Strategies for Measuring Airborne Nanomaterials

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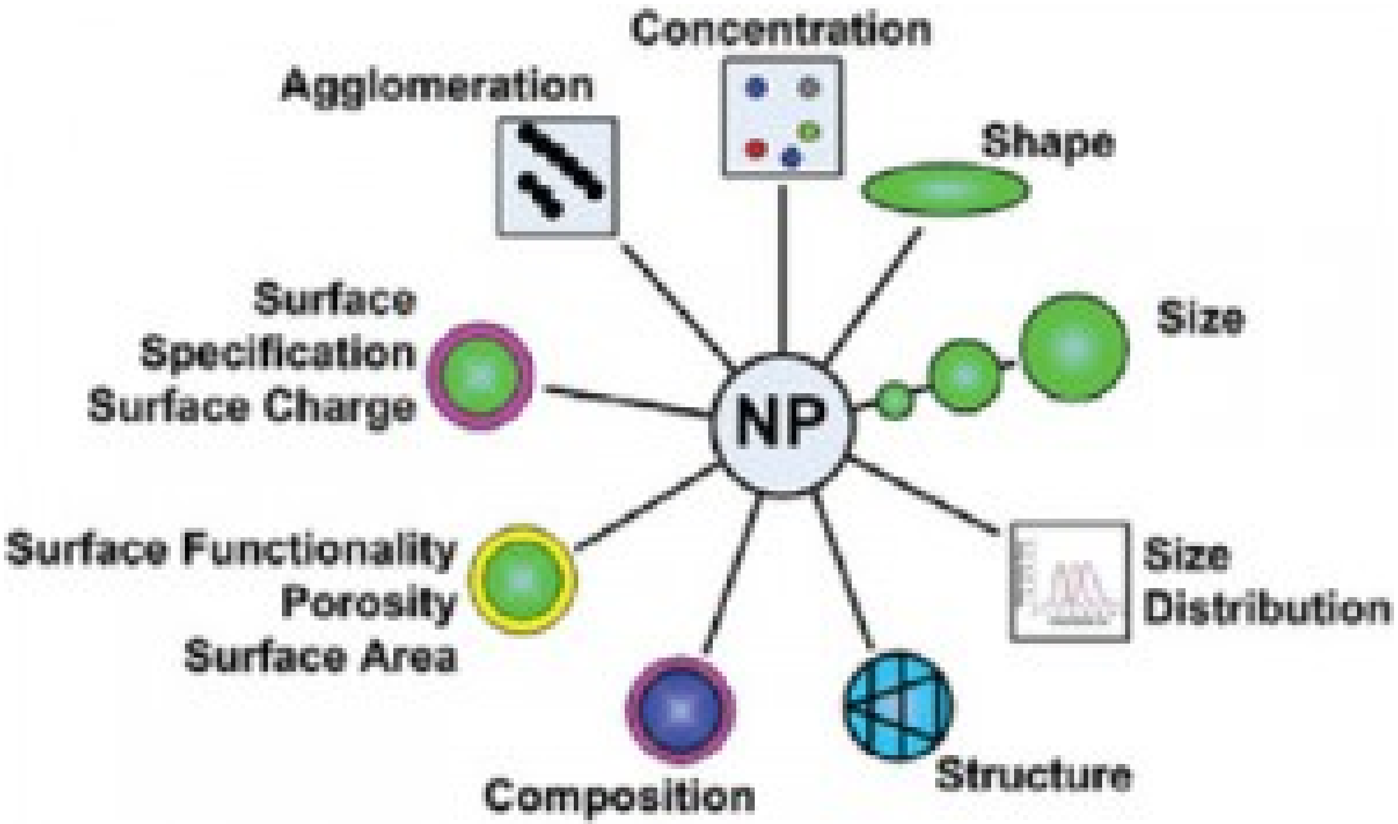
Objective

- Review the fundamentals of engineered nanomaterials (ENMs), occupational exposure assessment, and the outcomes of a workshop held in 2011 to provide a basis for developing an exposure assessment strategy
- Review advances since 2011 in the strategies for assessing occupational exposure to engineered nanomaterials (ENMs)
- Save suggestions and recommendations for future development of exposure assessment strategies until the panel discussion

Risk Assessment Paradigm

- Risk = Exposure + Hazard
- Exposure: inhalation, dermal, ingestion (non-dietary) at a level to cause concern
- Hazard: the ENM has the physical and chemical properties to cause an adverse health outcome

Physicochemical Properties



NSF Workshop Conclusions (2011)

- Dr. Sudipta Seal and Dr. Barbara Karn hosted a NSF sponsored workshop "Nano Workshop: Safety aspects of Nanostructures and Infrastructure for Sustainability"
- State of the Science
  - Portable instrumentation becoming available
  - Metrology and characterization methods developed
  - Strategies for task based, spatial-temporal mapping, and emissions estimation exposure assessment available
- Challenges and Needs
  - Exposure assessment strategy development, standardization, and validation lacking for ENMs
  - Merge toxicology data with engineering/science advances to develop new devices that provide information relevant to health
  - Multifunctional devices: many physicochemical characteristics, fast, inexpensive, and small

