Assessment of Arsenic Surface Contamination in a Museum Anthropology Department

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Objective: To assess potential arsenic (As) contamination of work surfaces to improve upon the control strategy at an anthropology department in a large natural history museum. **Methods:** Workpractices were observed and control strategy reviewed to inform an occupational hygiene assessment strategy utilizing surface wipe sampling. A total of 35 sampling targets were identified, focusing on surfaces that receive high touch traffic, including workstations, artifact transport carts, and elevator buttons. Arsenic sampling and analysis were performed using reference method Occupational Safety and Health Administration ID-125G. **Results:** Four of the sampling areas returned detectable levels of As, ranging from 0.052 to 0.350 μg/100 cm^2. **Conclusion:** Workplace observations and wipe sampling data enabled the development of recommendations to help to further reduce potential occupational exposure to As. Continuous reduction of surface contamination is prudent for known human carcinogens.

The use of inorganic arsenic (As) preparations for the preservation of organic artifacts and biological specimens for museum items and other collections has been documented as far back as the late seventeenth century and well into the late twentieth century.[1] Arsenic compounds were utilized because As is toxic to various microbes and pests that could damage museum pieces, and the use became popular during the late eighteenth and early nineteenth centuries because these compounds were less likely to damage artifacts than alternative preservation processes, such as pickling in alcohol, drying, or embalming.[2,3] The use of As preservatives in museum settings was recorded up until the late 1970s, and use in the field to preserve artifacts for transfer to museums was noted as late as 1993.[1,2] Arsenic trioxide was the most common of these compounds and could be applied dry, in solution, or mixed with a soap for ease of application.[2] Arsenic residues can persist on these museum objects, and degradation or mechanical disturbance may dislodge As-contaminated particles from an artifact onto workplace surfaces, creating continued exposure opportunities for museum employees, volunteers, visitors, maintenance workers, repatriation workers and their communities, outside collectors, and, potentially, their household contacts.[1–8]

We evaluated workplace surfaces for potential As contamination in the anthropology department of a large natural history museum. This department already had programs for identifying As-contaminated artifacts, controlling contamination on work surfaces, and preventing exposure to employees. The overall objective of this study was to examine the effectiveness of the current control strategy for As in this anthropology department. Specific objectives were to review current written control policies and procedures, perform workpractice observations to inform an occupational hygiene assessment strategy, measure potential As contamination on workplace surfaces, and make recommendations to further reduce potential As exposure.

Although an extensive surface wipe sampling campaign was planned, sampling was discontinued after 2 weeks to allow for facility renovations to begin. Despite this shortened sampling program, several areas of detectable levels of As and workpractice concerns were identified. An understanding of contamination transfer and preventive recommendations could benefit others working with artifacts where preservation with As or other hazardous materials is known or suspected.

METHODS

Study Location

This study was performed in the anthropology department at the Field Museum of Natural History in Chicago, Illinois. The main portion of the anthropology department was located on one floor of the museum but utilized storage facilities on several other floors. The department consisted of a large central room with multiple worktables, computer workstations, storage cabinets, and bookcases. Several offices and laboratories were adjacent to this central room, as well as an additional room utilized as a lunch and conference space. There were approximately 12 personnel in the anthropology department, including fulltime employees, interns, and volunteers. Tasks included cataloging and photographing pieces, restoring artifacts, and preparing items for study or exhibition.

Review of Current Control Strategy

An earlier review[9] of museum documents found the use of As noted as late as the 1930s in this specific facility. The museum implemented a control strategy to protect employee health, including worker training, artifact testing and labeling for As surface contamination, safe workpractices, housekeeping procedures, and use of personal protective equipment (PPE) to mitigate employee and community exposures. We reviewed these written policies to evaluate the current occupational hygiene practices and inform recommendations.

