Nanotechnology and the Environment: Benefits and Risks

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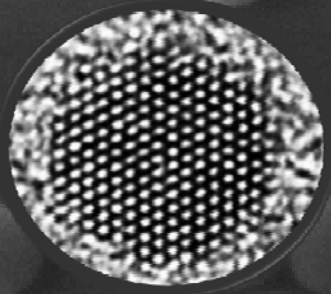
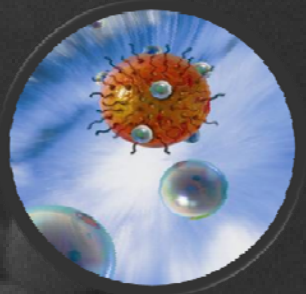
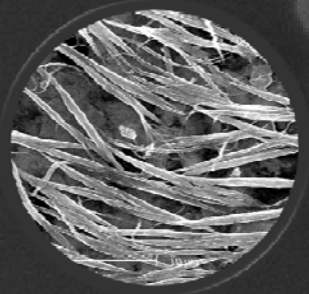
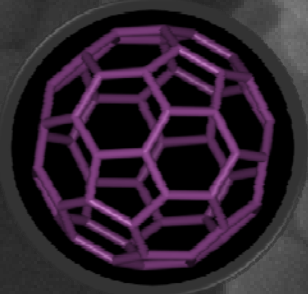
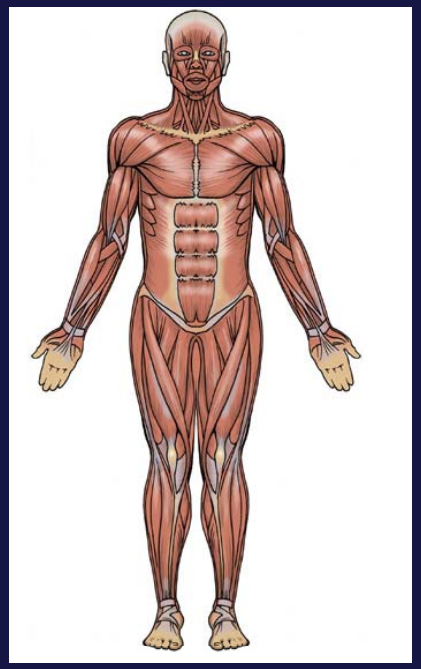
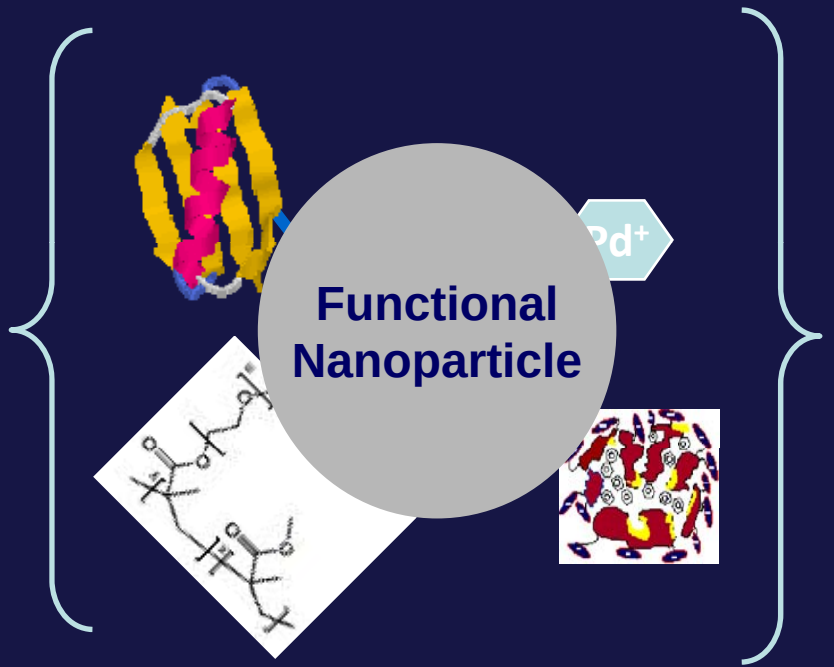





Center for Biological & Environmental Nanotechnology

Research | **Education** | **Outreach**





Theme 2: Nanoparticles for Bioengineering

Theme 1: Nanoscience at the Wet/Dry Interface

Theme 3: Nanoparticles & Environmental Engineering

International Council on Nanotechnology

INCLUSIVE

Multistakeholder cooperation

GLOBAL

International perspective

TECHNICAL

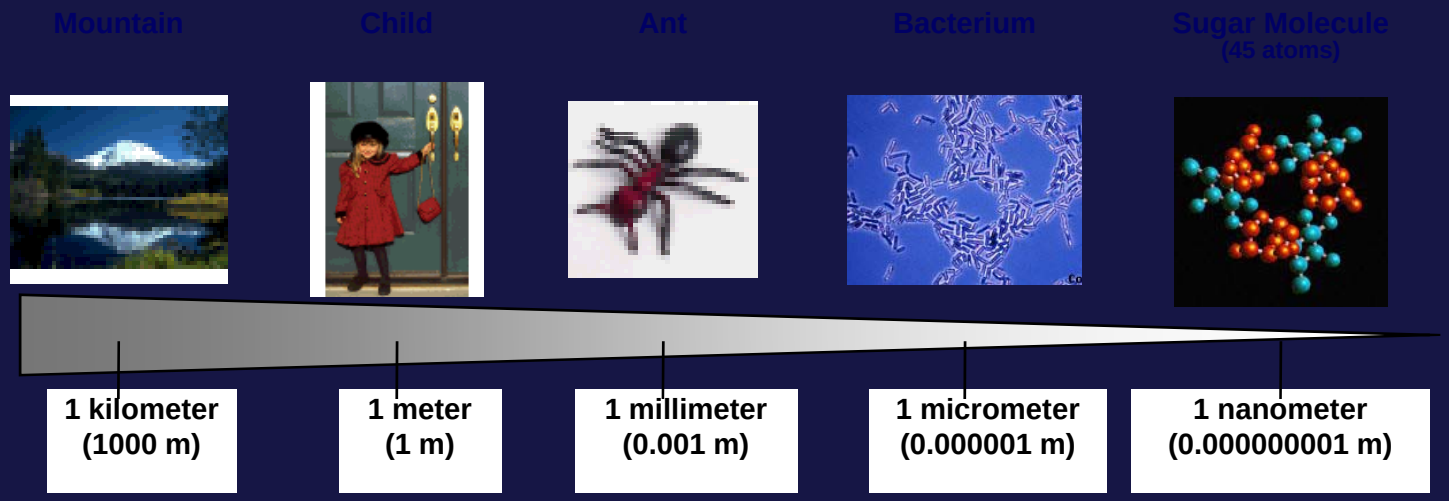
Grounded in science

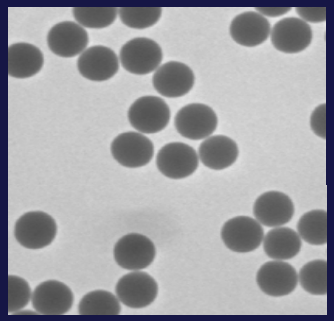
PROACTIVE

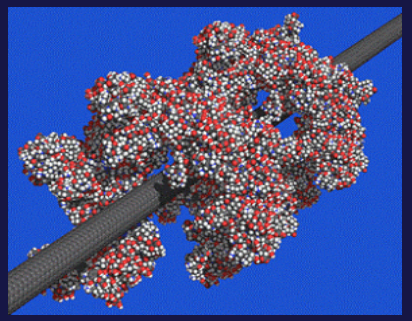
Stewards for sustainability

What is Nanotechnology?

Nanotechnology is the study and use of materials with nanometer-scale dimensions.







