DONALD BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
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GROUP PROJECT BRIEF

REVIEW OF CURRENT ENVIRONMENTAL HEALTH AND SAFETY PRACTICES IN THE NANOTECHNOLOGY INDUSTRY

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Study Synopsis

- **Nanomaterials are exploited for their unique physical and chemical properties, and have been broadly applied commercially.**
- **There is concern regarding potential health risks associated with their small size and increased possibility for inhalation, ingestion, and dermal exposure.**
- **Nanomaterial safety practices in the workplace remain largely unregulated.**
- **A gap exists between best practices and current practices in the nanotechnology workplace – this study focuses on current practices.**
- **Our findings provide a foundation for the development of industry safety standards.**

INTRODUCTION

Nanotechnology is the understanding and control of engineered materials at dimensions of one to 100 nanometers, i.e. at the "nanoscale." Nanomaterials are designed to exhibit novel or enhanced properties that affect their physical and chemical behavior, thus presenting opportunities to create new and improved products such as coatings, textiles, medicines, and photovoltaic cells. It is estimated that global sales of nanomaterials could exceed $1 trillion by 2015.

However, nanotechnology also presents new challenges for measuring, monitoring, managing, and minimizing contaminants in the workplace and the environment. The properties for which novel nanoscale materials are designed may generate new risks to workers, consumers, the public, and the environment. Novel risks associated with new properties cannot easily be anticipated based on existing data. In the absence of specific information concerning risks and hazards associated with new nanomaterials, nanotechnological manufacturing industries may be implementing workplace safety and product stewardship practices that are both inspired by existing knowledge and, in some cases, are in response to anticipated hazards. Such practices could lay the foundation for industry standards, either voluntary or regulated. A survey of current practices is critical for both assessing the maturity of practice development and for communicating practices throughout the many nanotechnological sectors.

PROJECT PURPOSE

In response to the need for a consolidated understanding of current health, environmental, and stewardship practices in nanomaterial manufacturing, the International Council on Nanotechnology (ICON) issued a Request for Proposals in December 2005 for the performance of a survey of current practices.

An interdisciplinary team of researchers at the University of California at Santa Barbara (UCSB) was selected to perform this study. The specific goals of this project included:

- Catalogue existing and planned global efforts to discover and summarize current industrial practices in workplace safety, environmental protection, and product stewardship. Identify current gaps in knowledge.
- Survey the global nanotechnology industry concerning current practices in environmental health and safety (EHS), waste handling, risk management, monitoring, and product stewardship.
- Generate a baseline understanding of current industrial practices.

Survey Approach

Survey nanotechnology organizations worldwide via telephone, written/internet formats, and third parties.

Nondisclosure

Researchers created and followed a confidentiality protocol per the UCSB Human Subjects process. Data were aggregated to protect participant organizations' identities. Participants were not required to respond to all questions.

Survey question categories

- Nanomaterials characteristics
- Environmental health and safety (EHS) programs
- Engineering controls
- Personal protective equipment
- Ambient workplace monitoring
- Waste management practices
- Product stewardship
- Reported impediments to EHS program development
- Risk beliefs

Participant Characteristics

Sample description

- 337 organizations were contacted out of more than 1,600 worldwide
- 64 organizations participated in the survey, for an *overall response rate of 19%*

Participant organizations

- 80% private sector
- 9% research labs
- 9% university labs
- 1 consulting firm

Organization characteristics

- Located in 14 different countries on four continents
- 86% working with nanomaterials 10 years or less
- Majority have fewer than 50 employees handling nanomaterials – only 4 have more than 250

The intent of this study was not to determine *best* practices, but rather to begin to fill the gap for a global review and analysis of *current* nanomaterial safety practices in order to aid the development of effective industry safety standards.

SIGNIFICANCE

While some compiling of practices has occurred, existing or ongoing studies:

- Do not regard both EHS and stewardship practices, or
- Do not make information freely available to the public, or
- Have gathered data only in a limited geographical area, or
- Results will not be available for some time.

These preliminary findings via literature review and informational interviews reinforced the need for our survey to identify current practices.

