2022 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
University of Calabria, Italy, October 19-21, 2022

Comparison process of air quality measurement systems applied to the context of cultural heritage

Nicoletta Lotrecchiano[1], Maria Ricciardi[2,3], Concetta Pironti[3], Andrea Bergomi[4], Valeria Comite[4], Vittoria Guglielmi[4], Paola Fermo[4], Daniele Sofia[1], Oriana Motta[3], Antonio Proto[2]

[1]DIIN-Department of Industrial Engineering, University of Salerno, Via Giovanni Paolo II, 132, 84084, Fisciano, Italy, nlotrecchiano@unisa.it, dsofia@unisa.it
[2]DCB – Department of Chemistry and Biology, University of Salerno, Via Giovanni Paolo II, 132, 84084, Fisciano, Italy, aproto@unisa.it, mricciardi@unisa.it
[3] Department of Medicine and Surgery, University of Salerno, via S. Allende, 84081 Baronissi, SA, Italy, mricciardi@unisa.it, cpironti@unisa.it, omotta@unisa.it
[4] Department of Chemistry, University of Milan, Via Golgi 19, 20133 Milan, Italy, andrea.bergomi@unimi.it, valeria.comite@unimi.it, vittoria.guglielmi@unimi.it, paola.fermo@unimi.it

***Abstract* – Air pollution is a problem that affects both human health and the state of historical artifacts. The interaction between pollutants and historical artifacts leads to a material degradation and therefore to the ruin of the artistic heritage. To define the impact of air quality on historic artifacts, it is necessary to measure these levels through an air quality measurement system. In this study the levels of particulate matter, PM10, PM2.5 and PM1, measured in the historic sanctuary of the Beata Vergine dei Miracoli in Saronno (Varese) were analysed using two measuring devices. Two air quality sensors, operating 24/24h and 7/7 days, were installed inside the sanctuary near the "Last Supper" wooden sculptural group realized during Renaissance period by Andrea da Corbetta and decorated by Alberto da Lodi. Similar concentration values and trends were observed with the two devices. Particulate matter levels were often above the recommended values for conservation and this may pose a threat to the artifacts present in the sanctuary. The two sensors return similar values in both trends and measured concentrations. From the analysis of the particulate matter levels it can be seen that they are high and sensitive to the activities, such as religious services, that take place in the sanctuary.**

I. INTRODUCTION

As defined by the US Environmental Protection Agency (EPA), particulate matter, also known as particles pollution or PM, is a complex mixture of extremely small particles and liquid droplets. Particles pollution is made up of a number of components, including acids (such as NOx and SO_2), organic chemicals, metals, and soil or dust particles [1]. The particulate is divided according to the aerodynamic diameter into PM10 with an aerodynamic diameter of less than 10 µm, capable of penetrating the upper respiratory tract and PM2.5 with an aerodynamic diameter of less than 2.5 µm, capable of reaching the lungs and secondary bronchi. The ultrafine PM1 fraction has an aerodynamic diameter of less than 1 µm and can more easily penetrate the respiratory system [2]. The fine particles are characterized by long residence times in the atmosphere and can, therefore, be transported even at a great distance from the emission point.

The dangerous effects on human health depend on both chemical composition and particle size. The larger ones (PM10) give rise to irritation and allergies; those with a diameter between 5 and 10 µm reach the trachea and bronchi; finally, those with a diameter of less than 5 µm can penetrate to the pulmonary alveoli and interfere with the natural gas exchange within the lungs [3]. Moreover, fine particles can carry on their surface other pollutants such as heavy metals and hydrocarbons (high molecular weight polycyclic aromatic hydrocarbons), which are known to have severe repercussions of human health [4]. In fact, chronic exposure to particulate matter contributes to the risk of developing respiratory and cardiovascular diseases as well as an increase in the risk of lung cancer [5].

