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REVIEW

SUSTAINABLE USE OF COATINGS IN MUSEUMS AND ARCHIVES – SOME CRITICAL OBSERVATIONS

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There is increasing pressure to use coatings in a more sustainable way in our society and museums and archives are not exempt from this. Coatings, including those presumed to be “green” products, have been examined in terms of their suitability for collection preservation. To be more sustainable, museums should both avoid applying a coating as much as possible. When the need is essential, then they should consider choosing, recycled paints, and select those coatings that would have the least impact on human health and the environment. Low-VOC emulsion (latex or water-borne) paint is the most promising coating and is suitable for preservation purposes. The emphasis remains on avoiding the use of any coating based on drying oils inside enclosures, such as display cases. Drying oils may seem to be green products but they release harmful peroxides and low molecular weight carboxylic acids during the curing process.

1 Introduction

Paints and varnishes are coatings used in all buildings for aesthetic reasons or to protect a substrate. In museums and archives, coatings are also used to reduce harmful volatile emissions from wood surfaces, and to block dust released from a concrete surface. From the points of view of sustainability and of safeguarding the object, we must ensure that a new coating applied in a room or inside enclosures such as display cases, storage cabinets and transportation cases will not release a significant amount of harmful compounds. The key to minimising this risk to the object is to select recommended coatings and allow an adequate drying or curing period before installing vulnerable objects in the newly coated environment.

During the last decade, there has been increasing interest in healthier and sustainable approaches to coatings, either by the selection of greener coatings or by rethinking their use. Contrary to popular belief, greener paints do not necessarily mean that they are safer for objects. The goal of this paper is to provide critical observations on coatings associated with the concept of green living or sustainability, and to determine which of these can be used safely in the context of cultural heritage preservation.

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2 Volatile Organic Compounds

One of the most common concerns about coatings and other construction products is the emission of volatile organic compounds (VOCs). The definition of VOCs has changed slightly over the years. The Environmental Protection Agency (EPA) in the United States now defines a VOC as “any organic compound which participates in atmospheric photochemical reactions”.[1] Such reactions contribute to the formation of smog. At ground level, photochemical smog is constituted of airborne particles and ozone, which are threats to both human health and heritage collections. To give more flexibility to industry, the EPA excludes the following single-carbon compounds from its VOC definition: carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate. The EPA also excludes some compounds from the VOC definition. They are called VOC-exempt compounds, that is, compounds that are known not to participate in photochemical processes. Examples include methane (which is a significant greenhouse gas) and many fluorine-containing compounds. However, these compounds can be still harmful to the environment and humans.

The European Union regulations and the World Health Organisation (WHO) define a VOC as any organic compound having an initial boiling point less than or equal to 250 °C measured at a standard atmospheric pressure of 101.3 kPa.[2,3]

The reduction of VOCs in different products will help to reduce the formation of smog which affects human health and the environment. The ozone formed by photochemical reaction of VOCs in the atmosphere is also known to be harmful to many organic materials.[4,5] The question of whether VOCs that are generated indoors are directly harmful to heritage materials is another matter and one that is not well understood. The VOCs known to be harmful to objects are mainly low molecular weight carboxylic acids such as formic and acetic acid. To better preserve collections, we should focus on the level of specific pollutants in the room or inside a display case rather than on the total amount of VOCs. Pollutants, whether they are gases, aerosols, liquids, or solids of either anthropogenic (human activities) or natural origin, are substances that are known to cause adverse effects (i.e. damage) to objects.[6-9] Trying to achieve realistic levels of key pollutants, such as acetic acid, hydrogen sulphide, nitrogen dioxide, ozone, fine particles and sulphur dioxide, is already a difficult task for museums.[6] From the point of view of safely preserving an object, trying to establish a maximum limit for VOCs surrounding the collection is not justified.

In 1997, CCI reported that lower amounts of VOCs do not mean a reduction of ammonia (a non-VOC) or acetic acid from emulsion coatings.[10] Even with today’s new paint formulations, there is no proof linking low VOC content with low amount of pollutants surrounding the collection. In 2009, acetic acid emissions were detected in newly applied paint even when it was known that there was no acetic acid in the paint.[11] The ingredient glycol ester was thought to be the source because this low-volatile solvent forms carboxylic acids such as acetic acid during hydrolysis. Low-VOC paints still contain low to negligible levels of volatile glycols that can release a small amount of acetic acid as a by-product.

