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INVESTIGATION OF RESIDUAL CONTAMINATION INSIDE STORAGE CABINETS: COLLECTION CARE BENEFITS FROM AN INDUSTRIAL HYGIENE STUDY

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Closed storage cabinets become the repository for hazardous vapors emitted by collections, deteriorating cabinet construction materials, and/or collection storage materials, especially wood products and many plastics. Cabinet replacement has been a major goal in the collection care program at the Smithsonian's National Museum of Natural History. The museum has targeted over 5000 old storage cabinets with interior wood framing and wooden drawers for disposal or surplus as funding permits. These cabinets had housed, or continued to house, anthropology and vertebrate zoology collections as well as papers, books, and photographic materials. The cabinets and their past or present contents were known to have been subjected to various pesticide treatments, many of which were presumed to have adsorbed onto or absorbed into cabinet interior materials. In order to understand the risk and to best sequence a staged replacement of old cabinets, the museum administration sought the expertise of occupational health and safety specialists to analyze both the cabinet interior environment and the health exposure risks to anyone accessing the cabinets. Forty volatile organic chemicals were detected in parts per billion (ppb) levels within the cabinets, using the USEPA TO-15 Compendium Method. This dataset and the personal exposure monitoring data set collected showed levels that were significantly less than respective Occupational Exposure Levels, suggesting that human health risk in accessing these cabinets was low. However, the identified chemicals suggest a risk to the collections themselves from continued use of the cabinets. Based on the results of this study, the museum was able to prioritize cabinets for replacement.

KEYWORDS: *Collection care, health and safety, storage environment, collection hazards, past treatments, residual contaminants, exposure monitoring, industrial hygiene*

1. INTRODUCTION

Although engaged in the rehousing of collections for several decades, the Smithsonian Institution's National Museum of Natural History (NMNH) still has collections that are housed in wood-framed, sheet-metal cabinets that have been in use for the better part of a century (Jackson 1926) (fig. 1). Staff using the collections raised concerns about the gas-phase emissions that were readily detectable when accessing these cabinets. To understand the potential impact on human health and safety, the NMNH conservation, collection management, facilities, and administrative staff developed a partnership with industrial hygienists from the Smithsonian's Office of Safety, Health, and Environmental Management (OSHEM) to determine whether chemicals known to have been used in past collection treatments (Williams and Hawks 1987; Goldberg 1996) had accumulated within these old storage cabinets and if so, to what degree these posed hazards to human health or risk of cross-contamination to any collections now housed in the cabinets.

The study was coordinated by the NMNH Collections Program. Collection managers knew cabinet contents, past treatments of cabinets, and lengths of time cabinets had been unopened (i.e., which ones

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FIG. 1. Example of an empty wooden storage cabinet. Note that the cabinet is accessed by removing the door, and both are constructed of a wood frame with metal cladding. Wooden drawers (not pictured) can be installed, as needed, in the wooden tracks. The gasket material is red felt.

were likely to have the greatest vapor accumulation). Facility staff knew which departments previously used now-empty cabinets. The museum's conservator knew past treatment histories and the pollutants known to damage collections. Industrial hygienists from OSHEM had expertise in environmental monitoring methods. Scientists from Analytics Corporation, a laboratory accredited by the American Industrial Hygiene Association (AIHA), determined the most realistic combination of sampling methodologies for the wide range of suspect agents. Because there were 5000+ cabinets of concern, the primary challenges were determining which cabinets would be used as the sample set, which chemicals could or should be studied, and which environmental sampling methods would most efficiently and cost-effectively identify and quantify these chemicals.

The results were designed to allow the stakeholders to arrive at decisions regarding cabinet access restrictions, if needed; storage space constraints from disposal of contaminated cabinets; potential re-purposing of cabinets for other uses; and the need for new cabinet purchases. The results supported this design, allowing the museum's administration to secure resources to move the cabinet replacement program forward at an increased pace.

2. Defining the Cabinet Sample Population

The first step was to gauge the magnitude of the sample size and any commonalities that could allow valid sample set groupings. Cabinets from several storage conditions were considered in defining the sample population.

- Cabinets housing treated collections, with probable accumulated interior vapor contaminants from those collections and/or the cabinet construction materials.
- Cabinets re-purposed to store office supplies, personal files, and personal reprint libraries, with the concern that contaminants from past holdings would still pose a health hazard and/or contaminate the non-collection personal materials.
- Now-empty cabinets awaiting re-assignment to other departments or awaiting disposal, which may have ad/absorbed volatile chemicals from previously treated holdings.

The museum's detailed records provided the location and tag numbers of the cabinets originating from each department.

Cabinets from the same departments, which were currently filled or had been empty for at least two years, could yield data on the degree to which empty cabinets retained contaminants, and thus pose risk to future storage use. Collection managers and the museum conservator identified both empty and specimen/object-filled cabinets that represented past uses and treatment histories. Sample sets were then grouped as follows:

(1) Mammals (149 cabinets)
  - 100 filled cabinets, mixed representative study skins, skeletal materials, and taxidermy mounts (fig. 2)
  - 4 "special" cabinets, filled with mixture of specimens and grease-saturated skeletons that were suspected of being heavily treated with toxic chemicals in the past and had been access-restricted for at least one year
  - 45 empty cabinets

(2) Anthropology (367 cabinets)
  - 250 filled cabinets randomly selected by collection staff, targeting physical, ethnological, and archaeological materials
  - 75 cabinets now used for non-collection material storage
  - 42 empty cabinets, randomly selected by surveyors

The 516 sample cabinets were either verified by the departments not to have been opened recently or tagged as restricted access for several months prior to

FIG. 2. Example of a wooden case, in use, with mammal study skins. Image credit: Evan Cooney, Smithsonian Institution 2017.

this study. This ensured accumulated interior concentration of vapors.

3. Selecting Chemical Agents for Study

The primary basis for determining the compounds to be studied was the extensive literature and oral history review of NMNH pest control measures undertaken by Goldberg in 1996. Particulates were not the focus of her survey as identification of these residuals had been previously conducted by the NMNH and controlled through safe work practices such as barrier gloves, lab coats, respirators (as needed), and routine HEPA-vacuum cleaning of cabinets, work areas, and where warranted, collections. These agents included: non-volatile particulates (DDT and isomers, sulfur, strychnine) and heavy metal particulates (arsenic, lead from paints on cabinets and room walls, and lead from some old specimen tags).