Using the pollutants measured concentrations it is possible to evaluate human exposure [6]. The presence of outdoor pollutants is due to various sources such as vehicular traffic, industrial emissions, domestic heating, biomass burning [7] or accidental events such as explosions or fires [8]. Pollutants, such as particulate matter, tend to form also indoors and hence accumulate with the outdoor particles [9]. It is known that human activities (cooking food, cleaning with chemical agents, etc.) [10] [11] and the substances present in all the furnishing elements, add to external pollutants coming from outdoor and accumulate in the walls of homes or workplaces. In the World Health Organization (WHO) report "Ambient Air Pollution: a global assessment of exposure and burden of disease, atmospheric pollution (outdoor and indoor)" indoor air pollution is recognized as the main environmental risk factor for the world population's health. In fact, it is estimated that in developed countries the population spends 90% of their time indoors (homes, offices and schools), hence indoor air quality becomes crucial for health and well-being [12] [13].

The harmful effects of indoor and outdoor pollution also affect artworks, in fact air pollution and climatic factors contribute synergistically to accelerate the natural deterioration processes of the materials that make up the artworks. The variety of degradation types on cultural heritage generally depends on the composition of the materials making up the monuments and on the climatic, environmental and topographical characteristics of the territory with which the assets interact. In the troposphere which represents the part in contact with the earth's surface, there are naturally many organic and non-organic compounds, including nitrogen oxides, sulphur and atmospheric dust. The latter consists of a multiplicity of metal-based substances that can be classified as an inert powder [14]. In urban environments, on the other hand, there is a greater formation of nitrogen oxide and particulate matter deriving largely from the combustion of petroleum derivatives, especially from diesel engines [15]. This imbalance also accentuates the formation of strongly oxidizing substances, such as ozone, which contribute to the formation of new pollutants of secondary origin. In closed environments, airborne particulate is produced by combustion such as from candles, cigarettes and fireplaces and is mainly below the micron. So, in places such as churches, museums, historical buildings, where there are often candles, incenses or tourists, it is necessary to limit the sources due to small combustions and to have good ventilation to avoid the pollutants accumulation [16] for both the people who work there and for the artistic works therein.

Most of the entire world historical-artistic heritage is found in Italy, with over 60,000 cultural assets registered on the national territory [17]. In recent decades, the historical-artistic heritage has, in general, undergone a greater deterioration than that which has been seen in the past, so much so that atmospheric pollution is considered one of the most important contributing causes of this process [18]. The main causes of material degradation can be natural (such as frost, saline crystallization, microclimate and temperature changes) and anthropogenic, mainly represented by atmospheric pollution. Atmospheric pollution modifies the chemical, physical and biological properties of the air, inducing more or less serious alterations to human health and artefacts. The impact of atmospheric pollution on inert materials such as monuments is huge and irreversible, due to the lack of self-defense systems and the disposal of toxic elements, which are instead present in humans. The European guidelines on air pollution are currently aimed at the protection of human health and natural ecosystems and do not yet include the protection of the historical and artistic heritage; the only exception is for the artworks exhibited inside museums for whom recommended values and guidelines are defined.

The particulate deposition on the surfaces of artifacts of historical and artistic interest is not a simple phenomenon of absorption on the surface [19] [20], as the powders are often cemented in a physico-chemical process that includes the deposition of a veil of water and chemical reactions between the material and the acids contained in this corrosive solution, thus becoming an integral part of the material; as well as occurring on the surface, these reactions can also affect deeper layers of the material. As for the particulate matter, its effect on historical artifacts is given by the fouling determined by the deposit of carbonaceous particles [21] on the monument surface and which occurs instead in areas protected from rain and physical stress (determined by climatic and microclimatic factors). Physical stress considers some parameters such as: the wetting time (evaluable as the annual period in which the relative humidity is higher than 80%), the ambient temperature frequency oscillation around 0 ° C and the freezing of the material [22].

To verify the effects of atmospheric pollution on cultural heritage located outdoors, monitoring campaigns are carried out to measure the main pollutants [23] [24] [25] [26] and then an attempt is made to correlate the pollutant concentrations measured with the absorption by the monuments [27].

