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Original article

Proposal for a new environmental risk assessment methodology in cultural heritage protection

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ABSTRACT

In this paper, it is proposed a new methodology for the environmental risk assessment in cultural heritage, developed in close collaboration with conservation scientists and library collection managers. This New rIsk assessment methodology for Cultural HEritage protection (NICHE) is specifically addressed to the protection of cultural heritage housed in museums, galleries and archives. At the present stage of development, our proposal can be considered as a "relative risk assessment methodology" for the environmental risks to cultural heritage, as are many other methodologies for the risk assessment of works of art. However, NICHE is grounded in a new general definition of risk; it is inserted in a more general and wider conceptual framework, as far as the definition of risk is concerned. In addition, although it is a relative risk assessment methodology, NICHE takes explicitly into account the effects of microclimatic conditions on the works of art, based on the current scientific knowledge and requirements reported in international norms. Here the NICHE approach is applied to the results of two measurement campaigns carried out in 2014 over two different periods, considered "extreme" from the climatic point of view, in the Classense Library of Ravenna (Italy), a famous historical library which houses many books of great value. In these measurement campaigns, various indoor environments were characterized. Even though we focus our attention mainly on the risks related to effects of the microclimatic environment on the works of art, future extensions to other classes of risks, such as structural, related to usage, arising from natural phenomena (earthquakes, floods, storms. . .), infesting agents (pests, insects, moulds. . .), technical malfunctions, etc., can be easily performed. In fact, all situations where the effects of the sources of risk on the targets of interest can be described with an *S* shaped function (for example, a Dose-Response Curve, a Probit or a Logit models) can be treated with the NICHE approach, grounded in the comparison with threshold reference values reported in the technical/scientific literature and norms.

1. Research aims

NICHE, acronym of New rIsk assessment methodology for Cultural HEritage protection, an innovative methodology for relative environmental risk assessment in cultural heritage is described. This proposal derives from the awareness that the environmental conditions inevitably cause some changes (in many cases with relevant degenerative, irreversible effects) in the works of art over long time [1–5]. The innovation of our methodology lies in the wide and general conceptual framework and in the explicit consideration of the effects of microclimatic conditions on the works of art,

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based on the current scientific knowledge and consequent standard requirements. The methodology was applied to data obtained during two measurement campaigns of the microclimate conditions of the historical Classense Library. With the support of conservation scientists and library collection managers, we propose a new environmental risk assessment methodology, specifically addressed to the protection of paper based materials housed in libraries, archives or historical buildings, in relationship with their indoor microclimatic conditions. The proposed approach for the risk assessment of works of art is based on a new definition of risk [6], substantially different from many others [7]. Although the described methodology focuses on peculiar needs of the Classense Library, owing to its generality and wide applicative capacity, it can be easily extended to other environments and targets of interest, maintaining its basic structure.

2. Introduction

Over the last decades, many observations and studies [1–5,8] about the impact of the microclimate conditions on cultural heritage, both outdoors and indoors, have provided a better understanding of the mechanisms and kinetics of interactions between microclimate and works of art. This new knowledge has provided useful tools for the preservation management and for the definition and planning of cultural heritage preventive conservation actions [9]. These actions can contribute to the development of pragmatic policies of prevention against the effects of microclimate conditions in the context of cities, museums, galleries and archives, thus supplying new tools to collection managers, conservation scientists and other professionals for the preservation of cultural heritage. According to this perspective, preventive actions become the foundations of any cultural heritage protection plans.

These recent approaches to the problems of cultural heritage safety and preservation, mediated from other branches of knowledge (e.g., chemical or nuclear engineering, environmental sciences, toxicology) are based on risk management techniques [1,5,9,10].

Actually, the concept of risk is present in many modern scientific and technological fields; furthermore, over the last decades, the risk management field has developed many innovative approaches, well founded from the theoretical point of view [11–15].

