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POLLUTANTS IN THE MUSEUM ENVIRONMENT – MINIMIZING DAMAGE IN STORAGE AND DISPLAY

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ABSTRACT

Natural history collections contain the wide spectrum of materials found in most encyclopedic collections. The growing field of preventive conservation addresses the many sensitivities of all kinds of materials found in collections to the environmental agents to which they are exposed over their lifetimes in storage and display. Although mineralogical collections may seem to have little in common with taxidermy, caretakers of these collections require practical, useful information about how to extend the lifetimes of these materials. This paper presents an overview of how and why materials in museum collections may deteriorate, and provides strategies and solutions for minimizing deterioration on display and in storage.

Keywords: Natural history collections, preventive conservation, deterioration, display, storage

RESUMO [in Portuguese]

As colecções de história natural contêm um largo espectro de materiais encontrado na maioria das colecções enciclopédicas. O campo crescente da conservação preventiva aborda as várias sensibilidades de todo o tipo de materiais encontrados em colecções e os agentes ambientais a que estão expostos durante o tempo que passam amazenadas ou em exposição. Embora as colecções mineralógica pareçam ter pouco em comum com a taxidermia, os curadores destas colecções necessitam de informação útil e prática sobre como extender o tempo de vida destes materiais. Este artigo apresenta uma visão global de como e por que os materiais em colecções de museus podem deteriorar-se, providencia estratégias e soluções para minimizar a deterioração na exposição e em reserva.


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INTRODUCTION

To those working in cultural institutions, the extent to which environmental factors determine the health and longevity of collection materials is no longer a surprise. In the 1920s, Alfred Lucas, an analytical chemist working with archeologists in Egypt noted the effects of changing environments on the objects he excavated with archeologists like Howard Carter (Lucas, 1924: 45). Pliny, writing in the first century AD noted the corrosion of lead caused by vapors from roof timbers (in Rackham, 1968). Damage from soot, sulfur dioxide and acids seen on paintings and shell collections was documented as early as the 19th century (Eastlake et al., 1850; Kenyon, 1897). By 1971, the first review of damage from volatile pollutants in storage cabinets on collection objects had been published (FitzHugh and Gettens, 1971). Over time, chemical interactions between the materials of cultural heritage and light, heat (or cold), moisture (or lack of it), and pollutants have played a significant role in the deterioration of collections. This paper focuses on pollutants and their effects on collections: how they interact with materials, and how to mitigate these effects as we make choices about handling, exhibition, storage and packing of the collections in our care. Although sometimes vastly different in scale, paleontological materials, natural history collections, fine art and architecture alike share similar sensitivities to pollutants and will benefit from an informed use of stable, inert materials used in their environments. The presence of pollutants in storage or exhibition cases, together with other factors like high relative humidity causes the formation of unusual organic corrosion products on metals (sodium copper acetate on bronze, for example), the alteration of mineral specimens due to inappropriate relative humidity levels, the presence of sulfur or acids (Waller, 1999), the formation of calcium acetate on shells, also known as Byne's disease, calcilacte (calcium acetate dichloride hydrate) on limestone (Van Tassell, 1945; FitzHugh and Gettens, 1971). One particularly dramatic example of irreversible alteration occurred a number of years ago in Verona. The Museo Civico di Storia Naturale in Verona is known for its spectacular collection of marine fossils from Bolca quarry, as well as prehistoric lithic artifacts. In 2008, parts of the collections were moved from their original locations to a newly restored, decommissioned military Arsenal, intended to serve as the permanent site for the archeological section of the museum. The lithic artifacts, including flints, were reorganized and stored in newly prepared cabinets. Soon after the rehousing, an odd and very distinctly blue color was observed on some of the flints (Abbot, 2010, figure 1). This strange phenomenon created a furor in the national and international news, resulting in a petition to the Italian Minister of Culture to identify the source of the problem, assign blame and provide punitive action for “severe chemical contamination of archaeological material, causing irreversible alteration to the archaeological materials with enormous loss of scientific information and to the National Patrimony” (Drahl, 2010: 32-33). In 2010, samples analyzed at the University of Padua found that the surfaces showed pervasive contamination by various hydrocarbons and plasticizers such as phthalates and BHT (butylated hydroxytoluene; Drah, 2010). Traces of these substances were also found on bones and ceramics stored there, but no color alteration was visible. Most of the time, a dramatic, clearly visible alteration is not evident. However, mechanical and chemical alterations may have taken place unnoticed, and lead to accelerated deterioration of collection materials.

