Characterizing and communicating hazards posed by engineered nanomaterials (ENMs) in construction

Society for Chemical Hazard Communication Annual Meeting

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CPWR
THE CENTER FOR CONSTRUCTION
RESEARCH AND TRAINING

CPWR has served as the NIOSH National Construction Center since 1990

- Non-profit organization
- Created by **N**orth **A**merica's **B**uilding **T**rades **U**nions

www.cpwr.com

CPWR's mission is to reduce occupational injuries, illnesses, and fatalities in the construction industry

I'd like to thank and acknowledge our big nano team

Bruce Lippy, PhD, CIH, CSP, FAIHA

Sara Brooks, MPH

Leonard Burrelli, MS

Andreas Saldivar, MS

Bill Perry, MS, CIH

Mark Nealley MS, CIH

Bill Kojola, MS

Michael Cooper, MPH, CIH, CSP

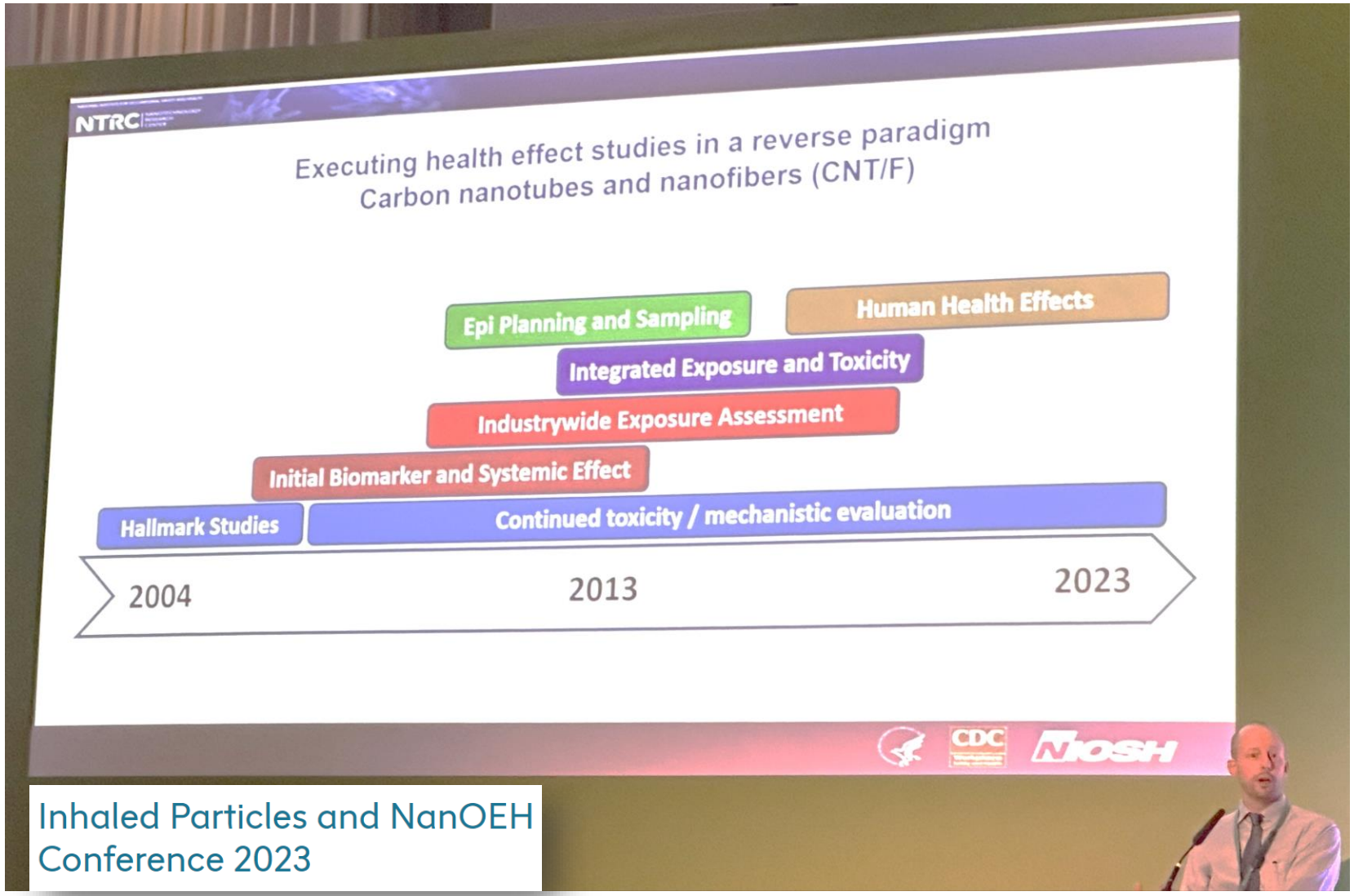
After today you should be able to:

1. Explain the types of data available for ENM hazard classification
2. Describe research on ENM exposure risks and hazard communication in construction
3. Compare standards and guidance pertaining to labeling and hazard communication for ENMs
4. Apply resources to develop informative safety data sheets for ENMs

Objective #1

Explain the types of data available for ENM hazard classification

Dr. Aaron Erdely, a partner we work with from NIOSH, gave a keynote lecture last year in which he described conducting health effect studies in a reverse paradigm for carbon nanotubes and nanofibers



Legacy nanomaterials like carbon black have been studied more extensively

- Manufactured for > 80 years
- 9.6 million tons per year worldwide
- Workers show decreases in lung function

Photos courtesy Wikimedia

Carbon black worker, 1941, Sunray, TX
Photo courtesy John Vachon and Wikimedia

A 2017 study estimated that $24 million of up-front research into lead and asbestos could have saved up to $359 billion

Published in final edited form as:
J Environ Manage. 2017 December 15; 204(Pt 1): 472–485. doi:10.1016/j.jenvman.2017.09.026.

People, planet and profit: Unintended consequences of legacy building materials

Anthony T. Zimmer[a], **HakSoo Ha**[b]

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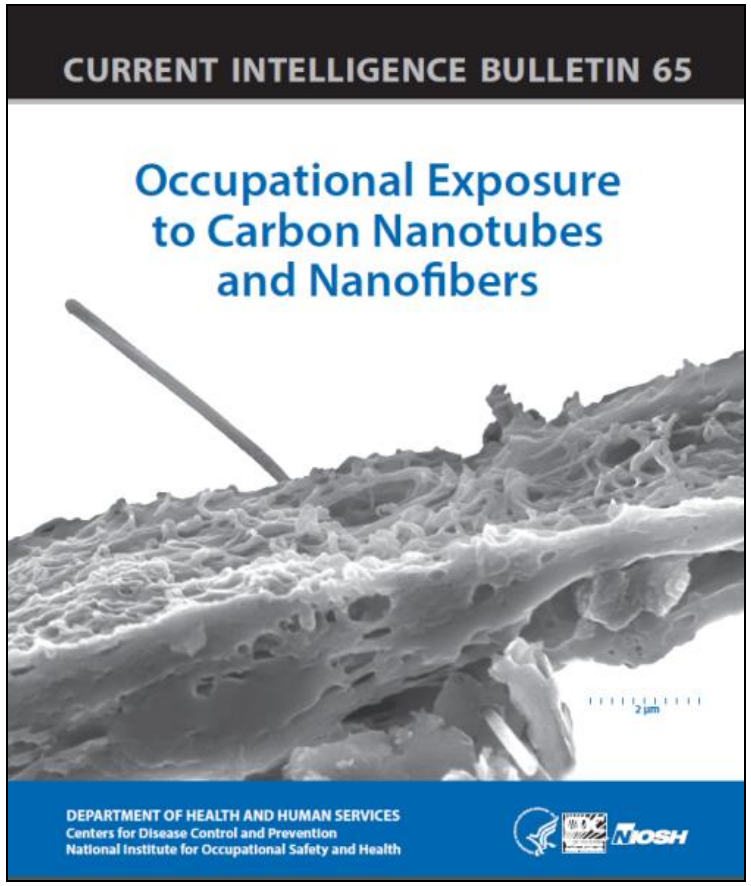
Multi-walled carbon nanotubes have caused asbestos-like disease in laboratory animals

(Suzui 2016; Takagi 2008; Poland 2008)

Multi-walled carbon nanotube penetrating the pleura of the lung.
Courtesy of Robert Mercer, and Diane Schwegler- Berry, NIOSH

Despite similarities to asbestos, uncertainties exist in assessing risks to workers exposed to carbon nanotubes (CNTs)



- Animal studies of CNTs show pulmonary inflammation and rapidly developing, persistent fibrosis (NIOSH 2013; Wang et al. 2016).
- Occupational exposure to CNTs is associated with biomarkers of early effect for fibrosis, inflammation, oxidative stress, and cardiovascular responses in workers. (Beard et al. 2018)

https://www.cdc.gov/niosh/topics/nanotech/pubs.html

More toxicological information is available for certain ENMs

- Silver nanoparticle inhalation in rats caused decreased lung function, inflamed lung tissue, and changes in the liver and kidney.
- TiO_2 nanomaterial inhalation in rats leads to pulmonary inflammation, oxidative stress, and lung cancer (Baranowska-Wójcik et al. 2020; NIOSH 2011).

https://www.cdc.gov/niosh/topics/nanotech/pubs.html

A 2019 review of worker health effects by Schulte et al concluded:

Published in final edited form as:
Scand J Work Environ Health. 2019 May 01; 45(3): 217–238. doi:10.5271/sjweh.3800.

Current state of knowledge on the health effects of engineered nanomaterials in workers: a systematic review of human studies and epidemiological investigations

Paul A Schulte, PhD[1], **Veruscka Leso, MD, PhD**[2], **Mamadou Niang, MS, MPH**[3], and **Ivo Iavicoli, MD, PhD**[2]

[1]National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Cincinnati, OH, USA.

[2]Department of Public Health, University of Naples Federico II, Naples, Italy.

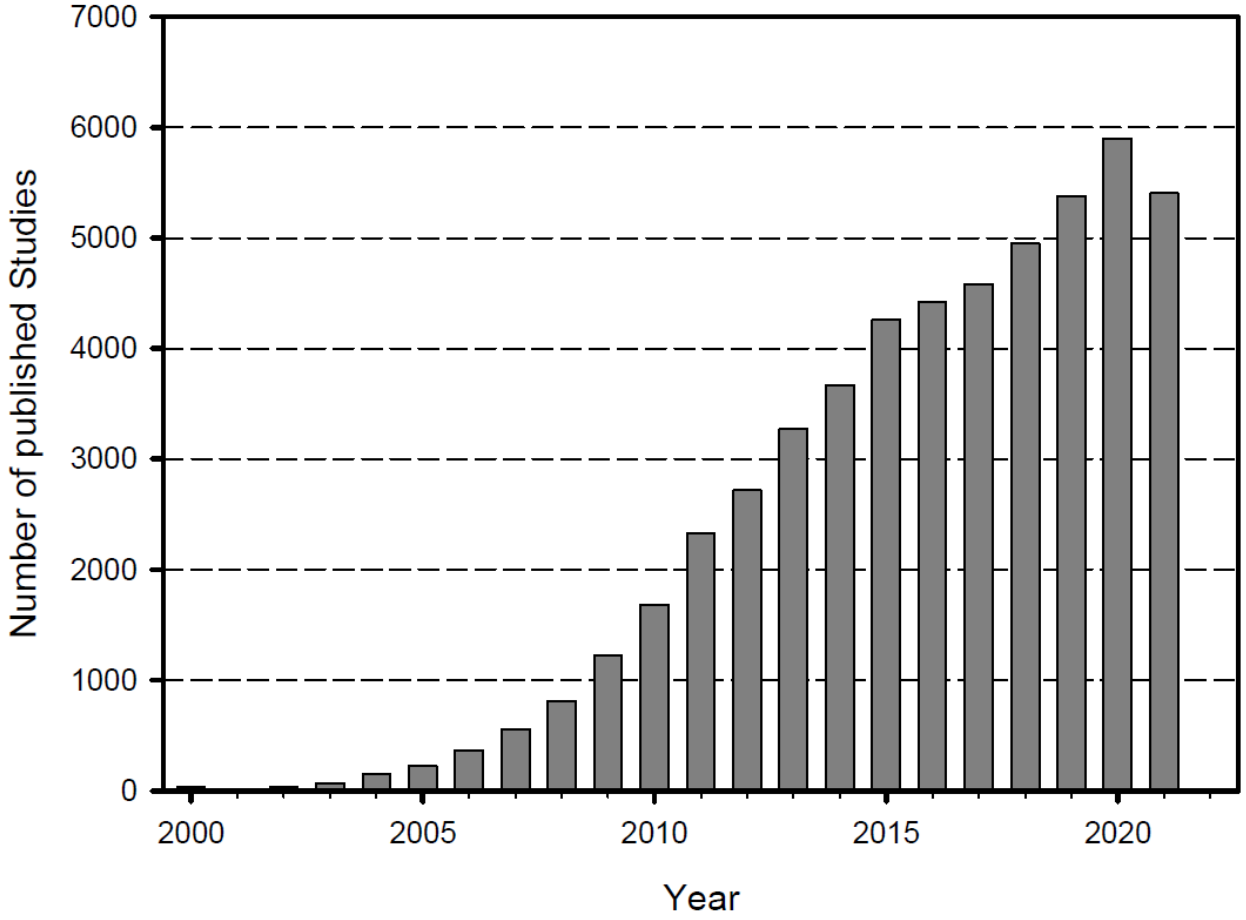
[3]Department of Environmental Health, University of Cincinnati, Cincinnati, OH, USA.

