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Environmental parameters in museums

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Abstract

During the last decade, the environmental conditions of the museum exhibition facilities and storage areas have been shown to be the most crucial factor, concerning the preservation of collections and artifacts. The pollution (chemicals and noise), the humidity, the temperature and the lighting can possibly deteriorate or even destroy the material cultural goods that are kept, protected and displayed in museum collections. Therefore, the aim of the present report is to define the threats that museum collections may suffer under inappropriate environmental conditions where they are housed.

Keywords: Museum environment; Air pollution; Humidity; Noise; Light; Temperature

1. Introduction

An important number of institutions, organizations and individuals are responsible for the care and preservation of several important cultural collections, such as [1]:

- archives (of texts, sounds, drawings, maps, photographs, films, etc.);
- libraries;
- museums;
- several institutions and organizations (e.g. Ministries, Universities, the Mass Media, etc.);
- cultural and antropological/folklore societies and associations; and
- several private collections.

In the past, the environmental control in housing institutions, as those mentioned above, was (whenever existed) orientated towards *the convenience of the visitors and the staff*. However, contemporary research shows that the control of environmental parameters in indoor areas in which cultural collections are housed should be based on the *preservation of the materials*, otherwise there is a danger of deterioration or even destruction of exhibits [1–19]. Environmental parameters—such as, relative humidity, environmental temperature and the temperature of exhibits, as well as improper lighting and atmospheric pollution—can deteriorate several cultural exhibits and have a great impact on their proper preservation.

2. Environmental parameters affecting the preservation of collections humidity

2.1. Humidity

There are three major categories of exhibits' deterioration affected by the relative humidity of the environment [1,5,6,11,16,17,20–22]:

1. changes in the size and the shape of the exhibits;
2. changes in the rate of the deterioration chemical reactions; and
3. changes in biological deterioration sources.

2.1.1. Changes in the size and the shape of exhibits

Materials—like wood, bones, ivory, parchment, leather, cloth, basketry (basket-weaving) products, straw material and several kinds of glue—that absorb humidity are expanded (inflated) when relative humidity rises and shrink when it falls. It is also well known that animals and plants contain a large amount of water and that products coming from these (organic) materials are to contain certain degree of humidity. On the one hand, when humidity is extracted from materials like wood, ivory or skeleton bones, these

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materials get smaller and often deformed; they may also crack and break. When humidity is extracted from layered organic materials—like paper, parchment, leather and cloth—these materials become fragile and their fibres are much easier to break. In contrast with lack of humidity, high humidity, even if it does not lead to an immediate and intense natural corruption, favors the development of mould and other microorganisms on exhibits, especially on those exhibits that are mostly composed of organic materials.

It is also known that objects created by several materials are housed in museums and that these materials usually absorb humidity. As expected, these materials have different reactions to the presence or absence of humidity and, whereas the highest degree of inflation of one of these materials could lead to the detachment of part of an object, it may also lead to its destruction. Inflation can also occur in objects of the same material as well as in different directions or velocity. The presence of inflation is primarily due to environmental parameters like temperature.

It is therefore evident that humidity must be controlled and remain stable in museums. The modification of humidity within 24 h or between seasons contributes to continuous alterations in the size and shape of the objects, thus accelerating their corruption and even their destruction. It should be noted, however, that the measurement of the absolute humidity of the air does not control the humidity in museums sufficiently because, if, for example, the humidity is defined in 10 g/m^3 of air and the air has high temperature, a dangerous drying can be caused on exhibits, while if the air has low temperature it can even lead to the condensation of humidity onto exhibits. In this case, relative humidity (RH) is preferred to absolute humidity and is represented in the following mathematical relation [17,23]

$$\mathrm{RH} = \frac{\text{water quantity in a specific air quantity}}{\text{highest water quantity that air can retain in this temperature}} \times 100\%.$$

2.1.2. Change in the rate of the deterioration chemical reactions

There are four major categories of chemical reactions that can lead to the deterioration or destruction of materials in a museum:

- the commencement or acceleration of metal corrosion [20,24];
- the fading of dye materials (on cloth or paper objects, as for example uniforms, vestments, paintings, etc.) [10,21,25,26];
- the decrease of paper and cloth resistance [6,27–30]; and
- the deterioration of some glass materials [17].

Even if the minimum relative humidity (i.e. 40–45%) for humidity-absorbing exhibits is selected in most museums, attention should also be paid to the maximum relative humidity so not to exceed the rate that is required for the preservation of unstable iron [*ferrum*] and bronze with traces of chloride salt and other unstable glass objects. Objects that are made of clear and good quality *ferrum* (i.e. of low sulfur content) or bronze with stable patina may be safe in relative humidity of 55% [17]. On the occasion that the *ferrum* is unstable, exhibits have to be kept in showcases. If dehumidified elements are used in showcases where valuable metal exhibits are stored, then the chloride lithium should be avoided as a drying material, because it is an electrolyte and can corrode metal objects, if transferred by air through dehumidified elements to metal surfaces. Dehumidified elements containing silica gel are more preferable in this case [10,17].

