

THE Monitor

 AMERICAN SOCIETY OF SAFETY ENGINEERS

www.asse.org

Nanotechnology: The Next Industrial Revolution?

By Michael Weeks, CIH, Fred W. Boelter, P.E., CIH & Catherine Simmons, CIH

The field of nanotechnology promises to impact our future significantly. Nanosized materials are already used in numerous products on the market, and many more products are in development. Researchers project that nanomaterials may help us solve the world's energy and environmental crises as well as find a cure for cancer.

But these breakthroughs bring many unknowns. How will nanomaterials affect the human body? Will they harm the environment? In fact, those new to nanotechnology still ask, "Just what is this stuff?" These questions dwarf the available answers. Yet, as industrial hygienists, we must protect workers from the potential risks these materials may present. With so much uncertainty, are we able to do our jobs?

The answer is yes—we must be. Although much remains to be discovered about nanomaterials, this lack of knowledge does not release us from our duty to protect. And while it certainly presents a challenge to our profession, we can apply what we do best—hazard anticipation, recognition, assessment and control—to the little that we know about these materials.

What Is Nanotechnology?

Given the wide range of materials being created, defining nanotechnology and nanomaterials has proven difficult. The ASTM International Committee on Nanotechnology, E56, recently finalized a standard, E2456-06, Standard Terminology Relating to Nanotechnology, which provides some guidance on what is generally agreed upon throughout industries that use these materials. This standard is available for download at the ASTM website free of charge.

Nanotechnology can be loosely defined as technology that uses engineered materials with at least one dimension measuring between 1 and 100 nanometers. In this extremely small size range, these materials are created and manipulated at a molecular level. Within this broad definition, different materials have been created, but some subcategories exist. Two of the more common nanomaterials are carbon nanotubes, which come in single-walled and multi-walled varieties, and fullerenes or "buckyballs," which are usually a spherical arrangement of carbon atoms. Other materials include nanoclays, nanofibers, nanoplates and nano-

ropes. These materials all have many applications, and each application demands a nanoparticle that is engineered to best suit it.

It may also be helpful to distinguish what materials are not necessarily nanomaterials. For instance, many particles, such as volcanic ash, are created naturally and often fall into the same size range as nanoparticles. Fumes created by diesel engine combustion or welding activities also fall into this range, but they usually do not fit the definitions of nanotechnology. These types of particles are categorized as ultrafine particles, a term that may or may not include engineered nanoparticles.

What separates nanomaterials from these more randomly occurring particles is the fact that they are engineered to have a specific atomic structure and to fall within a specific size range. The reproducibility of these extremely tiny materials makes this technology exciting.

Guidance & Regulation

In December 2006, the International Conference on Nanotechnology Occupational and

In This Issue

2007 ■ Vol. 6, No. 3

3
Integrating
Ergonomics

5
Update on Revised
Z9.5 Standard

7
Product
Stewardship

8
The Last Frontier
Dilemma?

9
Sick Air Quality
Building

14
The Role of
Asbestos Training

continued on page 11

Nanotechnology

continued from page 1

Environmental Safety and Health: Research to Practice took place in Cincinnati, OH. NIOSH, the University of Cincinnati and other contributors sponsored and organized this event. The conference brought together government agencies and SH&E practitioners, laboratory managers, CEOs, toxicologists, labor, the insurance industry and academia to discuss the current state of knowledge and what problems researchers and industries working with nanomaterials still need to solve.

One consistent theme throughout was a perceived lack of guidance from government agencies on how to handle nanomaterials. NIOSH currently has a draft available for public comment titled, "Approaches to Safe nanotechnology: An Information Exchange with NIOSH." Several NIOSH representatives spoke at the conference, and all stated their desire for industries to cooperate with them so as to share and coordinate research efforts.

OSHA representatives explained that while no specific nanotechnology standard currently exists, many of the standards currently in place apply to nanotechnology and could also be enforced. These standards include hazard communication, respiratory protection, PPE, the laboratory standard and permissible exposure limits. OSHA's general duty clause could apply as well.

