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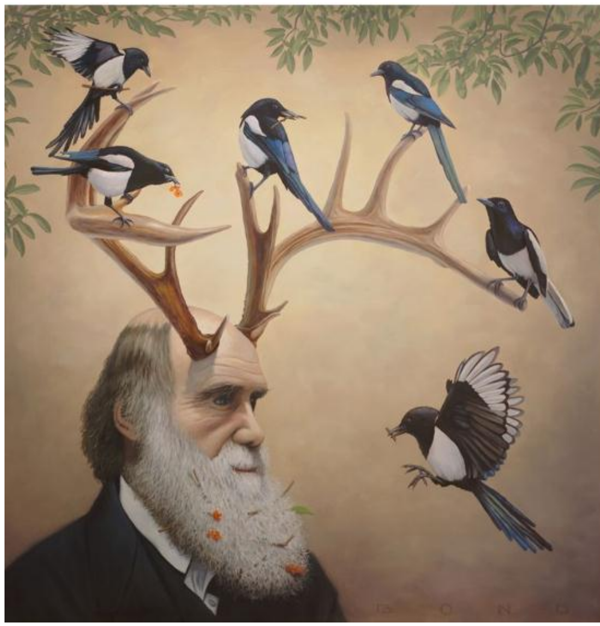

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A Review On Airborne Particulate Soiling Defect On Users And Artefacts In The Museum Environment

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Abstract

Recent studies have reported soiling defects and health hazard caused by particulate matter, poor Indoor Air Quality (IAQ) conditions, and damages caused by varying microclimate conditions in the museum. When airborne particulates combine with various substances in the air, a chemical reaction occurs, which results in the formation of inorganic and organic compounds. These compounds are then deposited on the surfaces of artefacts which reduces the aesthetic properties and value of the artefacts through a process known as soiling. Additionally, airborne particulates can trigger various health effects on museum users. Such as cough, sneezing, lungs irritation, itchy eye, cancer, heart attack, and can lead to death.

Purpose: This research is, therefore aimed at reviewing the recent trends in countries annual mean concentration of Particulate matters, characteristics of museum collections, sources of Particulate Matter in the museum, and its effect on artefacts and museum users, and concentration and chemical compositions of airborne particulate in

Finding: Several studies have been published in relating to the concentration and chemical compositions of airborne particulates in Europe and Asia. However, detailed research is still lagging on the composition of Airborne particulate in Malaysian

Implication: Therefore, more research needs to be conducted based on this research gap to enable risk assessment inside Museum Environment.

Keywords: Particulates Matter, Microclimate, Soiling, Artefacts, Museum.

UNA REVISIÓN DEL DEFECTO DE SUELO DE PARTÍCULAS EN EL AIRE EN USUARIOS Y ARTEFACTOS EN EL ENTORNO DEL MUSEO

Resumen
Estudios recientes han reportado defectos de suciedad y riesgos para la salud causados por partículas, malas condiciones de calidad del aire interior (IAQ) y daños causados por las condiciones variables del microclima en el museo. Cuando las partículas en el aire se combinan con varias sustancias en el aire, se produce una reacción química que da como resultado la formación de compuestos inorgánicos y orgánicos. Estos compuestos se depositan en las superficies de los artefactos, lo que reduce las propiedades estéticas y el valor de los artefactos a través de un proceso conocido como suciedad. Además, las partículas en el aire pueden desencadenar diversos efectos sobre la salud de los usuarios del museo. Tales como tos, estornudos, irritación de los pulmones, picazón en los ojos, cáncer, ataque cardíaco y pueden provocar la muerte.

Propósito: Esta investigación, por lo tanto, tiene como objetivo revisar las tendencias recientes en los países con una concentración media anual de partículas, características de colecciones de museos, fuentes de materia particulada en el museo y su efecto sobre artefactos y usuarios del museo, y la concentración y composiciones químicas de partículas en el aire en

Hallazgo: Se han publicado varios estudios relacionados con la concentración y las composiciones químicas de partículas en el aire en Europa y Asia. Sin embargo, la investigación detallada aún está rezagada en la composición de partículas en el aire en Malasia

Implicación: Por lo tanto, es necesario realizar más investigaciones basadas en esta brecha de investigación para permitir la evaluación de riesgos dentro del Museo del Medio Ambiente.

Palabras clave: materia particulada, microclima, suciedad, artefactos, museo.