Exposure Characterization Questions

- What is the type of ENM in the occupational environment?
- What is the source of exposure?
- What is the persistence of the ENMs?
- Are the ENMs physically and chemically stable?
- Any sources of natural or anthropogenic nanoparticles that could confound ENM exposure measurements?
- Is there a potential for exposure misclassification?
- What are the likely exposure routes?
- What is the suitable exposure metric (mass, number, area, etc.)?
- How do ENMs translocate across the body?
- What are the key mechanisms of toxicity?

- Answers will provide insight into the exposure assessment design, the types of instruments used, and the need for real-time or offline data

Exposure Assessment Strategy: Approaches

NEAT

- Nanoparticle Emission Assessment Technique (Methner et al., 2010)
- Identify potential sources of emissions using a CPC and OPC
  - Two methods span the size range of ENMs: 10 nm to > 1000 nm
- Collect air samples on filter media for offline analysis to differentiate ENMs from other nanomaterials
  - Mass concentration, chemical composition, elemental analysis, size distribution, morphology

AIHA Based Framework

- Ramachandran et al (JOEH, 2011) adapted the AIHA general framework for exposure assessment to be specific to ENMs
- Intended to be a practical guide for managing ENM risks in workplaces
- Identifies jobs or tasks with high exposures while requiring a modest level of resources
- Features
  - Workplace characterization
  - Assessment of exposure potential
  - Accounts for background aerosols
  - Constructs similarly exposed groups
  - Selection of appropriate instrumentation
  - Providing appropriate choice of exposure limits
  - Decision matrix for making exposure management decisions

Exposure Assessment Strategy: Devices

Common Devices

Highlights of European Union Research (2013)

	Metric	Size Range	ENM Identification	Other
Low-Cost Total Active Surface Area Monitor	Surface area	0.01 to 3 μm	No	Personal or stationary
NanoGuard	Number concentration Surface area	< 20 to 400 nm	Offline	Real-time
NanoGuard Samplers	Size distribution and concentration, morphology, toxicology	< 20 to 400 nm	Offline	ESP, TP, Cyto-TP
Real-time CNT Monitor	Number concentration	Not specified	CNTs only	Stationary or personal
Personal Nano-sampler	Mass concentration and size distribution	2 nm to 5 μm	Offline	Diffusion separation sub-300 nm
Pre-separators	Not applicable	5 nm to 5 μm	Not applicable	Diffusion and/or aerodynamic separation to physiologically relevant portions of respiratory tract

Source: www.nano-device.eu

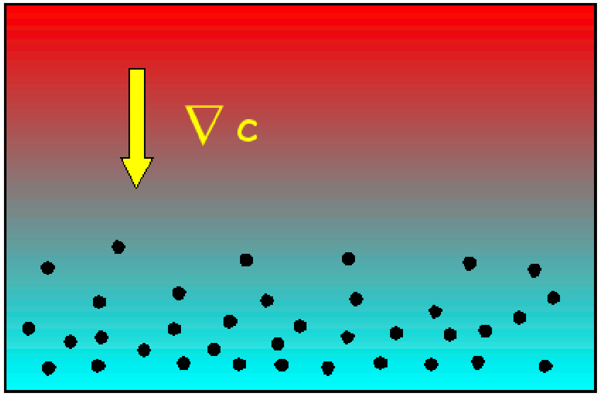
NIOSH and MSHA Devices

- Airtec (FLIR) Diesel Particulate Monitor developed in 2011 based on NIOSH research (Noll et al., 2007)
  - Noll et al., (2013) validated the device
  - Measures elemental carbon using laser extinction (transmittance) at 650 nm through a Teflon filter

- Thermo Scientific Personal Dust Monitor 3700
  - Tapered Element Oscillating Membrane (TEOM) based device to provide real-time data
  - Does not distinguish ENM from other types of aerosols

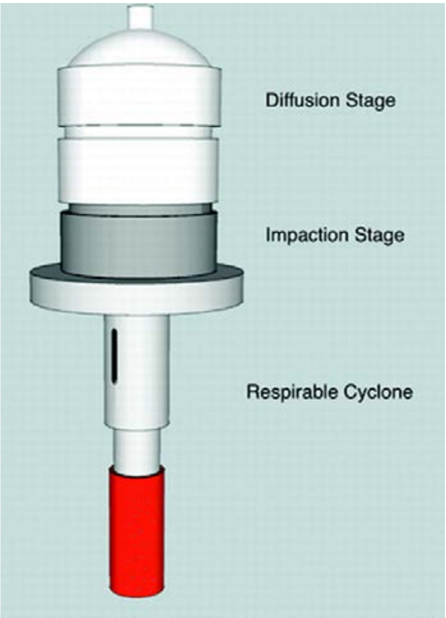
Thermal Precipitator

- Multiple devices are available
  - Azong-Wara et al. (J. Nanopart. Res., 2009)
  - Thayer et al. (Aerosol Sci & Tech, 2011)
  - Miller et al. (Aerosol Sci & Tech, 2012)
- An extremely high temperature gradient across a small gap produces thermophoretic diffusion and ENMs deposition on a substrate.
- Substrate analyzed by TEM to count, size and classify the ENMs