The outdoor air quality measurement systems generally used are represented by the networks of national public institutions which, however, have a low spatial and temporal resolution. In recent years, numerous technologies based on the Internet of Things (IoT) have been developed that allow the pollutants measurement with high spatial and temporal resolution [28]. These measurement tools are the basis of appropriately designed networks [29] capable of measuring the pollutants levels that represent the starting point for studies that can provide detailed information on air quality [30] [31] and be supportive of the implementation of policies for their reduction [32]. To further increase the spatial resolution of the measured data, real-time on-road monitoring systems have been developed in recent years which provide information on pollutants with a resolution of 1 km^2 [33] [34]. The knowledge of the pollution levels can lead to the analysis of the events that influence this phenomenon [35]. In particular, the Saharan dusts being classified as PM10, are seen by the measurement systems that include them in the measured concentration without splitting the type of particle: urban particulate is made of metals while Saharan dust particle are made of siliceous compounds [36] [37]. So, the knowledge of the parameters that could influence the pollutant accumulation is fundamental for a correct air quality analysis. Modern smart measurement systems provide real-time data and are also used for the measurement of indoor pollution for which they are designed to integrate perfectly with the furniture.

The aim of this work is to compare the two air quality sensors installed inside the sanctuary between 27/04/2022 and 14/05/2022. The values measured have been compared and the results analysed accounting also for the sanctuary activities that may influence the pollutant levels.

II. MATERIALS AND METHODS

A. Site description

The sanctuary of the Beata Vergine dei Miracoli, located in the northern Italian city of Saronno (VA) was built between the fifteenth and sixteenth centuries. There are numerous artworks that decorate the sanctuary. Bernardino Luini, a disciple of Leonardo da Vinci, was entrusted from 1525 to 1532 with the decoration of the entire initial part, creating the frescoes in the presbytery, and the cloister. In the side chapels there are two wooden sculptural groups created by Andrea da Corbetta and decorated by Alberto da Lodi. The wooden statues of the "Last Supper", as shown in Figure 1, and of the "Deposition" stand out among all the artistic artefacts. The sanctuary is regularly open to the public and welcomes daily numerous tourists and worshippers from all over the world.

Fig. 1. Wooden statues of the Last Supper.

B. Air quality data

To monitor the levels of airborne pollutants dispersed within the sanctuary, two different sensors were installed at sensitive points regarding the artworks. The sensors were installed near the wooden statues representing the "Last Supper", near the altar. In Figure 2 it is possible to see the two sensors installed vertically (S1 and S2). The Sensy (S1) sensor at the top developed by Sense Square (WIPO 2018/225030AI) and the PersonalDustMonit (S2) sensor by Contec, are laser scattering sensors that allow the continuous measurement of PM10, PM2.5 and PM1 particles with a high temporal resolution and microclimatic parameters such as temperature, atmospheric pressure and relative humidity. The sensor characteristics are reported in table 1.

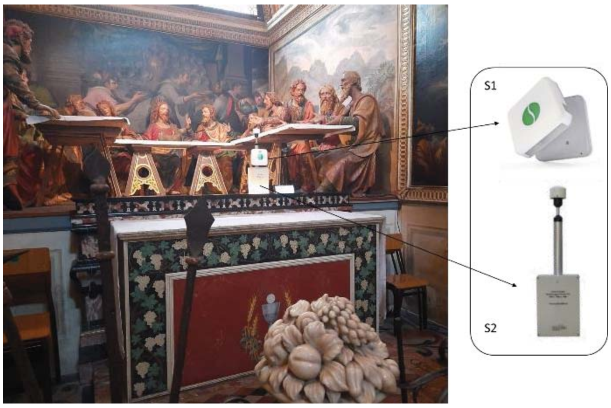

Fig. 2. Sensors' location.

Table 1. Sensors' characteristics.

Parameter	Sensitivity	Technology
Temperature	±0.3 °C	Band-Gap
Relative Humidity	±2%	Capacitive
PM10	±5 μg/m^3	Laser scattering
PM2.5	±5 μg/m^3	Laser scattering
PM1	±5 μg/m^3	Laser scattering

III. RESULTS

From the data obtained in the monitoring days, the daily averages of S1 and S2 for the pollutants considered (PM10, P2.5 and PM1) were calculated. Figures 3-5 show the trends of the daily average concentrations and the relative 75th and 25th percentiles. In Figure 3 is also reported the limit range as suggested in the D.M. 10/05/2001, "Guidance document on technical-scientific criteria and on the functioning and development standards of museums" [38] by the Italian Ministry of Cultural Heritage (MIBACT) for the indoor pollutants limits (20-30 μg/m^3) for the PM10. PM2.5 and PM1, being a fine particulate fraction and for this reason its measurement is very sensitive to the instrument used, for the moment it is not included in the legislation and therefore Figures 4-5 does not contain any limits.