Nanomaterials

Materials

~1-100 nm

Special properties*

Different Types of Nanomaterials

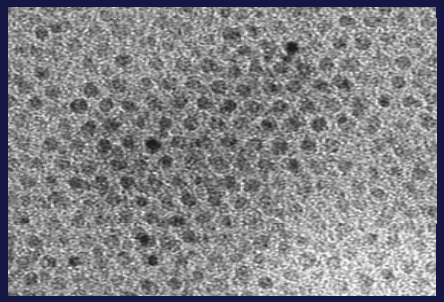
Engineered nanomaterials are very diverse with near limitless tunability

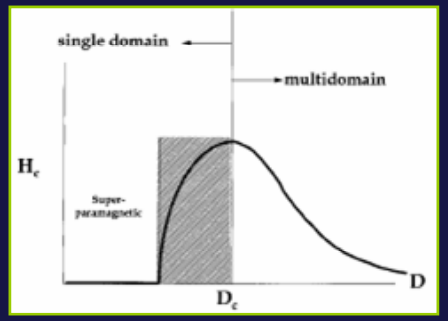
Naturally Occurring	Human Origin (incidental)	Human Origin (engineered)
Forest fires	Cooking smoke	Metals
Sea spray	Diesel exhaust	Quantum dots
Mineral composites	Welding fumes	Buckyballs/Nanotubes
Volcanic ash	Industrial effluents	Sunscreen pigments
Viruses	Sandblasting	Nanocapsules

Nanotechnology

Size-Dependent Properties

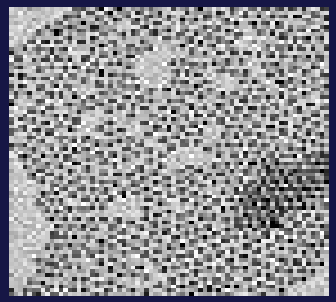
Fe_3O_4, Magnetite (4 nm)

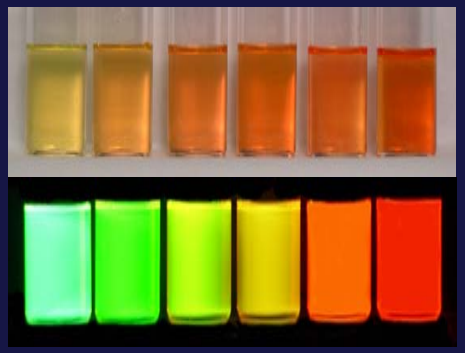




Magnetism

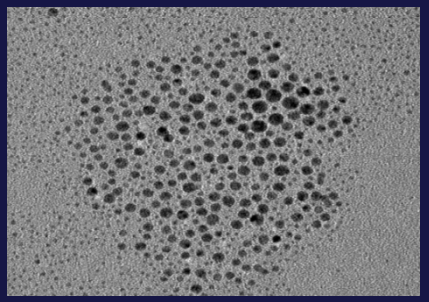
CdSe (8 nm)

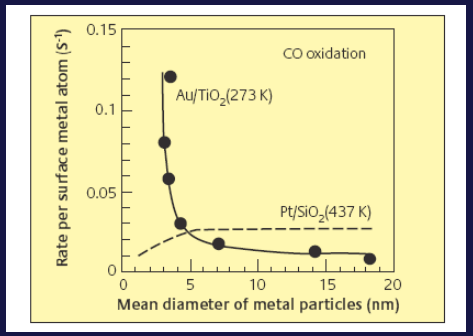




Emission

Gold (~ 10 nm)



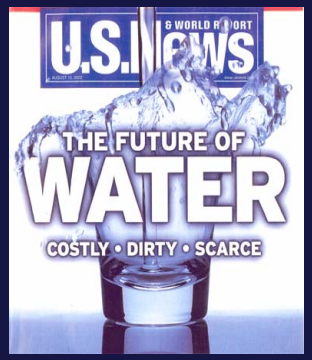


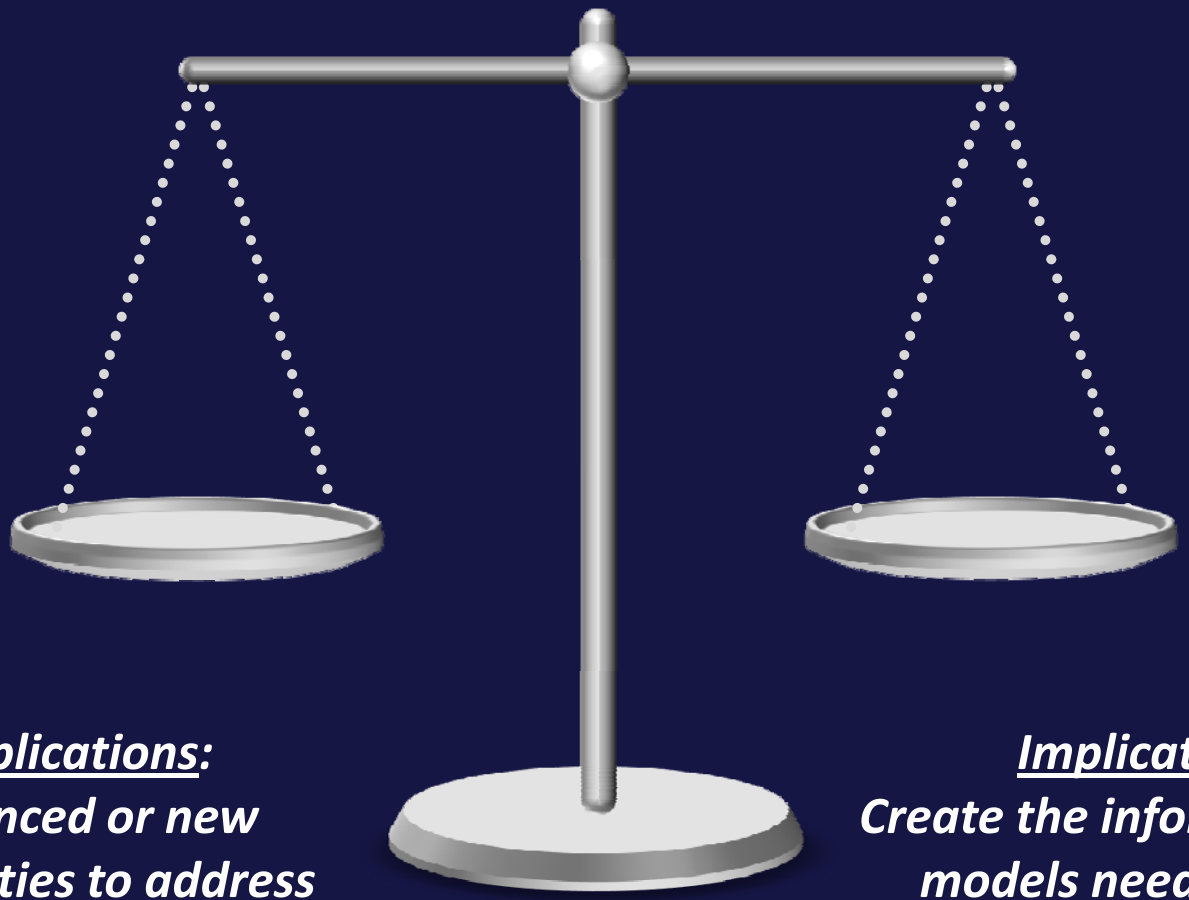
Reactivity

Special [*chemical, physical, electrical, mechanical, thermal*] properties

Special BIOLOGICAL, ENVIRONMENTAL properties

Balancing the Benefits and Risks





<u>Applications</u>:
Enhanced or new capabilities to address existing and future environmental problems.

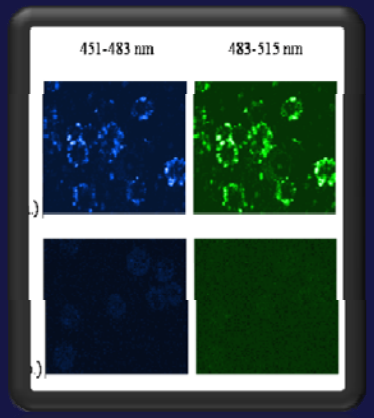
<u>Implications</u>:
Create the information and models needed to use nanomaterials in a sustainable manner

Beneficial Interactions

Cancer Therapy

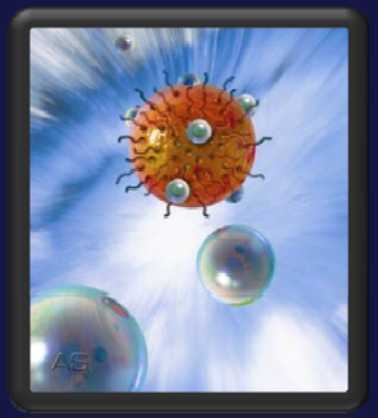
J. West et al.

