

# *Unintended Consequences of Persistent Residual Vapor-phase Chemicals within Collection Storage.*

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# Study Summary

- 39 volatile and semi-volatile organic compounds detected inside several hundred collection storage cabinets
- Sampled using evacuated canisters via USEPA TO-15 Method; analysis by GC/MS
- Empty and filled cases
- Various treatment histories
- Anthropology objects, vertebrate zoology specimens, photographs & other collection documentation, and periodicals



Screening survey for human health and collection health implications of lingering vapor-phase chemicals

US Environmental Protection Agency Method TO-15 for monitoring, via specially-prepared evacuated canisters and analysis by gas chromatography/mass spectrometry, detected thirty-nine ambient volatile/semi-volatile organic compounds inside several hundred collection storage cabinets at the National Museum of Natural History. Both empty and filled cases, with different treatment histories were selected, representing anthropology objects, vertebrate zoology specimens, photographs and other collection documentation, and periodicals. All concentrations detected were in the parts per billion (ppb) range. Possible sources include both past treatment chemicals and structural/atmospheric agents: pesticides/fumigants; preparation chemicals, preservatives (ethanol, benzene, chlorinated degreasers); wood degradation; varnishes and paints; housekeeping chemicals; and HVAC systems (Freon).

# Historic Treatments

Pesticides/fumigants & other treatments used since at least the 18<sup>th</sup> C

Retained by specimen tissues, lipids.  
Damages proteins, specimen integrity



Easily ad/absorbed into wood, paper-based supplies, metal/glass



Particularly problematic for a museum with ~6,000 old cabinets with interior wood framing & drawers

Numerous treatments have been used to prepare and preserve collections, and to protect against pests. Persistent residual vapor-phase chemicals, accumulating over time in closed cases, pose often unintended adverse effects, not only on the objects and specimens, and their users, but on the storage furniture itself. Organic chemicals penetrate and **absorb** into wooden storage furniture and paper-based storage supplies, and **adsorb** on metal, glass, and other non-absorptive materials. Many are easily retained by specimen tissues and lipids. This is particularly problematic when dealing with nearly 6,000 old cabinets with interior wood framing and wooden drawers.

# Legacies of Historic Treatments

Residual Organic Vapor-phase Chemicals Detected  
Inside Storage Cabinets

Study Conducted at the National Museum of Natural  
History, Washington DC

This survey was conducted out of concern for both human health and collection health implications of lingering vapor-phase chemicals inside storage cabinets, particularly those with wood components. We sought to find out whether empty cabinets themselves can produce vapor phase contaminants long after initial treatments.

# Chemical Retention in Cabinet Wood

## Study to determine

ID of organic vapors within cases housing treated collections

*Assess risk implications to health and collections*

Determine possible sources for mitigation options

*Prioritize/expedite case replacement*



The National Museum of Natural History conducted an environmental sampling study to:

1. detect and identify concentrations of organic vapors from the interior of old cabinets with wood framing and drawers that were known to have housed treated specimens and objects,
2. assess the risk implications for humans and collections from persistent residues, and
3. develop efficient mitigation plans.

# Past-Use Chemical Agents

- **JAIC 35(1996):23-43** Extensive literature and oral history review. L. Goldberg, “A history of pest control measures in the anthropology collections, National Museum of Natural History, Smithsonian Institution”
- Past treatment records, where available

The basis for the compounds to be studied was the extensive literature and oral history review published in JAIC 35(1996):23-43, L. Goldberg, “A history of pest control measures in the anthropology collections, National Museum of Natural History, Smithsonian Institution,” along with any other known treatment histories.