Allowing adequate drying time is an important means of minimizing the risk of damage caused by harmful compounds released by paints – including those recommended for conservation purposes. The amount of volatile compounds released by paints in a ventilated place decreases exponentially over time. In general, the emission rate levels off or least slows down greatly after 4 weeks.[10] Most volatile compounds released by recommended paints are not harmful but since the exact nature of all raw materials and secondary emission are usually not known, a delay of 4 weeks is recommended before installing objects inside a painted enclosure. It is recognised that this four-week period remains a challenge for most museums dealing with tight exhibition deadlines. The drying period may be reduced if it is verified that the vapours emitted will not be harmful to objects inside the painted enclosure. Table 1 shows a list of possible pollutants released by coatings.

Pollutant	Damage	Possible Sources (Substrates and Coatings)
Ammonia	Crystal growth on a cellulose nitrate object,[6] yellowing of linseed oil.[12,13]	Concrete and many emulsion paints
Low molecular weight carboxylic acids, such as formic and acetic acids	Corrosion of lead and copper,[14] alteration of alkali silicate glasses,[15] formic acid makes paper more fragile,[16] acetic acid affects colour photographs,[17] hinokitiol, emitted by *Cupressaceae* (cypress family), was found corrosive for copper and iron and reacts with some lead-based pigments.[18]	Wood products, emulsion, alkyd, drying oil, oil-modified urethane, epoxy ester, melamine, under-baked alkyd enamel, two-part epoxy, and two-part urethane
Dust	Deposits on objects and can be difficult to clean	Wood products, concrete, stucco, brick, plaster or any adobe-type of surfaces
Peroxides	Affect many organic objects (such as cellulose[19]), tarnish silver, create formation of black spots on black & white photographs,[20] Oxidize aldehydes and form carboxylic acids.	Formed during oxidation polymerization as a secondary product in alkyd, drying oil, oil-modified urethane, epoxy ester, under-baked alkyd enamel, two-part epoxy and two-part urethane
Reduced-sulfur compounds	Cause tarnishing of silver and copper,[6] darkening of white lead pigment.[21]	Rare, but can be present in any coating. Consult the MSDS to see if there are sulphur compounds reported as combustion products during fire; otherwise, sulphur can be detected with the lead acetate test.[22]

Table 1. Pollutants released by coatings and substrates and their effect on objects.

3 Green/Sustainable Certification Programmes

Certified green coatings must fulfill many criteria, not only VOC emission levels. These criteria may be different from country to country and even within a country. In Canada, there is the EcoLogo program and in the United States, there is LEED. In Europe, there is the EU EcoLabel programme. These programmes (Figure 1) are recognised by many other governments and professional bodies related to the construction industry. It is important to note that these certification programmes do not deal with the preservation of collections nor historic houses.

Figure 1: EcoLogo, LEED and EU Ecolabel logos.

3.1 EcoLogo

Founded in 1988 by the Government of Canada, the Environment Choice Program, EcoLogo, provides a detailed list of performance standards required for coatings, as well as a list of banned compounds such as phthalates and formaldehyde, and the maximum concentrations of VOCs, defined by US EPA.[23] These amounts are shown in Table 2. By 2010, seven paint companies in Canada had certified some of their paints in this voluntary program.

Surface coating	Maximum VOC allowed (g/L)
Flat	50
Non-flat	100
Gloss	150
Stain	175
Varnish	250
Recycled water-based paint	150

Table 2. Maximum allowable content of VOCs in coatings according to the EcoLogo Program.[24,25]

3.2 LEED

The U.S. Green Building Council (USGBC) is a nonprofit organisation focussing on cost-efficient and energy-saving, green buildings.[26] In 1998, the USGBC launched a voluntary certification programme called Leadership in Energy and Environmental Design, better known as LEED certification. LEED defines the maximum permissible amount of VOCs that can be released by coatings, differently from EcoLogo, and also sets different maximum levels (Table 3). Both programmes consider recycled paint content in a manufacturer's application for certification.