In consultation with the analytical laboratory chemists, the non-particulate compounds documented by Goldberg were examined as to their volatility, as a possible measure of persistence, and ease of detectability by methods with low limit of detection and high percentage recovery rates from sampling media. The chemicals were sorted as shown below:

- Highly volatile, with least likelihood of persistence over time: ethylene oxide, ethylene chlorohydrin.
- Volatile, likelihood of retention via specimen and wood ad/absorption, with dynamic revaporization: carbolic acid (phenol), the mixture of carbon tetrachloride and ethylene dichloride (Dowfume®), ethylene dibromide and methyl bromide; and vapor from recrystallized particulate residues: naphthalene and 1,4-dichlorobenzene (PDB) (Ormsby et al. 2006; Makos and Hawks 2014).
- Semi-volatile, likelihood of retention with some re-vaporization: carbon disulfide, camphor, thymol, pentachlorophenol, and 2,2-dimethyl dichlorovinyl phosphate (DDVP/Dichlorvos/Vapona), which can decompose through reaction with substrate and air to a host of aldehydes, acids (Williams et al. 1986).
- Volatile with low likelihood of retention given contractor-application in commercial trailers exterior to the building, and purging per regulatory standards prior to release to the museum: sulfuryl fluoride (Vikane).
- Volatile inorganic mercury, likely to be present in collections incorporating or having been treated with mercury salts.

In addition, closed storage containers can become repositories for outdoor pollutants, mechanical system treatment chemicals, and cleaning chemicals as well as deterioration of cabinet materials, storage materials, and even the collections themselves (Hawks 1988; Hatchfield 2002; Grzywacz 2006; Gribovich et al. 2013; ASHRAE 2015; Curran and Strlic 2015). The ramifications from all these residues are threefold: collections are potentially at risk of undergoing physical and chemical changes that limit their future utility; humans are at risk of health hazards that range from temporary irritation to potential exposure to carcinogens; and contaminants from the collections or their environment adversely affect facility indoor air quality, generating complaints from building occupants.

The challenge was to plan the most cost-effective way to screen for as many of the likely agents as possible, while being efficient with time and personnel. The sampling goal was to integrate all methods simultaneously and consistently upon opening each tested cabinet.

4. Sampling Methods

Risk to both collections and humans is based on the same principle: identified hazard multiplied by duration/frequency of exposure. In this case, this equates to constant contact in closed storage for collections, and concentration inhaled, absorbed, and/or ingested over time of contact during a typical eight-hour workday for humans. The severity of risk then involves the degree to which the hazardous agent impacts the object/specimen through deterioration or degradation, or human body through trauma or illness. Therefore, the methods for hazard identification in this study must target two different zones of impact: inside closed cabinets and the worker's breathing zone. Each zone required different sampling apparatuses and techniques.

(1) Point source monitoring within storage cabinets. Ambient air sampling for pollutants can be accomplished through *direct-reading* instruments that instantaneously measure agents or a *grab sampling* technique involving air collection in a sample bag, flask, or evacuated canister for subsequent analysis by instrumentation such as gas chromatography (GC), infrared (IR) spectroscopy or mass spectrometry (MS).
(2) Personal exposure monitoring via devices with specific collection media that would be worn by staff accessing treated cabinets. This technique represents typical work exposures by integrating detected concentrations over the time sampled.

4.1 Point Source Monitoring

4.1.1 direct-reading instruments

Some direct-reading instruments, such as photoionization detectors, can analyze multiple agents and are most useful for leak detection or indoor air quality screening where the likely contaminant(s) are known. Readings are compared to ionization potential charts for selected agents. Field-portable GC–MS units or IR gas analyzers are compact enough to be managed on a cart, with samples collected through flexible sampling tubes. They require frequent recalibration in the field and a qualified analytical operator with access to a large GC detector or IR spectral library of various compounds to interpret spectral interferences and unknown peaks (Dietrich 1997; Todd 1997).

Fig. 3. Image of two SUMMA® canisters, similar to those used in this study to carry out testing according to "Compendium Method TO-15 for Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed by Gas Chromatography/ Mass Spectrometry (GC/MS)". Image credit: Con-Test, 2017.

Other direct-reading instruments are agent- or test-gas specific, such as colorimetric detector tubes, electrochemical sensors, or inorganic mercury vapor analyzers. Mercury vapor was expected to be present from both intrinsic (e.g., pigments) and acquired sources, such as treatment with mercury salts as fungicides or pesticides. Mercury vapor was sampled by OSHEM industrial hygienists using a real-time Jerome 431-X Mercury Vapor Analyzer.

4.1.2 grab sampling techniques

A preferred method for identifying a mixed-contaminant air stream, especially with multiple, unknown contaminants, would be an instantaneous grab sample of a known volume of air directly into a specially designed synthetic plastic bag (e.g., Tedlar®, Teflon®) or preevacuated stainless steel canister, for analysis by a qualified laboratory. This type of point sampling technique usually has very low detection limits; the rigid canister also provides non-leaking stability after sampling.

The US Environmental Protection Agency (EPA) Second Edition of the *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air* contains a set of 17 peer-reviewed standardized methods for volatile, semi-volatile, and selected toxic organic pollutants in the air. Industrial hygienists and analytical chemists on this study recommend the "Compendium Method TO-15 for determination of volatile organic compounds (VOCs) in air collected in specially-prepared canisters and analyzed by gas chromatography/mass spectrometry (GC/MS)" (USEPA 1999). The TO-15 Method Analyte List of 62 polar/non-polar VOCs includes those of most concern to this study. The limit of detection is very sensitive, 0.2-25.0 parts per billion by volume (ppb), which is the pollutant range of concern in collection storage.

Air is collected into a leak-free 6 L stainless steel canister, initially evacuated to 0.05 mm Hg (fig. 3). The sampling train is composed of flexible non-absorbent tubing connected to a flow-restrictive inlet, preset by the laboratory to the desired sampling duration. When the canister is opened to the atmosphere, the differential pressure causes the sample to flow into the canister. For this study, each cabinet was opened slightly, and the tubing was moved through the cabinet interior from bottom to top and in between drawers, as consistently as possible to standardize the sample collection methodology. This method always included lower areas where vapors were expected to pool or reside in larger concentrations.

A separately prepared canister was used for each of the six sample sets, as defined in Section 2 of this paper. After each sample set was completed, the canister valve was closed and the canisters were transported to the laboratory for analysis. The analytical strategy for Compendium Method TO-15 involves using a high-resolution GC coupled to a MS to identify and quantitate target compounds. MS is considered a more definitive identification technique than single specific detectors such as flame ionization detector, electron capture detector, photoionization detector, or a multi-detector arrangement of these. The GC-MS approach also reduces the chances for misidentification (USEPA 1999).

