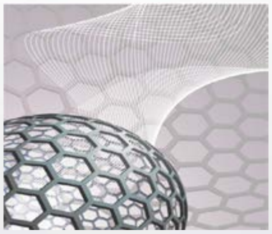
PERSONAL PROTECTIVE EQUIPMENT FOR ENGINEERED NANOPARTICLES

Fact Sheet Sponsored by the AIHA®
Nanotechnology Working Group



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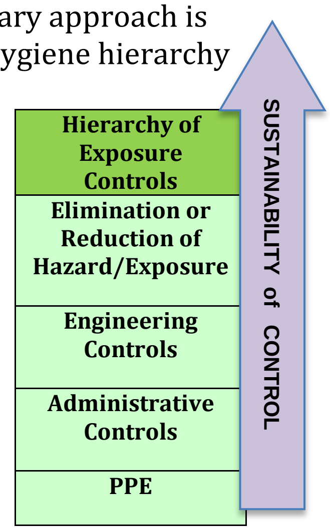
General Overview

Engineered nanoparticles (ENPs) are intentionally produced solid particles with at least one dimension in the size range of approximately 1 to 100 nanometers. Industrial hygienists have helped workers understand and manage health risks associated with incidentally produced nanoparticles (e.g., welding fumes) and naturally occurring nanoparticles (e.g., dust, viruses) for many years. Recent studies and experience support the fact that traditional exposure control approaches can also work for intentionally produced nanoparticles when selected and implemented as part of a comprehensive occupational safety and health plan.

Hierarchy of Controls

Both the nanomaterial hazard and risk of exposure (as well as the level of uncertainty about each) should be considered when selecting controls. When uncertainty about hazard and/or exposure risk exists, a precautionary approach is recommended. Manage exposure risks by following the industrial hygiene hierarchy of controls approach. For best results, consider exposure prevention and control measures early in the planning of experiments, development of products, and design of manufacturing processes, so that appropriate controls can be planned and selected.



A combination of controls from the hierarchy of controls approach, prioritized as follows, is often used to achieve exposure minimization goals.

- Elimination or reduction of hazard/exposure, e.g., by handling material in slurry form rather than as dry particles to reduce exposure risk of a task, or using a surface modified particle that reduces hazard potential
- Engineering controls, e.g., process enclosure, local exhaust ventilation, exhaust filtration
- Administrative controls, e.g., limiting process area access to workers trained and authorized to enter

Personal protective equipment (PPE) is the last line of defense and used when these controls are not feasible or not effective in reducing exposures to acceptable levels, or while controls are in the process of being implemented. PPE may also be used to supplement other control measures for added precaution, and should be used as part of a comprehensive workplace PPE program.

PPE Effectiveness

While PPE can be effective to protect workers handling ENPs, PPE should not be the primary control. In general, PPE recommendations for nanoparticle handling will be the same as for exposures to other powders, fine dusts, or aerosols. PPE selection must be based on many considerations, such as chemical identity and known toxicology of the nanoparticle; quantity handled and physical state (e.g., dry powder vs. liquid suspension); existing exposure controls in place; PPE performance requirements and limitations; and other hazards present (e.g., presence of combustible dust and need for static dissipating footwear and clothing). PPE selection decisions should be communicated to workers.

PPE can offer protection only if it is properly selected, well maintained, and properly worn during all potential exposures. Supervisors overseeing ENP operations and workers required to wear PPE must be trained to:

- Recognize the need to wear PPE: what must be worn (including right size for proper fit) and what tasks require specific PPE.
- Properly don, adjust, wear, and remove PPE without contaminating oneself or introducing cross contamination to the workplace.
- Recognize PPE limitations and possible performance degradation, and when to change out PPE.
- Properly inspect, store, maintain, decontaminate, and dispose of PPE.

Protective clothing and gloves have not been widely tested for effectiveness against ENPs. PPE performance against most nanoparticles can only be evaluated with respect to "relative" effectiveness (e.g., percentage of penetration or percentage of exposure reduction) at this time. Research continues to develop and validate methods to measure effectiveness of PPE as a barrier to nanoparticles. It is important to periodically re-evaluate PPE selections in workplaces where ENPs are handled.

PPE Type

Respirator

Respiratory protection, used as part of a comprehensive respiratory protection program, should be included in the risk management plan in any scenario where ENPs may be released to the work environment. All respirators used in United States workplaces must be certified by NIOSH.