Surface coating	Maximum VOC allowed (g/L)
Architectural paints:	
- Flat	50
- Non-flats	150
Anti-corrosion paints	250
Clear wood finishes:	
- Varnish	350
- Lacquer	550
Floor coatings	100
Sealers (waterproofing)	250
Shellacs:	
- Clear	730
- Pigmented	550

Table 3. Maximum allowable content of VOCs from coatings based on LEED: new commercial construction.[27]

3.3 EU Ecolabel

European Union has also established their eco-label for paints and varnishes[28] which has set the maximum content of VOCs for different types of coatings (Table 4). They defined VOCs based on their boiling points which is different than the North American programme. The Ecolabel programme states that ingredients known to be harmful for human must not exceed 0.05% (m/m) in a paint formulation, and ingredients known to be dangerous for the environment must not exceed 0.1% (m/m). Some specific ingredients have different limits. For example, ammonia has no limitation but 2- methyl-2H-isothiazol-3-one, a biocide, must not exceed 0.0015% (m/m).[2]

Surface Coating	Maximum VOC Allowed (g/L)
Interior matt	15
Interior glossy	60
Interior trim and cladding for wood and metal including under-coats	90
Interior trim varnishes and wood paints, including opaque wood stains	75
Interior minimum build wood paints	75
Primers	15
Binding Primers	15
One-Pack performance coatings	100
Two-pack reactive performance coatings for specific end use such as floors	100
Decorative effect coatings	90

Table 4. Maximum allowable VOCs from coatings based on the EU EcoLabel Programme.[2]

3.4 Others

Other programmes such as Greenguard,[29] National Green Building Program,[30] Extreme Green,[31] and Green Seal[32] share the goal of improving sustainable products and activities. Many coatings may not be certified by a recognised programme, but many coating producers try to produce less toxic products.

In Australia, even painters can be accredited as "green." Green painters will supply environmentally sustainable paints, consultancy and other services, and products.[33] They also adhere to a code of ethics.

4 New Trends in Coatings

This title may encourage false expectations. In fact, there is not much that is new with coatings. For more than 15 years, coating companies have gradually reduced toxic compounds and the VOC content in their formulations. Traditional or artist paints such as casein paint seem to have attracted some attention, but not on an industrial scale. They have a limited market, and are not regulated to the same performance standard as synthetic resins. A coating based on soy protein may look promising as a green coating, but it is still too early to know how it will perform and at which scale of production. All these "trendy coatings" can be described in terms of sustainability and suitability with collections. Table 5 summarizes the use of coatings in conservation, and includes common commercial coatings that were previously investigated by the Canadian Conservation Institute (CCI).[10,22] More information on the use of coatings in museums is also available elsewhere.[7]

Table 5. Summary of recommendations for coatings in a collection preservation context (on the next page).

4.1 Zero- and Low-VOC Coatings

The paint industry has gradually reduced the amount of VOCs in paint formulations over the last 15 years. Many emulsion coatings are now certified by the EcoLogo program and are available in hardware stores (emulsion coatings are often called latex coatings in North America). Some specialized paints, such as two-part epoxies or two-part urethanes, are also available as zero- or low-VOC products. The actual VOC content of a specific coating can be found either in the product's technical data sheet or in the Material Safety Data Sheet (MSDS), provided at the point of sale or acquired through the manufacturer's website.

The only two zero- and low-VOC types of paint recommended in Table 5 are from the emulsion paints and the 2-part systems, either epoxy or urethane. The recommendation is based on the fact that these types of paints (emulsion and 2-part systems) are generally suitable for museums and archives as long as there is sufficient drying time, and therefore the low-VOC paints of these types could be recommended as well. The nature of new, less volatile compounds used in paint formulations is not always known, the recommendation of 3-4 weeks drying period[10,22] before the installation of an object inside of a painted enclosure remains the same. This period could be reduced in the future if there is data to support it. It is important to notice that low-VOC alkyd paints will remain a problem. See Section 4.2 for more details.

The total amount of VOCs reported for a coating excludes the presence of colourants. The addition of a colourant to the paint, however, increases the VOC content. This is true for all "regular" and low-VOC paints. The colourant added in the store is typically composed of a pigment, a blend of surfactants, and glycol; the last two components may release VOCs. When a large addition of a colourant is added, it not only releases more VOCs, it creates a sticky surface on the paint that may remain for a long period, due to the colourant's high glycol content. An object placed on a highly coloured or dark painted surface, therefore, can still stick to it even after the paint film has dried for many months — even years.

