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APPLICATION OF THE QUALITY NORMS TO THE MONITORING AND THE PREVENTIVE CONSERVATION ANALYSIS OF THE CULTURAL HERITAGE

Abstract: *In recent years, the study of the indoor microclimate has assumed increasing importance, especially for the problems associated with the conservation of the cultural heritage housed in museums, galleries and libraries. In this paper, we describe the most important national standards relative to the procedures for the measurements and the analysis of the environmental conditions regarding the preservation of the works of art. These methods are related to the measurement techniques, which have to be applied for monitoring and analyzing the microclimatic conditions of museums, galleries and archives; these norms report, also, the threshold reference values for optimal climatic conditions. Furthermore, we present some considerations on the importance and on the foundations of the proposed scientific/methodological approaches.*
Finally, we have done a reasoned analysis on some reference values reported by the international regulations with some considerations on the possible chemical/physical mechanisms of degradation of the valuable objects.
Keywords: *Standards for the microclimatic quality analysis, preventive conservation analysis, indoor microclimatic conditions, heritage science*

1. Introduction

The story of the standards starts in the middle of the twentieth century, when in London, delegates, coming from different countries, began to discuss about the idea of international standards. Therefore, in 1951, the first ISO standard, about reference temperature for industrial length measurement, has been published. Since then, many norms have been published in many fields of interests. In this paper, we investigate the role of national standards for the protection and the conservation of the cultural heritage. In particular, in order to evaluate the microclimate of the confined environments where the artifacts are housed, we have applied two standards: the UNI 10586 and UNI 10829. Before entering into the merits of the arguments, it may be appropriate to introduce some key-concepts like the "preventive conservation" and the "risk" for the cultural heritage resulting from microclimate conditions. For this reason, first of all, it is appropriate to define the idea of "preventive conservation", which recently

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has highlighted the importance of taking measures to avoid future restoration works. The aim of this approach, in fact, is to focus our attention on the causes rather than on the effects. In this way, the question about the conservation of cultural heritage is indissolubly linked with the concept of risks to which the works of art are subject to. In the past, the conservation managers paid attention to the loss of cultural property due to episodes which could be defined, in some ways, extreme, like, for example: fires, thefts, earthquakes etc. Nowadays, the meaning of conservation includes also the probability of losses like the damages caused by the environmental conditions. In particular, during the last two decades, the environmental conditions of the museums and, more generally, of the storage area of artworks, have been shown to be the most crucial factor in order to preserve the collections and the artifacts. In the past, as mentioned above, the environmental monitoring did not play an important role in the management of a museums or archives. Furthermore, if the control of the environmental conditions was expected, it was mainly oriented towards the convenience of the visitors and the staff of the museums, rather than the degradation of the artifacts (Pavlogeorgatos, 2003). In this regard, several writers and scientists have investigated the role and the importance of monitoring the environmental parameters including Camuffo *et al.* (2001), Camuffo (1998) and Thomson (1986). Furthermore, in a museum or in a library, a great number of artifacts are storage and, usually, these are composed by different materials (from the paper to the wood, from to the stone to the marble, and so on). This enormous variety of valuable objects complicates the actions to protect them from the degradation processes, and for this reason, the study of microclimate conditions becomes essential. In particular, it means to evaluate "the environmental physical conditions due to either the atmospheric variables (temperature, humidity, sunshine and airspeed) or the exchanges with other bodies over a period of time representative of all the conditions determined by the natural and manmade forcing factors" (Camuffo, 1998). Therefore, it is necessary to monitor parameters like temperatures, humidity, lighting and pollutants concentrations in order to avoid or slow down the deterioration of several cultural objects. Because of the variety of the materials that composes the works of art, incorrect microclimatic values can be the cause of damage but, at the same time, also any environmental alteration can produce unwanted side effects for the deterioration of the artefacts (Corgnati *et al.*, 2009). For all these reasons, standards and norms are indispensable to assess and to advise the optimal values of the microclimate parameters. In particular, in this paper, we investigate the role of the procedures to monitor, to elaborate and to analyze the microclimate data exposed in the Ministerial Decree 10th May 2001 (MIBACT, 2001) and in two Italian standards (UNI10829, 1999 and UNI10586, 1997).