# Survey Methodology

Likely to persist; detected by USEPA TO-15 Method	Highly or semi-volatile; unlikely to be detected by TO-15; possible “Tentatively Identified”
Carbolic acid (phenol)	Dimethyl formamide
Naphthalene	Ethylene oxide (ETO) Highly Volatile
PDB	(Ethylene chlorohydrin: Possible reaction product between ETO & halide treated organic specimens) Highly Toxic; Highly Volatile
Ethylene dichloride	Thymol
Carbon tetrachloride	Dichlorvos, DDVP
Ethylene dibromide	Camphor
Methyl bromide	Benzene hexachlorides
Carbon disulphide	Pentachlorophenol

An external analytical laboratory, after considering our long list of possible pollutants, recommended the US EPA’s TO-15 Method for ambient source sampling, which targets 60+ volatile organic compounds. The TO-15 method will capture the volatiles of most concern, that is, those most likely to have **ad** or **absorbed** onto/into the wood, other storage materials, and specimens or objects.

# Survey Methodology

## **Mercury vapor**

- Expected to be present through all collections

## **NOT included in this study**

- Non-volatile particulates (arsenic, DDT, sulphur)
- Extremely high volatiles (ethylene dioxide, dimethyl formamide) unlikely to have persisted or purged for clearance by contracted applicator (Vikane)

Mercury vapor was expected to be present throughout a wide variety of collections/cabinets from both intrinsic (e.g., pigments) and acquired sources, such as treatment with mercury salts as fungicides or pesticides.

Heavy-metal (arsenic, lead) or non-volatile (DDT, sulphur) particulates were not the focus of this survey, as exposure to and removal of these substances can be controlled through HEPA-vacuuming, and the use of barrier gloves and lab coats as needed.

Also excluded were extremely high volatiles (ethylene dioxide, dimethyl formamide, Vikane) which were unlikely to have persisted or would have been purged for clearance by contracted applicators.

# Survey Methodology

## EPA TO-15 Method

- Specially prepared evacuated canisters w/flow regulators. Ambient sample collected
- GC/MS
- 60+ target VOC compounds



## Jerome Mercury Vapor Analyzer

- Real-time measurements collected at same time as canister ambient samples



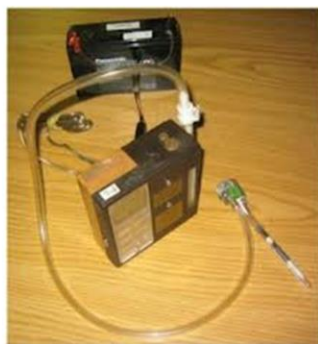
Concentrations of volatile organic compounds (VOCs) were collected in specially-prepared evacuated canisters, then analyzed by gas chromatography/mass spectrometry (GC/MS) in accordance with the USEPA compendium method TO-15. This method addresses the VOCs included in the hazardous air pollutants list of the Title III, Clean Air Act.

Inorganic mercury was sampled with a real-time Jerome Mercury Vapor Analyzer.

# Survey Methodology: Personal Exposure

## Industrial hygiene validated methodology

- Calibrated pumps; sampling media, worn on collar “breathing zone”
- Captures dose exposure over duration of work tasks



## Chemicals sampled on collections staff and survey staff

- P-dichlorobenzene
- Naphthalene
- Ethylene dichloride
- Carbon tetrachloride
- Ethylene chlorohydrin
- DDVP (dichlorvos)

Reasoning: Above were used extensively at NMNH and residuals are persistent

The TO-15 is a screening survey for chemical vapors. The results may imply a health hazard but cannot be directly compared to health standards for personal exposure levels. However, the results can act as a flag for follow-up occupational sampling should high-hazard compounds be detected, especially in significant concentrations.

Consequently, occupational exposure samples were collected on persons doing collections work as well as those accessing cases for the study itself.

For personal monitoring we focused on commonly used pesticides such as paradichlorobenzene (which had been used up to the last few years as part of the museum’s pest management program), naphthalene, and components of “Dowfume” (ethylene dichloride and carbon tetrachloride) which had been applied extensively pre-1990 through soaked cotton wads in metal holders inside the case doors.