4.2 Natural Drying Oils

A drying oil forms a film by chemical reaction with atmospheric oxygen. Oils commonly used for coatings are tung, cottonseed, corn, soybean and linseed. Traditionally, linseed oil has been most commonly used for the formulation of paints. The oil is modified to make the paint film thicker and to cure faster. Some of these treatments involve the introduction of petroleum-based solvents, acid and, in the past, even some metal complexes such as cadmium, cobalt or lead compounds.[13,36] The green paint certification programmes, however, have banned the use of heavy metals including antimony, cadmium, chromium, lead and mercury.[24]

Drying oils are known to release peroxides and low molecular weight carboxylic acids as secondary emissions during their curing.[37,38] Formic acid has been found to be emitted in significant quantities from various drying oils for periods of up to three months.[39] Tung oil varnish has been found especially corrosive for lead, copper and silver.[40] Modified drying oils such as oil-based alkyd and oil-modified urethane were also reported as corrosive.[36,40] Low-VOC alkyds and any paints based on drying oil remain a problem since the same oxidation processes occur during film formation.

4.3 Casein

Before the arrival of acrylic emulsion paints, casein paint was commonly used. Now, it is used on a small scale by craftsmen, but interest in applying casein paint on interior surfaces is growing. Casein is made from milk, which is why it is also called "milk paint." Casein from cow milk contains around 0.7% of sulfur[41] but it is unlikely that casein generates substantial amounts of sulfur compounds in enclosed spaces. Nevertheless, inside any airtight enclosure, it may be wise to avoid casein where hypersensitive objects such as silver are present. In some formulas, acid compounds from lemon juice or vinegar are added to the casein paint, as well as small amounts of a drying oil.[42] Paints containing drying oils should be avoided inside enclosures (see section 4.2 above). In 2010, no casein paints were certified by EcoLogo. This may have been due to the small-scale production of this product in addition to the difficulty in meeting EcoLogo performance standards.

4.4 Soy

The coating industry traditionally uses natural oils to produce alkyds. The oil comes from different sources including soy bean and linseed. When made of soy

Table 5. Summary of recommendations for coatings in a collection preservation context (on the next page).