Many risk assessment methodologies are grounded in a definition of Risk (R) as the product of the Danger (D) of the surrounding environment for the Vulnerability (V) of the works of art, that is [1,10]:

$$R = D \times V \tag{1}$$

Conversely, NICHE is based on a new definition of risk grounded in the systems theory and in the probability concepts [6]. It was developed to comply with the contingent needs of the Classense Library of Ravenna (Italy) and it was applied by the Director of Classense Library for the refurbishment (done in 2014–2015) of some halls of the building.

3. Material and methods

3.1. The experimental base

The experimental base of our methodology is represented by data collected during two measurement campaigns carried out, in the Classense Library, in two periods of 2014, considered to be "extreme" from the climatic point of view [8].

The choice of a given time interval depends on the aims of the monitoring and the available resources. The applied strategy can be considered also in accordance with the criteria of the so-called "macro-scale risk assessment" reported by some authors [9].

Different indoor environments of the Classense Library have been characterized in terms of several climatic parameters (for more details, see [8]). Monitored data have been compared with the specific values recommended by different standards for the preservation of the texts [3,16,17] and they have been used to define "Performance Indexes" of the building [18–20].

3.2. The adopted definition of risk

The present approach for the risk assessment of works of art is based on an innovative definition of risk [6,7], substantially different from the generally accepted definitions [1,5,9,10,21,22], including that reported in Eq. (1).[4]

As previously stated, the adopted approach defines the risk on the basis of fundamental concepts, such as the systems theory [23,24] and the probability [25,26]. In this way, it is possible to frame, in a single, broad and general theoretical context, basic concepts and principles applicable in many different fields of risk assessment. According to the proposed definition [6]:

The risk R for the Targets of Interest $\{T_i\}$, due to an Anomalous State ST_a of the System S which produces a Source of Risk SoR of Magnitude M_d, is given by the probability of an Adverse Effect E_a on $\{T_i\}$ caused by the SoR.

$$R = Pr\,(E_a, M_d) \tag{2}$$

In Fig. 1, we report the background definitions and their mutual conceptual relationships.

For the case study of the described methodology, the system S under consideration is represented by some halls of the Classense Library. The targets of interest $\{T_i\}$ are the paper based materials housed in, the possible adverse effects $\{E_a\}$ are the chemical-physical changes and consequences of the degradation mechanisms (e.g., browning of the pages, acidification and deterioration of the paper, loss of value etc.). The anomalous states $\{ST_a\}$ are the indoor microclimatic conditions. The magnitude M_d is expressed by the difference between monitored data and threshold values reported by the reference norms [3,16,17] (i.e., above an upper threshold, or below a lower threshold. A more precise and mathematically formal definition of M_d is reported below).

Thanks to the known general properties of unconditional and conditional probabilities [25,26], the risk can be rewritten as follows [6]:

$$R = Pr\,(E_a, M_d) = Pr\left(E_a \,\middle|\, M_d\right) \cdot Pr\,(M_d) \tag{3}$$

where:

$Pr(M_d)$ is the *unconditional probability* that the system S produces a source of risk of magnitude M_d and $Pr(E_a|M_d)$ is the *conditional probability* of an adverse effect E_a on the targets of interest $\{T_i\}$, due to M_d [6].[5]

Depending on the theoretical and operating approach to determine the $Pr(M_d)$ and $Pr(E_a|M_d)$ probabilities, we can recognize two different classes of risk assessment methods: the so-called "Absolute Risk Assessment Methodologies" (ARAMs) and the "Relative Risk Assessment Methodologies" (RRAMs).

The result of the application of an "Absolute Risk Assessment Methodology" is a probability, which is a pure number: $0 \le R \le 1$. Clearly, 0 is the (in some sense *idealistic*) situation of no risk for the targets of interest in the analyzed scenario and, on the other hand,

[4] This definition can be seen as a special case of the more general definition that we have applied and we hereafter present.

[5] It is conditioned by the occurrence of the source of risk *SoR* of magnitude M_d in the system *S*.

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