A Review of the Literature on the Effect of Airborne Particulates Matter Towards Museum Visitors and Museum Artefact

Article *in* World Applied Sciences Journal · December 2016

DOI: 10.5829/idosi.wasj.2016.1659.1666

CITATIONS
0

READS
14

4 authors:

Shamzani Mohd Din
International Islamic University Malaysia
22 PUBLICATIONS **41** CITATIONS
SEE PROFILE

Nur Baiti Mat Husin
International Islamic University Malaysia
3 PUBLICATIONS **1** CITATION
SEE PROFILE

Rashidi Othman
International Islamic University Malaysia
95 PUBLICATIONS **128** CITATIONS
SEE PROFILE

Awangku Hassanal Bahar Pengiran Bagul
Universiti Malaysia Sabah (UMS)
32 PUBLICATIONS **16** CITATIONS
SEE PROFILE

World Applied Sciences Journal 34 (12): 1659-1666, 2016
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2016.1659.1666

A Review of the Literature on the Effect of Airborne Particulates Matter Towards Museum Visitors and Museum Artefact

[1] Shamzani Affendy Mohd Din, [1]Nur Baiti Mat Husin,
[1] Rashidi Othman and [2]Awangku Hassanal Bahar Pengiran Bagul

[1]Kulliyyah of Architecture and Environmental Design,
International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia
[2]Faculty of Business, Economic and Accountancy, University Malaysia Sabah, Malaysia

Abstract: Airborne particulates matter is significantly harmful towards museum visitors and displaysartefact. The suspension of airborne particulates such as dust, pollens and particles originated from various indoor sources like dusting, sweeping, vacuuming, openings and museum visitors. Meanwhile, the outdoor sources are from construction, industrial, agricultural and transportation activity. Once airborne particulatesinteract with various substances in the air, it formedinto organic or inorganic chemical compounds and thendeposited onto the surface of theartefact, which creates deterioration in terms of soiling defect. Besides, particulatesalso can reach the human lung, enter deep into alveoli and dissolve into blood capillaries, thus cause heart attack to the museum visitors. So, the aim of this paper is to review the sources and effects of air pollution and airborne particulates matter, which give the significant impact towards tourist and soiling artefact. This paper reviews the current knowledge of air pollution, particulates pollutants inside museum environment, theimpact of airborne particulates towards museum tourist and chemical characteristics of soiling artefact. The currently available studies are biased towards chemical properties of airborne particulates, which affect human health. However, more information on the chemical effect of heavy metal elements such as Ferum, Manganese, Copper, Lead and Zinc towards inorganic artefact and tourist healthis needed to enable risk assessment inside National Museum of Malaysia.

Key words: Airborne Particulates Matter · Soiling Defect · Artefacts · Tourist · Museums

INTRODUCTION

Air pollution significantly affects global climate, human health, flora, fauna and materials. A new WHO air quality model confirms that 92% of the world's population lives in places where air quality levels exceed WHO limits[1]. The museum included, where it is a building that stores and conserves all types of national artefact. The outdoor air pollutants will enter museum building from different sorts of opening such as doors, windows, air duct and visitors.

The pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_X), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter (PM), soot particles and ozone (O_3) will enter the museum[2, 3]. Then, they settled inside the museum gallery horizontally and vertically either on the walls or floors.

The airborne particulates matter deposition significantly harmful towards museum artefact as it causes thematerial to decay. The deterioration of artefact includes metal corrosion, surface cracking, painting discolouration, fading of dyes and soiling defect[4, 5]. Carbonaceous compounds (elemental carbon and organic carbon), sea salt, mineral dust, biological materials (pollens, spores, bacteria, viruses), heavy metals (Al, Fe, Cu, Zn, Pb), secondary sulphate, nitrate and ammonium particles are some of the chemical components in the airborne particulates that trigger the soiling defect of artefact.