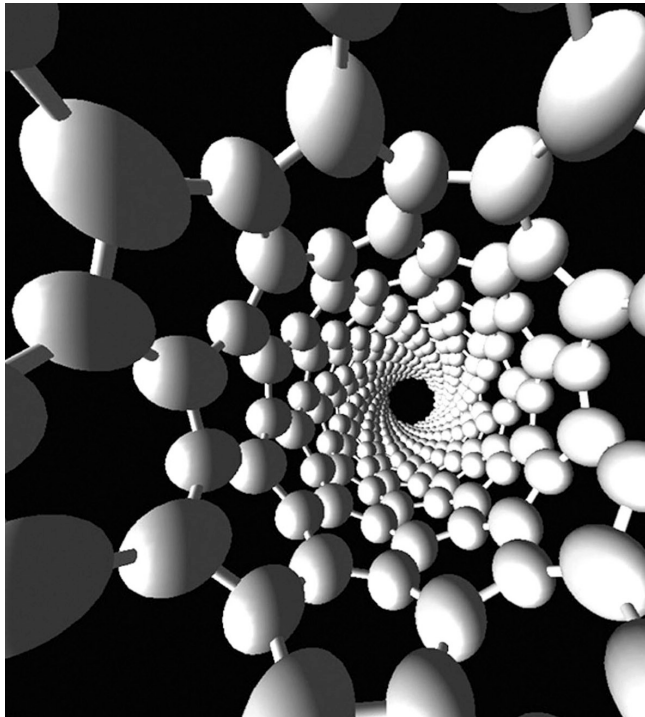
Nanomaterial Properties

Many nanomaterial properties differ from particle to particle, which makes characterization difficult. In fact, this is a primary reason why there are no developed standards, not only regarding occupational health, but within industry as a whole. However, certain nanomaterial properties are commonly shared, and these properties raise more questions and possibly provide potential answers.

One concern is surface area. Since the material is so small, its exposed surface area is a very high percentage of its total mass. This means that even a very small amount of material may quickly and easily react with substances with which it comes in contact. If the material were to find its way into a person's body, this

could cause harm. In addition, the materials' small size may affect how they enter the body.

Some nanomaterial properties can provide clues as to how we may be able to manage them in an occupational setting. While nanomaterials exhibit many unique properties, most researchers agree that these particles behave just like all other particles aerodynamically. Since these particles exhibit the same behaviors as many workplace contaminants we have previous-



ly encountered, many methods and controls we currently use to reduce risk can effectively apply to nanotechnology.

Possible Routes of Exposure

Every common conceivable route of nanoparticle entry into the body is under investigation, but inhalation and dermal exposure have received the most attention.

Inhalation is of high concern because the particles are of respirable size, and they may become airborne during handling and/or manufacture. The particles' reactive nature and large surface area make dermal absorption a possibility. Some studies have also shown that if exposed to skin, nanoparticles can accumulate in small folds, such as the underside of the knuckles, or they may penetrate the skin.

Exposure Evaluation

The industrial hygiene community has

debated how to best quantify exposure to nanomaterials. Most occupational exposure limits (OELs) for particulate are expressed in terms of a mass-based concentration such as mg/m^3 . However, because of nanomaterials' high surface area, a very small mass of material may produce different effects than those of a more traditional size. For that reason, many question whether traditional OELs based on ppm or mg/m^3 , such as the OSHA PELs and ACGIH TLVs, can apply to nanotechnology.

How to measure these exposures is under debate, but consensus has not been reached mainly because of the lack of knowledge regarding nanomaterial toxicology. Some have suggested that new OELs based on measured or estimated surface area be used rather than mass-based concentration, while others have suggested that particle counting may provide a more accurate indicator of exposure. It is unlikely that any definitive method of exposure assessment will be available in the near future, however.

Given these unknown conditions, it is prudent to collect exposure samples for comparison to determine effectiveness of controls and for future analysis. Although interpretation of the samples may be difficult, gathering data for processes presently in place will prove valuable when more agreement is reached. Current sampling methods for the various components of nanomaterials can be applied, and OSHA has stated that PELs still apply to nanomaterials.

In the absence of air sampling, a tracer gas can be used as a surrogate for exposure at the source. A known amount of tracer gas is released at a source, exposure to the gas is measured in the worker's breathing zone, and a quantitative result is obtained.

Nanomaterial Control

The hazards nanomaterials present are largely unknown at this time, but that does not prevent us from taking action to protect employees. Just as we manage many other materials with unknown hazards, we can manage this one.

continued on page 12

If employee exposure to nanomaterials can be eliminated or reduced, then the risk that employees face is greatly reduced or eliminated altogether. The ideal way to accomplish this is through a completely closed process where all aspects of nanomaterial manufacture are contained. Creating a completely closed system is not possible for all processes, but it may reduce or eliminate employee handling of the material at some points during the process. Considerations for this may include glove boxes or other enclosed devices where employees can manipulate the material without being directly exposed. Designing and installing a closed process system is the most costly method of hazard control, but with proper maintenance, it is also the best way to reduce employee exposure to materials with unknown hazards.

