Research Need 2:

Identify Population Groups and Environments Exposed to Engineered Nanoscale Materials

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Environmental Exposure

- The link between hazard and risk for environmental stressors

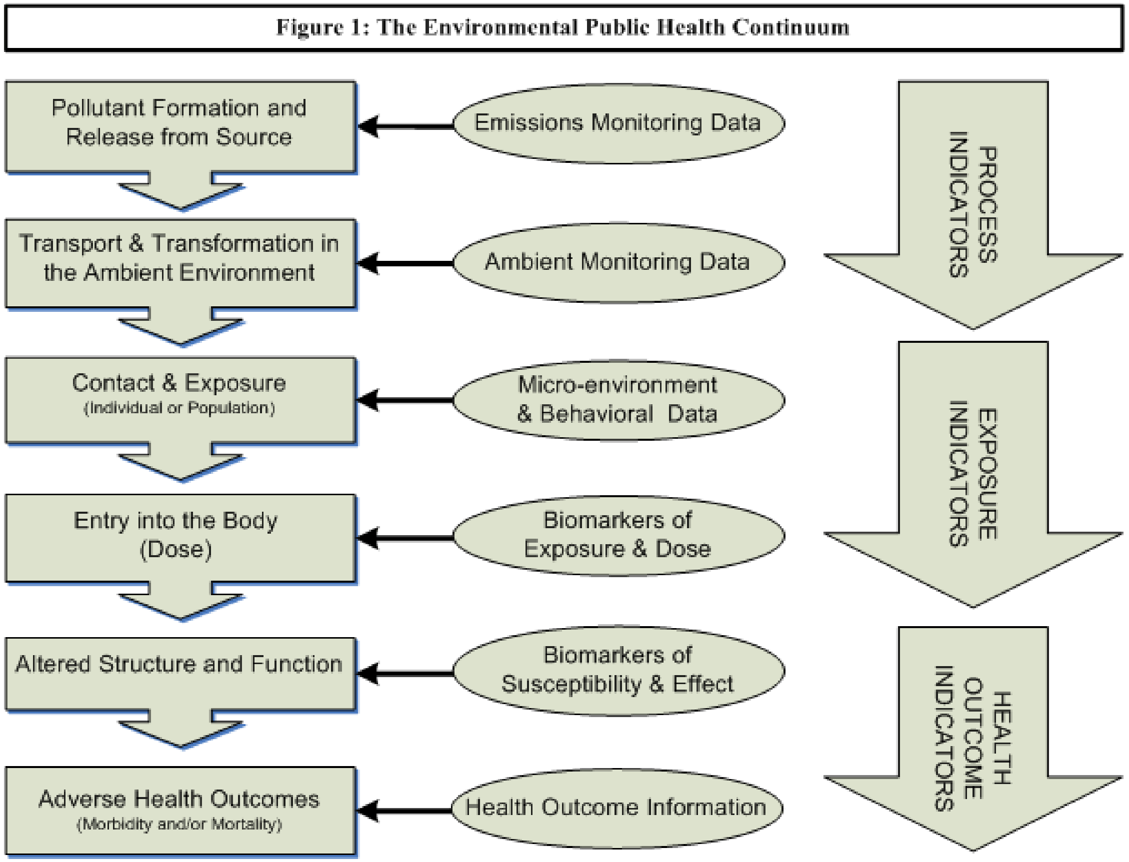
- Risk = f(exposure,toxicity)

- Knowledge of pathways, routes, and receptors is critical for well-founded risk management (NRC 2008)

Source: Spheres of Influence, Environmental Health Perspectives, 108(1), January 2000

