Strategies for Setting Occupational Exposure Limits for Engineered Nanomaterials: A Labor Perspective

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Definition

According to the US National Technology Initiative a process or product is properly described as nanotechnology if it is characterized by all of the following:

- **Researching and developing technologies that work at the atomic, molecular or macromolecular level of the scale of 1 to 100 nanometers**
- **Involving structures, devices and systems that have novel properties and functions because of their scale**
- **Controlling or manipulating materials at the atomic level**

What is New about Nanotechnology?

- **Nanomaterials have different properties from bulk chemicals because of**
  - **Scale**
  - **Surface area per unit of mass**
  - **Quantum effects**
- **The physical, chemical, and biological properties of materials at the nanoscale differ in fundamental and valuable ways from bulk matter.**
- **It is *our ability* to measure, manipulate and process at the nanoscale that is new**

Some Characteristics that Engineered Nanomaterials Share with Other Emerging Technologies

- Rapid introduction
- Broad distribution
- Complexity and range of materials
- Complex materials flows/multiple sources
- Hard to study and characterize risks
- Knowledge is limited, uncertain, and indeterminate regarding:
  - Cumulative and interactive effects
  - Potential effects from low level exposures

Penetration of Nanotechnology in Automobile and Automotive Parts Manufacturing

- Market for nano tire additives is already mature.
- Markets for nanoclay composites, wear and friction-resistant nanocoatings and mechanically enhanced nanocomposites are maturing.
- Many other nanomaterials are in the research and prototype stages, where occupational exposure, albeit to fewer workers, still occur.
  - Many of these are expected to enter the market within the next five years.

Nanomaterials that have already Entered the Automotive Market

- metal oxide nanopowder paint additives
- nanomagnetic fluid components
- anti-bacterial interior nanocoatings
- nanoclay polyurethane foams
- thermally conductive nanocoatings
- nanopowder catalysts and fuel cell additives
- carbon nanotube electrostatic paint
- nanofiber composites
- nanofluid coolants
- nanometal soldering additives
- anti-scratch nanocoatings
- anti-corrosion nanocoatings
- nanofiber engine filters and air filters

Potential Hazards of Engineered Nanomaterials

- **Size, shape, and strength create new hazards – new distribution; higher surface to mass, higher reactivity**
- **Hazards depend on:**

- Small size	**- Surface area**
- Shape	**- Chemical composition**
- Purity	**- Aggregation**
- Solubility	**- Dissolution and degradation (during release)**

Potential Hazards of Engineered Nanomaterials

- **Greater surface areas means increased bioactivity**
- **Inhaled nanoparticles reach deeply into the respiratory tract**
- **Nanoparticles can pass the blood/brain barrier[1] and some evidence of passage of blood testis barrier[2]. These properties can be therapeutic or toxic**
- **Small size and shape leads to rapid uptake into cells and more effective transport to target organs.**
- **Nanomaterials may be "carriers" for other more toxic molecules.**

[1] JM Koziara, PR Lockman, DD Allen and RJ Mumper (2003). In Situ Blood–Brain Barrier Transport of Nanoparticles. Pharmaceutical Research: 20(11), 1772-1778
[2] Lan Z, Yang WX. Nanoparticles and spermatogenesis: how do nanoparticles affect spermatogenesis and penetrate the blood-testis barrier. Nanomedicine (Lond). 2012Apr;7(4):579-96.

Petrochemical Revolution

- **Produced many benign and beneficial substances. *The same can be expected for many nanomaterials.***
- **Also produced tetraethyl lead, DDT and Benzene. *We can expect that some nanomaterials will be bad actors as well***
- **Lesson: technological revolutions must be accompanied by regulatory regimes that can adequately distinguish between benign and harmful technologies and can restrict harmful technologies *before* exposure is widespread**

Reactive Policy: Making the Same Mistake Again

- **Develop technology without constraints and fix problems once they occur**
- **Wait until we have perfect evidence before establishing OELs**
- **Treat uncertainty and lack of information about harm as evidence of safety**
- ***This amounts to taking no action until the body count is indisputably large***

Lessons from Past Policy Mistakes

- **Investigate potential hazards of a new technology before it gets widely introduced**
- **Assume that, when dealing with complex technologies, hazard information will always be incomplete**
- **Act on partial and/or accumulating knowledge**
- **Design technologies with an eye towards potential health, safety, environmental implications**

Setting Nanomaterial OELs

- Develop ways to rapidly assess hazard and degree of concern
- Prioritize for immediate action those uses of greatest concern
- Develop lists of nanomaterials of concern

Uncertainty in Setting Nanomaterial OELs

- **Information is always incomplete and more so for new materials**
- **OELs may need to be revised as additional information becomes available**

Control Banding May Offer Methods for Dealing with Incomplete Information and Uncertainty

CB Nanotool Risk Level Matrix

Probability

Severity

	Extremely Unlikely (0-25)	Less Likely (26-50)	Likely (51-75)	Probable (76-100)
Very High (76-100)	RL 3	RL 3	RL 4	RL 4
High (51-75)	RL 2	RL 2	RL 3	RL 4
Medium (26 -50)	RL 1	RL 1	RL 2	RL 3
Low (0-25)	RL 1	RL 1	RL 1	RL 2

RL 1: General Ventilation
RL 2: Fume hoods or local exhaust ventilation
RL 3: Containment
RL 4: Seek specialist advice

Paik, S, Zalk, D, and Swuste, P. (2008) Application of a pilot control banding tool for risk level assessment and control of nanoparticle exposures. *Annals of Occupational Hygiene* 52 (6): 419-428.

Livermore Probability Scores

- Estimated amount of material used (25 pts)
- Dustiness/mistiness (30 pts)
- Number of workers with similar exposure (15 pts)
- Frequency of operation (15 pts)
- Duration of operation (15 pts)

Livermore Severity Scores

- Nanomaterial: 70% of Severity Score
  - Surface Chemistry (10 pts)
  - Particle Shape (10 pts)
  - Particle Diameter (10 pts)
  - Solubility (10 pts)
  - Carcinogenicity (7.5 pts)
  - Reproductive Toxicity (7.5 pts)
  - Mutagenicity(7.5 pts)
  - Dermal Toxicity (7.5 pts)
- Parent Material: 30% of Severity Score
  - Occupational Exposure Limit (10 pts)
  - Carcinogenicity (5 pts)
  - Reproductive Toxicity (5 pts)
  - Mutagenicity (5 pts)
  - Dermal Toxicity (5 pts)

(Maximum points indicated in parentheses)

Handling Missing Information

- **For a given hazard category, the Livermore group gave an unknown rating 75% of the value of a high hazard rating, which is higher than a medium rating**
- **The group assigned a risk level of 3 (second highest) to substance for which all hazards are unknown. Risk level 3 requires containment.**
- **If one risk category is high and all others are unknown, the substance was assigned to the highest risk level**
- **The authors indicated that this system was an incentive to seek information.**

Summary

- Learn from pasts mistakes
- Act before there are countable bodies
- Reduce and prevent exposure while information is still incomplete
- Control banding may be a way of controlling exposures with incomplete information