"In this state of uncertainty, **precautionary controls for each engineered nanomaterial are warranted** while further study of potential health effects continues."

A 2017 World Health Organization (WHO) report classified the hazards of a limited number of nanomaterials

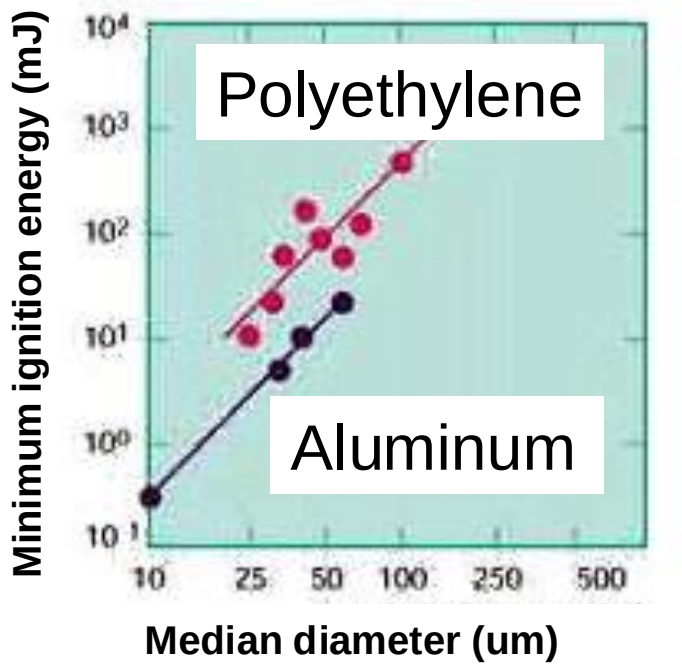
MNM	Acute toxicity	Skin corrosion/ irritation	Serious eye damage/eye irritation	Respiratory or skin sensitization	Germ cell mutagenicity	Carcinogenicity	Reproductive toxicity	Specific target organ toxicity (single exposure)	Specific target organ toxicity (repeated exposure)
Fullerene (C_{60})	No[a]	No	No	No	No	No data[b]	No data	No data	No
SWCNT	No	No	No	No	**Cat 2B[c] (L)[d]**	No data **IARC[e] 3**	No data	No data	**Cat 1 (L)**
MWCNT	No	No	**Cat 2A (H)[g]**	No	**Cat 2 (H)**	**MWCNT–7: Cat 2 (M)[f], IARC 2B Other MWCNTs: IARC 3**	No	No data	**Cat 1 (M)**
AgNP	No	No	No	**Cat 1B (M)**	No	No data	No	No data	**Cat 1 inhalation (H) Cat 2 oral (H)**
AuNP	No data	No data	No data	No data	No data	No data	No data	No data	**Cat 1 inhalation (H)**
SiO_2	No	No	No	No	No	No data	No	No data	**Cat 2 inhalation (H)**
TiO_2	No	No	No	No	No	No data; **IARC 2B**	**Cat 2 (L)**	No data	**Cat 1 inhalation (H)**
CeO_2	No	No data	No data	No data	No data	No data	No data	No data	**Cat 1 inhalation (M)**
Dendrimer	No data	No data	No data	No data	No data	No data	No data	No data	No data
Nanoclay	No data	No data	No data	No data	No data	No data	No data	No data	No data
ZnO	No	No	No	No data	No	No data	No	No data	**Cat 1 inhalation (M)**

Over 40,000 nanotoxicology studies have been published over the last two decades



Krug HF. Collection of Controlled Nanosafety Data-The CoCoN-Database, a Tool to Assess Nanomaterial Hazard. Nanomaterials (Basel). 2022 Jan 28;12(3):441.

From a safety perspective, flammability and explosivity of nano-powders must be considered

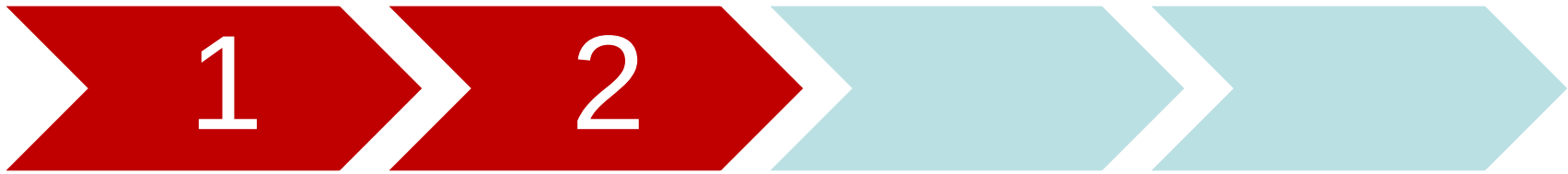


Netherlands Organization for Applied Scientific Research

Slide courtesy John Howard

Learning Objective #2

Describe research on ENM exposure risks and hazard communication in construction



CPWR researchers and others have been working to answer these questions

- Based on available products, where is there potential for exposure?
- What forms of ENMs are released from construction materials?
- What levels of exposure are likely during different tasks?
- Do these exposures exceed OELs or pose health risks?
- Are exposure controls effective?

CPWR maintains the most comprehensive source of information on reported use of nanomaterials in construction (https://nano.elcosh.org/)

elcosh NANO
Construction Nanomaterial Inventory

Product Categories | News/Info | About | elcosh Home | Query

Construction is seeing the introduction of remarkable new nano-enabled products that are lighter, stronger, more wear-resistant and better insulators. But some nanoparticles added to these products may cause health problems and very little worker exposure measurements have been collected, particularly in construction. That is why CPWR created this inventory. We believe, at a minimum, construction workers and contractors have a right to understand which products may contain nanoparticles so they can better consider the benefits and risks.

Enter search terms...

Product Categories

- Abrasive blasting media (1)
- Additives for asphalt (6)
- Additives for coatings (3)
- Additives for concrete/cement (19)
- Adhesives (16)
- Boiler additives (1)

Proshield+

THERMAL-XR® HVAC Coating System

NEWS AND RELATED INFORMATION

Mosquito bite prevention with cellulose nano crystals

Mosquitos spread potentially fatal diseases affecting humans, including malaria, zika, chikungunya, and yellow fever — making mosquitoes the deadliest animals on Earth. However, treating cellulose with sulfuric acid prompts it...

'Nano inks' could passively control temperature in buildings, cars

Toxicology and exposure studies have primarily examined nanomaterials before they are added to products like coatings or cement

Photo courtesy: NIOSH and Nanocomp Technologies, Inc.

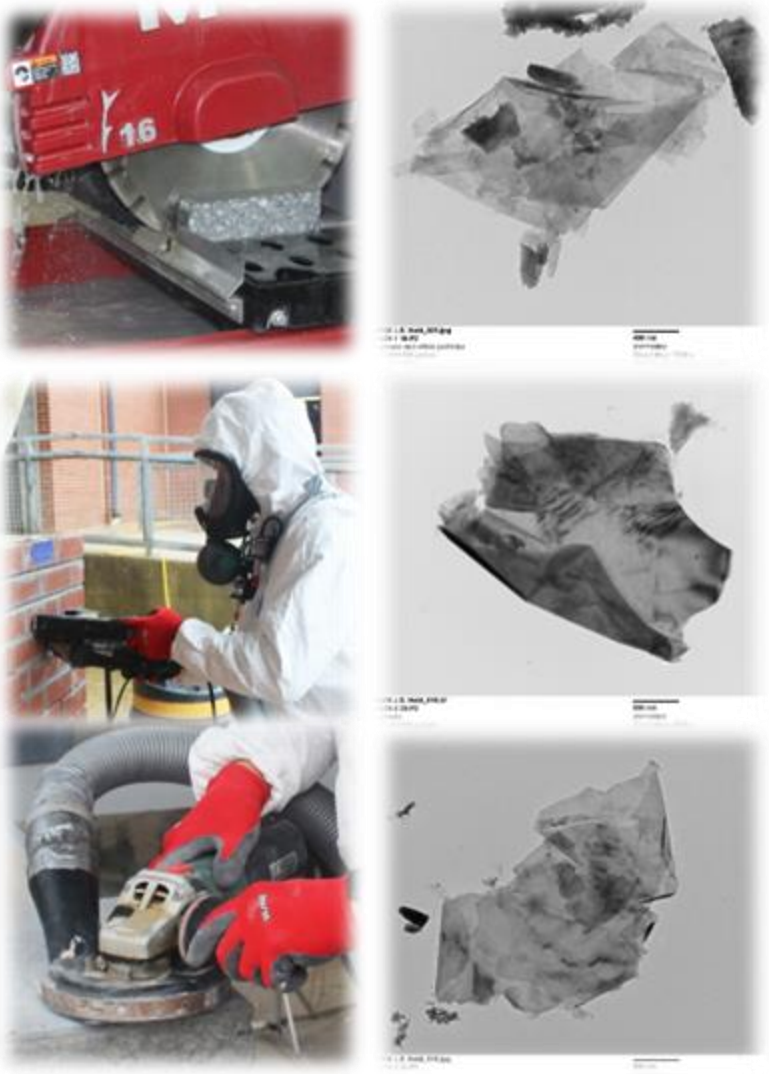
VERSUS

Enclosed furnace used to produce carbon nanotubes

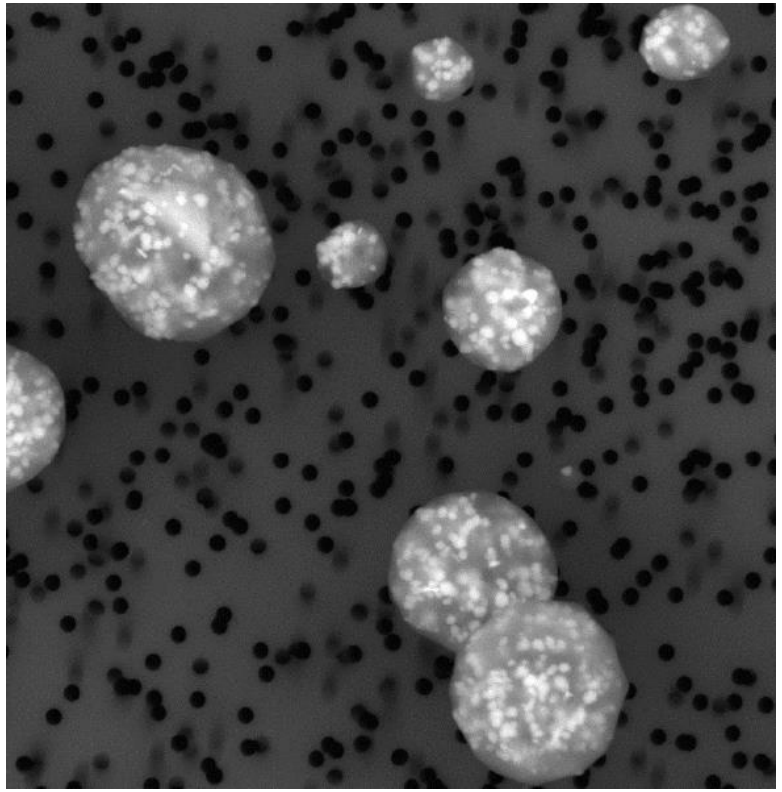
Photo courtesy: VA Dept of Transportation