Source-to-Dose Assessments

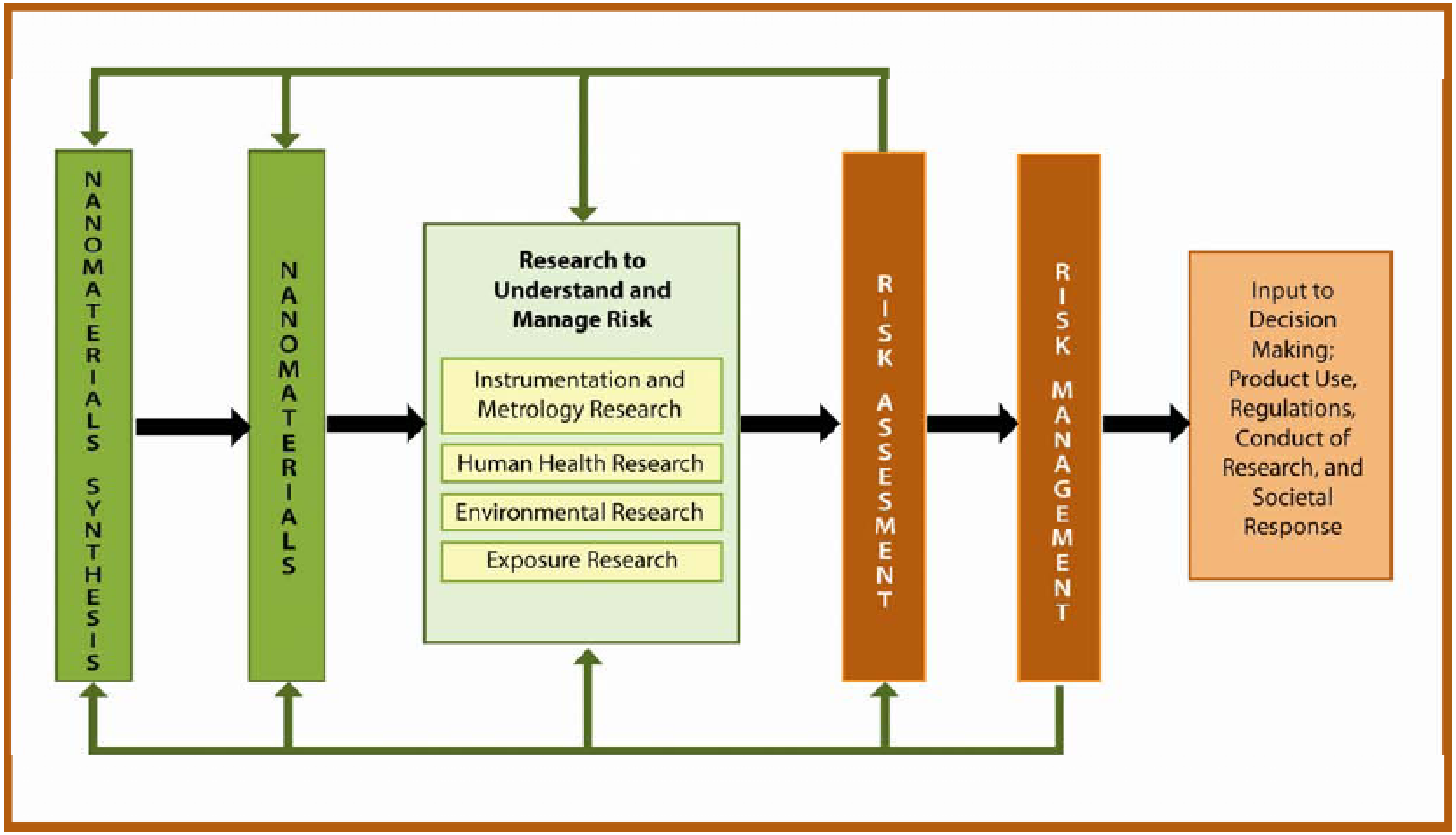
- Current approach
- Starts with emissions or environmental concentrations
- Considers transport, transformations, fate, and contact with stressor or associated media
- Reflects empirical knowledge about physicochemical properties that influence those processes



Source: http://es.epa.gov/ncer/rfa/2007/2007_star_health_indicators_001.gif

Exposure to Engineered Nanomaterials

Figure 1. Role of nanotechnology-related EHS research in risk management of nanomaterials



Source: Nanotechnology Environmental Health Implications Working Group. 2008. National Nanotechnology Initiative Strategy for Nanotechnology-Related Environmental, Health, and Safety Research, February 2008, p. 4

Prioritized Exposure Needs (NEHI 2008)

Research Category: Human and Environmental Exposure Assessment

Total estimated funding in FY 2006: $1.1 million
Total projects: 5
Agencies supporting research in this category: DOD/AF, NIOSH, NSF