Where the handling of nanomaterials is unavoidable, some form of protection against the inhalation of material must be in place. This may be best accomplished by effective local exhaust ventilation. Again, because these small particles behave like gases, we can rely on a well-designed local exhaust ventilation system to remove contaminants from the breathing zone. Often, work can be performed in a laboratory hood or similar device. In other cases, a small, movable exhaust system can be used.

One unique consideration should be made when designing local exhaust ventilation for nanotechnology applications. Since the quantities of material produced are generally small and expensive to produce, companies will want to lose as little of this material as possible. Therefore, they may want to research ways to conserve the captured material.

When designing a ventilation system, the capture method is always important. One common method is filtration. While some questions remain as to the efficacy of the filters currently in use, it is generally accepted that HEPA-type filters (i.e., 99.97% efficient at 0.3 μ m) will capture particles in the nanosize range. Because particles can be captured in a filter by many different methods (e.g., impaction, interception, electrostatic forces, Brownian motion, etc.), these filters are probably effective. In addition, in most cases,

nanoparticles will behave like other particles in this size range and will agglomerate or create groups or chains of particles that are much bigger than the individual particles. Super ultra low penetration air (SULPA) and ULPA filters are also available that capture particles at efficiencies of 99.9999% and 99.999%, respectively.

Like any other engineering controls, closed systems and local exhaust ventilation must be properly maintained and evaluated periodically. Standard methods of control evaluation can be used since nanomaterials will behave like a gas when airborne. For a quantitative result of the capture efficiency of a system, a tracer gas, such as sulfur hexafluoride, can be used.

If employee exposure to nanomaterials can be eliminated or reduced, then the risk that employees face is greatly reduced or eliminated altogether.

Several standard methods of performing these evaluations exist. Smoke tubes and/or air velocity measurements can be used to give a qualitative indication.

Unless using a completely closed system, respiratory protection may be advisable for some points of the process. The type of respiratory protection required will depend on the potential for material release and will vary from location to location.

Protection of the skin is also critical. Gloves should always be worn. Employees should have as little skin exposed to the material as possible, and they should have no skin exposed around the hands or wrists. This area will be most active in handling the material and also the most likely to be breached. A common mistake is to wear a protective suit and a pair of gloves but to leave the wrist exposed. Employees should avoid this practice.

Employee training in the handling of nanomaterials is essential. Proper work practices must be followed. This includes the slow and careful handling of the material, taking care to allow as little of it to become airborne as possible. It also includes the proper maintenance and use of PPE. Also, maintenance employees who

may enter these work areas will require different work practices and training.

Finally, other methods can be used to reduce exposures. Administrative controls, such as reducing an employee's time in an area with potential nanoparticle exposure, are one option. Other traditional methods of dust control also can be used. For example, on a small scale, wet methods, such as solutions or slurry, can prevent particles from becoming airborne.

Conclusion

The toxicological data on nanomaterials is scarce and will be for some time. Still, SH&E professionals must continue to protect workers. The tools that we currently use can still be applied. The application of sound methods of industrial hygiene—anticipation, recognition, evaluation and control—can protect workers from the uncertain hazards of nanomaterials.

References

- American Conference of Governmental Industrial Hygienists. (2001). *Industrial ventilation: A manual of recommended practice* (24th ed.). Cincinnati, OH: Author.
- ASTM International. *Standard Terminology Relating to Nanotechnology*. E2456-06. West Conshohocken, PA: Author.
- Dunn, K. (2006). Nanotech exposure controls and best practices. Paper presented at the International Conference on Nanotechnology Occupational and Environmental Health & Safety: Research to Practice, USA.
- Ellenbecker, M. (2006). Controls and practices overview. Paper presented at the International Conference on Nanotechnology Occupational and Environmental Health & Safety: Research to Practice, USA.
- Hull, M. (2006). Luna Innovations NanoSafe framework for managing EHS risks. Paper presented at the International Conference on Nanotechnology Occupational and Environmental Health & Safety: Research to Practice, USA.
- Methner, M. (2006). The NIOSH Nanotechnology Exposure Assessment Field Research Program. Paper presented at the International Conference on Nanotechnology Occupational and Environmental Health & Safety: Research to Practice, USA.

continued on page 16

Product Stewardship

continued from page 7

extend your business reach to a level where you must interact regularly with the business team. You must become an integral member of the business team. You must translate what you have done for employee safety and health into the businesses offerings and become intimately involved in product development and launch. Product stewards can influence how businesses do their work and what products they offer. But with this increased visibility and influence comes increased responsibility and accountability.

