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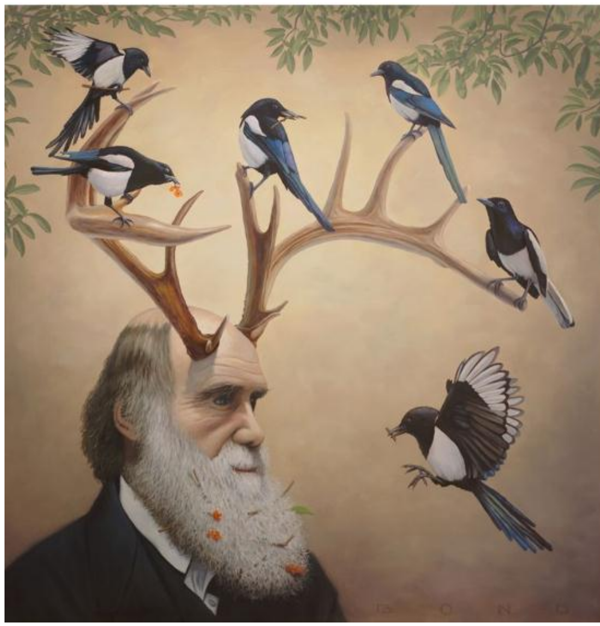

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Airborne Particulates Relationship With Ambient Temperature And Relative Humidity In Determining Soiling Defects On The Artefacts At The National Museum, Kuala Lumpur, Malaysia

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ABSTRACT

Artefacts in the Museum are continuously exposed to adverse climatological conditions such as the high concentration of Particulate Matter, unstable Temperature and Relative Humidity. These adverse climatological conditions can cause varieties of mechanical, chemical and biological damages to the exhibits in a museum and cultural heritage building collections. Thus, this research is aimed at determining the airborne particulates relationship with the ambient temperature and relative humidity in relation to the soiling defects towards the artefacts in Gallery A and Gallery B of the National Museum, Kuala Lumpur, Malaysia. The researchers collected data for 40 days. The microclimate results show that there is an unwanted variability in most of the sample stations during the period of this research.

The variation can cause several damages to artefacts present in both Galleries. Most of the Temperature and Relative Humidity results in Gallery B were beyond the acceptable limits with the location of indoor area and unglazed ceramic exhibition box falling 16 % above ASHRAE fluctuation limit for Relative Humidity. However, the values of Relative Humidity at all sample locations were observed to be within limits set by Italian Standard (UNI 10829/99). In Gallery A, a strong negative correlation of 0.6 and 0.7 were observed between the average Temperature and respirable mass concentration, and average Temperature and Total inhalable mass concentration, consecutively, although a relatively positive relationship of 0.5 was observed between average Relative Humidity and respective mass concentration values. In contrary to Gallery A's results, the relationship between the mass concentration of respirable and total inhalable Particulate matters and T and RH observe in Gallery B, shows a weak positive and negative relationship in some cases and no relationship in others. The research concludes that the climatological conditions of Gallery A and Gallery B of the National Museum Malaysia are in the worst condition and urgent attention needs to be arranged to negate the possibility of its effects.

Keywords: Temperature, Relative Humidity, Airborne particulates, Soiling defects, Museum.

EL TRANSPORTE AÉREO PARTICULA LA RELACIÓN CON LA TEMPERATURA AMBIENTE Y LA HUMEDAD RELATIVA AL DETERMINAR LOS DEFECTOS DE SUELO EN LOS ARTEFACTOS EN EL MUSEO NACIONAL, KUALA LUMPUR, MALASIA

RESUMEN

Los artefactos en el museo están continuamente expuestos a condiciones climatológicas adversas como la alta concentración de partículas, temperatura inestable y humedad relativa. Estas condiciones climatológicas adversas pueden causar una variedad de daños mecánicos, químicos y biológicos a las exhibiciones en un museo y colecciones de edificios del patrimonio cultural. Por lo tanto, esta investigación tiene como objetivo determinar la relación de partículas en el aire con la temperatura ambiente y la humedad relativa en relación con los defectos de suciedad hacia los artefactos en la Galería A y la Galería B del Museo Nacional, Kuala Lumpur, Malasia. Los investigadores recolectaron datos durante 40 días. Los resultados del microclima muestran que existe una variabilidad no deseada en la mayoría de las estaciones de muestreo durante el período de esta investigación. La variación puede causar varios daños a los artefactos presentes en ambas galerías. La mayoría de los resultados de temperatura y humedad relativa en la Galería B superaron los límites aceptables con la ubicación del área interior y la caja de exhibición de cerámica sin esmaltar que cayeron un 16% por encima del límite de fluctuación ASHRAE para la humedad relativa. Sin embargo, se observó que los valores de humedad relativa en todas las ubicaciones de la muestra estaban dentro de los límites establecidos por la norma italiana (UNI 10829/99). En la Galería A, se observó una fuerte correlación negativa de 0.6 y 0.7 entre la temperatura promedio y la concentración de masa respirable, y la temperatura promedio y la concentración de masa inhalable total, consecutivamente, aunque se observó una relación relativamente positiva de 0.5 entre la humedad relativa promedio y la masa respectiva valores de concentración. Al contrario de los resultados de la Galería A, la relación entre la concentración de masa de partículas respirables y las partículas inhalables totales y T y RH observadas en la Galería B, muestra una relación débil positiva y negativa en algunos casos y ninguna relación en otros. La investigación concluye que las condiciones climatológicas de la Galería A y la Galería B del Museo Nacional de Malasia están en las peores condiciones y que se debe prestar atención urgente para negar la posibilidad de sus efectos.