4.2 Occupational/Personal Exposure Monitoring

Sampling for employee exposure to gases or vapors involves the use of a device calibrated at a method-specific flow rate to draw air through an adsorbing or absorbing medium, in order to capture the contaminant. When the collecting medium is analyzed, the contaminant concentrations can be averaged over the sample time to obtain the calculated exposure levels. To measure inhalation exposures, as in this study, the sampling device is worn (with the medium clipped on in the "breathing zone", or within a 2-ft. radius around the head) throughout the work task to represent inhaled dose over that time frame (fig. 4). This type of sampling, representative of the entire exposure period in a work day, is necessary because worker exposures may vary in duration and frequency depending on the task. Instantaneous grab or point sampling does not integrate these variables, and thus the results cannot be directly correlated with established time-weighted average occupational exposure standards. Point sampling does, however, indicate presence of a hazard, and can serve as a red flag for further study.

Fig. 4. Detail of an employee wearing a personal exposure sampler, consisting of a pump clipped onto the pants' waistband and the sampling media clipped to the collar, to monitor the air within the employee's "breathing zone."

Personal exposure samplers were worn by (1) collection care staff accessing 1900 cabinets from the Department of Vertebrate Zoology's Division of Birds during pest inspections, routine curation, and specifically for the purposes of this study, and (2) by the staff opening cabinets and conducting TO-15 surveys for this study. Both pest inspection and curation were considered by collection managers as representative of typical cabinet access. All personal exposure samples were collected on agent-specific media via calibrated GilAir high- and low-flow sampling pumps, in accordance with National Institute for Occupational Safety and Health (NIOSH 2003) and Occupational Safety and Health Administration (OSHA 1986) standard industrial hygiene methods, and analyzed by an AIHA accredited laboratory.

Personal samples were collected for certain compounds known to be recently used in vertebrate cabinets, such as naphthalene and PDB as well as ethylene dichloride and carbon tetrachloride that were part of a commercial mixture used pre-1990. The collecting media were activated charcoal (SKC 226-01) tubes, analyzed per NIOSH Method 1003 (Method 1501 for naphthalene). Also monitored were two VOCs that were suspected of being present but not included in the TO-15 Analyte List: ethylene chlorohydrin, a highly toxic chemical formed by the reaction of ethylene oxide (another past fumigant) and objects or specimens treated with or containing chlorinated chemicals. These were collected on Anasorb® 747 sorbent tubes, analyzed per NIOSH Method 2513; and 2,2-dimethyl dichlorovinyl phosphate (dichlorvos/Vapona, used inside cabinets in the past), collected and analyzed on XAD-2/glass fiber filter (OVS) media, per OSHA Method 62 Modified.

5. Results and Discussion

5.1 Mercury Vapor

The measured mercury vapor concentrations in each tested cabinet were less than the instrument's analytical limit of detection of 0.003 milligrams mercury per cubic meter of air (mg/m^3); significantly less than the 0.025 mg/m^3 as an 8-hour time-weighted average (TWA) threshold limit value (TLV) established for elemental inorganic mercury vapor by the American Conference of Governmental Industrial Hygienists (ACGIH 2016).

Mercuric chloride was known to have been used as a pesticide/fungicide on some anthropological collections, and mercury pigments can be found on many ethnographic and archaeological objects (Goldberg 1996; Hawks and Makos 2000; Cross and Odegaard 2009). Mercuric chloride was sometimes injected into vertebrate specimens as a fixative for soft tissues during field preparation of study skins (Williams and Hawks 1987). Mercury salts on cellulose-based materials are also known to readily emit mercury vapor (Hawks and Bell 1999; Hawks et al. 2004).

The non-detected mercury levels within anthropology cabinets in this study may have been caused by the previous removal from these cabinets of many ethnographic materials likely to be sources; also, the archaeological materials did not appear to be heavily pigmented. Previous surface wipe testing by OSHEM in vertebrate zoology collections had confirmed the presence of mercury on collections and in storage cabinets. However, the non-detected ambient levels in this study may suggest that the applied mercury had chemically bonded to cysteine in specimens, thereby preventing volatilization (Edsall and Wyman 1958).

5.2 TO-15 Data

Forty VOC of the possible sixty-two in the TO-15 Compendium Method Analyte List were detected in the cabinets, in parts per billion by volume concentrations (ppb). However, not all of these VOCs were detected in every sample set. Data are presented in Table 1, with the detected results in bold. The highest concentrations detected were acetone (15–79 ppb), ethanol (26–260 ppb), isopropanol (1.5–73 ppb) and pesticide treatments known to have been applied routinely throughout these collections: naphthalene (1.8–35 ppb), PDB (22–350 ppb), and the mixture of carbon tetrachloride (0.09–7.6 ppb) and ethylene dichloride (0.28–110 ppb).

The TO-15 Method can quantify 62 target compounds whose identity can be confirmed against a software library of over 250,000 GC-MS known standards. Chemicals observed in the analysis, but not on the "Target Compound List" are referred to as unknown compounds. When this library is searched for an unknown compound, it can frequently provide a Tentatively Identified Compound (TIC), although the reported concentrations and identity are always an estimate (USEPA 2006). However, we requested the additional TIC results from our analytical laboratory (Table 2) in order to enhance potential future analyses of possible contaminant sources in the storage environments as well as possible future health surveys by industrial hygienists. For instance, it is interesting to note that while aldehydes are not on the TO-15 Target Compound List, "aldehydes" (expected from wood products) were tentatively identified in all cabinets. The TIC uncertainty factor suggests that actual concentrations inside the cabinets could be higher than reported, further justifying the museum's concern over accumulated contaminants.

Data were not significantly different between empty and filled cabinets in any department. It is not clear whether specimens/objects have equilibrated to the cabinet environment or the cabinets themselves have reached a state of stasis in terms of vapor accumulation either inherent (to the cabinet) or acquired from any source. The age of the cabinets and their past uses seem to have had little discernable impact on this finding.

Although ambient point source concentrations cannot directly be compared to established occupational health exposure levels (OELs), it is useful to note that concentrations inside the cabinets were 75 to over 100 times less than their respective OELs (Table 1). The only red flag was the detection of ethylene dibromide in all tested vertebrate zoology cabinets, even those that were empty. Both ethylene dibromide and methyl bromide were reportedly used at NMNH in the past, although written documentation is lacking (Goldberg 1996). Bromide fumigants are listed as one of the required/approved treatments by the US Customs and Border Protection for wood packaging materials entering the country (USCBP 2016) and by the US Department of Agriculture (USDA 2013); it is unknown if these were the sources of this chemical. The concentrations detected (0.061–0.61 ppb) were low as compared with the NIOSH Recommended Exposure Level of 45.0 ppb (NIOSH 2015). However, ethylene dibromide is highly toxic, with a short-term maximum allowable exposure level of 130 ppb. Further exposure monitoring should occur when these cabinets are accessed in the future.