Although work is still ongoing, chemists and geoarcheologists have identified three new pigment molecules by HPLC, which they called Romeo Blue, Juliet Blue, and Flint Blue. They belong to the triphenylmethane dye family, an old class of synthetic colorants related to brom cresol green, the pH indicator. The additive was identified as an antioxidant: 2,2,4-trimethyl-1,2-dihydroquinoline. HPLC identified the three pigments. The color change was traced to an antioxidant added to the synthetic rubber mats used in the armory storage cabinets, which somehow desorbed from the mats to the tools and trimerized to form the blue contaminants (Tapparo et al., 2011). Were it not for the color change of some of the flints, contamination of the archeological objects would probably have escaped detection in the absence of thorough scientific analyses. According to Laura Longo, the former curator of Verona’s Natural History Museum, the adsorbed organic compounds could bias important analytical results such as those conducted on Neanderthal DNA (Lalueza-Fox, 2007), especially those obtained with techniques probing extremely low amount of material (Drah, 2010). Clearly we need to be extraordinarily careful about the materials used in proximity to collection objects, and to understand their history when undertaking preservation activities and analysis.
POLLUTANTS

A pollutant may be defined as an impurity in the environment, derived either from natural or man-made sources. Pollutants are agents of deterioration that have the potential to interact with materials of art in damaging ways. They are reactive chemical compounds, which may be, in a gaseous, liquid or solid state. Liquids may be also vapor based, or in aerosol form. Semi-volatile pollutants such as plasticizers also pose risks. Pollutants are generated in the exterior environment, either from natural, biological sources, or by man-made, industrial processes and activities. The most common pollutants in the environment include sulfurous compounds, nitrogen oxides, ozone, ammonia, formaldehyde and acidic compounds. Some of these species may be damaging on their own, or after interacting with atmospheric moisture to become acids or other harmful species.

Externally generated pollutants range widely outdoors. For example, hydrogen sulfide levels may measure as high as 5000 parts per trillion (ppt) (7.03 µg/m³) in urban areas, but as low as 50 ppt in remote areas. Between 1900 and 1970, nitrogen oxide emissions increased by an alarming 690%, clearly related to industrialization. Since 1970, most emissions have decreased by about 40%, initially due to the oil shortages of the 1970s, and increasing awareness about health and other dangers of air pollution (Gradael et al., 1981, cited in Hatchfield, 2002).

In interior spaces, construction materials, furnishings and combustion activities such as burning fuel for heating generate most pollutants, and they often build up to very high levels in enclosed areas, being unable to dissipate. Sometimes, collection objects themselves generate substances such as sulfur that are harmful to other specimens or other objects. For this reason, it is
critical to understand the chemical nature of materials found in the collection, in addition to understanding housing materials and the museum environment. Furthermore, many gases considered stable under normal circumstances react readily in the presence of certain chemical species such as free radicals that may be created in photochemical reactions. Light will enhance degradation processes for many materials. For example, the degradation of leather in the presence of sulfur dioxide can produce the phenomenon of red rot (see also Rae, this volume).

It is also important to consider the potential for damage by particulates, or dust. Typically hygroscopic and usually abrasive, they act as nucleation sites for corrosion on metals, or chemical interactions on other materials. They are generated in the exterior environment by biological processes such as combustion, microorganisms and decay, and non-biological elements like salts, vehicular traffic and construction (Table 1). Indoors, they are produced by combustion processes such as cooking or heating, construction processes, soiling and textiles (Table 2). New materials brought into collection environments, either for construction or storage housings contribute significantly to the overall quality of air in the building. Building materials like wood products, insulation, wall coverings, paints, floor finishes or ceiling tiles can be significant sources of pollutants, especially when large surface areas are involved. The volatile organic content (VOC) of many construction materials may be extremely high. VOCs in construction materials have high vapor pressures and will continue releasing chemicals, attempting to come into equilibrium with their concentration in the surrounding air.

More than 900 VOCs have been identified in indoor environments, 250 of them at greater than 1 parts per billion (ppb). As an example, consider that silver tarnishes at 0.2 ppb hydrogen sulfide. In a typical museum environment, hydrogen sulfide is typically found at higher levels than this, and in some exhibition cases has been measured at as high as 50 ppb. Many other examples of alteration of collection specimens like limestone, metals, organics and synthetic materials have been documented (Hatchfield, 2002: 32-42). In addition to the collection objects, construction and preparation materials brought in to house objects must be carefully considered. Particularly with old display or storage cases and historic exhibits such as dioramas, construction materials are likely to be a source of pollutants. These may include wood products, oil paints, plant fibers, plastics, oil-based clays, waxes, and many materials used in taxidermy.

