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Indoor air quality in passive-type museum showcases

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ABSTRACT

Air pollution in museum showcases is one main problem within preventive conservation. Applied materials for construction and decoration of showcases are potential emission sources for a broad variety of volatile organics. These might accumulate under those almost static conditions that are set within showcases due to conservation requirements. In particular, the knowledge of the potential hazardous impact of airborne pollutants on cultural assets caused a fundamental shift in material selection for showcase production during the last decades. However, systematic indoor air analyses within those modern-type showcases are missing so far. Hence, there is no knowledge if there has been achieved any improvement of air quality compared to traditional enclosures. In order to make the first move for evaluating the current situation in museum showcases, air analyses within passive-type enclosures of different construction types and ages have been performed. The focus was on concentrations of volatile and semi-volatile organic compounds (VOCs/SVOCs). Formaldehyde and organic acids have also been considered due to their known corrosive impact. All these target compounds have been determined by active and passive sampling and subsequent chemical analysis. It was found that in contrast to old-type showcases main emission sources have shifted from wood-based products and acid curing silicone rubbers to solvent-borne lacquers and neutral curing sealants. Due to secondary reactions, levels of acetic acid are still elevated. Thus, damage on artefact materials can still be suspected. The results reveal that a careful selection of construction materials is often not sufficient to lower air pollution levels. The development of risk assessment strategies and new technologies is therefore recommended.

1. Introduction

Showcases are today an integral part of museums' furniture as many museum institutions are using a so-called "box in a box-model" [1] as an underlying strategy to preserve artefacts in an optimum way. In order to achieve an all-embracing control of the surrounding conditions and to minimize environmental influences (climate fluctuation, entry of polluted outer air), climatic demands within:

- the museum building;
- galleries, exhibition areas and storage rooms;
- showcases;

are closely defined.

Showcases are therefore both to protect the items on display against undesired environmental influences and mechanical impact. In order to meet these requirements, the vast majority of showcases are constructed as airtight as possible at the request of conservators and exhibition technicians as the microclimate inside seems to be more controllable than within non-airtight enclosures, e.g. in regards to the entry of dust, pollutants, climatic fluctuations or pests. Some showcases might also be equipped with technical devices, i.e. for active air ventilation, positive pressure or with inert gas. However, due to financial reasons most showcases are passive systems with no active air ventilation and/or filtration. The resulting almost static conditions combined with a variety of construction and decoration materials favours the accumulation of chemical emissions inside. Moreover, particularly smaller showcases are characterized by a high surface-to-volume ratio. These parameters set the museum situation apart from normal indoor scenarios. Hence, the comparison of the indoor environment as a "reaction vessel", as stated by Weschler and Shields [2], comes to a head in museum showcases.

The fact that materials applied for showcase production might contribute to a bad air quality or even cause damage on artefacts was early observed and attracted the attention in the last decades [3–5]. Accordingly, main research focussed on formaldehyde, formic acid and acetic acid as degradation effects appear quickly at exposure to these volatiles [6–9]. Corresponding reaction mechanisms were therefore utilized for developing accelerated corrosion tests to check the suitability of materials for applica-

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tion in the museum environment in a simple and inexpensive way without the need of sophisticated laboratory facilities [10–13]. Consequently, specific materials for showcase production known for emitting hazardous compounds, such as wood-based products and acid curing silicone sealants, were increasingly substituted by so called inert materials and products which are assumed to be low-emissive. Nevertheless, complaints are still expressed by conservators. Special problems seem to be significant odorous loads, high pollution levels and unspecific signs of damages.

1.1. Research aims

Even though the protection performance of showcases was discussed by Camuffo et al. [1] and first insights into the air pollution problem were given by some previous studies [14–17], fundamental investigations on air quality within museum enclosures are missing so far. Furthermore, volatile and semi-volatile organic compounds (VOCs/SVOCs) have not been considered until now, although it was reported that they are significantly influencing indoor air quality with a potential impact on cultural assets and human health [18] as demonstrated in some previous studies [19,20].

