Nanomaterials and the Environment

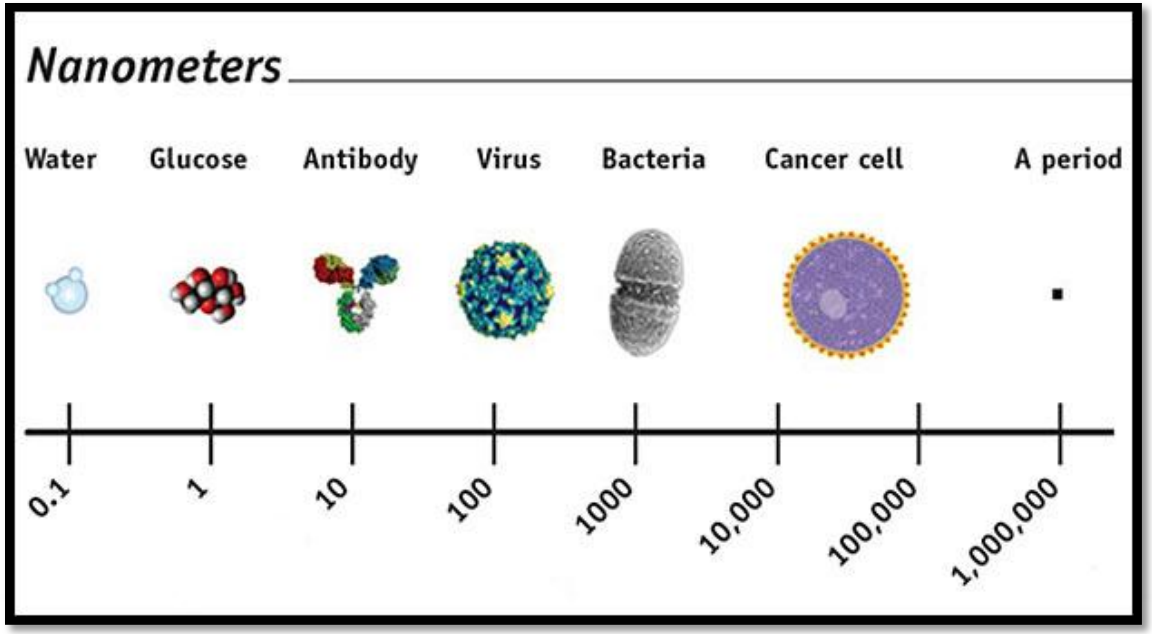
Stephanie C. Bolyard, Graduate Research Assistant

Kunal Nayee, Undergraduate Research Assistant

Debra R. Reinhart, PhD, PE, BCEE

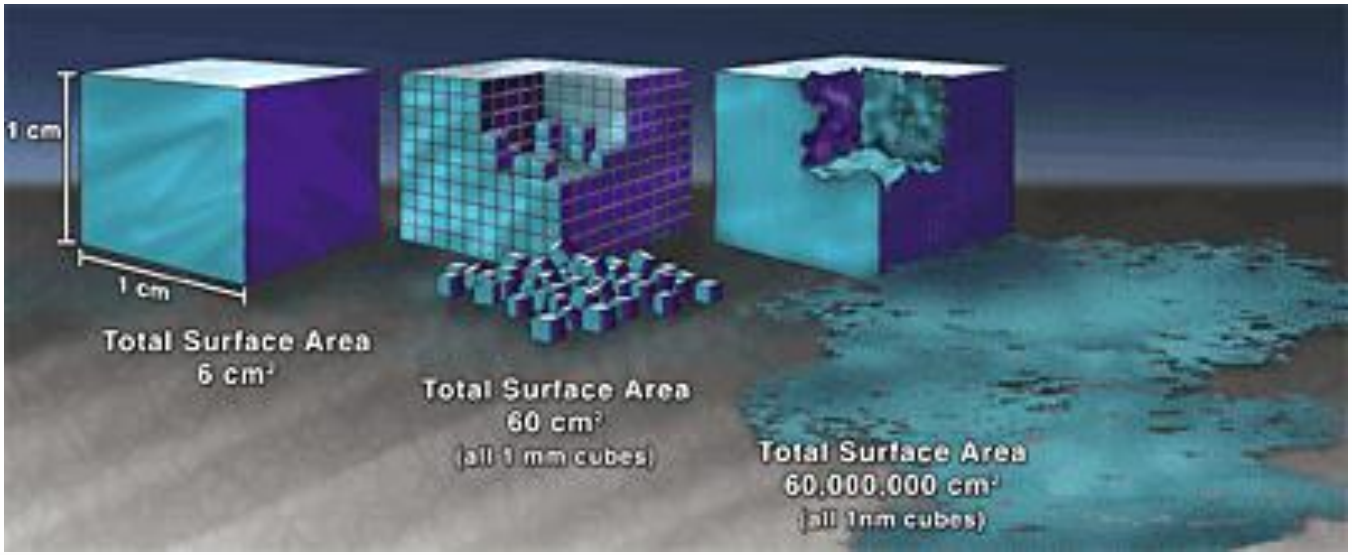
What is a Nanoparticle?