Recent studies on effectiveness of respirators to minimize exposure to nanoparticles (see NIOSH Science Blog resource at end of Fact Sheet) indicate that with proper use of OSHA and NIOSH respirator selection tools, different types of respirators (e.g., filtering facepiece, half-facepiece elastomeric, full facepiece elastomeric, powered air purifying, airline, or self-contained breathing apparatus), and different levels of filter efficiency (95%, 99%, or 99.97% [also known as HEPA or High Efficiency Particulate Air Filters]), can provide the expected protection to airborne nanoparticles. In general, respirator filter media has been found to efficiently capture nanoparticles, mainly by diffusion and electrostatic forces. Classical single fiber theory predicts that filtration efficiency will increase as particle size decreases. Filter efficiency research for the smallest nanoparticles (<2 nm) continues, but it is clear that a compromised respirator facepiece seal is a more likely cause of nanoparticle inhalation than is penetration through respirator filter media, so proper fit and seal must be emphasized.

Considerations for selecting a respirator include: the type, size, and concentration of airborne ENPs and other contaminants present; the potential exposure situation (working conditions/task duration/process, etc.); the respirator's expected level of exposure reduction (i.e., the assigned protection factor [APF]); and cartridge or filter maximum use limits. If there is an occupational exposure limit (OEL) or an organizational internal control target established specific to the ENP, use it for respirator selection. If there is an OEL established for the same chemical substance, although not specifically for the nanoscale material, that value may be helpful to guide respirator selection, keeping in mind that some materials may be more biologically active at the nanoscale. In these cases, and in cases where the ENPs are in the respirator filter's most penetrating particle size range, consider increasing the level of protection by choosing a respirator with higher APF or higher filter efficiency. If there is no relevant OEL available, respirator selection must be guided by existing toxicity information using a precautionary approach. Respirator cartridge change-out schedules must be developed for the specific situation.

Chemical Protective Clothing

While inhalation is considered the most common route of exposure to ENPs, good industrial hygiene practice also recommends use of personal protective clothing to prevent dermal contact and contamination of personal clothing. Select chemical protective clothing (CPC) based on the materials being handled (e.g., any solvents as well as the nanoparticle) and the risk of exposure. For some situations (low hazard material, low exposure risk), use of cotton or cotton-polyester lab coats or coveralls may provide sufficient protection. For higher risk scenarios (high hazard material or high ENP exposure potential), CPC should be made from a low dust-retention/low dust-release fabric. Nonwoven textiles (e.g., high-density/airtight polyethylene) can provide a high level of protection. Avoid protective clothing made of paper, wool, cotton, or other woven fabrics (e.g., polyester) for handling materials of high concern. Common types of CPC for powder handling include a laboratory coat, long sleeves without cuffs, long pants without cuffs, coveralls, closed-toe shoes made of low-permeability material, and shoe covers. When a high level of protection is needed, consider using CPC with a hood. Interfaces between CPC and respirator, protective footwear covering, and gloves can be sealed with tape to increase protection.

Gloves

Good industrial hygiene practice requires gloves to be worn when ENPs are handled to minimize dermal exposure. This is particularly important when skin is compromised by cuts or scrapes. Some research study results on glove effectiveness for ENPs are available, but routine testing has not been completed on the wide range of ENPs being handled in workplaces. As with other chemical exposures, gloves should be selected for their effectiveness against the composition of both the nanoparticle and other materials being handled, while considering other performance requirements like mechanical or heat challenges. If ENPs are suspended in liquids, take into account the resistance of the glove to both the particles and the liquid. Safety data sheets (SDSs) may provide useful guidance. For many ENP handling tasks, good-quality, single-use, disposable polymer gloves (e.g., of neoprene, nitrile, latex, or other chemical-resistant material) may be adequate.

Glove quality and glove thickness contribute to effectiveness. Particle penetration is more likely when gloves are subjected to repeated mechanical deformation and when particles are present in colloidal solutions. Choose thicker gloves for these exposure scenarios and change them out regularly. A precautionary approach includes double-gloving, especially when using thinner gloves or when handling materials of high concern. The inner glove can also provide protection when removing a contaminated outer glove. Gauntlet-type or extended sleeve gloves can protect wrists from exposure via a gap between a CPC sleeve and glove. Removal of hand and wrist jewelry is preferred over coverage by long gloves.