We also sampled for dichlorvos and ethylene chlorohydrin (a highly toxic chemical formed by the reaction of ethylene oxide with specimens or objects that contain halides), because they were not expected to be detected by TO-15.

All personal exposure samples were collected in accordance with NIOSH and standard industrial hygiene scientific methodologies, and analyzed by an American Industrial Hygiene Association accredited laboratory.

# Survey Methodology: Sites for Testing

## Empty cases, previously filled

- 100 Anthropology
- 45 Mammals\*
- 75 Anthropology cases now filled with non-collection books and papers

\* *Routine Dowfume (>20 yrs ago), PDB until recently*

## Currently filled cases

- 250 Anthropology (basketry, textiles, clothing, photographs, archaeological objects)
- 100 Mammals specimens\*
- 4 Mammals cases\* restricted due to old specimens w/heavy pest treatments and grease-saturated bones; closed for a decade

The museum identified several collection groups of both empty and specimen/object-filled cases that represented pesticide and other treatment histories. T0-15 sampling in both empty and filled cases in the same collection grouping would indicate if the source of chemicals detected was solely the collection items or were contaminants retained and re-emitted by the storage furniture. The cases selected were presumed not to have been opened recently (in some situations, closed for years) and would be representative of accumulated interior concentrations.

# Survey Results: Mercury Vapor Subset

***NO mercury vapor detected in any cabinet tested with Jerome Mercury Vapor Monitor***

- 55 cases of mammal skins, mounts
- 100 cases of Anthropological objects
- 50 empty cases (past Anthro object housing)

55 cases of mammals, 100 cases of anthropological objects, and 50 empty cases that had previously held anthropological materials were sampled for mercury vapor and none was detected.

# Survey Results: TO-15

- 39 volatile organic compounds were detected (parts per billion range) within 574 cabinets sampled
  - Data **not** significantly different between empty or filled cases
  - Concentrations were orders of magnitude less than the established occupational exposure limits, with a red flag of concern re: bromides

39 volatile organic compounds were detected in the parts per billion range, shown in red in the following charts. Data were not significantly different among empty and filled cabinets. Concentrations were orders of magnitude less than the established occupational exposure limits.

# Survey Results: TO-15

Analyte	Mammals			Anthropology			ACGIH TLV ppb
	empty	special	filled	empty	NonCol	filled	
<b>Acetone</b>	<b>68</b>	<b>56</b>	<b>51</b>	<b>15</b>	<b>79</b>	<b>30</b>	<b>200,000</b>
<b>Benzene</b>	<b>0.32</b>	<b>0.25</b>	<b>0.26</b>	<b>0.2</b>	<b>0.3</b>	<b>0.28</b>	<b>500</b>
<i>Benzyl chloride</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>Bromodichloromethane</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>Bromoform</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>Bromomethane (ethyl bromide)</b>	<b>0.092</b>	<0.035	<b>0.054</b>	<0.035	<0.060	<0.060	<b>5000</b>
<i>1,3-Butadiene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>2-Butanone (MEK)</b>	<b>2.1</b>	<b>2.4</b>	<b>2.5</b>	<1.4	<b>4.3</b>	<2.4	<b>200,000</b>
<i>Carbon Disulfide</i>	<0.35	<0.35	<0.35	<0.35	<0.60	<0.60	
<b>Carbon Tetrachloride</b>	<b>7.6</b>	<b>7.1</b>	<b>4.8</b>	<b>0.088</b>	<b>0.2</b>	<b>0.15</b>	<b>5000</b>
<i>Chlorobenzene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>Chloroethane</i>	<0.035	<0.035	0.098	<0.035	<0.060	<0.060	
<b>Chloroform</b>	<b>0.17</b>	<b>0.13</b>	<b>0.14</b>	<b>0.039</b>	<b>0.39</b>	<0.060	<b>10,000</b>

As we go through the slides, note that there appears to be very little difference between the detected concentrations in empty cases versus filled, in any collecting unit. This would suggest the case itself is a significant source of, or sink for, VOCs.