- Nanoparticles are defined as particles with three dimensions less than 100 nm (British Standards, 2007),
- Nanomaterials are identified as a material with at least one dimension between 1 nm to 100 nm (Roco, 2003).



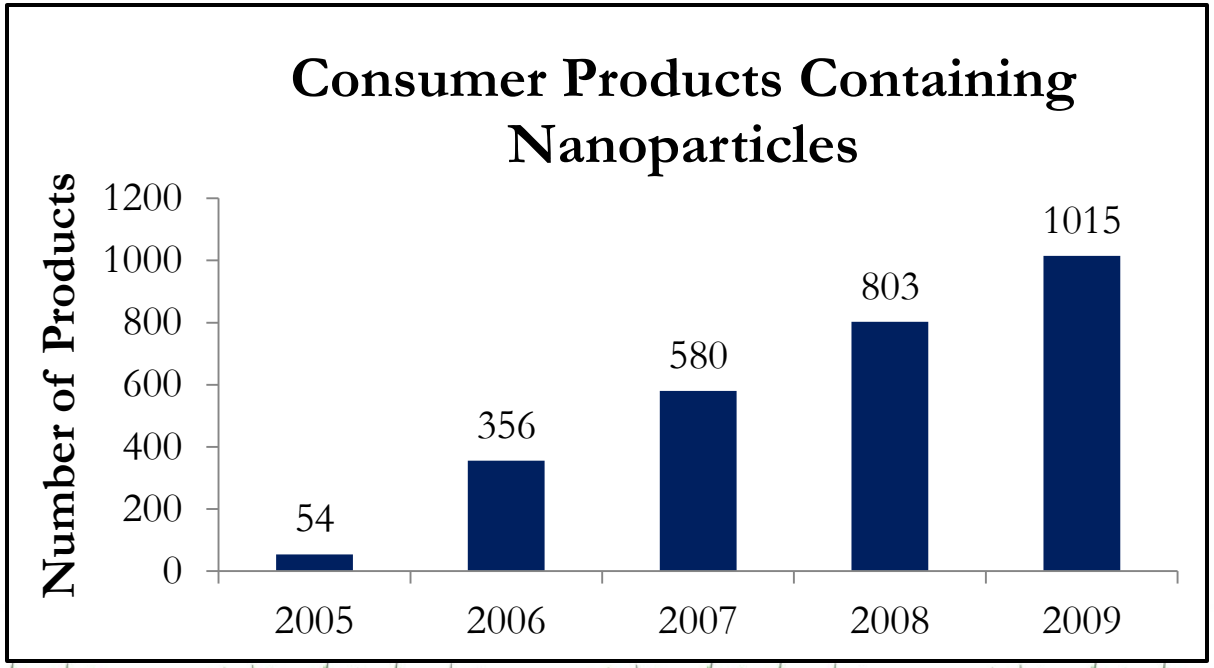
Properties of Nanoparticle

- NMs possess large surface area and they exhibit unique properties (such as electronic, optoelectronic, thermal and catalytic) in comparison to their bulk counterparts, thus making them particularly useful



Use of Nanoparticles

- By 2014 nanotech products are projected to account for 15% of products produced globally, totaling USD 2.6 trillion
- The use of engineered nanomaterials (NMs) in commercially available products is increasing exponentially.