Enclosure for bridge lead abatement

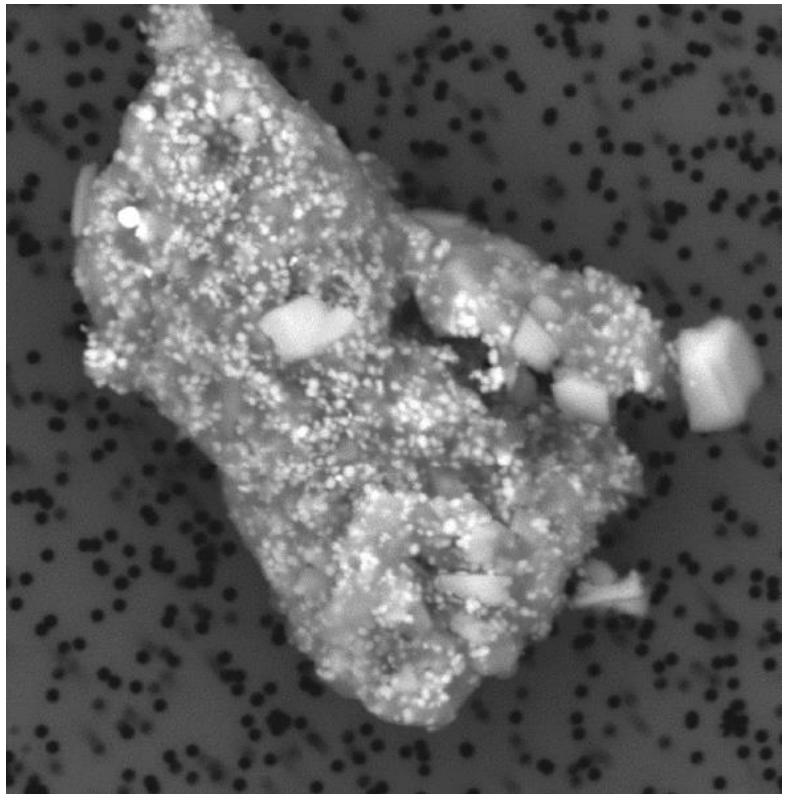
CPWR has studied release of ENMs from construction products and measured exposure levels during a range of tasks



Most studies show that ENMs tend to remain embedded in the construction materials to which they are added…



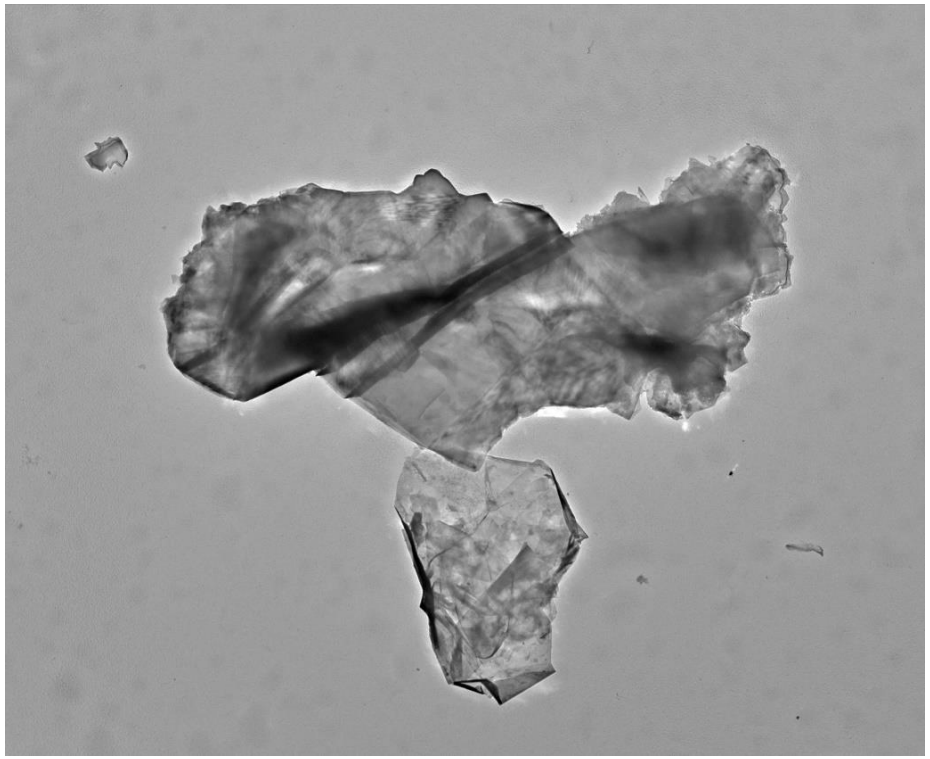
Paint spray with white nanoparticles



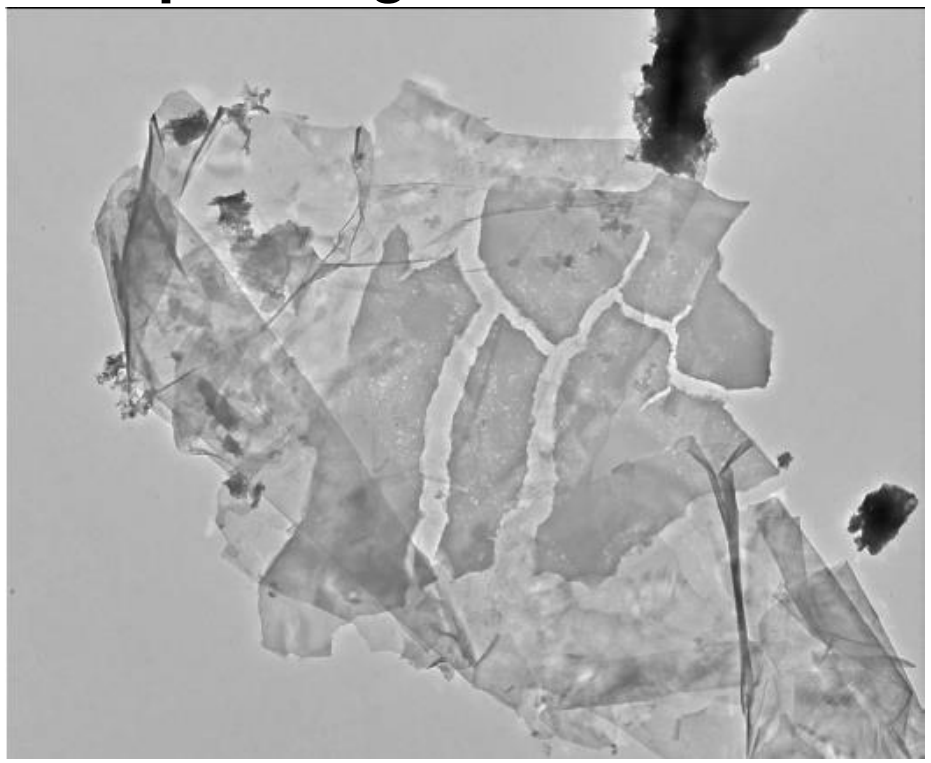
Sanding debris with white nanoparticles

… but we have also observed release of free ENMs during construction activities

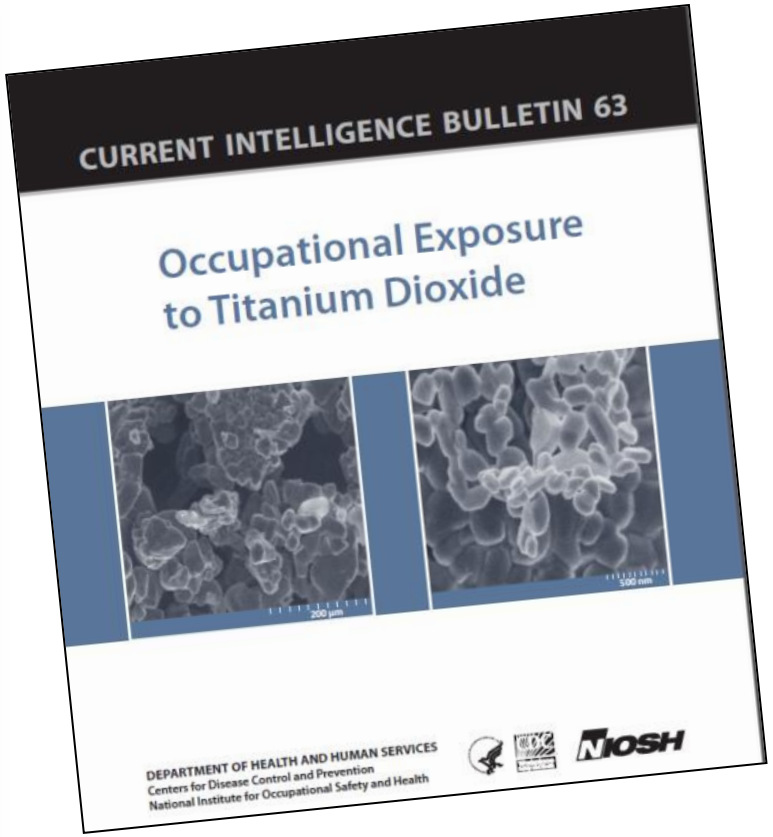
Graphene before it was added to mortar

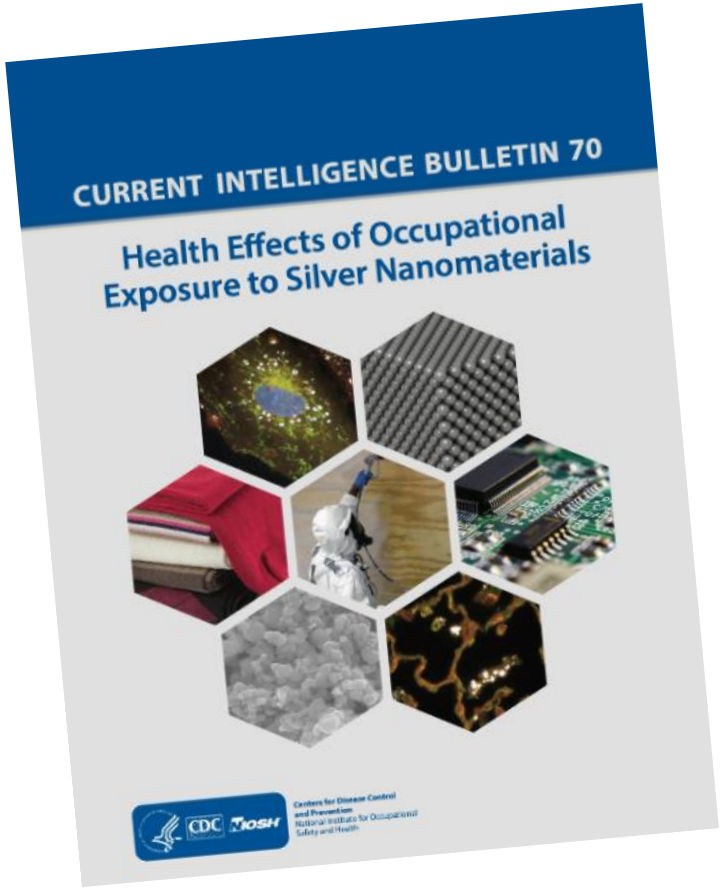


Graphene released during tuckpointing



CPWR studies show potential to exceed NIOSH RELs during airless spraying of paint



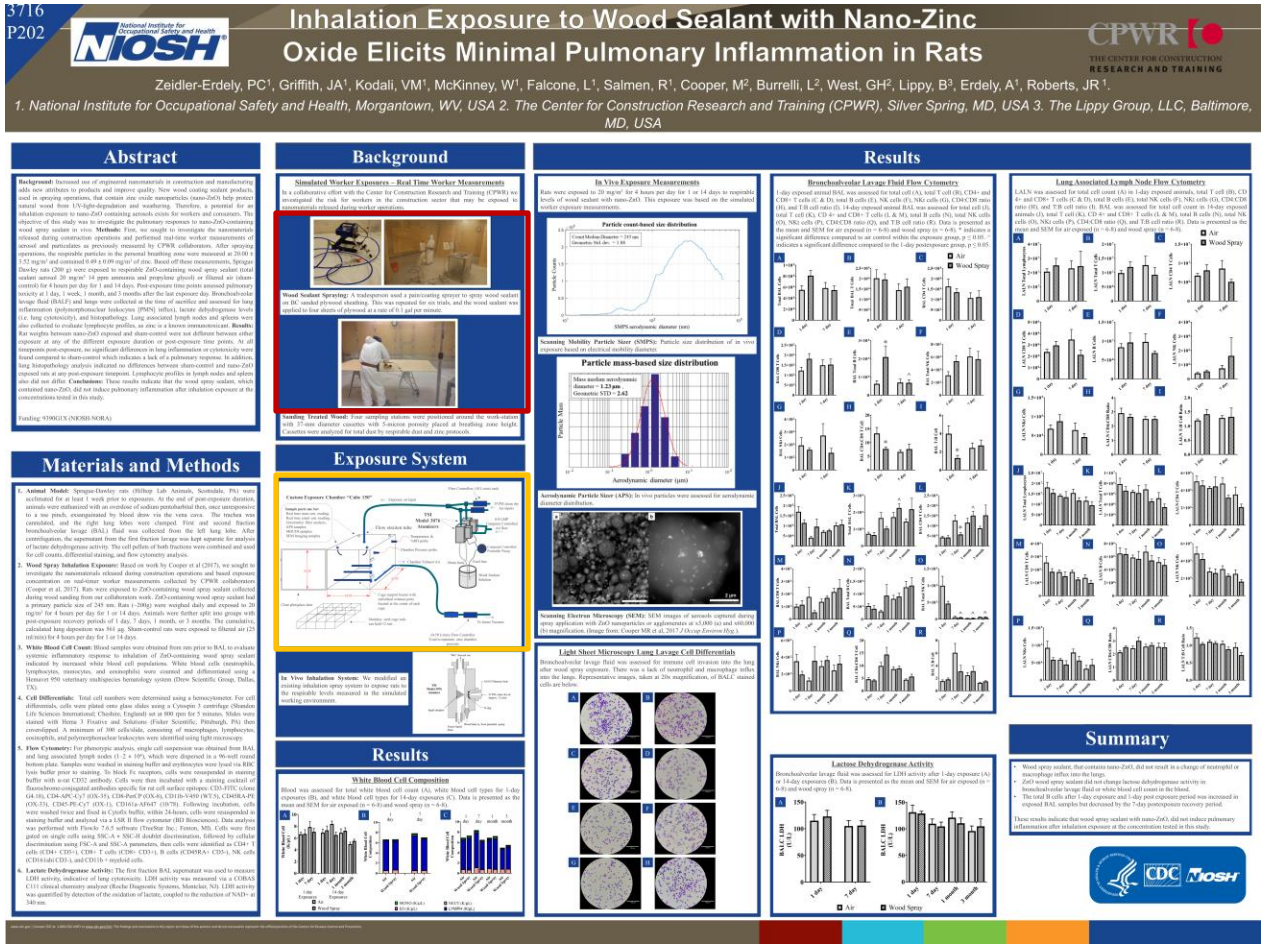


CPWR collaborates with NIOSH Health Effects Laboratory Division researchers to conduct integrated exposure and toxicity research