Workpractice Observations

Two days were dedicated to workpractice observation. Worker methods of retrieving items from storage rooms and moving them to laboratory work areas were studied and surfaces touched by employees were recorded. Museum employees were observed restoring, cataloging, and photographing various artifacts at workstations throughout the laboratory. Museum employees did not have assigned workstations but chose a workstation depending on the specifications of the given artifact and the specific tasks to be performed. Cataloging and photographing were performed primarily in the central workspace, whereas the majority of the restoration processes were performed in the smaller adjacent laboratory spaces.

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Observation of workpractices informed our occupational hygiene assessment strategy. A surface wipe sampling campaign was selected to target high touch traffic areas that workers could have potentially contaminated immediately after handling an artifact or surfaces touched at some later time without consideration for possible contamination.

Surface-Wipe Sampling

A total of 31 areas of concern throughout the anthropology department were identified. These areas included computer workstations, door handles, and elevator buttons and were expected to be representative of potential routes of As exposure throughout the anthropology department. Additional four sampling targets were identified on day 2 of sampling for a total of 35 samples that day. All four additional targets were on multishelf artifact transport carts that seemed to have a large amount of settled dust/debris on the disposable paper cover sheets used to protect objects. The 2 days of sampling were conducted 1 week apart; no housekeeping occurred between sampling events.

Samples were collected on 42.5-mm-diameter Whatman 540 grade hardened ashless filter papers that were wetted with deionized water to facilitate surface contaminant capture. All wiped surfaces measured approximately 100 cm^2, and wiping was performed according to Occupational Safety and Health Administration method ID-125G. Each sample was immediately placed in a petri dish and sealed for shipment to laboratory for analysis. New nitrile gloves were utilized for each sample to limit any possible crosscontamination between samples. One blank sample was also wetted with deionized water and included on each day of sampling.

An American Industrial Hygiene Association–accredited laboratory performed the sample analysis. The samples were digested utilizing an automated microwave digestion system (CEM Discover SP-D [CEM Corporation, Matthews, NC] with Explorer 24/48). Arsenic concentration in the digested solution was determined by a Thermo Electron ICP-MS X Series II (Thermo Fisher Scientific Inc, Waltham, MA) with Cetac ASX-520 autosampler (CETAC Technologies, Omaha, NE). There are no known interferences for this method.

RESULTS

Current Control Strategy

Training

A computer-based training presentation was given to all incoming anthropology department employees. The training included proper handling of museum artifacts and what to do in case of emergencies. The training presentation also covered a list of items on which As may be present and the ongoing testing and labeling identification system used by the museum for artifacts with As contamination. The training presentation recommended that employees utilize laboratory coats and nitrile gloves as protective measures when working with any artifact because not all pieces in the museum collection had been tested for As presence. In addition, designated eating and drinking areas in the facility were identified to limit potential ingestion of As. New employees were also provided with a copy of the safety and health training presentation for their reference.

Testing and Labeling

Artifact surfaces may be tested for As contamination by trained museum personnel using wipe sampling media with x-ray fluorescence mass spectrometer analysis. Items may be tested when the museum obtains funding to test a specific part of its collection, when the museum receives reliable information that items may be contaminated, or when department members request that a specific item be tested. When an item was identified as positive for As contamination, the item and its storage box were wrapped in plastic bags and labeled with As-positive identification tags (Fig. 1). The As-positive bagged and labeled items were then kept with their respective collections.

FIGURE 1. Warning label for artifacts.

Housekeeping

Housekeeping personnel cleaned the laboratories and offices of the anthropology department approximately once every 3 weeks. The cleaning consisted of wiping down flat surfaces, such as computer desks, worktable surfaces, and the conference/lunch room table, and then mopping the floor in the main laboratory area. For security reasons, housekeeping personnel did not have access to storage rooms or two of the smaller laboratory rooms. Housekeeping personnel received separate new employee training with annual refresher courses that included a review of hazardous materials that may be found in the museum. Training did not include information about specific hazards, such as As on artifacts that could contaminate the work areas designated for cleaning.

A thorough cleaning of a portion of the department was performed twice per year by anthropology department staff. This cleaning involved a wipe down of all surfaces in the designated portion of the department using wetted paper towels. A 3-year cycle of these special cleanings was necessary to complete the cleaning of all areas of the department.