2. Analysis of the norms

Since Roman period, in Italy, the need and the duty to protect the cultural heritage have been considered very important (Lorusso *et al.*, 2014). The first research activities in the field of cultural heritage can be traced back to a joint initiative of the National Research Council (CNR) and the Central Institute for Restoration (ICR). In fact, in 1977, the NorMaL was established; it is a commission whose aim is to develop standard methods for the study of the alterations of stone materials and for the control of the efficacy of conservative treatment of artifacts of historical-artistic interest. In later years, (from 1996), the Commission has expanded its sphere of interest until has been reached a formal agreement between the current Ministry for Heritage and Cultural Activities and the Tourism (MIBACT) and the Italian Authority for Standardization (UNI). The

purpose of this committee is to develop a set of national technical norms. From that moment, the production of these norms, including the above mentioned UNI10586 and UNI10829, began.

Nowadays, a very important text in the current normative scenario is represented by the above mentioned Ministerial Decree 10th May 2001 entitled: 'Guideline on technical and scientific criteria and standards of functioning and development of museum'. The recommendations of this Decree are based on a deep analysis of the international documents developed by the American Association of Museum (AAM), the code of practice of the International Council of Museum (ICOM) and the Registration Scheme for Museum (as reported in the Decree itself). This decree defines, as suggested in the title, "the technical-scientific criteria and the minimum standards to be observed in order to ensure an appropriate level of collective fruition of the cultural properties, their safety and the prevention of the risks" (MIBACT, 2001). It is interesting to note that, for the first time, the lemma '*standard*', deduced from the English, is introduced in an Italian law. Usually, especially in Italy, it has the primary meaning of unit of measure chosen by an authority, or for a custom or for a unanimous consent; in this sense, the concept of standard is linked to meanings such as model, example, sample, criterion, rule, principle, parameter, grade or level (MIBACT, 2001). With regard to these aspects, it is appropriate to quote the definition of the term 'standard', as reported by European Regulation 1025 of 25th October 2012, that is: "a technical specification, adopted by a recognized standardization body, for repeated or continuous application, with which compliance is not compulsory and which is one of the following international standard, European standard, harmonized standard, national standard" (European Regulation N.1025, 2012).

We have been applied the methodologies and the procedures suggested in these standards in several case of study of microclimatic analysis of historical building (museum and library) in the urban area of Ravenna (Italy). The detailed results of these monitoring campaigns will be presented in other papers. However, on the other hand, in this paper, we would show an indispensable interpretation key for the results. In particular, we consider the two UNI norms and the Ministerial Decree, which we are going to analyze in detail.

2.1. UNI 10586:1997 - Climatic conditions for storage environments of graphic documents and features of the housings

This norm defines the microclimatic parameters (units and limits) for a correct conservation of the *graphic documents*, defined as an "information recorded on a support essentially consisting of paper material and parchment" (UNI10586, 1997). These documents may be stored in new or in historical buildings. First of all, we underline the relevant distinction between various typologies of conservational environment:

- Local for the storage: place where graphic documents are usually stored;
- Local for the consultation, reading and exhibition: rooms in which graphic documents are consulted and/or temporarily exposed.
- Local for photo-reproduction and restoration: in which graphic documents remain only for the time necessary to reproduce or restore them.
- Local for the access and the service: places that, generally speaking, represent the optional locations to those defined above, in which graphic documents can only pass for few a minutes.

Therefore, this norm suggests the correct microclimatic parameters for all the just characterized typologies and for their retention. This paper is concerned about the suitable environments for the conservation of artifacts. Therefore, in details, we analyze the most important limitations reported. The norm UNI10586 exhorts to follow some rules, but sometimes, these rules may involve some complications. For example, the norm underlines that the air conditioning or ventilation system have to ensure, continuously, from 5 to 7 re-circulation of the air (14-20% of air circulating in mass) per hour but, at the same time, the opening of the doors or the windows is forbidden (except for emergency cases, upon authorization). It is follow that, especially in historical buildings, in which is more improbable to find a new and an adequate air conditioning-ventilation system, it's quite complicated ensure, at the same time, these air exchange rates and the prohibition to open the windows. Regarding microclimatic parameters, the UNI 10586:1997 reports also thermo-hygrometric conditions, lighting values and indoor air quality limits.

In a place intended for the conservation of the library heritage, the acceptable range for the Temperature (T) is from 14°C to 20°C; furthermore, the Relative Humidity (RH) have to be kept constant between 50% and 60%. The norm, as consequence of the contingent daily or seasonal gradients of these variables, reports an acceptable tolerance of ± 2°C and ± 5%, respectively for T and RH. Thermo-hygrometric values have to be record uninterruptedly (by analogic instruments) or with a time interval not greater than 30 minutes.