Image courtesy Earl Dotter

Dr. Jenny Roberts (NIOSH) speaks with a CPWR study participant through an observation window of the test chamber

NIOSH collaborators presented initial findings at the 2024 Society of Toxicology Annual Meeting



1. Our team published a prior study on exposure to nano zinc oxide
2. NIOSH collaborators exposed rats 4 hours per day for up to 14 days
3. Assessed toxicity for up to 3 months post-exposure
4. Occupationally relevant exposure levels induced minimal pulmonary inflammation, which is good news for workers!

Some good news is that CPWR studies show that engineering controls effectively reduce nanoparticle exposures

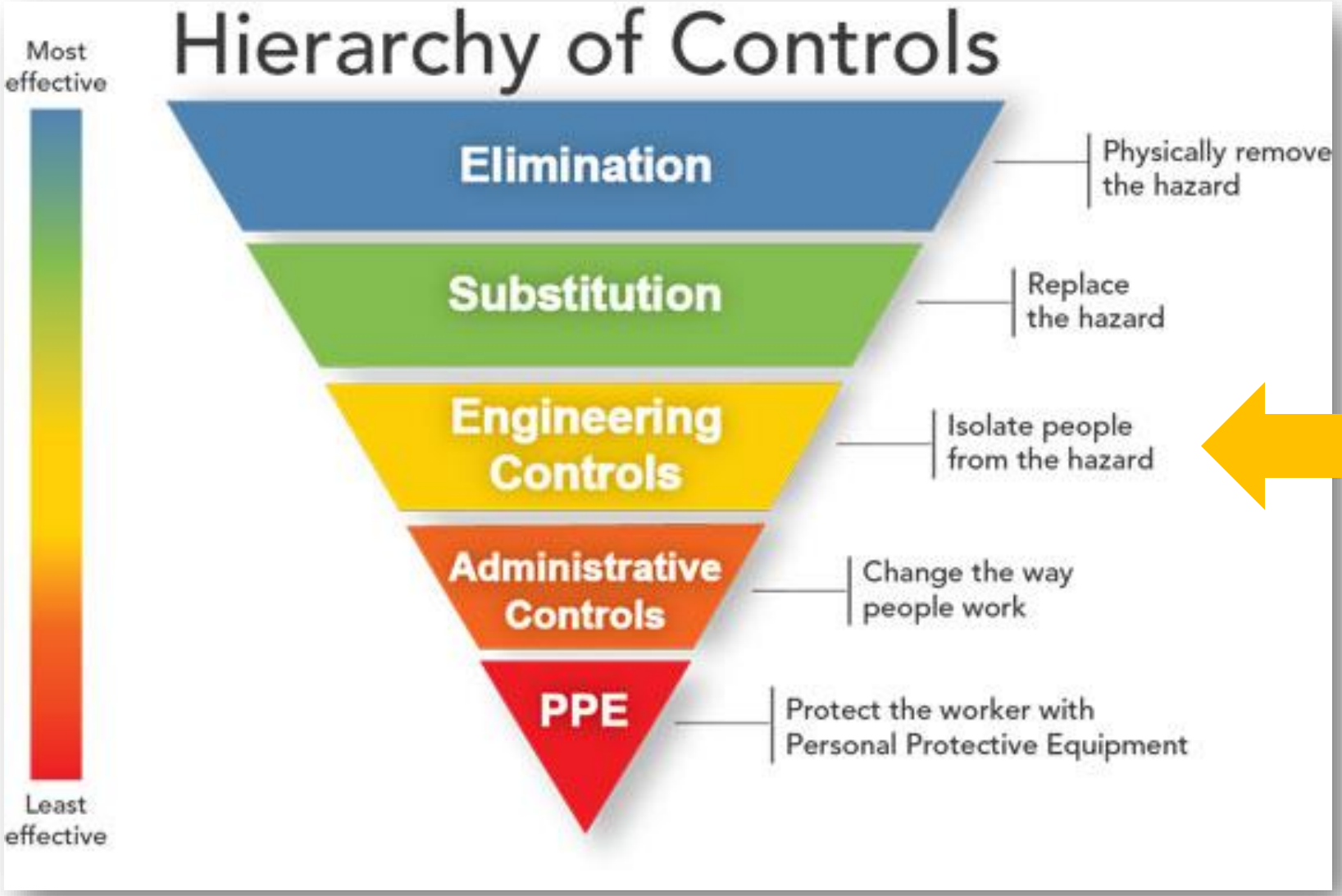
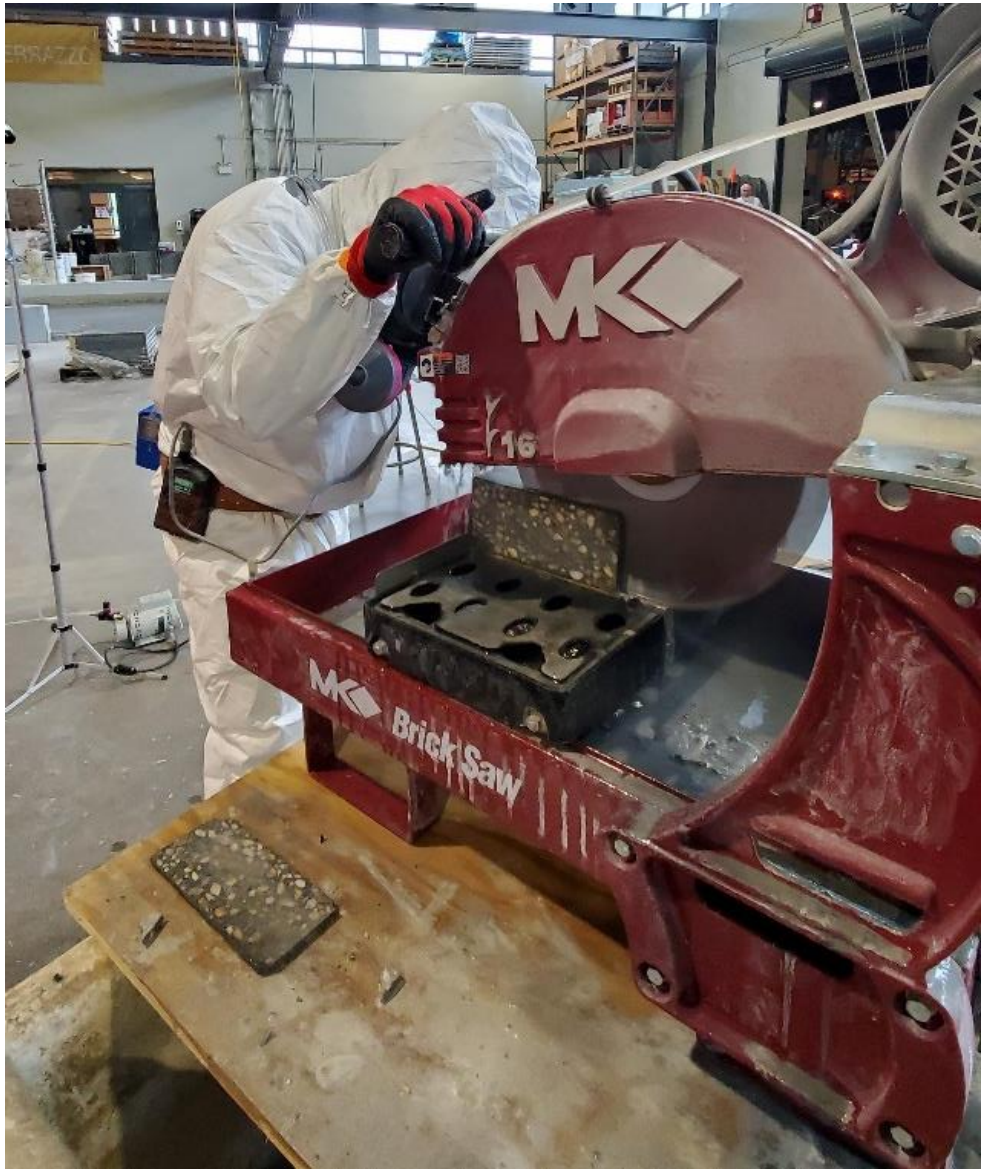


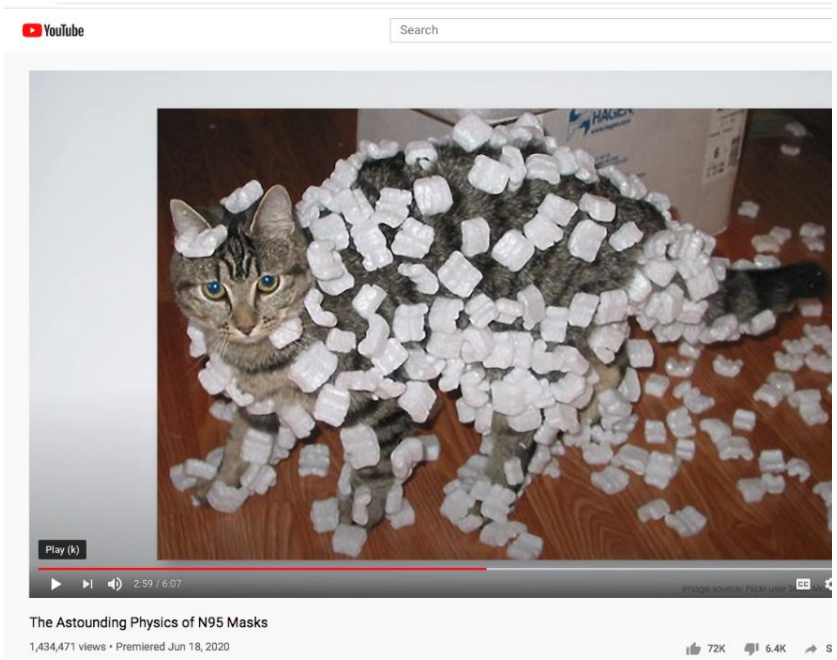
Photo courtesy
Earl Dotter

We found that wet methods work too



And Yes! HEPA filters capture nanoparticles

3M half-face air-purifying respirator with P100 particulate filter
and organic vapor (OV) cartridges



Great video on how filtration works!