A two-year research project targeted therefore to create a comprehensive picture of the current situation of air quality in museum enclosures. The study has been realised in close cooperation with showcase manufacturers with a special focus on passive-type showcases. In a first step, a broad range of materials that are currently widely used for showcase production were subjected to material emission analyses. In order to obtain an exact identification and quantification of released substances, sophisticated material emission tests were used [21]. The results are reported elsewhere [22,23]. Subsequently, air analyses within showcases of different construction types (airtight vs. open) and ages (days vs. years) have been performed. These comparative tests targeted on revealing differences and/or correlations between the spectrum of emitted substances and the range of pollution levels, also over long term. In addition, it should be answered if any improvement has been achieved by the shift in material selection. Influencing factors, such as air exchange rates, artificial lighting and emissions from artefact materials themselves [24] have additionally been considered. Emphasize was on VOCs and SVOCs as this is the major category among indoor air pollutants. Formaldehyde, formic acid and acetic acid have also been included due their known corrosive impact. According to findings from indoor chemistry, it was furthermore of interest if secondary reactions [25] proceed within showcases.

2. Experimental

2.1. Showcase selection and preparation

During this study, two main showcase construction types were distinguished (a) modern-type showcases and (b) old-type showcases. Modern-type enclosures are predominantly built from e.g. glass, powder coated or lacquered metals, neutral curing silicone rubber and just rarely wood-based products. They have been examined both directly after production at the manufacturers site (N) and after different time in museum use (M). Old-type showcases (O) are of traditional style and predominantly constructed by wood-based products, felt and acid curing silicone sealants. Those types were mostly constructed before the 1990s. Regarding showcases in museums, no detailed information was available about specific construction and decoration materials due to different reasons. Some enclosures were several years old and no documentation about the purchase was on hand, for other showcases, no material information was provided by the manufacturers. Therefore, Table 1 gives a brief overview of the tested showcase types by providing general information about the kind of use, construction types and applied building products. In contrast, technical data regarding modern-type showcases that were tested immediately after production (N) were made available by the manufacturers and are listed in Table 2.

The showcases were closed at least one week before start of investigation in order to reach equilibrium of material emissions and air concentration. During sampling it was not allowed to open the enclosure. Air was sucked through small tubes, which were brought in from outside, where they were coupled with the sampling devices. During measurements, showcases had no technical equipment, e.g. buffer materials or lighting. Parallel to showcase analyses, air sampling was performed in the environmental room to reveal possible diffusion processes between the indoor air and the showcases air and, thus, for clear identification of emission sources.

2.2. Sampling and analysis

2.2.1. Volatile organic compounds

Active air sampling of volatile organic compounds (VOCs) (150 ml min^{-1}, 40 min) was done with stainless steel desorption tubes (Perkin Elmer) filled with Tenax TA® (60/80 mesh, Chrompack). Multibed sorbent tubes packed with Tenax TA® and CarboTrap® (20/40 mesh, Chrompack) were utilized for sampling volatile monoterpenes [26]. Passive air sampling was performed if showcase volumes were too small, especially regarding table display cases, or if no outer access was available. Tenax TA®-tubes were hung with one closed end and one end equipped with a diffusion cap in the showcase for 14 days. After exposure, the tubes were thermally desorbed (320 °C, 10 min; Perkin Elmer ATD 400) into a GC/MS system (Agilent 6890/5972). The compounds were separated on a HP-5 MS column (60 m × 0.25 mm, 0.25 μm). Qualifying was based on a PBM library search [27]. Moreover, mass spectra and retention data were compared with those of reference compounds. Regarding active air sampling, all identified compounds were quantified using their own response factors. The areas of unidentified peaks were converted to concentrations using the toluene response factor. For calibration a linear regression model was used [28]. Results obtained by passive sampling were calculated using diffusive uptake rates [29] and substance-specific conversion factors.

Table 1
Investigated showcase types, their kind of use, ages and applied construction materials.

Showcase type	Kind of use	Age	N	Short description of construction type
Modern-type (N)	Directly after production	1–28 days	7	Freestanding showcases, highly sealed, glass cubes with glass cover plates, lacquered fibreboard base plates, no technical equipment
Modern-type (M)	In museum use	2–4 years	11	Freestanding showcases, highly sealed, glass cubes, lacquered wooden base plates, lacquered metal/wooden cover plates
Old-type (O)	In museum use	Several decades	14	Freestanding or wall showcases, glass cubes, lacquered wood-based materials (base and cover plates, back boards), partially felt

N = number of investigated showcases.