Coating	Enclosures (default drying time: 4 weeks*)	Rooms** including walls, floors, exterior of cases (default drying time: 4 days)	Comments (see Table 1 for the impact of pollutants on objects)
Common emulsion (latex or waterborne) coating, recycled emulsion coating; excludes alkyd emulsions	Suitable	Suitable (For floors, use a harder resin such as acrylic-urethane resin.)	Medium-to-good vapour barrier. Acetic acid emissions level off after 4 weeks during the drying process. The resin and a good part of solvents are from petroleum resources (as are many synthetic coating resins). Brushes and rollers, while still wet, are cleaned easily with water. No petroleum based solvent is required for cleaning.
Zero- or low-VOC emulsion coating	Suitable	Suitable	Darker colours have increased VOC content. A very dark paint film will remain sticky for a long time. Emission of acetic acid and ammonia during the drying process.
Two-part epoxy or two-part urethane (including low VOC formulation)	Suitable, provided the mixing is done carefully	Suitable	More expensive, less common to find on the market and less green than emulsion coatings. Well adapted for public or industrial floors. The film is formed by catalyzed polymerisation and solvent evaporation.[10,22] These coatings should be safe to use after the recommended drying time. A solvent is needed to clean brushes and rollers.
Shellac or any film formed by solvent evaporation	Suitable in enclosures. Avoid direct contact with object in a humid environment (surface becomes sticky).	Safe for most types of collections. See comments for its limitations	Tends to be a poor vapour barrier unless varnish is built up in many layers. The dry film becomes sticky in moist environments and can get stained easily by moist fingers. Denatured alcohol is the main VOC.
Casein and soy protein (non alkyd based)	Suitable for most objects. Use with caution for sulfur-sensitive objects	Suitable	Be sure there is no drying oil in the formula. The long-term risk to objects by contact with casein is unknown. Brushes and rollers, while still wet, should clean easily with water.
Cellulose-based	Insufficient data: probably suitable	Suitable	Be sure there is no drying oil or alkyd resins in the formula. Casein or soy protein may be present.
Mineral (potassium silicate and whitewash)	Suitable	Suitable	Appropriate for concrete, stucco, brick, plaster or any adobe-type of surfaces. Brushes and rollers, while still wet, should clean easily with water.
Natural drying oil, (unbaked) alkyd solvent based, alkyd emulsion, oil modified urethane, epoxy ester (1-paint), melamine, recycled alkyd, soy-based alkyd as well as soy protein and casein paints having drying oil in it	Not recommended	Not recommended for large surfaces. Acceptable for small surfaces when applied in a ventilated room.	Known to release peroxides for the first few days and carboxylic acids for many weeks or many months. A solvent is needed to clean brushes and rollers.
Moisture-cured urethane, marine coating	Insufficient data. Caution required	Caution is recommended for large surfaces. Acceptable for small surfaces when applied in a ventilated room.	Cures in the presence of humidity in the air. Needs at least 35% RH; otherwise, the film does not cure fully and remains sticky. VOCs have a very unpleasant smell.
Alternatives to wet coatings			
Powder coating (all resins)	Suitable. Can be used immediately (no airing out required).	Suitable. Can be used immediately (no airing out required).	Usually used on metal structures. Some can be applied on medium density fibreboard. No solvent involved in the film forming process. Emissions from the coating after baking is assumed to be safe for collections (an odour can be detected).
Baked (alkyd) enamel coating	Suitable if properly baked. Preferable to let it ventilate a few weeks before using	Suitable. Can be used immediately (no airing out required).	For metal structures. If the coating is under-baked, it may release some harmful vapours, just as unbaked alkyd does.
Radiation-cured coating	Suitable. Can be used immediately (no airing out required).	Suitable. Can be used immediately (no airing out required).	Mainly for varnished wood panels or boards. After curing, the amount of VOCs emitted is expected to be negligible.
Laminate of phenol and/or melamine formaldehyde for wood panels	Suitable, as long as no unsealed surfaces of wood are exposed inside the enclosure (e.g. end grain). Can be used immediately	Suitable. Can be used immediately (no airing out required, except if needed for airing out emissions from the glue)	Very good vapour barrier properties. The amount of pollutants emitted by the laminate itself is negligible. Contact cement (made of neoprene and/or synthetic rubber) is the most-recommended adhesive. They could contain sulphur compounds, but according to the literature, this is unlikely. Polyvinyl acetate (PVAc or white glue) may be also used to glue the laminate, although acetic acid will be emitted from the edges.
Laminated aluminium foil, heat-sealed onto wood surfaces	Suitable, as long as no unsealed surfaces of wood are exposed inside the enclosure. Can be used immediately	Suitable. Can be used immediately (no airing out required).	Excellent vapour barrier, as long as the aluminium foil is not damaged. In North America, Marvelseal 360 is commonly used. Examples of application are found in the literature.[34,35] Note: The use of metal foils may not be a greener option compared with paint.

* The four-week drying period also helps to minimize the risk of an object sticking to the painted surface. Use of an interleaf such as sheet of Melinex (Mylar) is recommended to avoid potential damage due to direct contact.
** Excludes contact of coating with objects.

oil, the alkyd may carry its full descriptive name: soy bean oil-based alkyd. In other words, the new trade name “soy paint” may refer simply to an old-fashioned or traditional alkyd paint. Harmful vapours released during the curing of oil-based alkyds will be similar to those of the natural drying oils discussed above in Section 4.2.

On a much smaller production scale, soy flour or protein can be used to replace casein in a water-based paint.[43] The suitability of this coating for a heritage collection may be similar to casein paint in terms of physical resistance properties. Soy protein should be safe to use in preservation as long as no drying oil is added.

4.5 Cellulose

Cellulose and cellulose derivatives can be used in coatings. Compounds such as methyl and ethyl cellulose, carboxymethyl cellulose and hydroxyethyl cellulose can either be used as a binder or as an additive in coatings.[44] With the exception of cellulose nitrate, it is unlikely that cellulose compounds themselves cause damage to objects. However, casein, soy, alkyd and natural drying oil could be used in their formulation and their presence should be investigated. The degradation of cellulose nitrate itself is known to produce corrosive, acidic and oxidizing gases.[45] Typically the main problem of cellulose-based paints is they can contain a high amount of alkyd resins.

