ADVICE SHEET

Air Pollution

Museums Galleries Scotland

Introduction

Museums and galleries bring together collections and the public. On most days of the year visitors enter the building. Their surroundings must be at a comfortable temperature and the air they breathe must be fresh. People's health and safety require a certain kind of environment - and the law insists that institutions provide it. Fresh air is therefore allowed to enter the museum through open doors and windows, or is drawn in by means of a ventilation system.

Museum objects also require a certain kind of environment, which includes an atmosphere free of dust and pollutants. Unfortunately the outdoor air, brought in for the wellbeing of visitors and staff, is often polluted. This is particularly the case in towns and industrial areas, where vehicles, heating systems and industry produce harmful pollutants. Materials used for the construction of the building, display and storage may also give off harmful substances that pollute the air, and furnishings and visitors add to the pollution with fibres and skin flakes.

This factsheet is about the pollutants that can be found in outdoor air. The effects of gaseous pollutants generated indoors are not discussed here, as they are outlined in a separate factsheet: *The Effects of Storage and Display Materials on Museum Objects.* Outdoor air pollutants may be divided into gaseous pollutants and particulate pollutants.

Gaseous Pollutants

Much outdoor air pollution is associated with towns and industry, and is almost entirely caused by the burning of fuels in power stations, factories, vehicles and heating systems. When fuel oil or coal are burnt in power stations, or diesel fuel is burnt in a vehicle engine, the sulphur content combines with oxygen in the air to form **sulphur dioxide** (SO_2). Sulphur dioxide, which is also naturally present in outdoor air due to volcanic activity, has become the most significant pollutant in Britain. It reacts with the ever-present water molecules in the air to form **sulphuric acid** (H_2SO_4). Other common gaseous sulphur compounds include **hydrogen sulphide**, **carbonyl sulphide** and **carbon disulphide**. Many fuels now have reduced sulphur content to help reduce sulphur dioxide pollution and its consequences.

Cars and other vehicles produce **nitrogen dioxide** (NO_2) as a by-product of combustion of petrol and diesel. It can also be produced by power stations and industrial processes. It forms into **nitric acid** (HNO3) with water from the air. Nitrogen dioxide also reacts in the

presence of sunlight to form **ozone** (O_3) and **PAN** (peroxyacyl nitrate) and these pollutants are therefore together referred to as 'photochemical smog'. Many vehicle exhaust systems now include a catalytic converter that splits the polluting nitrogen dioxide back into harmless nitrogen (N_2) and oxygen (O_2).

Ozone is also naturally present in the air at a height of 20-30 km, where the ozone layer protects life on earth from harmful short wave ultraviolet radiation. However, the increase in ozone at ground level is such that it has become a threat to both people and objects.

These gaseous pollutants can be divided into two main groups: those that are acidic and those that have an oxidising effect.

1. Acidic Substances

Acidic substances such as sulphuric acid and nitric acid are corrosive because they readily **react** with many materials and cause permanent changes. They affect the surface of materials such as metals where they cause corrosion, and calcareous stones such as marble and limestone where they cause discolouration and loss of surface integrity. They cause **hydrolysis** in cellulose materials such as cotton fabrics and paper; this is a process of decomposition which induces the breakage of molecular chains, causing a loss of strength and eventually the disintegration of the affected material.

Acidic substances can have the following effects on museum items:

- Limestone, marble and other calcareous materials weaken, discolour and dissolve;
- Iron and other metals corrode;
- Leather suffers from "red rot": it loses its strength and flexibility due to hydrolysis of the leather fibres and eventually is reduced to powder;
- Cotton, linen and viscose discolour and become very weak and brittle;
- Wool and silk are weakened, though as naturally acidic materials they are more resistant to acid attack;
- Paper objects become yellowed and brittle;
- The silver in photographic images yellows and fades;
- Gelatin and the filmbase polymers of negatives degrade;
- Both traditional and modern dyes and pigments may fade.

2. Oxidising Substances

Oxidising substances bring about **oxidation** reactions. The process involves the formation of **free radicals**, acids and other compounds in many materials, but especially organic materials. These free radicals and acids can reduce chain length in polymers, making them weaker, and can cause new cross-links in the molecular structure of materials, making them very brittle. Double bonds in long-chain carbon molecules are broken, thus damaging almost all organic materials. Pigment compounds are oxidised to new compounds which may be colourless or even a quite different colour from what the maker intended.