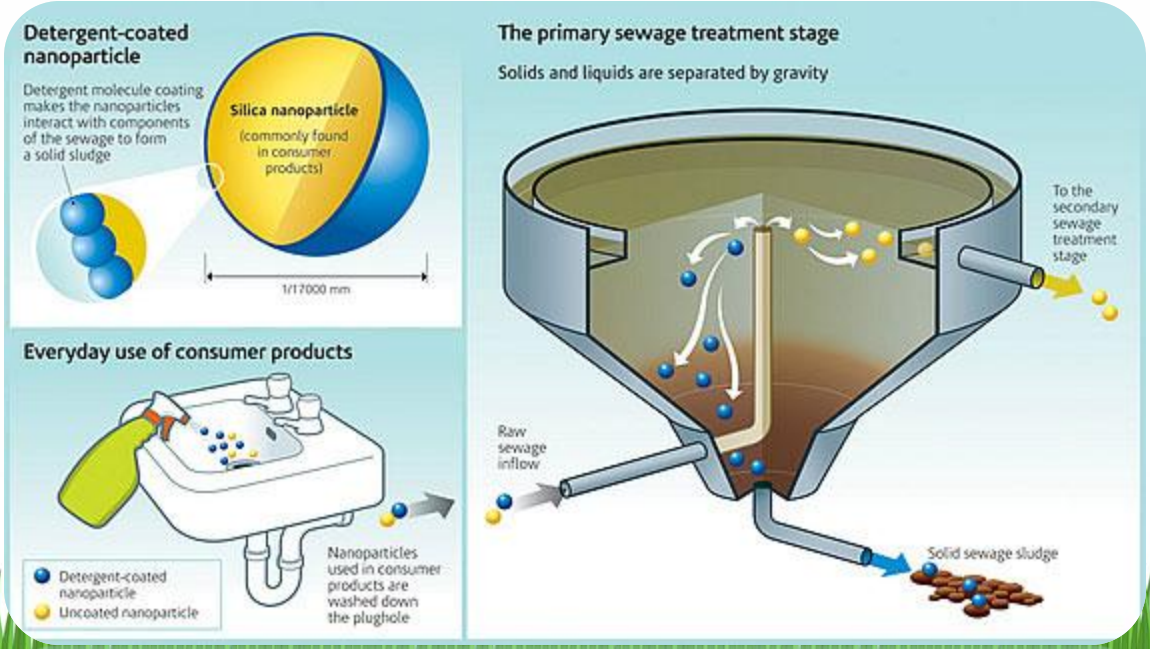


Use of Nanoparticles

- Project on Emerging Nanotechnologies reported that 1,015 nanotechnology consumer products are currently available.
- Health and fitness products dominate the inventory with a total of 605 products available on the market.
- NMs have been incorporated into cosmetics, clothing, and personal care products (such as Ag (as an antibacterial agent), SiO_2 (as a polishing and binding agent), TiO_2 (in solar cells) and ZnO (as a UV-absorber in sun screen lotion).

NMs and Wastewater Treatment – Potential Pathways

- Bind with organic matter and removed during treatment
- Bind with organic matter and transport to the environment
- Adhere to selective surfaces (i.e. membrane treatment)
- Bind other contaminants and transport to the environment
- Enter sludge and transport to landfill, land application
- Become airborne when sludge is dried

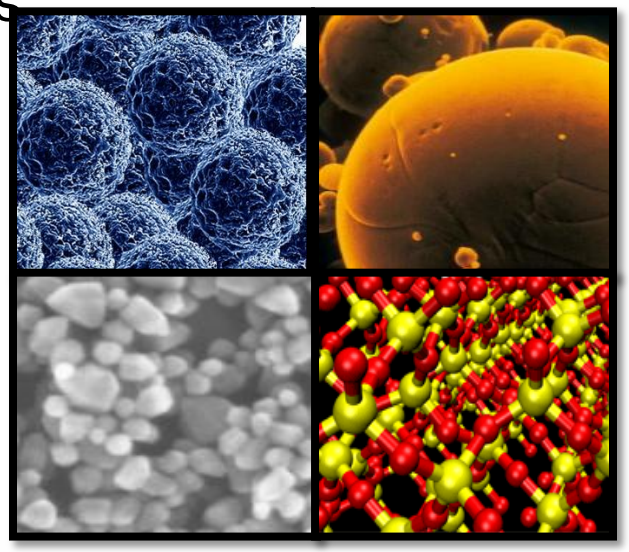


NMs and Landfills – Potential Pathways

- Leached by infiltrating liquids
- Adhere to surfaces
- Aggregate and removed by solid waste
- Stabilized in leachate
- Inhibit biological landfill processes
- Move through engineered containment system

