Assessing the risks of engineered nanomaterials

Setting the Scene

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Defining Nanotechnology
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Nanotechnology:
“The art and science of building stuff that does stuff at the nanometer scale”

(1943 - 2005)
What has risk got to do with nanotechnology?

- New ways of doing things mean new risks to human health and the environment.

- The long-term success of nanotechnology will depend on identifying, assessing and managing potential risks.

- Defining nanotechnology risk research:
  - The art and science of addressing how *stuff that does stuff at the nanometer scale* might harm our health and the environment.
Nanotechnology Risk has relatively little meaning... 
...unless we apply appropriate boundaries to the discussion
Setting Boundaries
Engineered nanomaterials which potentially present new challenges

- **Criteria:**
  - Nanomaterials capable of entering or interacting with the body or environment
  - 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

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

- **Unintentional use**
  - Potential exposure from unanticipated/unintentional use
What makes nano different: The significance of structure
ZnO: One chemistry, many shapes - Courtney of Prof. Z.L. Wang, Georgia Tech
Nanotechnology and potential risk
A thought experiment in the significance of structure on potential impact

Physical Structure
Low

Conventional Understanding
Macro-Materials
Liquids
Gases & Vapors

Unconventional Understanding
Nano-Materials & Devices

Compositional Structure
Low

Size
Shape
Surface Area
Surface Activity
Nano-Structure

Mass
Composition
Physicochemistry and the lungs
Comparison of insoluble materials with different biological activities

![Graph showing the relationship between inflammatory response and particle surface area dose for various materials.]

- Fine TiO$_2$ (Tran)
- Fine TiO$_2$ (Oberdörster)
- BaSO$_4$ (Tran)
- Ultrafine TiO$_2$ (Oberdörster)
- Crystalline SiO$_2$ (Porter)

Physicochemistry and the skin
Dermal Penetration - Quantum dots

4.6 nm diameter quantum dots
Different coatings
Confocal Microscopy / fluorescence analysis
Scale bar: 50 μm

Physicochemistry and Translocation
Translocation Following Inhalation - Lungs to Liver

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

Nano is NOW
Nano-Consumer Products

Nearly 400 manufacturer-identified “nano” consumer products are commercially available worldwide

www.nanotechproject.org/consumerproducts
Addressing Potential Impact

Exposure Routes → Exposure → Dose → Risk → Health Effects → Toxicity

Characterization → Education → Control → Reduced Impact

Knowledge Level: Poor to Good
Responding to the challenge

- **Sound Science**
  - Identifying critical questions, and finding applicable answers

- **Specificity**
  - Focusing on how the technology is used, not the technology itself

- **Simplification**
  - Identifying patterns and commonalities which will transform apparently intractable problems into a merely difficult ones
Measuring exposure to airborne nanostructured particles

Many potentially significant attributes: Few measurement metrics
Classifying Engineered Nanoparticles

Some thoughts

- **Compact/Sphere**
  - Homogeneous

- **High aspect ratio**
  - Homogeneous

- **Complex non-spherical**
  - Homogeneous

- **Heterogeneous aggregates**
  - Many particle classes

- **Homogeneous agglomerates**
  - Single particle class

- **Heterogeneous Core-surface**

- **Heterogeneous Distributed**

- **Active**
  - External stimuli

- **Multifunctional**
  - Complex responses

Note: size is treated separately
Identifying important attributes
Some more thoughts

- Differentiated component release
- Core-surface Heterogeneity
- Response to environment
- Response to stimulus
- Surface Chemistry
- Composition
- Solubility
- Shape
- Charge
- Porosity
- Surface Area
- Crystal Structure
- Distributed Heterogeneity
- Propensity to change structure
Matching exposure metrics, attributes and particle class

Shape
Surface area
Surface chemistry
Composition
Core-surface composition heterogeneity
Distributed composition heterogeneity
Solubility
Charge (in lung fluid)
Crystal structure
Porosity
Changes in particle size/structure following deposition
Preferential release of constituent components following deposition
Stimulus-associated behavior
Functional response to environment

Relevance
- High
- Medium
- Low
- None

Exposure Metric
Surface Area Concentration

Aitken and Maynard (2007), Nanotoxicology. In Preparation
Number Concentration

- Shape
- Surface area
- Surface chemistry
- Composition
- Core-surface composition heterogeneity
- Distributed composition heterogeneity
- Solubility
- Charge (in lung fluid)
- Crystal structure
- Porosity
- Changes in particle size/structure following deposition
- Preferential release of constituent components following deposition
- Stimulus-associated behavior
- Functional response to environment

Aitken and Maynard (2007), Nanotoxicology. In Preparation
Mass Concentration

- Shape
- Surface area
- Surface chemistry
- Composition
- Core-surface composition heterogeneity
- Distributed composition heterogeneity
- Solubility
- Charge (in lung fluid)
- Crystal structure
- Porosity
- Changes in particle size/structure following deposition
- Preferential release of constituent components following deposition
- Stimulus-associated behavior
- Functional response to environment

Relevance:
- High
- Medium
- Low
- None

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The Challenge:

**Sound Science**
Identifying critical questions, and finding applicable answers

**Specificity**
Focus on how the technology is used, not the technology itself

**Simplification**
Identifying patterns and commonalities which will transform apparently intractable problems into a merely difficult ones
Further Reading


Further Information

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