Analyzing the results obtained by the two sensors, it can be seen that they have the same trend. The difference in the measured values lies in the different positioning height. From the analysis of Figures 3-5 it can be seen how the values remain in a range of medium-high values until 1/06.

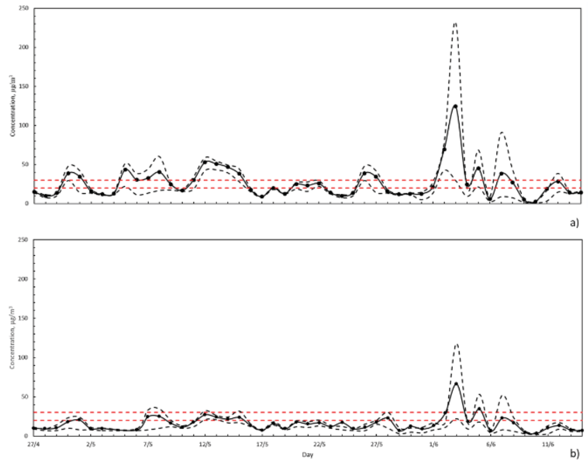

Fig. 3. PM10 daily average concentration (solid black line) measured in a) S1 and b) S2. 25th and 75th percentile of the daily averages (black dashed line), and PM10 daily limit between 20 and 30 μg/m³ according to D.M. 10/05/2001 - MIBACT 2001 (red dashed line).

In general, PM10 reaches high values in correspondence with events that include small combustions such as lighting of candles and incense. In particular, the measured peaks (Fig. 3) are in correspondence with specific events such as, religious services or the lighting of the incense on the altar in the immediate vicinity of the suction point of the S1 measuring device. Analyzing the daily trends (Figures 3-5), there are some peaks in the measurements obtained that have higher values in the S1 measurements. The two measuring devices used are different both in the geometry and in the instruments sensitivity. However, taking the long-term average, the values obtained are similar; the Sensy (S1) measuring system is however more sensitive to impulsive phenomena that are captured well by the sensor.

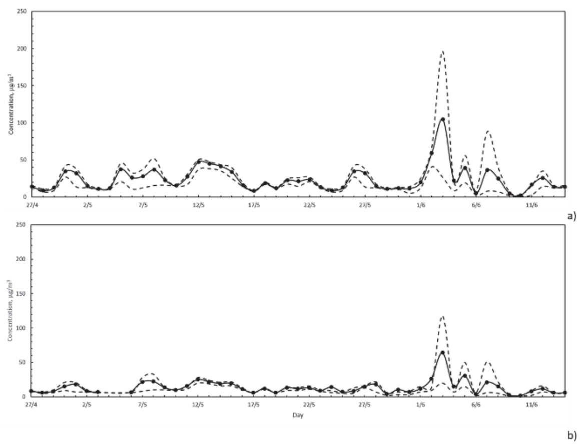

Fig. 4. PM2.5 daily average concentration (solid black line) measured in a) S1 and b) S2. 25th and 75th percentile of the daily averages (black dashed line.

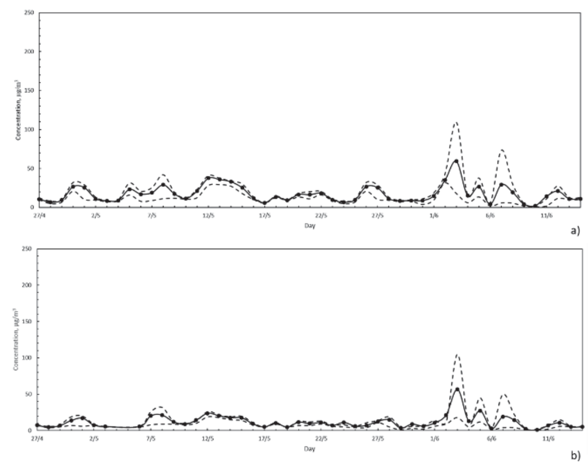

Fig. 5. PM1 daily average concentration (solid black line) measured in a) S1 and b) S2 25th and 75th percentile of the daily averages (black dashed line).