Prioritized EHS Research Needs for Human and Environmental Exposure Assessment	FY 06 funding Estimate $K (% of total)	Number of Projects (% of total)
1. Characterize exposures among workers	879 (77%)	2 (40%)
2. Identify population groups and environments exposed to engineered nanoscale materials	--	--
3. Characterize exposure to the general population from industrial processes and industrial and consumer products containing nanomaterials	--	--
4. Characterize health of exposed populations and environments	--	--
5. Understand workplace processes and factors that determine exposure to nanomaterials	265 (23%)	3 (60%)
Multiple: Projects that capture multiple needs	--	--
Other: Not captured in needs above, but of benefit to the research category	--	--

Source: Nanotechnology Environmental Health Implications Working Group. 2008. National Nanotechnology Initiative Strategy for Nanotechnology-Related Environmental, Health, and Safety Research, February 2008, p. 33

State of Knowledge (NRC 2008)

One of the strengths of the 2008 NNI strategy document is that it clearly identifies exposure research as a high-priority need and articulates its relevance to risk assessment. It also highlights the paucity of research in this regard and reflects on the nascent nature of nanotechnology (NEHI 2008, p. 34) and lack of exposure information.

Source: Review of the Federal Strategy for Nanotechnology-Related Environmental, Health, and Safety Research, National Research Council, The National Academies Press, December 2008, p. 78

Review of the Federal Strategy for Nanotechnology-Related Environmental, Health, and Safety Research

Committee for Review of the Federal Strategy to Address Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials

Board on Environmental Studies and Toxicology

Division on Earth and Life Studies

National Materials Advisory Board

Division on Engineering and Physical Sciences

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Point Sources: National

- Where are the manufacturing sources of engineered nanomaterial emissions to the environment?
  - Companies
  - Universities
  - Government
  - Other

Map of publicly available information maintained by the Project for Emerging Nanotechnology

www.nanotechproject.org

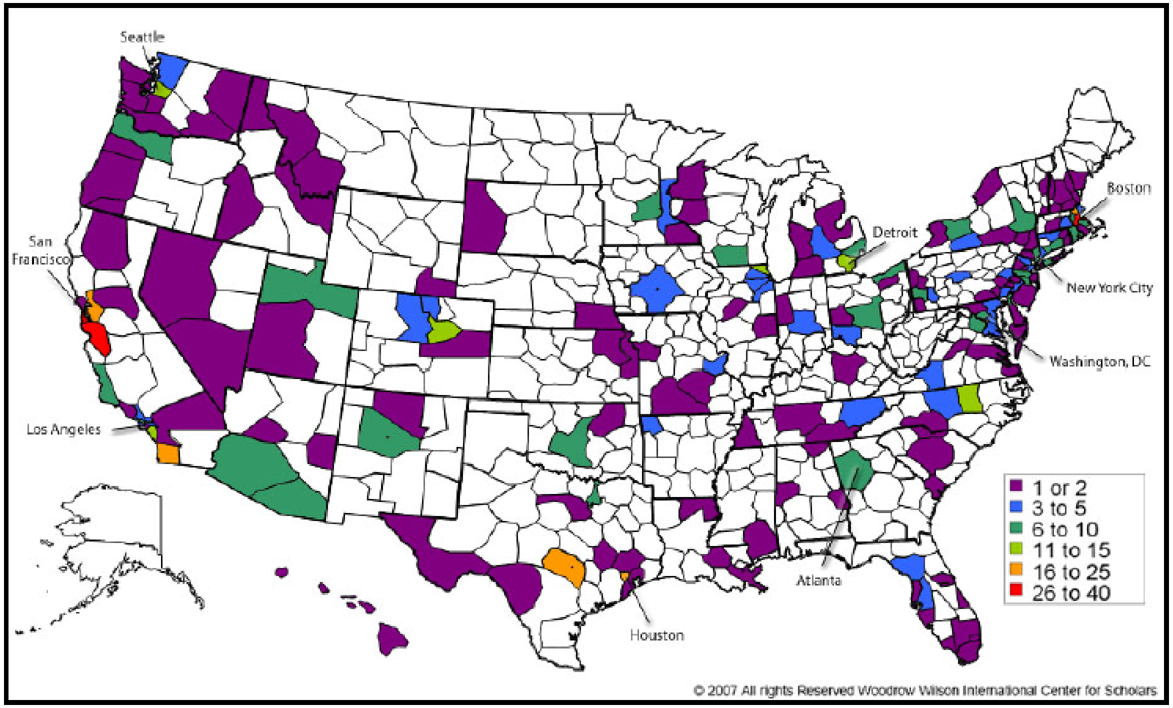

Figure I. Number of companies, universities, government laboratories, and/or organizations working in nanotechnology and located in each 3-digit zip code Nano Metro (820 Total).

