

# Update on Nanomaterials in Construction: Epidemiology, Exposures and Worker Awareness

## **CPWR Webinar Series**

**December 13, 2018**

**Bruce Lippy, Ph.D., CIH, CSP, FAIHA**

**Gavin West, MPH**

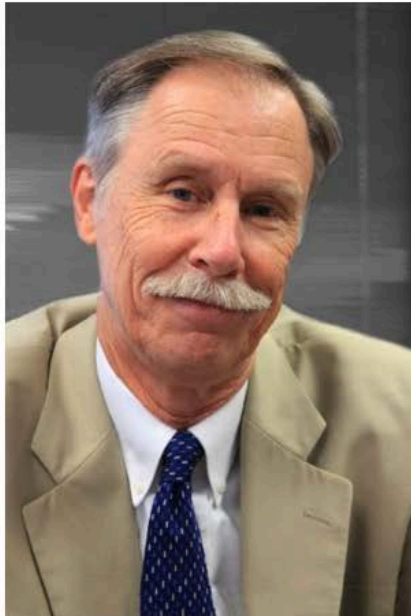
**Laura Boatman**



THE CENTER FOR CONSTRUCTION  
RESEARCH AND TRAINING

# Introduction of speakers (in order of presentation)

**Bruce Lippy**



**Gavin West**



**Laura Boatman**



What are **some highlights** of the current state of knowledge on health effects of ENMs on workers?

Bruce Lippy

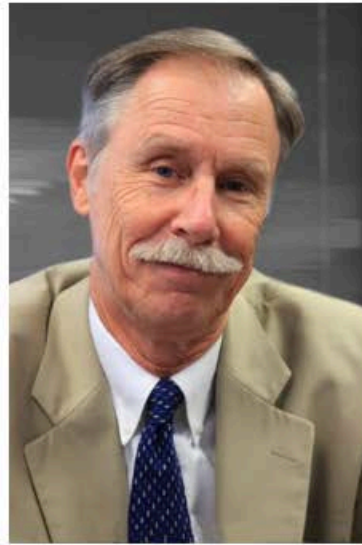


# Graphic depiction of my epidemiological expertise



0

**Gondolier**



28.62

**me**



100

**Real  
epidemiologist,  
Dr. Carlo Catassi**

**Slides graciously provided by  
Paul Schulte, NIOSH, from his  
excellent presentation at ICOH  
2018 in Dublin**



**Conference Center on River Liffey**

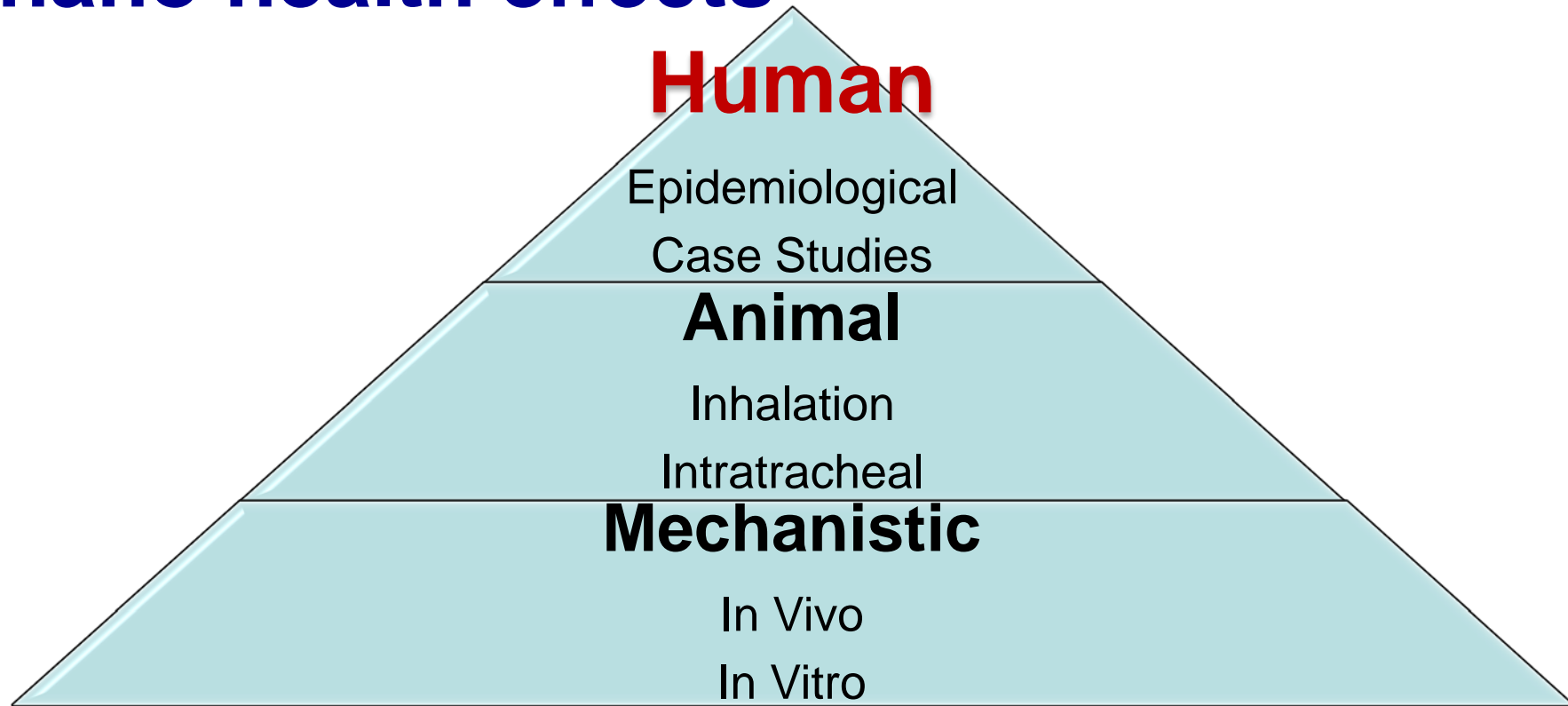
**Paul is so dedicated he could moderate a session on nanotechnology, while...**



...outside in the sunlight, amazing things were happening in Ireland



# Human epidemiological data is still a small subset of our knowledge on nano health effects



Graphic courtesy Paul Schulte, NIOSH



# Dr. Schulte noted the importance of “legacy” ENMs like carbon black

- 9.6 million tons per year worldwide
- Generic name for family of materials that have been **manufactured for >80 yrs**
- Primary particle range 10-500 nm, but many aggregates and agglomerates



Photos courtesy Wikimedia

# Carbon black workers show alterations in respiratory function and inflammatory cytokines (Zhang et al 2014)

- **Strong** epidemiologic evidence of association of nonmalignant respiratory disease and decreases in pulmonary function, symptoms of chronic bronchitis (Gardiner et al 2001; VonTongeren et al 2002; Harber et al 2003, Neghah et al 2011)
- Animal studies showed pulmonary inflammation (Vesterdahl et al 2010; Niwa 2008)



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

# Lung cancer evidence is **inconsistent** for carbon black (IARC, 2010)

- Industry-based case/control or cohort studies and community studies were assessed
- 7 of 13 were considered informative for lung cancer (3 in production workers)
- Generally small cohorts; cigarette smoking could be confounding factor
- Animal studies **support** that carbon black can cause lung cancer (IARC 2010)

# Synthetic amorphous silica (SAS) primary particles are less than 100 nm

- Intentionally manufactured; forms aggregates and agglomerates
- No measureable levels of crystalline silica
- Been in commerce for **more than 60 years**
- **Not** comprehensively studied

# Case study showed pulmonary fibrosis, inflammation and pleural granuloma

- 7 female workers (18-47 yrs)
- Exposed to silica nanoparticles (2-20 nm)
- Team used electron microscopy to identify nanoparticles in lung tissue
- **Conclusion:** “Given the well-documented toxicity of microscale silica, it is possible that these silica nanoparticles may have contributed in part to the illness reported in these workers.”

# Many nanomaterials have **little or no** toxicological or epidemiological evaluation

- **Aluminum oxide:** no epi studies
- **Zinc oxide:** no epi studies
- **Barium titanate:** relatively high production level, but no documentation of occupational exposure or animal inhalation studies
- **Cerium oxide:** used in broad array of application, but epidemiological studies of workers are lacking

# Significant quantities, missing epidemiology

Nanomaterial	Commercial Tonnage (WHO 2017 report)	Epidemiologic findings pathologic effects in workers
Carbon black	9,600,000	Nonmalignant respiratory disease
Synthetic amorphous silica	1,500,000	<b>Not Available</b>
Aluminum oxide	200,000	<b>Not Available</b>
Barium titanate	15,000	<b>Not Available</b>
Titanium dioxide	10,000	lung cancer Nonmalignant respiratory disease
Cerium dioxide	10,000	<b>Not Available</b>
Zinc oxide	8,000	(metal fume fever)

# Recent epi studies of **titanium dioxide workers** reported **markers of oxidative stress**

- Lipid oxidative markers (Pelclova et al. 2017)
- Significant **dose dependent** increase in the biomarkers of lung damage in employees of a nano-TiO<sub>2</sub> manufacturing plant in eastern China (Zhao et al. 2018).
- Alterations in cardiovascular disease markers (Zhao et al. 2018).



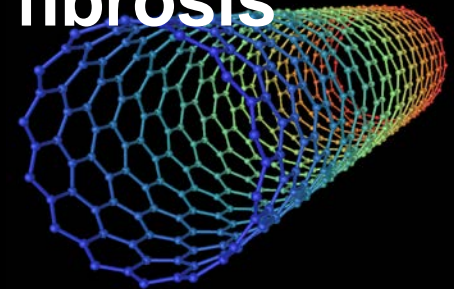
# Epi studies for carbon nanotubes showed cellular changes

- 10 MWCNT exposed and 12 non-exposed controls
- Exposure associated with significant increases in inflammatory cytokines and a marker of lung disease

**Futkhutdinova et al 2016**

- 8 MWCNT exposed and 7 non-exposed
- Dysregulated mRNA and miRNA associated with pulmonary inflammation and fibrosis

**Shvedova 2016**



# Recent cross-sectional study showed **early effects on lung health and immune system among MWCNT workers**

- 22 MWCNT-exposed and 39 age/gender-matched controls
- Significant upward trends in immune and pulmonary markers

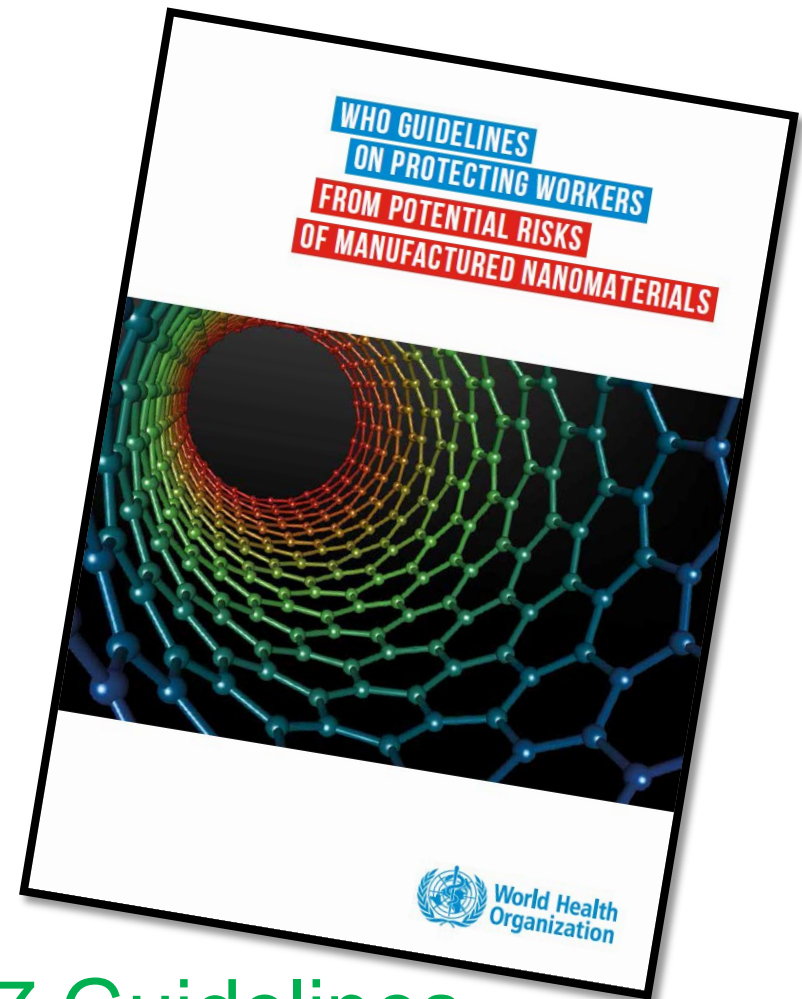
Vlaanderen et al 2017

# Dr. Schulte concluded:

- ENMs need to be considered by type with regard to health effects
- Generally there are **few studies of health effects of contemporary ENMs**; some for legacy ENM but findings are suggestive
- Need to take next step and further study worker populations
- Need to conduct animal studies to support worker findings
- Need to assess biomarkers across studies as well as within them
- **Precautionary approaches** are still warranted