The particulate levels measured by the S1 and S2 measuring devices, as shown in figures 3-5, are very close and indicate a constant condition of medium-high pollution with PM10 average values of 26 and 16 µg/m³ for S1 and S2 and of 23 and 13 µg/m³.for PM2.5 for S1 and S2 respectively. In closed places, such as museums or in this case a sanctuary, ventilation is always very poor. This leads to the accumulation of pollutants that can derive, as mentioned above, from small combustions. The more pollutants persist in the environment, the greater the absorption of them by people and works of art. It is worth noticing that PM10 concentration registered are often higher than the values suggested by the Italian D.M. 10/05/2001

IV. CONCLUSION

Two sensors for the particulate matter measurement were installed near the wooden statues in the sanctuary of the Beata Vergine dei Miracoli in Saronno (Milan, Italy). These sensors, placed vertically near the altar, gave consistent values. The sensors use the same measurement principle but the suction section is placed at different heights so that the sensor closest to the pollution source is more influenced and therefore higher measurements were observed. The measurements values difference depends on the instruments design and sensitivity and, S1 is more sensitive to impulsive phenomena. The measured particulate values – PM10, PM2.5 and PM1 – are around medium-high values. Furthermore, in predominantly closed places such as the sanctuary analyzed, it is strongly recommended to use ventilation systems that allow air changes to reduce particulate levels to reduce the pollution exposure both for humans and artifacts.

REFERENCES

[1] US Environmental Protection Agency (EPA) available online at www3.epa.gov/region1/eco/uep/particulatematter.ht

ml#:~:text=%22Particulate%20matter%2C%22%20also%20known,and%20soil%20or%20dust%20particles

[2] R.Brugha, J.Grigg, "Urban Air Pollution and Respiratory Infections", Paediatric Respiratory Reviews, Vol. 15, No. 2, 2014, pp. 194–99. DOI: 10.1016/j.prrv.2014.03.001

[3] F.Schulze, X.Gao, D.Virzonis, S.Damiati, M.R.Schneider, R.Kodzius, "Air Quality Effects on Human Health and Approaches for Its Assessment through Microfluidic Chips", Genes (Basel), Vol. 8, No. 10, 2017, doi: 10.3390/genes8100244.

[4] J.A.Araujo, A.E.Nel, "Particulate matter and atherosclerosis: role of particle size, composition and oxidative stress", Part Fibre Toxicol, Vol. 6, No. 24, 2009, https://doi.org/10.1186/1743-8977-6-24

[5] World Health Organization, "WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide", World Health Organization, 2021, https://apps.who.int/iris/handle/10665/345329.

[6] N.Lotrecchiano, L.Montano, I.M.Bonapace, G.Tenore, P.Trucillo, D.Sofia, "Comparison Process of Blood Heavy Metals Absorption Linked to Measured Air Quality Data in Areas with High and Low Environmental Impact", Processes, Vol.10, 2022, https://doi.org/10.3390/pr10071409

[7] A. Bergomi, C. Morreale, P. Fermo, G. Migliavacca. "Determination of pollutant emissions from wood-fired ovens". Chemical Engineering Transactions, Vol. 92, 2022, Pages 499-504.

[8] N.Lotrecchiano, D.Sofia, A.Giuliano, D.Barletta, M.Poletto, "Pollution dispersion from a fire using a Gaussian plume model", International Journal of Safety and Security Engineering, Vol. 10, 2020, pp. 431–439, doi:10.18280/ijsse.100401.

[9] G.Settimo, "Existing Guidelines for Indoor Air Quality : The Case Study of Hospital Environments", Indoor Air Quality in Healthcare Facilities, 2015, pp. 13–27.

[10] L.Stabile, G.Buonanno, P.Avino, Afrattolillo, E.Guerriero, "Indoor Exposure to Particles Emitted by Biomass-Burning Heating Systems and Evaluation of Dose and Lung Cancer Risk Received by Population" Environmental Pollution, Vol. 235, 2018, pp. 65–73.