5.3 Personal Exposure Data

Analytical results for the personal samples reported concentrations less than the limit of quantitation (LOQ) (i.e., non-detected in the inhalation breathing zone of the workers) for the six specific chemicals studied (Table 3). Notably, the LOQ data points themselves were less than 10-25% of the chemical agents' respective OELs (including the not-to-be exceeded ceiling concentration for ethylene chlorohydrin). The TO-15 Method did detect PDB, ethylene dichloride, carbon tetrachloride and naphthalene within cabinet interiors (Table 1); however personal sample data

Table 1 Analyte concentrations (ppb by volume) in case interiors measured by USEPA Compendium Method TO-15, compared to THRESHOLD LIMIT VALUES (TLV) and maximum short-term exposure levels. Samples collected 12-20-2012 through 01-04-2013

	Mammals Cases			**Anthropology Cases**				
	45 Empty	4 Filled w/Specially Treated Collections	100 Filled w/Collections	42 Empty	75 Office Storage	250 Filled w/Collections	ACGIH TLV in ppb	Max Short-Term Exposure Level
				≤ Less than analytical detection limit				
Acetone – ◊	68	56	51	15	79	30	200,000	
Benzene + ◊ *	0.32	0.25	0.26	0.2	0.3	0.28	500	2500
Bromomethane (methyl bromide) ◊	0.092	< 0.035	0.054	<0.035	<0.060	<0.060	1000	
2-Butanone (MEK) + –	2.1	2.4	2.5	<1.4	4.3	<2.4	200,000	300,000
Carbon Tetrachloride ◊	7.6	7.1	4.8	0.088	0.2	0.15	5000	10,000
Chloroform * +	0.17	0.13	0.14	0.039	0.39	<0.060	10,000	
Chloromethane (methyl chloride) *	1.7	2.5	1.5	0.56	0.89	0.72	50,000	100,000
Cyclohexane + –	0.11	0.095	0.18	<0.035	1.1	<0.060	100,000	
1,2-Dibromoethane (ethylene dibromide) * ◊	0.6	0.061	0.21	<0.035	<0.060	<0.060	**NIOSH limit:45**	**NIOSH limit:** 130
1,2-Dichlorobenzene (ortho) ◊	0.44	0.21	0.28	0.096	<0.060	0.12	25,000	50,000
1,3-Dichlorobenzene (meta) ◊	0.051	<0.035	<0.035	<0.035	<0.060	<0.060	(Not established)	
1,4-Dichlorobenzene (para) (PDB) ◊	350	120	300	35	22	28	10,000	
Dichlorodifluoromethane (Freon 12) * +	0.36	0.41	0.41	0.42	0.33	0.42	1,000,000	
1,2-Dichloroethane (ethylene dichloride) ◊	110	49	48	0.28	0.92	1.2	10,000	
1,2-Dichloropropane (propylene dichloride) *	0.69	0.48	0.4	<0.035	0.11	<0.060	10,000	
1,4-Dioxane + – ◊	0.094	<0.035	<0.035	<0.035	<0.060	<0.060	20,000	
Ethanol ◊	120	170	260	26	77	28		1,000,000
Ethyl Acetate + – ◊ ▪	1.4	0.61	1.9	0.23	1.1	<0.060	400,000	
Ethylbenzene +	0.18	0.15	0.17	0.06	0.99	0.12	20,000	
4-Ethyltoluene + –	0.055	0.055	0.042	<0.035	0.42	<0.060	(Not established)	
Heptane + ◊	0.42	0.6	0.41	0.1	0.76	0.23	400,000	500,000
2-Hexanone (MBK)	0.5	0.56	0.52	0.11	0.49	0.28	5000	10,000

Continued

Table 1 Continued

	Mammals Cases			Anthropology Cases				
	45 Empty	4 Filled w/Specially Treated Collections	100 Filled w/Collections	42 Empty	75 Office Storage	250 Filled w/Collections	ACGIH TLV in ppb	Max Short-Term Exposure Level
Isopropanol + ◊	8.2	73	14	1.5	41	3.4	200,000	400,000
Methylene Chloride – ◊	0.67	0.47	0.7	<0.35	0.84	0.81	50,000	100,000
4-Methyl-2-pentanone (MIBK) +	0.21	0.11	0.17	0.052	0.47	0.12	20,000	75,000
Naphthalene ◊	35	6.3	13	5.6	4.4	1.8	5000	
Styrene + –	0.14	0.11	0.19	0.051	0.55	0.15	20,000	40,000
Tetrachloroethylene *	0.089	0.11	0.12	<0.035	0.061	0.1	25,000	100,000
Tetrahydrofuran –	0.14	0.12	0.11	0.29	0.66	0.083	50,000	100,000
Toluene + ◊	1.4	1.2	1.2	0.57	6.3	1.3	20,000	
1,2,4-Trichlorobenzene *	0.073	0.15	0.039	<0.070	<0.12	<0.12	5000 Ceiling Limit	
1,1,1-Trichloroethane (methyl chloroform) * –	<0.035	0.041	0.048	<0.035	<0.060	<0.060	350,000	450,000
1,1,2-Trichloroethane –	0.28	0.15	0.18	<0.035	<0.060	<0.060	10,000	
Trichloroethylene ◊	0.12	0.064	0.06	<0.035	<0.060	<0.060	10,000	25,000
Trichlorofluoromethane (Freon 11) * +	0.23	0.23	0.73	0.28	0.3	0.25	(Not established)	
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) * +	0.065	0.072	0.079	0.069	0.078	0.076	1,000,000	
1,2,4-Trimethylbenzene *	0.17	0.18	0.14	0.066	25	0.12	25,000 for mixed isomers	
1,3,5-Trimethylbenzene	0.042	0.045	0.038	<0.035	3.2	<0.060		
m- and p-Xylene + – ◊	0.58	0.46	0.44	0.15	1.6	0.32	100,000 for mixed isomers	
o-Xylene + – ◊	0.2	0.16	0.15	0.057	0.52	0.12		

Possible origins of analytes occurring in storage cabinets
*Outdoor Environment (Windholtz et al. 1983; Lloyd 1997; Hatchfield 2002; TRI-Listed Chemicals 2016).
+Indoor Environment (housekeeping, mechanical system, and/or building construction materials) (Windholtz et al. 1983; Hatchfield 2002; USEPA 2011; Curran and Strlic 2015).
–Storage Materials (housings, supports, office materials (paper, photographs, film), and/or cabinet construction materials) (Windholtz et al. 1983; Nishimura 1995; Hatchfield 2002; Curran and Strlic 2015).
◊Museum-Applied Treatments (preparation, pest mitigation, and/or conservation) (Windholtz et al. 1983; Williams and Hawks 1987; Duckworth et al. 1993; Pool et al. 2005).
•Specimen/Object/Label (Williams and Hawks 1987).