# The World Health Organization supports his conclusions, stressing:

- **Precautionary approach**
- **Hierarchy of controls**



WHO 2017 Guidelines

# What are the latest exposure and control findings by CPWR?

Gavin West



# Workers can be exposed across the life cycle of building materials

Production



Installation



Maintenance



Demolition



Disposal  
Recycling

\*Mining & Extraction not shown

# CPWR researchers are investigating exposures to nanomaterials during **routine installation and maintenance**

Production



Installation



Maintenance



Demolition



Disposal  
Recycling

# First study involved cutting, drilling, and nailing of photocatalytic roofing tiles





# The roofing tile study was published in 2016

**Journal of Nanoparticle Research**

An Interdisciplinary Forum for  
Nanoscale Science and Technology

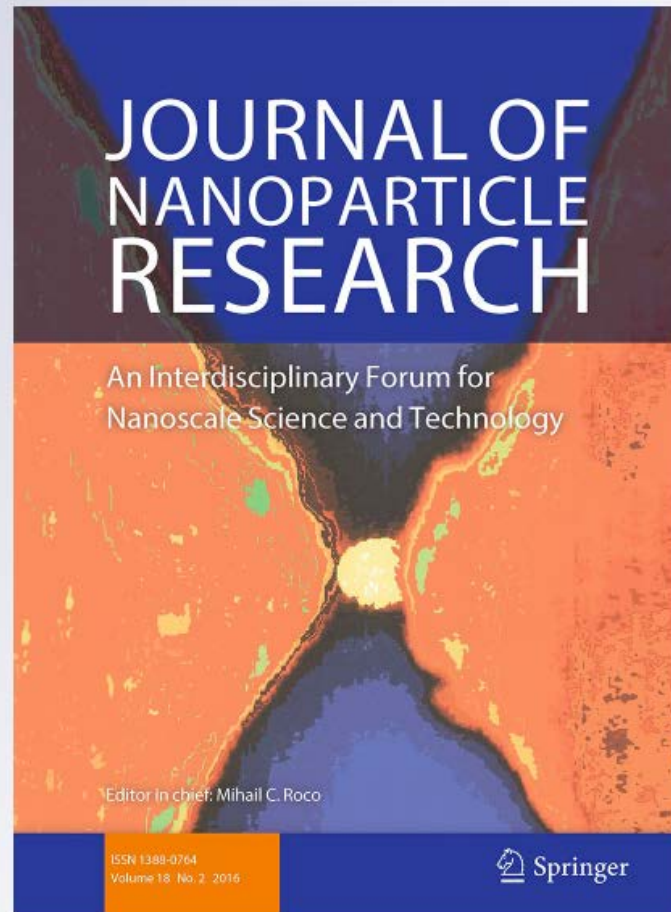
ISSN 1388-0764

Volume 18

Number 2

J Nanopart Res (2016) 18:1-27

DOI 10.1007/s11051-016-3352-y



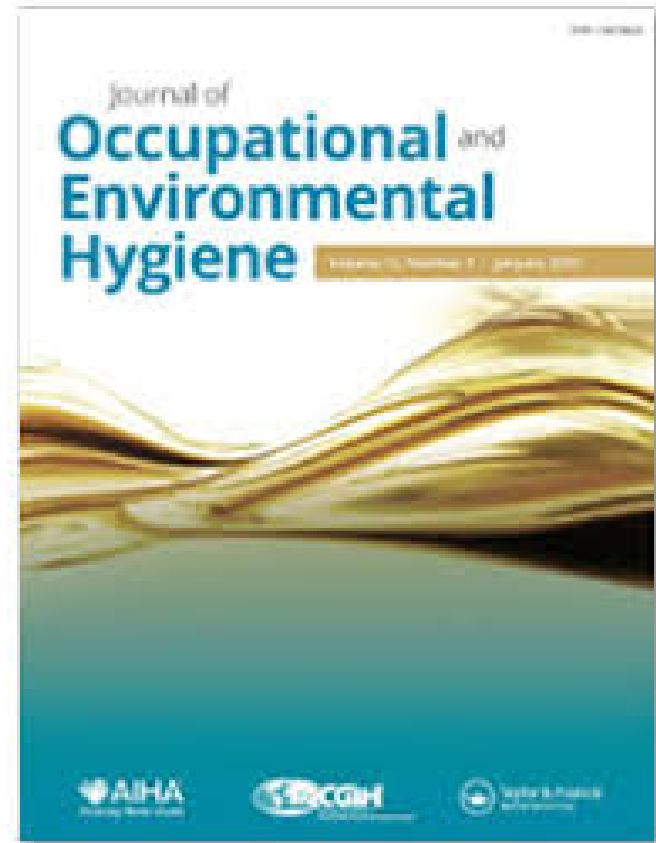
<https://link.springer.com/article/10.1007%2Fs11051-016-3352-y>

# Second study examined **wood sealant** containing **nano zinc oxide**

Exposures while:

- Spraying
- Sanding

Published in 2017



<https://www.tandfonline.com/doi/abs/10.1080/15459624.2017.1296237>

# Today we'll discuss our latest study published last month



Journal

**Journal of Occupational and Environmental Hygiene** >

Latest Articles

Submit an article

Journal homepage

45

Views

0


CrossRef citations  
to date

0

Altmetric

Articles

## Exposure to airborne nano-titanium dioxide during airless spray painting and sanding

Gavin H. West , Michael R. Cooper, Leonard G. Burrelli, Daniel Dresser & Bruce E. Lippy

Received 12 Jul 2018, Accepted 14 Nov 2018, Accepted author version posted online: 19 Nov 2018

Download citation

 <https://doi.org/10.1080/15459624.2018.1550295>

 Check for updates

 Full Article

 Figures & data

 References

 Citations

 Metrics

 Reprints & Permissions

Get access

<https://www.tandfonline.com/doi/full/10.1080/15459624.2018.1550295>

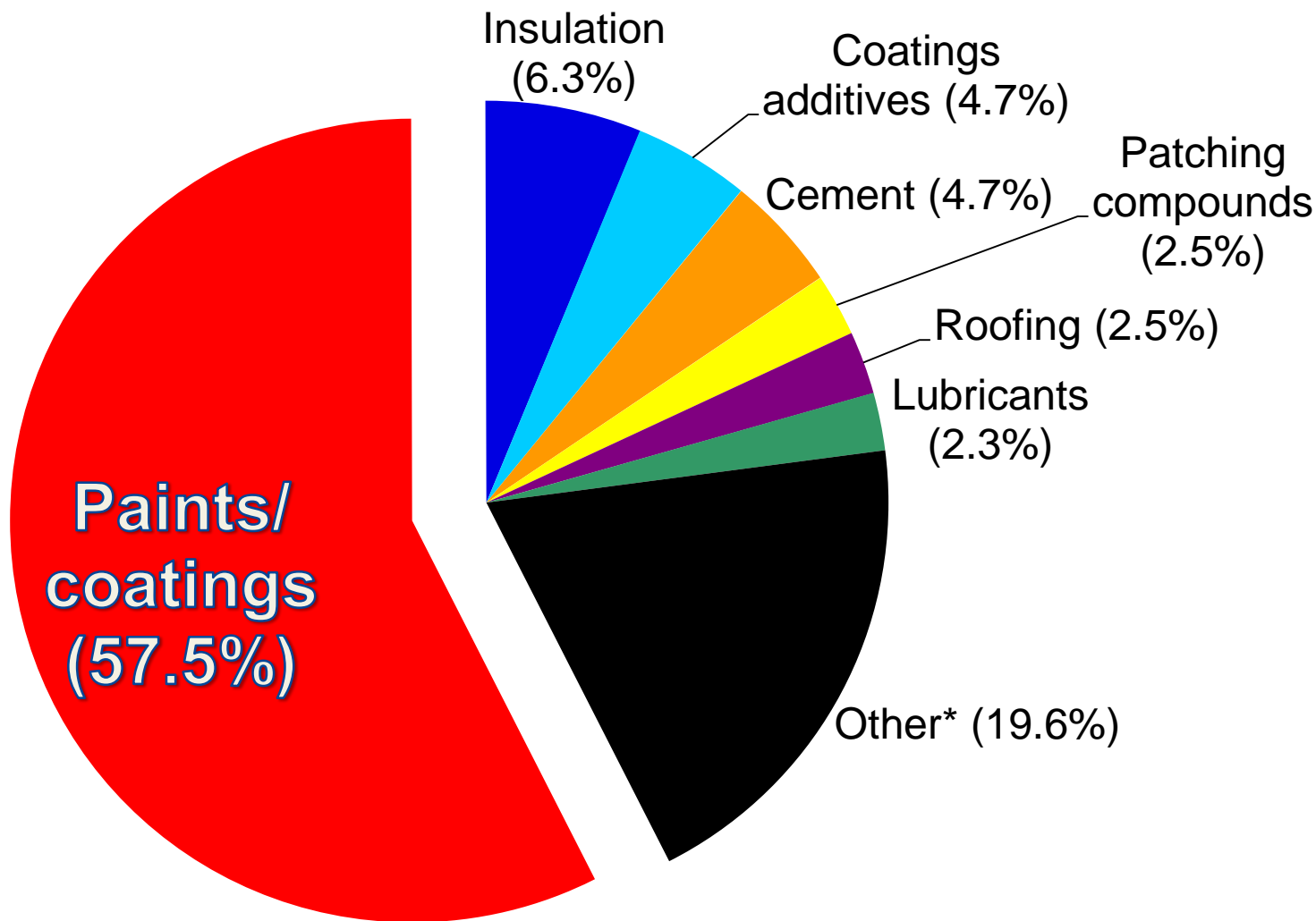
**Let's begin with a brief  
background & rationale  
for the study**

CPWR has identified  
~600 construction products  
reported to be nano-enabled



[www.nano.elcosh.org](http://www.nano.elcosh.org)

# CPWR's Construction Chart Book shows that most products in the eLCOSH nano inventory are **paints and coatings**

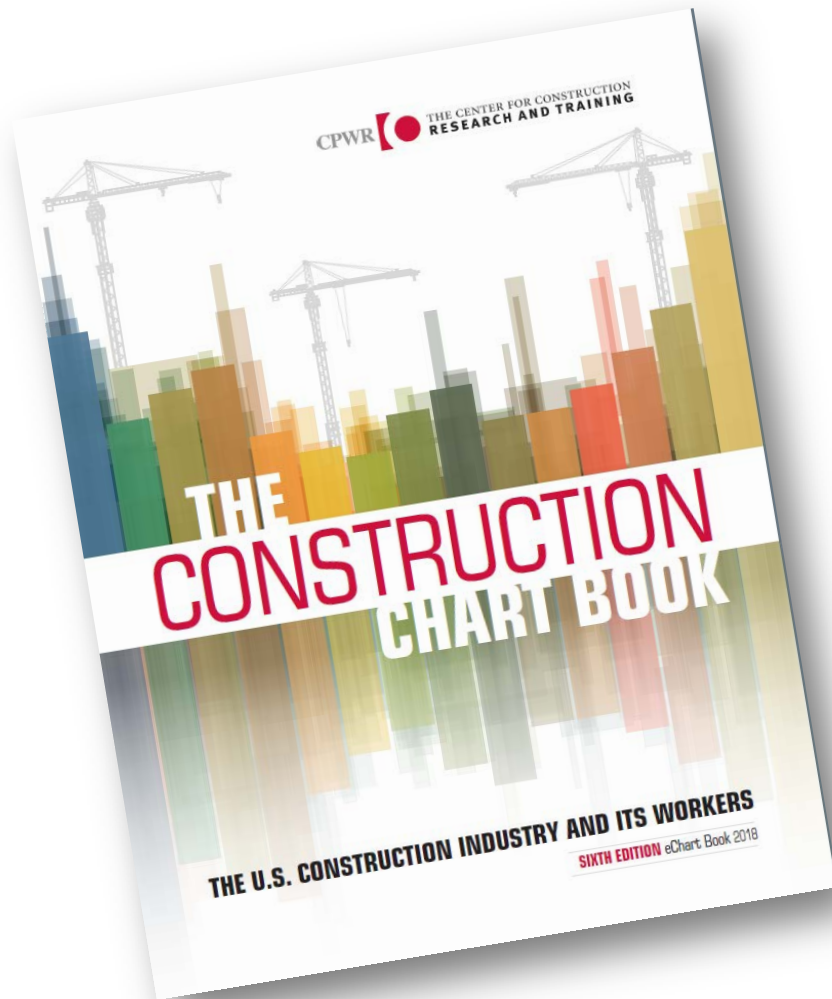


\*Other includes surface preparation, thermal spray coating materials, adhesives, additives for concrete/cement, flooring, glass and solar panels, metal, weld overlays, drywall, miscellaneous, HV/AC, prepregs, weatherproofing membranes, additives for asphalt, caulking, joint sealants, lighting, lumber, boiler additives, fasteners, fuel additives, and interior design.

Note: Data are based on 557 products in the inventory as of July 7, 2017.

Source: eLCOSH Nano, Construction Nanomaterial Inventory (2017). [www.nano.elcosh.org](http://www.nano.elcosh.org)

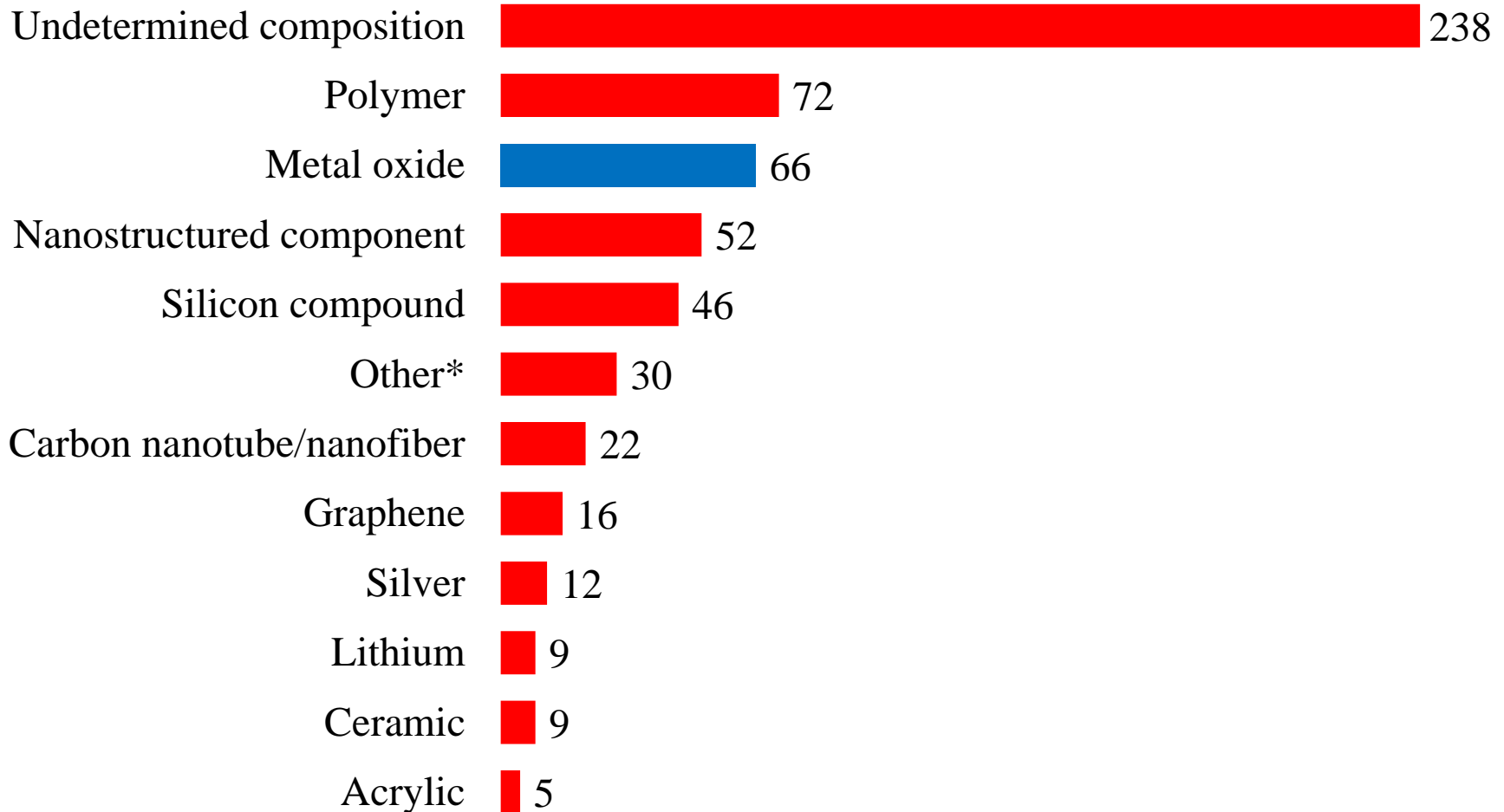
# Unfamiliar with the Chart Book? New 6<sup>th</sup> edition is online and free!



