Indoor air pollution in museum display cases

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ABSTRACT
Formic acid and acetic acid are indoor air pollutants that will engage in corrosion or other material deterioration processes. Objects attacked by these compounds can be destroyed beyond rescue by any conservation treatment. This is a special concern in the museum environment, as these acids are emitted from a range of display construction materials, including wood products. It is demonstrated that high concentrations of those acids can be obtained in confined spaces, such as cases, which often are characterized by a low air exchange rate and a high inner surface to volume ratio. By passive sampling, concentrations of 477 μg/m^3 formic acid and 11 327 μg/m^3 acetic acid were measured in a case with oak wood shelves. A lead coupon in the case was heavily corroded after 14 months. Whenever possible, non-emissive construction materials should be used for display areas for museum objects.

INDEX TERMS
Museum; Acetic acid; Formic acid; Material emission; Passive sampler

INTRODUCTION

Among the environmental factors which influence the condition of objects in museums and other cultural heritage institutions, indoor air pollutants are of increasing concern. In particular, carboxylic acids emitted from construction materials have proved to participate in aggressive deterioration processes such as corrosion of lead (Tennent and Cannon, 1993), bronze (Tennent and Baird, 1992), and salt efflorescence on calcareous objects (FitzHugh and Gettens, 1971; Tennent and Baird, 1985; Gibson *et al.*, 1997a). Special microclimate situations arise in museum display cases, if constructed from materials that give off chemical pollutants. As the air exchange rate of display cases is often low (1 day^{-1} or less), and the inside surface to volume ratio is high, extremely high concentrations (>10 mg/m^3) of acetic acid, for example, can build up inside the case. The source is often wood products or sealants, used in case construction (Figure 1).

EXPERIMENTAL

In order to demonstrate the high levels of carboxylic acids that can build up inside a case constructed from wood, the following experiment was carried out:

Two Plexiglas (polymethylmethacrylate) cases were used. Each case had two shelves, one case had metal shelves and the other had shelves made of planed oak wood. Oak was chosen because this acidic wood species is commonly known to emit high quantities of acetic acid. Despite this, oak is a fairly common material for wooden cabinets, etc., also in museums. The volume of each chamber was 0.125 m^3, the surface areas of the two oak shelves was 1.064 m^2. The air exchange rate of the chambers was determined by measuring the decay of a tracer gas (N_2O), which showed one air exchange in approximately 48 h. The concentration of formic acid and acetic acid was measured by passive samplers, in each of the two cases, and in the surrounding room air. Sampling time was 21 days, with a detection limit of 114 μg/m^3 for formic acid and 187 μg/m^3 for acetic acid. The method was in accordance with that of

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Gibson *et al*. (1997b). The experiment was performed at room temperature (ca. 21°C). To assess the corrosive effect of the atmosphere inside the chambers, a 2 × 2 cm lead coupon was placed in each chamber, not in physical contact with the shelves.

Figure 1 Seventeenth century lead bullet with white corrosion. The bullet was exhibited in a display case with a wood fibre backboard. The corrosion has been identified by Fourier-transform infrared spectroscopy to be basic lead carbonate. This corrosion product is caused by exposure to acetic acid, and the natural CO_2 in air. From the collection of the National Museum of Denmark. Photo: Birthe Gottlieb.

RESULTS

The acid concentrations in the room air and in the case without wood shelves were both below the detection limits. However, in the second case, with the oak shelves, the concentration was as high as 477 μg/m^3 formic acid and 11 327 μg/m^3 acetic acid. Indeed, the vinegar smell of acetic acid was detectable by nose when opening the case.

The experiment was initiated in November 2001. After 14 months, upon inspection, the lead coupon in the case with oak shelves was found completely covered by a distinct brown corrosion layer, whereas the coupon in the case without lead had no visible surface corrosion.

DISCUSSION

The experiment demonstrates clearly that it is easy to produce a large build up of pollutants in confined air volumes if the construction contains emissive materials. The level of carboxylic acids, which was produced in this experiment, is similar to those levels reported in literature at which damage to materials was observed. Cellulose in paper has shown a reduced degree of polymerization, and has a lower pH, after having been exposed to concentrations between 3000 and 20 000 μg/m^3 acetic acid, in a laboratory test (Dupont and Tétreault, 2000). Salt efflorescence on limestone has been reported at concentrations of 335 μg/m^3 formic acid and 11 384 μg/m^3 acetic acid (Gibson *et al*., 1997a,c). This is very similar to the conditions we created in this experiment.

A large survey (Grzywacz and Tennent, 1994) of sites where artefact deterioration had been observed due to carbonyl pollution consisted of over 50 sites in European museums, with formic acid concentrations ranking between <0.6 and 116 μg/m^3 and acetic acid between 50 and 1836 μg/m^3. These values are even lower that the concentrations that were generated during this experiment.

Material deterioration such as corrosion is a cumulative process. Therefore the area-specific flux of pollutant molecules onto the objects' surface is the important factor, rather than concentration in air. However, concentration is normally the preferred means of reporting air

pollution levels; besides this, does the high concentrations of carboxylic acids measured in this study imply that a high emission of the acids takes place inside the case.

Several approaches are used in museums to minimize or eliminate such indoor pollution problems. Avoiding construction materials, which emit harmful compounds, is, naturally, the most effective way to go. At the National Museum we screen display construction materials before use for the possible release of formic acid and acetic acid, with chamber tests. Emission is sampled on Solid Phase Micro-Extraction (SPME), and analysed on a GC/MS system (Ryhl-Svendsen and Glastrup, 2003).

When an emissive material must be used, despite failing a chamber test, mitigative measures must be undertaken in the display case design. Vapour barrier applied to all inner surfaces of a display case is one possibility, which works satisfactorily. However, great care must be taken to avoid even the slightest pinholes, and the surface finish can be problematic from an aesthetic point of view. Forced ventilation is another solution. This can be conducted by introducing a computer fan on an air-inlet at the display case, which ventilates the case through a dust filter. However, this necessitates that the surrounding room air is of a satisfactory air quality, both with regard to pollution levels and moisture content.

CONCLUSION

Carboxylic acids, normally not regarded problematic in indoor environments, do pose a threat in special situations. Being corrosive, formic acid and acetic acid emitted from wood are able to engage in material deterioration. In confined spaces, such as museum display cases, these pollutants can reach high concentrations of several mg/m^3. Care should be taken not to use wood or wood-based products as construction materials for display of sensitive museum objects. Instead, other non-emissive materials should be identified by testing and used as replacements.

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