# Survey Results: TO-15

Analyte	Mammals			Anthropology			ACGIH TLV ppb
	empty	special	filled	empty	NonCol	filled	
<b>Chloromethane (methyl chloride)</b>	<b>1.7</b>	<b>2.5</b>	<b>1.5</b>	<b>0.56</b>	<b>0.89</b>	<b>0.72</b>	<b>50,000</b>
<b>Cyclohexane</b>	<b>0.11</b>	<b>0.095</b>	<b>0.18</b>	<0.035	<b>1.1</b>	<0.060	<b>100,000</b>
<i>Dibromochloromethane</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>1,2-Dibromoethane (ethylene dibromide)</b>	<b>0.6</b>	<b>0.061</b>	<b>0.21</b>	<0.035	<0.060	<0.060	<b>45</b>
<b>1,2-Dichlorobenzene (ortho)</b>	<b>0.44</b>	<b>0.21</b>	<b>0.28</b>	<b>0.096</b>	<0.060	<b>0.12</b>	<b>25,000</b>
<b>1,3-Dichlorobenzene (meta)</b>	<b>0.051</b>	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>1,4-Dichlorobenzene (para)</b>	<b>350</b>	<b>120</b>	<b>300</b>	<b>35</b>	<b>22</b>	<b>28</b>	<b>10,000</b>
<b>Dichlorodifluoromethane (Freon 12)</b>	<b>0.36</b>	<b>0.41</b>	<b>0.41</b>	<b>0.42</b>	<b>0.33</b>	<b>0.42</b>	<b>1,000,000</b>
<i>1,1-Dichloroethane</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>1,2-Dichloroethane (ethylene dichloride)</b>	<b>110</b>	<b>49</b>	<b>48</b>	<b>0.28</b>	<b>0.92</b>	<b>1.2</b>	<b>10,000</b>
<i>1,1-Dichloroethylene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>cis-1,2-Dichloroethylene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>trans-1,2-Dichloroethylene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	

The concentrations detected were compared against the Occupational Exposure Limits established by the American Conference of Governmental Industrial Hygienists to determine if any high hazard compounds should be studied further.

Detected concentrations inside the cases were generally over 100 times less, often 1000 times less, than their respective Threshold Limit Values, suggesting a low probability of adverse exposure to staff accessing the cases.

One red flag potential exposure might come from highly toxic ethylene dibromide for which more personal exposure monitoring should be conducted in the future.

# Survey Results: TO-15

Analyte	Mammals			Anthropology			ACGIH TLV ppb
	empty	special	filled	empty	NonCol	filled	
<b>1,2-Dichloropropane (propylene dichloride)</b>	<b>0.69</b>	<b>0.48</b>	<b>0.4</b>	<0.035	<b>0.11</b>	<0.060	<b>10,000</b>
<i>cis-1,3-Dichloropropene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>trans-1,3-Dichloropropene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>1,4-Dioxane</b>	<b>0.094</b>	<0.035	<0.035	<0.035	<0.060	<0.060	<b>20,000</b>
<b>Ethanol</b>	<b>120</b>	<b>170</b>	<b>260</b>	<b>26</b>	<b>77</b>	<b>28</b>	
<b>Ethyl Acetate</b>	<b>1.4</b>	<b>0.61</b>	<b>1.9</b>	<b>0.23</b>	<b>1.1</b>	<0.060	<b>400,000</b>
<b>Ethylbenzene</b>	<b>0.18</b>	<b>0.15</b>	<b>0.17</b>	<b>0.06</b>	<b>0.99</b>	<b>0.12</b>	<b>20,000</b>
<b>4-Ethyltoluene</b>	<b>0.055</b>	<b>0.055</b>	<b>0.042</b>	<0.035	<b>0.42</b>	<0.060	
<b>Heptane</b>	<b>0.42</b>	<b>0.6</b>	<b>0.41</b>	<b>0.1</b>	<b>0.76</b>	<b>0.23</b>	<b>400,000</b>
<i>Hexachlorobutadiene</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<i>Hexane</i>	<1.4	<1.4	<1.4	<1.4	<2.4	<2.4	
<b>2-Hexanone (MBK)</b>	<b>0.5</b>	<b>0.56</b>	<b>0.52</b>	<b>0.11</b>	<b>0.49</b>	<b>0.28</b>	<b>5000</b>