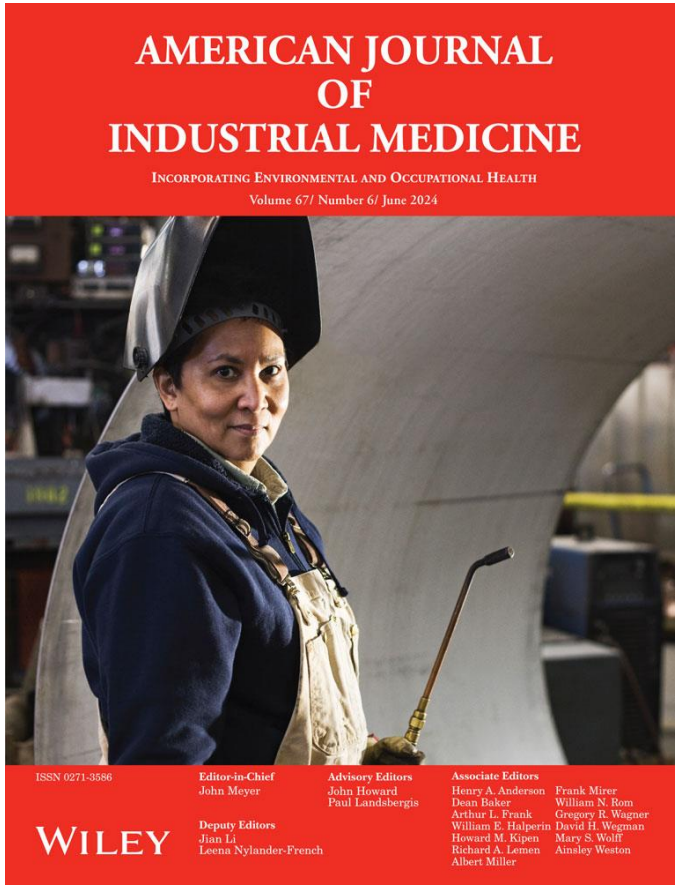
https://www.youtube.com/watch?v=eAdanPfQdCA&feature=youtu.be&t=9

Images courtesy 3M Corp and Wikimedia Commons

Prior studies concluded that hazard communication needs improvement when it comes to engineered nanomaterials

- Safe Work Australia (2010)
- Lee et al (2012)
- Eastlake et al (2012)
- Hodson et al (2019)

CPWR published a study this summer in the American Journal of Industrial Medicine (AJIM)



Lippy BE, Brooks SB, Cooper MR, Burrelli LG, Saldivar A, West GH. **Characterizing applications, exposure risks, and hazard communication for engineered nanomaterials in construction**.

Am J Ind Med. 2024;1-15. doi:10.1002/ajim.23618

Scan the QR code to access the free full-text!

A primary data source for the study was CPWR's construction nanomaterial inventory

elcosh NANO
Construction Nanomaterial Inventory

https://nano.elcosh.org/

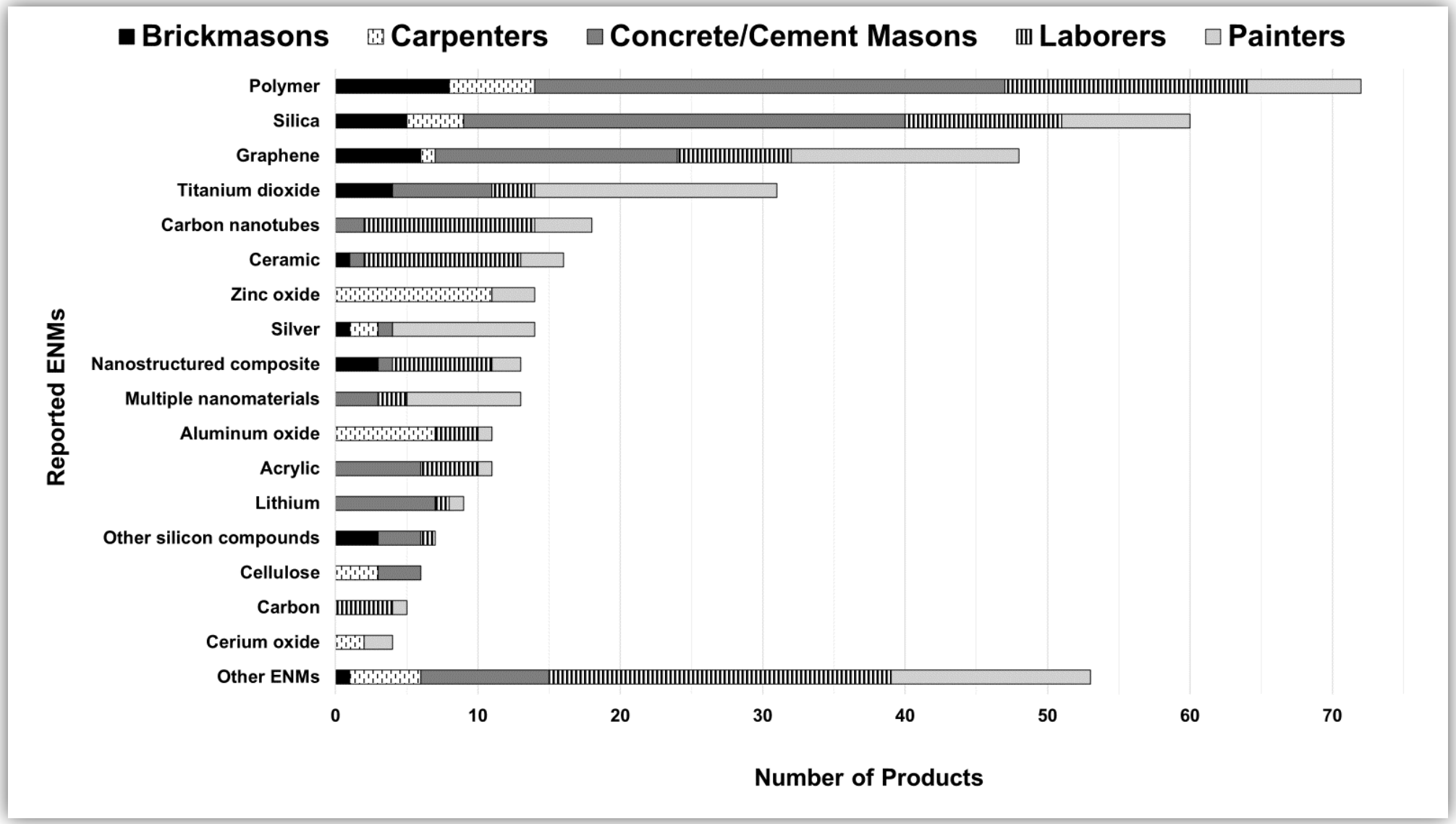
The study identified construction products that are frequently reported to be nano-enabled…

Product Category	Number of Products (n=907 total)	Percent
Paints & Coatings	483	53.3%
Pre-market additives	108	11.9%
Cementitious	68	7.5%
Thermal insulation	38	4.2%
Lubricants	23	2.5%
Flooring	20	2.2%
Glass and solar panels	17	1.9%
Adhesives	16	1.8%
Surface preparation	16	1.8%
HVAC	15	1.7%
Other	103	11.4%

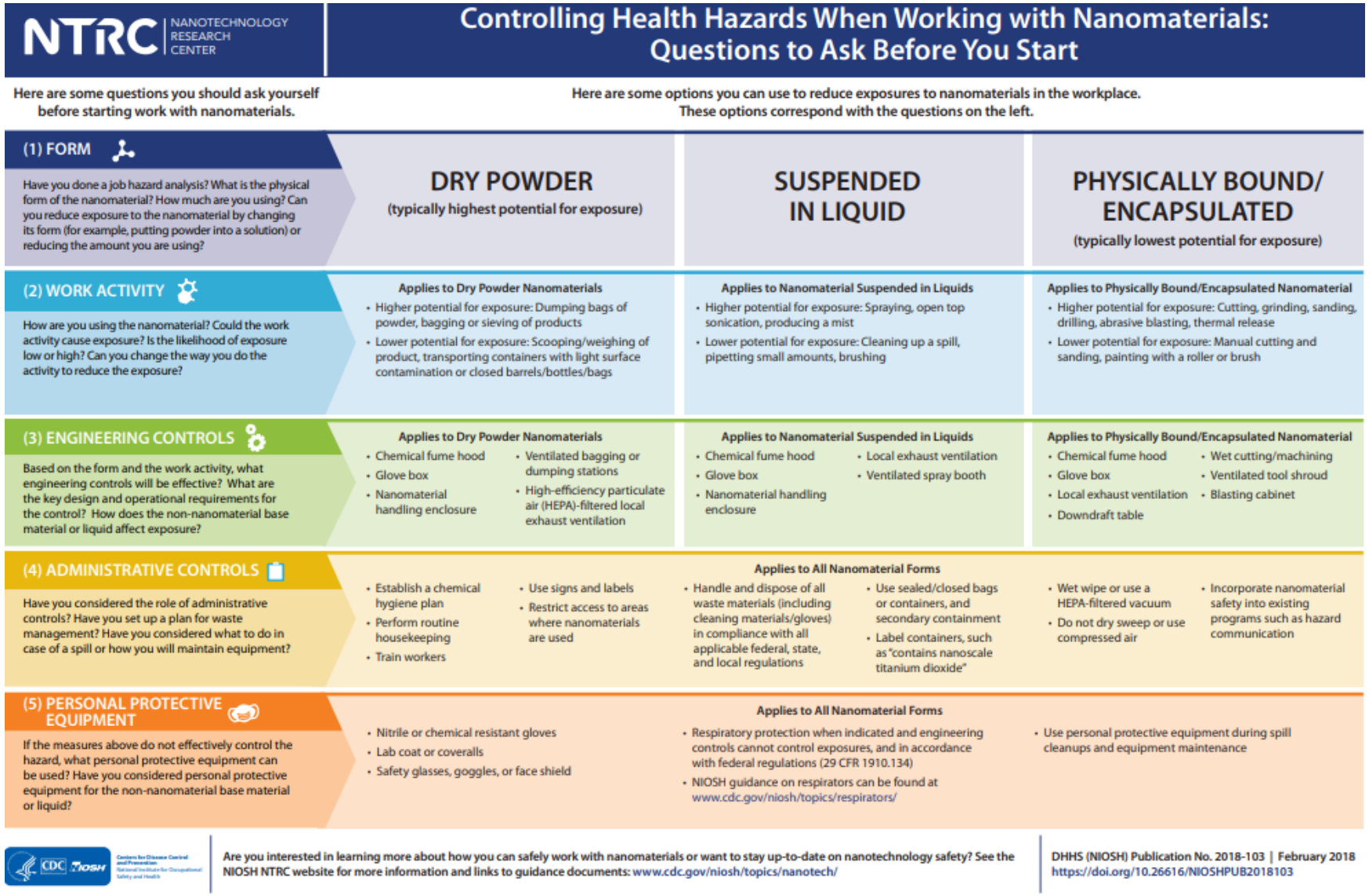
Trades most likely to handle these products…

Primary Trade	Number of Products (n=907 total)	Percent
Concrete/Cement Masons	201	22.2%
Painters	156	17.2%
Laborers	153	16.9%
Carpenters	66	7.3%
Brick masons	53	5.8%
Glaziers	46	5.1%
Insulators	36	4.0%
Carpet & Tile Installers	24	2.6%
Roofers	24	2.6%
Operating Engineers	23	2.5%
Other	125	13.8%

And the types of nanomaterials to which these trades could be exposed



We used this practical workplace guidance from NIOSH to classify exposure potential for each product category



NTRC NANOTECHNOLOGY RESEARCH CENTER

Controlling Health Hazards When Working with Nanomaterials: Questions to Ask Before You Start

Here are some questions you should ask yourself before starting work with nanomaterials.

Here are some options you can use to reduce exposures to nanomaterials in the workplace. These options correspond with the questions on the left.