UCF Research

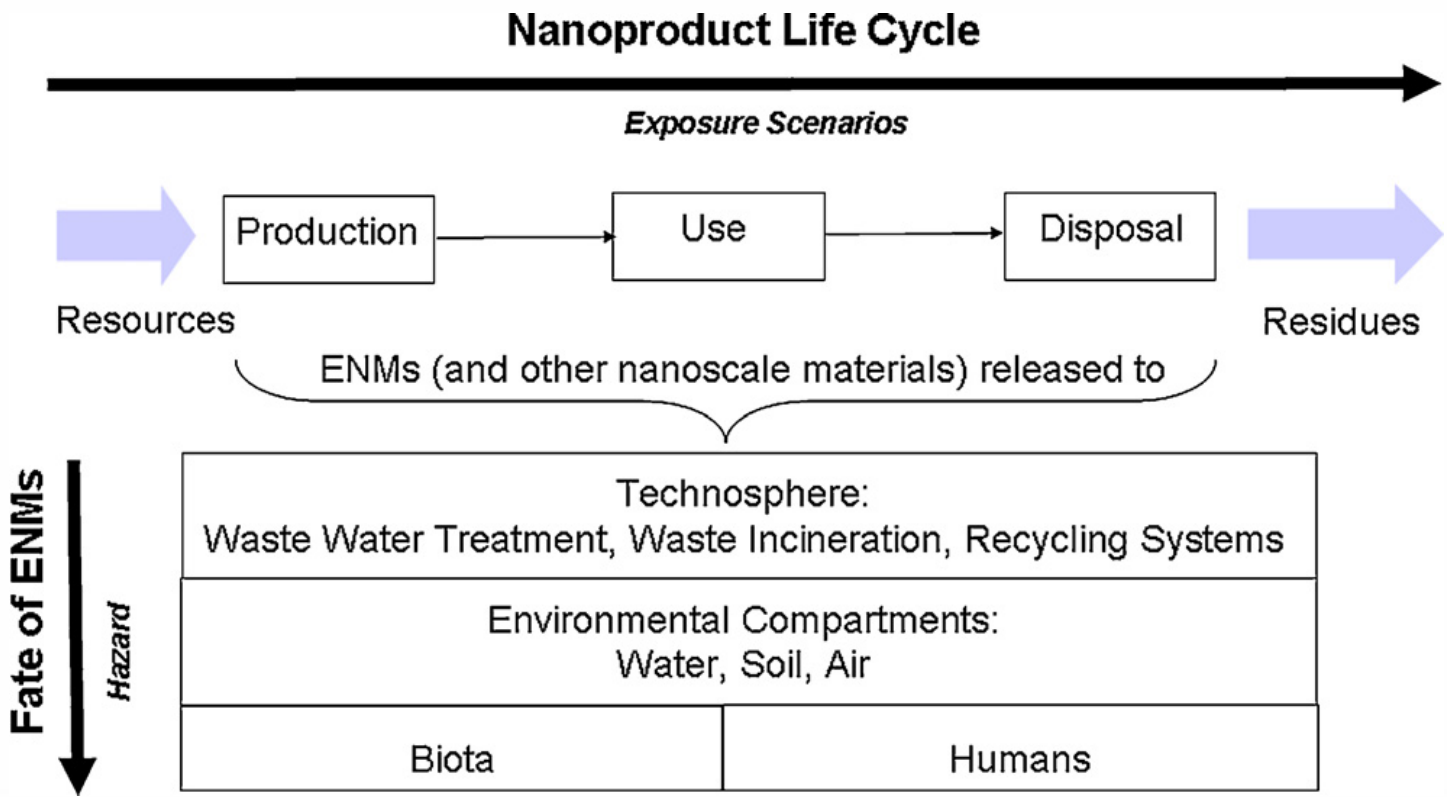
- Fate of Nanomaterials in MSW Landfills
  - MSW: Residential and Commercial Garbage
- Purpose: evaluate the potential inhibitory effects on landfills processes
  - Aerobic: with O_2
    - Leachate Treatment
  - Anaerobic: without O_2
    - Methane Production
- Nanoparticles that will be studied
  - ZnO, TiO_2, Ag
- The specific objectives are to evaluate:
  - How the presence of metallic ENPs will affect biological landfill processes
  - How the presence of leachate constituents (e.g. organic matter, ammonia, and pH) will affect ENP characteristics and
  - How the presence of ENPs will affect leachate treatment



(A) Nano Silver (Ag), (B) Titanium Dioxide (TiO_2), (C) Zinc Oxide (ZnO), (D) Silicon Dioxide (SiO_2).

Life Cycle Analysis

Must consider all life stages of NMs and nanoproducts and all exposure situations and routes