These show the range and levels of compounds detected in the survey. Note that all are in ranges considered safe for people, although perhaps not necessarily safe for collections.

# Survey Results: TO-15

Analyte	Mammals			Anthropology			ACGIH TLV ppb
	empty	special	filled	empty	NonCol	filled	
<b>Isopropanol</b>	<b>8.2</b>	<b>73</b>	<b>14</b>	<b>1.5</b>	<b>41</b>	<b>3.4</b>	<b>200,000</b>
<i>Methyl tert-Butyl Ether (MTBE)</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>Methylene Chloride</b>	<b>0.67</b>	<b>0.47</b>	<b>0.7</b>	<0.35	<b>0.84</b>	<b>0.81</b>	<b>50,000</b>
<b>4-Methyl-2-pentanone (MIBK)</b>	<b>0.21</b>	<b>0.11</b>	<b>0.17</b>	<b>0.052</b>	<b>0.47</b>	<b>0.12</b>	<b>20,000</b>
<b>Naphthalene</b>	<b>35</b>	<b>6.3</b>	<b>13</b>	<b>5.6</b>	<b>4.4</b>	<b>1.8</b>	<b>5000</b>
<i>Propene</i>	<1.4	<1.4	<1.4	<1.4	<2.4	<2.4	
<b>Styrene</b>	<b>0.14</b>	<b>0.11</b>	<b>0.19</b>	<b>0.051</b>	<b>0.55</b>	<b>0.15</b>	<b>20,000</b>
<i>1,1,2,2-Tetrachloroethane</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>Tetrachloroethylene</b>	<b>0.089</b>	<b>0.11</b>	<b>0.12</b>	<0.035	<b>0.061</b>	<b>0.1</b>	<b>25,000</b>
<b>Tetrahydrofuran</b>	<b>0.14</b>	<b>0.12</b>	<b>0.11</b>	<b>0.29</b>	<b>0.66</b>	<b>0.083</b>	<b>50,000</b>
<b>Toluene</b>	<b>1.4</b>	<b>1.2</b>	<b>1.2</b>	<b>0.57</b>	<b>6.3</b>	<b>1.3</b>	<b>20,000</b>
<b>1,2,4-Trichlorobenzene</b>	<b>0.073</b>	<b>0.15</b>	<b>0.039</b>	<0.070	<0.12	<0.12	
<b>1,1,1-Trichloroethane (methyl chloroform)</b>	<0.035	<b>0.041</b>	<b>0.048</b>	<0.035	<0.060	<0.060	<b>350,000</b>

