THE INFLUENCE OF AIR POLLUTANTS ON DIFFERENT MATERIAL USED IN CONSTRUCTION OF MONUMENTS

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Abstract: *Urban pollution is one of the most important causes of historical buildings' degradation, thus losing valuable architectural vestiges. This paper presents a literature review concerning the damaging effects of various pollutants on broadly used materials in constructing monuments and buildings, part of the cultural heritage.*

Keywords: air pollution, cultural heritage, atmospheric corrosion

INTRODUCTION

Air pollution prevails to be the main challenge for urban areas and not only when it comes to designing policies that have to meet on the one hand goals regarding traffic efficiency, urban development and on the other hand, to address matters of well-being and conservation of the cultural heritage. Although, many steps of progress have been made in the last decades concerning reducing the level of emission for different pollutants, such as Sulfur dioxide (SO2), through the advancements in the industry and the heating systems of households – no longer being predominantly based on burning fossil fuels (Grøntoft, et. al., 2019; Patrón, et al., 2017). However, new emerging problems have accelerated the adverse effects of atmospheric pollution.

The poor construction management planning of the recent years in the main urban areas (Arsovski, et al., 2018) and the natural conditions of those regions, for example, wind circulation (Battista & Lieto Vollaro, 2017), generated changes in the quality of living. Traffic emissions continue to be a significant source of harmful pollutants (Vidal, Vicente, & Mendes Silva, 2019) - sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM), causing premature deaths (Arsovski, et al., 2018) and having an extensive role in the degradation of materials used in construction, notably in the case of buildings part of the cultural heritage (Christodoulakis, et al., 2017).

Modification in climatic factors, such as rainfall; wind circulation; temperature variations - caused by the increasing levels of pollution and the adverse effects of climate change (Christodoulakis, Tzanis, Varotsos, Ferm, & Tidblad, 2017; Vidal, Vicente, & Mendes Silva, 2019), lead to the accelerated destruction of the monuments and buildings included in those area's cultural heritage. These processes could have irreversible adverse effects not only on the aspect of individual cities but also on the general view of a country, as many times the aesthetic of a country's building heritage is associated with its global image (Arsovski, et al., 2018; Patrón, et al., 2017).

The primary atmospheric pollutants causing material degradation of building heritage are sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM). Sulfur dioxide (SO_2) is emitted through the combustion of sulfur-containing fuels. In contrast, nitrogen dioxide (NO_2) is formed mainly by the oxidation of nitrogen monoxide (NO) after combustion processes which take place at high temperatures (Benga, 2019; Boamfă, et al., 2018). Particulate matter (PM) is the generic term used for a mixture of aerosol particles (solids and liquids), with different sizes and chemical compositions. PM can come from natural sources: sea salt; suspended dust; pollen; volcanic ash or anthropogenic sources, especially from the burning of fuels for the production of heat and electricity (Benga, 2019; Vidal, et al., 2019).

This paper aims to present an opinion concerning the damaging effects of various pollutants on broadly used materials in constructing monuments and buildings, part of the cultural heritage.

The influence of pollutants on metals

The main damaging effect of pollutants on metal objects or surfaces of heritage buildings and monuments is corrosion due to environmental conditions (Vidal, et al., 2019). Corrosion is an irreversible electrochemical reaction between the metal and the compounds present in the environment, which leads to the modification of the metal or the initial alloy (Benga, 2019). These processes affect the overall aesthetics of the specific surface and decrease the metal's mechanical properties (Vidal, et al., 2019).

The presence of an electrolyte induces a corrosive reaction. Therefore, the exposure of the metal objects to wetness, due to condensed humidity (Vidal, et al.,2019), as a result of rainfalls, depending on their acidity, or thermal inversions (Patrón, et al., 2017), could be the main damaging factor of monuments and sculptures made by metal. In a study focusing on the impact of air pollution in Athens, the authors underline, also based on previous studies, that carbon steel is affected the most by corrosion processes (Christodoulakis, et al., 2017). Additionally, studies mapping pollutants impact in Mexico has demonstrated that degradation of its building heritage is mainly caused by acid rains (Castillo-Miranda, et al., 2017).

The influence of pollutants on glass

Atmospheric weather pollution is one of the main phenomena affecting glass surfaces. These processes can alter the glass's clarity, resulting in decreasing natural light levels and affecting the overall aesthetics of the building itself (Vidal et al., 2019).

Reversing soiling processes could represent a costly challenge to preserve glass surfaces. Soiling is connected with atmospheric pollution, being an easily noticeable effect of traffic emissions and acidic rainfalls. Grøntoft et al. (2019) present the cleaning costs of sheltered white painted steel and modern glass in their study. Reducing pollution levels could also reduce the amount of European money city administrations spend on cleaning due to air pollution.

The influence of pollutants on limestone, stone, marble

As in the case of metal objects and surfaces, in the case of limestone; stone and marble surfaces of buildings part of the cultural heritage, exposure to different environmental processes, such as acid rain; temperature variations, or acid depositions (Vidal et al., 2019) could cause irreversible aesthetic and structural damages.

The severity of the building's degradation effects depends mainly on the percentage these stone materials take up in the specific facility's entire surface (Lefevre, et al., 2016). The more porous is the stone material used for the construction, the more water it will take in, leading to the dissolution of carbonate minerals, gypsum formation, and in the most severe cases, even cracking (Castillo-Miranda, et al., 2017; Ortega-Morales, et al., 2019). Studies concerning pollutants impact on stone materials were conducted mostly in Europe, focusing on cases such as the one of the St. Rumbold's Cathedral in Mechelen, Belgium, where the erosion of its limestone surfaces was linked to gypsum formation (Castillo-Miranda, et al., 2017).

Several other processes regarding pollution can influence the appearance of stone surfaces. For example, surface deposits on stone, such as dust, black crusts, and soiling in general, are the ones that decrease the most of the aesthetic of these materials, ultimately also their resistance in time. However, the monitoring of these processes could improve the understanding of certain changes in pollution levels in a specific area (Ortega-Morales, et al., 2019; Patrón, et al., 2017) contribute to the implementation of more well-thought urban management programs.

The influence of pollutants on concrete and mortars

Carbonation is the most extensively studied influence of pollutants on concrete and mortars, as this process implies a chemical reaction between the atmospheric CO_2 and the cement products. This process reduces the cement's ph and leaves the surfaces without protection in corrosion (Vidal, 2019). When the layer of concrete weakens, it will undermine the building's structural resistance and lead to cracking and detaching. Thermal variations and

increased humidity, especially in valleys, can affect the concrete and mortar surface through volume contractions (Ortega-Morales, et al., 2019).

Conclusions

The decrease in coal use as a primary heating source leads to significant improvements in air quality and pollution tackling processes. However, global climate change (Patrón, et al., 2017) and other pollutants represent still a challenge to ensure the well-being and preserve cultural heritage.

The influence of pollutants on the different materials used for the construction of buildings, part of the cultural heritage, is a matter which impacts not only the structural resistance of these buildings but also the aesthetics of those areas, with lasting effects on living conditions and tourism.

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