Ozone and PAN are powerful oxidants. Ozone in particular is very reactive and will form new chemical compounds with almost any material it happens to encounter. Some of these compounds will themselves be chemically active and further reactions may occur with

unpredictable consequences. Many organic materials contain anti-oxidant compounds (e.g. ascorbic acid, also known as Vitamin C) which fight the oxidation reactions; once the anti-oxidants are exhausted, deterioration processes can become more rapid.

Oxidants can have the following effects on museum objects:

- Dyes and pigments fade or are altered;
- Rubbers and plastics crack;
- Textiles become brittle;
- Paint binder resins are attacked;
- Shell, marble and some geological specimens suffer surface alteration;
- The tarnish rates of metals such as silver, copper and iron are increased.

Particulate Pollutants

Particulate pollution comes in a range of sizes and types. Some particles may be large and heavy enough to settle in still air (dust, grit and fibres). Such large particles are often abrasive and may cause surface scratching when the object is handled or cleaned. Other particles are so small that they remain suspended until trapped or held down on some surface by electrostatic attraction. These can enter display cases through the tiniest cracks, deposit on objects, and soil the surface.

Particles are usually **acidic** due to adsorbed sulphur dioxide and therefore affect all acid-sensitive materials. Acidic particles are hygroscopic: they attract water and thus can cause corrosion of metals and/or assist the growth of fungi. They may also contain **traces of metals** such as iron or copper which can catalyse (speed up) the deterioration of organic materials. Burning fuel in vehicle engines, power stations and heating systems produces black **sooty and tarry** particles which are then dispersed into the air and often cause soiling in urban museums (particularly noticeable around window frames).

New concrete and plaster emit **alkaline** particles. These darken oil paint films and discolour some dyes and pigments. Protein-based materials, such as wool, silk and gelatine (found in photographic materials) lose their strength when exposed to alkalis.

Coastal areas are affected by high levels of **salt crystals** in the air. Salts absorb water from the air, creating droplets with high salt concentrations. These will corrode most unprotected metals. High moisture levels around salt-containing dust particles can also support the growth of fungi and micro-organisms even when the surrounding appears quite dry.

Externally-generated particles such as soil grains, pollen and fungal spores can combine with internally-generated particles such as textile fibres and skin fragments to form an attractive food source for insects and fungi which may then affect museum objects.

How to Reduce the Risk of Damage Due to Pollution

First of all, it is important to find out what the pollution levels in your area are, as they are difficult to monitor or observe directly. The Environmental Health Department of the Local District Council can be contacted about pollution levels. National Governments and the European Union release information about pollutants in a variety of ways including publicly-

accessible websites. If you think there is a specific problem in your museum, an environmental scientist with experience in monitoring IAP (Indoor Air Pollution) should be invited to monitor the museum air for the suspected pollutants.

In general, urban and industrial areas, and those locations that are downwind of such areas, are likely to suffer the most from externally generated pollution. However, even the most rural areas may suffer from significant levels of sulphur dioxide and ozone. Marine locations may suffer from salt spray especially in windy weather. Whatever the location of the museum, action should be taken to prevent damage to the collection from pollutants.

The most effective action is to **prevent pollutants from entering the museum building**. This will only be possible when the building provides an effective envelope for the collection, so that no uncontrolled air can enter. It is important to ensure that doors and windows close properly, and that a policy is developed to minimise the opening of doors and windows. Traditional windows can let in a lot of exterior air even when closed (as witnessed by black particulate soiling on and around the window frame) but retrofitting of seals and/or secondary glazing can reduce the problem.

In general, the building should be free of any leaks or drafts (but it should be noted that some controlled ventilation, e.g. airbricks, may be necessary to preserve the fabric of the building and this should not be blocked). It is possible to leak-test buildings to help find the most problematic leaks and fix them.

Many museums like to keep their front doors open during opening hours to appear welcoming to visitors. However, such action will also welcome in pollutants, as well as increasing environmental variation in the museum. Sometimes it is possible to create a porch or lobby that allows external glass doors to be kept closed while still creating a welcoming appearance.

Museum design is important (where this is an option) as the walls and ceilings of internal lobbies can provide surfaces for the safe deposit of active pollutants, and internal doors between galleries will help to control airflow that brings unwanted pollutants with it. Stores should ideally be placed deep within the structure of the museum building to ensure minimal levels of exposure to outdoor air and its pollutants.