1. INTRODUCTION

Air pollution is a modern-day curse, a consequence of increasing industrialisation and urbanisation. Air pollution can be defined as the release of harmful substance to the atmosphere to such an extent that it affects human health and its environment. Hannah & Roser (2019) revealed that air pollution encapsulates several pollutants, including SO2, NOx, O3, PM, CO, and volatile organic compounds (VOCs). Exposure to these pollutants are of increasing concern, effects are observed in a broad range of pollutants levels, and many people are at risk. These pollutants affect individuals differently depending on the genetic susceptibility, and individual responses, for example, the younger children and elderly will be more susceptible to cardiovascular and respiratory diseases, and workers at an industry may be at high risk depending on individual exposure pattern.

2. LITERATURE REVIEW

2.1 Recent Trend in Countries Annual Mean Concentration of Particulate Matters

Air pollution is escalating at a frightening rate, which poses a significant threat to human's health, destroys materials and affects climate change. Air pollution is a global environmental risk; it affects people's Quality of life (QoL), which leads to significant chronic disease and sometimes leads to death. Both indoor and outdoor air pollution causes an estimated amount of 7 million premature death every year which can be traced to the increased mortality rate from lung cancer, heart diseases, stroke, chronic obstructive pulmonary disease and acute respiratory infection (WHO, 2018). A recent report by World Health Organisation (WHO) in 2019 estimated an 8% increase in the outdoor air pollution in the last five years from over 3,000 cities, with billions of people now exposed to polluted air. It was observed that 91% of the world's population lives in places exceeding the WHO air quality guidelines. The summary of the annual mean concentration of PM2.5 and PM10, the most prominent region around the world based on a recent survey by WHO, 2018 is presented in Table 1. The level of ultra-fine particulate matter of less than 2.5 microns (PM2.5) is highest in India (Fang et al., 2018). Air substantial increase on air quality has been seen in China over the past nine years, now only has five cities which include Beijing, Tianjin, Shijiazhuang, Baoding and Xingtai with 85, 87, 121, 126 and 128 µg/m3 respectively are among the top 30. Other countries, including Pakistan and Iran, have one city among the first 30 (Fang et al., 2018; WHO, 2018).

For larger PM10, India has eight cities in the World's top 30, followed by Nigeria, Saudi Arabia and Pakistan which have two cities each in the top ten. The most contaminated city in the World according to WHO is Onitsha, located in Southern Nigeria recorded a 594 µg/m3 of PM10 around 30 times the recommended level of 20 µg/m3 as stated by WHO. Cities such as Sydney (17 µg/m3), New York (16 µg/m3), and London (22 µg/m3) registered a lower value of PM10 although the data only includes measurement of PM and no other forms of air pollutants such as NO2 and O3.

Table 1: The Summary of the Annual Mean Concentration of PM2.5 And PM10, the Most Prominent Region Around the World.

Region/Country	Annual average concentration (2016) ($\mu g/m^3$)	
	$PM_{2.5}$	PM_{10}
ASIA		
Gwalior, Indian	176	329
Xingtai, China	128	193
Baoding, China	126	190
Petaling Jaya, Malaysia	25	47
Karachi, Pakistan	88	290
Peshawar, Pakistan	111	540
Riyadh, Saudi Arabia	156	368
Al Jubail, Saudi Arabia	152	359
MIDDLE EAST		
Zabol, Iran	217	527
AFRICA		
Bamenda, Cameroon	132	142
Onitsha, Nigeria	66	594
EUROPE		
Tetovo, Macedonia	81	
Muonio, Finland	2	4
Campisábalos, Spain	5	6
SOUTH AMERICA		
Coyhaique, Chile	64	75
NORTH AND		

CENTRAL AMERICA	42	77
San Salvador, El Salvador	3	5
Norman Wells, Canada		

Source. WHO (2018)

According to the report by WHO, most regions were affected but developing cities in the middle east, south-east Asia and western Pacific are most impacted with pollution levels about ten times the amount recommended by WHO as illustrated in Figure. 2. Air pollution causes over 3 million of death in a year, more than most common disease such as malaria and HIV/Aids and, it is the leading causes of death in the world (Lelieveld et al., 2015). Pollutants such as nitrates, sulphate and carbon penetrate deep into the respiratory and cardiovascular systems posing a high risk to human health. It can, therefore, be decided that as the urban air quality reduces, the risk of diseases such as stroke, lung cancer, chronic and acute respiratory diseases as well as asthma increases for the people that live in them.

