U.S. Department of Energy

Office of Inspector General

Office of Audits and Inspections

AUDIT REPORT

Follow-up Audit of Nanoscale Materials Safety at the Department's Laboratories

OAS-M-15-08

August 2015

Department of Energy
Washington, DC 20585

August 18, 2015

MEMORANDUM FOR THE ASSOCIATE UNDER SECRETARY FOR ENVIRONMENT, HEALTH, SAFETY, AND SECURITY
ACTING DIRECTOR, OFFICE OF SCIENCE
DIRECTOR, AUDIT COORDINATION AND INTERNAL AFFAIRS
ASSOCIATE ADMINISTRATOR FOR SAFETY, INFRASTRUCTURE, AND OPERATIONS, NATIONAL NUCLEAR SECURITY ADMINISRATION

FROM: Rickey R. Hass
Deputy Inspector General
for Audits and Inspections
Office of Inspector General

SUBJECT: INFORMATION: Audit Report: "Follow-up Audit of Nanoscale Materials Safety at the Department's Laboratories"

BACKGROUND

The Department of Energy (Department) participates in the U.S. Government National Nanotechnology Initiative, which was established in 2003 to coordinate Federal nanotechnology research and development activities across agencies. Nanotechnology activities involve nanoscale materials, substances that are controlled at the scale of approximately one-billionth of a meter. Due to their small size, nanoscale materials may potentially pose health risks to those who come into contact with them. The Department supports Nanoscale Science Research Centers (NSRCs), located at six national laboratories.[1] The NSRCs are user facilities that provide access to leading-edge synthesis, characterization, and computational tools, as well as scientific expertise for interdisciplinary research at the nanoscale. In addition to the activities being conducted at the NSRC, the six national laboratories conduct nanoscale research activities at other facilities within their sites.

In February 2008, the Office of Inspector General reported that the Department and its laboratories had not always employed nanoscale materials precautionary measures in the areas of medical surveillance, workplace exposure monitoring, training, and engineering controls (*Nanoscale Materials Safety at the Department's Laboratories*, DOE/IG-0788). This occurred because the Department relied upon each separate laboratory to develop and implement

[1] The six national laboratories with NSRCs are Brookhaven National Laboratory, Oak Ridge National Laboratory, Argonne National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories, and Los Alamos National Laboratory.

protective measures, and it had not provided laboratories with comprehensive guidance on what specific procedures should be followed. In response to the audit, in May 2011, the Department issued Department Order 456.1, *The Safe Handling of Unbound Engineered Nanoparticles*, which established requirements to ensure that work involving nanomaterials occurred in a safe and secure manner that protected workers, the public, and the environment.

Research and development with nanoscale materials is expected to yield advances in numerous fields including electronics, medicine, and materials sciences. However, the potential adverse health effects of working with nanoscale materials are still not well understood. Accordingly, due to the potential health and safety risks posed by exposure to nanoscale materials, we initiated a follow-up audit to determine whether the Department effectively managed the handling of nanomaterials.

RESULTS OF AUDIT

We found that the Department and its laboratories have made progress in ensuring the safe handling of nanomaterials; however, opportunities for improvement remain. In particular, each of the four Department laboratories we visited had established procedures for the safe handling of nanomaterials to satisfy Departmental requirements. However, we noted that actions at three of the four sites were not always consistent with locally established procedures. Specifically, we found that nanomaterial storage containers and potentially contaminated equipment were not always appropriately labeled, and nanoscale chemical inventories were not accurately managed.

The issues we identified primarily occurred because the laboratories did not consistently follow their own procedures regarding the safe handling of nanomaterials at their non-NSRC facilities. Most of the exceptions we observed occurred at older facilities or research facilities outside of the NSRC. Furthermore, although the Department had established requirements for the safe handling of nanomaterials, it had not established specific requirements for managing and tracking the inventory of nanomaterials. As a result, we determined that workers' potential health and safety risks from exposure to nanomaterials were not fully minimized due to labeling and inventory deficiencies. This is significant, in our opinion, because experts acknowledge the risks posed by nanomaterials exposure are not yet fully understood.