A ventilation system may have been installed in the museum with the prime aim of meeting the regulations with regard to the provision of fresh air for the building's users. But museums also require particular control of the incoming air to ensure that pollutants are not distributed amongst the collections. The air that is brought into the building by the ventilation system should be fully controlled. This can be achieved by:

- Filtering out particles with HEPA high-performance particle filters which are far more effective than the standard low-grade filters designed for use in industrial and commercial buildings.
- Filtering out pollutant gases, either with a water spray system (not effective for ozone) or with activated carbon filters, or both.

Such air management systems can be expensive to install and run, and require ongoing maintenance by expert staff or contractors. Re-circulating the air once it has been filtered

will make the system more cost-effective, as this saves energy, especially in winter. Ensuring the museum has control of factors such as the airspeed of the ventilation system and the rate of change of the air in the building will be advantageous, as slower speeds reduce pollutant intake and distribution. Reports on the performance of the system and the actions undertaken to maintain it should be made available to the museum managers, as a poorly-run system may have a highly negative effect on collections.

If in doubt, advice should be sought from Preventive Conservators with experience of managing ventilation systems, and/or from Mechanical and Electrical Engineers with an understanding of the needs of museums with regard to air quality. In some cases negotiations with the Planning Authority can lead to a relaxation of the ventilation requirements for public spaces in new or refurbished buildings.

It is not always possible to achieve a situation free of pollutants by the methods described above. Limitations in budget or building consents (for historic buildings) may make it difficult to install major air filtering plants even where these are considered the best answer to a museum's needs Much depends on the individual situation and the main aim should be to **prevent harmful substances from reaching the object.**

There are several other options that will help to prevent damage from pollutants:

- Place the objects in an **enclosure**. This can be a cupboard, a storage box or a display case. It is important that only those materials are used that do not give off harmful substances themselves and do not create an adverse micro-climate. A series of archival enclosures (e.g. a bag within a box within a cupboard) provides a great deal of protection for the object. Avoid open display and storage, and use dust covers for items that cannot be stored in boxes.
- Use materials that act as **absorbers** of pollutants, such as (buffered) acid-free paper and board; however do not use buffered material near items that are affected by the buffering agent, such as photographic materials and textiles, as these require **unbuffered** storage materials.
- **Activated carbon** is a powerful absorber of pollutants and has been used in a variety of products including carbon cloths which may be used in showcases and storage boxes. However there is no way to tell when the carbon is filled to capacity and in some circumstances it may release the pollutants it has absorbed.
- Use **conservation storage materials** that have been designed to protect objects from pollutants, such as Silversafe™ and Microchamber™ papers and boards for photography collections, Pacific Silver Cloth™ and Tarnprufe Cloth™ for silver objects, and Corrosion Intercept™ plastic enclosures for metal objects such as coins and medals.
- Maintain a regular **housekeeping** programme, to prevent the build-up of dust, dirt, fibres etc. throughout the building.
- Use **room air cleaners**. A room cleaning unit consists of a filter or filters mounted in a box with a fan to draw the room air through the filter. Some models can remove both particulate and gaseous pollution. Room air cleaners do not require any ducting and may be a suitable alternative for listed buildings and historic houses where pollution is considered a problem, though maintenance may be an issue.
- Where environmental control systems are present, aim for **cooler** conditions as these will slow many chemical reactions. Where the option may safely be applied,

less humid conditions (e.g. 50%RH as opposed to 60%RH) will also slow many of the chemical reactions caused by pollutants.

- Minimise or **stop up** air ventilation systems in areas used for the storage of collection items as these will often not be required to meet the building regulations that control air changes in public areas.

Note that many of these actions will be beneficial, depending on the circumstances, in controlling air pollutants of exterior origin, but pollutants generated indoors should also be considered and their effects mitigated or removed where possible, as discussed and advised in the Museums Galleries Scotland advice sheet *The Effects of Storage and Display Materials on Museum Objects*.

Further information and advice

This is one of a series of advice sheets produced by Museums Galleries Scotland on common collections care and preventive conservation issues. For more details, signposting to further sources of advice or information on how to contact a conservator, see our website at: www.museumsgalleriesscotland.org.uk.

Selected reading

The National Trust Manual of Housekeeping
Butterworth-Heinemann, 2006
ISBN 0750655291

Hatchfield, P
Pollutants in the Museum Environment
Archetype, 2002
ISBN 1873132964

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