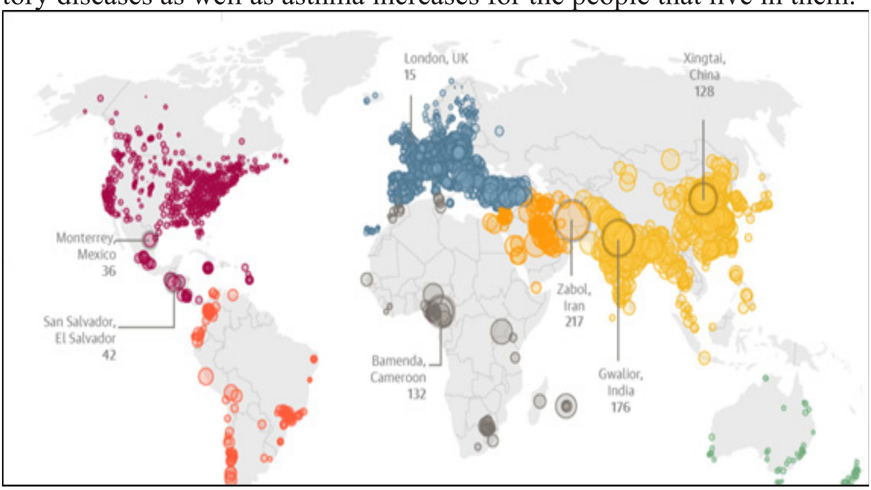

Figure 2: Annual Mean Concentration of Fine Particulate Matter (2.5 Micrometres or Less) in Micrograms Per Cubic Meter for Over 3000 Cities Across the World.
Source. WHO (2019)

2.2 Airborne Particulates Matter in Museums

Artefacts are repeatedly exposed to adverse climatological conditions such as precipitation, fluctuating temperature and wind. The damages caused by these conditions are a function of material types and conditions and are related to the anthropogenic air pollutants. Particulates soiling of museum artefacts is an expensive and uncontrolled phenomenon. The effect is unsightly and reduces the value of buildings and monuments, and maybe particularly damaging to old, fragile, textiles and tapestries, especially once they have become soiled. However, removal techniques may cause more damaging than soiling layer, by merely exposing a new and therefore more chemically active surface to attack.

Outdoor airborne coarse particles cluster into distinct different size ranges with different chemical properties. Particles larger than 2 µm in diameter contains mostly soil dust, road dust and sea salt. A fine particle smaller than 2 µm in diameter consists of vehicle exhaust, soot, ammonium sulphate and nitrate, and sulfuric acid. Infiltration of the outdoor air to the indoor environment through the HVAC system, makes the indoor environment contain a proportionate mixture of coarse and fine particulate material. Both the fine and coarse particles are characteristically black and brown, respectively, when collected on the white surface material (Heritage, 2012; Nazaroff et al., 1993). If soiling is to be prevented, a sound knowledge of the control of the fine and coarse particles must be considered.

2.3 Museum's Collections and Characteristics

Materials are more vulnerable to or unstable than other materials. They may have varied in temperature (T) and relative humidity (RH) requirements and may be more sensitive to environmental fluctuation. Cultural object vulnerability is determined by their physical and chemical composition and is broadly divided into three (Joan & Brynn, 2016). The organic, inorganic and composite.

2.3.1 Organic Objects

These are objects obtained from previously living plants or animals include wood, paper, textile, leather, skin, horn, bone, teeth, ivory, plastics, grasses and barks, some pigments, shell, specific fossil that are not fully lithified, and biological specimens (Joan & Brynn, 2016). Figure 3 are examples of some organic artefacts found by a group of glacial archaeologists in Norway. The characteristics of organic materials are

i. They always contain an element of carbon.

ii. They are made up of complex molecular structure that is susceptible to deterioration from variation in RH and temperature.

iii. They are hygroscopic, which implies that they can absorb H2O from and emit H2O to the adjoining air in an ongoing attempt to reach an equilibrium.
iv. They are subtle to light.
v. Organic objects serve as breading space for mould, insects, rodents and other museum pests.