[11] L.Stabile, E.R.Jayaratne, G.Buonanno, L.Morawska, "Charged Particles and Cluster Ions Produced during Cooking Activities", Science of the Total Environment, Vol. 497, No. 498, 2014, pp. 516–26.

[12] J.Saini, M.Dutta, G.Marques, "Chapter 6 – Indoor air pollution: a comprehensive review of public health challenges and prevention policies", Editor(s): Gonçalo Marques, Joshua O. Ighalo, In Intelligent Data-Centric Systems, Current Trends and Advances in Computer-Aided Intelligent Environmental Data Engineering, Academic Press, 2022, pp. 105-126, https://doi.org/10.1016/B978-0-323-85597-6.00006-9.

[13] P. Ielpo, C. Mangia, G. de Gennaro, A. Di Gilio, J. Palmisani, A. Dinoi, A. Bergomi, V. Comite, P. Fermo. "Air Quality Assessment of a School in an Industrialized Area of Southern Italy. Applied Science, Vol. 11, Issue 19, 2021, pp 8870-8881.

[14] S.G.Poulopoulos, "Chapter 2 – Atmospheric Environment", Editor(s): Stavros G. Poulopoulos, Vassilis J. Inglezakis, Environment and Development, Elsevier, 2016, pp. 45-136, https://doi.org/10.1016/B978-0-444-62733-9.00002-2.

[15] M.Guevara, "Emissions of Primary Particulate Matter, in Airborne Particulate Matter: Sources", Atmospheric Processes and Health, 2016, pp. 1-34 DOI: 10.1039/9781782626589-00001.

[16] R.Debnath, R.Bardhan, R.Banerjee, "Taming the Killer in the Kitchen: Mitigating Household Air Pollution from Solid-Fuel Cookstoves through Building Design." Clean Technologies and Environmental Policy, Vol. 19, No. 3, 2017, pp. 705–19.

[17] Ministero dei beni culturali ed ambientali – Istituto centrale per il restauro, "Carta del Rischio del Patrimonio Culturale", ATI – MARIS , Vol. 1, Roma 1996.

[18] P.Bonanni, R.Daffinà, R.Gaddi, V.Silli, M.Cirillo, C.Cacace, A.Giovagnoli, "I risultati dello studio sperimentale APAT-ICR per la valutazione del danno dei beni storico-artistici esposti all'aperto", APAT report, 2006, ISBN 88-448-0170-1

[19] M.Baglioni, G.Poggi, D.Chelazzi, P.Baglioni, "Advanced Materials in Cultural Heritage Conservation", Molecules, Vol. 26, No. 13, 2021, doi: 10.3390/molecules26133967.

[20] M.Aucouturier, E.Darque-Ceretti, Evelyne, "The surface of cultural heritage artefacts: Physicochemical investigations for their knowledge and their conservation", Chemical Society reviews, Vol. 36, 2007, pp.1605-21. 10.1039/b605304c.

[21] A. Bergomi, V. Comite, C. Della Pina, C. Cavaterra, V.L. Gianelle, P. Fermo. "Development of a new procedure for the assessment of particulate matter (PM) carbonaceous fraction on stone materials exposed to atmospheric pollution. Journal of Physics: Conference Series, Vol. 2204, 012106, 2022.

[22] P.Bonanni, C.Cacace, A.Giovagnoli, R.Gaddi, "Gli effetti dell'inquinamento atmosferico sui beni di interesse storico-artistico esposti all'aperto", APAT – Dipartimento Stato dell'Ambiente e Metrologia ambientale, Servizio Inquinamento Atmosferico e Ambiente Urbano, 2006.

[23] S.Lopez-Aparicio, T.Grøntoft, E.Dahlin, "Air quality assessment in cultural heritage institutions using EWO dosimeter", E-Preservation Science, Vol. 7, 2010.

