



The Department of  
Environmental  
Health and Safety

# Nanowaste Disposal (No Small Problem)

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# Objectives

- Review existing waste disposal regulations with regard to nanomaterials.
- Review the common nanomaterial inventory and provide sample waste determinations.
- Suggest possible strategies for managing nanowaste.
- Comment on the EPA's nanotechnology white paper.

# Question #1

What do lead, asbestos,  
PCBs and nanomaterials  
all have in common?

## Question #2

Which EH&S regulations  
were broken when waste  
was buried at Love Canal?

# History tells us.....

- Useful materials have, on occasion, later been found to negatively impact human health and the environment.
- Without adequate knowledge and/or regulatory guidance, poor decisions have been made managing waste.
- History can repeat itself with nanomaterials unless we are really careful.

# Existing Waste Regulations

- Resource Conservation and Recovery Act (RCRA)
- 40 CFR 260 – 279
- Listed hazardous waste
- Characteristic hazardous waste
- Storage time limitations
- “Cradle to Grave” tracking of waste

# Listed Hazardous Waste?

- Not likely!
  - Sole active ingredient
  - Used materials are not listed waste
- My review of nanomaterials did not reveal chemicals on the "P-list" or "U-List"
- Subject to change

# Characteristic Hazardous Waste?

- Four characteristics
  - Ignitability
  - Corrosivity
  - Reactivity
  - Toxic
- Material size can affect waste characteristics
  - Zinc vs. zinc powder
  - Aluminum vs. aluminum powder

# Ignitable Waste (D001)

- Liquid with a flash point less than 140 °F
- Solid capable of causing fire through friction, absorption of moisture or spontaneous chemical changes and, **when ignited, burns so vigorously and persistently that it creates a hazard**
- Ignitable compressed gas
- An oxidizer

# Corrosive Waste (D002)

- Aqueous, pH < 2 or >12.5
- Liquid and corrodes steel
- Nanomaterials, being solid can't be corrosive
- Nanomaterials suspension media?

# Reactive Waste (D003)

- Normally unstable and readily undergoes violent change
- **Reacts violently with water**
- Forms potentially explosive mixtures with water
- Generates toxic gases when mixed with water
- Cyanide or sulfide bearing waste
- Capable of detonation or explosive reaction

# Toxic Waste

- 10 Volatile organics
- 11 Semi-volatile organics
- 8 Pesticide/herbicide
- 8 Metals
  - arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver

# Waste Determinations

- Failure to make a waste determination is the most common violation in RCRA.
- Waste may be “declared” hazardous with little documentation.
- Waste determined to be non-hazardous requires analysis or good “generator knowledge”.
- Need to know the nanomaterial and the media it is stored in.
- Non-RCRA does not always mean non-hazardous.

# Fullerenes & Nanotubes

- All carbon or carbon with functional groups
- Conflicting hazard data
  - Some sources say they are “highly flammable”
  - Others indicate NFPA = 0
- Ignitability likely dependent on physical state
  - Pelleted, powdered, in solution
- Disposal suggestions
  - Dissolve in flammable solvent (incin/BIF)
  - Incinerate as a solid

# Elemental Nanoparticles

- Carbon, silicon or one of many metals
- Carbon
  - Likely ignitable (D001)
  - Mix with solvent for incineration
- Silicon
  - Available dry or in water, solvents or oil
  - Likely in suspension when received as waste
  - Stabilize for Subtitle C landfill (water)
  - Incineration (solvents, oil)
- Metals
  - Many are RCRA hazardous waste
  - Stabilize for Subtitle C landfill

# Binary Compounds

- Primarily metal oxides and nitrides
- May be RCRA hazardous waste
  - Toxic metals
  - Oxidizers
  - Water reactive (aluminum nitride)
- Waste management
  - Consider reuse (many are expensive)
  - Consider long term storage for non-hazardous
  - Lab pack hazardous for Subtitle C landfill

# Complex Compounds

- Primarily doped metallic oxides and alloys
- May be RCRA hazardous
  - Metals
- Waste management
  - Reuse (extremely expensive materials)
  - Long term storage (non-hazardous)
  - Subtitle C landfill (hazardous)

# Quantum Dots

- Nanocrystals in water
- Can be as small as 2 – 10 nm!
- All contain one or more toxic metal
  - Cadmium, lead, mercury, selenium
- Waste determination
  - Declare hazardous or analyze for total metals
- Waste management
  - Reuse
  - Stabilize for Subtitle C landfill
  - Use super absorbent polymer for stabilization

# Nanowires

- Metals, metal oxides and metal nitrides that are 10s of nm wide with L:W aspect ratios of 1000 or more.
- Many contain RCRA metals, such as lead and silver.
- Some are water reactive.
- Dry material should be lab packed for Subtitle C landfill.
- Liquid suspensions solidified before lab pack and Subtitle C landfill.

# Nanofibers

- Nonwoven fibers less than 100 nm diameter.
- Primarily polymer, carbon and a few semiconductors.
- My search did not encounter any nanofibers that would be considered RCRA hazardous waste.
- Organics are suitable for incineration.
- Inorganics for lab pack until we have better data.
- Consumer products are presently managed at Subtitle D landfills.

# Nanowaste Hierarchy

- Reuse/recycle
  - Cost of material inspires conservation
- Incinerate organics
  - Mix with solvent or ship solid
- Labpack RCRA inorganics
  - Storage limitations force disposal (SAA?)
  - Subtitle C landfill
- Long-term storage for non-RCRA inorganics
  - Until we know the best management practice
  - Subtitle C landfill as the alternative
- Subtitle D landfill

# EPA White Paper

- Workgroup established in 2004
- External Review Draft published 12/02/05
  - 134 pages, mentions RCRA 15 times
- Peer Review Report published 07/07/06
  - 150 pages, mentions RCRA 3 times
  - “discussion of RCRA is very cursory”
  - “focuses almost exclusively on Subtitle C”
  - “neglects to consider a number of relevant topics”
    - Presence in consumer products
    - Nonhazardous industrial material
    - Potential for exhibiting waste characteristics
    - Secondary use of recycled materials

# EPA White Paper

- Final White Paper published 02/15/07
  - 132 pages, mentions RCRA 6 times
  - Discusses potential environmental benefits
  - Summarizes potential risks
  - Review of research needs
    - Chemical identification/characterization
  - No guidance for “right now”
    - Not even where we are going

# Nanomaterial Regulation

- RCRA
  - Presently no listed wastes
  - Many characteristic wastes
  - Watch the Federal Register for changes
- TSCA
  - Manufacturers must submit hazard data
  - Potential for material recall, restriction or bans
  - Watch the Federal Register for changes
- CERCLA
  - Will address tomorrow what we manage incorrectly today
  - Use Subtitle C landfills

# Questions & Discussion?

“One doesn't discover new lands without consenting to lose sight of the shore for a very long time.”

- Andre Gide