It should, nevertheless, be pointed out that, even if lead, pewter and silver are protected from corrosion by extremely dry environmental conditions and, even if these conditions may cause some problems, these problems are not so serious to require low humidity. For example, the tarnishing of silver is accelerated by high relative humidity, whereas the gold—compared to all metals—is unassailable by humidity of the surrounding environment.

2.1.2.1. The alteration of dye materials It can be claimed that the vast majority of the cotton, linen, wool and silk textiles are usually altered more in high relative humidity than in low humidity. However, the alteration rate of dye materials due to relative humidity of 60% in comparison to that of 30% is less than 2 on most occasions [17]. Thus, measures for the protection of textiles in a museum housing objects made by various materials are not advisable, unless these objects are of great historical or artistic value. Yet, when the majority of museum exhibits are textile materials, measures should be taken so that the relative humidity shall be about 45%. Moreover, tungsten rather than fluorescent lighting should be used, since the heat of tungsten (wolfram) lighting would make the relative humidity level lower than that in the surrounding area.

2.1.2.2. The glass exhibits case Even if glass materials are mainly used to store water and/or other liquids, there are some kinds of glass sensitive to humidity. There are indeed some specific glass structures in which sodium and potassium ions keep a small level of solubility. Eventually, with the presence of humidity sodium and potassium ions of these glass structures turn into sodium and potassium hydroxides, and—with the presence of carbon dioxide in the air—can also alter into carbonic sodium and potassium. Furthermore, combinations soluble in water attract humidity and result in the appearance of spots (drops) on the glass. During this process, small cracks appear on the surface of the glass, while it is very likely that the glass will lose its

transparency and acquire a gray or white color and a series of small-scale deteriorations. Relative humidity for glass should not exceed 40% [17].

2.1.3. Changes in biological deterioration sources

The development of mold is favored in relative humidity higher than 70% and especially in a hot environment with static air. The development of bacteria usually requires higher relative humidity.

2.2. Atmospheric pollution

Atmospheric pollution is probably the most important threat for the preservation of museum collections [1]. The influx of atmospheric pollutants—such as sulfur and nitrogen oxides, ozone, particulates and other combinations of local interest—and their ability to deteriorate and corrupt various exhibits significantly are of global and local concern [1,3,9,11,17,21,25,28,31–48].

2.2.1. Particulates

The combustion of fossilized fuels has increased the presence of particulates in the atmosphere of urban areas [1]. The use of contemporary air filters can cause the removal of 90% of particulates whose diameter is up to 2 nm small. However, 20% of suspended particulates have a smaller diameter [17]. The suspended particulates, especially fume, can:

1. smooth (and, eventually, corrupt) details of museum exhibits;
2. increase the possibility of the development of microorganisms;
3. leave traces of aesthetic and chemical pollution on the surface of exhibits; and
4. give a sense of neglectfulness.

The removal of particulates can be successful if mechanical filters of several types and rates and/or electrostatic filters are used. However, the use of electrostatic filters in museums is forbidden because they produce ozone. Ozone is a powerful oxidant in almost every object that could be housed in a museum. It also increases the oxidation of iron and silver and the sulfurization of silver and copper. It finally breaks any double bond in every carbon chain in contact, thus causing the creation of vertical cracks on a series of materials.

2.2.2. Sulfur oxides

With the aid of humidity, sulfur dioxide can turn into sulfuric acid, causing significant deterioration on a wide variety of exhibits. Exhibits endangered by the presence of sulfur oxides in their environmental area are those exhibits composed of:

1. carbon calcium (marble, limestone, wall-paintings);
2. cellulose (paper, cotton, linen);
3. silk;
4. iron; and
5. steel.

Table 1
Removal ability of air pollutants from air conditioning systems with water spraying and use of active carbon filters [17]

	Water spraying in air conditioning systems	Use of active carbon filters
Sulfur dioxide	Yes	Yes
Nitrogen dioxide	Yes	Some
Ozone	No	Yes

2.2.3. Nitrogen oxides

With the presence of humidity, the nitrogen dioxide can easily turn into the powerful nitric acid. It is worth mentioning that nitric acid is volatile. It has the same influences with the sulfur dioxide on exhibits, and causes or intensifies the corrosion of metal, thus accelarating the hydrolysis of cellulose.

2.2.4. Removal of air pollutants

As discussed above, air pollutants—such as, particulates, sulfur and nitrogen oxides and ozone, to mention a few—can cause and accelerate the deterioration and corruption of museum exhibits. Nevertheless, the deterioration and corruption of collections and museum exhibits can also be accelerated by a range of other environmental parameters, such as:

- abundant illumination;
- their continuous exposure to UV radiation;
- high temperature; and
- high relative humidity.