4.6 Mineral

A traditional method of coating is to use potassium silicate (or “silicate”) dispersion paint. The mineral solidifies by reaction with the carbon dioxide in the ambient air to form a binder made essentially of silicon dioxide.[42] This coating is compatible with mineral wall surfaces such as concrete, stucco, brick, drywall (without the protective paper layer), and stone. It is not well-adapted for wood and metal. Due to its simple composition, this mineral paint is probably suitable for use with heritage collections.

Another traditional way to cover a surface is to use whitewash. A film of whitewash is made of calcium carbonate which resulted from a series of chemical transformations of limestone.[42] The film formed is a thin layer of plaster and can contain some additives such as pigment, glue, soap, casein, flour and linseed oil. Whitewash works well on plaster or any adobe-type of surface. The weak point of whitewash is that the coated surfaces remain slightly powdery, which is a concern in terms of dust generation.

4.7 Shellac

Shellac is a resin secreted by the female lac bug, *Laccifer lacca*. Shellac is sold in flakes and must be dissolved in ethanol for application. Note that ethanol can be produced either by petrochemical processes or by fermentation (the latter being a more sustainable production method). Ethanol is a VOC but is not harmful to objects, so shellac is not usually a problem in conservation. The film formed by a shellac solution is thin and often must be applied in more layers than any other type of coating. Orange shellac is very efficient for sealing knots before applying a primer or a top coating on a wooden surface. Unfortunately, shellac coatings are vulnerable to water staining and moist fingerprints.

4.8 Radiation-Curable Coatings

Ultraviolet (UV) and electron beams (EB) are the most common sources of radiation used to cure paint films. Coatings for UV radiation contain prepolymers that are polymerized by exposure to UV with the help of a photo-initiator such as benzophenone.[46] Electron beam-cured coatings do not need an initiator. The energetic electrons create radicals that contribute to cross-linking. Acrylic polymers are most frequently used for this form of curing.

The curing of coatings on wooden panels is done by the manufacturer and sold by suppliers pre-coated. Usually, a high-solid-content paint is used that will not release many VOCs during curing and even fewer when the product is purchased at the store or delivered to the institution. A small amount of ozone and nitrogen dioxide is released but only during the curing process.[46] The cured coating itself should be safe to use around collections.

4.9 Recycled Coatings

Recycled coatings are made of unused portions of recovered coatings with a small amount of additives to improve the formulation. In 2010, six North American companies offered recycled coatings and the company Newlife Paints Ltd in United Kingdom is the only one currently known in Europe.[47] In Canada, the Boomerang company is the only one meeting the EcoLogo’s requirement regarding recycled emulsion (latex) paints.[25] Other companies offer recycled paints without necessarily achieving the EcoLogo criteria or without making use of the EcoLogo program. Any recycled emulsion paint can be treated as a typical emulsion paint. They are economical and good enough for walls and ceilings as well as inside enclosures, but usually are not hard enough for floors. The choice of colour is limited and can be difficult to reproduce from batch to batch. The main disadvantage of those coatings is the difficulty of finding them locally.

Recycled alkyd coatings in the form of (pigmented) paint, varnish or stain are also available on the market but, as with all alkyd paints, they are not recommended for use in an indoor museum context.

5 Options for Sustainable and Safe Practices

Many popular coatings, such as acrylic latex paints, are based on petroleum extracts — which are not considered sustainable. Even with coatings based totally or partly on renewable sources, there may be problems: some can be harmful for the collection, some are only produced on a small scale, and some do not fulfill performance standards. Since there are few coatings available that are green, easily available, and completely safe for use in proximity with museum collections, a strategy could be adopted to use what is available in a more sustainable way. It is understood that sustainability is not the only factor influencing the selection and use of coatings in museums today. Other influences include the desire for a new look, specific colour or texture, as well as available resources. The following considerations for sustainability and preservation are generic and should be adapted according to context.