Tumor Detection



R. Drezek et al.

Water Treatment

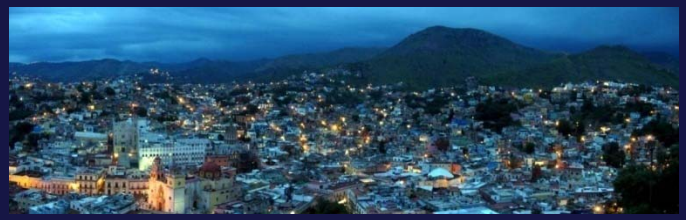


V. Colvin et al.

RICE

Pilot Project Tests Nanoparticle-Enabled Water Treatment & Reuse

"NanoRust" and novel derivatized fullerenes to remove hazardous water pollutants in municipal systems



Guanajuato, Mexico
(UN Heritage, pop. 80,000)

Wastewater Treatment Plant

Grad Student Jesse Farrell

- First known test of nanoparticles in municipal water and wastewater treatment
- Test bed will explore (1) using a sand-nanomagnetite in-line filter to remove arsenic in a well field, and (2) wastewater photo-disinfection with fullerenes
- Partnership with Municipal Water and Sewerage Authority of Guanajuato.
- **Project Team: Alvarez, Li, Tomson, Lou, Colvin**

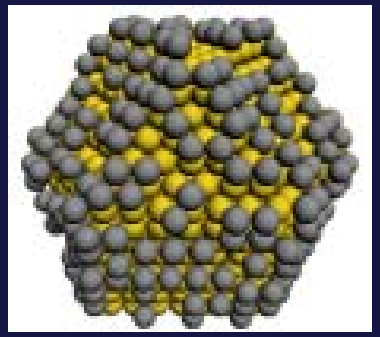
CENTER FOR BIOLOGICAL AND ENVIRONMENTAL NANOTECHNOLOGY CBEN RICE UNIVERSITY

SIMAPAG

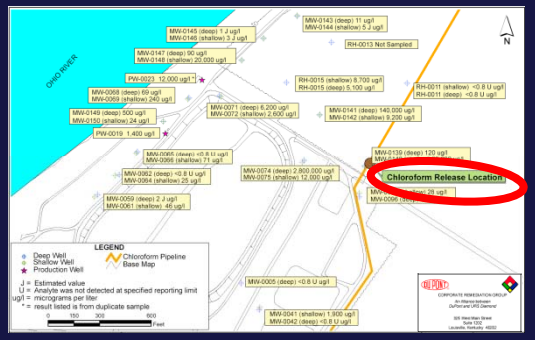
Universidad de Guanajuato

Bimetallic Nanoparticles for Reductive Catalytic Treatment

Mixed metal nanocrystals can reduce and detoxify chlorinated solvents such as TCE



Pd-on-Au



DuPont remediation site

Prof Mike Wong

- Pd-on-Au bimetallic NPs break down chlorinated compounds
- Pd catalysts work; Pd-on-Au catalysts work 100x better
- Being tested on contaminated DuPont site
- **Project Team: Wong, Alvarez**

Potential Targets of Risk

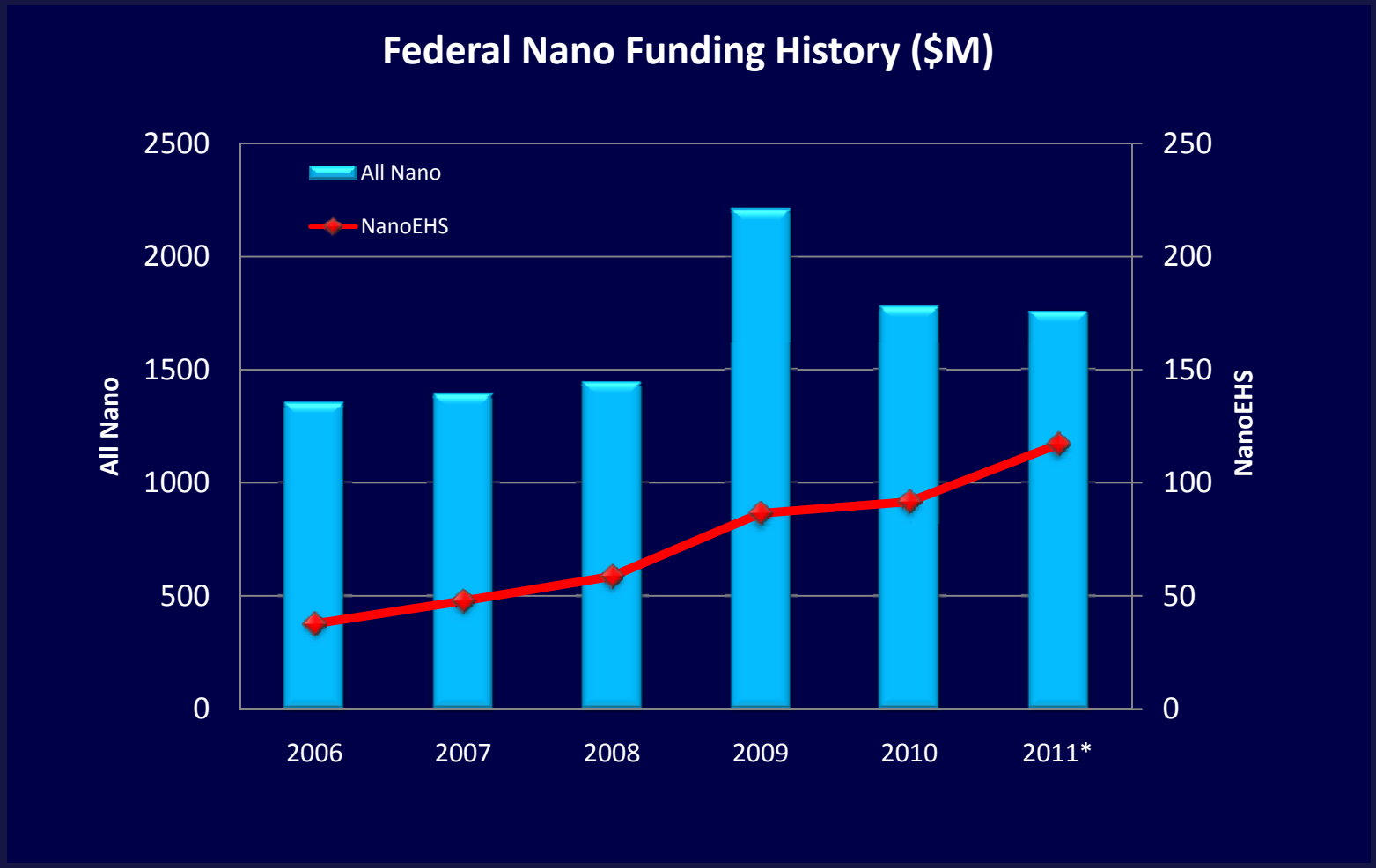
Workers

Consumers

Environment

What is known about the impacts of engineered nanomaterials?

US Federal Funding for Nanotechnology



Environmental, Health and Safety (EHS) research has made up 3-7% of the federal US nanotechnology budget

Cataloguing and Discussing the Research

nanoEHS VIRTUAL JOURNAL

The Virtual Journal of Nanotechnology Environment, Health and Safety

HOT PAPER: "Nucleation of protein fibrillation by nanoparticles," Linse, S., C. Cabaleiro-Lago, Xue, W.-F., Lynch, I., Lindman, S., Thulin, E., Radford, S. E., Dawson, K. A. (2007). Proceedings of the National Academy of Sciences of the United States of America XXX(XXX): XXX.