	DRY POWDER (typically highest potential for exposure)	SUSPENDED IN LIQUID	PHYSICALLY BOUND/ ENCAPSULATED (typically lowest potential for exposure)
(1) FORM Have you done a job hazard analysis? What is the physical form of the nanomaterial? How much are you using? Can you reduce exposure to the nanomaterial by changing its form (for example, putting powder into a solution) or reducing the amount you are using?			
(2) WORK ACTIVITY How are you using the nanomaterial? Could the work activity cause exposure? Is the likelihood of exposure low or high? Can you change the way you do the activity to reduce the exposure?	**Applies to Dry Powder Nanomaterials** • Higher potential for exposure: Dumping bags of powder, bagging or sieving of products • Lower potential for exposure: Scooping/weighing of product, transporting containers with light surface contamination or closed barrels/bottles/bags	**Applies to Nanomaterial Suspended in Liquids** • Higher potential for exposure: Spraying, open top sonication, producing a mist • Lower potential for exposure: Cleaning up a spill, pipetting small amounts, brushing	**Applies to Physically Bound/Encapsulated Nanomaterial** • Higher potential for exposure: Cutting, grinding, sanding, drilling, abrasive blasting, thermal release • Lower potential for exposure: Manual cutting and sanding, painting with a roller or brush
(3) ENGINEERING CONTROLS Based on the form and the work activity, what engineering controls will be effective? What are the key design and operational requirements for the control? How does the non-nanomaterial base material or liquid affect exposure?	**Applies to Dry Powder Nanomaterials** • Chemical fume hood • Glove box • Nanomaterial handling enclosure • Ventilated bagging or dumping stations • High-efficiency particulate air (HEPA)-filtered local exhaust ventilation	**Applies to Nanomaterial Suspended in Liquids** • Chemical fume hood • Glove box • Nanomaterial handling enclosure • Local exhaust ventilation • Ventilated spray booth	**Applies to Physically Bound/Encapsulated Nanomaterial** • Chemical fume hood • Glove box • Local exhaust ventilation • Downdraft table • Wet cutting/machining • Ventilated tool shroud • Blasting cabinet
(4) ADMINISTRATIVE CONTROLS Have you considered the role of administrative controls? Have you set up a plan for waste management? Have you considered what to do in case of a spill or how you will maintain equipment?	• Establish a chemical hygiene plan • Perform routine housekeeping • Train workers • Use signs and labels • Restrict access to areas where nanomaterials are used	**Applies to All Nanomaterial Forms** • Handle and dispose of all waste materials (including cleaning materials/gloves) in compliance with all applicable federal, state, and local regulations • Use sealed/closed bags or containers, and secondary containment • Label containers, such as "contains nanoscale titanium dioxide"	• Wet wipe or use a HEPA-filtered vacuum • Do not dry sweep or use compressed air • Incorporate nanomaterial safety into existing programs such as hazard communication
(5) PERSONAL PROTECTIVE EQUIPMENT If the measures above do not effectively control the hazard, what personal protective equipment can be used? Have you considered personal protective equipment for the non-nanomaterial base material or liquid?	• Nitrile or chemical resistant gloves • Lab coat or coveralls • Safety glasses, goggles, or face shield	**Applies to All Nanomaterial Forms** • Respiratory protection when indicated and engineering controls cannot control exposures, and in accordance with federal regulations (29 CFR 1910.134) • NIOSH guidance on respirators can be found at www.cdc.gov/niosh/topics/respirators/	• Use personal protective equipment during spill cleanups and equipment maintenance

CDC NIOSH Centers for Disease Control and Prevention National Institute for Occupational Safety and Health

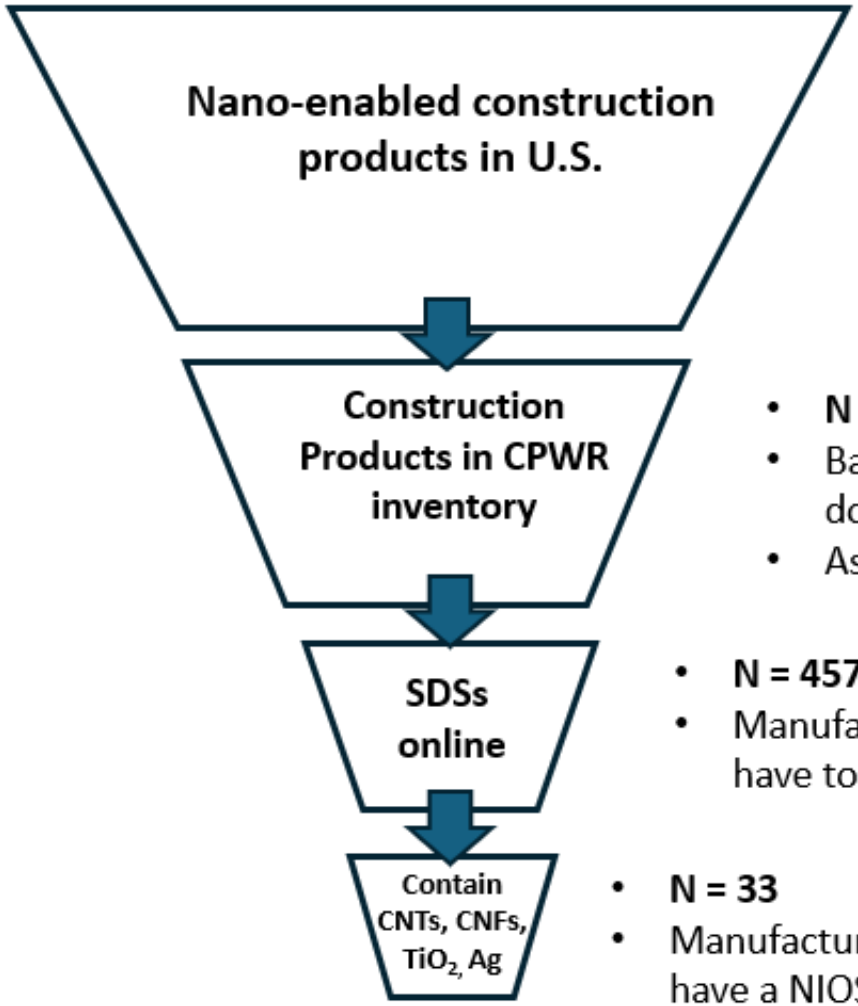
Are you interested in learning more about how you can safely work with nanomaterials or want to stay up-to-date on nanotechnology safety? See the NIOSH NTRC website for more information and links to guidance documents: www.cdc.gov/niosh/topics/nanotech/

DHHS (NIOSH) Publication No. 2018-103 | February 2018
https://doi.org/10.26616/NIOSHPUB2018103

TABLE 2 Identifying the potential for occupational exposure based on product availability, use, and physical form.

Product Category	N	Form	Examples of Work Activities with Potential for Exposure	Exposure Potential
Coatings - mineral surfaces	158	Suspended in liquid	Spray application, polishing after application	Higher
			Application with roller or brush	Lower
Coatings - multi-surface	146	Suspended in liquid	Spray application, polishing after application	Higher
			Application with roller or brush	Lower
Coatings – metal	53	Suspended in liquid	Spray application, sanding after application	Higher
			Application with roller or brush	Lower
Coatings – wood	46	Suspended in liquid	Spray application, sanding after application	Higher
			Application with roller or brush	Lower
Coatings – paints	41	Dry powder	Pouring, mixing	Higher
		Suspended in liquid	Spray application, sanding after application	Higher
			Application with roller or brush	Lower
Coatings - glass/ceramic	39	Suspended in liquid	Spray application, polishing after application	Higher
			Wipe application	Lower
Insulation - Heat/Frost	38	Physically bound/ encapsulated	Cutting, demolition	Higher
Cement-based	32	Physically bound/ encapsulated	Breaking cured/dried masonry	Lower
			Cutting, grinding, sawing, drilling, tuckpointing	Higher
		Dry powder	Pouring, mixing	Higher
Lubricants	23	Suspended in liquid	Pouring, spreading	Lower
			Spray application to construction equipment and tools	Higher

This figure shows how we obtained our sample of safety data sheets (SDSs)



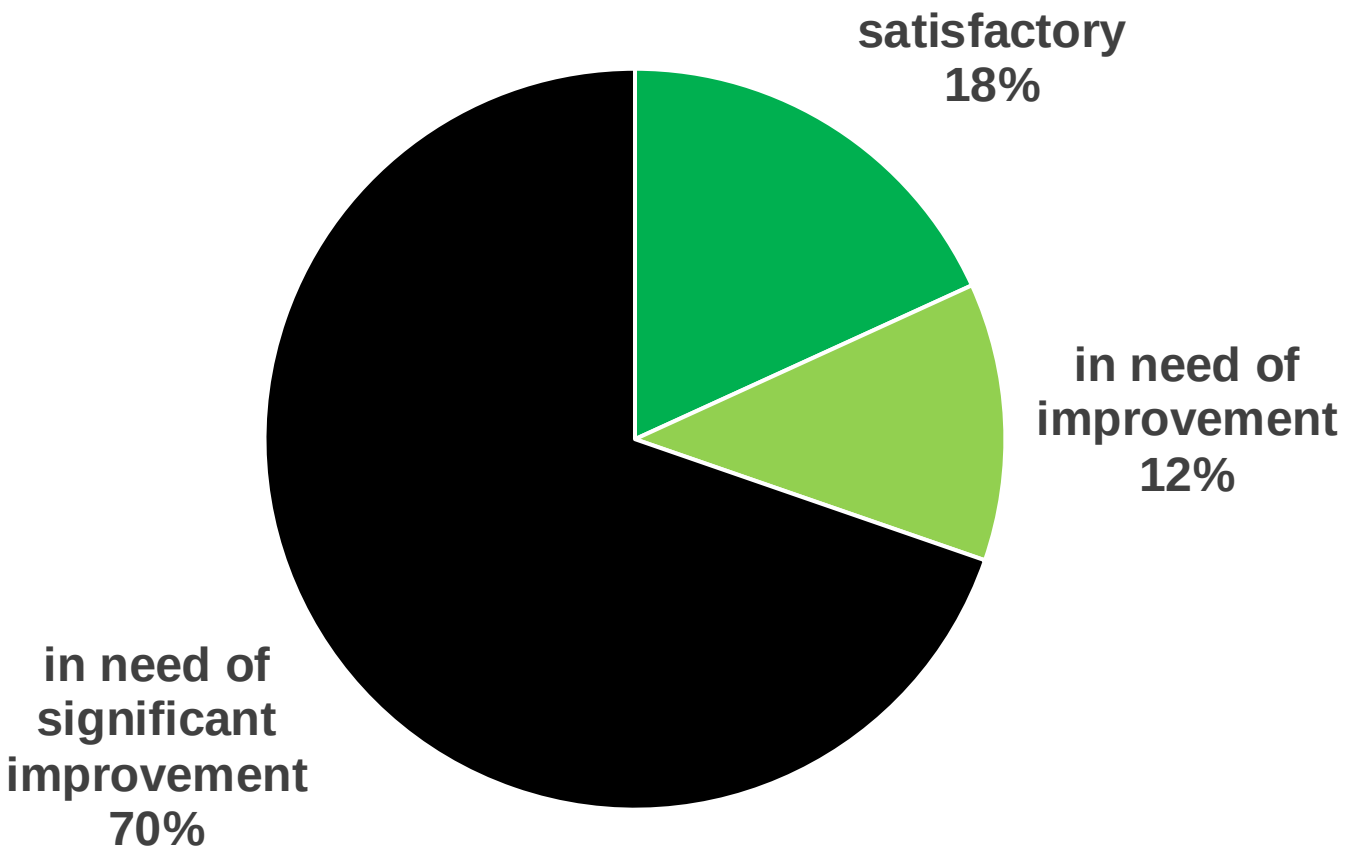
- **Unknown number**
- No registry or reporting requirements
- No way to estimate amount of products

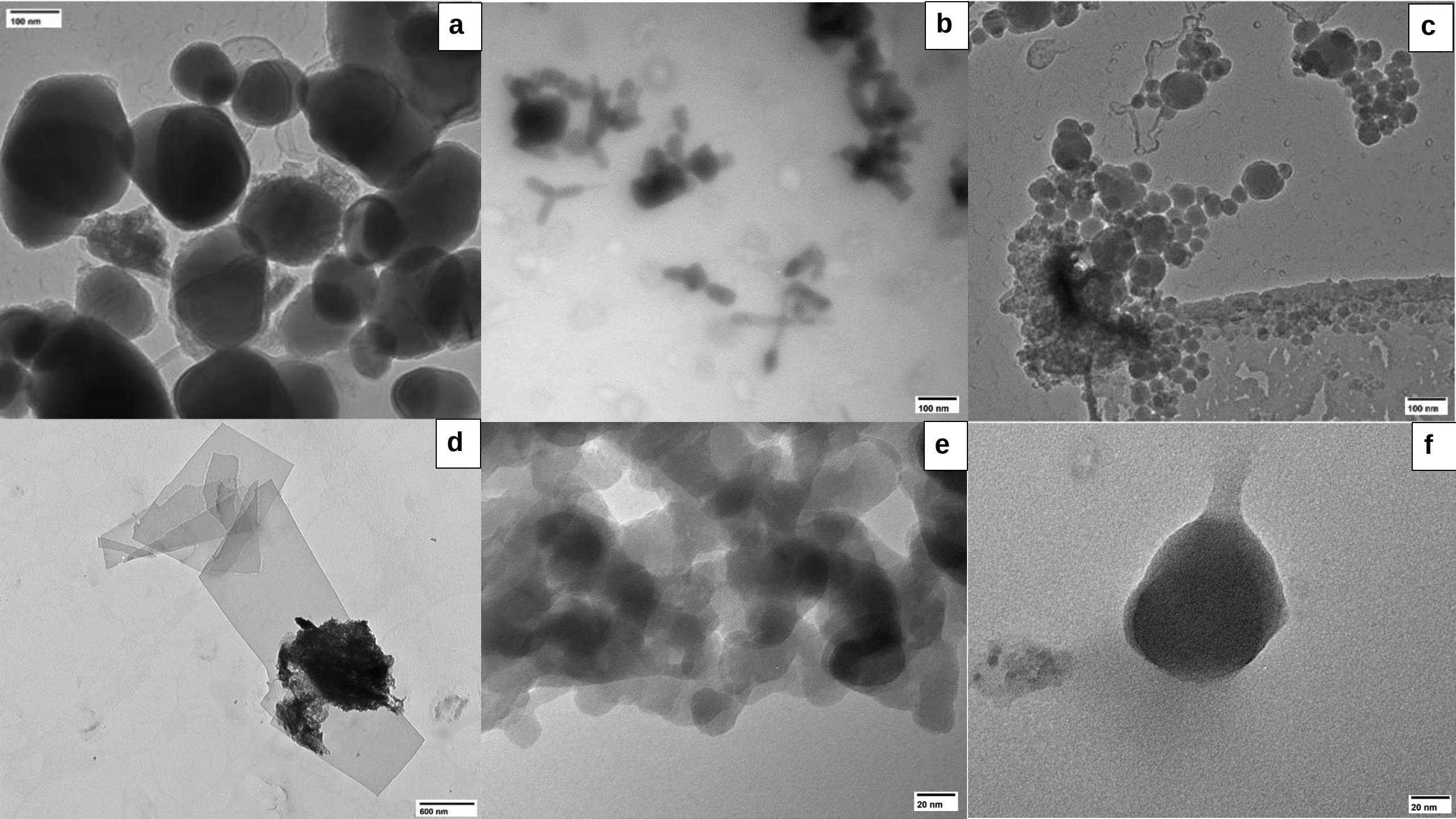
- **N = 907**
- Based on search criteria that do not include verification
- As of January 2024