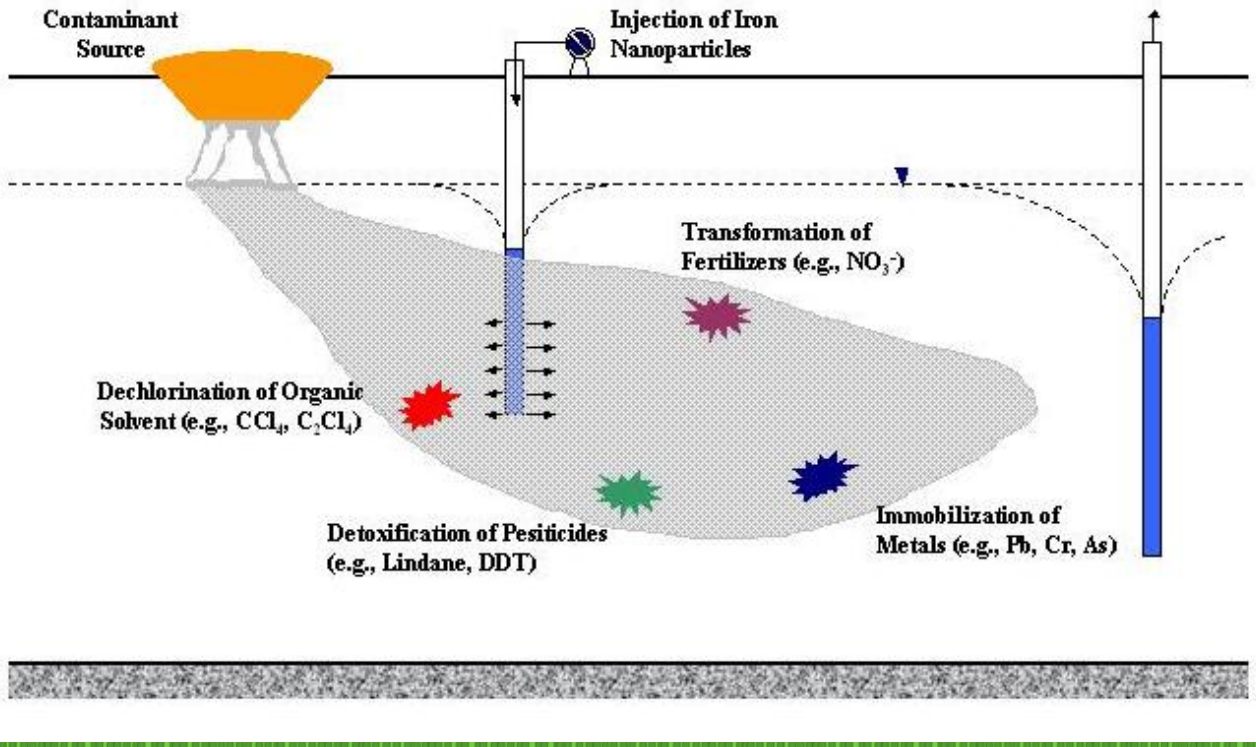


C. Som et al, 2010

Positive Impacts on Environment

- Environmental cleanup and remediation
- Improved uptake of fertilizers
- Chelating agents
- Replace hazardous feedstocks
- Environmentally responsible nanoproducts

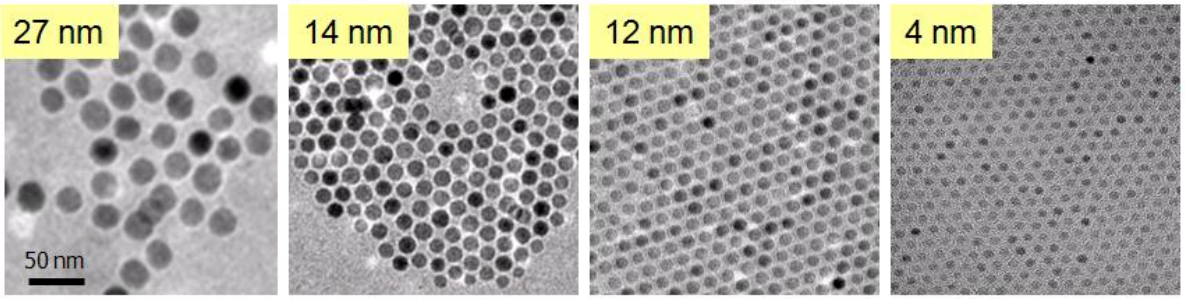
Zhang, 2003

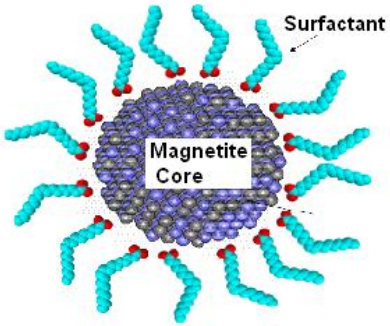


Environmental Uses of NMs

- TiO_2 to degrade pollutants and as a disinfectant
- Nanostructured sorbent can capture air and water pollutants (e.g. magnetite (Fe_3O_4) coated with mesoporous silica)
- Catalysts to reduce mobile source emissions
- Carbon nanotubes are used for the removal of metals from water