AIHA has already recognized the changing landscape and has established a Stewardship and Sustainability Technical Committee. AIHA has recognized this committee as one of the more energetic and forward-thinking committees, and it will continue to contribute excellent insights, standards and guidelines for SH&E professionals.

Product stewards help businesses manage their risks and improve the long-term sustainability of their portfolio. By doing this valuable work for the business, SH&E professionals gain an important and influential role in the business that can be quite rewarding and challenging while using and expanding on the skill set they have developed as SH&E professionals. With an increased focus on business stewardship, now is the time to think about a potential shift in where you focus your talents and skills as you become more sustainable SH&E professionals. This is the next progression for those who want to have a stronger impact on business while maintaining our basic skill sets. ■

Aaron Chen, CIH, is the global product steward/senior industrial hygienist for the DuPont Clean and Disinfect businesses. He has worked for DuPont for nearly 20 years. Chen is a member of AIHA's Practice Standards and Guidelines and Stewardship and Sustainability technical committees. He is also a member of the Joint Industrial Hygiene Ethics Education Committee and communications director for the Delaware AIHA Section. Chen holds a master's degree in public health from Tulane University. He is a member of AIHA, ASSE and the Health Physics Society, and he is a diplomate of ABIH. He writes articles on ethics and is jointly teaching a session on product stewardship at AIHce in June 2007 in Philadelphia. Chen can be reached at (302) 695-4332 or aaron.chen-1@usa.dupont.com.

Nanotechnology

continued from page 12

Monteiro-Riviere, N. (2006). Assessing the dermal effects of nanomaterials. Paper presented at the International Conference on Nanotechnology Occupational and Environmental Health & Safety: Research to Practice, USA.

Schuman, L. (2006). Regulatory and risk overview: OSHA perspectives. Paper presented at the International Conference on Nanotechnology Occupational and Environmental Health & Safety: Research to Practice, USA. ■

Michael Weeks, CIH, has practiced industrial hygiene since 1996. He is a member of AIHA's Exposure Assessment Strategies and Student and Early Career Professionals committees, and he was a member of the inaugural class of the AIHA's Future Leaders Institute. He may be reached at (847) 685-9287; mweeks@boelterassociates.com.

Frederick W. Boelter, P.E., CIH, has more than 30 years' industrial hygiene, environmental engineering and risk management experience. He is the principal consultant of Boelter Associates Inc., a licensed engineering firm that provides solutions to occupational health, public health and environmental problems. Boelter is a 2005 recipient of the Edward J. Baier Technical Achievement Award and the 2004 recipient of the Best Quantitative Risk Assessment Award, both from AIHA. He is also a Fellow of AIHA.

Catherine Simmons, CIH, has more than 21 years' EHS experience in conducting, managing or directing environmental, health and safety risk assessments. Simmons is president of the Chicago AIHA Local Section and a member of the national AIHA Exposure Assessment Strategies Committee.

Legs & Regs

continued from page 13

Oregon

OR 27654 Hexavalent Chromium
OR 28014 Respiratory Protection

Pennsylvania

PA 4155 Standards for Contaminants/
Mercury

Utah

UT 29282 Incorporation of Federal
Standards

Washington

WA 24810 Work Platforms
WA 26469 Respirator Assigned
Protection Factors (APFs)
WA 26472 Heat-Related Illness
Prevention

*Compiled by Douglas S. Cody, M.S., M.A., CSP,
CSHM, Nesconset, NY.*

**NAOSH Week
2007**

**BE SAFE AT
WORK**

Support North American
Occupational Safety
& Health Week

May 6 - May 12

**For information, visit
www.asse.org/naosh07.**



**American Society of Safety Engineers
Industrial Hygiene Practice Specialty
1800 East Oakton Street
Des Plaines, Illinois 60018-2187**

**PRESORT STD
US POSTAGE
PAID
PERMIT NO. 401
DES PLAINES, IL**