Figure 3: Sample of Organic Artefacts.
(a) Iron Age Tunic Dated to c. AD 300 (Marten Teigen, Museum of Cultural History) (b) An Arrow Shaft, Radiocarbon-dated to c. 2000 BC. (Oystein Ronning-Anderson, Secrete of the ice/Oppland County council). (c) Walking Stick with Runic Inscriptions dated to 11th Century AD (Vegard Vike, Museum of Cultural History).
Source. Jason (2018)

2.3.2 Inorganic Objects
These objects originate from minerals such as metals, ceramic, glass, stone, minerals, fully lithified fossils, and some pigment. Figure 4 shows the samples of some inorganic artefacts found at the Islamic Arts Museum Malaysia Inorganic objects share some specific vulnerability and characteristics;
i. They may have undergone extreme pressure and heat.
ii. They are not usually combustible at an average temperature.
iii. They react with the environment, which results in a change to their chemical structure.
iv. Inorganic object may be porous (unglazed ceramic and stone) and will absorb contaminant (such as water, salt, pollution and acid).
v. They are generally not sensitive to light, except certain types of

glass and pigment.

Figure 4: Sample of Inorganic object.
(a) Silver Betelnut Container Malay Peninsula (19th century AD). (b) Gold and Silver Betelnut Box Malay Archipelago (19th century AD). (c) Blue and White Porcelain ewer Jiajing Period, Ming Dynasty China (16th-17th century AD).
Source. Islamic Arts Museum Malaysia, (2017)

2.3.3 Composite Objects

These kinds of objects include both organic and inorganic materials and have the characteristics of both and so may react with the environment in different ways and rates. Artefacts composed of different materials may react in opposition to each other, as such, creating physical stress and causing chemical interaction that leads to deterioration (Joan & Brynn, 2016). Example of composite materials includes books, paintings, musical instrument and jewellery, as shown in Figure 5.

Figure 5: Sample of Composite Artefacts
(a) Sultan Abdul Jalil Kris Riau, Indonesia (1712 AD). (b) Compendium of Astronomy by Abu Ma'shar al-Balki Shiraz (Iran 1347 AD).
Source. Islamic Arts Museum Malaysia (2017)

Museum collections are affected by ambient temperature and relative humidity in several ways. Material adjusts to the temperature of its surroundings in order to reach thermal equilibrium. Expansion occurs when temperature increase whereas, a decreased temperature will cause contrition. An uncontrolled ambient temperature can hasten varieties of chemical, biological and physical processes that can damage collections in a museum. At an increased temperature, exhibits such as plastic, acidic paper, and photographic materials may deteriorate because of evaporation from their surfaces which may result in cracking. Insect and mould breed faster at specific temperature range which may be disastrous to collections. However, low temperature may cause organic collections to be brittle and susceptible to cracking and other damages. Mostly, organic objects such as wood, oil, acrylic paints are at risk at cold temperature, therefore needs to be handled with care (Joan & Brynn, 2016).

As it is well known that there is an inverse relationship between Relative Humidity and Temperature, that is, for a volume of air, humidity reduces as temperature increases and vice versa. In a museum environment, relative humidity is vital because of the role it plays in both chemical and physical form of deterioration. Organic materials and few of the inorganic materials absorbs or releases moisture from the air depending on the percentage of moisture content around its surroundings. However, high relative humidity may cause damages such as corrosion of metals and mould growth. Cracking and shrinkage may as well occur in low RH (Joan & Brynn, 2016).

2.4 Sources of Airborne Particulate in Museum

Studies have determined the sources of airborne particles in museum buildings over several recent decades, and their results have highlighted that the increased concentration PM in the museum indoor environment was from sources such as shed from people such as visitor, employee clothing and shoes (Camu et al., 2001; Delalieux et al., 2004; Fall et al., 2003; Lazaridis et al., 2018; Young et. al., 2001), dust resuspension (Delalieux et al., 2004; Saraga, Pateraki, Papadopoulos, Vasilakos, & Maggos, 2011), inadequate cleaning (Lazaridis et al., 2018), storage condition, and emission from old building materials (Saraga et al., 2011).

Museum artefacts and humans are exposed to PM from the HVAC system because PM enters through this source from outdoor to indoor indirectly. Infiltration from openings such as windows, doors and other open entrances will also increase the level of mass concentration in the museum. The traffic and construction work around the museum are the primary source of particulates, especially when the museum has many openings. Vacuuming process (Fall et al., 2003; Nazaroff et al., 1993) has been linked to dust trapping in the indoor environment of the museum as well as inside the showcase. It is therefore recommended that the cleaning process must be scheduled by the museum management to avoid dust trapping occurrence. Display artefacts/work of art (Schieweck et. at., 2005; Shamzani et al., 2018) can also be another source of indoor air pollutant in the museum environment. In the area of high relative humidity, microorganism, dust particles, pollens may react with moisture content in the air in the presence of high temperature to cause damage to artefacts such as corrosion of metals, mould growth on organic artefacts as well as brittleness of textiles and paper artefacts.