Personal Protective Equipment

The PPE in the anthropology department included laboratory coats and disposable nitrile gloves. A central station with access to laboratory coats and disposable nitrile gloves was located in the main room of the anthropology department. After each use, laboratory coats were placed in a bin to be washed in the on-site washer and dryer on an as-needed basis by an anthropology department employee. Nitrile gloves were disposed of in normal trash containers.

Workpractices

The museum specified rigorous procedures for handling items that have been identified as positive for As contamination. These procedures included creating an open space around the object during work to minimize potential for other surfaces becoming contaminated; washing hands immediately after handling the objects; wearing PPE; proper packaging of the item in a labeled plastic bag; and posthandling cleanup including wiping down the work surfaces. General compliance with the required use of nitrile gloves was observed but some employees did not consistently remove the gloves to use the phones, push elevator buttons, or use computer keyboards. It was noted that workers were extremely careful when handling all artifacts, and this limited the possibility of dust/debris dislodging from the artifacts. Not all As-positive items, however, were wrapped in plastic bags as required, and some were simply labeled as As contaminated (Fig. 1).

Wipe Sampling Results

Wipe samples were taken in 31 locations on day 1 of sampling and in 35 locations on day 2 of sampling, and two blanks were included for each day. The concentrations of As from each sampled surface are reported in Table 1 and ranged from less than 0.050 to 0.350 μg/100 cm^2. Detectable results are highlighted, whereas those below the method reporting limit of 0.050 μg are noted as "nondetectable" (ND). There is currently no occupational exposure guideline for As surface contamination, so results from the 2-day sampling program were used simply as indicators of As contamination.

All day 1 sampling results were ND, whereas day 2 sampling results included a number of positive results. Specifically, all cart paper cover sheets that were sampled (numbers 17 and 33 to 36) were positive for As contamination. No transport cart handles or sandbags used to secure artifacts during transport tested positive for As.

Only one workstation tested positive for As. The laboratory in which this workstation was located had not been used in several months and was not regularly cleaned by housekeeping. All other workstation samples were ND, including computer stations in the same laboratory that had a positive result. An artifact container similar to those that had previously tested positive for As under the museum's artifact testing program was also positive. The final positive wipe sampling result was from the elevator buttons inside the elevator used to go to the downstairs storage area. Buttons and phones outside the elevator had ND results. Other target surfaces of concern such as doors, lunchroom table, microwave, refrigerator, drawer handles, and sinks throughout the anthropology department all returned ND results.

TABLE 1. Arsenic Wipe Sampling Results

Sample Location	Sample As Concentration on Day 1 (μg/100 cm^2)	Sample As Concentration on Day 2 (μg/100 cm^2)
Main laboratory workstation table top	ND	ND
Main laboratory workstation table top	ND	ND
Main laboratory storage cabinet handle	ND	ND
Adjacent laboratory door handle	ND	ND
Adjacent laboratory door surface	ND	ND
Office workstation table top	ND	ND
Adjacent laboratory door	ND	ND
Adjacent laboratory door handle	ND	ND
Lunchroom table	ND	ND
Lunchroom sink	ND	ND
Lunchroom refrigerator door	ND	ND
Lunchroom microwave door	ND	ND
Transport cart handle	ND	ND
Transport cart handle	ND	ND
Storage room drawer handle	ND	ND
Storage room drawer handle	ND	ND
Transport cart cover paper	ND	**0.081**
Exterior elevator buttons	ND	ND
Interior elevator buttons	ND	**0.055**
Storage elevator phone	ND	ND
Adjacent laboratory storage shelves	ND	ND
Adjacent laboratory storage sandbags	ND	ND
Adjacent laboratory computer station	ND	ND
Adjacent laboratory sink	ND	ND
Adjacent laboratory workstation	ND	**0.070**
Adjacent laboratory computer station	ND	ND
Transport cart sandbags	ND	ND
Model tepee base	ND	**0.064**
Artifact container	ND	**0.078**
Key lanyard	ND	ND
Main laboratory computer station	ND	ND
Field blank	ND	ND
Transport cart cover paper	—	**0.350**
Transport cart cover paper	—	**0.052**
Transport cart cover paper	—	**0.290**
Transport cart cover paper	—	**0.054**
Laboratory blank	ND	ND

Nondetectable (ND) results were below the method reporting limit of 0.050 μg.—indicates no samples were collected.