It is possible to remove air pollutants and prevent all other environmental parameters that deteriorate museum exhibits by installing [8,10,17]: (1) air conditioning systems with water spraying, which can remove sulfur and nitrogen oxides from the environment of the museum, and (2) active carbon filters (see Table 1). Nevertheless, when installing active carbon filters, it should be considered that, although these filters can sustain sulfur oxides in a satisfactory removal rate, they cannot always do the same for nitrogen oxides. As far as ozone is concerned, it can be removed not by its absorption on active carbon but rather by its destruction on the carbon surface or on the organic material absorbed by the filters.

It is worth mentioning that when papers are to be stored, the sulfur dioxide concentration has to be lesser than 1 $\mu g/m^3$ and the nitrogen dioxide concentration lesser than 5 $\mu g/m^3$ [32] (see Table 2).

2.3. Noise and vibration

The erection of museums near powerful noise pollution sources—such as, airports, railway stations, highways,

Table 2
Suggested concentrations of atmospheric pollutants in museums [8,17]

Combination	Concentration ($\mu g/m^3$)
Sulfur dioxide	< 10
Nitrogen dioxide	< 10
Ozone	0–2

etc.—should be avoided. The desirable rate for museums is 35 NR [17] for the noise produced in museums. Noise in a museum can be produced by:

- the wheeled vehicles traffic;
- the existence of noise pollution sources near the museum (i.e. airports, the underground, railway stations, industrial units, clubs, etc.);
- construction works in the neighboring area or within the museum itself;
- the noise of air conditioning or cleaning systems; and
- visitors.

Noise and vibration in a museum can cause:

- damage or even destruction of crystal and glass exhibits in unstable condition;
- the detachment of parts of unstable exhibits; and
- the inconvenience of visitors.

2.4. Temperature

Temperature in exhibition and storing areas of collections of cultural character is the third important factor of deterioration, immediately after the humidity and pollution.

The increase of temperature in the interior of museums can cause a variety of reactions [7,10,11,17,49].

1. The acceleration of the chemical process of the deterioration of materials. For example, when temperature increases from 15°C to 20°C, it can accelerate the corrosion rate of cellulose to about 250% (in dark and stable relative humidity) [17].
2. The acceleration of natural processes, such as the movement of water and air through stable particulates. Usually, 5°C temperature raise can increase the rate of such processes from 100% to 130% [17].
3. The expansion of exhibits materials.
4. The partial drying up of exhibits (made of wood, paper, leather and other) may result in raising the fragility level of these objects, especially, if the humidity is not kept stable.

Finally, the increase of temperature within museums can be caused by the (natural and artificial) illumination of objects. The illumination of objects can cause the drying up of exhibits, even though this drying is controlled and the humidity of the environment remains stable. For example, a wolfram lamp 500 lux can raise the temperature of an exhibit 2–3°C, depending, of course, on the color of the exhibit and the distance of the illumination source from the object [17]. Comparatively speaking, a fluorescent light lamp of the same power can cause half of the temperature raise that a wolfram lamp 500 lux can do, while natural light can cause even less.

2.5. Illumination

It is well known that the deterioration process of materials requires energy. Light is the most powerful source of energy in museums. Thus, (natural and artificial) illumination in museums can [12,14,15,27,50–53]:

- accelerate the deterioration and corruption of several materials, because it acts as a catalyst to their oxidization;
- subsidize and raise the fragility level of cellulose fibres (wood, paper);
- discolor, fade or blacken the paper;
- fading and/or alter the dye/painting colors and materials of works of art;
- corrode significantly every natural fabric;
- deteriorate exhibits in Natural History Museums; and
- increase the surface temperature of exhibits.

There are nevertheless exhibit materials—such as stones, metals, glass and ceramics/pottery (with a few exceptions)—that are not affected by light [1]. Here, it should be considered that natural light has the highest UV radiation rate, a fact that makes the use of filters at the windows in museums a prerequisite. Of the two kinds of filters—i.e. glass filters and plastic UV radiation filters, plastic UV radiation filters are recommended for the removal of UV radiation, since glass filters are not considered as highly efficient as the plastic ones. It should also be mentioned that fluorescent light lamps have smaller UV radiation rate than natural light but the use of filters between these lamps and the exhibits is also required when these lamps are used. Finally, the use of wolfram lamps requires no UV radiation filters [17].

3. Conclusions

It is therefore conspicuous that the control of the environmental conditions in the space in which goods of significant cultural value are housed is necessary nowadays. Besides, creating museums for the protection and management of several collections without having ensured the proper conditions for their preservation seems to be a paradox. Research for the environmental conditions of the museums has significantly increased worldwide, especially during the last decade. Curators, directors, managers and the staff of museums try to be as informed as possible about contemporary protection methods and any other developments in the field. They also take every possible measure in order to keep safe the collections for which they are responsible.

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