<https://www.cpwr.com/publications/research-findings-articles/construction-chart-book>

## The Chart Book also shows that **nano-size metal oxides** are frequently reported in the eLCOSH nano inventory

Number of nanomaterials (Total=577)



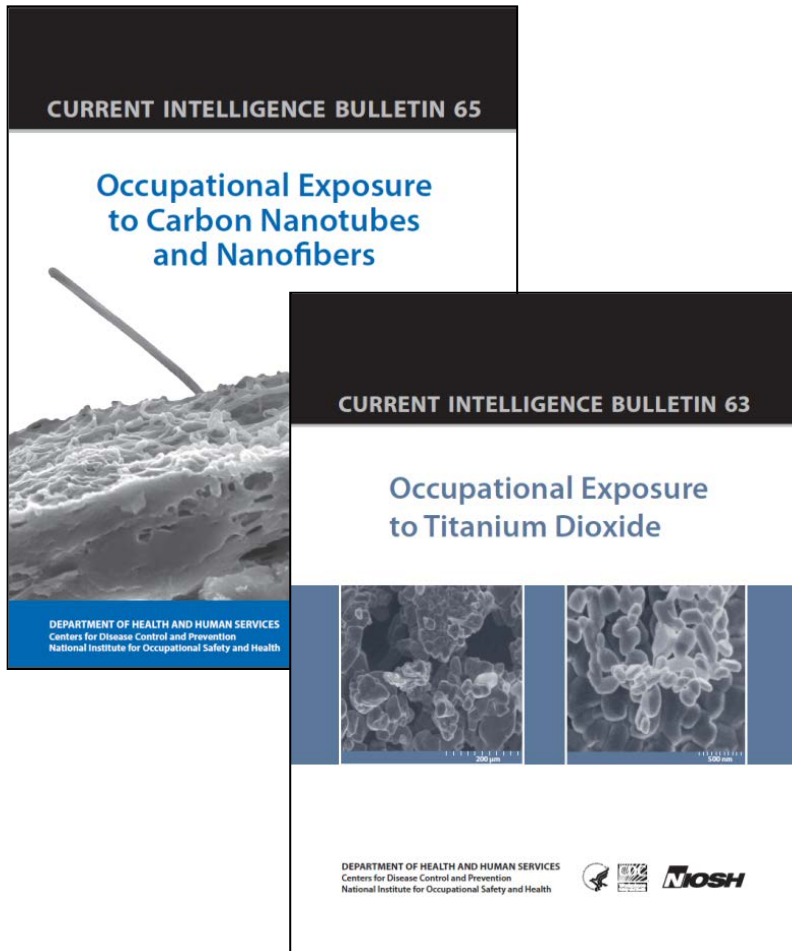
\*Other includes alumina, austenite, boehmite, calcium hydroxide, carbon, carboxylate, cellulose, clay, copper carbonate, diamond, magnesium, nylon, pigment, titanium nitride, tungsten carbide, tungsten disulfide, and zinc.

Note: Data are based on 577 nanomaterials reported for 557 products in the inventory as of July 7, 2017.

Source: eLCOSH Nano, Construction Nanomaterial Inventory (2017). [www.nano.elcosh.org](http://www.nano.elcosh.org)



# NIOSH has Recommended Exposure Limits (RELs) for nanomaterials

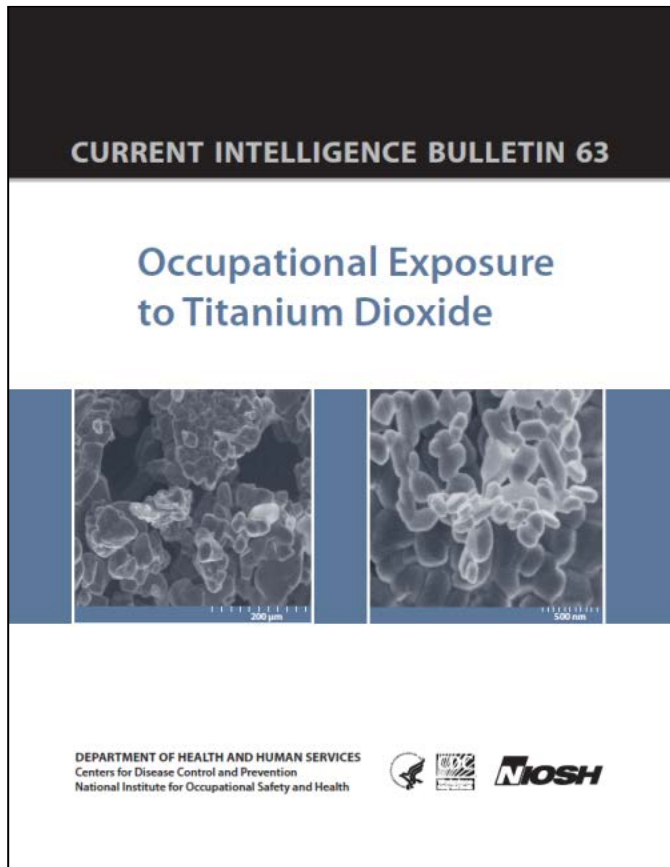


## Silver nanomaterials

- **Revised Draft**
- Posted 09/18/18
- Federal Register Docket #:  
[CDC-2016-0001](https://www.federalregister.gov/d/2016-0001)

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

# REL for nano-TiO<sub>2</sub> is 8x lower than fine

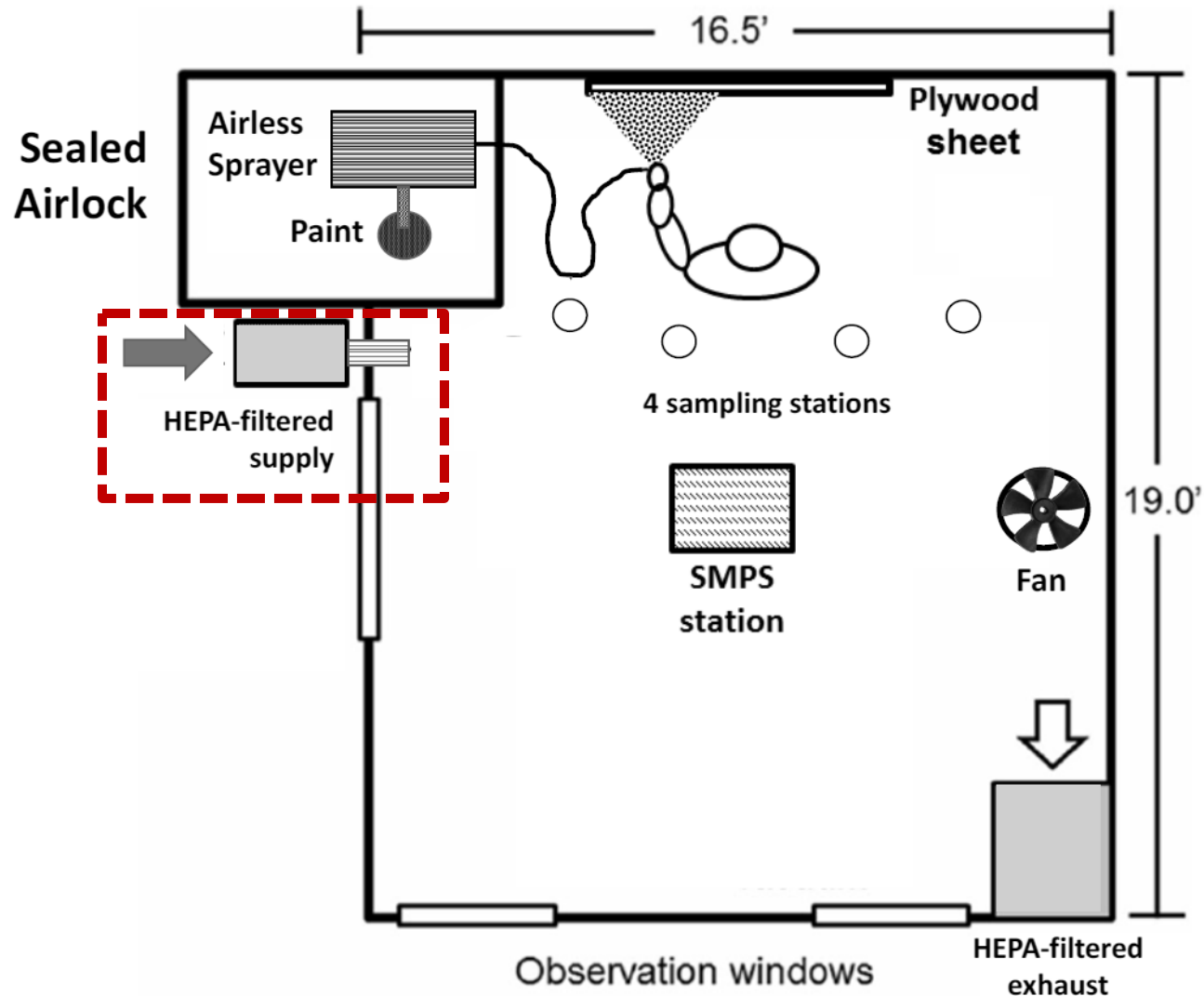


- 2.4 mg/m<sup>3</sup> (fine)
- 0.3 mg/m<sup>3</sup> (ultrafine)
  - Ultrafine includes engineered nanoscale
  - time-weighted averages up to 10 hours/day during 40-hour work week
- **Ultrafine** classified as a **potential occupational carcinogen**

# Objectives:

- 1. Measure exposure to nano-TiO<sub>2</sub> while painting, sanding**
- 2. Examine potential release of unbound TiO<sub>2</sub> nanoparticles**
- 3. Evaluate engineering controls**

# The study took place in a sealed chamber with HEPA-filtered air



Paint containing nano-TiO<sub>2</sub> was sprayed onto plywood then sanded



# Particle size distributions were measured with real-time instruments



Photo  
courtesy  
Earl Dotter

**TSI Scanning Mobility Particle Sizer  
and Optical Particle Sizer**

# Standard industrial hygiene methods gave mass concentrations of dusts and metals



Photos  
courtesy Earl  
Dotter

# Scanning electron microscopy (SEM) was used to characterize particles

- **Chemical composition**
  - energy dispersive spectroscopy
- **Shape, size, number**
  - on-screen observation
  - micrograph analysis

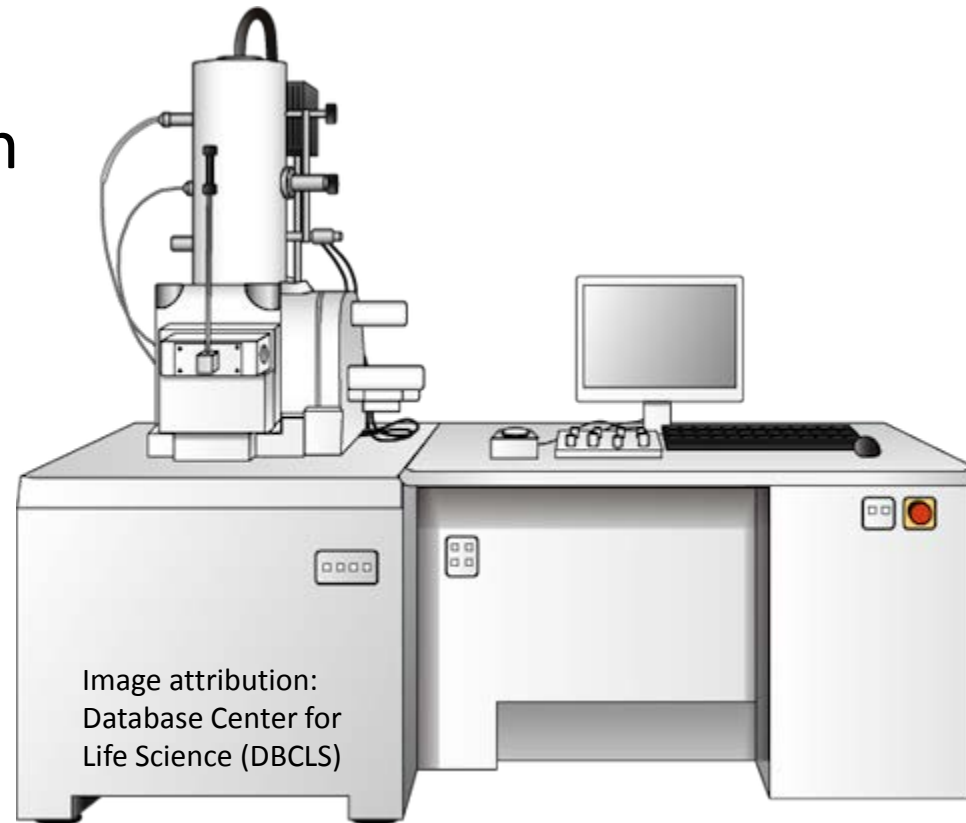
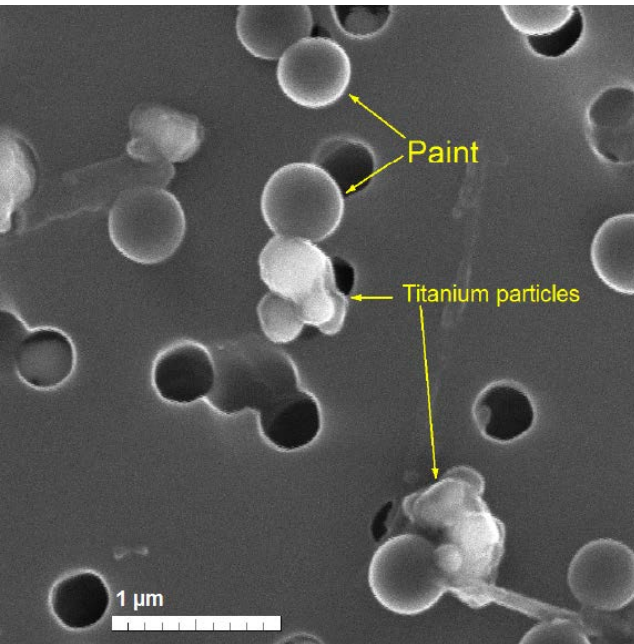