Another source of airborne particulates in the museum is floor/carpet condition (Saraga et al., 2011; Young et al., 2001). Rug or wood floor finishes will accumulate more dust particles, have higher dust resuspension rate and are susceptible to mould growth when compared plastic or rubber floor finishes. Synthetic floor, however, is more durable, easy to clean and inexpensive to replace. However, the synthetic floor is produced and installed by chemicals such as formaldehyde, asbestos and other cancer-causing carcinogens, which makes it suitable for public areas such as a museum. It is therefore advisable to use a low volatile organic compound product for floor finishing in the museum. Example of non-toxic, sustainable flooring materials are bamboo, ceramic tiles, cork, concrete and epoxy resins.

2.5 Airborne Particulates and Human Health

Pollutants in the indoor environment have caused several health issues, and it has been a dominant topic of discussion in the world over the past decades. The primary sources of air pollutants in Malaysia have discussed earlier are a motor vehicle, power stations, industrial processes, fuel burning, domestic fuel burning, burning of municipal and industrial waste (DOE, 2018).

PMs may have many adverse health effects, especially the fine particles that can be easily inhaled but may not be quickly exhaled. Studies have shown damaging health effect including decreased lung function, asthma, poisoning especially from highly toxic particles such as cadmium, lead and other metal, increase risk of heart attacks, irregular heartbeat, cancer, eye and skin irritation (Barnawal, 2018), osteoporosis (WenTe Liu, 2014), premature death (Janssen et. al., 2013), or pneumoconiosis which is sometimes known as "co-workers' lungs" or "dust in the lungs" (Min et al., 2016). When PM is breath in, many of the larger particles may be trapped by the upper respiratory system, which includes mucous membranes, nasal hairs or the trachea. However, some particles particularly the very fine or small particles, may reach deep into the respiratory system and become lodged. It can even extend as far as the alveolar (the area of the deep tissue of the lungs where air exchange takes place) where the most damaging health effect occurs (Brown et al., 2013; Peixoto et al., 2017). Because of the large number of populations of tourist entering the museum environment, the effect of airborne particulates towards them should also be given special consideration.

In addition to the primary health effect on the respiratory system, PM can also result in secondary health effect, which does not directly affect our bodies but have adverse health effects. These includes reduce visibility due to haze from the PM (Yao et al., 2018), machinery fouling especially during massive wind erosion event, where machinery such as tractors and automobiles may become clogged with heavy dust loading. Environmental damage or deposition occurs when PM substantially gets deposited into areas such as rivers and other water bodies which may have toxic effects to the aquatic ecosystem and aesthetic damage (Aggarwal et al., 2013; Osu & Ekpo, 2013). PM results in acid rain during the precipitation event. This acid rain may over time degrade building and monuments, especially those made of limestone and other essential materials (Osu & Ekpo, 2013).

The infant, pregnant woman, elderly, people with critical illness and workers in a particular industry are the most susceptible to the effect of particulates pollution owing to their biological sensitivities and different exposure pattern (Kapoor et al., 2017; Lee et al., 2012; Salje et al., 2013). The effect of airborne particulates towards museum visitors includes coughing, heart diseases, respiratory diseases, asthma and may sometimes leads to mortality (Affendy et al., 2016).

2.6 Airborne Particulates and Museum Artefacts

The artefacts displayed in a museum provides the new generation with a unique connection to the past, which might otherwise be lost. Airborne pollutants have been reported to pose a significant threat to these artefacts, as they are invisible, destructive and rarely detected. When considering the preservation of artefacts for years, substance seemingly as innocuous as water can be seen causing damage. Considering the gases commonly referred to as pollutants in the context of conservation practice which includes: SO2, H2S, O3, the NOx, acid and alkali particles, HCHO, volatile acids and possibly fungal spores. The effects of air pollutants on materials found within the museum are summarised in Table 2.

Table 2: Effects of Air Pollutants on Materials Found Within the Museum.