Table 2 Tentatively Identified Compound concentrations (ppb by volume) in case interiors measured by USEPA Compendium Method TO-15. Samples collected 12-20-2012 through 01-04-2013

	Mammals Cases			Anthropology Cases		
	45 Empty	4 Filled w/Specially Treated Collections	100 Filled w/ Collections	42 Empty	75 Office Storage	250 Filled w/ Collections
Acetaldehyde *	7.5	5.9	6.4			
Acetic acid, 1,1-dimethylethyl ester + –	2.3	1	1.4			
Benzene, 1,2,3-trimethyl- +					37	
Benzene, 1,2,4,5-tetramethyl-					32	
Benzene, 1,3-diethyl- +					57	
Benzene, 1-methyl-2-(1-methylethyl)				65		
Benzene, 1-methyl-2-propyl-					53	
Benzene, 1-methyl-3-propyl-					86	
Benzene, 2-ethyl-1,4-dimethyl-					43	
Benzaldehyde +	5.2	4.3	3	0.84		1.6
Butanal * +	1.4	1.8	1.9	0.57		1.3
Butanal, 3-methyl- *			2.8			
Butane * +	1.4	1	1.1	0.76		
1-Butanol * –	1.5	1.4	1.1			
3-Carene + – ◊ ▪	2.2		0.61			
Decane					34	
Ethane, 1,1-difluoro – * ◊		1.4	3.4			
Furan, 2-pentyl- + –	1.4					
Furfural –	2.6	1.3	1.6			
2-Heptanone	1.1	0.97	0.89			
Hexanal	6.8	5.1	4.5	0.97		2.4
1-Hexanol, 2-ethyl-		1.8				
d-Limonene +	4.5	6.5	8.4	1.8		2.6
Nonanal	1.1	1.2				
2-Nonanone +		1.1				
Octanal	1.6	3.1	1.3			
Pentanal	2.9					1.2

Continued

Table 2 Continued

	Mammals Cases			Anthropology Cases		
	45 Empty	4 Filled w/Specially Treated Collections	100 Filled w/ Collections	42 Empty	75 Office Storage	250 Filled w/ Collections
Pentane +	0.85		0.78			
1-Pentanol +	1.1		0.63			
1-Pentene +		0.98				
a-Pinene +	2.6	3	1.2	0.82		2

Possible origins of analytes occurring in storage cabinets

*Outdoor Environment (Committee on Aldehydes and Board on Toxicology and Environmental Health Hazards 1981; TRI-Listed Chemicals 2016).

+Indoor Environment (housekeeping, mechanical system, and/or building construction materials) (Committee on Aldehydes and Board on Toxicology and Environmental Health Hazards 1981; Windholtz et al. 1983; Hatchfield 2002; Rossol 2011).

¯Storage Materials (housings, supports, office materials (paper, photographs, film), and/or cabinet construction materials) (Windholtz et al. 1983; Nishimura 1995; Hatchfield 2002; Curran and Strlic 2015).

◊Museum-Applied Treatments (preparation, pest mitigation, and/or conservation) (Windholtz et al. 1983; Pool et al. 2005).

•Specimen/Object/Label (Windholtz et al. 1983; Williams and Hawks 1987).

Table 3 Personal Exposure Sample Results from Case Access Work Tasks, Compared To THRESHOLD LIMIT VALUES (TLV)

			p-Dichlorobenzene		Ethylene Dichloride		Carbon Tetrachloride		Ethylene Chlorohydrin		DDVP		Naphthalene	
Sample Date	Staff Work Task	Sample + Exposure time (minutes)	ppm Detected	TWA-ppm	ppm Detected	TWA-ppm	ppm Detected	TWA-ppm	ppm Detected	TWA-ppm	mg/m³ Detected	TWA mg/m³	ppm Detected	TWA-ppm
IPM Inspection: Dept. of Vertebrate Zoology, Div of Birds														
11-10-2012	Inspecting skins	189	<LOQ 0.09	<0.035	<LOQ 0.07	<0.028	<LOQ 0.08	<0.030						
11-10-2012	Inspecting skins	361	<LOQ 0.04	<0.030	<LOQ 0.03	<0.026	<LOQ 0.04	<0.030						
16-10-2012	Inspecting skins	440	<LOQ 0.04	<0.037	<LOQ 0.03	<0.028	<LOQ 0.04	<0.037						
16-10-2012	Inspecting skins	205	<LOQ 0.08	<0.034	<LOQ 0.08	<0.034	<LOQ 0.07	<0.030						
05-11-2012	Inspecting skins, skeletons	400	<LOQ 0.04	<0.033	<LOQ 0.03	<0.025	<LOQ 0.04	<0.033						
05-11-2012	Inspecting skins, skeletons	317	<LOQ 0.05	<0.033	<LOQ 0.04	<0.026	<LOQ 0.05	<0.033						
Staff conducting ambient sampling of cases interiors														
20-12-2012	VZ Mammals 4 specially treated cases	65	<LOQ 0.25	<0.034	<LOQ 0.18	<0.024	<LOQ 0.24	<0.033	<LOQ 0.45	<0.061	<LOQ 0.003	<0.0004	<LOQ 0.28	<0.038
20-12-2012	VZ Mammals 3rd floor Collection-filled cases	125	<LOQ 0.13	<0.034	<LOQ 0.10	<0.026	<LOQ 0.12	<0.032	<LOQ 0.24	<0.063	<LOQ 0.001	<0.0003	<LOQ 0.15	<0.039
02-01-2013	Anthropology 3rd floor Main filled cases	120	<LOQ 0.14	<0.035	<LOQ 0.10	<0.025	<LOQ 0.12	<0.030	<LOQ 0.25	<0.063	<LOQ 0.001	<0.0003	<LOQ 0.15	<0.037
American Conference of Governmental Industrial Hygienists (ACGIH-2016) TLV TWA				10.0 ppm		10.0 ppm		5.0 ppm		1.0 ppm Ceiling		0.1 mg/m³		10.0 ppm

TWA = calculated 8-hour time-weighted average based on concentration detected during exposure time; <LOQ = less than the analytical limit of quantitation; mg/m³ = milligrams per cubic meter of air; DDVP (Dichlorvos) = 2,2-Dimethyldichlorovinyl phosphate.

suggests cabinet access work does not pose exposure risk. Ethylene chlorohydrin and DDVP were not part of the TO-15 Analyte List.

