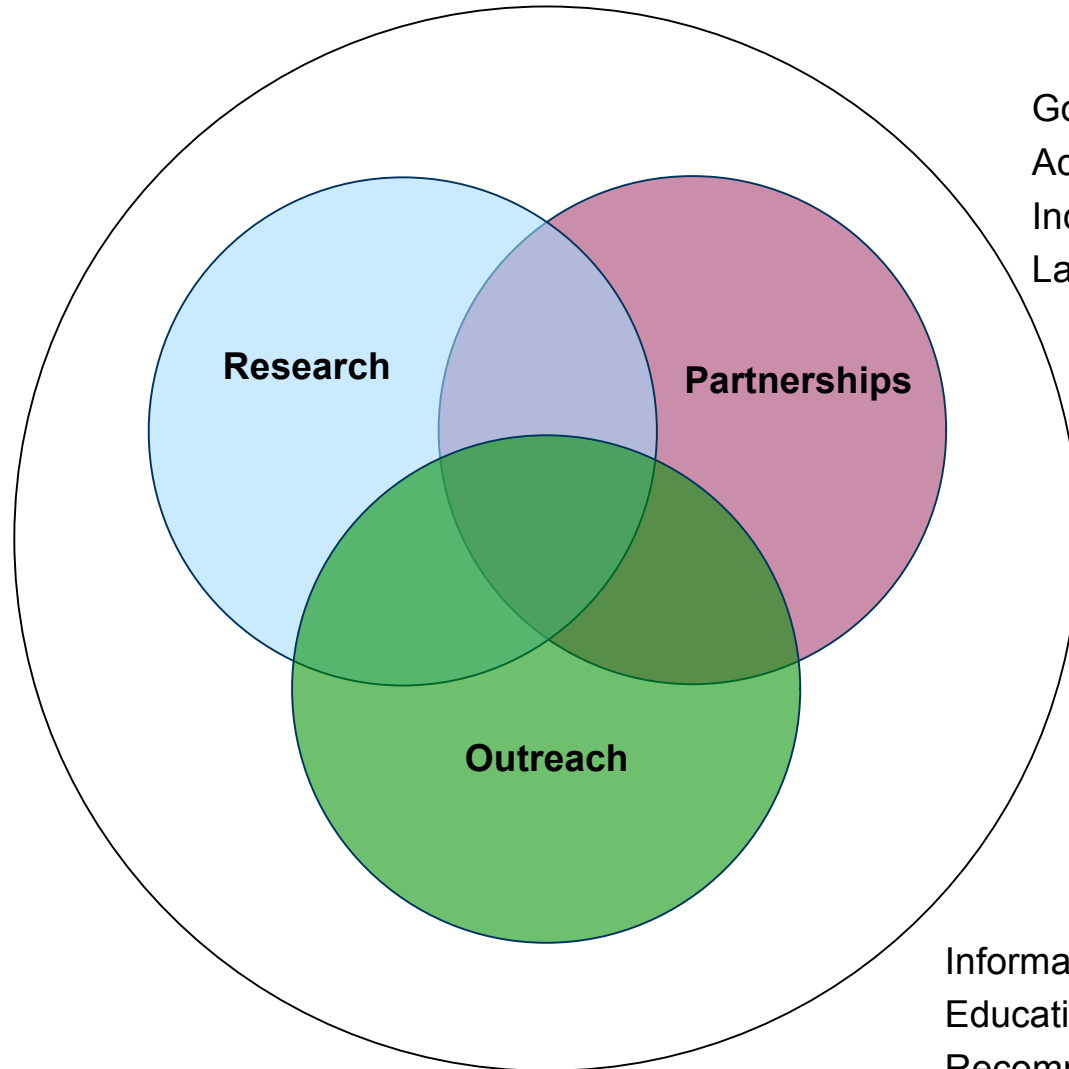
Qualitative



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



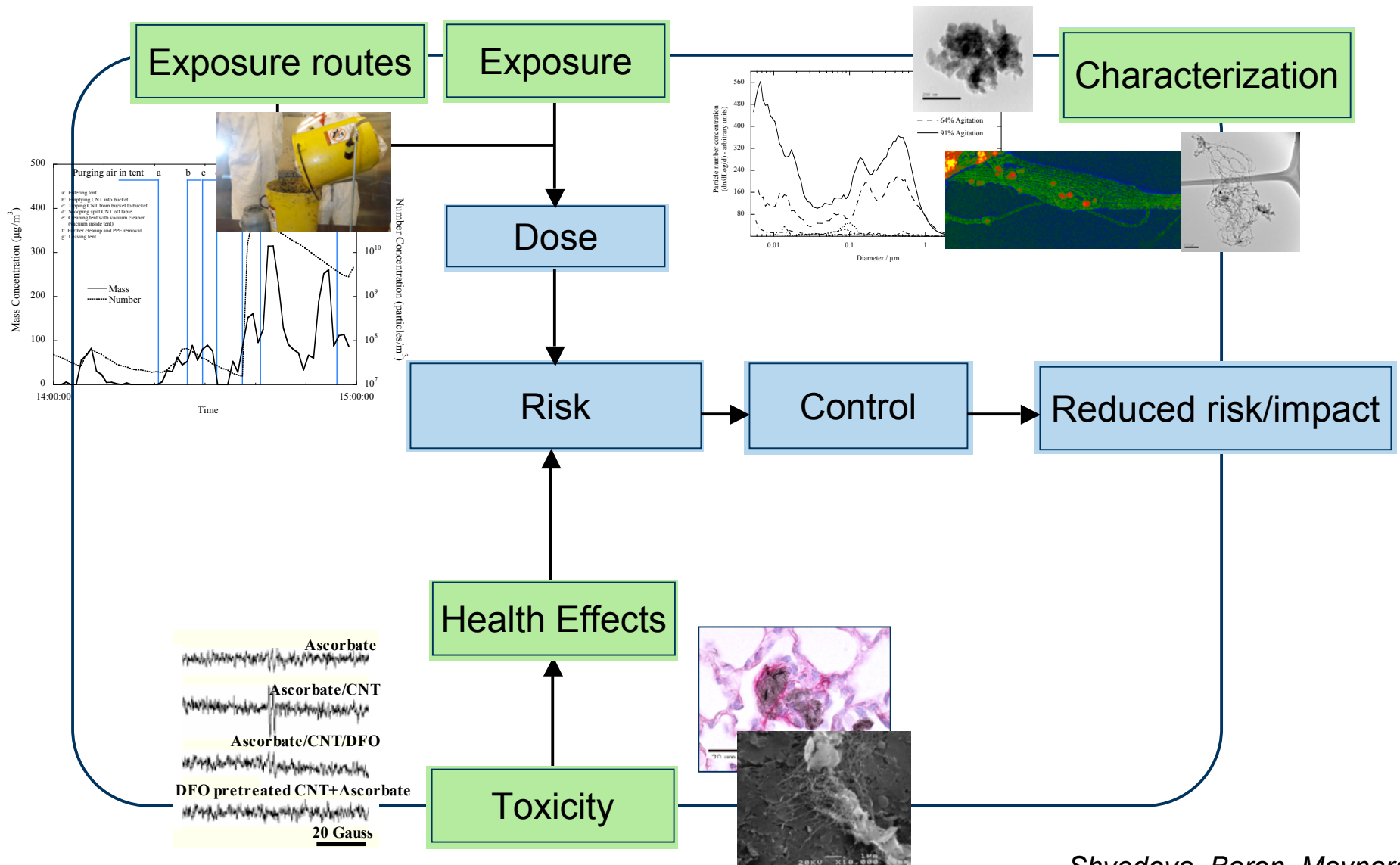
Government
Academia
Industry
Labor

Information
Education
Recommendations



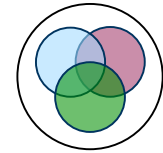
Research (Example)

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

NIOSH Safety and Health Topic: Nanotechnology

Nanotechnology Highlights:

- NIOSH, "Nanotechnology and Occupational Safety and Health: Research Opportunity Report" (October 2004)
- NIOSH Position Statement on Nanotechnology: Advancing Research on Occupational Health, Hazards, and Assessments
- NIOSH publishes a CIB on Engineered Nanomaterials

