Lessons learned from the field, how to protect yourself from occupational exposure to engineered nanomaterials.

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ABSTRACT

NIOSH created a nanotechnology field team in 2006 to assess potential workplace exposures to engineered nanoparticles. The field team evaluated work places and used portable direct-reading instrumentation (condensation and optical particle counters) supplemented by filter-based air samples (source-specific and personal breathing zone [PBZ]) for analysis by electron microscopy and elemental analysis. This technique has been used 26 times at 19 facilities to assess workplace emissions and potential worker exposure. Lessons learned from the field have been used as a resource for preparing the NIOSH guidance in Approaches to Safe Nanotechnology: Managing the Safety and Health Concerns Associated with Engineered Nanomaterials.

Keywords: guidance, control, safe work practices.

1 INTRODUCTION

Health, safety, and environmental issues continue to be a high priority area to be addressed during the commercialization of nanomaterials or nanomaterial-enabled products [1]. Facilities engaged in the production or use of engineered nanomaterials, specifically nanoparticles, have expressed an interest in learning if their processes present any potential for worker exposure. To assist with answering this question, NIOSH created a nanotechnology field research team whose mission is to visit facilities and conduct assessments to determine the extent of release of nanoparticles and potential worker exposure.

The field research effort was designed to:

- Characterize processes and identify potential emission points or sources that could result in worker exposure
- Evaluate potential workplace exposures using a variety of measurement techniques
- Identify and evaluate existing exposure controls
- Recommend safe work practices.

The field team conducted walk-through observations and utilized portable direct-reading instrumentation (condensation and optical particle counters) supplemented by a filter-based air samples (source-specific and personal breathing zone [PBZ]) to evaluate nanomaterial emissions. The use of the filter samples were crucial for identification purposes because the particle counters are generally insensitive to particle source or composition and make it difficult to differentiate between incidental and process-related nanoparticles using number concentration alone.

The field team has conducted 26 assessments at 19 facilities. The results of these assessments has led to recommendations involving a variety of work practices that can be applied to other facilities interested in protecting workers from exposure to engineered nanomaterials.

2 METHOD

A detailed description of the analytical approach was presented at NSTI 2009 and is also available in Appendix A in Approaches to Safe Nanotechnology [2, 3]. The purpose of this paper is not to re-publish the technique using the portable direct-reading instrumentation (condensation and optical particle counters) supplemented by filter-based air samples (source-specific and personal breathing zone [PBZ]), but rather to present a summary of observational findings and recommended safe work practices that were issued to the participating facilities [4].

3 RESULTS

Facilities evaluated included research and development laboratories synthesizing or handling carbon nanotubes, fullerenes, metal oxides, and quantum dots; pilot plants producing carbon nanotubes, and metal oxides, and facilities engaged in incorporating the engineered nanomaterial into a final product or creating nanomaterials as part of a process. Examples of the materials evaluated at the large-scale production facilities include metal oxides, carbon nanofibers, continuous filament Nylon 6 nanofiber and a silica-iron compound. The most common processes observed and evaluated include weighing, mixing, collection of product, manual transfer of product, cleaning operations, drying, spraying, chopping and sonication. Processes used to synthesize various quantities of product (milligrams to kilograms) include pulsed laser deposition, chemical vapor deposition, gas-phase plasma condensation, organic chemical synthesis, radio-frequency induction plasma and a spray deposition chamber [4].

Engineering controls used to control emissions during various processes/tasks included portable shop-style vacuums with pleated paper filters, shop vacuums with high efficiency particulate air (HEPA) filters, laboratory fume hoods, portable local exhaust ventilation (LEV) used at the source of emission, ventilated walk-in enclosures, negative pressure rooms, gloveboxes (ventilated and nonventilated) and complete enclosures [4].

Figure 1. Use of local exhaust ventilation to control fugitive emissions during cleaning of a metal oxide reactor.
(Photo courtesy of M. Methner, NIOSH)

Figure 2. Partial enclosure of a process that required a worker to enter the space. Notice that the exhaust is incorrectly located above the breathing zone of the worker.
(Photo courtesy of M. Methner, NIOSH)

Figure 3. Complete enclosure of a process.
(Photo courtesy of Nanocomp Technologies, Inc.)

Personal protective equipment (PPE) used by those engaged in operations identified by the facility as having any potential for respiratory or dermal exposure to the nanomaterials included paper surgical masks, N95 filtering facepiece respirators, P100 half-face elastomeric respirators, supplied air respirators, safety glasses, various glove types, lab coats, full-body protective suits and shoe covers [4].