Pollutants	**Effects**	**Reference**
Sulfur dioxide (SO_2)	Tarnishing image Damaging paint and die. Reduces the strength of textiles Weakens leather Attack photographic material	(P. Brimblecombe, 1990) (Shahani & Wilson, 1987) (Workneh & Gholap, 2018) (Elshabrawy, 2018)
Hydrogen sulfide (H_2S)	Tarnish metal Causes damage to paint and dyes. Attacks photographic materials.	(P. Brimblecombe, 1990) (Workneh & Gholap, 2018) (Muros & Scott, 2018) (Vermeulen et al., 2017) (Vagnini et al., 2018) (Elshabrawy, 2018)
Nitrogen dioxide (NO_2)	Induces fading in textile dyes It reduces the strength of textile. It damages photographic films.	(P. Brimblecombe, 1990) (Workneh & Gholap, 2018) (Peter et al., 2001) (Konstantinidou, Strekopytov, Humphreys-Williams, & Kearney, 2017) (Elshabrawy, 2018)
Ozone (O_3)	Cracks rubber Induces fading in dyes Attacks photographic materials Damages book	(P. Brimblecombe, 1990) (Workneh & Gholap, 2018) (Porck, 2015) (Elshabrawy, 2018)
Hydrogen peroxide (H_2O_2)	Discolours photographic prints	(Muros & Scott, 2018) (Vermeulen et al., 2017) (Vagnini et al., 2018)
Formaldehyde (HCHO)	Affects photographs and metal objects	(P. Brimblecombe, 1990) (Vermeulen et al., 2017)
Organic acids	Damages metals Damages rocks and shells	(P. Brimblecombe, 1990) (Workneh & Gholap, 2018)
Organo-sulfides	Aids metal corrosion	(P. Brimblecombe, 1990) (Workneh & Gholap, 2018)
Diethylamino-ethanol ($C_6H_{15}NO$)	Damages to vanishes	(P. Brimblecombe, 1990)
Alkaline	Damages paintings	(P. Brimblecombe, 1990)
Ammonium sulphate $(NH_4)_2SO_4$	Induces bloom on vanishes	(P. Brimblecombe, 1990) (Muros & Scott, 2018)
Particles	Soils paintings, frescos, paper, wax, damage magnetic recordings	(P. Brimblecombe, 1990) (Porck, 2015) (Baer & Banks, 1985) (Daher et al., 2011)

2.7 Concentration and Chemical Composition of Airborne Particulate in Museums

The study of the chemical composition of airborne particulates inside a museum has an increasing concern and result of previously published articles are reviewed in this section. Carneiro et al. (2013) asses the IAQ of the Oscar Niemeyer Museum (MON) in Curitiba, Brazil. The result shows an average concentration (100 – 10 ng/m3) of the elements such as S, Cl, and K, whereas, Fe and Zn were below the concentration of 10 ng/m3. Their results also revealed that six significant types of aerosols were encountered which include biogenic, calcium, carbonate, calcium sulfate, soil dust, and organic soot. Acetic acid was detected at low concentrations in both studied building whereas, formic acid the "eye" building. Benzene, toluene, ethylbenzene and xylene (BTEX) concentration was also found to be higher at the main building than the one at the "eye" building. Finally, BC concentrations were found to be directly linked to the intensity of the vehicle traffic in the surrounding area.

Cao et al. (2011) investigation on the chemical composition of the indoor and outdoor atmospheric particles at the Emperor Qin's Terra-cotta Museum in China revealed that sulfate, nitrate, carbon, and geological matter were among the component of PM. Their result also shows a higher concentration of acidic particles in the indoor environment, which will have a significant risk towards the terra-cotta Figures upon particle deposition, especially on the high variation of temperature and RH.

Chianese et al. (2012) carried out a periodic air quality control check at the Capodimonte Museum in Naples, Italy and found a low concentration of atmospheric substances such as nitrogen oxide, sulphur dioxide, and O3. Low level of NO results in the low concentration of nitrous acid. BTEX registered a high concentration at both indoor and outdoor areas. Low levels of benzoic acid, limonene, and naphthalene were also obtained, but their presence inside the museum may contribute to the development of other chemical reactions which may be harmful to the museum artefacts.

Delalieux et al. (2004) determine the chemical composition of the outdoor and indoor area at the Royal Museum of fine arts, Antwerp, Belgium. The joint contribution of low-Z, S-rich, and Fe-rich particles to 0.5-1.0 µm size range were 15% in the winter and 90% in the summer. The total contributions to the entire size range were 20% in winter and 49% in the summer. A higher concentration of harmful particles was obtained during the summer. However, S and Fe concentration, which are the most crucial element in terms of conservation, was measured to low with a value of 0.25 µg/m3.