This work explores the role that nanoparticles play in accelerating the rate of a process called protein fibrillation, which has been linked to amyloid diseases. Amyloid diseases are a broad class of ailments that result when amyloid proteins misfold and form insoluble fibrous plaques (fibrils) that deposit in the tissues of the body. Linse et al. noted an increased rate of protein fibrillation when beta 2-microglobulin, an amyloid protein associated with complications from kidney dialysis, was put into solution with nanoparticles. Four different types of nanoparticles (copolymer particles of N-Iso-propylacrylamide (NIPAM) and N-tert-butylacrylamide (BAM), cerium oxide particles, CdSe or CdSe/ZnS quantum dots and multi-walled carbon nanotubes) each accelerated the production of small seeds upon which fibrils form most effectively. However this study did not determine that nanoparticles can cause human disease.

For a general overview on nanoparticles and amyloid diseases, see here.

For questions and answers about nanoparticles and amyloid diseases, see here.

More information.

Recent Additions the full issue

Recent Virtual Journal Issues: April 2007

Bello D, Hsieh SF, Schmidt D, Rogers E
Nanomaterials properties vs. biological oxidative damage: Implications for toxicity screening and exposure assessment
Nanotoxicology

★★★★★ *submitted by Kampers* [about me] [report this]
"This is a good example of the kind of work that needs to be done all over the world to assess the hazards of nanoparticles."

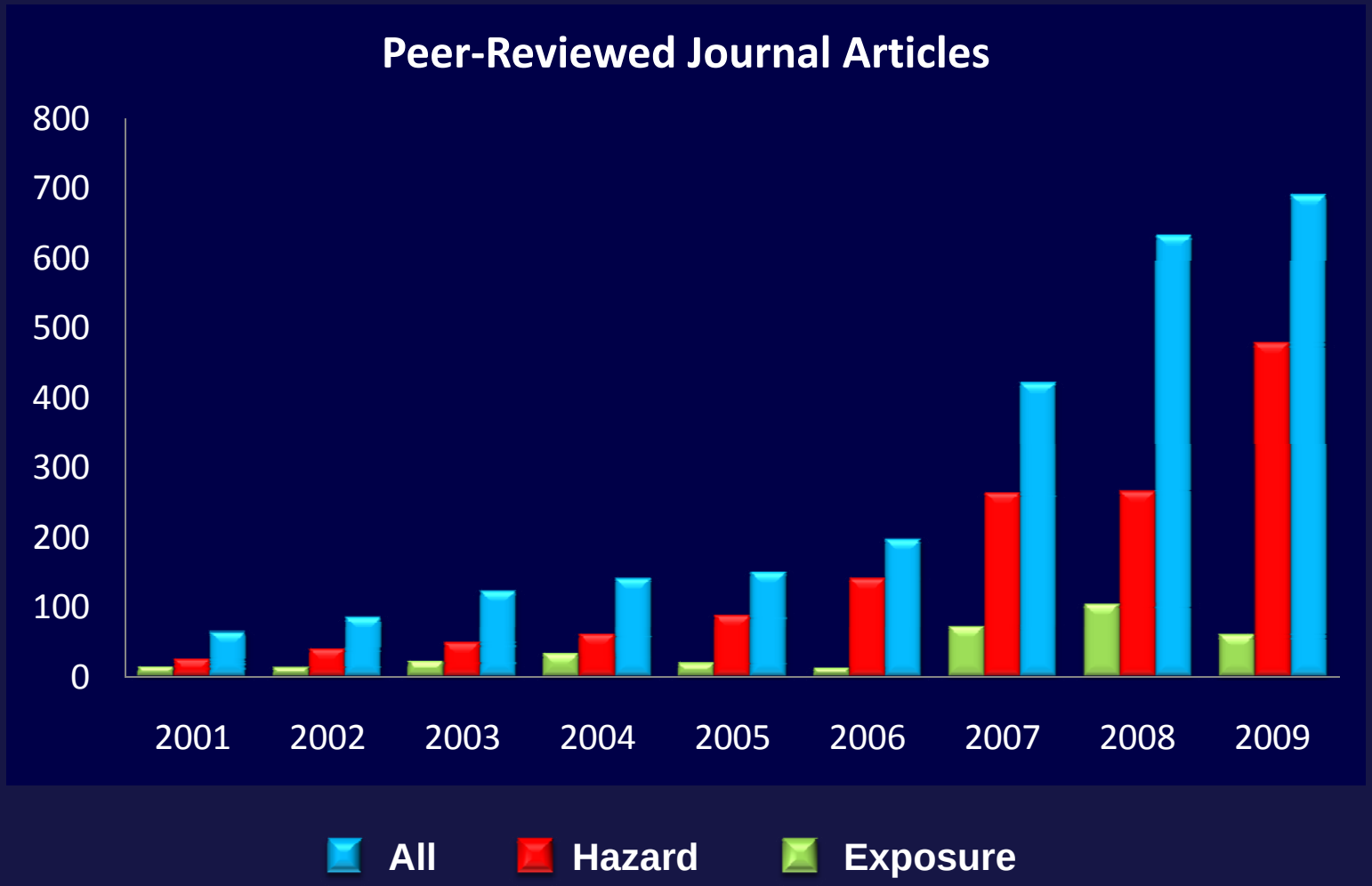
- Monthly updates
- Over 3900 records
- Backgrounders on key literature

★★★★ [out of five]
"This paper makes a major contribution to the literature …"

http://icon.rice.edu/VirtualJournal.cfm

EHS Publication Pace is Increasing…

…but exposure assessment lags behind



Source: http://icon.rice.edu/report.cfm

A Sampling of the Hazard Literature

Lung

- SWCNT and ultrafine TiO_2—Fibrosis
- Up to 50% of inhaled NPs may deposit in gas exchange region

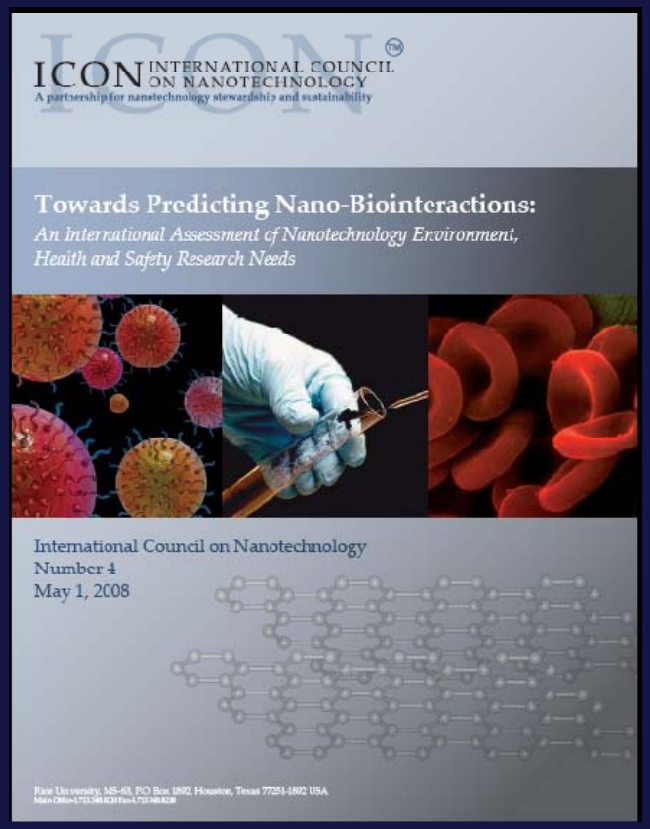
Cardiovascular

- Air pollution epidemiology
- Inflammation

Brain/CNS

- Nose to brain pathway

Info Needs for Predicting Nano Impacts



http://tinyurl.com/cbxogv

Towards Nanomaterial Classes

(January 2007)

- *Need tools and models able to describe dynamic nature of NMs throughout lifecycle*
- *Need to correlate the functional properties of NMs with potential for biointeraction*

