# PERSONAL PROTECTIVE EQUIPMENT FOR ENGINEERED NANOPARTICLES

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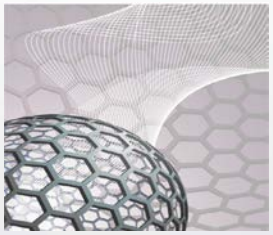

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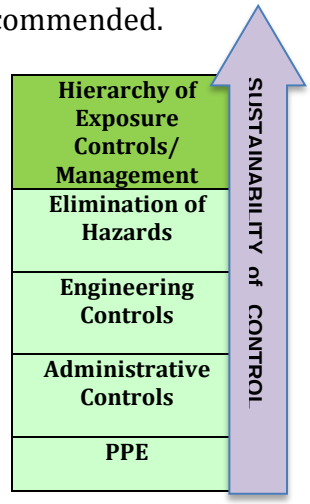
## General Overview

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., viruses) for many years. Recent studies and experience support that familiar 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 (and 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. Exposure risks may be best managed by following the industrial hygiene hierarchy of controls approach. For best results, consider exposure prevention measures and control selection early in the planning of experiments, development of products, and design of manufacturing processes.




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

- elimination or reduction of hazard, e.g., by substitution of particles in slurry rather than dry
- 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 is used when these controls are not feasible or not effective in reducing exposures to acceptable levels, or while other controls are being implemented. PPE may also be used to supplement other control measures for added precaution.

## PPE Effectiveness

While PPE can be effective to protect workers handling engineered nanoparticles, 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); other 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 specific 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. Without established occupational exposure limits (OELs), PPE performance against nanoparticles can be evaluated with respect only to "relative" effectiveness (e.g., percentage of penetration or percentage of exposure reduction). Research continues to develop and validate methods to measure effectiveness of PPE as a barrier to nanoparticles. It is important to stay informed and to periodically re-evaluate PPE selections in workplaces where ENPs are handled.

## PPE Type

**Respirator**

Respiratory protection, used as part of a complete respiratory protection program, should be included in the risk management plan in any scenario where engineered nanoparticles may be released to the work environment. All respirators must be certified by NIOSH (or its equivalent approval agency outside the United States).

Recent studies (see NIOSH Science Blog resource at end of Fact Sheet) indicate that different types of respirators (e.g., filtering facepiece, half-facepiece elastomeric, full facepiece elastomeric, powered air purifying, airline, or self-contained breathing apparatus) can provide the expected protection to airborne nanoparticles according to OSHA and NIOSH respirator selection tools.

Select a respirator consistent with the type, size, and concentration of airborne ENPs and other contaminants present, the specific potential exposure situation (working conditions/process), the respirator's assigned protection factor (APF), and cartridge or filter maximum use limits. A number of studies have looked into the effectiveness of respirators to minimize exposure to nanoparticles. In general, respirator filter media has been found to efficiently capture nanoparticles, mainly by diffusion and electrostatic forces as predicted by conventional single fiber theory, and filtration will be better as particle size decreases, down to an as yet undetermined aerosol diameter.

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. Respirator cartridge change-out schedules must be developed for the specific situation.

**Chemical Protective Clothing**

Use chemical protective clothing (CPC) to prevent both dermal contact and contamination of personal clothing. CPC should be selected 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.

**Gloves**

For many ENP handling tasks, good-quality, disposable, single-use polymer gloves (e.g., of neoprene, nitrile, latex, or other chemical-resistant material) should be

adequate. As in other chemical exposure situations, gloves should be selected for their effectiveness against the characteristics of the nanoparticles and other materials being handled, also considering other performance requirements (e.g., mechanical or heat challenges). If suspended in liquids, take into account the resistance of the glove to both the ENPs and the liquid. Safety data sheets (SDSs) may provide useful guidance.

Glove thickness also contributes to effectiveness. Particle penetration is more likely when gloves are subjected to repeated mechanical deformation and when particles are present in colloidal solutions. Gloves should be changed out regularly. A precautionary approach includes double-gloving, especially when using thinner gloves or when handling materials of high concern. Gauntlet-type or extended sleeve gloves can protect wrists from exposure via a gap between a CPC sleeve and glove.

### Eye Protector

Use protection to prevent ENP exposure to the eyes. If respiratory protection devices do not protect the eyes, such as would be accomplished with a full facepiece respirator, then select appropriate eye protection based on the potential exposure hazard. For higher exposure potential (e.g., airborne dispersion of nanoparticles), tight-fitting, dustproof safety goggles are recommended.

## Other Considerations

### Maintenance Work

Maintenance work, such as cleaning or equipment repair or changeovers, warrants special consideration. This is because workers may be in frequent direct contact with nanomaterials by opening otherwise infrequently accessed and closed equipment spaces. 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 other scenarios, and care must be taken to ensure that this can be done safely for the tasks required, with the worker being careful not to introduce new hazards (e.g., heat stress). These same issues must be addressed for emergency response spill cleanup.

## PPE Reuse and Disposal

For PPE (e.g., lab coats or coveralls) that will be reused, secondary exposure must be prevented prior to, or during, cleaning or laundering. Provide for removal of dirty PPE in a manner that does not contaminate the worker or the general work area. When respirators are worn they should be removed after other PPE. For disposable items, ensure that contaminated PPE is disposed of in the proper waste stream. 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. Workers should be educated on methods and practices to prevent them from inadvertently taking ENP contamination home.

## Additional Information 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