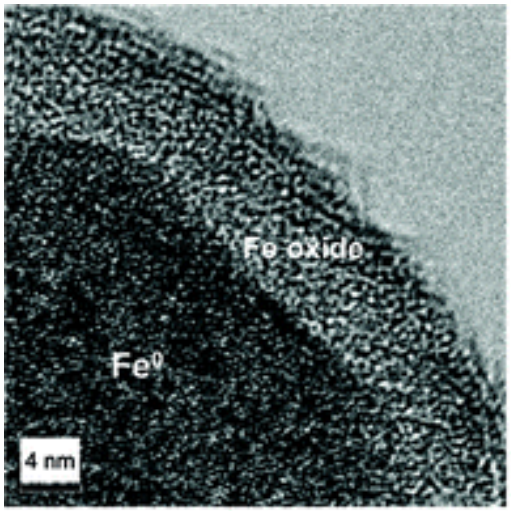
$$FeO(OH) + OA \xrightarrow[ODE]{\Delta} Fe(Oleate)_3 + H_2O\uparrow \xrightarrow[ODE]{\Delta 320^{oC}} Fe_3O_4 \text{ nanoparticles}$$

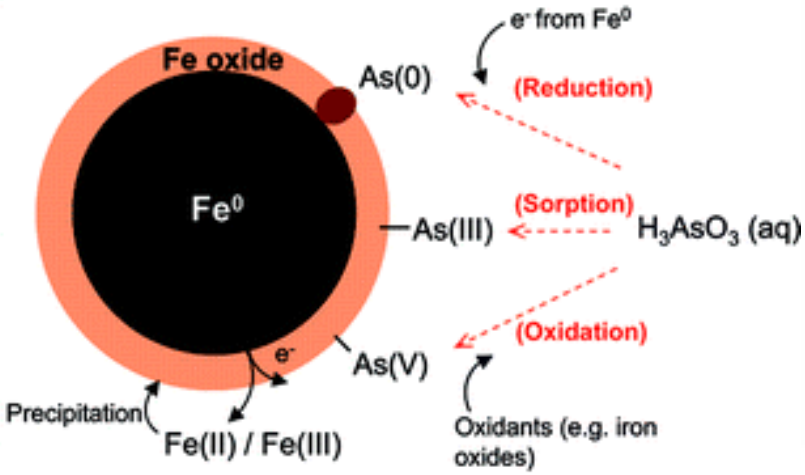




Environmental Uses of NMs

- Zerovalent iron nanoparticles or Iron nanoparticles for dehalogenation of PCBs, organochlorine pesticides and organic solvents in groundwater
- Amphiphilic polyurethane (APU) nanoparticles for removal of PAHs from contaminated soils.