4 RECOMMENDED SAFE WORK PRACTICES

Currently, there are no established occupational exposure limits or regulations specific to engineered nanomaterials. However it is good occupational safety and health practice to keep exposures to new and uncharacterized materials as low as possible. Operations should be carried out in a manner that minimizes the risk of exposure to nanomaterials from inhalation or dermal contact. Principles that contribute to minimizing the risk of exposure to nanomaterials include the following:

- Nanomaterials in dry powder form pose the greatest risk for inhalation exposure and must be handled with care to minimize the generation of airborne dust and to minimize dermal contact.

- Nanomaterials suspended in a liquid present less risk for inhalation exposure than nanomaterials in dry powder form, but may present more risk from skin contact. However, liquids that are agitated (e.g. sonication) may produce aerosols that may contain nanomaterials.

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- Nanomaterials incorporated into a solid matrix present the least risk for inhalation exposure due to their limited mobility. However, there may be circumstances when certain nanomaterials incorporated into bulk solids may still pose some risk if the solid matrix is cut, sawed, drilled, sanded or handled in any way that creates a dust or releases the nanomaterial.

- Irrespective of its physical form, the *quantity* of material handled contributes greatly to the risk of exposure. Operations involving the use of nanomaterials should always use the minimum quantity required for the particular experiment or process.

The following safe work practices should be followed:

- Avoid manipulating nanomaterials in open systems (*e.g.*, handling dry nanopowders on a bench top). Preferably (1) keep them bound in a matrix, (2) suspended in a liquid, or (3) sealed in a container.

- If nanomaterial powders must be handled outside of a ventilated enclosure, use appropriate respiratory protection.

- Transfer nanomaterial samples between workstations (such as exhaust hoods, glove boxes, furnaces) in unbreakable, closed, labeled containers.

- Store nanomaterials in unbreakable, sealed outer containers in labeled cabinets. Segregate incompatible materials and include secondary containment, as appropriate.
- When synthesizing nanoparticles or incorporating into a product, consider the hazardous properties of the precursor materials and processing chemicals as well as those (possibly unknown) of the resulting nanomaterial or product.

- Carry out all manipulations of free nanomaterials in a chemical fume hood, glove box or other ventilated enclosure whenever possible. For larger processes that cannot fit in a fume hood or glovebox (e.g., injection molding), control emissions from those processes with properly-designed local exhaust ventilation or enclosure.

- Isolate nanomaterials in liquid state during mixing operations where a high degree of agitation is involved (such as sonication) as airborne inhalable nanoparticles may be released into the air [5].

- Use good housekeeping in areas where nanomaterials are handled. Clean all working surfaces potentially contaminated with nanomaterials (i.e.,benches, glassware, apparatus, exhaust hoods, support equipment) at the end of each day using a HEPA vacuum pickup and/or wet wiping methods. Do not dry sweep or use compressed air.

- Vacuum up dry nanomaterials only if the vacuum cleaner has a tested and certified HEPA filter.

- As an alternative to HEPA-vacuuming bench tops, bench top protective covering material (e.g., Absorbant Surface Liner) may be used.

- Use shoe covers or sticky mats at the entrance to rooms where nanomaterials are handled.

- Establish criteria and procedures for installing and evaluating engineering controls to ensure proper operating condition.

- Develop specific procedures for using fume hoods, biological safety cabinets, vented balance safety enclosures and glove box isolators. Train personnel in their use.

- When working with nanomaterials use space that is isolated as much as possible from the rest of the facility, with as few people in that space as possible.

- Balance ventilation systems so that air flows into work rooms from corridors.
- Post appropriate warnings including measures to be taken to protect workers and visitors from exposure.
- Use color contrast where possible to visualize exposure. For example, use light colored gloves, lab coats, and work bench surfaces which would highlight contamination by dark carbon nanotubes.
- Make sure workers are trained on how to check and use exposure control methods (e.g., exhaust ventilation systems).

- Systematically evaluate exposures to ensure that control measures are working properly and that workers are being provided the appropriate protective equipment.

- Collect waste in sealed, labeled containers approved for the particular waste stream in a manner that minimizes potential exposure during the transfer of waste into the container. Store the container in secondary containment.

- Develop procedures to properly select, maintain, don, doff and decontaminate personal protective clothing and equipment.
- At minimum, wear laboratory coats, eye protection and appropriate chemical-resistant gloves for all activities.
- Frequently change gloves to prevent cross-contamination.
- Respiratory and face protection, full-body suits or chemical resistant protective clothing may need to be worn, depending on the hazard of the material(s) handled, the availability of appropriate controls and the exposure risks.
- Respirator selection should follow the NIOSH Respirator Selection Logic and should at a minimum be a NIOSH-certified N95 respirator [6].
- Make use of hand washing facilities before eating, smoking, or leaving the worksite.
- Use facilities for showering and change clothes to prevent the inadvertent cross contamination of other areas (including take-home).
- Educate workers on the sources and job tasks that may expose them to nanomaterials and train them on how to use appropriate controls and work practices to minimize exposure.
- Do not eat or drink in the areas where nanomaterials are handled.

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