Point Sources: Local Scale

- Where are the manufacturing sources of engineered nanomaterial emissions to the environment?
  - Companies
  - Universities
  - Government
  - Other

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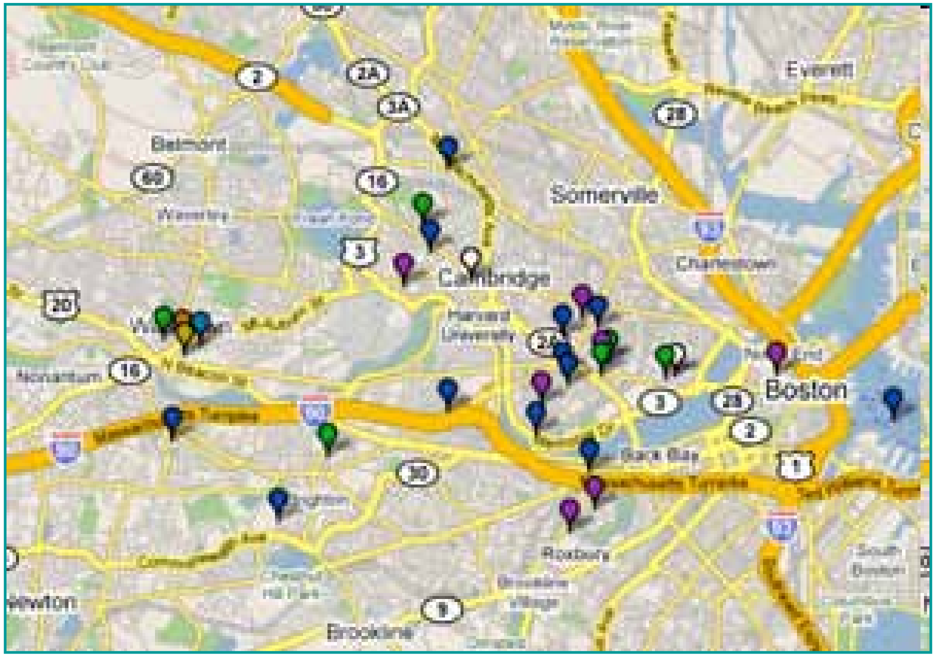
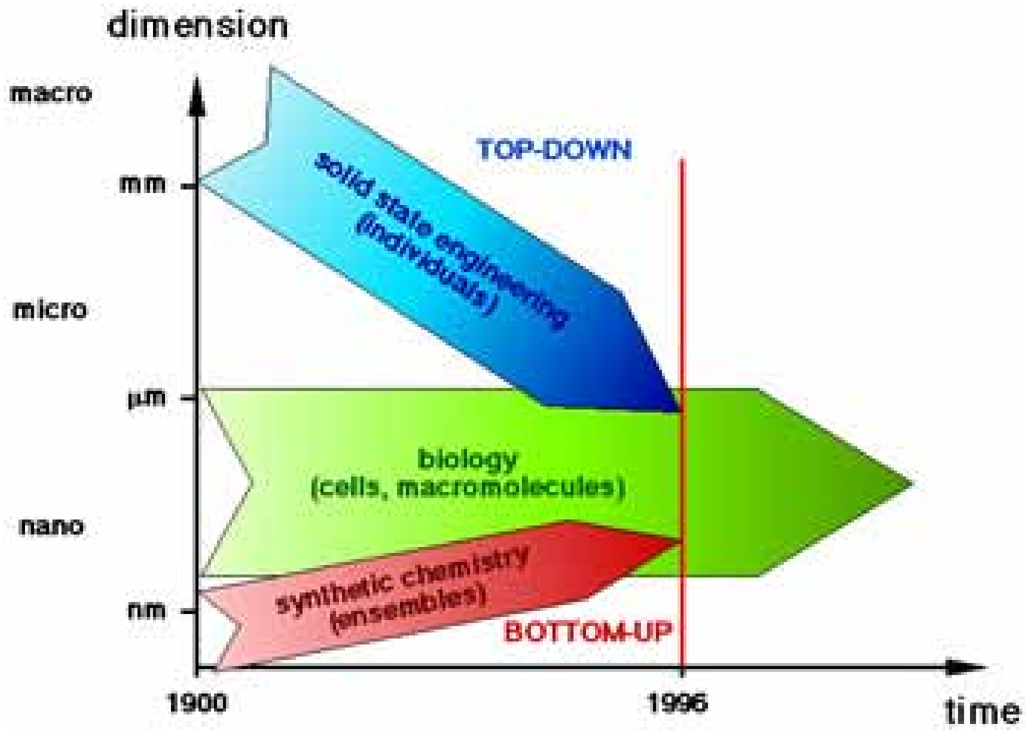