Nanomaterials Labeling

Labeling requirements were not always followed at the Department's laboratories. Department Order 456.1 required that nanomaterial storage and transfer containers be properly labeled. However, we found that two of the four sites we visited did not appropriately label their nanomaterials. For example, we identified three containers of nanomaterials at Brookhaven National Laboratory (BNL) and four containers at Los Alamos National Laboratory (LANL) that were not appropriately labeled. Specifically, the containers at BNL were neither labeled by the manufacturer nor the site to indicate their contents. Although the containers at LANL had labels such as "Qdot Streptavidin" and "Rhodamine B," these labels did not clearly indicate that these were nanomaterials. Department Order 456.1, as well as procedures at both sites, required that containers be labeled to plainly indicate that the contents included nanomaterials. The unlabeled containers of nanomaterials were observed at research facilities outside of the NSRC at both

BNL and LANL. Subsequent to our site visits, BNL and LANL told us they appropriately labeled the containers of nanomaterials mentioned above. Both sites provided examples of the labels they asserted were affixed to the containers.

Additionally, two of the four sites we visited did not appropriately label equipment and equipment system components that were potentially contaminated with nanomaterials, as required by their procedures. The procedures at both sites required that equipment with potential contamination be labeled and that the label remain as long as the potential contamination existed. In particular, at BNL and Oak Ridge National Laboratory (ORNL), we observed certain equipment that may have contained dispersible forms of nanomaterials that were not labeled. The equipment included items such as a vacuum cleaner equipped with a high-efficiency particulate air (HEPA) filter, a local exhaust ventilation system consisting of a HEPA-filtered hood, and a piece of research equipment used for nanomaterial processing. Without appropriate labels, personnel working with the equipment were not warned of the nanomaterial hazards, thus increasing their risk of potential exposure. The unlabeled equipment at BNL was observed at a research facility outside of the NSRC, while the unlabeled equipment at ORNL was observed at its NSRC. In response to our observations, both sites affixed appropriate labels to the equipment shortly after our site visits.

Inventory Management

Nanoscale chemicals were not accurately managed in the chemical inventory systems at three of the four sites we visited. Although there was no regulatory requirement to manage and track the inventory of nanomaterials, each site had a procedure that required hazardous chemicals, including those in nanoscale form, to be maintained in a chemical inventory system. Further, each site had procedures that required the standardization of inventory methods, including barcoding chemical containers and maintaining the chemical inventory system by adding and deleting chemicals as the inventory status changed or through a periodic reconciliation. However, we observed that chemical inventory systems were not entirely accurate or effective in identifying the presence and location of nanomaterials at three of the four sites we visited.

Recording Nanomaterials

We found nanoscale chemicals that were present in the laboratories but were not recorded in their chemical inventory systems. During our facility observations, we judgmentally selected nanoscale chemicals physically held in the laboratories to determine whether they were properly recorded in the inventory system. We found 3 containers of nanomaterials at BNL and 20 containers at LANL that were not included in their inventory systems. After further inquiry, we were informed that some of these materials may have been acquired by other methods or may have been sent directly to the researchers by the vendors, thus circumventing the formal process of barcoding and entry into their inventory systems by the shipping and receiving warehouse upon receipt. The nanomaterials that were not accounted for in the inventory systems were observed at research facilities outside of the NSRCs at both BNL and LANL.

Locating Nanomaterials

We noted nanoscale chemicals that were recorded in the chemical inventory systems but could not be physically located in the laboratories. During our facility tours, we judgmentally selected nanoscale chemicals recorded in the inventory system to physically verify their existence in the laboratories. We could not physically locate 2 of the 6 (33 percent) nanomaterials we sampled at 3 laboratories at ORNL and 3 of the 16 (19 percent) nanomaterials we sampled at 2 laboratories at LANL, despite the materials being recorded in their respective inventory systems. Laboratory officials presumed these nanomaterials were consumed during work performed by the researchers. The exceptions we noted at ORNL occurred at its NSRC, while the LANL exceptions were observed at a research facility outside of its NSRC.

Tracking Nanomaterials

Although not required by contract or regulation, the four sites we visited had established chemical inventory systems as a best management practice. However, we noted that the chemical inventory systems were not fully searchable for nanoscale chemicals because they were either not identified as a separate category of materials or there were limitations to the search functionality and capability. For example, a regular search in the chemical inventory system could pull up nanomaterials, but one laboratory official warned us that it may not accurately reflect the inventory of nanomaterials because "nano" is in the names of chemicals that are not necessarily nanomaterials. Thus we were not able to obtain a complete and accurate list of all nanomaterials at each site. When we informed the laboratories we sampled of our test results, all of them acknowledged that our results were indicative of a systemic problem with chemical inventory systems. In fact, a BNL official stated there will always be some level of untracked chemicals, including nanoscale chemicals, and cited the results of a benchmarking study performed in 2007 by the Energy Facility Contractors Group, which showed that the accepted level of chemical inventory accuracy is 80–97 percent. Further, an ORNL official acknowledged that its chemical inventory system will never be 100 percent accurate due to delays or omissions in updating its system.