# Survey Results: TO-15

Analyte	Mammals			Anthropology			ACGIH TLV ppb
	empty	special	filled	empty	NonCol	filled	
<b>1,1,2-Trichloroethane</b>	<b>0.28</b>	<b>0.15</b>	<b>0.18</b>	<0.035	<0.060	<0.060	<b>10,000</b>
<b>Trichloroethylene</b>	<b>0.12</b>	<b>0.064</b>	<b>0.06</b>	<0.035	<0.060	<0.060	<b>10,000</b>
<b>Trichlorofluoromethane (Freon 11)</b>	<b>0.23</b>	<b>0.23</b>	<b>0.73</b>	<b>0.28</b>	<b>0.3</b>	<b>0.25</b>	
<b>1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)</b>	<b>0.065</b>	<b>0.072</b>	<b>0.079</b>	<b>0.069</b>	<b>0.078</b>	<b>0.076</b>	<b>1,000,000</b>
<b>1,2,4-Trimethylbenzene</b>	<b>0.17</b>	<b>0.18</b>	<b>0.14</b>	<b>0.066</b>	<b>25</b>	<b>0.12</b>	<b>25,000</b>
<b>1,3,5-Trimethylbenzene</b>	<b>0.042</b>	<b>0.045</b>	<b>0.038</b>	<0.035	<b>3.2</b>	<0.060	
<i>Vinyl Acetate</i>	<0.070	<0.070	<0.070	<0.070	<0.12	<0.12	
<i>Vinyl Chloride</i>	<0.035	<0.035	<0.035	<0.035	<0.060	<0.060	
<b>m&amp;p-Xylene</b>	<b>0.58</b>	<b>0.46</b>	<b>0.44</b>	<b>0.15</b>	<b>1.6</b>	<b>0.32</b>	
<b>o-Xylene</b>	<b>0.2</b>	<b>0.16</b>	<b>0.15</b>	<b>0.057</b>	<b>0.52</b>	<b>0.12</b>	<b>100,000</b>

Note that Freon is highlighted in green. The Freon is from HVAC equipment used in controlling the general museum environment.

# Survey Results: Personal Exposure

- All personal exposure samples on staff were non-detectable (below laboratory limit of quantitation) for five specific chemicals studied

Range of Detected Concentrations (ppm) – Collections Staff		
PDB	Ethylene Dichloride	Carbon Tetrachloride
<LOQ 0.04 – 0.09	<LOQ 0.03 – 0.08	<LOQ 0.04 – 0.08
<i>ACGIH Threshold Limit Value as an 8-hr time weighted average</i>		
<i>10.0 ppm</i>	<i>10.0 ppm</i>	<i>5.0 ppm</i>

In addition to the low concentrations detected by the TO-15 method, personal breathing zone samples from the collections and survey staff indicated that concentrations were all non-detectable (below the reporting limits) for the chemicals considered likely to have been used extensively in the past.

# Survey Results: Personal Exposure

Range of Detected Concentrations (ppm) – Survey Staff					
PDB	Ethylene Dichloride	Carbon Tet	Naphthalene	Ethylene Chlorohydrin	DDVP (mg/M3)
<LOQ 0.13-0.25	<LOQ 0.10-0.18	<LOQ 0.12-0.24	<LOQ 0.15-0.28	<LOQ 0.24-0.45	<LOQ 0.001-0.003
<i>ACGIH Threshold Limit Value as an 8-hr time weighted average</i>					
<i>10.0 ppm</i>	<i>10.0 ppm</i>	<i>5.0 ppm</i>	<i>5.0 ppm</i>	<i>1.0 ppm ceiling max</i>	<i>0.10 mg/M3</i>

# Discussion: Detected Chemicals

- No significant difference between concentrations detected in empty vs filled cabinets.
- Wood-framed cases = sink for ad/absorbed residual organics
  - ▣ Difficult to remediate
  - ▣ Continued interior off-gassing hazard to collection and staff
- **Cannot distinguish if primary source was the cabinet or object/specimen**
- No concurrent outdoor sampling; data may include atmospheric or building general ventilation chemicals

There was no significant difference between concentrations detected in empty vs filled cabinets.

Wood-framed cases appear to be a sink for ad/absorbed residual organics

The study data, as collected, cannot distinguish if the primary source was the cabinet or object/specimen

There was no concurrent outdoor sampling; so data may include atmospheric or building general ventilation chemicals.