Testing for pollutants

Testing for pollutants is often done at the building level. Information about the environment within the building is particularly valuable to compare to the exterior, and also to the pollutant levels within display cases. These comparisons can help identify the locations, if not the sources of problematic pollutant species (Grzywacz, 2006). Rather than requiring sophisticated equipment, some companies offer

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**Table 1: Outdoor sources of pollution**

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen oxides</td>
<td>Combustion (diesel, coal) and industrial production; agricultural fertilizers; lightning; smog increased 17% since the U.S. Clean Air Act of 1970</td>
</tr>
<tr>
<td>Sulfur oxides</td>
<td>Combustion, energy and industrial production; paper plants; refineries</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>Bioeffluents, combustion</td>
</tr>
<tr>
<td>Carbonyl sulfide</td>
<td>Biochemical sources, geochemical processes</td>
</tr>
<tr>
<td>Ozone</td>
<td>Light, high temperatures</td>
</tr>
<tr>
<td>Particulates</td>
<td>Combustion, road salt, organic matter</td>
</tr>
<tr>
<td>Ammonia/alkaline aerosol</td>
<td>Microbial activity, fertilizers</td>
</tr>
</tbody>
</table>

**Table 2: Indoor sources of pollution**

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen oxides</td>
<td>Fuel combustion; cellulose nitrate degradation</td>
</tr>
<tr>
<td>Sulfur oxides</td>
<td>Acidic materials from manufacturing processes</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>Construction materials, wood, rubber, paints</td>
</tr>
<tr>
<td>Carbonyl sulfide</td>
<td>None</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>Construction materials, especially wood products, adhesives, sealants</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Construction materials, surface finishes, paints, adhesives, coatings</td>
</tr>
<tr>
<td>Formic acid</td>
<td>Oxidation of formaldehyde, paints coatings</td>
</tr>
<tr>
<td>Ozone</td>
<td>Photocopyriters, printers, particle filters</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Alkyd paints</td>
</tr>
<tr>
<td>Particulates</td>
<td>Combustion, heating, carpeting, HVAC, copiers, concrete, plaster</td>
</tr>
<tr>
<td>Ammonia, alkaline aerosol</td>
<td>Cleaning agents, paints</td>
</tr>
</tbody>
</table>

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Hatchfield, 2014: MINIMIZING DAMAGE IN STORAGE AND DISPLAY
environmental testing methods involving the exposure of metal coupons which are sent back to the company for evaluation (www.purafile.com/products/monitoring/air_quality.aspx). Other simple environmental tests may be done with a minimum of expense or equipment (Hatchfield, 2002: 46-47).

TESTING MATERIALS

The idea of testing every product considered for use may be overwhelming, but it is possible to gain considerable insight into the nature of materials by reviewing their product literature and Material Safety Data Sheet (MSDS) or Safety Data Sheet (SDS). These sheets contain information about the physical characteristics, behavior and health risks of products (for example, flammability, reactivity, toxicology and spill procedures). It is important to keep in mind that the information relates primarily to health and safety, not to interactions with materials. For example, many materials giving off acidic vapors might not be considered a health risk, but might very well damage sensitive materials. Nevertheless, examination of the product literature and SDS will reveal information allowing identification of certain classes of materials known to be problematic, such as alkyd resin paints or plasticized polyvinyl chloride. Even in cases where the MSDS indicates a safe material, products must be tested to be certain harmful compounds are not present.

The damaging effects of pollutants may be caused by volatile compounds such as acidic gases, semi-volatile compounds such as plasticizers, or non-volatile components such as fire retardants in fabrics, which may only pose problems through direct contact with objects or specimens. A range of spot tests are simple to conduct; however, these typically test for very specific compounds such as sulfur, chlorine, cellulose nitrate or acetate (Hatchfield, 2002: 45-54). The benefit to these tests is that results are immediately obtained. A more generalized test done in many museums today is an accelerated aging test known as the modified "Oddy Test", requiring exposure of cleaned, degreased coupons of lead, copper and silver with individual samples under specific conditions at elevated temperature and relative humidity for 28 days. These coupons are compared visually to a control set of metals which were exposed under identical conditions, but without the test material in question (Thickett and Lee, 2004). These tests are typically done without the metals in direct contact with test materials; however, direct contact testing between materials and coupons is often conducted in addition to determine that direct physical contact between artifacts and construction materials will not be problematic.