Concerning the lighting, the UNI10586 considers the intensity, the duration and the distribution of the light sources. First of all, the direct sunlight have to be avoid; secondarily, it suggests the radiations with wavelength in the range from 400 to 760 nm. From these considerations, it's follow that it is preferred the radiation in the visible spectrum. Then the illuminance should be less than 75 lux, as a daily mean, and always less than 150 lux, during the period of time to enter into these rooms or for reading and consultation purposes.

The recommended air quality levels depend on the chemicals under consideration. In details, the norm indicates concentration limits for SO_2, NO_X, O_3 and PM (without specifying the particulate diameters). The acceptable values reported in the UNI 10586:1997 norm are:

- SO_2 and $NO_X \leq 10\ \mu gm^{-3}$
- $O_3 \leq 2\ \mu gm^{-3}$
- $PM \leq 50\ \mu gm^{-3}$

In this short summary of the UNI10586 norm, we have focused our attention on the characteristics of the places of conservation; however, we would underline that this norm shows, also, the recommended procedures and the features of the other places we have mentioned above.

2.2. UNI 10829:1999 – Properties of historical and artistic interest – environmental conservation – measurement and analysis

This norm prescribes the methodologies to measure thermo-hygrometric and lighting values in order to protect the cultural heritage. This norm gives, also, some recommendations about the procedures for processing and summarizing the monitored data in order to assess the state of conservation of the works of art and to avoid the eventual degradation processes. On this regard, values for the air temperature and for the relative humidity are suggested, as well as their daily gradient, maximum of luminance, maximum of ultraviolet radiation and maximum yearly light. We would underline that, in this norm, are reported reference values which have to be considered if no other specific recommendation are relevant. At this purpose, we highlight, as mentioned above, that the degradation processes depend on the nature of materials that compose the artifacts

under evaluation. In fact, in the scientific and technical world literature, one can find up to 33 categories of art of works, divided according to their organic, inorganic or mixture nature.

In the UNI 10829:1999 norm, there are, also, technical specifications about the characteristics of the instruments of measurement instruments (e.g. the range and the accuracy of the measures) and about the spatial extensions and temporal duration of the measurement campaigns. However, it should be interesting to note that it is necessary to get the measurements for a minimum of 15 days and, preferably, planning them in order to meet possible unusual, worst, climatic conditions. The norm highlights, also, the need, during the monitoring, of recording some information (for example: the doors and windows opening/closing time, the number of visitors, the time and the operational set up of the ventilation/conditioning system, the processes for the air exchange rate and so on). Furthermore, this norm incentivizes the partnership with the conservation responsible, also for the compilation of the forms reported at the end of the UNI10829.

With regard to optimal conditions for the paper documents, the UNI10829 suggests, in particular, that the temperature T has to be between 13°C and 18°C and that the Relative Humidity RH can range from 50% to 60%. The maximum daily thermic gradient is not reported, while the maximum recommended daily relative humidity gradient is 5%. In this way, it is possible to note some disagreement between UNI10829 and UNI10586. However, the just mentioned values are indicated for archival documents on paper or parchment, papyrus, manuscripts, printed books only. The UNI10829 explicitly reports the need to refer to the UNI10586 for graphic documents on paper or parchment.

2.3. D.M. 10th May - Guideline on technical and scientific criteria and standards of functioning and development of museum

This relevant Italian Decree prescribes that the possibility or the necessity of changing the conditions of the museum environments, according to the values reported below, should be evaluated after having carefully assessed the state of conservation of the artifacts, the geographical area where the museum is situated and the real possibility to ensure the regularity of the values. In details, we herewith report the values for the optimal conditions for conservation mentioned in the Decree:

- Paper and paper-mache 19°C - 24°C for T and 50% – 60 % for RH.
- Books and manuscripts: 19°C - 24°C for T and 50% – 60 % for RH.
- Papyrus: 19°C - 24°C for T and 35% – 50 % for RH.

Then the Decree suggests microclimatic conditions for the prevention by microbiological contaminates, too: in details, for the paper: 40-55 % for RH, 6% as the maximum daily gradient for RH (ΔRH_{24}), 18-22°C for T and 1.5°C as the maximum daily gradient for T (ΔT_{24}); for the books and manuscripts, 45%-55 % for RH, 5% as the ΔRH_{24}, T < 21°C and 3°C as the ΔT_{24}.

The Decree highlights that the proposed values for the microclimatic conditions are the most wide reported by the worldwide-specialized literature. Also in this case we underline some differences and discrepancies between the values suggested by the same norm; however, the same norm explains also that, in every case, the curators of the museum or of the library have to decide the most suitable conditions and, under appropriate situations, to resort all the actions, e.g. the use of cabinet, in order to realize the optimal conditions, even if different, in various part of the same environment.