5.1 Avoiding Coatings

Uncoated metal and wooden structures can stain other materials by contact. Uncoated wood can release acid vapours and both wood and concrete can generate dust. A common approach, therefore, is to coat these materials. Apart from providing a barrier against the migration of harmful compounds into objects or the surrounding environment, coatings may add to the aesthetics of the display, and can protect the surface of walls, floors and exteriors of display cases against abrasion, scratches, discolouration, and stains. One possible advantage of not applying coatings to wood and concrete is to use these materials for their moisture-buffering capacity.

Most permanent wall surfaces in museums are painted once every few decades (a situation typical of most public institutions). In museums, there is pressure for temporary exhibitions to present a new look or to harmonize the colour of walls or display cases with the theme of a new exhibition. Consequently, the tendency is to repaint frequently. When possible, museums should consider choosing a neutral paint colour that can be reused over multiple exhibitions. As an alternative to repainting, consider using other materials such as coloured papers, matboards, plastic sheets, and fabric to line the inside of display cases.

For wooden display cases or any enclosure having some wooden parts, there is a temptation to not apply coatings to any interior surface that is hidden from view. It is important to remember to seal those surfaces if there are objects vulnerable to organic vapours, especially if the object will be stored or displayed in proximity to these materials for long periods of time. It is not mandatory to paint if the objects are not, or are very minimally, acid-sensitive, or if the exposure time is short (e.g. the object is shipped inside a wooden transportation case). Painting the interior of the case requires careful planning to allow for sufficient drying time, which is often several weeks. If the short-term becomes a long-term function, however, the need for painting the interior must be reassessed. This may happen when a transportation case becomes a long-term storage box.

One way to avoid coating inside wooden enclosures is to use phenol and/or melamine laminate or a laminated aluminium foil (such as Marvelseal 360). The use of aluminium foil removes the need for an off-gassing period, although aluminium is very energy-intense to produce. If needed for aesthetic reasons, the laminated surface can be covered by fabric or a coloured matboard.

Objects vulnerable to organic acids such as lead objects are not safe inside a wooden enclosure whether coated or not. Consideration should be given to mitigation strategies[4] such as ventilation or filtration to reduce the level of harmful vapour, or decreasing the relative humidity in the enclosure to reduce possible reactions.

5.2 Reduction of the Use of New Coatings

To minimize the usage of new coatings, consider buying pre-consumer coatings, such as left-over materials from a store specializing in or unused construction products, or buy recycled coatings. Pre-consumer and recycled materials are encouraged by the LEED program, which may lead to LEED certification of the renovation work. Be aware of the recommendations and limitations of recycled coatings described above. Also, avoid acquiring a surplus of coatings by improving your estimate of the amount of coatings needed.

5.3 Select Coatings Carefully

Know the project's specific or unique needs and identify the desired properties of the coating. In general, walls and ceilings do not require stringent specifications, while floors may require good resistance to abrasion and, sometimes, chemicals. For example, casein paint is inappropriate for floors because it is not resistant to abrasions or scratches. Note that some coatings are more adapted for specific substrates such as wood, metal, stucco, and concrete. Technical data sheets or the paint dealer should be able to provide information leading you to the right selection. The international standard for Material Safety Data Sheets has a section on environmental impact that provides information that can help evaluate the effect a toxic compound may have when released into the environment. It also provides information on biodegradation, bioaccumulation, and environmental toxicity. Suppliers are required by law to make the MSDS on each commercial coating and construction product available to consumers.

When selecting a coating, ensure that it will present little or no risk to vulnerable objects in the collection by reviewing Tables 1 and 5. If possible, choose a zero- or low-VOC coating. This vigilance will reduce VOC exposure to those working with the paint. Compare the VOC content, obtained from the technical data sheet or MSDS, with amounts allowed by the Eco programmes (Tables 2, 3 and 4).

For significant and/or vulnerable objects, test selected coatings before their use. Some tests have been proposed in the CCI's Technical Bulletin 21.[22] A particular one is the Oddy Test, which is commonly used as an accelerated corrosion test.[22,48] In the 1990s, the British Museum tested 21 paints; of these, 30% were unsuitable for copper, 50% were unsuitable for lead, and 16% were unsuitable for silver.[22,49] The Oddy Test may be seen as extremely rigorous since the paint samples are heated at 60 ºC for 28 days at high relative humidity. Any coating passing this test is unlikely to emit significant levels of pollutant.

