Evaluation of stone decay hazard due to PM pollution using an "Heritage Climatology" approach: the case study of Milan

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Atmospheric Particulate Matter can induce the weathering of stone substrates exposed in urban environments (Camuffo 1982; Sabbioni 1995). In this respect, few literature studies have tried to evaluate the influence of PM with different chemical composition and properties, or the synergy between PM and thermo-hygrometric variations, exploiting an "Heritage Climatology" approach (Grossi et al 2011).

An assessment method for the evaluation of the decay hazard for stone materials is here presented: Deliquescence and Crystallization Relative Humidity (DRH and CRH) of $PM_{2.5}$ samples collected in Milan were experimentally determined with an electrical conductivity method in a custom-made Aerosol Exposure Chamber (AEC) (Ferrero et al. 2014). In the AEC humidification and dehumidification steps can be performed with a sensitivity up to 0.5%, and it is also possible to measure the electrical conductivity of PM samples during hygrometric variations. Observing the conductivity against RH plot, DRH and CRH values of forty $PM_{2.5}$ samples collected in the period 2006-2013 were determined (Table.1). Using a proper computation algorithm, DRH and CRH experimental values were compared with hourly environmental RH data provided from the local Environmental Protection Agency. In this way, indicators of stone decay hazard like Time of Wetness (TOW) and Number of Dissolution-Crystallization Cycles (Ncy) were derived (Casati et al. 2015). TOW was determined by adding up the hours in which PM was in a "wet" status: RH>DRH plus the hours in which RH was decreasing from DRH to CRH. A cycle was counted only when RH decrease under CRH starting from a condition in which PM was in a "wet" status. DRH and CRH depend on the PM chemical composition which depends on sites and meteorological conditions (Table.1).

TOW and Ncy describe different types of hazards since they are related to different decay-mechanisms. TOW suggests the possible presence of liquid water on stone surfaces, thus triggering several "chemical" decay-mechanisms. Ncy is related to mechanical stress occurring during crystallization events instead. Using the approach here described, it is possible to highlight that different stone decay hazards could be present according to the season (Fig.1). The "chemical" hazard prevails during winter which has high TOW (89±11%) and low Ncy (3±3 Ncy month^{-1}), while in summer the "mechanical" hazard is prevailing (TOW = 20±13%; Ncy month^{-1} =.11±5). Fall and spring present both high Ncy and TOW: they can be associated with the major potential impact for exposed stones. The results here presented are referred to the interesting case-study of Milan, where an huge built heritage lies in a European hot-spot for PM pollution (Po Valley). However the method is also applicable to different environmental situations . The method takes into account both the climatic and pollution characteristics at the site, providing a useful tool to evaluate stone decay hazard for the present or future scenarios.

	Winter	Fall + Sping	Summer
DRH	60±4%	61±3%	73±1%
CRH	39±6%	42±4%	52±5%
NO_3^-/Σ_{ions} %	53%	51%	11%
SO_4^{2-}/Σ_{ions} %	17%	21%	54%

Table 1. DRH and CRH seasonal mean values of Milan $PM_{2.5}$ samples. The abundance of Nitrates and Sulphates over the total ionic amount highlight the relationship between DRH and CRH and the chemical composition.

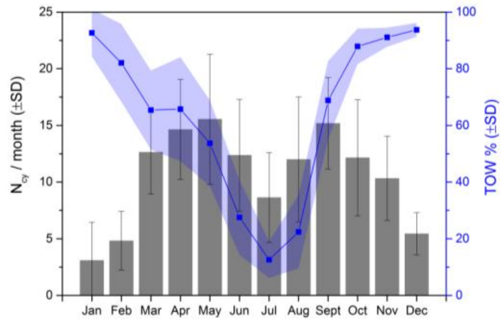

Figure 1. Mean TOW and Ncy computed for the last decade in Milan

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