Nanoparticle Respiratory Dose (NRD) Sampler

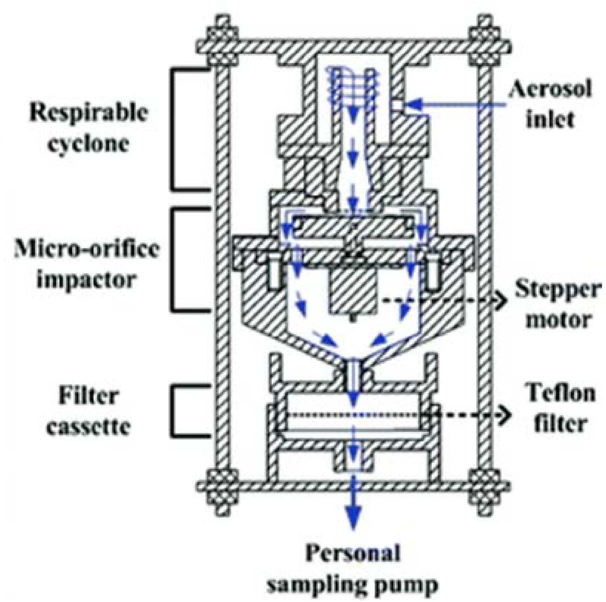
- The NRD has three components (Cena et al., ES&T, 2011)
  - A 25-mm respirable aluminum cyclone (Model 225-01-01, SKC Inc., Eighty Four, PA) to remove particles larger than the respirable size
  - An impaction stage to remove particles larger than 300 nm
  - A diffusion stage consisting of a stack of mesh screens designed to mimic the collection efficiency of the human respiratory tract
- Offline analysis for counting, sizing
- Personal sampler



Nanoparticle Respiratory Deposition (NRD) Sampler

Personal Nanoparticle Sampler (PENS)

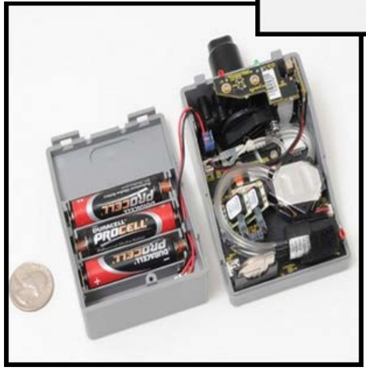
- C.J. Tsai lab developed the PENS (Tsai et al., ES&T, 2012)
- Uses respirable cyclone size select at 4 μm and a rotating plate impactor to separate at 100 nm
- Integrated with a 37 mm polycarbonate cassette



Other Devices

- Portable ultrafine particle counter developed by U. Cincinnati under a NIEHS grant (Ryan et al., Sci. Total Environ., 2015)
  - Developed for children but applicable to occupational exposure

- MicroPEM developed by RTI (Rodes et al., in preparation)
  - < 240 g with batteries
  - Real-Time PM detection ~3 to 15,000 µg/m^3
  - Integrated referee filter collection
  - Onboard accelerometer to sense movement
  - Easily modified for occupational exposure assessment



Exposure Assessment Strategy: Future

What Should Be Measured?

- Laboratory versus occupational evaluations
  - Lab = exposure identification, Occupational = exposure quantification
- Personal level, real-time exposure
  - Job specific exposures, concentration mapping
- ENM discrimination from other nanoparticles
  - Area monitoring, pre/post activity sampling
- ENM identification
  - Offline analysis
- Data quality indicators
  - Compliance with exposure assessment protocol to minimize exposure misclassification
  - Confidence in the accuracy and precision of the data by collecting secondary data (temperature, relative humidity, pressure differentials, accelerometry, calibration factors, etc.)

How Far Have We Advanced Since 2011?

- Exposure assessment strategy development, standardization, and validation lacking for ENMs
  - Strategy development: ☺ but are updates needed considering rapid evolution of exposure assessment devices?
  - Standardization: **?** Are existing strategies widely used?
  - Validation: **?** Adoption of strategies will validate their performance
- Merge toxicology data with engineering/science advances to develop new devices that provide information relevant to health
  - Progress limited to development of a few devices that measure physiologically relevant exposure concentrations
- Multifunctional devices: many physicochemical characteristics, fast, inexpensive, and small
  - Minimal progress outside of CNTs, especially for fast differentiation of ENMs from other nanoparticles

More Information

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