Based on the conditions identified above, nanomaterials could be unaccounted for or missing. Although, as previously noted, there was no regulatory requirement to manage and track nanomaterials, we believe there is value in establishing regulations because of the potential health and safety risks to personnel.

Controls Implementation

The issues we identified occurred primarily because the laboratories did not consistently follow their established procedures regarding the safe handling of nanomaterials. We noted that noncompliance with established procedures occurred predominantly in older facilities. While some exceptions were noted at the newer NSRC located at ORNL, all of the exceptions at BNL and LANL were observed at older facilities, or outside their NSRC. One LANL official stated that its nanomaterial safety procedure is institutional and should apply equally to both older and newer facilities at her site; however, she could not determine the reason why there was an inconsistency in the implementation of safety controls. Another official at BNL stated that more

stringent controls are needed at its newer facility due to the specific nature and volume of nanomaterial-related research activities conducted at its NSRC. The official further explained that, although a broad range of research activities is conducted at older facilities, those activities are not solely nanomaterial related. As such, safety controls at older facilities, in most cases, were not effectively followed due to other competing control requirements from various research activities.

These issues also occurred because the Department had not established specific requirements for the safe handling of nanomaterials. Specifically, the Department had not required its laboratories to manage and track the inventory of nanomaterials. According to a Department official responsible for developing safety policies, incorporating chemical management into Department Order 456.1 would be overly burdensome, but he subsequently stated that efforts are ongoing to assess whether the order should be revised to include requirements for chemical management. In addition, the official explained that the hazard assessment process identifies the inventory of potentially hazardous materials, such as nanomaterials and, therefore, requires the implementation of appropriate controls to mitigate the hazards. Although we agree that laboratories perform a hazard assessment at the beginning of a research project or when the scope of work changes, a project could last for an extended time, and the inventory of nanomaterials used is constantly changing. As such, an initial hazard assessment does not capture the inventory of nanomaterials in real time.

Worker Health and Safety

As a result of these issues, Department laboratory employees' potential health and safety risks posed by exposure to nanomaterials were not fully minimized. One of the Department's overarching goals is the safety of its employees, the public, and the environment. Studies by the National Institute for Occupational Safety and Health have shown that exposure to nanomaterials can cause possible pulmonary inflammation, and other studies suggest that some nanomaterials can move from the respiratory system to other bodily organs. In addition, the National Institute for Occupational Safety and Health has stated that the earliest exposures will likely occur for those workers conducting discovery research in laboratories, which applies to the nanomaterial research activities currently being performed at the various NSRCs and the Department's laboratories. Although the specific health effects of exposure to nanomaterials are still under study, we believe it is prudent for the Department and its laboratories to ensure that safety controls are followed to minimize potential employee health and safety risks.

RECOMMENDATIONS

To strengthen controls over the handling of nanomaterials, we recommend that the Acting Director, Office of Science and the Associate Administrator for Safety, Infrastructure, and Operations, National Nuclear Security Administration:

1. Direct the laboratories to take the necessary actions to ensure compliance with required safety controls at all facilities at their respective sites, including steps to:

a) Appropriately label nanomaterial storage containers and potentially contaminated equipment; and

b) Update the inventory status of nanoscale chemicals in a timely manner.

In addition, we recommend that the Associate Under Secretary for Office of Environment, Health, Safety, and Security evaluate the feasibility of incorporating a nanoscale chemical management requirement into Department Order 456.1 to ensure laboratories manage their inventories of nanomaterials effectively.

MANAGEMENT RESPONSE

Management concurred with the report's findings and recommendations and provided corrective actions to address the issues identified in the report. The National Nuclear Security Administration will provide direction to its national laboratories to fully comply with Department requirements for nanoscale materials safety and will schedule targeted assessments of nanoscale materials safety programs to verify compliance with Department Order 456.1. Office of Science management stated they will take necessary actions to ensure facilities under its purview appropriately comply with Department requirements. Finally, the Department's Office of Environment, Health, Safety, and Security has initiated the process to update Department Order 456.1 and will solicit comments on the potential for incorporation of a nanoscale chemical management requirement. Management's formal comments are included in Attachment 3.