Previous studies have reported that soiling defect of inorganic artefact i.e.; metal, stone and ceramic glass (refer Table 1 below)are influenced by the presence of heavy

Corresponding Author: Shamzani Affendy Mohd Din, Kulliyyahof Architecture and Environmental Design, International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia.

metal elements such as Fe, Mn, Cu, Pb and Zn which can catalyse the oxidation and hydrolysis of sulphur dioxide (SO_2) to form sulphuric acid[6].When sulphuric acid reacted with stone, aqueous ions were formed thus, mass from the stone was lost.

The inorganic artefact is being selected for this research because the soiling rate of inorganic artefact is higher as the time taken for the airborne particulates matter toreact with the surface of artefact is faster than organicartefact[7]. Hence, the inorganic artefact deteriorates faster.The organic artefact is those material made from animal and plant product while inorganic artefact is created from non-living materials[8].

Through some time, the surface of theinorganic artefact will be darkened and it will be difficult and expensive to clean the surface[9]. Thus, it is vital to preserve and conserve the artefact as the materials are valued solely for their visual qualities. These works of arts are irreplaceable and the value of some pieces is extraordinarily large. Even small rates of soiling may lead to unacceptable cumulative damage over centuries. Hence, the purpose of this paper is to review the sources and effects of air pollution and airborne particulate matter which give the significant impact towards soiling defect of museum artefact.

Table 1: Samples of Inorganic and Organic Artefact Taken During Site Visit to National Museum of Malaysia, Kuala Lumpur.

Organic Artefact	Old handwritten Al-Quran (Paper) 	Wayang Kulit (Leather) 	The Royal Headgear (Cotton & Silk) 
Inorganic Artefact	Stone Box (Stone) 	China Teapots (Ceramic Glass) 	Elephant Bell (Metal) 

Literature Review

Air Pollution: The World Health Organization (WHO) reported recent news in September 2016, which highlighted the effect of air pollution exposure with 3 million deaths each year. Moreover, about 6.5 million deaths, are 11.69% of all global death, were associated with indoor and outdoor air pollution [1]. This shows that air pollution is one of major concern towards global death.

According to the pie chart in Figure 1 below presented by [10],there are five major sources of gas emission to the environment. The sources are from electricity, transportation, industry, commercial, residential and agriculture sector. In 2014, the electricity sector was the largest source of U.S. greenhouse gas emissions, accounting for about 30% of the U.S. total. This is due to the release of gases during the combustion of fossil fuels, such as coal, oil and natural gas, to produce electricity to the country.

Meanwhile, in Malaysia, the Compendium of Environment Statistics (CES) 2015 had presented a statistics on the emission of pollutants to the atmosphere with the latest year in 2014[11]. It is shown in Table 2 below; the most significant emission source of pollutants in Malaysia is transportation sector with a figure of 2092.0 tonnes in the year 2014. The movement of people and goods by cars, trucks, trains, ships, aeroplanes and other motor vehicles produce carbon dioxide through combustion of thepetroleum-based product, like gasoline in internal combustion engines.

Thus, what can be concluded here is that the major sources of pollution in U.S is from electricity sector whereas in Malaysia, the transportation sector. U.S population and country is bigger compared to Malaysia. Thus they need more power to supply to each part of theindustry in the country.

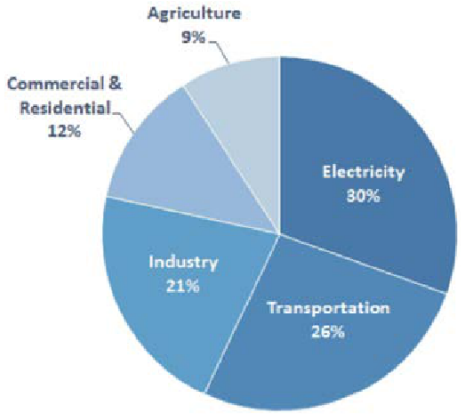

Fig. 1: The Total U.S Greenhouse Gas Emission by Economic Sector in 2014 [10]

Table 2: Statistics Emission of Pollutants to the Atmosphere[11]

	Year ('000 tonnes)	
Source of Emission	2010	2014
Industrial	113.9	101.9
Motor Vehicles	1829.7	2092.0
Power Plant	619.2	742.9

Air Pollutant in the Museum: When referring to the air pollutant, it can be defined as small particulates[12], anthropogenic chemical emission [13], or any solid, liquid or gases substances in the air that can cause harm towards human, environment, animals, vegetation and material [14]. Pollutants may include almost any natural or artificial composition of airborne matter capable of being airborne.