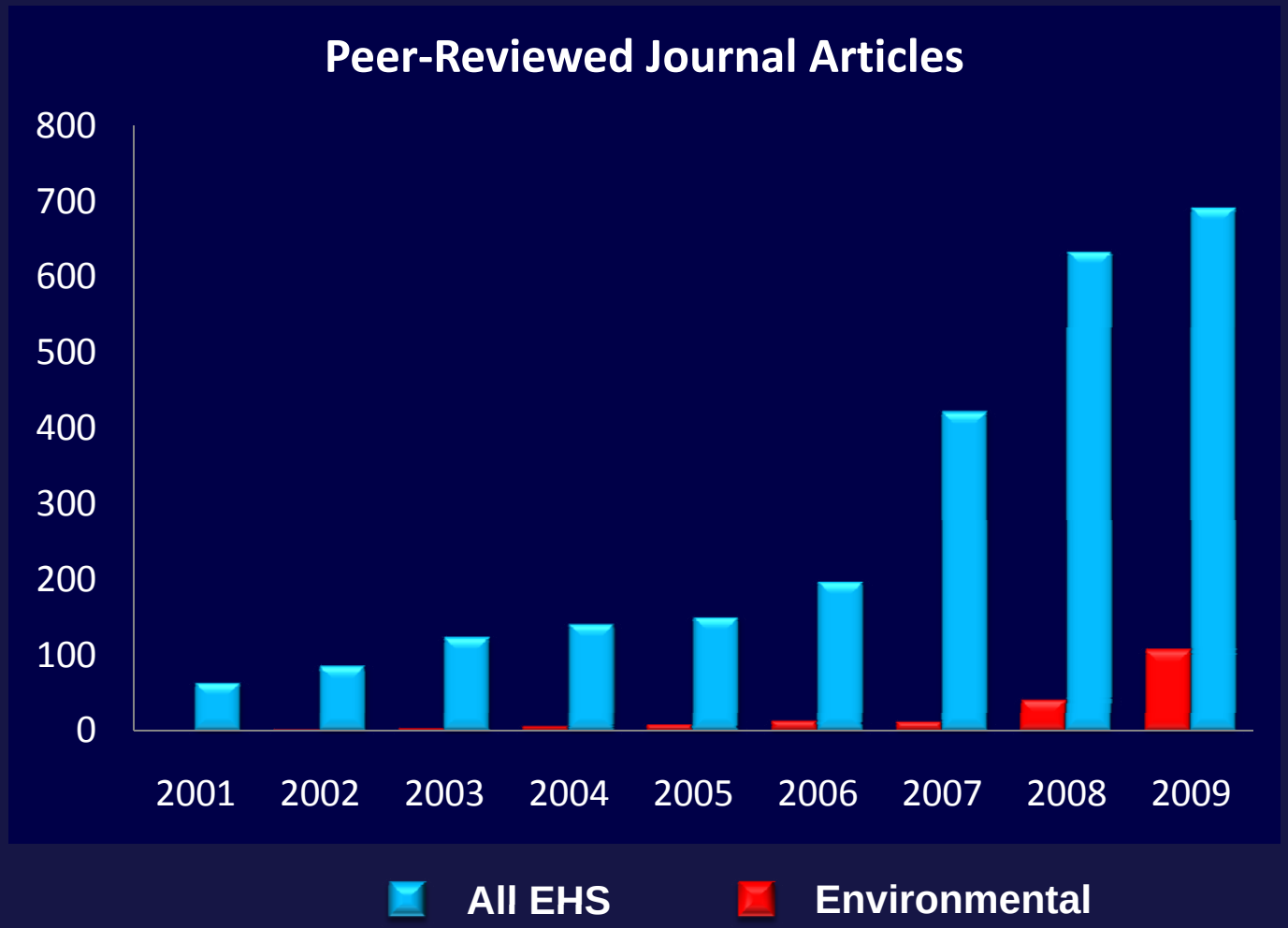
Towards Predicting Nano-Biointeractions

(June 2007)

- *Need models for how NMs properties control biointeractions at their surface*
- *Need independent validation of NM dose and dose rate*

Models capable of predicting nano-biointeractions may take 10 years

Environmental Research Constitutes Only 7% of NanoEHS Literature



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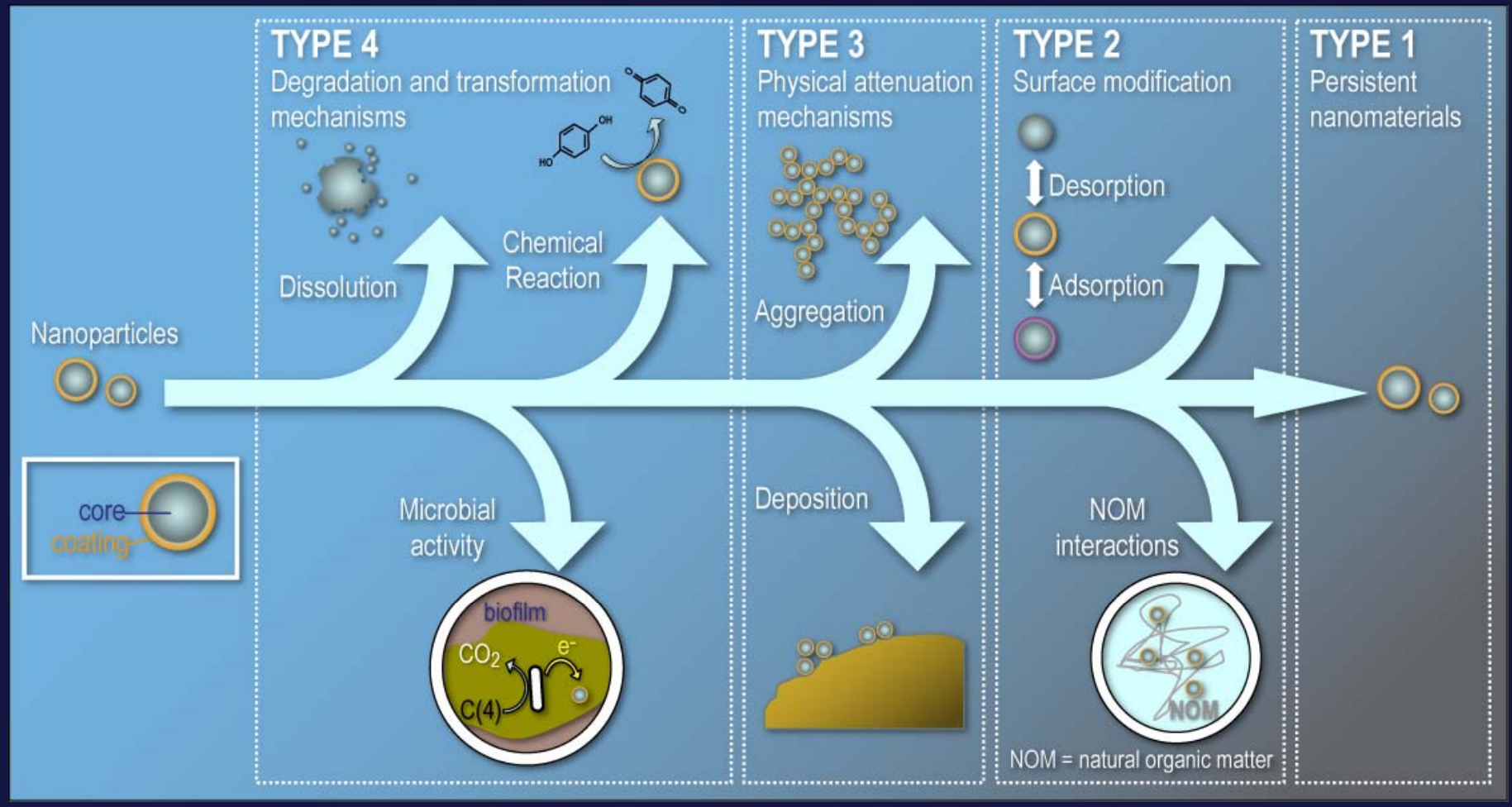
Nanoparticle Modifications in the Environment



Top Needs to Advance the Eco-Responsible Design and Disposal of Engineered NMs

Eco-Responsible Design

- Metrology
- Structure-Activity Relationships
- Predictive Modeling of Multimedia Fate and Transport
- Bioavailability and Effects