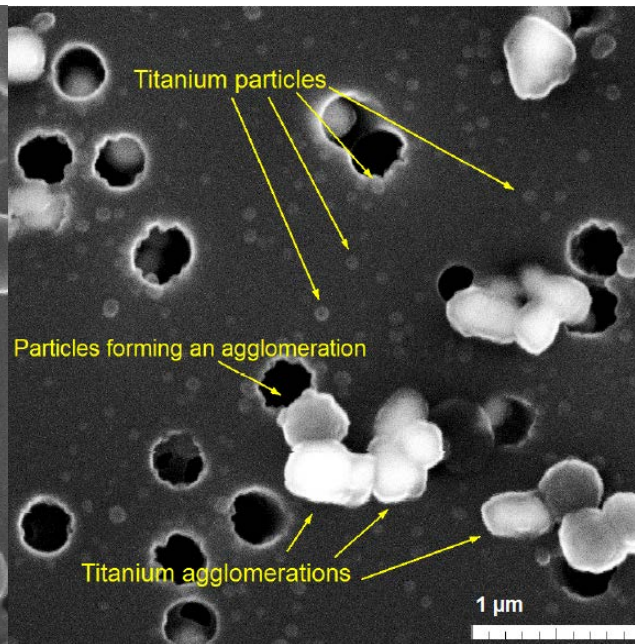
Image attribution:  
Database Center for  
Life Science (DBCLS)



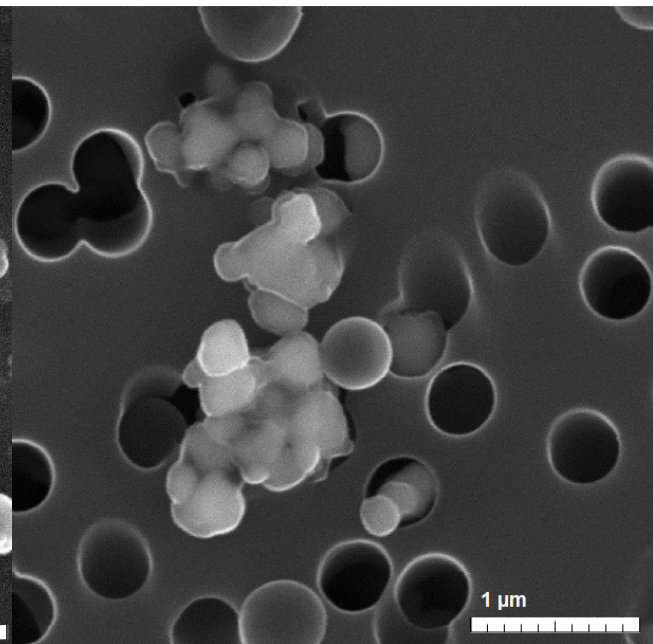
# Prior to sampling, the lab confirmed nanoscale $\text{TiO}_2$ in the **test paint**



**Test paint**  
sonicated in **water**



**Test paint**  
sonicated in acetone

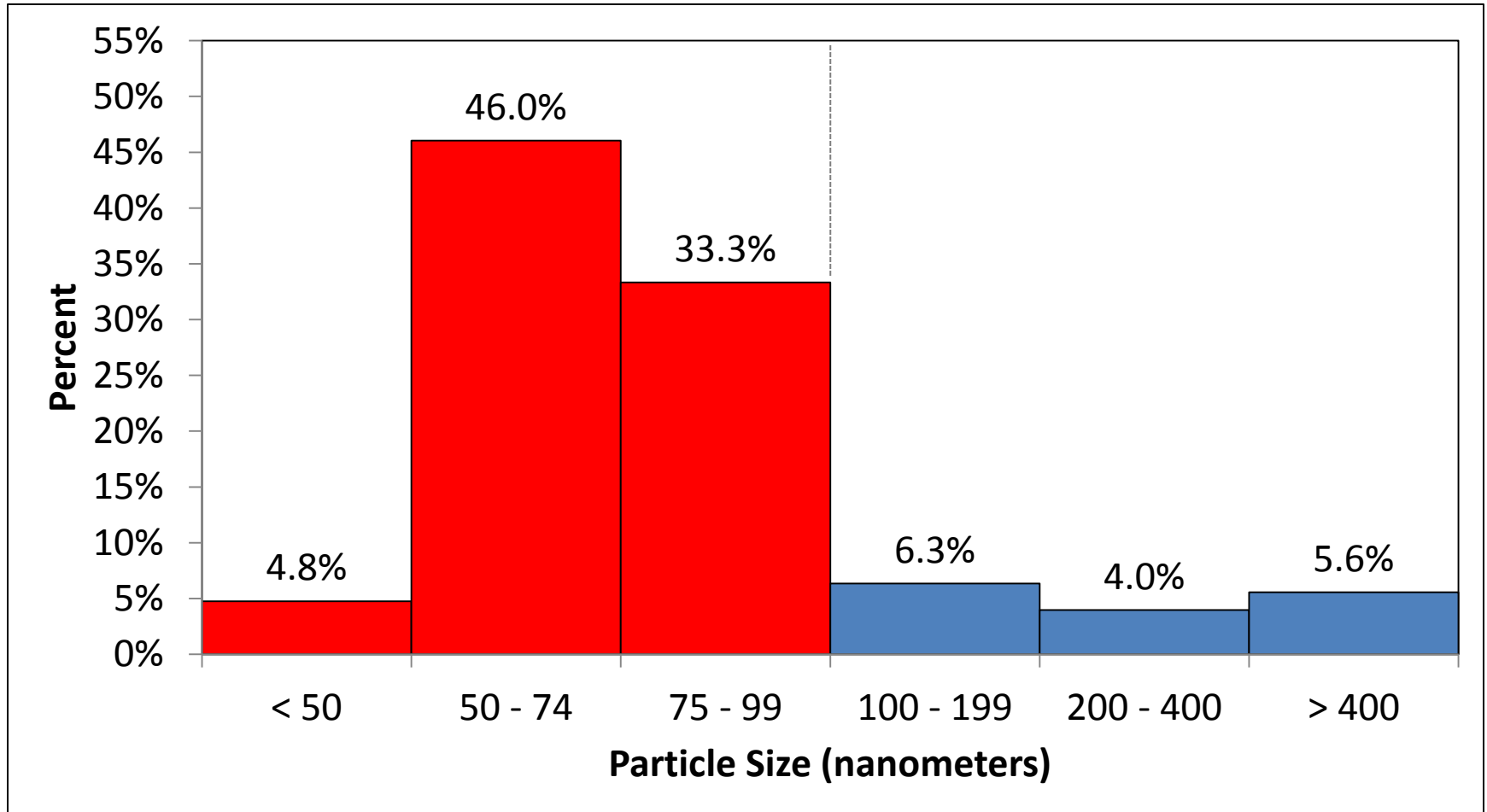


**Conventional paint**  
sonicated in acetone

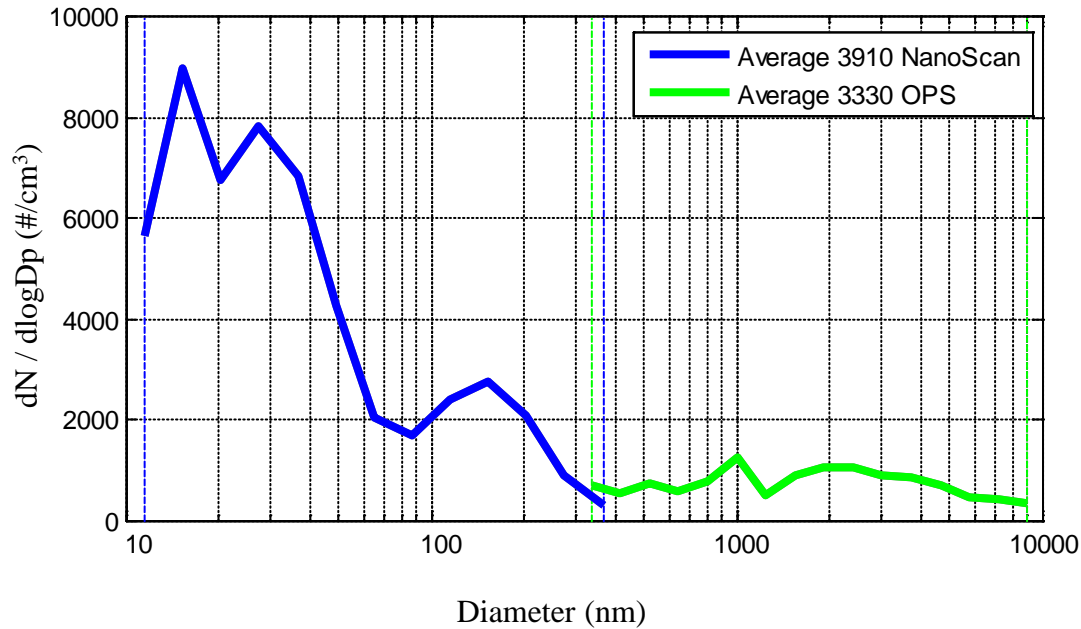


Sonication in acetone released  $\text{TiO}_2$  nanoparticles from agglomerates

# SEM prior to sampling estimated that 84% of TiO<sub>2</sub> particles were nanoscale

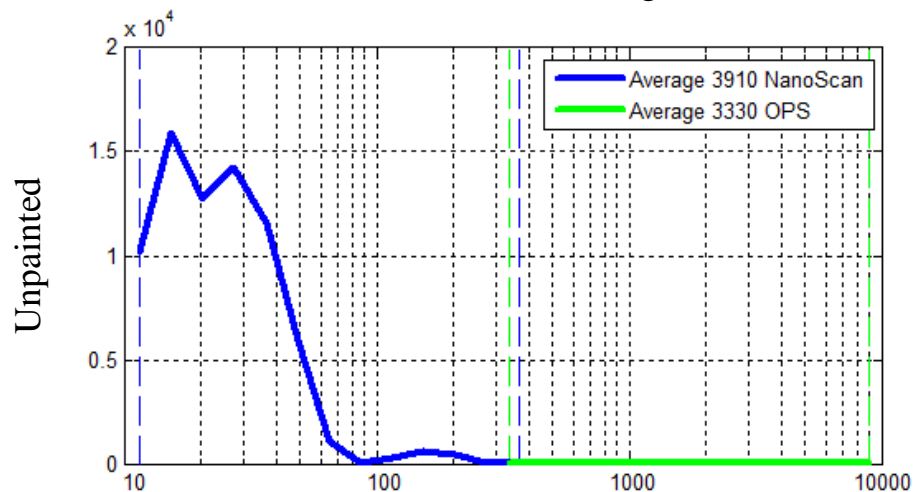


# Real-time instruments detected nanoparticle emissions during spraying...

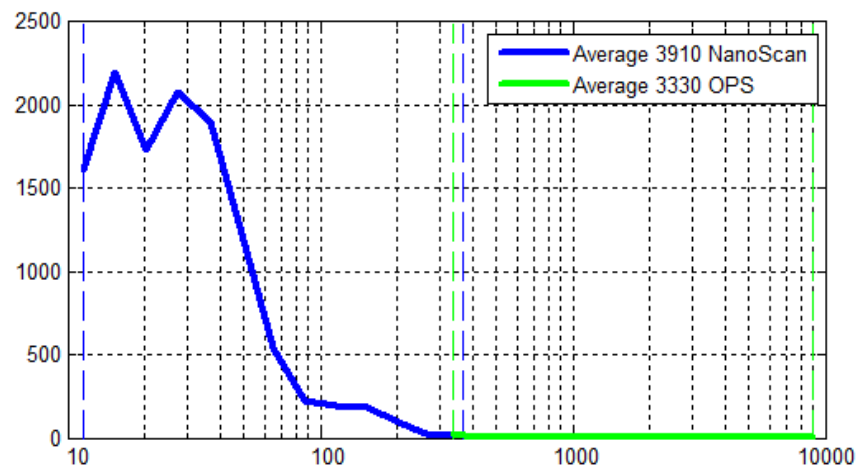
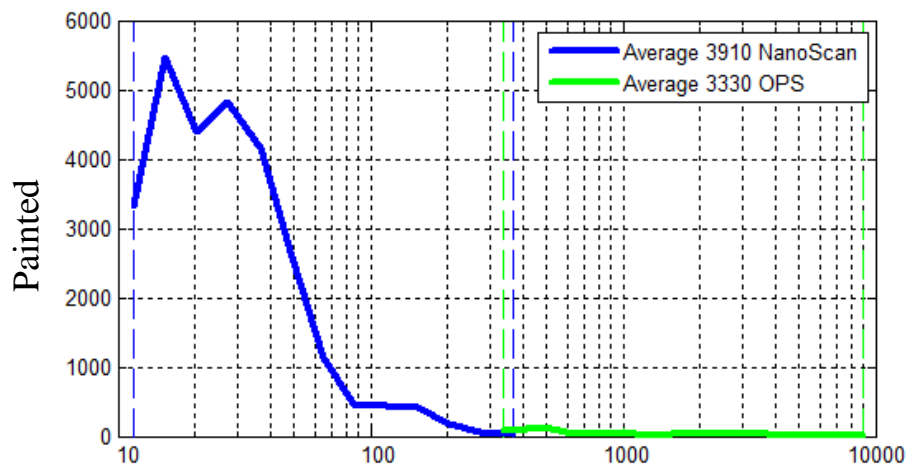
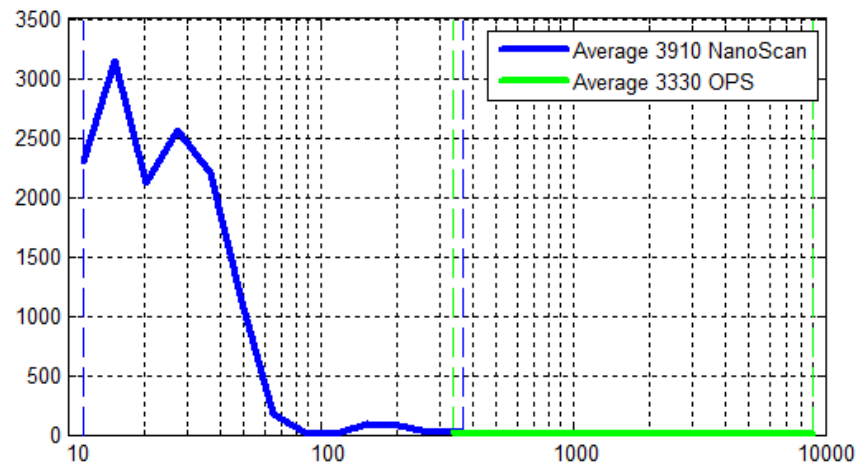