Air pollutants are grouped in categories for ease in classification; some of the categories are solids, sulphur compounds[2], volatile organic chemicals, particulate matter [3], nitrogen compounds [9], oxygen compounds [15], halogen compounds, radioactive compounds and odours[16].

Previously published studies have identified several factors of air pollutant inside the museum building. The increase of air pollutant are influenced by the reduced ventilation rates, tightly sealed buildings, use of housekeeping supplies, pesticides, furnishing and synthetic building materials [2, 17, 18]. The air pollutants also originated from area source, such as newly painted surfaces, or from point sources like storerooms[5, 19, 20].

Besides, the sources of air pollutants in the museum can be generated from combustion process from vehicles or wood products[7, 21]. Meanwhile, the process of heating and cleaningof museum gallery are the factor of air pollutant existence[22]. In addition, the building furnishings such as carpet, paints, boards and furniture made of pressed wood products are contributable towards the increase of air pollutant in the museum beside human occupancy [2, 23, 24].

It shows here that many factors contribute towards theincrease of air pollutants in the museum. It is easy for anoutdoor pollutant to penetrate indoor environment of themuseum. Thus the penetration and increase of air pollutant in the museum pose a significant risk towards artefact. Some of the pollutants are sulphur dioxide, nitrogen dioxide, nitrogen oxide, ozone and hydrogen sulphide[25–27]. Hence, the effects of indoor air pollutants towards materials are varied due to the types of pollutants exist in the air.

The Museum Environment: The conservation of museum artefact is influenced by theindoor environment of the museum such as the Museummicroclimate and air pollutants. Temperature and relative humidity (RH) variations, metabolic actions and excretions of microorganism and gaseous and airborne particulates matter all play an important role in the deteriorations of artefact [2, 28–30]. So, the temperature, humidity, particulate matter and gaseous buffering determine the microclimate of themuseum.

Camuffo [2] highlighting that the modern Europeanmuseum produced high microclimate variability. It is asimilar condition with the studies conducted in National Museum of Malaysia, where the level of moisture of indoor is not stable and are not well maintained. The main reason is that, lack of temperature and humidity buffering materials, low thermal mass and greenhouse effect of the glass and building walls.

Hence, with the combination of high changes in temperature and humidity andthe airborne particulates suspended in the museum gallery, it will then generate various harmful effects towards building facades and artefacts. The effects can besuch as mould growth, metal corrosion, paper brittleness, fragile textile, wood and cloth shrinkage, cellulose degradation, material expansion, painting discolouration as well as soiling defect[3, 16, 5, 27, 29, 31].Apart from that, an increase in temperature will significantly impact the chemical reaction of airborne particulates matter and thus, accelerate the degradation process of artefact

The temperature and humidity variance can be stabilised by incorporating the heating, ventilation and air conditioning (HVAC) systems. The HVAC systems are the key components that combine outdoor air with indoor air[17, 32]and one of their purposes is to prevent outdoor particulate matters from entering theindoor air.

The comparison from previous studies to see the efficiency of HVAC system which has been incorporated in the museum can be seen in the case study of Sepulveda House, California [5]. The indoor fine particle concentrations in the building were nearly identical to those outdoors because the building has no air filtration system. Whereas, at the other gallery where the HVAC system included, the indoor airborne particulates are mostly fine.Therefore, the microclimate variability may influence the conservator to regulate the indoor environment for the conservation of artefacts.

Airborne Particulates Matter: The airborne particulates matter, which includes dust, dirt, soot, smoke and liquid droplets emitted into the air, is small enough to be suspended in the atmosphere [3, 17, 27, 33, 4]. Airborne particulates may be a complex mixture of organic and inorganic substances and can be characterised by their physical attributes and their chemical compositions, which influence their effect on health. The smaller particles contain the secondarily formed aerosol

(gas-to-particle conversion), combustion particles and re-condensed organic and metal vapour. The larger particles usually contain earth crust materials and fugitive dust from roads and industries [5].