A study on the concentrations and chemical compositions in five Southern California Museums was measured in the winter and summer periods by Fall et al. (2003). The five museums are Sepulveda House, Southwest Museum, Norton Simon Museum, Scott Gallery and Getty Museum.   Species investigated are organic, elemental carbon, NO3, SO4, NH4, Na, soil, and others. The average indoor/outdoor ratio of individual chemical species during the summer and winter season are presented in Figure. 3.5. In few of the selected sites, I/O ratio of fine particulates matters varies from 0.96 at the Sepulveda House in summer to 0.16 in Norton Simon Museum in the winter. On the other hand, the coarse particulate ranges from 0.53 to 0.06 at Sepulveda House in the winter and Norton Simon Museum in the summer, respectively. This result implies that there is a higher concentration of fine particulates chemical composition in the indoor as when compared to the outdoor. The most substantial I/O ratio obtained for organic matters, a small ratio was obtained for nitrate and ammonium ions. The I/O ratio of the coarse particles of all species was lower than those from the fine particles.

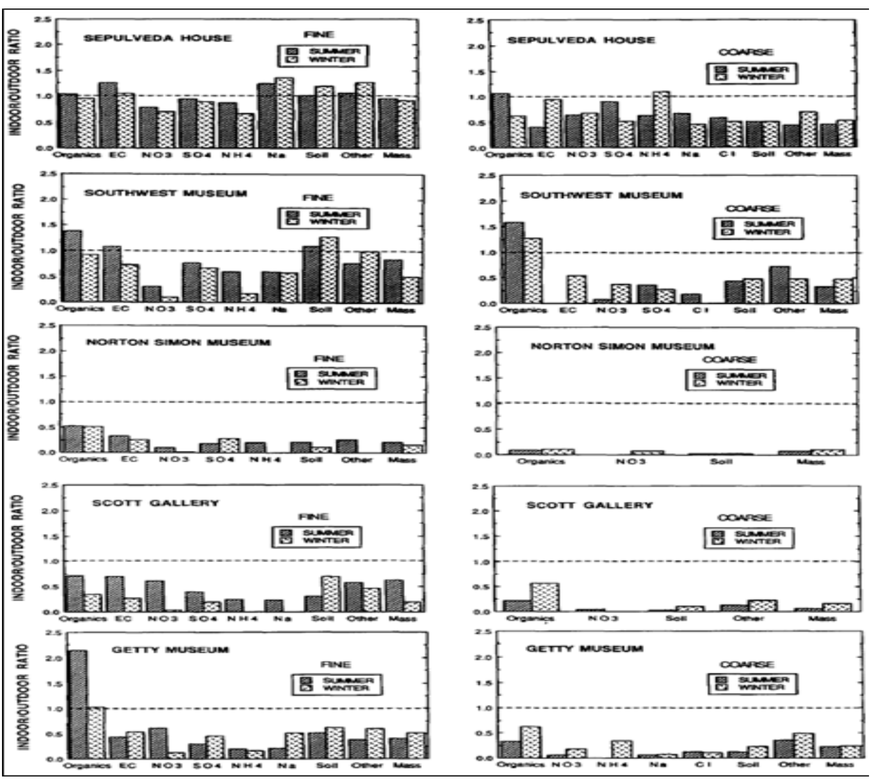

Figure 6: Seasonal Mean I/O Concentration Ration for Individual Chemical Species at the Southern California Museums.
Source. Fall et al. (2003)

2.8 Particulate Matter in the National Museum of Malaysia

Researchers have studied the Air quality of the National Museum Malaysia on several occasions. Hanapi & Mohd Din, (2018) researched on the mass concentration of airborne particulate in the indoor environment of some selected museum in Malaysia. Their result shows that the level of indoor air quality in all selected museum surpasses the standard limit set by the DOE and Malaysian Standard for total suspended particulates. This result means that the IAQ of the museums are poor especially that of the national museum with 0.455 mg/m3 total inhalable dust and may create a high risk of exposure towards airborne particulate to the building users. Furthermore, PM trapped in the museums may become a risk and create soiling effects on artefacts as well as several health problems to the museum users.