Personal samples are meant to represent actual body exposure, as averaged over a total work day, reflecting work task frequency and duration, break times, and control measures taken by the worker to limit exposure. Each staff member sampled was employing museum safe work practices, minimizing time spent in front of open cabinets, and wearing personal protective equipment during all of the tasks surveyed. Therefore, the personal exposure data suggests that using risk control measures can be effective in significantly lowering potential health risk from working with collections and cabinets known to be contaminated with past treatment chemicals. It is important to caution that naphthalene and PDB are reasonably anticipated to be human carcinogens by the US National Toxicology Program (USDHHS 2016); therefore continued vigilance in implementing safe work practice and other exposure control measures is extremely important.

Table 3 reports the data in two columns per chemical: the actual concentration detected, and the 8-hour TWA calculated by multiplying that concentration by the sample time (which were also the actual work/exposure times within the collection on those days) divided by 480 minutes. The non-exposure time during each of those sample days was time confirmed to be spent in offices or other space without potential for contaminant exposure. These TWA concentrations are then compared to the established OELs to standardize the evaluation of potential health risk. The OELs used in this survey were the ACGIH TLVs (2016).

5.4 Potential Sources of Chemicals

Possible sources of these chemicals are not only the specimen/objects and the cabinets themselves but also building systems (e.g., freons), wood/wood product degradation in the building, finishes such as varnishes and paints, deterioration of synthetic polymers, and cleaning compounds used in housekeeping (Hatchfield 2002; Grzywacz 2006, Curran and Strlic 2015). According to the USEPA 2011 compiled source of indoor air studies from 1990 to 2005, the VOCs most commonly detected in indoor air are due to background sources (i.e., naturally occurring, environmental pollutants from man-made materials, or industrial/commercial sources). These include: benzene, toluene, ethylbenzene, xylenes, chlorinated solvents such as chloroform, carbon tetrachloride, tetrachloroethylene, 1,1,1-trichloroethane and trichloroethylene. All these chemicals, also used as collection pesticide treatments, were detected in the TO-15 in-cabinet monitoring in this study, suggesting that indoor background air may have contributed to the data results.

However, a comparison of the personal exposure results from the survey in VZ Mammals 3rd Floor Collection-filled cabinets (Table 3) to corresponding TO-15 data collected at the same time (Table 1, Mammals Cabinets, 100 filled with collections) revealed that both PDB and ethylene dichloride concentrations within the cabinets (0.300 ppm and 0.048 ppm) were higher than the TWA for those two agents on personal samples (less than 0.034 ppm and less than 0.026 ppm respectively). The personal samples would have been capturing these VOCs from both the opened cabinet and the background indoor air in the hallways. This indicates that the source of these two commonly used pesticide treatment chemicals was from the cabinet interiors and not from background air.

Further investigation to more precisely determine whether the primary source of collection storage area contaminants was the cabinet or the VOCs in the general air circulation system could include stationary sampling both in front of opened cabinets and at the return air registers for the space. If the data at the cabinet fronts are significantly greater than at the return air register, then the primary source would be the cabinet as this air is then diluted over distance to the return air duct. Concurrent outdoor air sampling on the roof at air intakes might also provide a background profile; however this data may easily be skewed on any single day by unanticipated and spiked air inversions and adjacent intermittent point sources like chemical exhaust stacks. Environmental pollutant sources are also discussed in Hatchfield (2002), Publicly Accessible Standard 198 (PAS 2012), and ASHRAE (2015).

5.5 Potential Impact on Collections

With the significant exception of methyl bromide, the life safety issues discovered in the monitoring were minimal per current OELs. However, while human health is not permanently impacted in most cases from exposures at very minimal levels in the parts per million (ppm) range, collections have no recuperative powers. As a consequence, contaminants that threaten preservation are best correlated to ppb (Grzywacz 2006; ASHRAE 2015). This suggests that many of the compounds detected in this study could pose risks to collections if they can interfere with either long-term preservation or the research utility of the specimens or objects.

Visual and monitoring evidence suggest that both PDB- and naphthalene-treated specimens retain these chemicals in lipids. The chemicals tend to recrystallize in deposits of unsaturated fats on the surface of bone, recrystallize elsewhere on or in proteinaceous specimens, and appear to increase the mobility of some unsaturated fats. Research suggests that certain fumigants do not negatively impact DNA in the short term (Kigawa et al. 2011), but long-term ramifications of, for example, PDB and naphthalene on material deterioration requires research.

6. Summary

While the Museum knew prior to the study that volatiles would be present, the specific chemicals and their concentrations were unknown. This study was necessary to accomplish that identification. Both industrial hygienists and museum collection staff were needed to determine the types of analyses and the target cabinets. Surprisingly to the team, the personal exposure sampling results did not indicate a significant health risk. The TO-15 point sample results also were significantly lower than established OELs, although concentrations of ethylene dichloride, PDB, and carbon tetrachloride were elevated versus EPA background levels, suggesting the source was within the cabinets.

Overall, the ppb concentrations of all the VOCs identified inside the cabinets were sufficient to raise collection care concerns. The fact that any concentration of these VOCs was detected in permanent storage of collections suggests that there is a potential for long-term impact on collection care (Table 1). This was a driving factor in accelerated decisions for removing and replacing cabinets, knowing that further reduction of any potential health risks would also result.

6.1 Risk Control Decisions

The stakeholders, each slightly biased toward their department's goals, met to discuss the implications of the results upon their individual program needs. This was a benefit not a hindrance to the entire decision-making process. The group agreed on collaborative balance from the outset.

The data suggested that even empty wooden cabinets retain or off-gas a significant number of chemicals, some highly toxic. The industrial hygienist on the team argued that while the calculated exposure risk from these chemicals appears to be low, and safe work practices are designed to further protect staff, further mitigation of unnecessary hazard sources is both legally and ethically prudent. The museum safety manager noted that empty cabinets still retained contaminant odors which, regardless of low concentrations, resulted in employee indoor air quality complaints. He also stated that excess storage of empty wood cabinets without fire-retardant treatments increased the museum's fire-hazard load. Both the museum's hazardous waste coordinator and facility manager noted that flaking lead-based paint from the wood-core cabinets posed an environmental problem, a hazardous waste disposal expense, and necessitated special floor cleaning precautions by a specially trained labor crew. The greatest impact of the study's results was the need to effectively revise the Museum's cabinet replacement plan, a major part of its collection care program, in light of quantitative data, as well as update the Smithsonian Safety Manual to provide further guidance on collection-based hazards and disposal of collection storage cabinets with hazardous material components (Smithsonian Institution 2016).