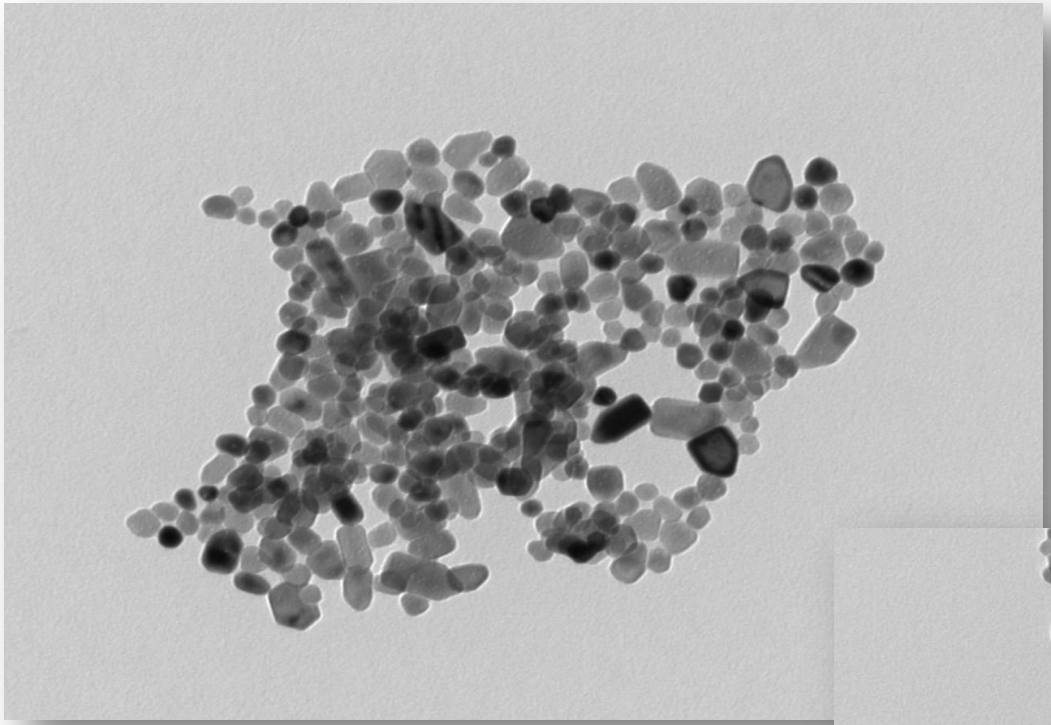




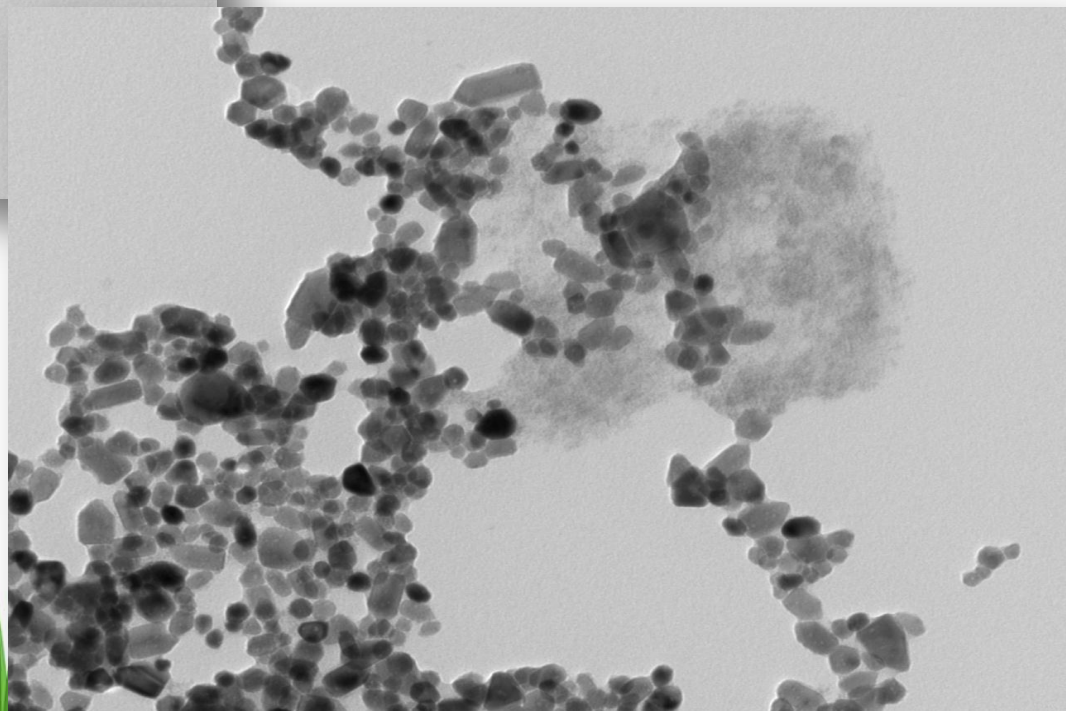
Conclusions

- The safe manufacturing, use, and disposal of NMs demands our attention.
- We have the unique opportunity to consider the environmental implications of a new class of material as they are developed, as opposed to the historical practice of cleaning up long after the release.
- Evaluation of NM environmental risks requires interdisciplinary team