# ... and during all sanding conditions

## Dust Collection Bag

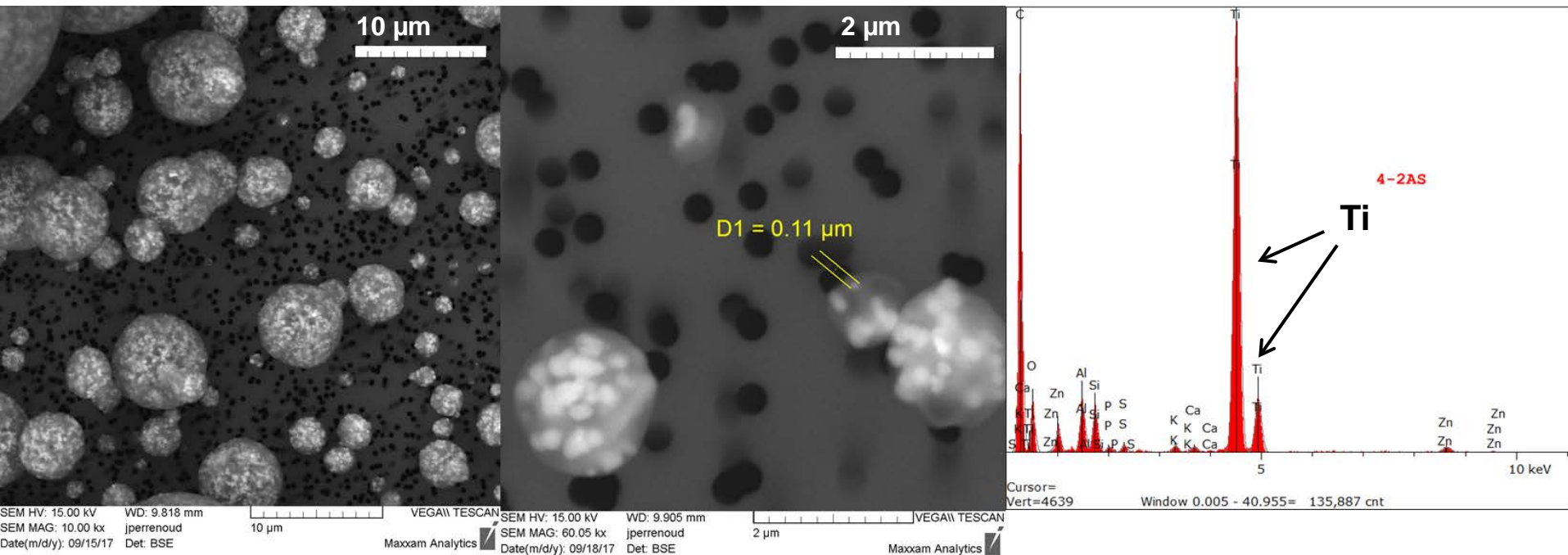


## LEV



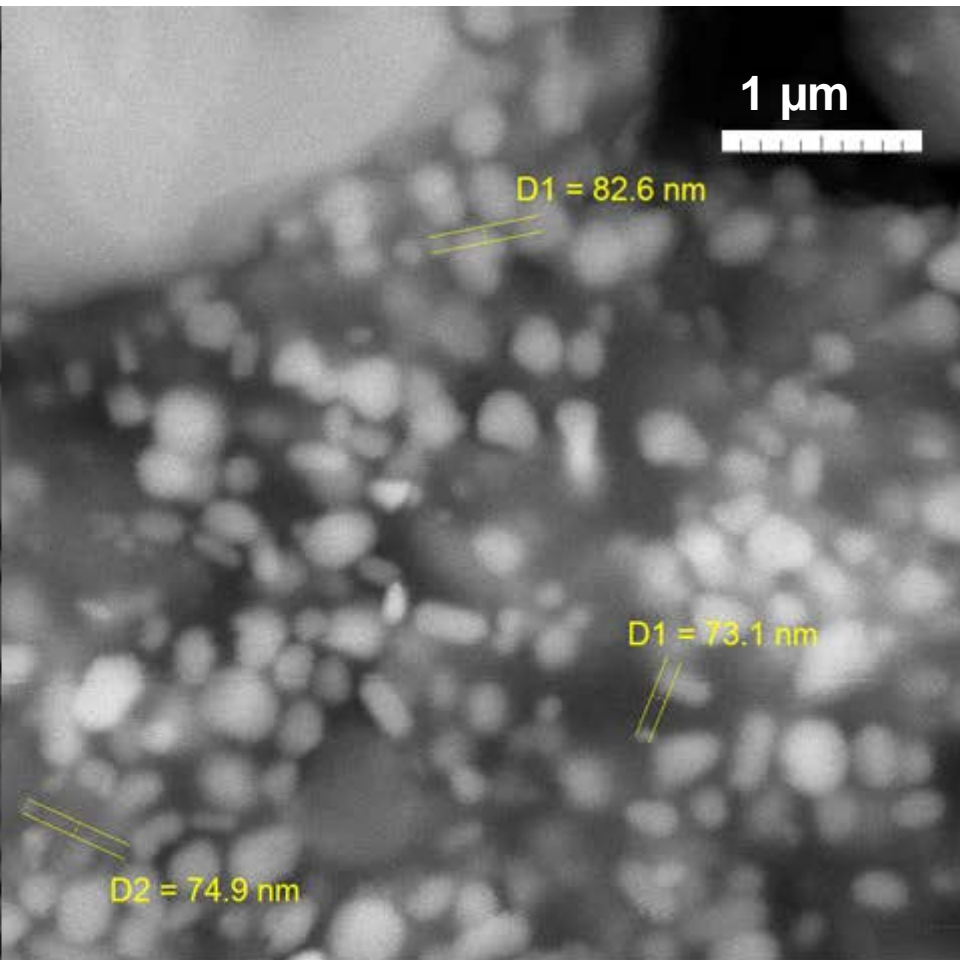
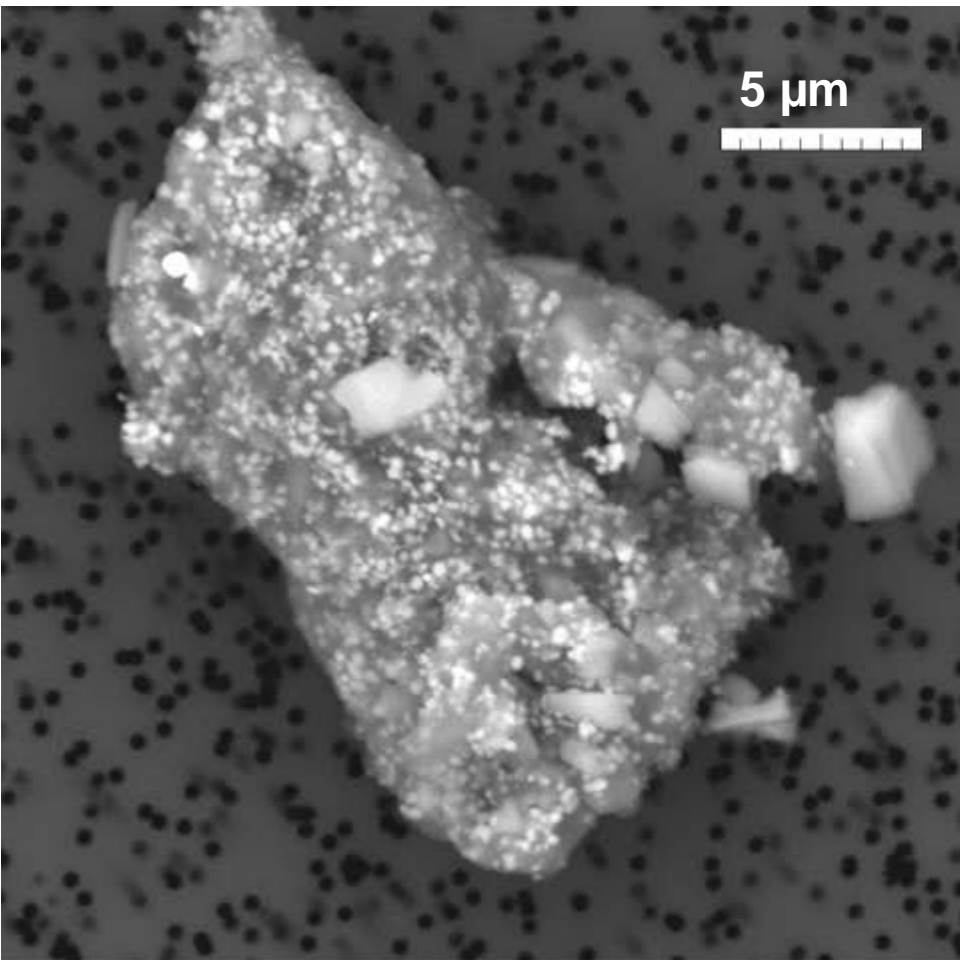
Vertical axes =  $dN / d\log D_p$  ( $\#/cm^3$ ), Horizontal axes = Diameter (nm)

But electron microscopy did not detect unbound nanoparticles in air samples collected during spraying



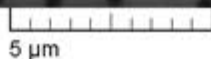
**Rather, titanium particles were contained within or protruding from the paint globules**

# The same effect was observed with the sanding debris



SEM HV: 15.00 kV  
SEM MAG: 16.00 kx  
Date(m/d/y): 12/01/17

WD: 10.62 mm  
jperrenoud  
Det: BSE

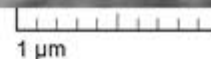


5  $\mu\text{m}$

VEGA\\ TESCAN  
Maxxam Analytics

SEM HV: 15.00 kV  
SEM MAG: 80.00 kx  
Date(m/d/y): 12/01/17

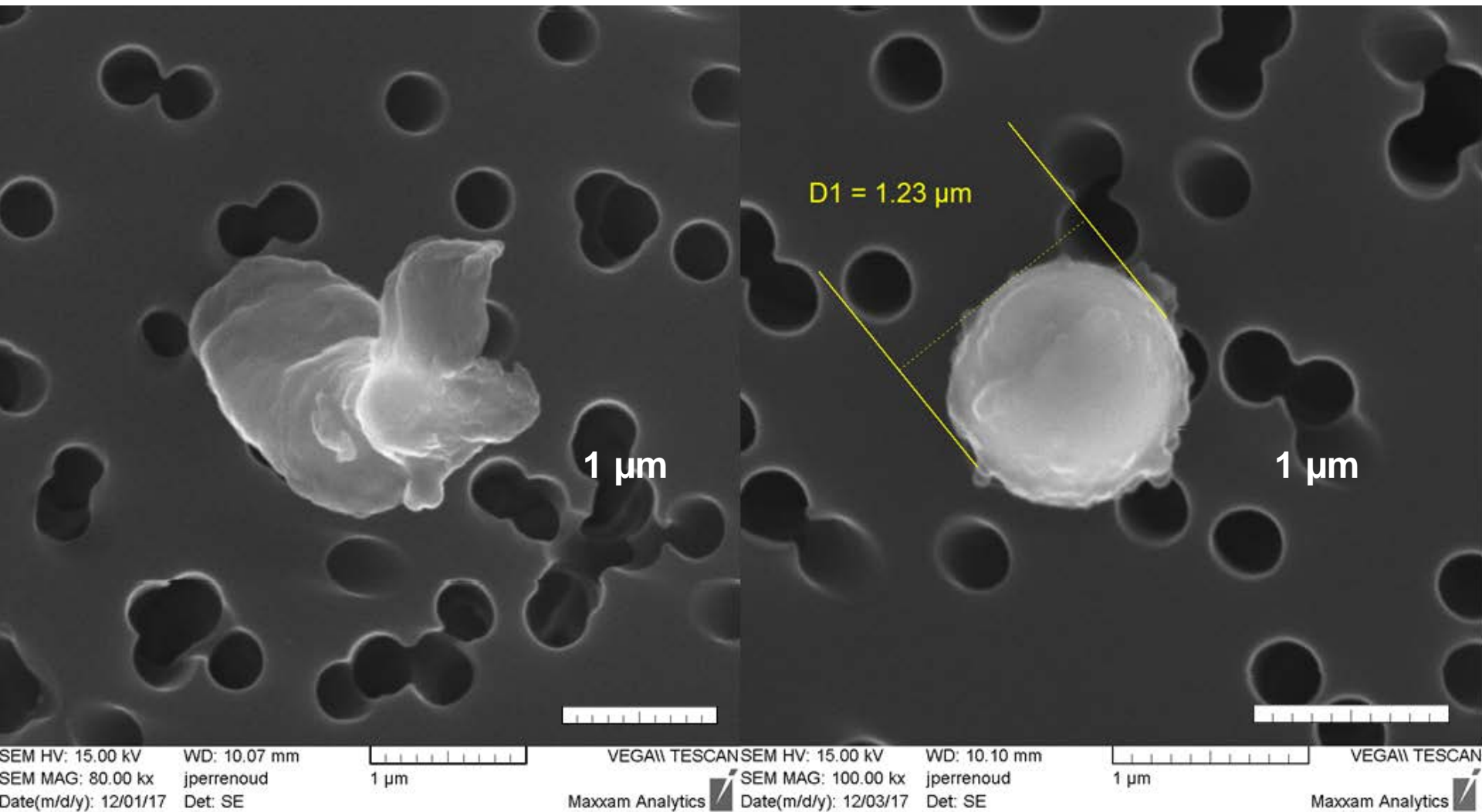
WD: 10.63 mm  
jperrenoud  
Det: BSE



1  $\mu\text{m}$

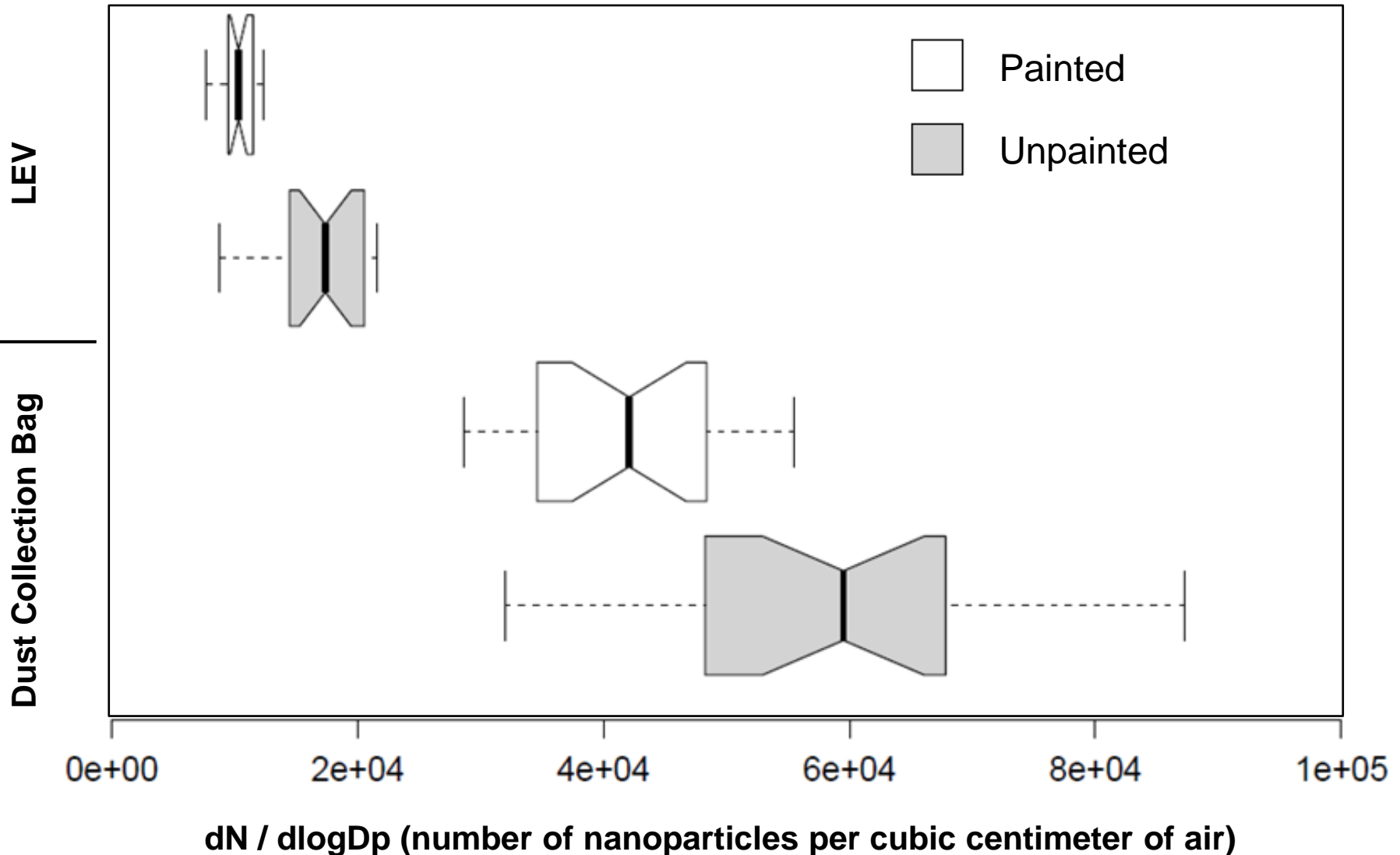
VEGA\\ TESCAN  
Maxxam Analytics

For comparison, sanding debris from unpainted plywood is shown on the left



Larger copper particles (right image) were also detected in air samples while sanding