The team agreed that the condition of all the objects and specimens involved in this study could be negatively impacted by the number and concentrations of the chemicals detected in the cabinet interiors. Rehousing collections into metal cabinets tailored to specific object or specimen types would alleviate many of these concerns. Up to this point, cabinet replacement sequencing generally was planned together with the museum's building renovation schedule, unless there was a distinctly imperative reason to do otherwise. Anthropology and vertebrate zoology collections were particularly impacted by this plan, as their departmental areas were not scheduled for building renovation and new storage environments for many years. The museum re-prioritized its cabinet replacement sequencing, and these departments obtained funding to expedite collection rehousing in newer and more appropriate storage cabinets off-site at the Smithsonian's Museum Support Center or onsite at the main NMNH building on the National Mall. Facility managers agreed to develop new material handling plans to meet the needs of this expedited additional cabinet disposal and replacement.

The study underscored the need to rid the museum of wood-framed cabinets in current use for any reason and rehouse collections into appropriately designed metal cabinets. In intervening years, cost-benefit analyses have led the administration to consistently increase annual funding for cabinet replacement. Additionally, the prioritized cabinet replacement plan has made the NMNH more competitive for in-house Smithsonian grant opportunities, such as the Collections Care and Preservation Fund administered by the National Collections Program.

Although not an ideal collections storage space due to environmental and security controls, the corridor around the fourth floor of the Rotunda of the Mall building have served in this capacity as the collections grew larger than could be accommodated in collection storage areas. The Assistant Director for Building Operations informed relevant departments that all old cabinets would be removed from these areas, which resulted in the rehousing of those collections into more appropriate cabinets and locations.

It is financially and logistically impractical to replace several thousand old cabinets at once. Even with expedited and re-prioritized cabinet replacement schedules, various interim engineering or barrier control options are necessary for minimizing risks to collections stored in lower priority wooden cabinets. The nature of the building as a storage facility is fraught with the challenges of many historic buildings. The size of the building is insufficient for the scope of the collection, which has resulted in storage overflow into corridors and other locations with less-than-ideal environmental conditions and security protocols.

Pollutant scavenger techniques are not currently used in the old cabinets, but testing of a potentially useful product is underway through a technology transfer program with the National Aeronautics and Space Administration as a possible interim solution for instances in which cabinet replacement is expected to take several years.

6.2 Hazard Communication and Safe Work Practices

The data suggest that occupational exposures were low to non-detectable for routine collection care tasks involving cabinet access. Collection managers could relay these results to staff, allaying concerns, while also using the study as a means to iterate the museum's continued commitment to safe work practices, per the Smithsonian Institution Safety and Health Program policy (SD 419) (Smithsonian Institution 2006). Staff exposures should always be controlled through a continuing health management program. The full team of stakeholders had an active part in funding, implementing, training, and promoting the additional safety efforts as a measure of prudent practice.

Each department has ready access to a HEPA-filtered vacuum to be used to clean drawers or cabinet interiors if evidence exists for residual hazardous particulates. Collection managers now plan resource-saving ways to include HEPA-vacuum use during other curation, pest management, or survey tasks. An OSHEM Occupational Health Nurse assisted the museum conservator to develop hazard warning signage, which the Collections Program funded for printing and placement throughout all departments (fig. 5). In addition, disposable nitrile glove stations were also provided through this funding in all collection storage areas. Each department was reminded to update and provide hazard communication training and fact sheets on the possible hazards of collections and storage furniture to staff, interns, new employees, contractors, docents, and visiting researchers (OSHA 2016a). Best practice training also includes instruction to minimize the time spent directly in front of an open cabinet, particularly if in doubt about chemical residues.

Fig. 5. Example of improved hazard communication signs within collection storage ranges and new glove stations to encourage their use.

7. Conclusion

Those who care for collections are responsible for ensuring the utility of these resources for present and future generations. Past treatments, detritus from building materials or old storage materials, pollutants from ambient building environments, and inherent hazards in collections result in residues that can pose risks to those handling collections as well as to the long-term utility of the collection for research, exhibition, or other uses (Goldberg 1996; Hawks 2001; Makos 2001; Pool 2004; Odegaard et al. 2006; Cross and Odegaard 2009; Simmons 2011).

Providing a safe environment for staff, researchers, and visitors, as well as collections is critical and a universal responsibility across museum disciplines. However, identifying where collections, human health, and safety risks intersect can be challenging (Hawks and Waller 2012). Indeed, an instance where a staff member discovers a collection-based hazard can valuably inform health and safety protocols. Conversely, a question raised in a museum related to potential health concerns can have an impact on collection care initiatives. Gathering stakeholders from various backgrounds and specialties from the outset is critical for identification of all risks associated with a particular scenario.

Successfully integrating health and safety evaluations into collections care protocols involves assistance from varied disciplines, such as industrial hygiene, occupational safety, health physics, fire protection, occupational medicine and environmental science. Resources directed at managing risk to workers can (with good planning) be consistent with the cost and effort expended toward managing risk to the collections (Hawks et al. 2011).

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Appendix

Environmental, Safety, and Health Technical Resources

- In North America, art galleries, natural science museums, or historical parks managed by governmental agencies, such as the US Department of Interior or the Smithsonian Institution, will have risk management staff.
- Collecting departments and on-site museums affiliated with an academic institution (e.g., state universities) will have access to health and safety staff for monitoring, controls, and training.
- Public health and safety regulatory agencies in countries around the world also offer complete program development and worker training resources: US Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH), the Canadian Centre for Occupational Health and Safety, and the UK Health and Safety Executive. Some services may be available at little or no cost, such as local fire departments and county environmental protection offices.
- Facilities in the US may qualify for free OSHA (2016b) On-Site Consultation assistance for program development, exposure sampling, and training. These resources should be consulted before beginning work with unfamiliar materials and conditions.

