



# Indoor air quality evaluation of two museums in a subtropical climate conditions

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## ABSTRACT

Indoor air quality can affect and influence the state of works of art exhibited inside museums. Museums, usually suffer badly from the generally higher levels of air pollution and the control of such contamination requires continual evaluation and the strict monitoring, using by using the most appropriate materials. The main aim of this paper was to characterize, analyze and determine indoor air pollutants in Cypriot-Archeological and Byzantine museum. Experimental measurements have been carried out concerning the measurements of CO, CO<sub>2</sub>, PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>7</sub>, PM<sub>10</sub>, Relative Humidity (RH), O<sub>3</sub>, NO, NO<sub>2</sub>, SO<sub>2</sub>, Benzene (BEN), Tulane (TOL), Ethylene (ETH), Xylene (XYL), NH<sub>3</sub>, H<sub>2</sub>S, for a period of 12 months. Considering the safety of exhibits in both museums and from the final results, the quality of air unfortunately cannot be described as satisfactory. The findings from this study are useful to policy makers in order to develop a new strategy plan for indoor air quality and especially for museums.

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## 1. Introduction

Air quality (indoor and outdoor) is considered to be one of the main environmental issues as most of them still face the problem of poor air quality (Krupińska, Van Grieken, & De Wael, 2013). The World Health Organization (WHO) mentioned that due to air pollution in yearly base we have more than  $7 \times 10^6$  premature deaths (WHO, 2014). Among the main reasons are the combustion processes in industry, transport, households and agriculture. These combustion processes lead to emissions of various substances which have an impact on the environment and human health: gases such as carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) and sulphur dioxide (SO<sub>2</sub>), volatile organic compounds (VOCs), particulate matter (PM) and soot particles (Nemery, 2003). Other substances, like tropospheric ozone (O<sub>3</sub>), are formed by chemical reactions in the air and are known as secondary pollutants. In addition to the adverse effects on health effects and the environment, pollution is also harmful to many materials. At a low degree of air pollution, its direct effects on the materials are rather limited, but over longer periods, more severe effects such as surface alteration, color change or even weakening of the material may occur. Therefore, vulnerable and sensitive materials with

a historical or cultural value are kept under controlled conditions free from air pollution (Krupińska et al., 2013).

There is a little doubt that certain air pollutants can have a damaging effect on objects d'art through museums. The state of works of art in museums is strictly affected by physical and chemical conditions (Chianese et al., 2012). However, with today's levels of pollution (and especially in the air) there is a need to maintain and control the level of environmental conditions. In a museum space, ideal for fragile materials and objects with significant cultural and historical value considers the atmosphere to be free and clear from any internal sources of pollutants. According to Krupińska et al. (2013) atmospheric pollution is a serious and significant problem especially in historical buildings, such as museums, because they were not created or designed to serve the purposes of museum sites in order to protect the exhibits in a sustainable way. Air pollution mainly comes from outside and moves inside of a building when exchanging indoor/outdoor air through cracks in the walls (physical or through erosion and especially for old buildings) or other interstice of the building such as opened windows, doors and ventilation systems. The transfer of undesirable polluting substances can also be caused by tourists or from the museum's staff (Krupińska et al., 2013), this is the reason why the last years there has been a growing concern among curators of museums located in urban centers (NRC, 1986; Nazaroff et al., 1988; Nazaroff, Salmon, & Cass, 1990; Thomson, 1986). According to several researches (Brimblecombe et al., 1999; Camuffo et al., 1999; Gysels et al., 2004), pollutants in the air may affect monuments and artworks with

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negative consequences. This has to do with the reaction that happens between the pollutants in the air, with the surface of the artworks or exhibits. Pavlogeorgatos (2003) mentioned that, several environmental parameters such as, the RH, the ambient temperature, the temperature of the exhibits and the inappropriate lighting, may affect many cultural exhibits which may also have great impact on their proper retention and protection.

### 1.1. Historical review on indoor air quality in museums

Eastlake, Faraday, and Russel (1850) described the influence of atmospheric pollution in oil paintings, in the National Gallery of London for first time. Follows the Byne (1899) highlighted the specific problems created by the production indoor pollutants, e.g. observed corrosion in various materials from the emissions that come from wood shelving for storage of monumental exhibits, also described the seashell erosion. However, Byne (1899) failed to relate the erosion with the poor conditions which explained later on from Scott (1921) and Nicholls (1934). Those two researchers observed that the erosion was related with the ambient moisture which reacts with the metals surface which kept into show-cases from oak. Also, Thomson (1965, 1986), Padfield, Erhardt, and Hopwood (1982) and Hackney (1984) described the damages that are caused to objects of art from the pollution into museums. Several studies in the past have shown that SO<sub>2</sub>, NO<sub>x</sub>, and O<sub>3</sub> which found in the outside air can run through the ventilation systems in museums affecting museum exhibits (Davies, Ramer, Kaspyzok, & Delany, 1984; Druzic, Adams, Tiller, & Cass, 1990; Hackney, 1984; Hughes & Myers, 1983; Shaver, Cass, & Duzik, 1983; Thomson, 1965). Hisham and Grosjean (1991) mentioned that air pollutants that come from internal sources, such as formaldehyde, formic and acetic acid and chlorinated hydrocarbons, are presented in the air of the museum sites. Brimblecombe (1990) also referred to the relations of indoor and outdoor air pollution and how those affect museums. Damages due to the presence of formaldehyde, ozone, nitrogen dioxide, and organic acids have been reported from many other researches in the past and those are presented in many materials such as metals, paper, textiles and organic dyes or colors (Graedel & McGill, 1986; Grosjean, Whitmore, Pamela De Moor, Cuss, & Druzik, 1987; Hatchfield & Carpenter, 1986; Spedding & Rowlands, 1971; Weyde, 1972). A comprehensive report was published regarding the conservation conditions of the various collections of cultural heritage in the United States. 47% of museum sites in U.S were “certain” or “significant” damage to the collections, because of atmospheric pollution (Ryhl-Svendson & Glastrup, 2002). Camuffo et al. (2001) indicate that the control of the microclimate for preserving cultural heritage needs a special attention because of the huge variety of various works of art displayed in museums. The microclimate plays a fundamental role in the process of deterioration of materials. In fact, a particular museum exhibit may consist of different parts and different materials which are at risk from the microclimatic parameters resulting in their decay over time (Pavlogeorgatos, 2003).