Moreover, particulate matters are divided into primary and secondary types. The primary particulates do not combine with other particles, while secondary particulate matter is the combination of two or more particles that forms a new composition[34]. The secondary particulates are more complex and more hazardous to human health and environment[4, 35].

The physical attributes of airborne particles include mass concentration and size distribution. Ambient levels of mass concentration are measured in micrograms per cubic meter ($\mu g/m_3$); size attributes are usually measured in aerodynamic diameter. Particulates matter (PM) exceeding 2.5 microns (μm) in aerodynamic diameter is defined as coarse particles as shown in Figure 2 below, while particles smaller than 2.5 microns ($PM_{2.5}$) are called fine particles [36].

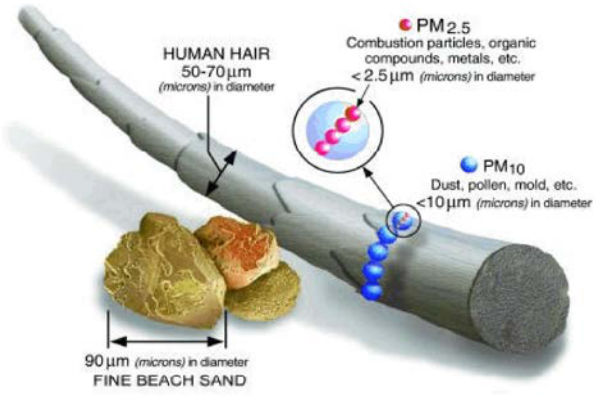

Fig. 2: The Size Comparison of PM Particles
(Source*: US EPA, 2016*[10])

Recent research by Mohd Din [37] supported the previous studies, which suggested that airborne particulates matters in museums originate from different kind of sources. The sources include the use of HVAC system [2, 17], cleaning services [19, 38], vacuuming process [19], particulates from displayed artefact or storage room [39, 40], open entrance [15, 31], particulates from outside and from visitors [41, 42] and occupants in the museums [24].From all the sources mentioned above, the airborne particulates matter will be suspended inside the museum gallery and then deposited onto the artefact either vertically or horizontally due to gravitational forces. The airborne will be deposited in the display boxes, display textile frames, gallery floors, painting, sculpture and exposed artefact. After sometimes, the soiling defects can be seen obviously such as through blackening of the surface or brownish spots on paper. So, it is supported that airborne particulate matter significantly affects the soiling of theartefact.

Effects of Airborne Particulatesmatter Towards Museum Visitor: Tourist is defined as aperson who spends at least one night in a destination to which he or she had travelled [43].In 2013, the total tourist arrived in Malaysia reached an amount of 25.72 million.Meanwhile, the amount of tourist visiting the National Museum is only 357,506 visitors[44]. The percentage of tourist who visited the National Museum over total tourism coming to Malaysia is only 1.39% which decreases35% from the previous year statistic with a total of 551,412 visitors[45]. The drop ofvisitors' percentageis due to the haze crisis called the 2013 South-east Asian Haze [46].

The 2013 South-east Asian haze was notable for causing record high level of pollution in Malaysia, Singapore, Indonesia, Brunei and Southern Thailand during the month of June and July [46]. As highlighted in the 2012 Annual Report of Jabatan Muzium Malaysia (JMM), the ratio of tourist from local, international and students are 0.59:0.24:0.17 respectively. This shows that more than half of the museum visitors are Malaysian.

Airborne particulates matter significantly impact human health[47, 48], flora, fauna, building materials[7]as well as global climate[49]. In the context of themuseum, the tourist health should be seriously considered as well.

Particulates pollution can be a life-threatening issuefor the museum visitors which include the four critical groups, i.e. infants[13]pregnant women[50] elderlyand people with critical illness[36]. The infant isvulnerable to particles pollutants as their organsystem and metabolic pathways are not maturedenough. Recent literature suggests that exposure to air pollution during pregnancy can cause health problem for the mother and child as well as preterm delivery and low birth weight.