- **N = 457**
- Manufacturers do not have to post SDSs online

- **N = 33**
- Manufacturers reported use of ENMs that have a NIOSH Recommended Exposure Limit

We rated SDSs using modified criteria developed by NIOSH researchers and found < 1 in 5 to be satisfactory




a
100 nm
b
100 nm
c
100 nm
d
600 nm
e
20 nm
f
20 nm

Here is one illustrative example of a safety data sheet in need of improvement

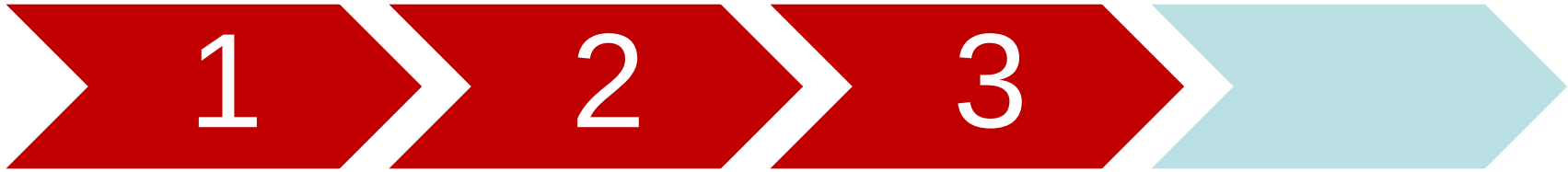
Section 3

Composition/ Information on Ingredients:

Chemical Name	CAS Number	Weight %
Dieethylene Glycol Monoethyl Ether	111-90-0	10 – 20%
Zinc Ammonium Carbonate Compound	38714-47-5	25 – 30%
Titanium Nano Drivers	13463-67-7	5 – 10%
Tributoxy Ethyl Phosphate	78-51-3	5 – 10%
Polymeric Hybrid Nano Particles	25586-24-7	1.0 – 3%
Plexi Acrylic Nano Fusion	9063-87-0	10 – 20%
Polycarbonate Nano Drivers	25037-45-0	15 – 25%
Hydrogen Hydroxide	7732-18-5	50 – 60%

Learning Objective #3

Compare standards and guidance pertaining to labeling and hazard communication for ENMs



Under REACH, the registration dossier for nano must include

- Size
- Shape
- Aspect ratio
- Assembly structure
- Rigidity
- Crystallinity
- Surface functionalization
- Surface area
- Dustiness
- Solubility
- Partial coefficient octanol/water

https://echa.europa.eu/regulations/nanomaterials

OSHA's revised hazard communication standard should improve Nano SDSs

9.	**Physical and chemical properties †**	~~(a) Appearance (physical state, color, etc.);(b) Odor;~~ ~~(c) Odor threshold;(d) pH;~~ ~~Melting point/freezing point;~~ ~~Boiling point or initial boiling point and boiling range;(g) Flash point;~~ ~~Evaporation rate;~~ ~~Flammability (solid, gas);~~ ~~(i) Lower and upper explosion limit/flammability limit;(k) Vapor pressure;~~ ~~(l) vapor density; (m) Relative density;(n) Solubility(ies);~~ ~~Partition coefficient;~~ ~~Auto-ignition temperature~~ ~~Decomposition temperature;(r) viscosity;~~ (a) Physical state (b) Color (c) Odor (includes odor threshold) (d) Melting point/freezing point (e) Boiling point (or initial boiling point or boiling range) (f) Flammability (g) Lower and upper explosion limit/flammability limit (h) Flash point (i) Auto-ignition temperature (j) Decomposition temperature (k) pH (l) Kinematic viscosity (m) Solubility (n) Partition coefficient n-octanol/water (log value) (o) Vapor pressure (includes evaporation rate) (p) Density and/or relative density
		(q) Relative vapor density (r) Particle characteristics

Upcoming changes are anticipated in Canada as well

"Overall, there is a serious lack of regulations specific to engineered nanoparticles worldwide. However, the **Canadian federal government is expected to adopt a new nanoparticle subsection under Canada Occupational Health and Safety Regulations** in the near future."

https://www.canada.ca/en/employment-social-development/services/health-safety/reports/engineered-nanoparticles.html#h2.4

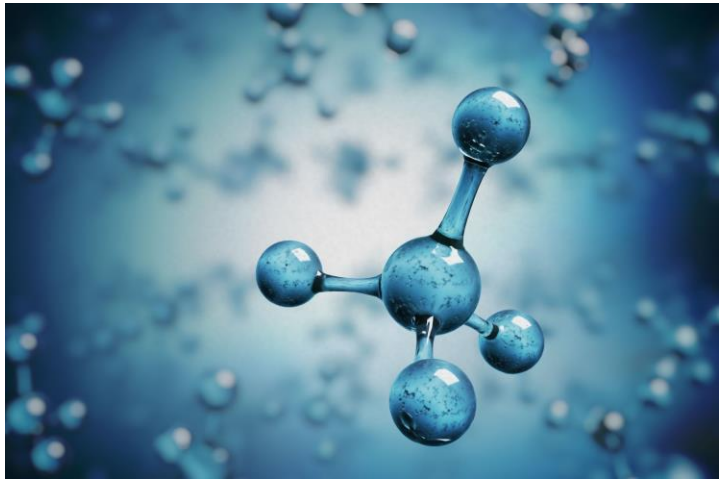
Image courtesy: Wikimedia Commons

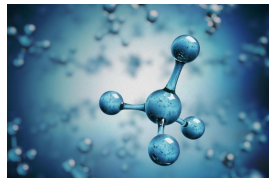
There is good guidance available for writing Nano SDSs (ISO/TS 13329)

Provide an SDS for nanomaterials and nanomaterial-containing products *regardless* of whether the material is classified as hazardous

A colleague with more applied hazcom experience than myself offered these words of advice:

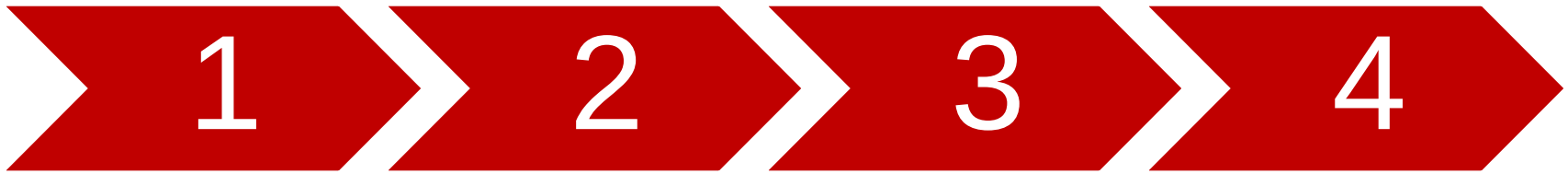
"Be extremely careful when conducting read-across for nanoscale forms of existing chemical substances."