# Despite limitations of real-time measurements, they showed a statistically significant reduction in airborne nanoparticles when using local exhaust ventilation (LEV)



Comparison of background adjusted airborne nanoparticle concentrations while sanding painted or unpainted boards with either the dust collection bag or LEV: Center lines show the medians; box limits indicate the 25th and 75th percentiles; whiskers extend 1.5 times the interquartile range (IQR);  $n = 22, 22, 21, 22$  sample points. The notches are defined as  $\pm 1.58 \cdot \text{IQR} / \sqrt{n}$  and represent the 95% confidence interval for each median. Non-overlapping notches give roughly 95% confidence that two medians differ.



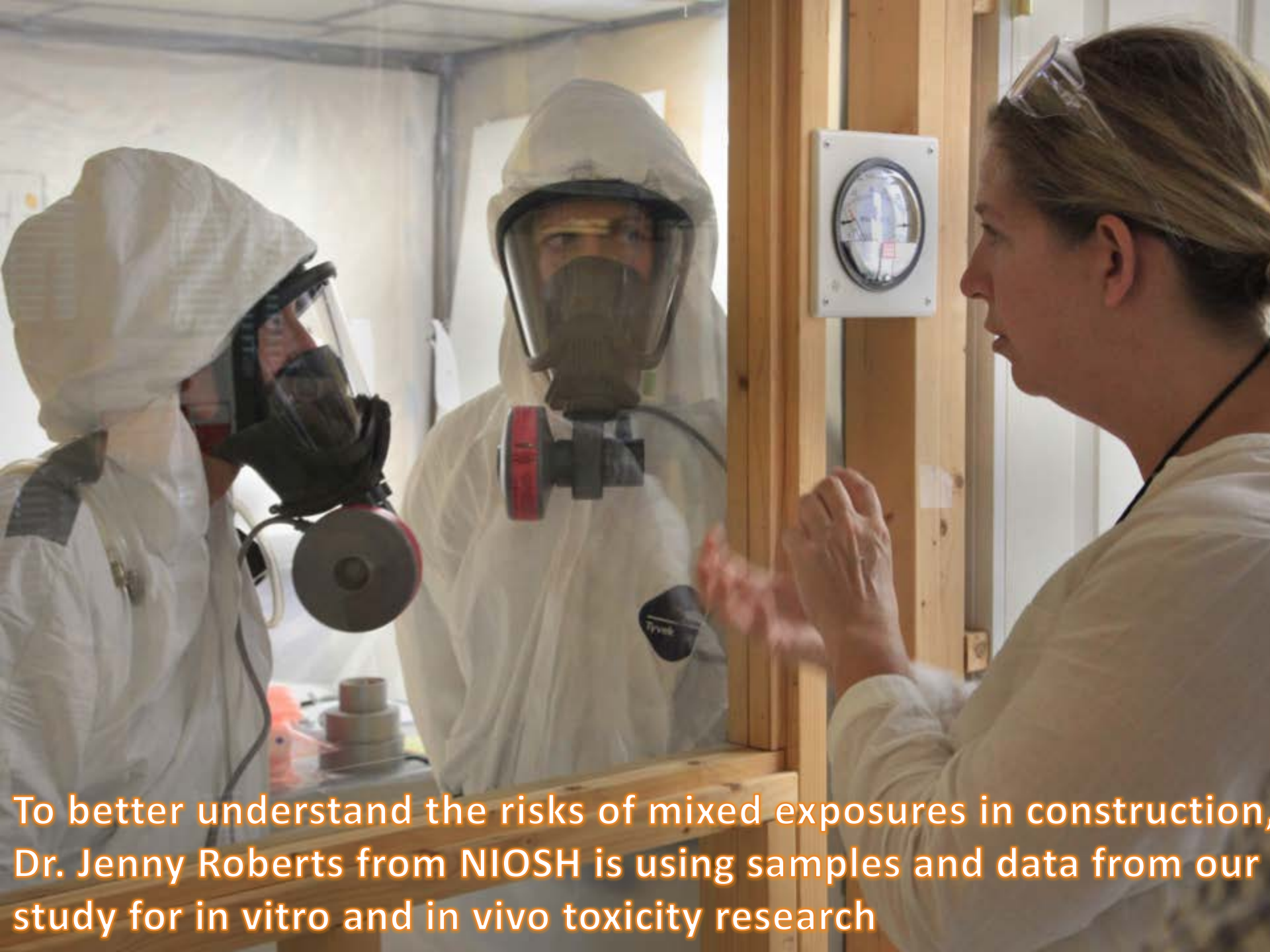
# Dust levels while sanding were low

- **Peak total dust (2.9 mg/m<sup>3</sup>)**
  - vs. OSHA PEL (15 mg/m<sup>3</sup>)
- **Peak TiO<sub>2</sub> (0.14 mg/m<sup>3</sup>)**
  - while sanding painted boards with dust collection bag
- **No respirable TiO<sub>2</sub> detected**

*What about the TiO<sub>2</sub> embedded in the larger dust particles and paint globules?*



Photo courtesy Earl Dotter



To better understand the risks of mixed exposures in construction, Dr. Jenny Roberts from NIOSH is using samples and data from our study for in vitro and in vivo toxicity research

## Breathing zone concentrations were much higher when spraying versus sanding

Exposure Agent	N	Mean Conc. (mg/m <sup>3</sup> )	Std. Dev.	95%CI
Total Particulate	5	35.8	8.6	25.1 - 46.5
TiO <sub>2</sub>	5	13.6	3.2	9.6 - 17.6
Respirable Particulate	5	2.1	0.7	1.2 - 3.0
<b>Respirable TiO<sub>2</sub></b>	<b>5</b>	<b>0.7</b>	<b>0.1</b>	<b>0.5 - 0.9</b>

***Respirable TiO<sub>2</sub> > NIOSH REL for ultrafine (0.3 mg/m<sup>3</sup>) but what fraction was nano?***

# Electron microscopy and putting parameters on the data helped answer this question

- **Upper limit for nano TiO<sub>2</sub> = 3x ultrafine REL**
  - Upper 95% CI for respirable (0.9 mg/m<sup>3</sup>)
- **Potential to exceed REL if >0.84% airborne particulate was nano TiO<sub>2</sub> by weight**
  - 38% total particulate = TiO<sub>2</sub>
  - 33% respirable particulate = TiO<sub>2</sub>
  - 84% TiO<sub>2</sub> primary particles < 100 nm
  - NIOSH REL applies to agglomerated nanoparticles
  - Nano-additives for coatings often > 1% by weight

**Weighing all these factors, we  
concluded there was**

*“evidence suggesting  
potential for overexposure to nano-TiO<sub>2</sub>  
during routine construction activity  
in reference to the NIOSH REL  
for ultrafine TiO<sub>2</sub>  
(0.3 mg/m<sup>3</sup> as a 10-hour TWA).”*

# Study recommends characterizing exposures, using hierarchy of controls to ensure painters are protected

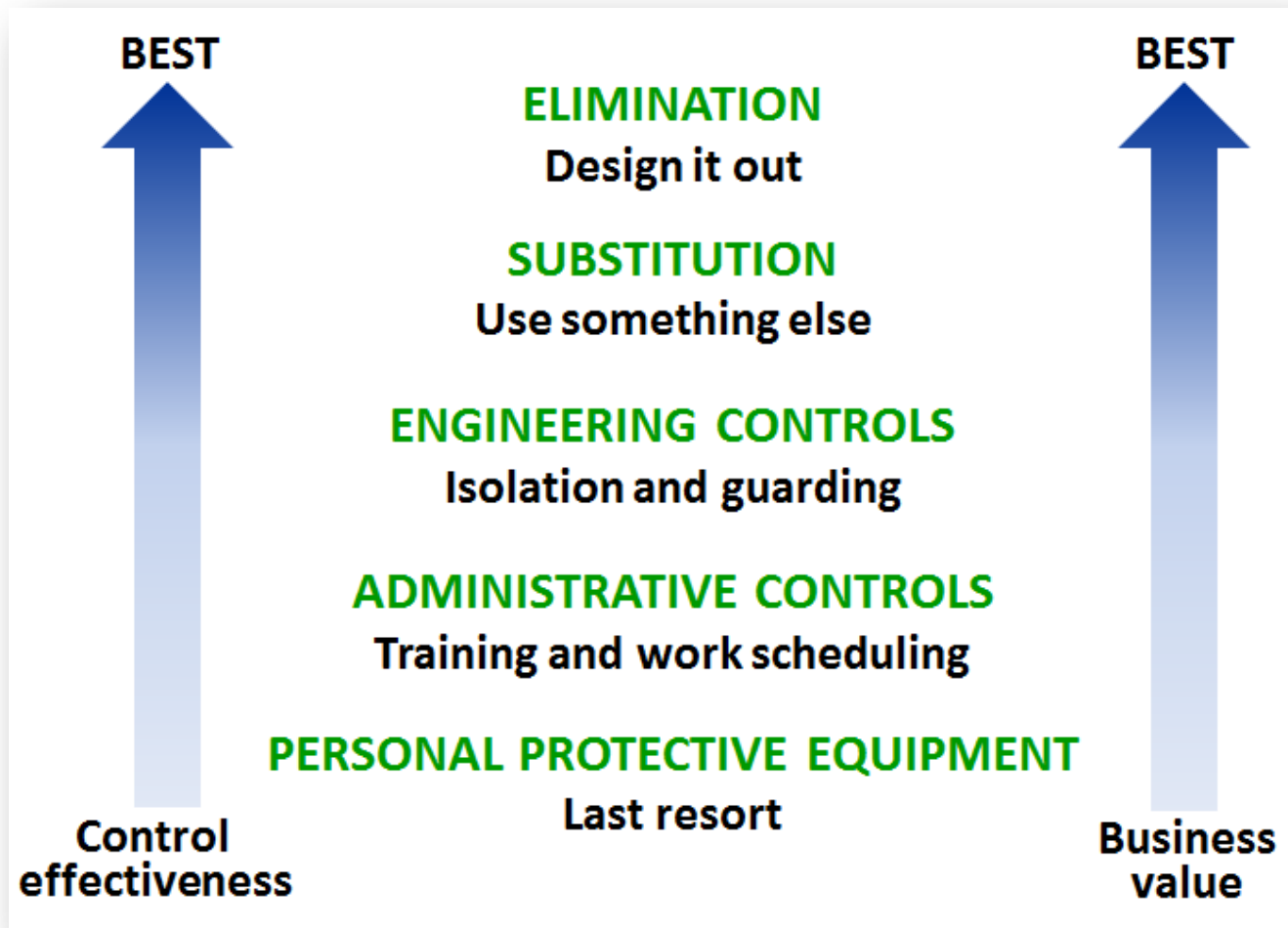


Image by  
NIOSH via  
Wikimedia  
Commons

# An EU-OSHA fact sheet posted on eLCOSH Nano last week offers similar guidance



Safety and health at work is everyone's concern. It's good for you. It's good for business.

Healthy Workplaces  
MANAGE  
DANGEROUS  
SUBSTANCES

European Agency  
for Safety and Health  
at Work

EUROPEAN UNION

Healthy Workplaces

## Manufactured nanomaterials in the workplace

### Key Points

- Manufactured nanomaterials are materials in which 30% or more of the particles have no or more dimensions between 1 nm and 100 nm. The smallest nano particles are comparable in size to atoms and molecules.
- The health effects of nanomaterials depend on their properties, for example what material they consist of, their size, shape and solubility of the particles, and their surface properties. In general, nanomaterials have the same kind of health effects as coarse particles of the same material, but other effects may also occur. The main exposure routes for nanomaterials are through inhalation and skin exposure.
- Exposure to nanomaterials must be managed and exposures kept well below threshold limit values for the bulk material (consisting of larger particles, but which may also contain nano particles), applying the precautionary principle.
- In industrial processes, it is an advantage if nanomaterials can be handled in, for example, slurry or paste form or kept in contained spaces to reduce emissions and prevent exposure to nanomaterials. In more complex situations, it is recommended that expert advice be sought.
- Non-chemical safety and health measures to reduce the risks involved. Therefore, workers, employers, and safety and health professionals dealing with nanomaterials in the workplace need to ensure that they keep updated with developments.

### Healthy Workplaces Manage Dangerous Substances

The European Agency for Safety and Health at Work (EU-OSHA) is running a Europe-wide campaign during 2018 and 2019 to promote the prevention of risks posed by dangerous substances in the workplace. The aim is to reduce the presence of and exposure to dangerous substances in workplaces by raising awareness of the risks and of effective ways of preventing them.