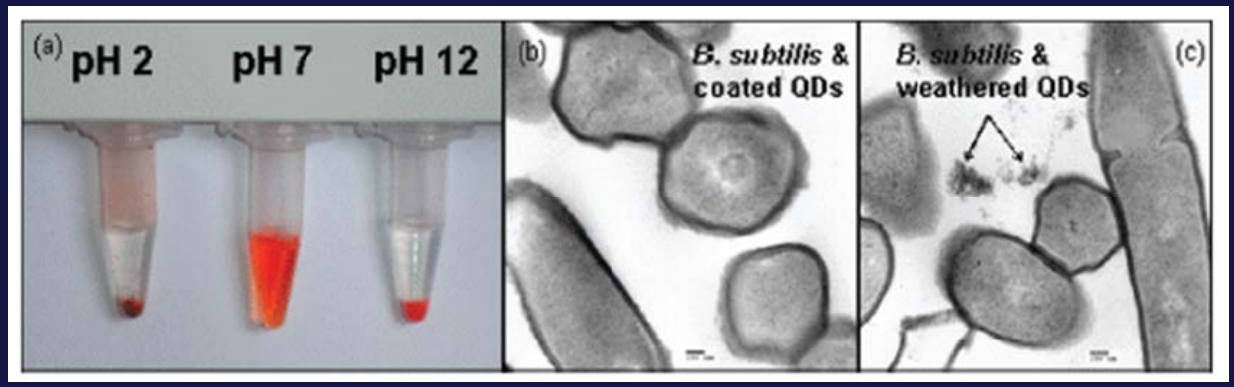
Eco-Responsible Disposal

- Release and Exposure Scenarios
- Reclamation, Regeneration and Reuse of Nanomaterials
- Emerging Issues for Environmental Protection Infrastructure
- Regulatory Framework for Nanomaterial Disposal

March 2009 ACS Nano, 2009, 3 (7), 1616-1619 July 2009 NSF CBET-0903936

Quantum Dot Weathering Results in Microbial Toxicity

Mildly acidic or alkaline conditions lead to QD breakdown, release of contents; neutral pH does not kill bacteria



Environ. Sci. Technol. 2008, 42, 9424–9430

- nC_{60} antibacterial activity due to direct oxidation
- Sorption of nC_{60} to natural organic matter removes toxicity in soil
- Degradation of QDs releases toxic metals
- **Project Team: Alvarez (CEVE), Colvin (CHEM)**

Potential Targets of Risk

Workers

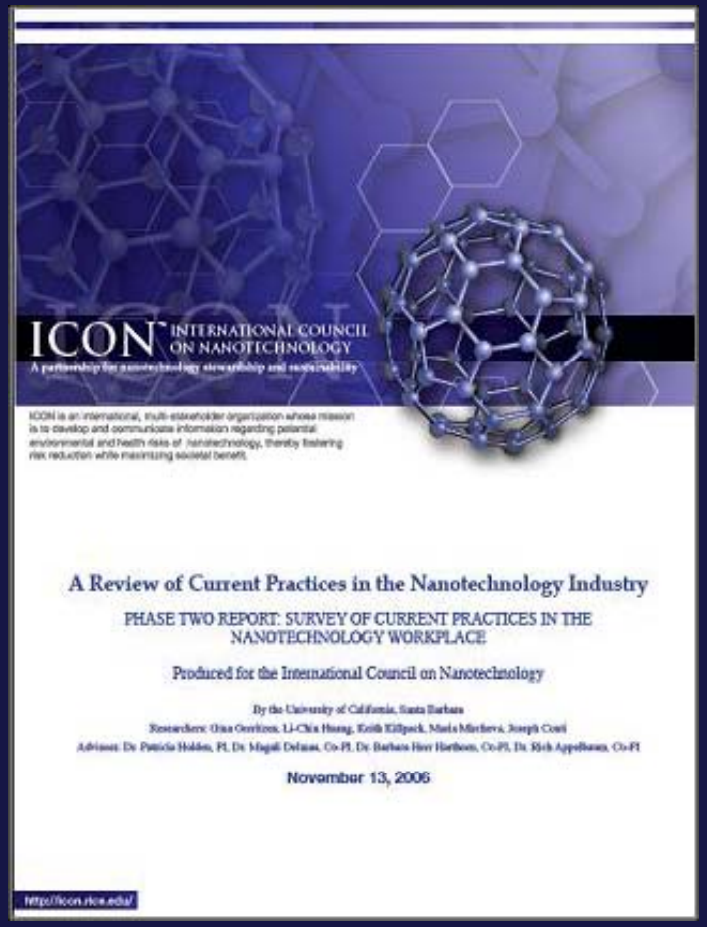
Consumers

Environment

Stakeholders Seek Info on Good Practice

Comprehensive, international survey of handling practices in the nanotech workplace

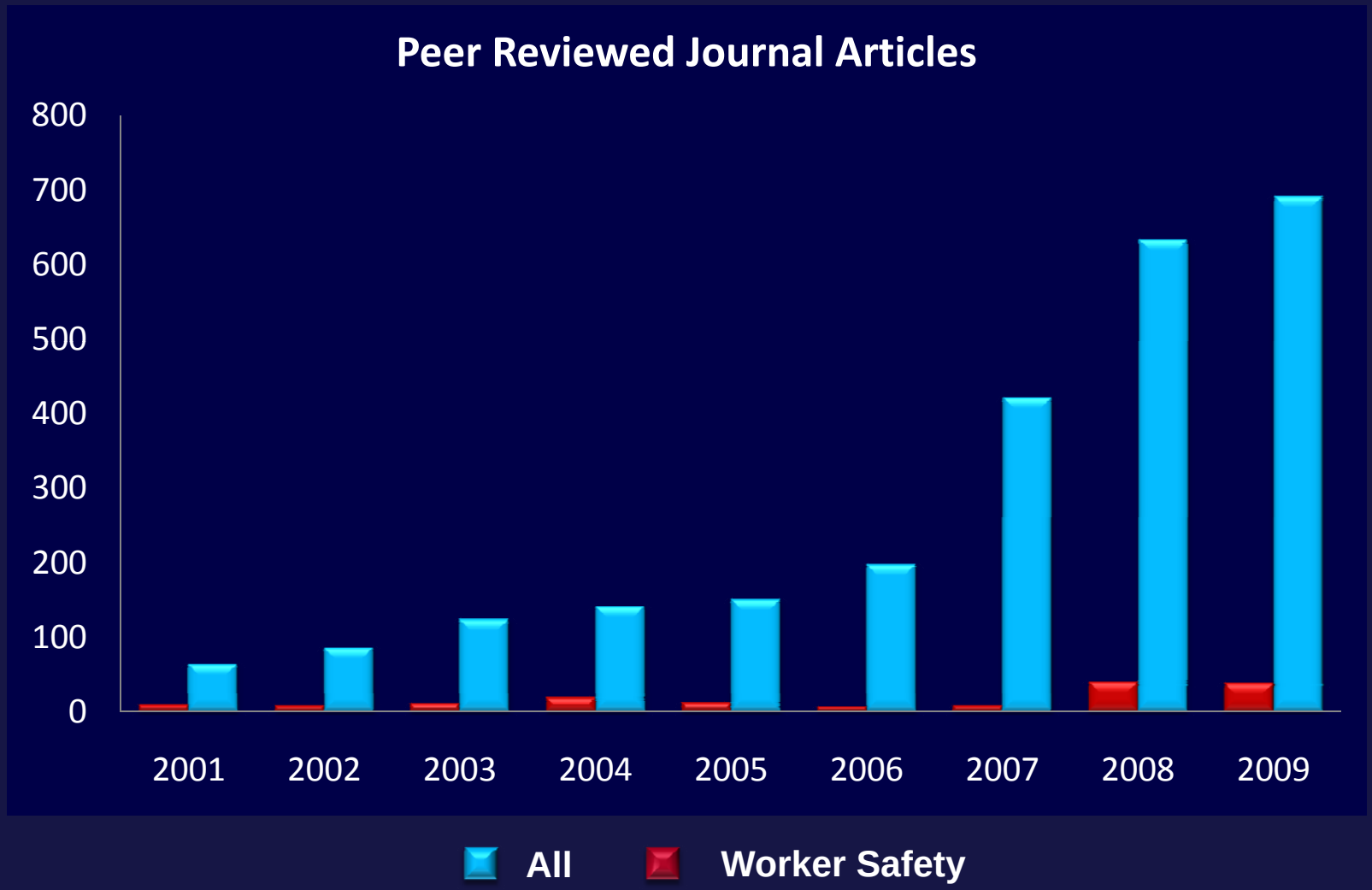
"Surveyed organizations reported that they believe there are special risks related to the nanomaterials they work with…and that they are actively seeking additional information on how to best handle nanomaterials."