Eye Protection

Use protection to prevent ENP exposure to the eyes. As for other chemical handling, select appropriate eye protection based on the material hazard and potential for exposure. Close-fitting safety glasses with side shields provide protection in low hazard, low exposure situations when the ENPs will not become airborne. Tight-fitting, dustproof (i.e., non-vented) safety goggles are recommended for higher hazard, higher exposure potential scenarios, unless respiratory protection devices protect the eyes, such as would be accomplished with a full facepiece respirator.

Other Considerations

Maintenance Work

Maintenance work warrants special consideration because workers may be in frequent, direct contact with nanomaterials by opening otherwise infrequently accessed and closed equipment spaces. Examples include cleaning and maintenance of analytical equipment in a research lab, housekeeping in a process area, and repair, changeover, or cleaning of process equipment. Note that some maintenance tasks are non-routine and occur during second or third shifts or on weekends. Such work may involve using PPE for exposure control when other controls are not possible (e.g., during maintenance of a local exhaust ventilation system). This may result in the worker wearing more PPE simultaneously than in typical work scenarios. Care must be taken to ensure that new hazards (e.g., heat stress or ergonomic/human factor difficulties) are not introduced. These same issues must be addressed for emergency response spill cleanup.

PPE Removal, Reuse and Disposal

Procedures for removing PPE, including sequence and technique, should be tailored to the specific combination of PPE worn and level of PPE contamination to prevent exposing the worker or contaminating the work area. Used PPE should be removed carefully in the designated area. Workers wearing potentially contaminated PPE should avoid touching surfaces that will be touched by others not wearing PPE. The worker should avoid skin contact with contaminated PPE surfaces and avoid stretching and 'snapping' gloves or elastic cuffs/closures to prevent release of ENP contamination into the air or onto other surfaces. When respirators are worn they should be removed after other outer PPE. An example sequence of PPE removal follows:

1. Remove disposable outer gloves. Allow first glove to turn inside out as it is being slowly removed; hold it in double-gloved hand then remove other hand's outer glove turning it inside out and pulling it over the first glove removed to contain it as if in a 'bag'. Discard into waste receptacle.
2. Remove goggles and place into cleaning receptacle, as needed.
3. Remove lab coat. If known to be contaminated, turn it inside out as it is removed, gently fold in on itself to keep contamination contained, and deposit into waste or laundry receptacle.
4. Remove respirator and place into waste or cleaning receptacle.
5. Remove inner gloves (as in #1 above), discard, and then wash hands and forearms.

For PPE (e.g., lab coats or coveralls) that will be reused, secondary exposure must be addressed prior to, and during, cleaning or laundering. A lab coat with no suspected or visible contamination that will be reused should be hung on an individual hook so the outside of one coat does not contaminate the inside of another. For disposable items, ensure that contaminated PPE is disposed of in the proper waste stream according to federal, state, or local regulations. If gross contamination of reusable PPE occurs, consider disposal rather than cleaning. Secondary contamination from used PPE may be prevented (whether prior to laundering or disposal) by collecting items in an appropriately labeled plastic bag or other sealable container as they are removed. Workers should be educated on methods and practices to prevent them from inadvertently taking ENP contamination home.

Resources

- PPE manufacturer. Contact the PPE manufacturer or supplier with questions regarding protection against specific nanomaterials or exposure scenarios.

- AIHA Nanotechnology Working Group. https://www.aiha.org/get-involved/VolunteerGroups/Pages/Nanotechnology-Working-Group.aspx.

- NIOSH nanotechnology overview. http://www.cdc.gov/niosh/topics/nanotech/

- NIOSH nanotechnology guidance and publications. Search NIOSH TIC–2 for PPE research articles. http://www.cdc.gov/niosh/topics/nanotech/pubs.html

- NIOSH Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials. http://www.cdc.gov/niosh/docs/2009-125/

- NIOSH science blog. "Respiratory Protection for Workers Handling Engineered Nanoparticles" by Ziquin Zhuang, PhD, and Dennis Viscusi. http://blogs.cdc.gov/niosh-science-blog/2011/12/07/resp-nano/

- OSHA fact sheet. "Personal Protective Equipment." https://www.osha.gov/OshDoc/data_General_Facts/ppe-factsheet.pdf.

- European Agency for Safety and Health at Work. E-FACTS #72: "Tools for the Management of Nanomaterials in the Workplace and Prevention Measures." https://osha.europa.eu/en/publications/e-facts/e-fact-72-tools-for-the-management-of-nanomaterials-in-the-workplace-and-prevention-measures.

- GoodNanoGuide. https://nanohub.org/groups/gng/personal_protection_measures