Can drill down to local scale

Point Sources: Manufacturing Process

- Does the type of manufacturing process influence emissions, transport, and fate?



Source: http://www.nanotechnology.ethz.ch/images/approaches.jpg

Product-based Sources

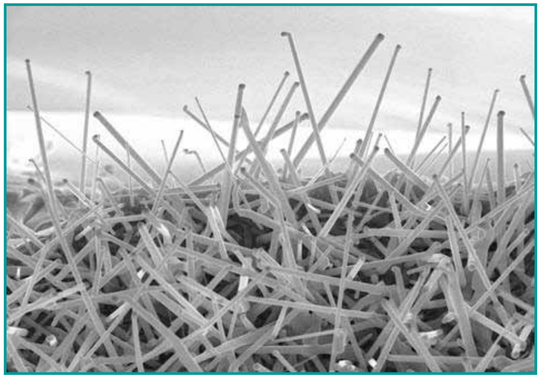
- Electronics
  - Semiconductor, data storage, sensors, solar cells
- Medical
  - Disease diagnosis, targeted drug delivery, imaging, anti-microbial, tissue engineering
- Coatings
  - Scratch proof, stain proof, self-cleaning, adhesive, antimicrobial
- Food safety
  - Antimicrobial films
- Personal care
  - Soap, toothpaste, shampoo, sunscreen, face cream, foundation, face powder, lipstick, blush eye shadow …

- *Higher Priority Products?*
  - Nanoparticles and nanotubes that are free
  - Includes some cosmetic uses and workplaces
- *Lower Priority Products?*
  - Nanomaterials or particles fixed to or within a material
  - Includes injection molded parts, films, etc.
  - Potential exposures should be considered nonetheless

Sources: Form

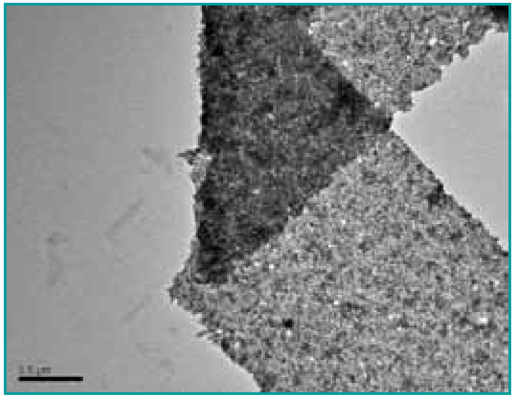
- Does the form of the nanomaterial produced or used influence which populations and environments are exposed?

Wires



http://web.mit.edu/mna/Public/nanowire1.jpg

Films



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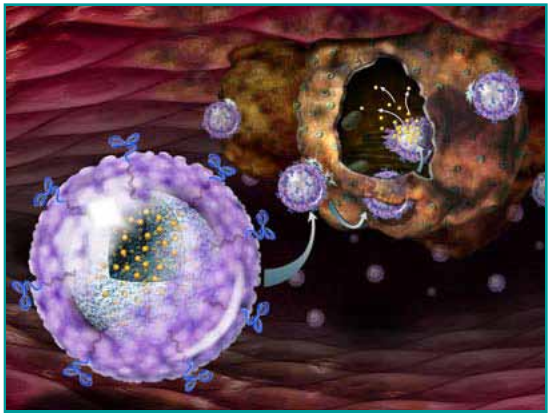
Particles



http://web.mit.edu/newsoffice/2008/nanoparticles.jpg

Diversity of Sources

- Myriad locations, types, and forms of sources
- Concepts of aggregate and cumulative exposure appear to be relevant
- NRC 2008
  - Consider grouping nanomaterials that have similar risk-relevant characteristics

- *Aggregate Exposure*
  - Contact with a single stressor through multiple routes and pathways
- *Cumulative Exposure*
  - Contact with multiple stressors that have negative effects on the same organ or organ system

Transport and Fate

- How do engineered nanomaterials differ from larger materials in properties that influence population groups at risk of exposure?
  - Will engineered nanomaterials in air coagulate and transform into accumulation mode particles like other aerosols?
  - Will engineered nanomaterials in water coagulate and deposit like many other suspended materials?