Choosing materials for proximity to collections

Although few materials considered for use in collection environments are truly inert, the term is commonly used to refer to materials with low VOC content, high stability and longevity, and low risk of reactivity. Wood, of course, is one of the most common construction products found in collection construction. Some woods are extremely acidic and have been known to reduce sensitive specimens to dust. Oak, for example, is one of the most acidic woods available, but acid is released from many woods, in varying quantities over time, and depending on many variables including time of year the wood was cut, where in the trunk the wood is harvested, drying and preparation procedures and length of storage prior to use. Published pH levels of woods vary greatly and do not necessarily relate to volatile acidity (Hatchfield, 2002: 67-70). Once combined with adhesives and additives in processed wood products such as particleboard or plywood, acidity may also vary depending on the nature of those additives. In general though, wood products intended for exterior use tend to be more stable and have lower volatile components from adhesive content. Some products marketed as “formaldehyde free” will still evolve significant acid and other compounds, because wood particles and adhesives are still present.

In areas where good air exchange exists, such as open gallery space, the use of such wood products is less problematic than in enclosed areas such as storage or display. Although commercially available coating materials seem an attractive choice to solve the problem of pollutant outgassing from wood products, there is no commercial product available that will prevent the evolution of acids and other pollutants from wood. Products developed for sealing wood are intended to protect the wood itself, not necessarily to prevent evolution of volatile material. Numerous possibilities exist, however, to prevent pollutants from emanating inside exhibition cases. A solid vapor barrier such as an aluminized film can be heat sealed on to all wood surfaces exposed to the interior of the case. Non-wood products such as acrylic, glass, polyvinyl ethylene or aluminum-faced construction panels can be used in place of wood. Fabrics, gaskets, mounting materials,
caulking and all other materials inside exhibition cases should be carefully considered before use. Some very brief guidelines are included here, in addition to a general guide for choosing case materials.

GENERAL GUIDELINES

Exhibition cases should be tightly constructed to reduce dust infiltration and the effects of humidity fluctuation on collections and also so microclimates differing from ambient conditions may be created where necessary. Use inert or low reactivity materials whenever possible. These include glass, acrylic sheeting, metal, and powder-coated metal. Minimize the use of wood products in exhibition case interiors. When wood must be used in a display area, it should be completely sealed with a vapor barrier such as the aluminum laminate Marvelseal® or Moistop® to prevent the emanation of pollutants from wood products. All sections of the case accessible to the display area must be sealed with Marvelseal® if wood products are used.

List of currently acceptable materials follow (Tables 3-11). Although certain classes of materials can be recommended for use, materials should always be tested, because product formulations can change without notice. Where microclimates are required, compartments should be built beneath the deck areas to house conservation materials such as silica gel. Access to those compartments should be provided from the case exterior so vitrines and displays are not disturbed. These compartments should be lined with an aluminum laminate such as Marvelseal®. Decks should be pierced with holes or gaps provided around the edges in order to allow air circulation between conservation material compartment and the vitrine area.

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>Powder-coated metals</td>
<td>Baked enamel metals</td>
</tr>
<tr>
<td>Metals including anodized aluminum, stainless steel, (although some can catalyze reactions with pollutants) <em>Note: rust inhibitor coatings on steel may contain sulfur.</em></td>
<td>Some woods and wood products including the following: Poplar, lauan.</td>
<td>Most other woods and wood products including the following: Oak - high volatile acidity Fir and birch plywood - moderate acidity and should not be considered.</td>
</tr>
<tr>
<td>Wood when completely wrapped with aluminum sheeting or aluminum-polyethylene laminates such as Marvelseal®</td>
<td>Medite II®</td>
<td>Medite</td>
</tr>
<tr>
<td>High-pressure phenolic laminates such as Formica</td>
<td>Medex®, a formaldehyde-free particleboard is considered safer than other particleboards, but still contain volatile acids.</td>
<td>Particleboards and chipboards (contain higher quantities of adhesives and more surface area of wood fiber than plywood and are generally more acidic than plywood).</td>
</tr>
<tr>
<td>Aluminum laminates such as Alucobond® or Dibond®</td>
<td>Use only plywood with exterior, &quot;type one&quot; (waterproof, usually phenol-formaldehyde) adhesive for pedestals. Medium density overlay (MDO) or high density overlay (HDO) are exterior plywoods made for signs and construction with a paper surface. These may be used if poplar or lauan are not available.</td>
<td>Plywoods with interior grade glues, depending on the adhesive used.</td>
</tr>
<tr>
<td>Tycore® (neutral pH paper honeycomb board)</td>
<td>Upson board is a pressed cardboard type product which is inherently acidic but seems to have low volatile acidity.</td>
<td>Tempered masonite (contain volatile products)</td>
</tr>
<tr>
<td>Ethafoam® 900</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Acceptability of construction materials
Table 4: Acceptability of support materials