5.4 Application of Coatings

The proper application of coatings can be broken down into three stages: before, during, and after application. Technical data sheets, MSDSs and many specialized websites (such as that of the Paint Quality Institute) provide information on applying coatings and should be consulted.[50] CCI's Technical Bulletin 21 on coatings also covers some of these issues.[22] In this section, only a few highlights will be covered.

The preparation method for an uncoated surface is normally specified by the technical data or by a paint expert or advisor. A primer may be needed. For previously coated surfaces, ensure that the new coating will be compatible.

There are sometimes concerns about the presence of lead in previously painted surfaces. Before 1960, 25% of houses were painted with lead paint. After 1980, lead paint was very rarely used in homes and after 1992, it was almost impossible to obtain in Canada and the United States.[51] Lead was used as a white ($PbCO_3$) and yellow ($PbCrO_4$) pigment. The concern with lead is that it is dangerous when absorbed in the human body: lead can cause anaemia and damages the brain and the nervous system. Removing lead paint, however, can cause more harm than good because of the likelihood of lead-containing dust becoming airborne and contaminating the surrounding area. In most instances, lead-based paint layers are covered by a non-lead paint, which essentially seals it and minimizes lead dispersion. Sometimes, strategies can be developed to avoid having to remove paint; for example, exterior windowsills with chipping and flaking paint can be covered with metal cladding. More information on lead paint can be found on the websites of Health Canada, and Canada Mortgage and Housing Corporation.[51,52]

Before applying a coating, remember to check the safety issues by referring to the product's MSDS. Basically, the health and safety warnings on an MSDS pertain to the protection of the eyes, lungs and skin of those using the product, and of people within a specified proximity. If the coating project is not a standard one, whether because of the special nature of the substrate or the use of a new type of coating, a small-scale test to ensure that the result will fulfill expectations should be carried out before applying the coating on a large scale.

For the application of any paint, it is best to follow the recommendations provided by the technical data.

Typically, the golden rule with the application of emulsion coatings on uncoated surfaces is to apply one layer of primer and two top coats.

Respect the recommended safety measures and ensure proper ventilation. When VOCs from coatings cannot be extracted or ventilated outside via open windows, the use of fans to disperse or flush out the VOCs to other aerated rooms may be an acceptable option. Unfortunately, this option may lead to more people complaining about the smell. As with all health issues, sensitivities vary; some people are more sensitive than others to even low levels of VOCs.

After finishing a project, seal the unused paint and store it properly. Securing the lid tightly will extend the life of the paint. Another storage suggestion is to cover the liquid paint in the can with a thin plastic film or simply to store the paint can upside down. Do not store paint cans where they can corrode and contaminate the remaining paint when lids are pried up. Leftover paint can be donated to a recycling store or brought to the closest hazardous waste disposal site. While going to the waste depot, why not bring all other paint cans, solvents, or laboratory chemicals that are old or no longer needed? Removing these materials may improve air quality in the chemical storage area and reduce a potentially dangerous fire combustion load.

As mentioned in Section 2, a conservative approach recommends that wet coatings applied inside enclosures be given four weeks to dry. For painted walls of a room, few days should be safe enough.

6 Conclusion

This paper provides some critical observations on the selection and use of 'greener' and 'regular' paints in terms of better preservation of collections and better sustainability practices. Low-VOC paints seem promising with the exception of low-VOC alkyds. Unfortunately, without data that proves otherwise a drying period of at least 4 weeks remains the safest practice for all recommended paints including low-VOC paints applied inside enclosures with objects. Also the use of any 'green' coating that contain drying oils is not recommended.

Without necessarily being accredited green, it would be beneficial to everyone if all professional painters adhered to sustainable practices. The concepts of "green living" and "sustainability" are still new in our culture, but we expect they are here to stay. Furthermore, these concepts will evolve with the development of new technologies and new standards, and with a new generation of people taking a firm stand on creating a better world. Applying greener coatings on a wall or other surfaces, or any use of products in a sustainable way is a small step in the right direction. An even greater step will be to rethink our models of consumption and business to include ethical considerations.

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