SURVEY RESULTS

Nanomaterials Characteristics

Participants[1] were asked to describe the nanomaterials handled or produced at their organization. Sixty-one out of 64 participants responded to this question. The four most commonly handled nanomaterials were described as nanopowders, carbon nanotubes, colloidal dispersions, and fullerenes, respectively (see Figure 1). Respondents indicated the elemental constituents of their nanomaterials are primarily carbonaceous, metal oxides, and metals. A large number of respondents (37%) handle nanomaterials both as a dry powder and in suspension. Twenty-three percent of respondents only handle the dry powder form. The form in which nanomaterials are handled determines the risk of exposure via inhalation, ingestion, and/or dermal contact.

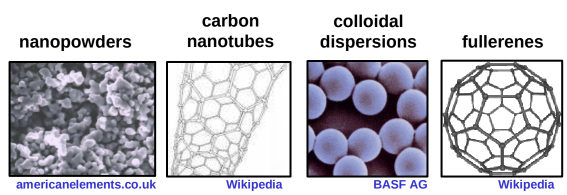

Figure 1. Four most commonly handled nanomaterials

EHS Programs

A majority of participants (92%, or 59/64) indicated they have an EHS program, and more than two-thirds of these organizations reported that they also have a "nano-specific" EHS program (37/59) or that one is being developed (3/59). Respondents from the U.S. reported the highest percentage of nano-specific EHS programs, followed by Asian, European and Australian respondents, respectively. Further, nano-specific EHS programs were more prevalent in organizations that have worked with nanomaterials for a longer time, have more employees handling

[1] **In our analysis we refer to the total number of participants (or participant organizations) as "participants" and to the number of participants that respond to a question as "respondents."**

Limitations of Study

- *Short turnaround time*. Compressed deadline constrained number of participants and project scope.
- *Relatively small sample size*. Data are descriptive and not necessarily representative of the global nanotechnology community.
- *Based on self-report data*. Responses were not verified.
- *Sample bias*. Participation was voluntary and therefore non-random.
- *Some missing data*. Participants were not obligated to respond to every question.

Recommendations for Future Research

- *Survey a larger sample size*. In particular, extending the survey period would help increase the response rate.
- *Conduct surveys in person or over the telephone*. Written and internet surveys proved less detailed for some questions and required clarification.
- *Conduct interviews at the organization's site*. This would allow the opportunity to verify responses.
- *Require survey participation, if possible.* Doing so helps eliminate sample bias.
- *Interview workers "on the floor."* Managers and EHS personnel may not be able to relay the reality of their workplace.
- *Utilize related nomenclature/ classification systems as they become available*.
- *Explore product end-of-life.* End-of-life was beyond the scope of this study, but is of particular interest.

nanomaterials, or believe there are special risks associated with their nanomaterials.

Engineering Controls

Participants were asked whether "nano-specific" facility design and engineering controls are used in the workplace to safely manage worker exposure. Most respondents reported using conventional engineering controls, such as those described in Figure 2. A subset reported using specialized approaches to minimize worker exposure to nanomaterials. Some of the features described include enclosed processes to reduce inhalation exposure, e.g., airlocks, and remotely controlled processes.

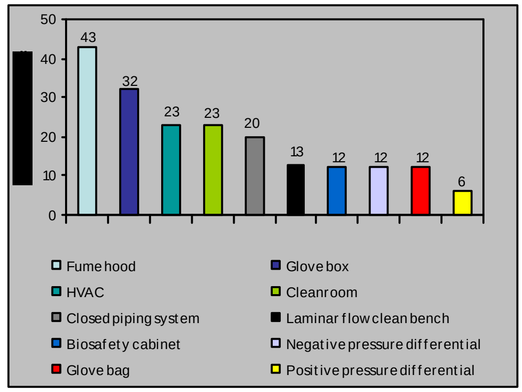

Figure 2. Reported engineering controls

Personal Protective Equipment

Personal protective equipment (PPE) is clothing and/or equipment worn by a worker to minimize exposure to hazardous materials. 84% of the survey sample indicated their organization has PPE recommendations for its employees. However, reported recommendations do not deviate significantly from conventional practices, such as the usage of lab coats, building suits, gloves, and goggles. Slightly more than half of the respondents indicated using respirators when working with nanomaterials, whereas filter specifications varied widely.