Din et al., (2018) discuss on the mass concentration of airborne particulates in terms total inhalable and respirable dust from the stone, metal and ceramic display at the National Museum by comparison between weekday and weekend samples. From their results, it is apparent that the mass concentration of the weekday of Gallery A for stone and ceramic showcase was the highest with the value of 0.660 mg/m3 and 0.347 mg/m3 respectively, while none of the mass concentrations at the weekend exceeds the DOSH standard. For Gallery B, mass concentration for stone and ceramic display showcase shows a considerable high value of 0.028 mg/m3, and 0.174 mg/m3 consecutively but none exceeds the standard set by DOSH. As for the respirable dust concentration, the mass concentration was much at the stone and ceramic artefacts due to the location of the display showcase as reported by the researchers. This high concentration of total inhalable and respirable dust concentration does not only cause harm to human health but also deteriorate the museum artefacts in terms of soiling. The findings from various publications stress the importance of monitoring and reducing the outdoor and indoor air pollution about its consequence on human health, and artefacts conservation and preservation by various conservationist and conservation bodies.

2.9 Airborne Particulates Soiling Defects in Museums Around Peninsula Malaysia

The term soiling refers to the discolouration of materials which reduces the aesthetics quality and usefulness of a surface, through the absorption and scattering of the incident light. According to Haynie & Spence (1984), defined soiling as degradation that can be undone by cleaning, washing and painting which is measured as reflectance contrast of a surface with deposited particles by comparison to the reflectance of the base substrate. Soiling defects start when airborne particulate interact with various substances in the air, thereby forming organic or inorganic chemical compounds, which then deposit to the surface of artefacts (Affendy et al., 2016). These depositions pose a significant threat to museum artefact as it causes material decay, metal corrosion, surface cracking, discolouration of paints, fading of dyes and soiling defects.

The "bulk chemical composition" also known as the major chemical components, is responsible for triggering the soiling defects of artefacts, and they consist of primary component such as carbonaceous compounds (EC and OC), sea salt, mineral dust, biological material (spores, pollen viruses, bacterial), heavy metals (Al, Fe, Cu, Zn, Pb) and secondary sulphate, nitrates and ammonia particle (Affendy et al., 2016; Din et al., 2017).

There have been few publications reporting the soiling effect towards museums artefacts in Malaysia in recent years. Shamzani et al., (2018), highlights that the soiling defects were more evident at the stone and ceramic artefacts in Gallery A and Gallery B of the National Museum Malaysia. The researchers, however, surveyed the National Museum Malaysia for defected artefacts caused by soiling, among their findings are shown in Figure 7. Soiling effects were evident in both organic and inorganic artefacts. The deterioration effect can be traced to factors such as high moisture content and temperature, particulates such as dust and pollens, light exposure, fungus growth, insect attack, chemical reaction of materials, mishandling and improper storage of artefacts.

Figure 7: Soiling defect of some Artefacts surveyed at the National Museum Malaysia

3. CONCLUSION

The review clearly explains the issues of air pollution as it affects individuals differently depending on genetic susceptibility and individual respons-

es. Trends in countries annual mean concentration of PM shows that an estimate of seven million premature death every year. Level of PM2.5 and PM10 is highest in India and Onitsha, respectively. Cities such as Sydney, New York, and London recorded a lower level of PMs. Through previous publications, the researcher has been able to come up with the various sources of airborne particles in the museum. These sources may include visitor, particulate resuspension, lack of adequate cleaning, HVAC system, infiltration from openings such as window and doors, and traffic and construction work around the building. Pollutants can come from various outdoor sources into the indoor environment by the mechanical ventilation system, natural ventilation and infiltration.
Artefacts soiling by particulate matter is an uncontrolled and expensive phenomenon which results in the reduction in the aesthetic properties and value of artefacts. Collections in the museum environment vary in characteristics, and they are vulnerable to soiling at a differing rate all which are discussed in this review. Furthermore, apart from soiling effect of airborne particulates on artefacts, PM may also affect the health of museum users such as workers and visitors. The infant, elderly, pregnant women, people with certain illnesses are more susceptible to this health effect because of the nature of their respiratory tract. Health effect which may arise, includes sneezing, coughing, heart diseases, asthma and may sometime lead to death. Numerous researchers have studied the concentration and chemical compositions of airborne particulate matter in Museum in Europe and Asia. However, a more detailed study is yet to be conducted with regards to this aspect in Malaysian Museums.

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