Environmental Fate: Industrial Nanomaterials Appear Vulnerable to Dispersal in Natural Environment

Laboratory experiments with a type of nanomaterial that has great promise for industrial use show significant potential for dispersal in aquatic environments – especially when natural organic materials are present.

When mixed with natural organic matter in water from the Suwannee River -- a relatively unpolluted waterway that originates in southern Georgia -- multiwalled carbon nanotubes (MWNTs) remain suspended for more than a month, making them more likely to be transported in the environment, according to research led by the Georgia Institute of Technology.

Carbon nanotubes, which can be single- or multiwalled, are cylindrical carbon structures with novel properties

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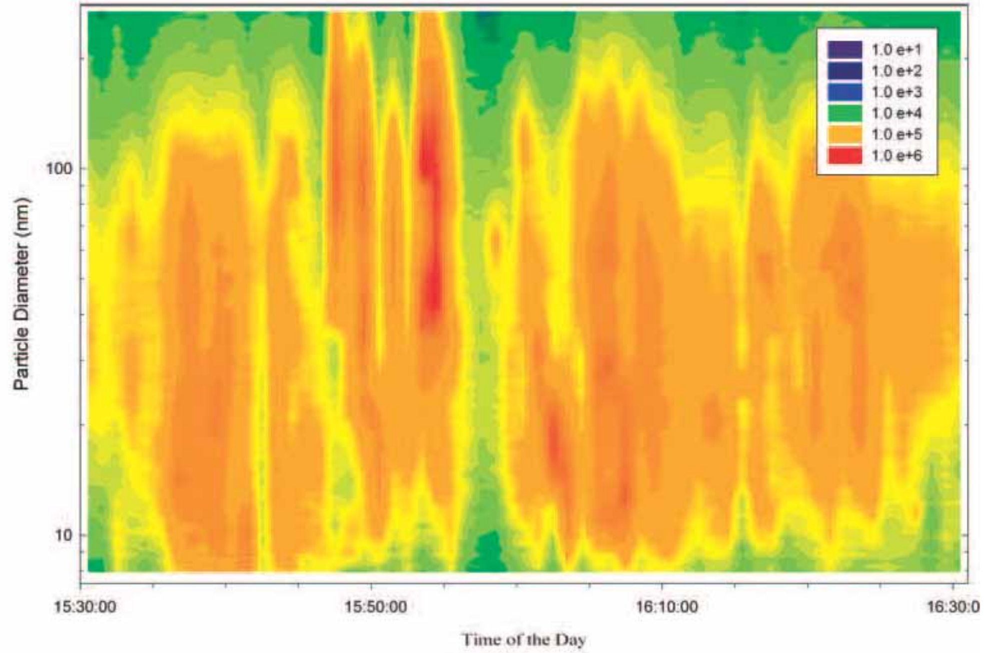
Measurements

- What techniques are appropriate for population-based exposure monitoring of engineered nanomaterials?
  - Distinguish from other nanoscale materials
  - Distinguish from other sources of the same elements or molecules

- Can we take advantage of lessons learned from previous analyses of aggregate and cumulative exposure?

- What are the appropriate risk-relevant metrics: mass, size, shape, surface area, charge, composition, other?

Source: Zhu et al. 2007, Environ Sci Technol 41:2138-2145



We are constantly exposed to nanoscale materials in air as a result of emissions from anthropogenic and natural sources of combustion. Units in figure is particles/cm^3.

Body Burdens

- Can biological indicators be used to identify populations exposed to engineered nanomaterials?
- Will engineered nanomaterials accumulate in biological tissue?
- Body burdens for analysis of exposure status and trends?