Finally, we can highlight the importance of these limits for the different nature of materials that compose the artifacts; at the same time, we would, also, underline the remarkable variety of the suggested standards. A comparative literature search on of the thermo-hygrometric data is reported in Aghemo *et al.* (1999).

3. Discussion

As we have previously said, the necessary conditions to obtain an appropriate building conservation must also consider the recommended values for airborne gaseous pollutants given below (Table 1). It's very interesting to note that the Ministerial Decree itself suggests different values for each compound, derived by other cases study or by other standard (as the same UNI10586).

Table 1. Recommended limits of concentration of airborne gaseous pollutants indicated in Ministerial Decree. For [a] the values derivate from NISO-TR01/95, for the [b] from a study of Brimblecombe (1990)

Pollutant	Archives[a]	Museum[b]	UNI 10586
Ozone	5 – 10 ppb	1 ppb	2 μgm^{-3}
Nitrogen dioxide	5 – 10 ppb	2.5 ppb	2 μgm^{-3} (for NO_x)
Sulfur dioxide	5 – 10 ppb	0.4 ppb	10 μgm^{-3}

To illustrate the typical range of air pollution in buildings that houses artifacts, we report some measurements about ozone and nitrogen dioxide, respectively, in Figure 1 and Figure 2, based on the results reported in Ryhl-Svendsen (2006). In the following figures, we sketch also the limits suggested by the above mentioned standards, referred to some experimental data published in the literature.

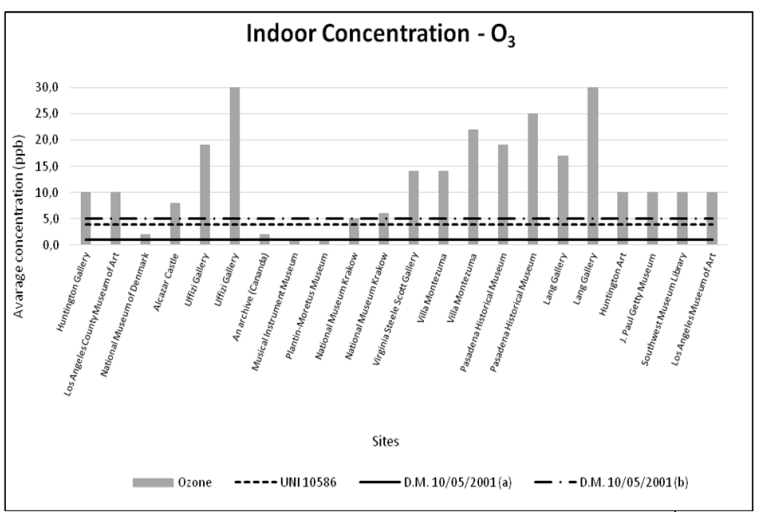

Figure 1. Indoor concentration of ozone (Ryhl-Svendsen, 2006)

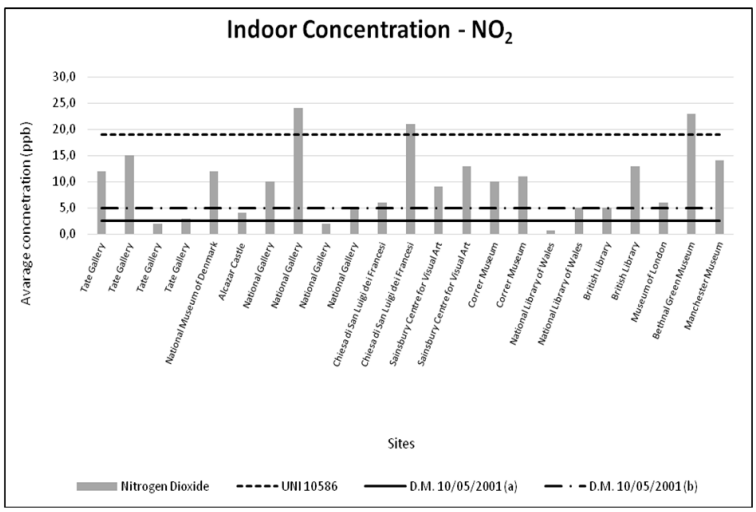

Figure 2. Outdoor concentration of nitrogen dioxide (Ryhl-Svendsen, 2006)