Background

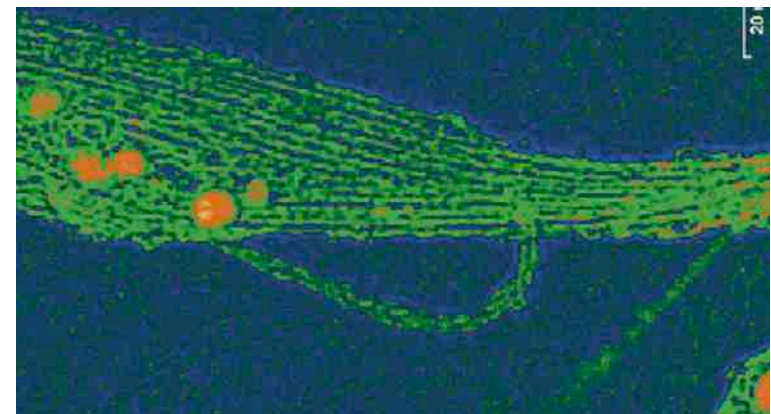
The past decade has seen intense interest in developing technologies based on the unique behavior of nanoscale-scale (1-to-100 nanometers) structures, devices and systems, leading to the rapidly expanding and highly diverse field of nanotechnology.

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 applications: electronic, magnetic, medical imaging, drug delivery, cosmetics, catalysis and materials applications. Between 1997 and 2003, worldwide government

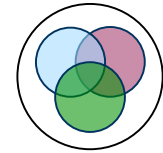
On This Page

www.cdc.gov/niosh/topics/nanotech



Nanotechnology
& Occupational Safety
and Health

Working in partnership



HEALTH & SAFETY LABORATORY

Nanomaterials - a risk to health at work?

First International Symposium on Occupational Health Implications of Nanomaterials

Organised by the UK Health and Safety Laboratory in collaboration with the UK Health and Safety Executive and the US National Institute for Occupational Safety and Health.

Venue: Palace Hotel, Buxton, Derbyshire, UK

Date: 12 - 14 October 2004

Key topics

- Current and future developments in the nanotechnology industry
- Health effects of existing nanomaterials and potential health effects of new materials
- Exposure assessment and control of nanomaterials
- Workshop on identifying gaps in knowledge of health effects, assessment and control
- Workshop on regulatory implications of nanomaterials

We intend to hold a poster exhibition for those with relevant new work to report. Three hundred word abstracts should be sent to the contact below by 2 August 2004.

For further information please contact Karen Wilkinson:

Telephone: +44 114 289 2023
email: karen.wilkinson@hsl.gov.uk
www.hsl.gov.uk/news/nanosymp.htm

2004 (UK)

2nd International Symposium on Nanotechnology and Occupational Health

October 3-6, 2005
Radisson Hotel Metrodome, Minneapolis, Minnesota
www.cce.umn.edu/nanotechnology

Call for Abstracts and First Announcement
Abstract Deadline: March 31, 2005

UNIVERSITY OF MINNESOTA

2005 (USA)

International Symposium

Miami, FL
January 30-February 3
2006

First Announcement

Nano - Toxicology: Biomedical Aspects

MIAMI

NANO TOX 2006

Nanotoxicology

2006 (USA)

Woodrow Wilson Center

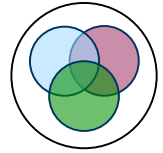
Project on Emerging Nanotechnologies

“[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

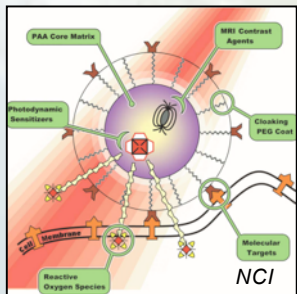
Looking to the Future

Moving beyond the health impact of 'simple' nanomaterials



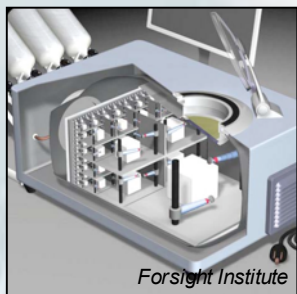
Safety

“Unconventional” and unanticipated behavior



Complex nanoparticles and nano-devices

Moving beyond simple response mechanisms



Convergence

Revolutionary health & safety challenges

Conceptual Space Elevator, Liftport Group