Moreover, the immune system of elderly already drops to 70% when they reach the age of 50's. The most dangerous situation is for the person that suffers chronic illness as their lung and heart cannot function well. If there is slight chemical pollutants enter their body, their illness will be more serious.

The adverse effects of airborne particulates towards visitor's health are like coughing, heart diseases, respiratory disease, asthma and even mortality.

Soiling Defect of Airborne Particulates

Matter: Most of the museums in the world are located in urban environments, where pollution, originating from domestic heating, construction works, traffic and industry have harmful effects on buildings and decorative materials [7, 23, 27, 31]. So, black crust formations, material decohesion and dust deposition often occur on the exterior of the buildings, which can cause undesirable aesthetic effects of the artefact [9, 5, 28].However, inside the museums, soiling and chemical weathering can occur due to both indoor and outdoor phenomena.

Several activities that taking place in a museum such as dusting, sweeping, spraying, vacuuming, floor waxing and interior furnishings[9, 5, 23],as well as the suspension of soil dust particles introduced by visitor [2, 16], have been found to be a significant indoor sources of air pollutant.In addition, deterioration, erosion procedures and restoration or construction works may cause higher particle abundance inside a museum.

Through museum activities, construction process and transportation emission, airborne particulates matter will react with chemical gases inside the museum and will be deposited onto artefact and thus cause soiling defect. Previous research has stated that soiling defect is also influenced by the presence of heavy metal elements such as Ferum, Manganese, Copper,

Lead and Zinc in the airborne particulates matter. Cadmium emission is originated from metal refining and smelting facilities; Mercury emission is from theindustrialsector and Lead emission is from road transport sector [6].

So, Lead emission is significantly impacted the soiling defect of museum artefact. The information above supported the previous studies by [37], which stated that the major source of air pollution in Malaysia is through transportation sector.

Research Gap: Through literature studies, there are various types of research in the museums around the worlds that have been widely investigated in aWestern country, European country, Middle East and Asian country [2, 3, 9, 5, 27]. Most of the studies are regarding chemical properties of airborne particulates soiling defect. However, there is still a lack of information in regards to the investigation of heavy metals in the airborne particulates matter, which deposited on the metal, stone and ceramic glass artefact. So the primary idea of this paper is to discuss the recent case studies from different countries around the world to determine the chemical characterisation of airborne particulates matter that cause soiling of artefact inside National Museum of Malaysia.

CONCLUSION

In overall, museum artefacts are prone to become soiled due to the exposure and accumulation of airborne particulates matter with theheavy metal element. The high concentration of airborne particulates matter from outside enters the museum galleries through openings and building cracks as well as visitor occupancy. The variability of temperature and relative humidity will encourage the heavy metal to react with airborne particulates matter.Thus, dust particles will suspend in the air and deposited onto the surface inorganic artefact such as metal, stone and ceramic glass. Besides causing soiling defect toward museum artefact, airborne particulates matter also expose tourist to severe asthma, coughing, heart diseases, respiratory disease and even mortality. Hence, the findings of this research could be used to help a betterment of HVAC system in the museum which displays Malaysian national heritage. At the same time, bring awareness towards museum visitor in regards to the impact of air pollution on human health.

ACKNOWLEDGEMENT

The researcher would like to acknowledge grant no. RIGS16-394-0558 which was awarded by Research Management Centre and facilities at Environmental Laboratory under Kulliyyah of Architecture & Environmental Design, International Islamic University Malaysia assistant in completing this study.

REFERENCES

1. WHO 2016. WHO releases country estimates on air pollution exposure and health impact. pp: 3-5.
2. Camuffo, D., R. Van Grieken, H.J. Busse, G. Sturaro, A. Valentino, A. Bernardi, N. Blades, D. Shooter, K. Gysels, F. Deutsch, M. Wieser, O. Kim and U. Ulrych, 2001. Environmental monitoring in four European museums. Atmos Environ, 35: 127-140. doi: 10.1016/S1352-2310(01)00088-7
3. Hanapi, N. and S.A. Mohd Din, 2012. A Study on the Airborne Particulates Matter in Selected Museums of Peninsular Malaysia. Procedia - Soc. Behav. Sci., 50: 602-613. doi: 10.1016/j.sbspro.2012.08.063.