*“spraying of nanomaterials in liquid media should be avoided, as nanomaterials may be inhaled in the aerosol”*

# Assessing Awareness and Training Needs among California Construction Trades

Laura Boatman





# Nanotechnology: Assessing Awareness and Training Needs Among California Construction Trades

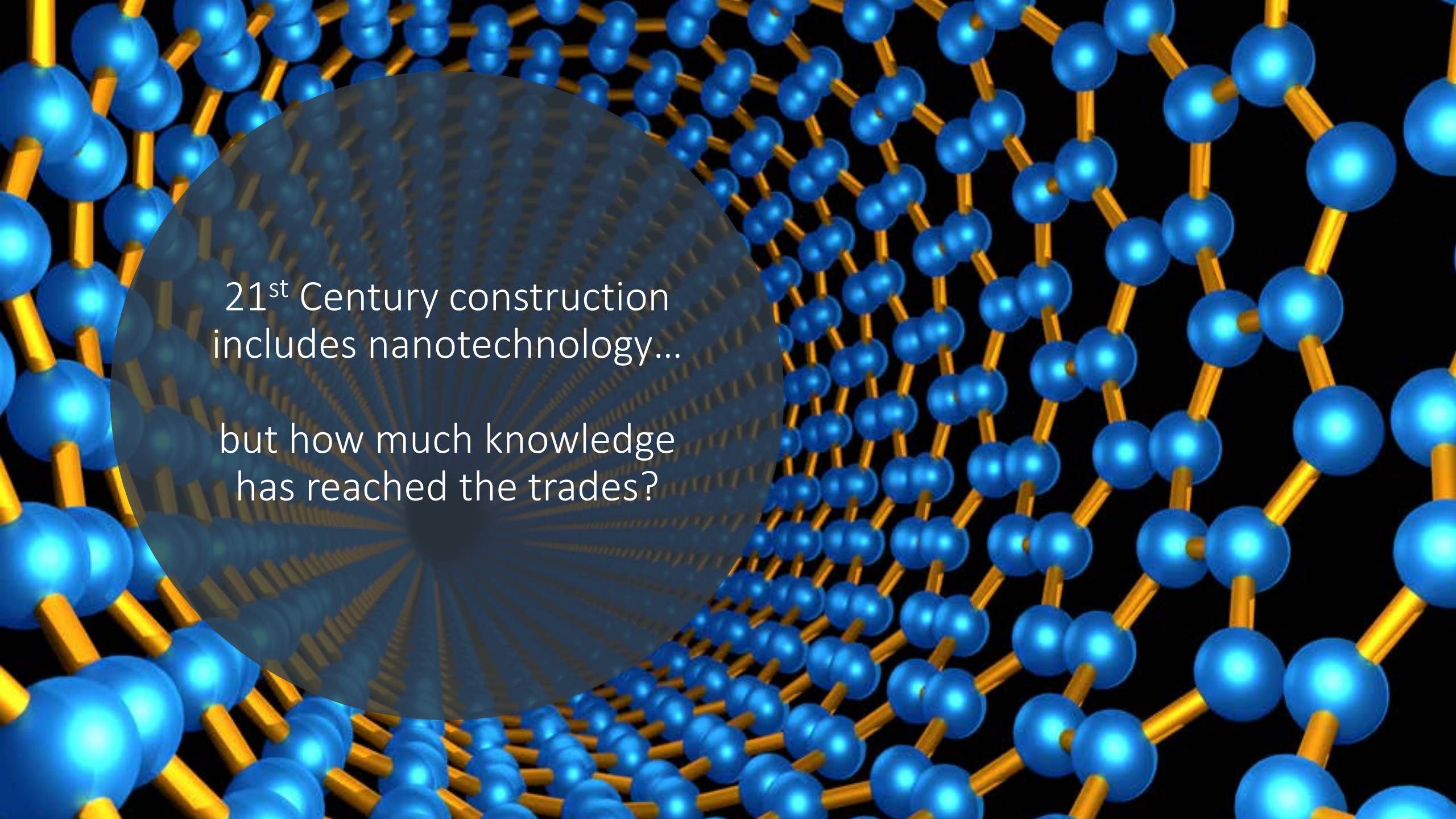


**Presented by: Laura Boatman, SBCTC Project Coordinator**



SBCTC—State Building  
and Construction  
Trades Council, AFL-CIO

Representing California  
unions since 1908



21<sup>st</sup> Century construction  
includes nanotechnology...

but how much knowledge  
has reached the trades?

“ If you were to walk up to the average construction worker and say, ‘Hey, can you explain what nanotechnology is in products in construction? They’d look at you like you were crazy ”

- Key informant quote

# SBCTC Small Study Grant from CPWR

Survey of Union and  
Apprenticeship staff

Report available online  
<https://bit.ly/2Rp2UhQ>

[www.cpwr.com](http://www.cpwr.com) • [www.elcosh.org](http://www.elcosh.org)



## **Nanotechnology: Assessing Awareness and Training Needs Among California Construction Trades**

Laura Boatman  
Debra Chaplan

State Building and Construction Trades Council of California

May 2018

8484 Georgia Avenue  
Suite 1000  
Silver Spring, MD 20910

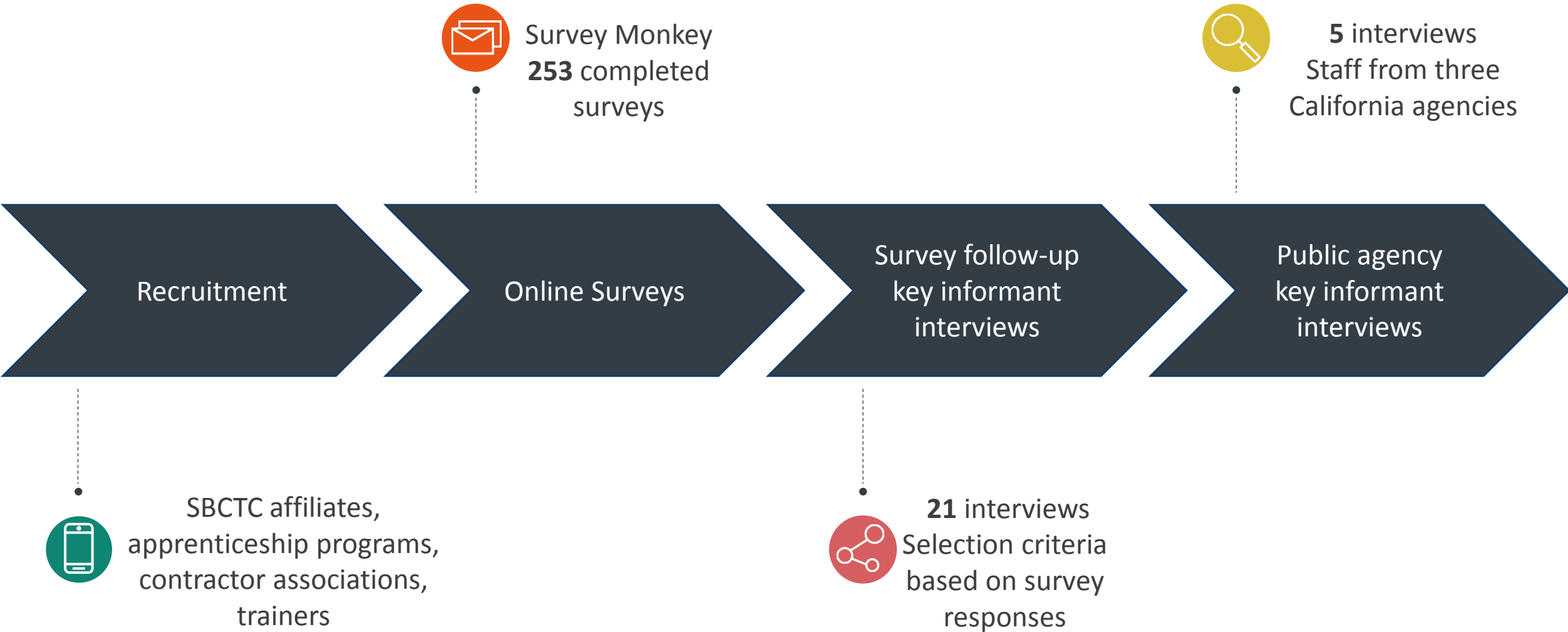
PHONE: 301.578.8500  
FAX: 301.578.8572



# Nanotechnology Small Study Goals

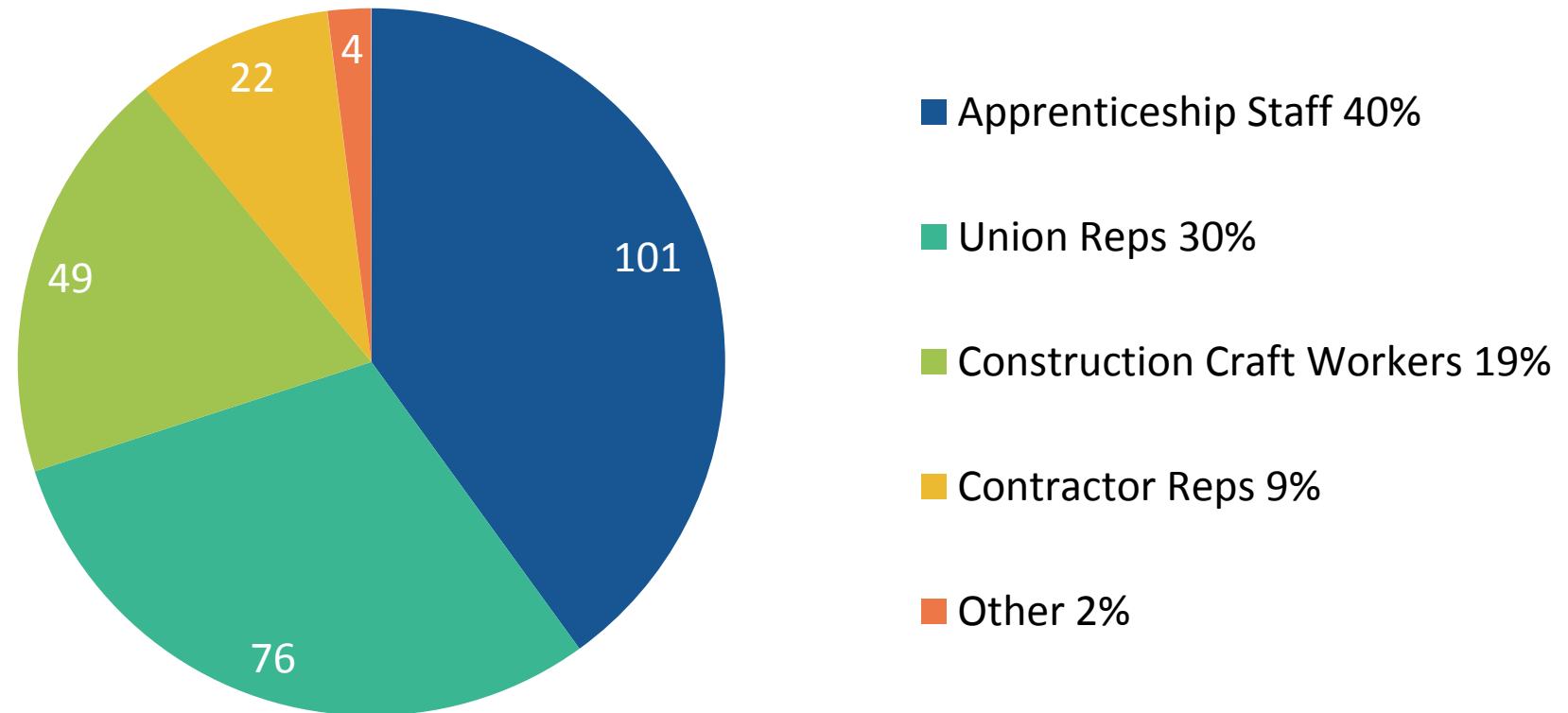
- Extent of **awareness** of construction applications
- Current status of nano **training**
- Identify **concerns** about nano-enabled materials
- Level of union/apprenticeship **attention** to nano
- Product **recognition**—test eLCOSH NANO Inventory
- **Government** agency monitoring/control/information

# Methodology



# Online Survey Results—253 Completed (study goal was 100!)

**Participant Affiliation**





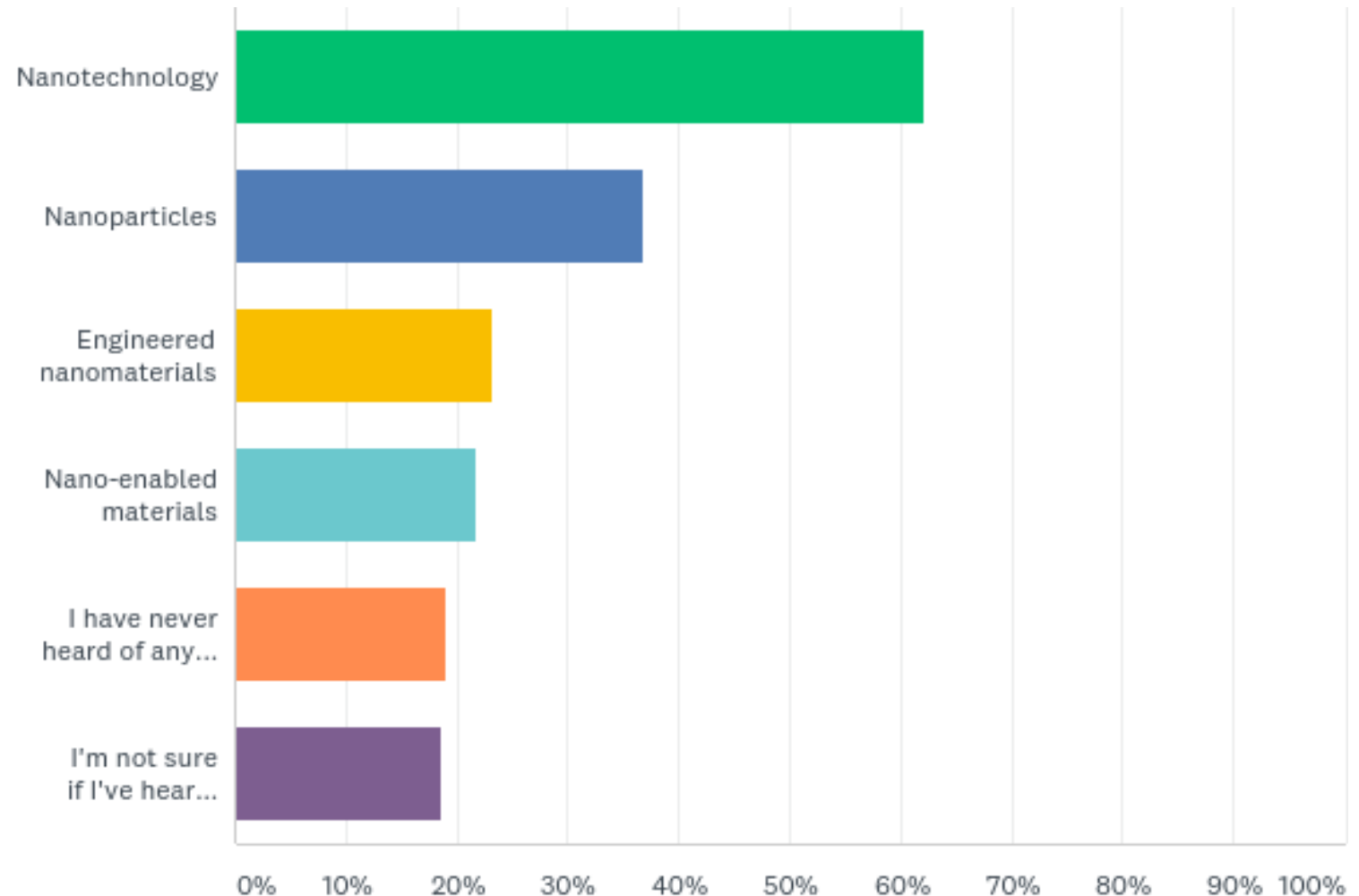
# Survey Participant Demographics

- 23 different crafts represented
- > 70% over 45 years old
- > 50% work for larger companies/orgs (>200 employees)
- > 40% worked in construction 30+ years
- > 77% provide construction training

# Key Findings—Awareness of terms

**>80% recognized 1 or more terms or weren't sure**

- 41 individuals recognized all 4 terms
- 11 recognized 3 terms
- 46 recognized 2 terms



# The more we asked, the less people knew

- Only **25%** of survey respondents were aware of nanomaterials in construction products or that nanotechnology applied to construction
- 10% knew other workers who use nano-enabled products
- 9% noticed products claiming nanotechnology or “nano” on-the-job
- Only **5%** had worked with a nano-enabled product first-hand

# Key Findings—Nanotechnology Training

Only 2% of all survey respondents had received training

5 people total!