<table>
<thead>
<tr>
<th>ACCEPTABLE</th>
<th>LESS STABLE</th>
<th>UNSUITABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tycore® (neutral pH paper honeycomb board)</td>
<td>Acid-free foam core products</td>
<td>Most other foam core products</td>
</tr>
<tr>
<td>Coroplast® (fluted polyethylene/polypropylene)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archival corrugated cardboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethafoam®</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Construction and support materials (Tables 3, 4)**

In general, metal and glass are materials that can be safely used in enclosures with specimens and artifacts. Wood and wood products are less stable and are likely to off gas acids and pollutants. However, if wood must be used in a display area, it should be coated with an approved water-borne polyurethane or sealed completely with aluminum sheeting or an aluminum laminate (Marvelseal®).

**Plastics**

A list of acceptable plastics is given in Table 5.

**Adhesives (Table 6)**

Adhesives should be water-based or solvated acrylics. Avoid the use of rubber based, polyurethane, or formaldehyde-based adhesives with the exception of phenolic adhesives for plywood.

**Gaskets, caulking, padding and tubing (Table 7)**

Gaskets and tubing should be made from silicone (neutral cure, the type made without acetic acid), polyethylene, polypropylene or Teflon. Test adhesive-backed types before use. Do not use polyvinyl chloride (PVC) products such as Tygon® tubing. These can evolve hydrochloric acid, and plasticizers may migrate from them. Rubber based products require testing before use. If silicone caulk is used, it should be neutral cure (without acetic acid), often specified for electrical applications.

**Coatings, stains, paints and varnishes (Table 8)**

Avoid the use of products containing oils or alkyd resins, including oil stains, oil-modified polyurethanes and oil paints. Some moisture-borne polyurethanes are safer for use. A minimum of three coats should be applied, and surfaces must be aired for at least three weeks before installing works of art. Acrylic paints can be used over sealed case interiors, but also should be allowed sufficient airing time before installation (at least three weeks).

**Fabrics (Table 9)**

Cotton or linen fabrics are often acceptable, but require testing before use. Surface treatments may contain formaldehyde or other volatile substances potentially damaging to works of art. Fire retardants can be extremely corrosive and should be avoided. Some dyes, particularly darker colors, may contain sulfur or acidic components. Wool and silk should not be used.

**Paper products**

A list of acceptable paper products is given in Table 10.

**Other materials**

A list of other acceptable materials is given in Table 11.
Table 5: Acceptability of plastics

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teflon®</td>
<td>Cellulose acetate</td>
<td>Cellulose nitrate</td>
</tr>
<tr>
<td>Polyethylene</td>
<td></td>
<td>Polyurethane foams (ester better than ether, but both unsuitable for long-term proximity)</td>
</tr>
<tr>
<td>Tyvek® spunbonded polyethylene non-corona treated, soft drape (wash first)</td>
<td></td>
<td>Polyvinyl chloride (PVC)</td>
</tr>
<tr>
<td>Polypropylene</td>
<td></td>
<td>Any highly plasticized or chlorinated plastic</td>
</tr>
<tr>
<td>Polyethylene terephthalate (MylarD®)</td>
<td></td>
<td>Sulfur vulcanized rubber</td>
</tr>
<tr>
<td>Acrylics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polystyrene (not a vapor-barrier)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polycarbonate (not a vapor-barrier)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Acceptability of adhesives