Survey respondents were nanomaterial manufacturers, users and researchers in industry, academia and independent and government labs from North America, Europe, Asia and Australia.

SOURCE: http://tinyurl.com/iconsurvey

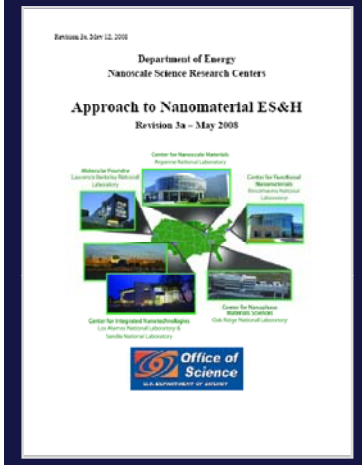
Limited Work of Occupational Relevance



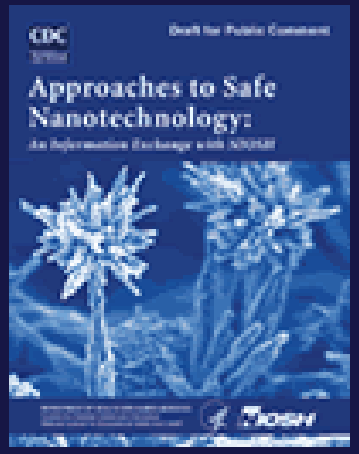
http://icon.rice.edu/research.cfm

Some Resources for Handling Nano

US



DOE NSRC

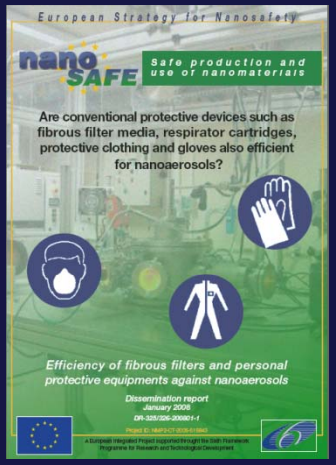


NIOSH

Canada

IRSST

Europe



NanoSafe2

BAUA

ASTM INTERNATIONAL

E2535-07

ISO International Organization for Standardization

ISO/TR 12885

BSi

PD 6699-2:2007

Common Messages

- Nanomaterial behavior may differ from that of non-nanoscale analogs
- Some nanomaterials may pose health risks if exposure is present
- Hazard and exposure data do not yet provide a clear picture of risk

MINIMIZING EXPOSURE IS PRUDENT


Barriers to Information Sharing
LAW

How do we get

Timely

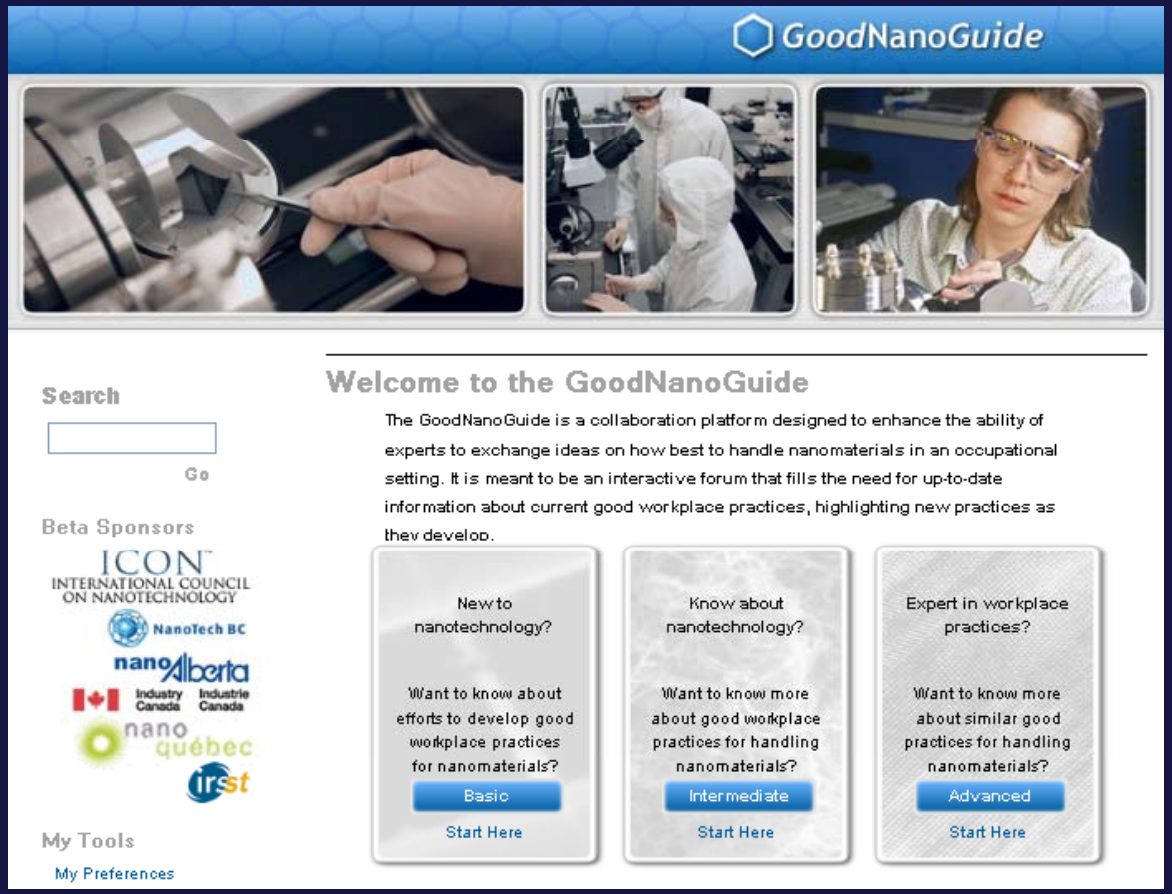
Practical

High-quality

information out

to ALL the target populations?

The GoodNanoGuide



- Protected Internet site on occupational practices for the safe handling of nanomaterials
- Multiple stakeholders contribute, share and discuss information
- Modern, interactive, up-to-date
- Launched 1 June 2009