4 of these were Insulators

Training provided by manufacturer of the nano-enabled product

Among survey respondents aware of nanotechnology, 74% were interested in more information

67% thought training on nanomaterials would be valuable

Key Informants want info on these topics:

- What “nano” means
- Where is it found?
- Risk-can it cause harm?
- Potential health effects
- Airborne nanoparticles
- Exposure controls
- Safety Data Sheets

“ I think it’s something amazing what they’re trying to create. I really believe that one day we’re going to be applying some of these products, but then again, how can we be prepared to train the construction worker that is going to crash into the high-tech industry? ”

- Key informant quote

# Key Findings—Benefits and Concerns (Likert scale)

Most responded neutral or did not know

“Nanomaterials likely to pose significant health risk to workers”

AGREE

“Use of Nanotechnology has potential to provide significant environmental and public benefit”

STRONGLY AGREE

“Use of nanotechnology has potential to significantly harm the environment”

SLIGHTLY AGREE—AGREE

“ We’re always behind the curve on the safety factors...because these new products get pushed out there on all of us, we will probably work with it for years before we realize if there’s anything that could be harmful for us.”

- Key informant quote

# Main concerns expressed

- The unknown/lack of information:
  - Don't know enough about materials
  - Materials used without proper testing
  - “What you don't know can kill you”
- Risk factors/health effects:
  - Respirable particles—lung damage
  - Routes of entry: skin and eye contact; ingestion
  - Nanoparticles crossing cell membranes , harm at cellular level
- Legacy of asbestos



“Anything man creates has some kind of potential impact to nature and the environment and I don't think really much is known about the possible implications of the stuff being made and what it could do. It's new technology...we're creating something unnatural.”

- Key informant quote

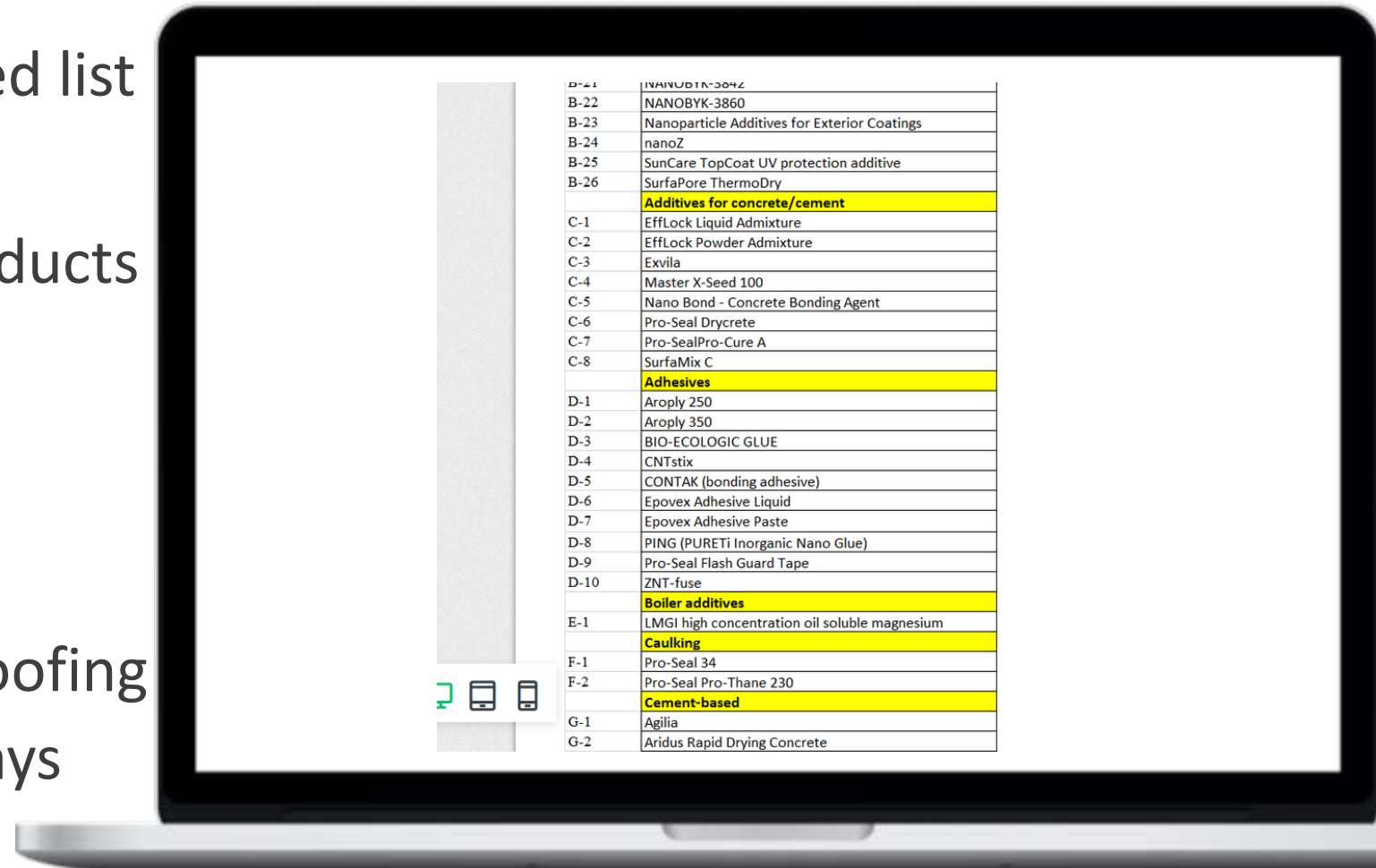
# eLCOSH NANO Inventory—product recognition

>70% of survey takers reviewed list

44% recognized/had used products

Top categories:

Coatings	Drywall
Lumber	Insulation
Caulking	Weatherproofing
Adhesives	Weld overlays

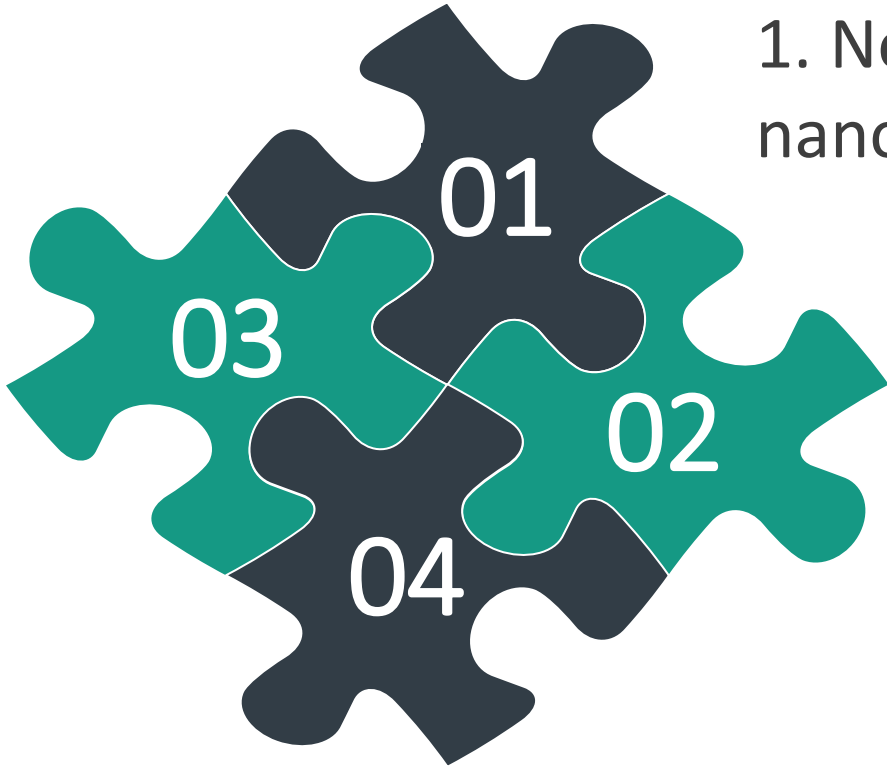


“ I would assume that before any product comes out containing nano...it's going to be somewhat regulated by agencies like OSHA and Underwriters Laboratories. I would think that any products used in the industry will be first vetted by agencies...to make sure they're not harmful...but that wasn't the case with silica or asbestos. ”

- Key informant quote

# Key Findings—Government Key Informants

Cal/OSHA, Public Health, Occupational Health, Toxic Substances Control



1. No current programs/initiatives targeting nanotechnology. All agencies have potential for action

2. Development of engineered nanomaterials outpaces efforts to monitor and research

3. No enforceable PELs specific to nanomaterials; performance standards could apply

4. Lack information about use of nano-enabled materials in construction

NEED MORE DATA

# Summary



Awareness levels  
and understanding  
of nanotechnology  
low among study  
subjects

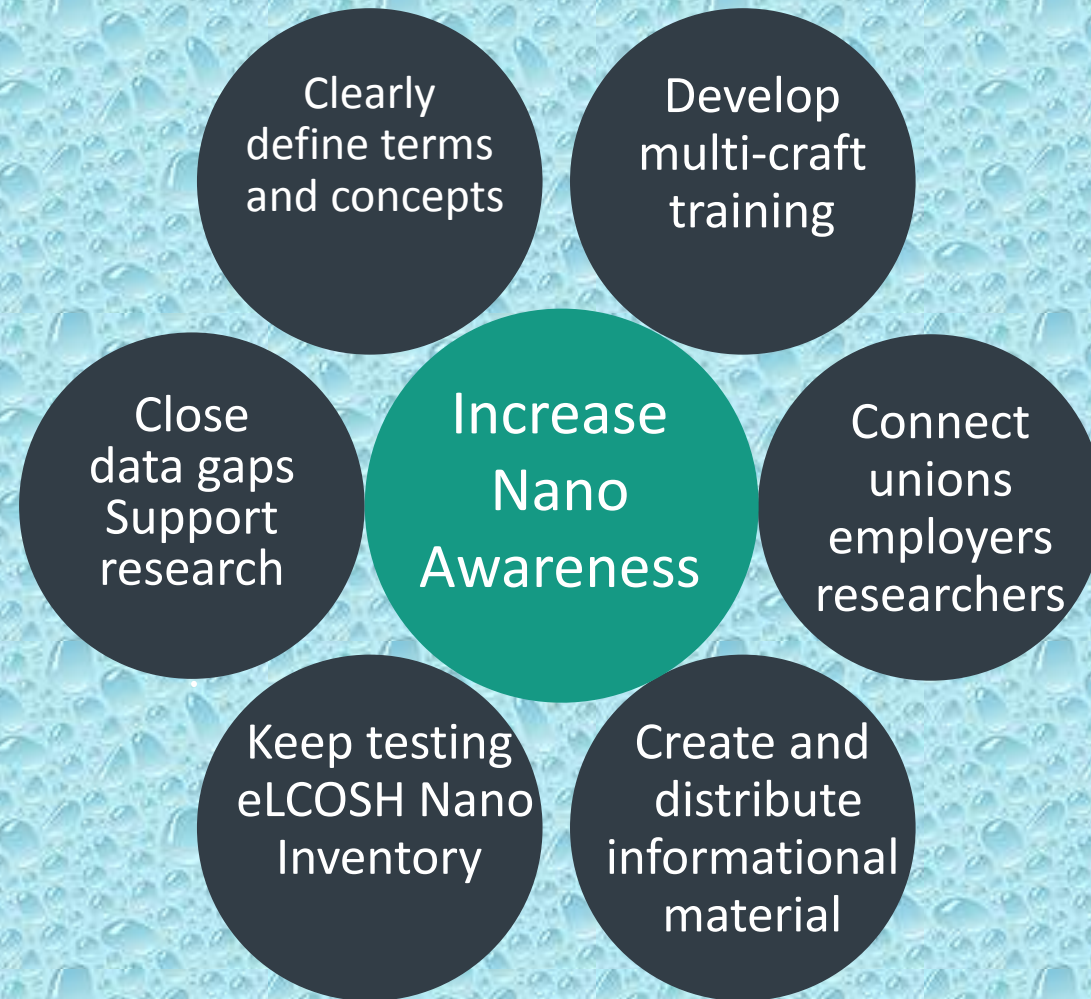


Strong need for  
research, data,  
training and  
education



New products are  
developing faster  
than knowledge

# Recommendations





Laura Boatman  
[lboatman@sbctc.org](mailto:lboatman@sbctc.org)  
916-443-3302

# Thanks! Questions?



Electronic Library of Construction  
Occupational Safety & Health

[Versión en Español](#) | [Other Languages](#)

Search:

Submit

Developed and maintained by CPWR - The Center for Construction Research and Training.

## Hazards



## Trades



## Jobsites



### Media

Presentations /  
Powerpoints  
Images  
Videos

All

### Documents

Toolbox Talks  
Training Materials  
Handouts  
Research Reports

All



### What's New

Model Silica Specifications  
for Masonry Grinding,  
Cutting and Sawing

An Evaluation of Silica  
Exposure Controls for  
Tuckpointing:  
DustControl 2900c  
Vacuum with the ICS  
Du...

An Evaluation of Silica



Join us