AUDITOR COMMENTS

We consider management's comments and planned corrective actions to be responsive to our findings and recommendations.

Attachments

cc: Secretary
Deputy Secretary
Administrator, National Nuclear Security Administration
Chief of Staff

OBJECTIVE, SCOPE, AND METHODOLOGY

OBJECTIVE

The objective of this audit was to determine whether the Department of Energy (Department) effectively managed the handling of nanomaterials.

SCOPE

This audit was performed between August 2014 and August 2015 at Department Headquarters in Washington, DC, and Germantown, Maryland; Brookhaven National Laboratory in Upton, New York; Oak Ridge National Laboratory in Oak Ridge, Tennessee; Sandia National Laboratories in Albuquerque, New Mexico; and Los Alamos National Laboratory in Los Alamos, New Mexico. The scope of the audit included policies, procedures, and implementation of safety controls related to the handling of nanomaterials in effect during fiscal years 2014 and 2015. The audit was conducted under Office of Inspector General project number A14LL056.

METHODOLOGY

To accomplish the audit objective, we:

- Reviewed applicable laws, regulations, and Department policies related to nanoscale materials safety.
- Reviewed industry best practices and Government standards related to industrial hygiene.
- Reviewed safety policies and procedures in effect at the Nanoscale Science Research Centers and other Department laboratories where nanoscale materials were handled.
- Toured various research facilities at Brookhaven National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratories, and Los Alamos National Laboratory.
- Obtained a listing of nanoscale chemicals from Brookhaven National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratories, and Los Alamos National Laboratory's respective inventory systems. Judgmentally selected a sample of nanoscale chemicals that were recorded in their inventory systems to verify their existence. Items were selected for testing based on the key word "nano," which indicated the chemical may be in nanoscale form. We also judgmentally selected a sample of nanoscale chemicals that were physically observed in the laboratories and traced the items back to the inventory systems to verify the accuracy of inventory records. We did not use statistical samples during the course of this audit. As a result, we could not project the results of our analyses to the population.
- Held discussions with key Department and laboratory personnel.

We conducted this performance audit in accordance with generally accepted Government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objective. We believe the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objective. The audit included tests of controls and compliance with laws and regulations to the extent necessary to satisfy the objective. We assessed the implementation of the *GPRA Modernization Act of 2010* as necessary to accomplish the objective and determined that performance measures related to the protection of worker health and safety were established as required. Because our review was limited, it would not necessarily have disclosed all internal control deficiencies that may have existed at the time of our audit. Finally, we did not rely on computer-processed data to achieve our audit objective and therefore did not conduct a data reliability assessment.

Management waived an exit conference.

RELATED REPORTS

- Audit Report on *Nanoscale Materials Safety at the Department's Laboratories* (IG-0788, February 2008). The audit determined that the Department of Energy (Department) and its laboratory contractors had not always employed precautionary measures as outlined by the Centers for Disease Control and the National Institute for Occupational Safety and Health. While some laboratories had established work practices concerning the safe handling of nanoscale materials, the Department's laboratories generally had not performed medical surveillance on individuals working with these materials, monitored the workplace environment for exposure to airborne nanoscale materials, provided specific training in the safe handling of nanoscale materials, and required that nanoscale materials research be performed in facilities equipped with all of the suggested engineering health and safety controls.

- *Environment, Safety, and Health Special Review of Work Practices for Nanoscale Material Activities at Department of Energy Laboratories Volume I - Summary Report and Volume II – Compilation of Field Reports* (August 2008). The primary focus of the Department's Special Review was to compare Department site operations to the approach outlined in the *Department of Energy Nanoscale Science Research Centers Approach to Nanoscale Environment Safety and Health* and other applicable requirements. The Special Review included onsite field reviews of work practices at 8 of the 16 laboratories performing nanoscale activities. While the results indicated there were significant improvements, implementation weaknesses were still prevalent in important aspects of nanomaterial safety practices, including chemical management, medical surveillance, contamination control practices, ventilation controls, communication of hazards to workers, use/control of personal protective equipment, shipment packaging and labeling, transport of shipments, and management of waste streams. The Special Review determined that implementation deficiencies primarily stemmed from a failure to clearly establish and communicate requirements in accordance with Department management systems.