Ambient Workplace Monitoring

Sixty-one percent of respondents stated they do not monitor the workplace for nanoparticles. Those that do (36%) most frequently measure particle concentration and size. Recent research suggests that total surface area may be the best metric for measuring exposure to nanoparticles.

Waste Management Practices

Most respondents reported discarding nanomaterials as hazardous waste or through a waste management company, whereas a few agglomerate, incinerate, store, or recycle nanomaterials. More than half of the respondents do not separate nano-waste from the corresponding bulk material waste. Most do not specifically label their waste as nanomaterial. Further, more than half indicated they handle spills containing nanomaterials the same as other spills. Respondents reported most frequently the use of wet wipes and vacuums for cleaning up spills containing nanomaterials.

Product Stewardship

Participants were asked what form of guidance information about the safe use and disposal of their nano-products they provide to customers. Nano-products were not specifically defined, but would include any product that contains nanomaterials. In the event that the organization did not have

Main Findings

- Nano-specific EHS programs and training are widely reported.
- Actual practices do not significantly depart from conventional safety practices for handling chemicals.
- Many organizations display active interest in additional information on how best to handle nanomaterials.

Overall Implications

- A lack of information and guidance are the main reported impediments to further developing and implementing nano-specific environmental health, safety and product stewardship programs.
- The most pressing need is for research on toxicology, hazard characterization and safe handling methods for nanomaterials.
- The two reports generated from this study are already being used for international policy design. Both reports are available at: **http://icon.rice.edu/**

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customers in the traditional sense, the definition of customers (in telephone interviews only) was broadened to include the exchange of nanomaterials between labs or departments. Material Safety Data Sheets (MSDS) and personal interactions were the most commonly described methods for transmitting information of product stewardship. Sixty-seven percent of respondents indicated they transmit information on the *safe use* of their nano-products to customers, of which 86% described using MSDS. Respondents in Europe more often described providing MSDS for safe use than respondents from other regions. Also, smaller organizations most often described providing MSDS and providing information to the public on safe use. Fifty-seven percent of respondents reported having formal guidance for the *safe disposal* of their nano-products. The most common recommendation to customers is to dispose of the nano-product as hazardous waste. None of the surveyed organizations stated their guidance for safe disposal is available to the public.

Reported Impediments to EHS Program Development

When asked if there were impediments to their organization's 'health and safety' management with respect to nanomaterials, 61% of participants responded affirmatively. Seventy-four percent of these respondents described internal and/or external impediments, the primary one being a lack of information or guidance. University labs most often cited internal impediments, e.g., cost concerns or a lack of prioritization of EHS issues.

Risk Beliefs

Participants were asked if they believe there are special risks associated with their nanomaterials. Forty percent described a specific or general type of risk (see Figure 3). A similar number of respondents believe there are no special risks associated with the nanomaterials handled at their organization. This response was most frequently described by respondents whose job title could be characterized as administrative or management. Approximately one-fifth of respondents stated that they do not know or need more information to assess the risks of their nanomaterials. EHS-personnel were more likely to state there is not enough available information. The leading risk concerns stated include inhalation exposure and flammability.

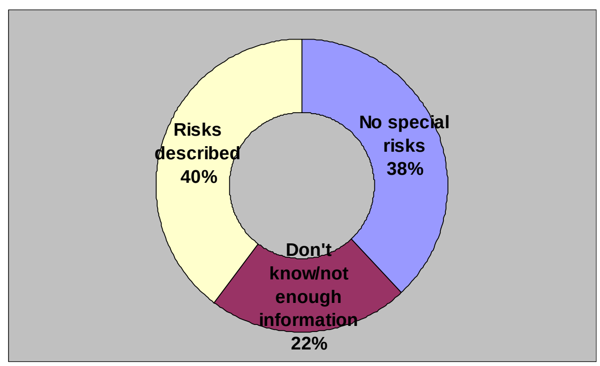

Figure 3. Reported risk beliefs