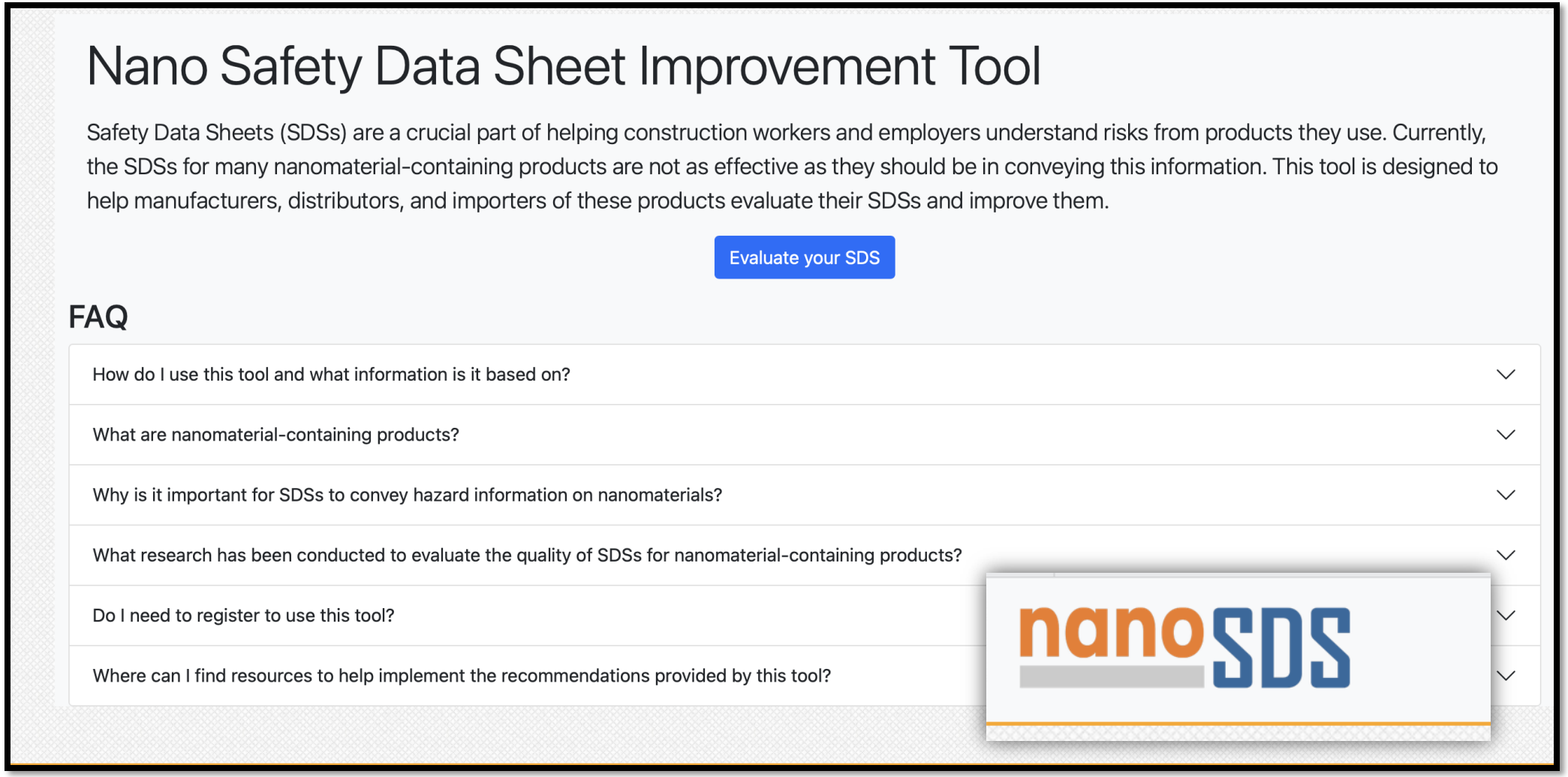


Learning Objective #4

Apply resources to develop informative safety data sheets for ENMs

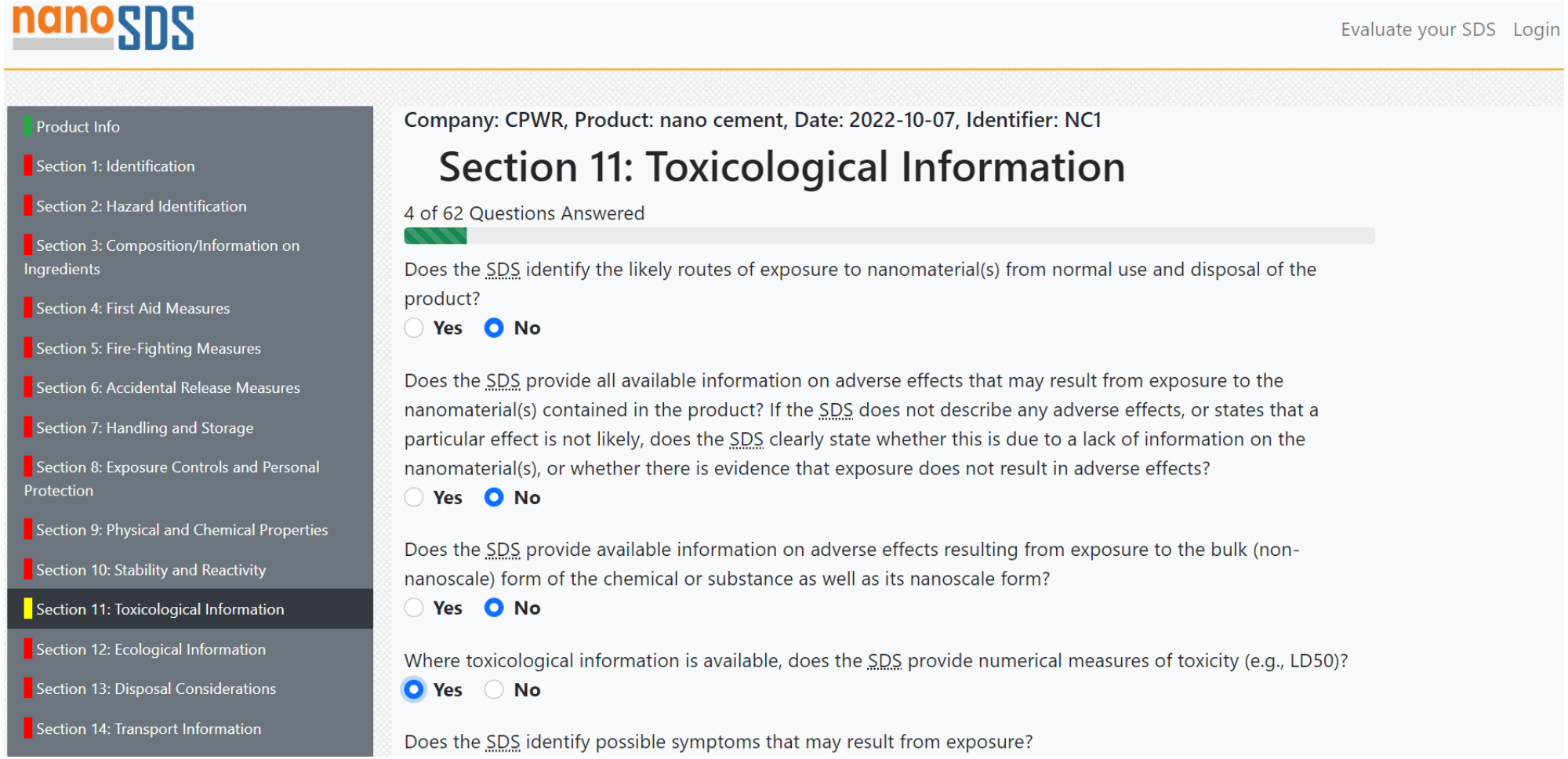


CPWR recently posted free SDS guidance



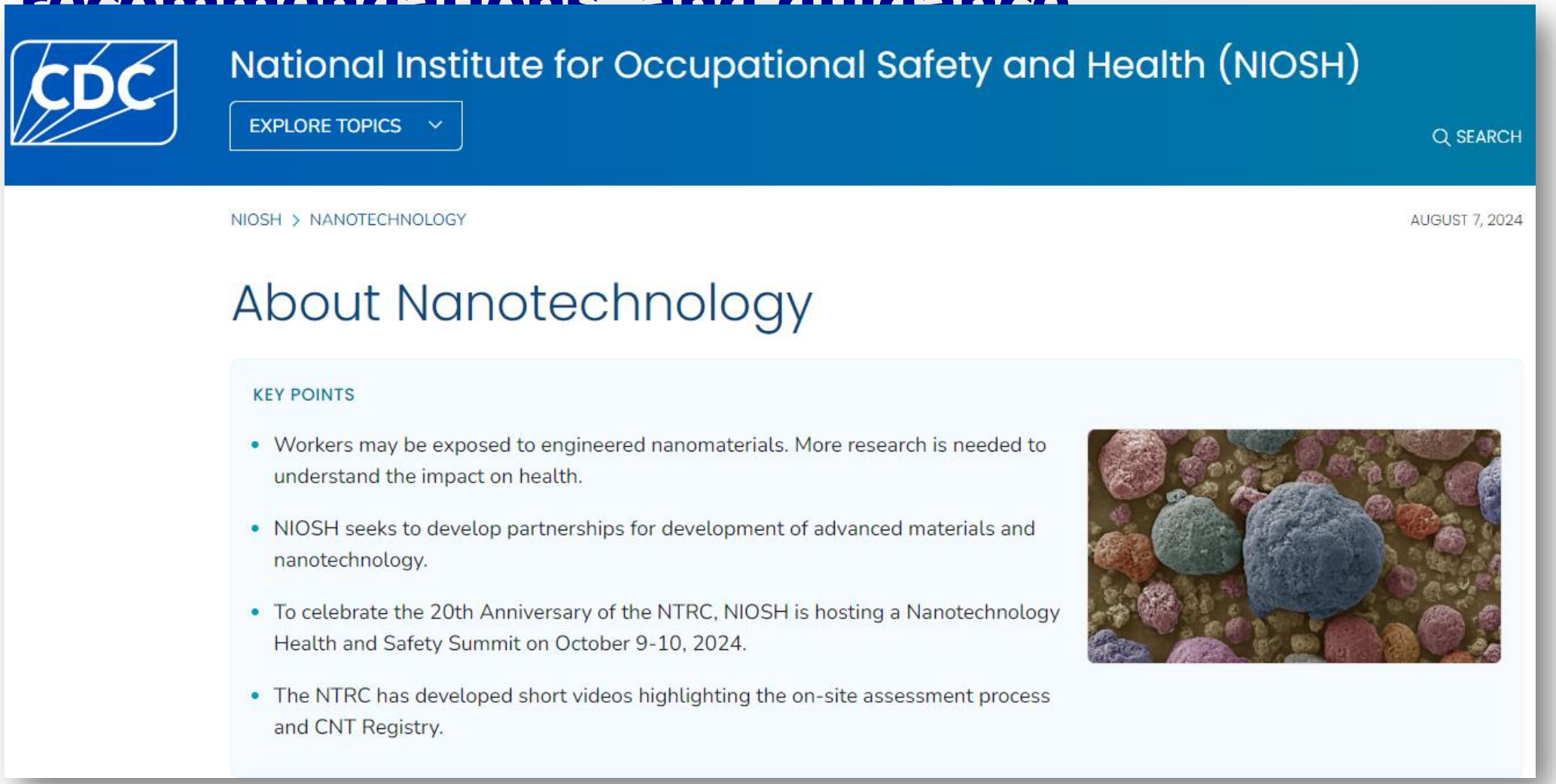
https://nanosds.elcosh.org

The interactive nano SDS tool can be used to evaluate and improve nano SDSs

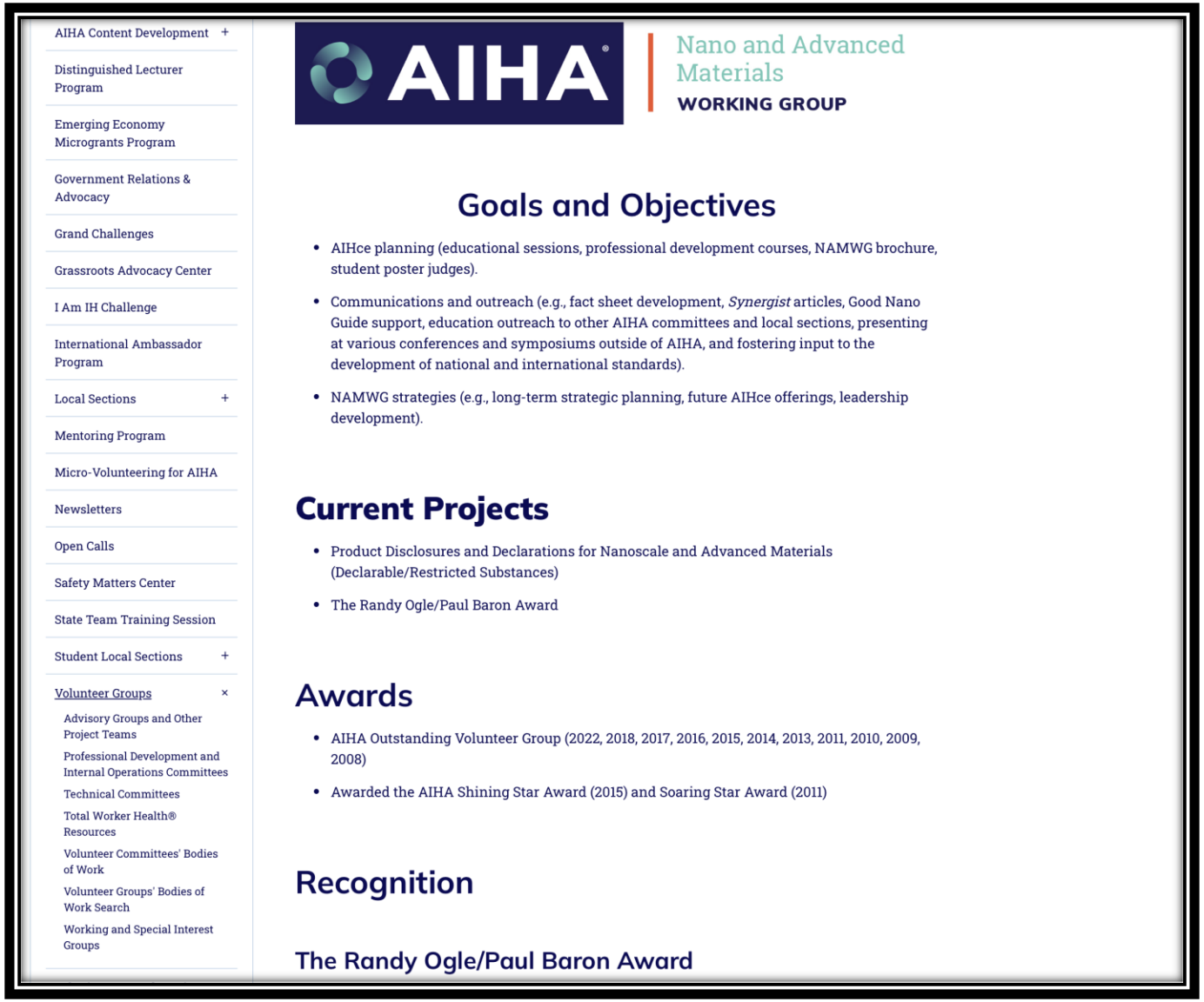


https://nanosds.elcosh.org/

The NIOSH nanotechnology website is a good way to stay up-to-date on the latest news, recommendations, and guidance



The AIHA Nano and Advanced Materials Working Group continues promoting Nano H&S



AIHA Content Development +
Distinguished Lecturer Program
Emerging Economy Microgrants Program
Government Relations & Advocacy
Grand Challenges
Grassroots Advocacy Center
I Am IH Challenge
International Ambassador Program
Local Sections +
Mentoring Program
Micro-Volunteering for AIHA
Newsletters
Open Calls
Safety Matters Center
State Team Training Session
Student Local Sections +
Volunteer Groups ×
Advisory Groups and Other Project Teams
Professional Development and Internal Operations Committees
Technical Committees
Total Worker Health® Resources
Volunteer Committees' Bodies of Work
Volunteer Groups' Bodies of Work Search
Working and Special Interest Groups

AIHA | Nano and Advanced Materials WORKING GROUP

Goals and Objectives

- AIHce planning (educational sessions, professional development courses, NAMWG brochure, student poster judges).
- Communications and outreach (e.g., fact sheet development, *Synergist* articles, Good Nano Guide support, education outreach to other AIHA committees and local sections, presenting at various conferences and symposiums outside of AIHA, and fostering input to the development of national and international standards).
- NAMWG strategies (e.g., long-term strategic planning, future AIHce offerings, leadership development).

Current Projects

- Product Disclosures and Declarations for Nanoscale and Advanced Materials (Declarable/Restricted Substances)
- The Randy Ogle/Paul Baron Award

Awards

- AIHA Outstanding Volunteer Group (2022, 2018, 2017, 2016, 2015, 2014, 2013, 2011, 2010, 2009, 2008)
- Awarded the AIHA Shining Star Award (2015) and Soaring Star Award (2011)

Recognition

The Randy Ogle/Paul Baron Award

Thank you! Questions?

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