4. Grau-Bove, J. and M. Strlic, 2013. Fine particulate matter in indoor cultural heritage?: a literature review. Herit. Sci., 1: 1-17.
5. Nazarofft, W.W., M.P. Ligocki, L.G. Salmon, T. Fall, M.C. Jones and G.R. Cass, 1993. Characteristics of Airborne Particles inside Southern California Museums. Res. Conserv., 27:
6. European Environment Agency, 2011. Heavy Metal Emissions. Denmark
7. Tzanis, C., C. Varotsos, J. Christodoulakis, J. Tidblad, M. Ferm, A. Ionescu, R.A. Lefevre, K. Theodorakopoulou and K. Kreislova, 2011. On the corrosion and soiling effects on materials by air pollution in Athens, Greece. Atmos Chem. Phys., 11: 12039-12048. doi: 10.5194/acp-11-12039-2011
8. Yusuf, A., 2008. Definition of Cultural Heritage. 1972 World Herit Conv A Comment, pp: 23-50.
9. Horemans, B., C. Cardell, L. Bencs, V. Kontozova-Deutsch, K. De Wael and R. Van Grieken, 2011. Evaluation of airborne particles at the Alhambra monument in Granada, Spain. Microchem. J., 99: 429-438. doi: 10.1016/j.microc.2011.06.018
10. US EPA 2016. Greenhouse Gas Emissions: Sources of Greenhouse Gas Emissions. https://www3.epa.gov/climatechange/ghgemissions/sources.html. Accessed 20 Nov 2016.
11. Department of Statistics Malaysia, 2015. Press Release Compendium of Environment Statistics 2015. Malaysia
12. Yang Razali, N.Y., M.T. Latif, D. Dominick and N. Mohamad, F.R. Sulaiman and T. Srithawirat, 2015. Concentration of particulate matter, CO and CO2 in selected schools inMalaysia. Build Environ., 87: 108-116. doi: 10.1016/j.buildenv.2015.01.015
13. Latif, M.T., S.M. Yong, A. Saad, N. Mohamad, N.H. Baharudin, Mokhtar M. Bin and N.M. Tahir, 2014. Composition of heavy metals in indoor dust and their possible exposure: A case study of preschool children in Malaysia. Air Qual. Atmos. Heal., 7: 181-193. doi: 10.1007/s11869-013-0224-9.
14. Zhang, Y., B. Zhao and X.T. Li, 2006. Perceived particle intensity: An indicator to evaluate indoor particle pollution. Indoor Built. Environ., 15: 155-164. doi: 10.1177/1420326X06063648
15. Blondeau, P., V. Iordache, O. Poupard, D. Genin and F. Allard, 2005. Relationship between outdoor and indoor air quality in eight French schools. Indoor Air, 15: 2-12. doi: 10.1111/j.1600-0668.2004.00263.x
16. Zorpas, AA. and A. Skouroupatis, 2015. Indoor air quality evaluation of two museums in a subtropical climate conditions. Sustain Cities. Soc., 20:52-60. doi: 10.1016/j.scs.2015.10.002
17. Fu, Z. and N. Li, 2006. Airborne Particulate Matter in HVAC Systems and its Influence on Indoor Air Quality. Distribution I:
18. Milanesi, C., F. Baldi, S. Borin, L. Brusetti, F. Ciampolini, F. Iacopini and M. Cresti, 2009. Deterioration of medieval painting in the chapel of the Holy Nail, Siena (Italy) partially treated with Paraloid B72. Int Biodeterior Biodegrad, 63:844-850. doi: 10.1016/j.ibiod.2009.03.004
19. Afshari, A., U. Matson and L.E. Ekberg, 2005. Characterization of indoor sources of fine and ultrafine particles: a study conducted in a full-scale chamber. Indoor Air, 15: 141-50. doi: 10.1111/j.1600-0668.2005.00332.x
20. Niesler, A., R.L. Górny, A. Wlaz³o, B.£udzeñ-Izbiñska, A.£awniczek-Wa³czyk, M. Go³ofit-Szymczak, Z. Meres, J. Kasznia-Kocot, A. Harkawy, D.O. Lis and E. Anczyk, 2010. Microbial contamination of storerooms at the Auschwitz-Birkenau Museum. Aerobiologia (Bologna), 26: 125-133. doi: 10.1007/s10453-009-9149-z
21. Ee-ling, O., N. Ili, H. Mustaffa, N. Amil and F. Khan, Source Contribution of PM 2.5 at Different Locations on the Malaysian Peninsula. doi: 10.1007/s00128-015-1477-9
22. Ferdyn-Grygierek, J., 2014. Indoor environment quality in the museum building and its effect on heating and cooling demand. Energy Build. doi: 10.1016/j.enbuild.2014.09.014
23. Mouratidou, T. and C. Samara, 2004. PM2.5 and associated ionic component concentrations inside the archaeological museum of Thessaloniki, N. Greece. Atmos. Environ., 38: 4593-4598. doi: 10.1016/j.atmosenv.2004.04.034
24. Hospodsky, D., J. Qian, W.W. Nazaroff, N. Yamamoto, K. Bibby, H. Rismani-Yazdi and J. Peccia, 2012. Human occupancy as a source of indoor airborne bacteria. PLoS One 7:e34867. doi: 10.1371/journal.pone.0034867
25. Reddy, M.K., M. Suneela, M. Sumathi and R.C. Reddy, 2005. Indoor air quality at Salarjung Museum, Hyderabad, India. Environ Monit Assess, 105: 359-367. doi: 10.1007/s10661-005-4344-z