Professional organizations world-wide, with technical information and listings for consultants, experts and clinicians, include:

International Network of Safety and Health Practitioner Organizations www.inshpo.org/index.php

Occupational Safety
American Society of Safety Engineers. www.asse.org/
US National Safety Council. www.nsc.org/
UK Institution of Occupational Safety and Health. http://iosh.co.uk/
Board of Canadian Registered Safety Professionals. www.bcrsp.ca/

Fire Protection
National Fire Protection Association. www.nfpa.org/
Society of Fire Protection Engineers. www.sfpe.org/

Industrial/Occupational Hygiene
American Industrial Hygiene Association. www.aiha.org/
International Occupational Hygiene Association. www.ohlearning.com/
Canadian Registration Board of Occupational Hygienists. www.crboh.ca/

Radiation Safety
Health Physics Society www.hps.org/

Occupational Medicine Clinics and Practitioners
American College of Occupational and Environmental Medicine. www.acoem.org/
Association of Occupational and Environmental Clinics. www.aoec.org/

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Sources of Materials

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Résumé - Les armoires fermées de rangement des collections recueillent les gaz toxiques émis soit par les objets, par les matériaux de construction du mobilier de réserve lors de leur dégradation, et/ou par les autres matériaux utilisés dans les réserves, particulièrement les produits du bois et de nombreux plastiques. Le remplacement des armoires a été l'un des aspects majeurs du programme de préservation des collections au Musée national d'histoire naturelle au Smithsonian Institution. Au fur et à mesure que les budgets le permettaient, le musée avait entrepris le remplacement de plus de 5000 armoires de rangement désuètes, avec structure intérieure et tiroirs en bois. Elles avaient contenu (jusqu'à leur remplacement pour certaines) des collections anthropologiques, zoologiques (des vertébrés), ainsi que des papiers, livres et matériaux photographiques. Il était certain que le mobilier, comme son contenu, récent ou ancien, avait reçu de nombreux traitements aux pesticides, et on présumait que ceux-ci avaient été adsorbés ou absorbés par les matériaux constituant l'intérieur des armoires. Afin de comprendre le risque et de mieux organiser l'ordre de remplacement des vieilles armoires, l'administration du musée a demandé l'avis d'experts de la santé au travail, pour qu'ils analysent à la fois l'environnement intérieur des armoires et les risques pour la santé de quiconque les utilisait. Quarante substances chimiques organiques volatiles ont ainsi été détectées en parties par milliard (ppm), suivant les règles de l'USEPA TO-15 Compendium Method (méthode de recueil TO-15 de l'Agence américaine de protection de l'environnement). Ces données, ainsi que celles tirées des dispositifs de contrôle d'exposition pour les employés, demeuraient beaucoup moins élevées que les niveaux recommandés dans le cadre professionnel, indiquant que le travail en contact ou à proximité de ces armoires présentait un risque faible pour la santé. En revanche, la composition des produits chimiques identifiés présentait des risques pour les collections elles-mêmes, dans le cas d'un rangement prolongé dans ces armoires. Les résultats de cette étude ont permis de prioriser le remplacement des armoires dans le cadre de la mission de préservation à long terme des collections du musée. Traduit par Claire Cuyaubère et Bruno Pouliot.

Resumo -Os armários de armazenamento fechados tornam-se o repositório para vapores perigosos emitidos pelas colecções, pela deterioração dos materiais de construção dos mesmos e/ou pelos materiais de armazenamento da colecção, especialmente, produtos de madeira e muitos plásticos. A substituição dos armários tem sido um dos factores mais importantes do Programa de Manutenção das Colecções do Smithsonian´s National Museum of Natural History (NMNH). O museu tinha assinalado que restavam mais de 5.000 antigos armários de armazenamento com

o interior em molduras de madeira e gavetas de madeira para arrumação ou para excedentes no caso de o financiamento o permitir. Esses armários armazenaram ou continuaram a armazenar colecções antropológicas e zoológicas bem como papéis, livros e materiais fotográficos. Os armários e os seus conteúdos, passados ou presentes, são conhecidos por terem sido expostos a vários tratamentos com pesticidas, muitos dos quais foram assumidos como tendo sido adsorvidos ou absorvidos pelos materiais no interior daqueles. Com o propósito de compreender o risco e de optimizar a substituição faseada dos antigos armários, a administração do museu procurou a experiência de especialistas em segurança ambiental para analisar tanto o ambiente interior dos armários como os riscos para a saúde de quem tivesse acesso aos mesmos. Quarenta produtos químicos orgânicos voláteis foram detectados em partes por bilhão (ppb) dentro dos armários, usando o USEPA TO- 15 Compendium Method. Tanto estes dados como a monitorização dos dados de exposição pessoal eram significativamente inferiores aos respectivos «Níveis de Exposição Ocupacional», o que sugere que o risco para a saúde humana era baixa em relação ao acesso a estes armários. No entanto, os produtos químicos identificados sugerem um risco para as próprias coleções pelo uso contínuo dos armários. Com base nos resultados deste estudo, o museu pode priorizar armários para substituir mantendo os objectivos do Programa de Manutenção das Colecções. Traduzido por Teresa Lança.
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Resumen - Los gabinetes de almacenamientos cerrados se convierten en el repositorio de vapores peligrosos emitidos por las colecciones, deteriorando los materiales de construcción de las cajas, y/o los materiales de almacenamiento de las colecciones, especialmente los productos de madera y muchos plásticos. El reemplazo de los gabinetes ha sido un factor importante en el programa de cuidado de colecciones del Museo Smithsonian de Historia Natural (NMNH). El museo ha identificado más de 5,000 gabinetes de almacenamiento viejos con estructura interior y gavetas de madera para desechar o identificar como excedente, dependiendo de la disponibilidad de fondos. Estos mobiliarios han almacenado o continúan almacenando colecciones de antropología y zoología de vertebrados, así como también papeles, libros y materiales fotográficos. Es sabido que estos mobiliarios y sus contenidos en el pasado y en el presente, han sido sometidos a varios tratamientos con pesticidas, muchos de los cuales se presume se han adsorbido en, o han sido absorbidos por los materiales interiores de los gabinetes. Para entender el riesgo y escalonar de la mejor manera un reemplazo de los gabinetes viejos, la administración del museo buscó a expertos en seguridad ambiental para analizar tanto el ambiente interior de los gabinetes como los riesgos de salud por exposición de cualquier persona que acceda a los gabinetes. Cuarenta químicos orgánicos volátiles fueron detectados en partes por billón (ppb) dentro de los gabinetes usando el Método de Compendio USEPA TO-15. Estos datos y los del monitoreo de exposición personal, fueron significativamente menores que los respectivos Niveles de Exposición Ocupacional, sugiriendo que el riesgo a la salud humana al acceder a los gabinetes era bajo. Sin embargo, los químicos identificados sugirieron un riesgo a las colecciones mismas por el uso continuo de los gabinetes. Basado en los resultados de este estudio, el museo pudo establecer prioridades para el reemplazo de los gabinetes y así mismo fomentar los objetivos de cuidado de colecciones. Traducido por Hilda Abreu de Utermolhen, revisado por María Esteva y Amparo Rueda.