# Source Analysis Needed

- *Which are environmental or facilities maintenance chemicals?*
  - **Freon**
- *Case construction materials?*
  - TO15 cannot detect acids, aldehydes, peroxides from wood degradation
  - Varnishes, paints, thinners, solvents
- *Or are these mostly from treatments (retained in specimens/objects and transmitted to cabinets)?*
  - Pesticides, fumigants,
  - Preparation and post-preparation treatment chemicals (ethanol, benzene from gasoline, chlorinated degreasers, carrier solvents)
  - Byproducts of halogenated and aromatic hydrocarbons

A conservation science analysis of the detected chemicals may ascertain the most likely sources in order to inform mitigation actions. Some of the chemicals are clearly outdoor environmental pollutants or HVAC additives which may not be easy to control. Some are from the wood itself. And of course most are undoubtedly from legacy pest treatments. Because the data did not show significant difference between empty and filled cases, it is reasonable to assume that disposal of old cabinets and storage supplies is preferable to re-use of these items.

# Current Treatment Consequences

## Collateral Damage: Examples from p-Dichlorobenzene & Naphthalene

A current example of continuing contamination of both collections and storage furniture and supplies is the use of PDB and naphthalene.

# Risks

- Human health (potential carcinogens)
- Integrity of specimens/objects (possible alterations)
- Budget (resources, staff time for cleaning)



The use of these chemicals continues, largely because of their widespread availability in this country. These pesticides re-crystallize on collections and storage equipment, resulting in a continual vapor equilibration and potential inhalation exposure upon case opening. Their use also necessitates extensive cleanup from the treatments.

# Risks – Human Health

## p-(1,4,)-Dichlorobenzene

- “Reasonably anticipated to be a carcinogen”  
*National Toxicology Program 2011*
- Eye/skin irritant
- Renal toxicity

## Naphthalene

- “Reasonably anticipated to be a carcinogen”  
*National Toxicology Program 2011*
- Eye/respiratory irritant
- Ocular toxicity
- Blood dyscrasia (hemolytic anemia, hemoglobinuria)
- Systemic poisoning from dermal absorption

Both PDB and naphthalene are reasonably anticipated to be human carcinogens by the National Toxicology Program. While there are other health consequences of exposure, this is certainly the most critical concern.

# Impact on Collections

- PDB/naphthalene retention in lipids
- Recrystallization in unsaturated fats
- Help move unsaturated fats to the surface



Visual evidence suggests 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.

# Impact on Collections

- Possible damage to proteins & other specimen/object materials from chlorinated organic chemicals
- *Research suggests that certain fumigants do not negatively impact DNA in short-term; however...*
- Long-term ramifications of PDB and naphthalene on material deterioration require research



Chlorinated organic chemicals (e.g., PDB) may damage proteins & other specimen/object materials. *Research suggests that certain fumigants do not negatively impact DNA in short-term; however...* Long-term ramifications of PDB and naphthalene on material deterioration require research that is not yet available.

# Impact on Storage Materials



- Cases retain in/on interiors
- Tightly adhered insect carcasses, in lipids solubilized via pesticide response
- Removal of residual organics, insect frass in sticky residues:
  - Labor-intensive cleaning or
  - Costly disposal of contaminated drawers

Treated cases also retain PDB and naphthalene in or on the case interiors. Wood and other cellulosic materials appear to **adsorb** and **absorb** these chemicals, with subsequent recrystallization. Glass, painted and unpainted metals also show recrystallization and in instances where painted surfaces are white, also show accumulations of tightly adhered insect carcasses that appear to have resulted from fats solubilized from the insects in response to the pesticides. These are likely to be present on other surfaces exposed to these chemicals (for instance, unpainted wood or other dark materials), but are difficult to see against anything other than a white background. Removal of these residues is costly in terms of staff time and other resources, when effective at all.

# Risk Control Recommendations

## Responsible and sustainable collection care practices

Storage improvement programs

Sound Integrated Pest  
Management (IPM)

Safe work practices

Hazard remediation measures

Responsible and sustainable collection care practices include a risk reduction and storage improvement program to mitigate the hazards of residual chemicals as well as sound Integrated Pest Management (IPM) and safe work practices.