26. Grzywacz, C.M., 2008. Monitoring for Gaseous Pollutants in Museum Environment. Getty Publication, Canada
27. Cappitelli, F., P. Fermo, R. Vecchi, A. Piazzalunga, G. Valli, E. Zanardini and C. Sorlini, 2009. Chemical-physical and Microbiological Measurements for Indoor Air Quality Assessment at the Ca' Granda Historical Archive, Milan (Italy). Water Air Soil Pollut., 201 :109-120. doi: DOI 10.1007/s11270-008-9931-5.
28. Gysels, K., F. Delalieux, F. Deutsch, R. Van Grieken, D. Camuffo, A. Bernardi, G. Sturaro, H.J. Busse and M. Wieser, 2004. Indoor environment and conservation in the Royal Museum of Fine Arts, Antwerp, Belgium. J. Cult. Herit., 5: 221-230. doi: 10.1016/j.culher.2004.02.002
29. Chianese, E., A. Riccio, I. Duro, M. Trifuoggi, P. Iovino, S. Capasso and G. Barone, 2012. Measurements for indoor air quality assessment at the Capodimonte Museum in Naples (Italy). Int. J. Environ. Res., 6: 509-518.
30. Hu, T., W. Jia, J. Cao, R. Huang, H. Li, S. Liu, T. Ma, Y. Zhu, 2015. Indoor air quality at five site museums of Yangtze River civilization. Atmos. Environ., 6-11. doi: 10.1016/j.atmosenv.2015.10.022
31. Anaf, W., B. Horemans, T.I. Madeira, M.L. Carvalho, Wael K. De and Grieken R. Van, 2012. Effects of a constructional intervention on airborne and deposited particulate matter in the Portuguese National Tile Museum, Lisbon. Env. Sci. Pollut. Res., 20: 1849-1857. doi: 10.1007/s11356-012-1086-7
32. Anaf, W., L. Bencs, R.E. Van Grieken, K. Janssens and K. De Wael, 2015. Indoor particulate matter in four Belgian heritage sites: Case studies on the deposition of dark-colored and hygroscopic particles. Sci. Total Environ., 506-507: 361-368. doi: 10.1016/j.scitotenv.2014.11.018
33. Loupa, G., E. Karageorgos and S. Rapsomanikis, 2010. Potential effects of particulate matter from combustion during services on human health and on works of art in medieval churches in Cyprus. Environ. Pollut., 158: 2946-53. doi: 10.1016/j.envpol.2010.06.005
34. WHO 2010. WHO guidelines for indoor air quality. Nutr J. doi: 10.1186/2041-1480-2-S2-I1
35. Tsai, J., K. Huang, N.H. Lin, S. Chen, C.T Lina, S.C. Chen, C.C. Lin, S.C. Hsu and W. Lin, 2012. Influence of an Asian Dust Storm and Southeast Asian Biomass Burning on the Characteristics of Seashore Atmospheric Aerosols in Southern Taiwan. Aerosol Air Qual. Res., 12: 1105-1115. doi: 10.4209/aaqr.2012.07.0201
36. WHO 2003. Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide. Rep a WHO Work Gr Bonn, Ger 13-15 January 2003 98. doi: 10.2105/AJPH.48.7.913