Analytical Challenges

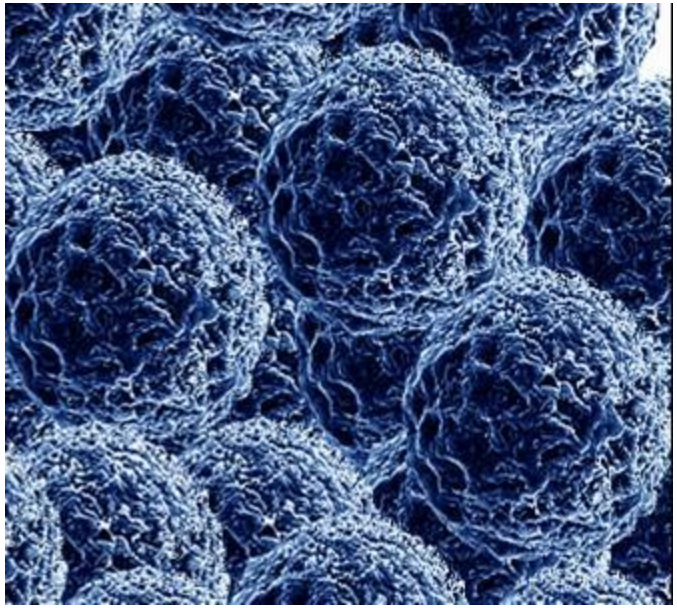


ZnO Nanoparticles



ZnO Nanoparticle in Leachate 18 Days

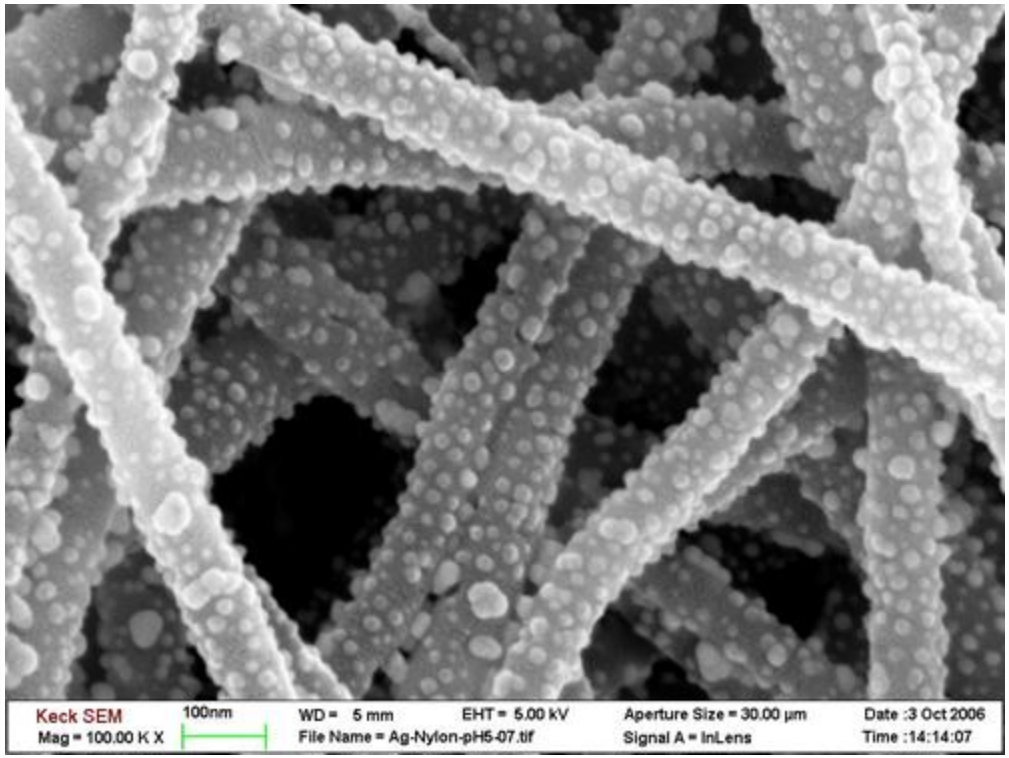
Nanoparticles



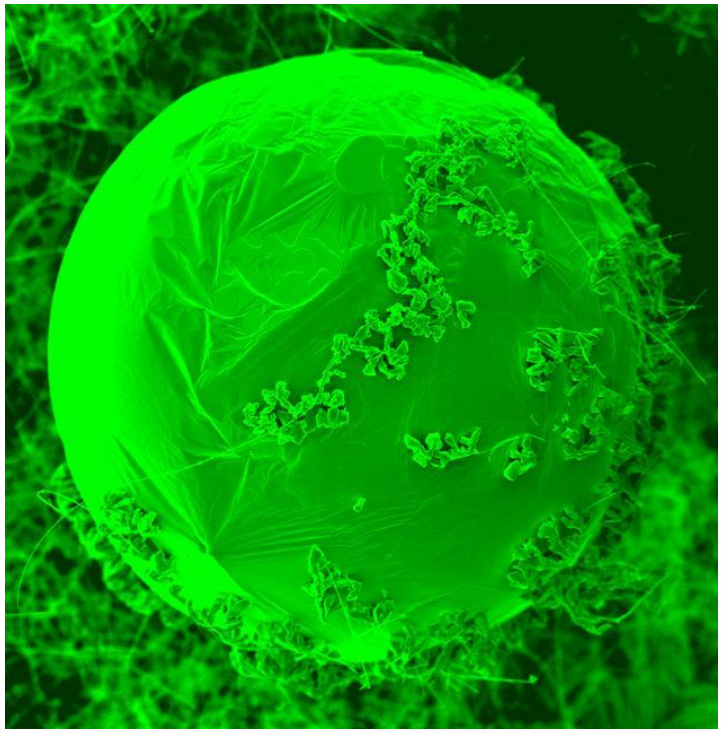
Silver Nanoparticles

White Light Nanoparticle (silver nanoparticle)
This nano-mirror works in tandem with a microscope to reveal not only the outer but also the inner microscopic structure of a specimen.

Nanoparticles



Electrospun nylon 6 nanofibers decorated with surface bound Ag nanoparticles. Use: antibacterial filtration



Combination of two naturally occurring molecules chlorophyll and lipids. Uses: Filled with drugs to treat the tumor, and photoacoustic imaging, which combines light and sound to produce a very high-resolution image

Application of Nanoparticles