The conservation and protection of typical collections such as woods, papers, leathers, among others, is directly related to the indoor environment of the museums, and it is especially sensitive to high levels of temperature and RH (Bencs et al., 2005; Cappitelli et al., 2009; Kontozova-Deutsch, Deutsch, Godoi, Van Grieken, & De Wael, 2011; Kontozova-Deutsch, Deutsch, Bencs et al., 2011; Lankester & Brimblecombe, 2012). When the RH is high, chemical reactions may start, just as when temperature is raised. Many chemical reactions require water which typically means that at high RH, chemical deterioration can proceed more rapidly. High RH also supports biological activity; for instance, mold growth is more likely as RH rises above 65%, as well as the insect activity (Godoi, Potgieter-Vermaak, Godoi, Stranger, & Van Grieken,

2008). For artwork, the best environment is a climatically stable one, where there is only slight variation in temperature and RH and where the air pollution concentration is sufficiently low. The synergism between pollutants, temperature and/or humidity can swell/shrink objects, and the results are destructive (Brimblecombe et al., 1999; Camuffo et al., 1999). The effect is remarkable because paint might crack on a canvas or pop off from a painted object, wooden veneers might peel away, glued joints on wooden furniture might fail, and wooden objects might be permanently warped. Looking at the air pollution indoors, where the most vulnerable artworks are stored, it is important to focus on components that have a potential deterioration effect such as some gases (e.g., NO<sub>2</sub>, SO<sub>2</sub>, and O<sub>3</sub>), particulate matter (PM) including black carbon (BC) (Kontozova-Deutsch et al., 2008). Acetic acid and formic acids (HAC and HFor), as well as VOCs like benzene, toluene, ethylbenzene and xylenes (BTEX), have also been considered due to their damage potential (Godoi et al., 2008; Schieweck, Lohrengel, Siwinski, Gensing, & Salthammer, 2005). These are also important facing the manifold sources of organic and inorganic pollutants in the indoor environment of museums.

In Mediterranean countries, such as Cyprus due to increased solar radiation, high temperature, high humidity and a growing use of vehicles, the photochemical air pollutants in combination with the above factors are considered to be important and significant that threaten museum exhibits. Many museum exhibits in Cyprus are hosted in old buildings with natural ventilation, and other modern buildings with central air conditioning, HVAC (heating, ventilation, and air conditioning). However, despite the keen interest that is observed worldwide for the indoor air quality in museums, in Cyprus, there is absence of interest and data regarding the quality of air inside the museums, galleries and exhibitors. Based on the literature and existing data, the research question that arises is: “how safe is the environment of museum spaces in relation to the quality of the air inside them and what problems arise with regard to the air quality of buildings in various museum exhibits”. Unfortunately, until now there is no proper strategy addressing the continued destruction of materials into a museum. The results will also allow estimating the quality of external and internal air, providing an insight idea of the potential risks for the collections of the museums that are exposed in the showcases and in galleries/halls. The development of new strategies for air pollution restrictions and new methodologies of protection is something new for Cyprus and it will lead to better environmental conditions.

The aim of this work is the characterization, analysis and the determination of indoor pollutants in Cypriot-Archeological and Byzantine museum which base in Capital Town (Nicosia). Through this research, suggestions for improving the quality of the interior environment in both museums are mentioned that can be taken into consideration to protect museum exhibits from possible future deterioration.

## 2. Materials and methods

### 2.1. Museums description

The Cypriot-Archeological museum is hosted in a building on Victoria St. in the old town of Nicosia, in the occupied part of the town. It was founded in 1888 as a privately run institution to protect the finds that started to come to light during the first legal excavations undertaken during the British rule of the Island. The museum currently consists of fourteen rooms surround an inner square shaped central area which includes offices, library, stores and maintenance areas findings. In the museum findings from the earliest periods of human presence on the Island are exhibited, from the 10th Millennium BC until the Roman period (Department of Antiques, Cyprus Ministry of Communication and Work, 2014).

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