37. Mohd Din, S.A., N.N. Nik Yahya and R. Othman, 0000. Museums' Showcase vs Indoor vs Outdoor Metal Found In Respirable and Inhalable Dust.
38. Guo, H., L. Morawska, C. He, Y.L. Zhang, G. Ayoko and M. Cao, 2010. Characterization of particle number concentrations and PM2.5 in a school: influence of outdoor air pollution on indoor air. Environ. Sci. Pollut Res. Int., 17:1268-78. doi: 10.1007/s11356-010-0306-2.
39. Nazaroff, W., 2002. Indoor Particulate Matter of Outdoor Origin?: Importance of Size-Dependent Removal Mechanisms., 36: 200-207.
40. Abdel-Kareem, O., 2010. Monitoring, controlling and prevention of the fungal deterioration of textile artifacts in the museum of Jordanian heritage. Mediterr Archaeol Archaeom, 10: 85-96.
41. Hu, T., J. Cao, K. Ho, Z. An, S. Lee, J.C. Chow, J.G. Watson and H. Li, 2011 Winter and Summer Characteristics of Airborne Particles Inside Emperor Qin's Terra-Cotta Museum, China: A Study by Scanning Electron Microscopy-Energy Dispersive X-Ray Spectrometry. J. Air Waste Manage Assoc., 61: 914-922. doi: 10.1080/10473289.2011.596740.
42. Horemans, B., O. Schalm, K. D Wael, C. Cardell and Grieken R. Van, 2012. Atmospheric composition and micro-climate in the Alhambra monument, Granada (Spain), in the context of preventive conservation. IOP Conf Ser Mater Sci, Eng., 37:12002. doi: 10.1088/1757-899X/37/1/012002
43. Navarro, D., 2015. Tourist Resources and Tourist Attractions?: Conceptualization, Classification and. pp: 481-484.
44. Jabatan Muzium Malaysia, 2013. Laporan Tahunan 2013 Jabatan Muzium Malaysia.
45. Jabatan Muzium Malaysia, 2012. Laporan Tahunan 2012 Jabatan Muzium Malaysia. Jab Muz Malaysia. doi: 10.1017/CBO9781107415324.004
46. Dotse, S.Q., L. Dagar, M.I. Petra and L.C. De Silva, 2016. Influence of Southeast Asian Haze episodes on high PM10 concentrations across Brunei Darussalam. Environ. Pollut, 219: 337-352. doi: 10.1016/j.envpol.2016.10.059
47. Adar, S.D., P.A. Filigrana, N. Clements and J.L. Peel, 2014. Ambient Coarse Particulate Matter and Human Health?: A Systematic Review and Meta-Analysis. pp: 258-274. doi: 10.1007/s40572-014-0022-z

48. Kim, K., E. Kabir and S. Kabir, 2015. A review on the human health impact of airborne particulate matter. Environ. Int., 74:136-143. doi: 10.1016/j.envint. 2014.10.005
49. Fisk, W.J., 2015. Review of Some Effects of Climate Change on Indoor Environmental Quality and Health and Associated No-Regrets Mitigation Measures. Build Environ., doi: 10.1016/j.buildenv.2014.12.024
50. US EPA 2010. Air Pollution and Pregnancy: Information for Prenatal Health Care Providers. 1-8.