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic adhesives (pressure-sensitive not in direct contact)</td>
<td>Some hot melt adhesives based on ethylene vinyl acetate</td>
<td>Urea-formaldehyde</td>
</tr>
<tr>
<td>Some hot melt adhesives based on polyethylene/polypropylene</td>
<td>Polyvinyl acetate-based caulk</td>
<td>Animal glue (sulfur)</td>
</tr>
<tr>
<td>Acrylic emulsion or dispersion adhesives</td>
<td>EPDM</td>
<td>Polyvinyl acetate (PVA or PVAc) emulsion adhesive</td>
</tr>
<tr>
<td>Acrylic caulk</td>
<td></td>
<td>Pressure-sensitive adhesives (contact)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rubber cement</td>
</tr>
</tbody>
</table>

Table 7: Acceptability of caulking and gasketing materials

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral cure silicone caulk</td>
<td>Ethylene-propylene-diene monomer (EPDM - note that some are vulcanized with sulfur)</td>
<td>Sulfur-containing rubber</td>
</tr>
<tr>
<td>Polyethylene foam</td>
<td></td>
<td>Polyurethane</td>
</tr>
<tr>
<td>Silicone foam (extruded)</td>
<td></td>
<td>Oil-based glazing compounds</td>
</tr>
<tr>
<td>Teflon®</td>
<td></td>
<td>Polyvinyl acetate-based caulk</td>
</tr>
<tr>
<td>Acrylic caulk</td>
<td></td>
<td>Tygon® tubing (PVC)</td>
</tr>
</tbody>
</table>

Table 8: Acceptability of coatings, stains, paints and varnishes

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic paints</td>
<td>Shellac (prolonged solvent retention)</td>
<td>Oil-based paints and coatings</td>
</tr>
<tr>
<td>Some water borne polyurethanes</td>
<td>Some polyurethane resins</td>
<td>Alkyd resin paints</td>
</tr>
<tr>
<td></td>
<td>Polyvinyl acetate (PVA or PVAc) emulsion paints</td>
<td>Urea resin</td>
</tr>
</tbody>
</table>
### Table 9: Acceptability of fabrics

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undyed, unbleached cotton or linen</td>
<td>Silk (always test first)</td>
<td>Wool</td>
</tr>
<tr>
<td>fabrics (after washing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some polyesters (always test first)</td>
<td>Fabrics containing sulfur-based dyes</td>
<td></td>
</tr>
<tr>
<td>Hollytex® or Reemay® spunbonded</td>
<td>Fabrics finished with formaldehyde</td>
<td></td>
</tr>
<tr>
<td>polyester</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 10: Acceptability of paper products

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid-free (neutral pH) paper products</td>
<td>Buffered papers – avoid use with</td>
<td>Glassine</td>
</tr>
<tr>
<td></td>
<td>photographic materials or naturally</td>
<td></td>
</tr>
<tr>
<td></td>
<td>acidic materials</td>
<td></td>
</tr>
<tr>
<td>Neutral pH tissue paper</td>
<td></td>
<td>Common tissue paper</td>
</tr>
<tr>
<td>Microchamber paper products</td>
<td></td>
<td>Kraft paper</td>
</tr>
</tbody>
</table>

### Table 11: Acceptability of other materials

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Less Stable</th>
<th>Unsuitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum laminate vapor-barrier</td>
<td>Fire retardants (if not direct contact);</td>
<td>Pesticides, fungicides</td>
</tr>
<tr>
<td>sheeting (e.g. Marvelseal®)</td>
<td>are non-volatile but toxic</td>
<td></td>
</tr>
<tr>
<td>Pacific Silvercloth® (for sulfur</td>
<td></td>
<td>Fire retardants (direct contact); can</td>
</tr>
<tr>
<td>scavenging)</td>
<td></td>
<td>be corrosive</td>
</tr>
<tr>
<td>Corrosion Intercept® (for pollutant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>scavenging)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CONCLUSION

Although the scale may be vastly different, paleontological collections, natural history and fine art collections remain remarkably similar in their sensitivity to environmental agents of deterioration. Particularly when housed in enclosed environments, these substances can accumulate at high levels. While some damage to collections caused by pollutants emanating from display or storage materials may be quite apparent, as in the color alteration of the blue flints in Verona, it may also accelerate aging processes, resulting in increased embrittlement or more subtle color changes. A thorough understanding of the composition of construction and storage materials will allow safe choices to be made in their selection, minimizing damage to collections.

### REFERENCES CITED


Lalueza-Fox, C., H. Römpler, D. Caramelli, C. Stäubert, G. Catalano, D. Hughes,


Additional images and material can be downloaded at http://www.jpaleontologicaltechniques.org/