These data regard several studies performed in different periods of time; periods, especially of some years ago, in which the monitoring of the outdoor pollution was not so cogent as it is nowadays. However, these limits seem to be unobtainable. This observation is referred, especially, for the ozone, whose suggested threshold limits of 2 mgm^{-3} are particularly low; this limit is, in fact, even lower to "Detection Limit" of many analytical methods. In fact, the indoor ozone levels are, in the great majority of the cases analyzed in the literature, 30% to 70% the corresponding outdoor levels (Weschler, 2000). Even with these low values of the Indoor/Outdoor pollutants concentration ratio (the so called I/O ratio) the average concentrations of O_3 in the external urban area, where are many museums are placed, make very difficult to obtain the extremely low limits reported in the literature. Unless you use specific (and expensive) systems to reduce the ozone air concentration. For this reason, we are led to consider that some suggested standards (as the values derived from NISO-TR01/95 included in the Ministerial Decree) are particularly stringent for the indoor environment without air conditioning systems equipped with filters with high removal rate.

The Ministerial Decree asserts that these values derive from the few available references and that they would require some deeper clarification: with regard to the threshold values for nitrogen oxides and ozone, the data reported by Brimblecombe are those considered more appropriate. Then, it is also explained that, in every situations, is always desirable to optimize the quality of the air, when it is possible. To achieve this goal, one has to start, from the environmental monitoring, in order to implement all those interventions and management acts to reduce the concentrations of the airborne pollutants. When one has to project a system for conditioning the physical environment, he must always plan to implement a filtering system of the airborne gaseous pollutants, both outside, in the points where the outdoor air enter into the building and inside (even if the indoor air is recycled), to avoid the possible increase in the indoor pollutant concentrations.It is our opinion that the extremely low threshold limits reported by the norms are due to the basic methodological approach followed for the assessment of the effects of pollutants on cultural heritage. In fact, for many pollutants (e.g.: for the NO_2 or the O_3) for which it is not experimentally possible to obtain a

NOAEL (i.e: a Not Observed Adverse Effect Level) the preventive conservative approach is based on the concept of LOAED (i.e.: Lowest Observed Adverse Effect Dose), closely related to the NOAEL one (Tétreault, 2003). The *Dose* is defined as: *Concentration x Time* and the LOAED is defined as the cumulative dose at which the first signs of adverse effects are observed (measured) on a material. When a NOAEL cannot be determined with confidence or when it is not feasible, a dose can be determined as the product of the concentration of pollutant and the time required to observed the first signs of the adverse effect (Tétreault, 2003). Therefore, it is clear that the LOAED strictly depends on the time one believes to be significant for the cultural heritage protection. Typically, it is assumed that a reasonable period of time for the protection of a work of art could be 100 years. This means that, in the case that one determines, by experimental testing, that a concentration C_y, within a year, produces a minimum observable adverse effects, the corresponding LOAED is given by the concentration C_y divided by 100. This should be the reason for the low values of LOAEDs that are found in the literature. But, in our opinion, this assumption is somewhat oversimplified; this hypothesis, in fact, does not take into account other possible important phenomena, which may affect the real value of LOAED; e.g.: possible, not well studied, so far, mechanisms of catalytic activation in the early stages of the process of degradation, reduction phenomena, over the time, of the degradation rate, due, for example, to the pollutant diffusion deeper and deeper in the artwork matrix, the actual pollutants concentration in contact with the targets. It is well known in literature that some pollutant-material systems follow a linear reciprocity principle according to an experiment, but this reciprocity usually is not linear over a wider range of doses. In fact, the deterioration versus the dose can follow auto-retardant patterns where fast deterioration is observed at the beginning and is progressively reduced over time (Tétreault, 2003). All mechanisms which, in our view, would require future, specific and detailed experimental and theoretical studies.

4. Conclusions

Finally, in this paper, we would like to highlight the benefits and the difficulties coming, generally, from the use of normalized system: doubtless, the possibility to refer to threshold reference values helps the responsible, the manager and the curator of the museum to protect the cultural heritage. Furthermore, these limits could make aware the visitors and, more generally, all the citizens on these arguments. However, somehow, we cannot overlook the so called "the other side of the coin": that is to say that these norms are, in some cases, contradictory and difficult to implement.

In order to have more coherence and to overcome these contradictions, it would be necessary to perform effective and exhaustive experimental studies to determine the real relationship between the contaminants exposure and their effects in terms of degradation of the artifacts. It would be necessary, in our opinion, to determine the dose-response function, at least for "key-pollutants", i.e.: NO_2, O_3, SO_2, PTS, acetic acid, RH, T (Tétreault, 2003). In this way, it would be possible, for example, to experimental estimate the NOAEL (Not Observed Adverse Effect Level) and/or LOAED (Lowest Observed Adverse Effect Dose), which represent the basis of every scientifically based risk assessment for the cultural heritage.

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