[24] V.Comite, A.Miani, M.Ricca, M.La Russa, M.Pulimeno, P.Fermo, "The impact of atmospheric pollution on outdoor cultural heritage: an analytic methodology for the characterization of the

carbonaceous fraction in black crusts present on stone surfaces", Environmental research, Vol. 201, No. 111565, 2021.
https://doi.org/10.1016/j.envres.2021.111565
[25] A.Winkler, T.Contardo, V.Lapenta, A.Sgamellotti, S.Loppi, "Assessing the impact of vehicular particulate matter on cultural heritage by magnetic biomonitoring at Villa Farnesina in Rome, Italy", Science of The Total Environment, Vol. 823, 2022, https://doi.org/10.1016/j.scitotenv.2022.153729.
[26] P. Fermo, V. Comite, C. Ciantelli, A. Sardella, A. Bonazza. "A multi-analytical approach to study the chemical composition of total suspended particulate matter (TSP) to assess the impact on urban monumental heritage in Florence". Science of the Total Environment, 740, art. no. 140055, 2020, DOI: 10.1016/j.scitotenv.2020.140055.
[27] C.M.Grzywacz, "Monitoring for Gaseous Pollutants in Museum Environments", Tools of conservation, 2006, Getty Publications, Los Angeles, California 90049-1682.
[28] D.Sofia, A.Giuliano, F.Gioiella, D.Barletta, M.Poletto, "Modeling of an air quality monitoring network with high space-time resolution", Computed Aided Chemical Engineering, Vol. 48, pp.193-198, 2018.
[29] D.Sofia, N.Lotrecchiano, A.Giuliano, D.Barletta, M.Poletto, "Optimization of number and location of sampling points of an air quality monitoring network in an urban contest", Chemical . Engineering Transactions, Vol. 74, 2019, pp. 277–282, doi:10.3303/CET1974047.
[30] N.Lotrecchiano, F.Gioiella, A.Giuliano, D.Sofia, "Forecasting Model Validation of Particulate Air Pollution by Low Cost Sensors Data", Journal of Modeling and Optimization, Vol. 11, No. 2, 2019, pp. 63–68, doi:10.32732/jmo.2019.11.2.63.
[31] N.Lotrecchiano, D.Sofia, A.Giuliano, D.Barletta, M.Poletto, "Spatial Interpolation Techniques For innovative Air Quality Monitoring Systems", Chemical Engineering. Transactions, Vol. 86, 2021, pp.391–396, doi:10.3303/CET2186066.
[32] D.Sofia, F.Gioiella, N.Lotrecchiano, A.Giuliano, "Mitigation strategies for reducing air pollution", Environmental Science Pollution Research, Vol. 27, 2020, pp. 19226–19235, doi:10.1007/s11356-020-08647-x.
[33] N.Lotrecchiano, D.Sofia, A.Giuliano, D.Barletta, M.Poletto, "Real-time on-road monitoring network of air quality", Chemical Engineering. Transactions, Vol. 74, 2019, pp. 241–246, doi:10.3303/CET1974041.
[34] D.Sofia, N.Lotrecchiano, P.Trucillo, A.Giuliano, L.Terrone, "Novel air pollution measurement system based on Ethereum blockchain", Journal of Sensors and Actuator Networks, Vol. 9, No. 49, 2020, doi:10.3390/jsan9040049.
[35] N.Lotrecchiano, V.Capozzi, D.Sofia, "An Innovative Approach to Determining the Contribution of Saharan Dust to Pollution", International Journal of Environmental Research and Public Health, Vol. 18, 2021, doi:10.3390/ijerph18116100.
[36] M.Chiari, A.Lucarelli, S.Nava, L.Paperetti, A.D'Alessandro, F.Mazzei, P.Prati, A.Zucchiatti, G.Marcazzan, G.Valli, et al, "Aerosol transport episodes in Italian urban environments detected by PIXE analysis", In Proceedings of the 10^{th} International Conference on Particle Induced X-ray Emission and Its Analytical Applications PIXE, Portoroz, Slovenia, 4–8 June 2004.
[37] M.Chiari, P.Del Carmine, F.Lucarelli, L.Paperetti, S.Nava, P.Prati, G.Valli, R.Vecchi, "Particulate matter characterization in an industrial district near Florence, by PIXE and PESA", In Proceedings of the 10^{th} International Conference on Particle Induced X-ray Emission and Its Analytical Applications PIXE, Portoroz, Slovenia, 4–8 June 2004.
[38] MIBACT, Atto di indirizzo sugli standard museali. Rome: Ministero per i Beni e le Attività Culturali, DL 10/ 05/2001 N 238.