# Storage Improvement

- Budget toward accelerated disposal of contaminated cases
- Use metal shelving or bookcases for non-collection items
- No re-use of contaminated cabinets
- Rehouse in all metal cabinets (may reduce pollutant loading from retention AND wood degradation)
- Re-house treated specimens in new cabinets, concurrently with chemical mitigation efforts on the collections themselves
- Segregate housing of non-treated objects from treated.

Institutions should budget resources toward disposal of contaminated cabinets. Empty wooden cases should be disposed of properly and not re-used. This survey demonstrated that empty wood cases retain or off-gas significant numbers of chemicals, some toxic, and the only ethical action is to not re-use these for other purposes.

Rehousing collections into clean metal cabinets tailored to specific object or specimen types removes a sink of retained organic chemicals which, even at extremely low concentrations, pose risks, including potential damage, to collections in storage.

It is important to explore mitigation efforts concurrent with rehousing, such as the use of pollutant scavengers to reduce contaminants from treated collections housed in new cabinets, and where possible, to segregate non-treated objects from treated ones to prevent cross-contamination.

# Integrated Pest Management

- Inspection & monitoring
- Removal of residues of past infestations
- Use of treatments only when essential
- Low-impact, low-toxicity treatment measures
- No use of highly toxic organic pesticides on specimens/objects

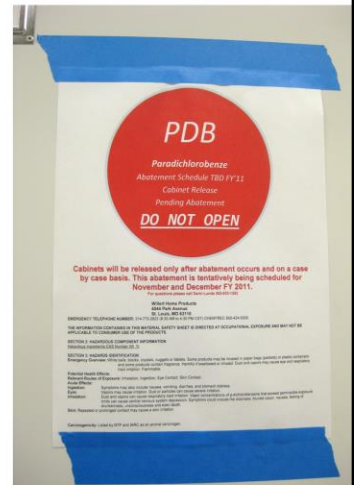
There should be strict adherence by all to a museum integrated pest management (IPM) program that would prevent or significantly reduce infestations from occurring.

Treatments for infestations should comply with regulations and rely on least-toxic-to-humans pesticides, or focus on non-toxic methods of eradication. **As a caveat**, use of heat treatments for any material known or suspected of having been treated with long-lived organic chemicals should be avoided unless adequate capture filtration can be provided for the vapor generated during treatment.

These steps can preclude the need for extremely potent chemicals that leave lingering safety risks.

# Safe Work Practices

- Warnings, access restrictions, Hazard Communication
- Appropriate gloves while handling contaminated materials
- Minimize time spent “browsing” in front of open cabinets - move drawer/object to well-ventilated study area
- HEPA-filtered vacuums to remove residual particulates from case interiors & drawers



A management-endorsed safety plan for preventing adverse human exposure to legacy chemicals also reflects good collection care practice. Staff exposures should be controlled through:

Warning labels and safety instructions, affixed to previously treated cases, alerting users to the possible presence of residual treatment chemicals

Staff training in safe work practices for handling contaminated storage materials and objects/specimens

Removal of specimens of interest for research to a cart or table, in a well-ventilated area

Each collecting unit should have ready-access to a HEPA-filtered vacuum cleaner to be used to clean drawers or case interiors if evidence exists for residual toxic particulates.

# Remediation Research

- New remediation methods that utilize filtration capture
- Cleaning methods that remove some reservoirs of contaminants, e.g, unsaturated fats
- Scavengers inside cabinets
  - ▣ Limited reduction for absorbed pesticides, but would reduce accumulated vapor concentrations
  - ▣ Costly change-out schedules; staff time constraints

Finally, there must be a call for scientifically validated remediation methods, to mitigate the hazards of residual vapor-phase organic chemicals from collections and storage furniture. The health of both our collections and our colleagues depends on this.

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Collections Program, and the Departments of Anthropology & Vertebrate Zoology, National Museum of Natural History