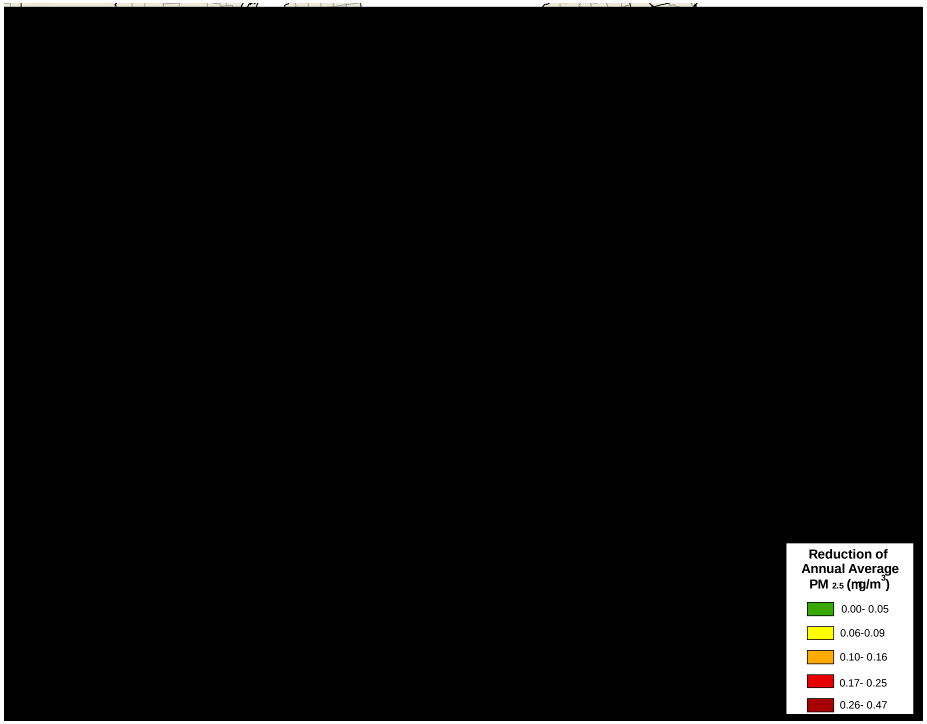
- *Signatures based on the optical or electrical properties of engineered nanomaterials*
- *Novel imaging techniques*
- *Biomarkers of effect specific to engineered nanomaterials*
- *Others?*

Platforms and Tools: Emissions

- Can emissions information for nanomaterials be added to our well developed set of inventories?
  - Toxics Release Inventory
  - National Emissions Inventories
  - Clean Air Markets Database
  - NPDES permits

Platforms and Tools: Transport/Contact

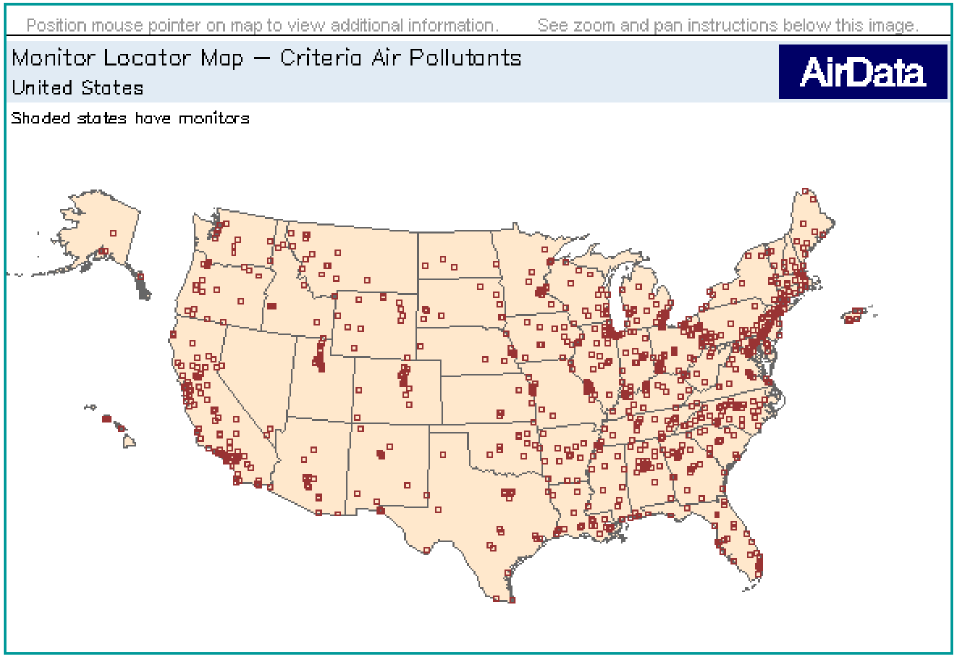
- Do we have the modeling capacity to predict or reconstruct transport and uptake?
- Air: CMAQ, AERMOD, CALPUFF
- Water: PRZM, EXAMS, EPANET
- Exposure: HEM, SHEDS, new or proprietary product use information, etc.