http://GoodNanoGuide.org

Interacting with the GoodNanoGuide

VIEW

No Registration Required

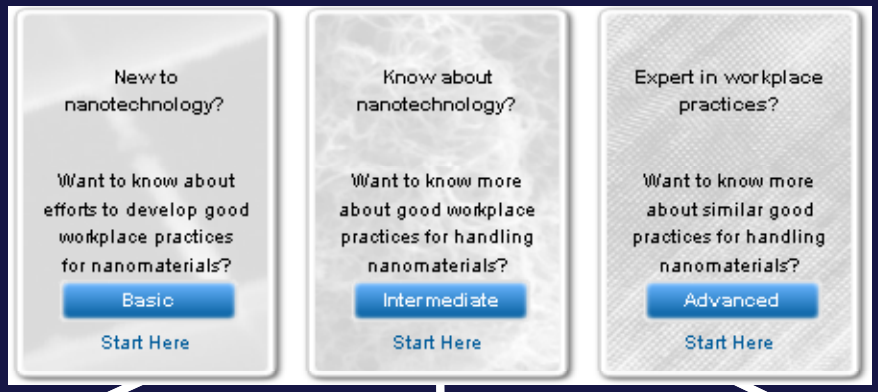
COMMENT

Register as a Community Member

CONTRIBUTE

Register as an Expert Provider

How Content is Organized



Basic

- Introduction to Nanotechnology
- Nomenclature and Glossary

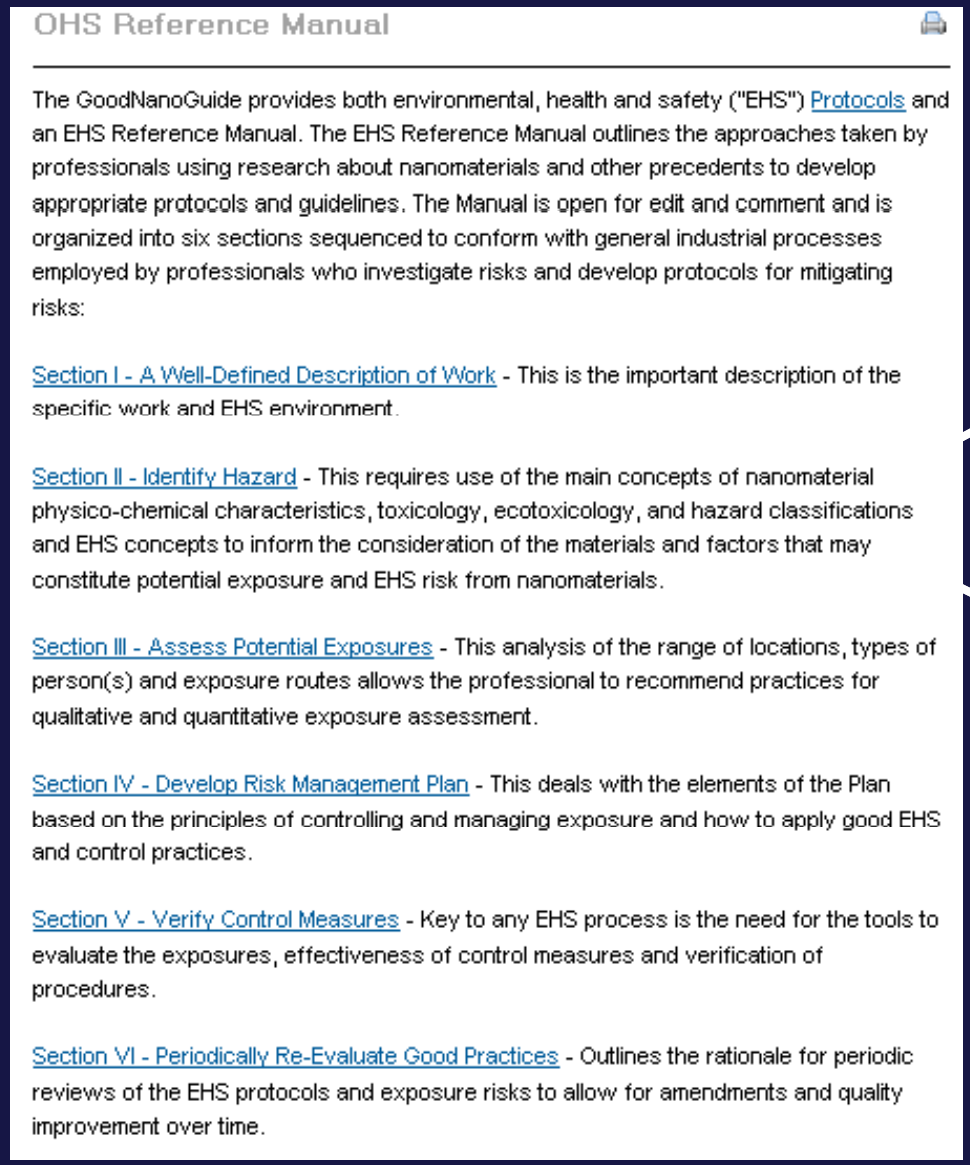
Intermediate

- OHS Reference Manual

Expert

- Expert Matrix
- Specific Protocols

OHS Reference Manual



OHS Reference Manual

The GoodNanoGuide provides both environmental, health and safety ("EHS") Protocols and an EHS Reference Manual. The EHS Reference Manual outlines the approaches taken by professionals using research about nanomaterials and other precedents to develop appropriate protocols and guidelines. The Manual is open for edit and comment and is organized into six sections sequenced to conform with general industrial processes employed by professionals who investigate risks and develop protocols for mitigating risks:

Section I - A Well-Defined Description of Work - This is the important description of the specific work and EHS environment.

Section II - Identify Hazard - This requires use of the main concepts of nanomaterial physico-chemical characteristics, toxicology, ecotoxicology, and hazard classifications and EHS concepts to inform the consideration of the materials and factors that may constitute potential exposure and EHS risk from nanomaterials.

Section III - Assess Potential Exposures - This analysis of the range of locations, types of person(s) and exposure routes allows the professional to recommend practices for qualitative and quantitative exposure assessment.

Section IV - Develop Risk Management Plan - This deals with the elements of the Plan based on the principles of controlling and managing exposure and how to apply good EHS and control practices.

Section V - Verify Control Measures - Key to any EHS process is the need for the tools to evaluate the exposures, effectiveness of control measures and verification of procedures.

Section VI - Periodically Re-Evaluate Good Practices - Outlines the rationale for periodic reviews of the EHS protocols and exposure risks to allow for amendments and quality improvement over time.

II. Identify Hazard

- Physicochemical Characteristics
  - Particle Size and Size Distribution
  - Surface Area
  - Surface Chemistry or Activity
  - Other Physicochemical Characteristics
- Toxicity Characteristics
- Ecotoxicity Characteristics
- Hazard Class Assignment
- Hazard Communication Plan

Intermediate

OHS Expert Matrix

Nanoparticles in: →	Dry Powder	Liquid Dispersion	Solid Polymer Matrix	Nonpolymer Matrix

Assessment should

- **Look at the form of the nanoparticle**
- **Consider the entire process**

Expert

Nanoparticles in: →	Dry Powder	Liquid Dispersion	Solid Polymer Matrix	Nonpolymer Matrix
First Step: Identify	Potential Hazard	Potential Hazard	Potential Hazard	Potential Hazard
Second and Third Steps: Risk Assessment and Management				
Material Unpacking	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Synthesis	Exposure Potential	Exposure Potential		
	Controls	Controls		
Weighing and Measuring	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Dispersing	Exposure Potential	Exposure Potential		
	Controls	Controls		
Mixing	Exposure Potential	Exposure Potential		
	Controls	Controls		
Spraying	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Machining	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Packing	Exposure Potential	Exposure Potential	Exposure Potential?	Exposure Potential?
	Controls	Controls	Controls	Controls
Process Equipment Cleaning	Exposure Potential?	Exposure Potential?	Exposure Potential?	Exposure Potential?
	Controls	Controls	Controls	Controls
Workspace Cleaning	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Spill Cleanup	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
Waste Management	Exposure Potential?	Exposure Potential?	Exposure Potential?	Exposure Potential?
	Controls	Controls	Controls	Controls
	Environmental Procedures	Environmental Procedures	Environmental Procedures	Environmental Procedures
Reasonably Foreseeable Emergencies	Exposure Potential	Exposure Potential	Exposure Potential	Exposure Potential
	Controls	Controls	Controls	Controls
	Environmental Procedures	Environmental Procedures	Environmental Procedures	Environmental Procedures

Please click here to access the OHS Reference Manual

GoodNanoGuide Goals

- Develop and publish more process-specific protocols
- Engage researchers users, contributors or Implementation Committee members
- Sustain the GoodNanoGuide as an open-access resource

NIOSH National Institute for Occupational Safety and Health

NanoTech BC

nanoAlberta

Industry Canada Industrie Canada
Canada

nano québec

irsst

http://goodnanoguide.org

Conclusions

- Research on nano impacts is accelerating
- Many knowledge gaps need to be filled to ensure the sustainable use of nanomaterials
- Industry is a key stakeholder in nano impacts issues

Upcoming Events

GC3 Green Chemistry & Commerce Council

5th Annual Green Chemistry and Commerce Council Innovators Roundtable

Sysco Corporation
1390 Enclave Parkway
Houston, Texas

April 26-28, 2010

Good things come from Sysco™

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