DISCUSSION

Arsenic is a human carcinogen with a number of other serious human health effects that poses a risk through inhalation, ingestion, and, under some circumstances, skin contact.[10,11] Reducing the potential for exposure to As compounds to the lowest possible level in museums and other settings is prudent.

Previous studies have documented the persistence of As and other hazardous preservative agents on museum artifacts.[2–5] Identifying which items in a museum's collections have been contaminated with As can involve potentially destructive sampling, so other methodologies have been attempted. Reviews of preservation records (which are often incomplete) and purchase orders for preservative have been used to identify potentially contaminated collections.[2] Other testing techniques, including artifact spot testing and surface wipe sampling, gas chromatography–mass spectrometry, and, more recently, x-ray fluorescence techniques, are providing a better understanding of which objects have surface contamination with As and other contaminants of concern.

Complete characterization of surface contaminants in collections remains a challenge. The variability of surface contamination on individual objects and the limitations of testing techniques can still contribute to false-negative results.[5,11] In addition, the size of collections at large museums makes thorough evaluation very challenging, and smaller collections may lack the staff, training, and resources for adequate testing.

In 2008, 29,100 persons were employed in museum settings as archivists, curators, conservators, or technicians.[12] This estimate, however, does not include some maintenance workers, contractors, unpaid volunteers, university workers, outside collaborators, and others who may be involved in museum activities. Repatriation workers and their communities can come in contact with contaminated

artifacts when they are returned and used in current cultural activities. Outside collectors, their household members, and contacts may also be at risk when preserved items are stored in less-controlled settings. Even museum visitors may be at risk of exposure in settings such as interactive exhibits with artifacts composed of fur, feathers, or hides that have been preserved with As. These nonemployee groups are difficult to identify but deserve further attention.

Recommendations

This museum had a strong program of awareness training and exposure prevention and continued efforts to reduce exposures were considered prudent. Recommendations included expansion of new employee training to include awareness of potential contamination transfer. It was recommended that housekeeping staff receive training on As hazards and other potential exposures in the workplace. Periodic wipe sampling and evaluation of workpractices were recommended as a part of a continuing assessment. It was recommended that the artifact testing and labeling program be expanded to include all items being worked on and that all items tested positive for As should be bagged when in storage.

Employees were encouraged to limit touching surfaces such as door handles, elevator buttons, or phones when wearing gloves. Hand washing and other appropriate hygiene habits should be encouraged to minimize contamination transfer between work and home. Employees should continue to use nitrile gloves and laboratory coats while working with artifacts and when moving dirty laboratory coats from the laundry bin to on-site washing machines. Establishing a disposal strategy for transport cart cover papers and adding disposable nitrile glove stations throughout the department were encouraged. The PPE should be cleaned and disposed of in accordance with hazardous waste recommendations provided by the Resource Conservation and Recovery Act. Despite negative wipe sampling results, access to the lunch/conference room should be reevaluated because of its close proximity to work areas and lack of physical barriers from the work areas. Finally, programs for As-exposure prevention should also apply to other museum areas with known or suspected As contamination, such as those containing taxidermy specimens.

CONCLUSION

The past use of As preservatives in museum artifacts can continue to pose an exposure risk for current employees and others. Arsenic is only one of the hazardous preservatives that may persist in museum collections. In view of the potential for serious health effects at even low levels of exposure to some of these preservatives, programs of exposure awareness and prevention should be evaluated to assess their effectiveness. Evaluation of potential exposure in other collections is also warranted. The collaboration of occupational health and safety professionals with conservators, collectors, and other stakeholders is essential to ensure that these programs are effective.

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