Example of high resolution air quality modeling on a regional scale with CMAQ.

Platforms and Tools: Measurements

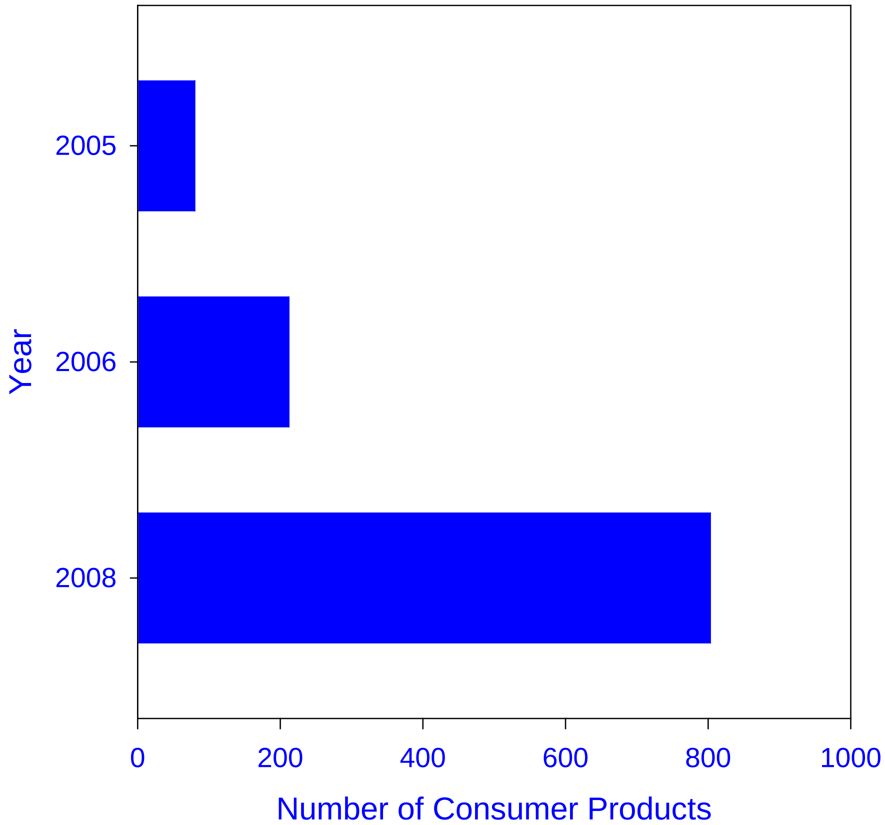
- Can engineered nanomaterials be included in our routine monitoring programs?
- Air: SLAMS, NAMS, STN, IMPROVE, CASTNET, etc.
- Water: National Aquatic Resource Surveys, municipal drinking water assays
- Food: Surveys conducted by FDA, USDA, and EPA



Map of 1,118 fine particle monitoring sites operated in the U.S. in 2008. EPA and the states operate over 4,000 air quality monitoring sites in total.

Platforms and Tools: Biomarkers

- How quickly can a record of body burdens be established for analysis of status and trends in exposure?
- CDC National Exposure Report Card
- EPA National Human Exposure Assessment Survey
- National Children's Study
- Other EPA exposure surveys



Rapid growth in the number of consumer products that contain engineered nanomaterials (Project for Emerging Nanotechnology, Inventories)

Summary and End

- What are the most important sources for exposure and risk?
- How is the transport and fate of engineered nanomaterials different from larger materials?
- What are the appropriate risk-relevant metrics?
- Can engineered nanomaterials be included in our routine monitoring programs?
- How quickly can a record of body burdens be established for analysis of status and trends in exposure?
- Are we prepared to address the gaps in exposure knowledge using **life cycle analysis** and **value of information** as overarching research themes?