MANAGEMENT COMMENTS

Department of Energy
Washington, DC 20585

July 24, 2015

MEMORANDUM FOR GREGORY H. FRIEDMAN
INSPECTOR GENERAL
OFFICE OF THE INSPECTOR GENERAL

FROM: MATTHEW B. MOURY
ASSOCIATE UNDER SECRETARY FOR
ENVIRONMENT, HEALTH, SAFETY AND SECURITY

SUBJECT: COMMENTS FOR IG DRAFT AUDIT REPORT on "Follow-Up Audit of Nanoscale Materials Safety at the Department's Laboratories" (A14LL056)

Thank you for the opportunity to comment on the Draft Report, "Follow-Up Audit of Nanoscale Materials Safety at the Department's Laboratories," provided to the Office of Environment, Health, Safety and Security (AU) on June 29, 2015. Following are consolidated comments from AU, the National Nuclear Security Administration, and the Office of Science.

National Nuclear Security Administration

Recommendation 1: To strengthen controls over the handling of nanomaterials, we recommend that the Acting Director, Office of Science and the Associate Administrator for Safety, Infrastructure, and Operations, National Nuclear Security Administration:

1. Direct the laboratories to take the necessary actions to ensure compliance with required safety controls at all facilities at their respective sites, including steps to:

   a. Appropriately label nanomaterial storage containers and potentially contaminated equipment; and

   b. Update the inventory status of nanoscale chemicals in a timely manner.

Management Decision: Concur.

Action Plan: The Associate Administrator for Safety, Infrastructure, and Operations, NA-50, will provide direction through the field element managers to our national laboratory partners to fully comply with DOE requirements for nanoscale materials safety. Deputy Associate Administrator for Safety, NA-51, in coordination with the field element manager, will schedule targeted assessments of nanoscale materials safety programs beginning in FY 2016 to verify compliance with DOE Order 456.1, *The Safe Handling of Unbound Engineered Nanoparticles*, at the three National Nuclear Security Administration national laboratories.

Estimated Completed Date: September 30, 2016

Office of Science

Recommendation 1: To strengthen controls over the handling of nanomaterials, we recommend that the Acting Director, Office of Science, and the Associate Administrator for Safety, Infrastructure, and Operations, National Nuclear Security Administration:

1. Direct the laboratories to take the necessary actions to ensure compliance with required safety controls at all facilities at their respective sites, including steps to:

   a. Appropriately label nanomaterial storage containers and potentially contaminated equipment; and

   b. Update the inventory status of nanoscale chemicals in a timely manner.

Management Decision: Concur. The Office of Science concurs with the above recommendations and will take necessary actions to ensure facilities under its purview appropriately comply with DOE established requirements.

Action Plan: The Office of Science will implement this management response as part of its line oversight responsibilities. Actions to be developed include:

Action 1: Discuss audit results at the upcoming Office of Science Field Managers meeting scheduled for July 21, 2015, and request that any Office of Science Laboratory dealing with Nanoscale Materials determine if they might have similar issues.

Estimated Completion Date: July 21, 2015

Office of Environment, Health, Safety and Security

Recommendation 1: In addition, we recommend that the Associate Under Secretary for Office of Environment, Health, Safety and Security evaluate the feasibility of incorporating a nanoscale chemical management requirement into DOE Order 456.1 to ensure laboratories manage their inventories of nanomaterials effectively.

Management Decision: Concur. DOE Policy and Order 456.1 are directives that specifically address nanoparticles. Title 10, Code of Federal Regulations (CFR) part 851, *Worker Safety and Health Program (Rule),* contains the requirements that apply to all hazardous substances when not specifically addressed by a specific standard. The Rule requires a hazard analysis be performed for materials and that appropriate controls be in place to protect workers. The Rule requires hazard identification and assessments (10 CFR 851.21) be conducted to identify existing and potential hazards. These assessments must be performed to obtain baseline information and, as often as necessary, to ensure compliance with the subpart. The Office of Worker Safety and Health Policy is in the process of assessing DOE Order 456.1 to determine if it should be revised and will review the need to include requirements for laboratory inventories during this process.

Action Plan: The Office of Health and Safety (AU-10) has initiated the process to update DOE O 456.1, *The Safe Handling of Unbound Engineered Nanoparticles*. During the review period, we will solicit comments on the potential for incorporation of a nanoscale chemical management requirement.

Estimated Completion Date: October 1, 2015

Attachment

FEEDBACK

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