Palabras clave: temperatura, humedad relativa, partículas en el aire, defectos de suciedad, museo.

1. INTRODUCTION

The National Museum of Malaysia located in Kuala Lumpur was chosen for a closer examination of mass concentration of the airborne particulates matter and microclimate parameters, to evaluate the soiling rate or artefacts. Mass concentration data were collected for respirable (PM2.5) and total inhalable (PM10) particulates matters sampled for 8 hours. Results of the outdoor and indoor mass concentrations were compared between weekdays and weekends and with the Department of Environment (DOE) and the Department of Occupational Safety and Health

(DOSH) Standards. Mass concentration result has been analysed and submitted for publication elsewhere. However, this present study evaluates the indoor microclimate data by comparing with the fluctuation limit stipulated in the 2015 ASHRAE Handbook and Italian Standards (UNI 10829, 1999). Comparison between obtained mass concentration data (PM2.5 and PM10) and observed microclimate results of Temperature (T) and Relative Humidity (RH) were further computed to examine the influence between climatological parameters.

2. LITERATURE REVIEW

The study of the effect of indoor climatological parameters such as particulate matter, temperature and relative humidity on materials found within the museum is not is not something new, and has been studied by several researchers (Cannistraro & Restivo, 2018; Carneiro et al., 2013; Delalieux et al., 2004; Krupińska, Van Grieken, & De Wael, 2013). However, there is a synergy between climate change and urban air pollution, especially in areas of high relative humidity and air pollutants rate such as Malaysia. Most of the world heritage collections are located in an area where there are limited resources to preserve collections and are found majorly in the tropical and subtropical regions (Carneiro et al., 2013). The soiling of exhibitions present in the museum is greatly influenced by the indoor climatological parameters (Din, Husin, & Othman, 2017). High relative humidity, for example, will cause damages such as mould growth on surfaces of artefact especially in the presence of dust (Joan & Brynn, 2016), corrosion of metal-based artefacts (Di Turo et al., 2016), and chemical soiling of organic-based materials. Mechanical damages to artefacts may also occur at the advent of fluctuation in the relative humidity and temperature, which arise as of the continuous expansion and contraction of materials. Additionally, higher temperatures and relatively low relative humidity will haste decay of chemically unstable artefacts (Joan et al., 2016).

Particulate matters in the atmosphere can also cause potentially soiling effects to artefacts mainly because they are invisible and hardly noticed. The damages caused by particulate matters arise as a result of direct release of toxic gaseous substances into the atmosphere, or the conversion of less corrosive substances into damaging agent such as the reaction to form acidic gases (Vallero, 2014). The damages caused by atmospheric pollutants to different materials found within the museum, the principal pollutants responsible and methods of prevention are described in Table 1.

Table 1: Effects of Air Pollutants on Materials Found within the Museum.

Materials	Kinds of impact	Primary air pollutants	Environmental factors	Method of sampling	Preventive measure
Metals	Corrosion, tarnishing	Sulphur oxides, hydrogen sulphide and other acidic gases.	Moisture, salt, air, PM, O_3	Weight changes after removal of corrosion products, change is surface characteristics	Coating of metals and other surfaces,
Leather, paper, paint and glass	Deterioration, cracking and tearing, brittleness, Blackens white and light-tinted paints, soiling	Sulphur oxides, hydrogen sulphide, nitrogen dioxide, peroxyacetyl nitrate, calcium sulphate	O_3, PM, moisture, sunlight, microorganism.	Tensile strength, weight measurement, chemical analysis	Storage of leather is so2 free area, coating
Rubber	Cracks, degradation	O_3, nitrogen dioxide	Sunlight, physical wear	The loss in elasticity and strength, measurement of crack frequency and depth.	Use of a highly saturated rubber molecule, the use of a wax inhibitor which will "bloom" to the surface, and the use of paper or plastic wrappings to protect the surface
Fabrics and dyes	Soiling Moreover, the loss of tensile strength, wear, fading	Sulphur dioxide, nitrogen dioxide,	PM, O_3	Reduce tensile strength, chemical analysis, shrinkage	Keep material in for away from PM
Stone	Soiling, deterioration, corrosion,	Sulphur dioxide, carbon dioxide, calcium sulphates,	Ionic strength and pH	Optical measurement.	Keep material in for away from PM

Source. Di Turo et al. (2016), Hanapi (2015) and Vallero (2014)

3. METHODS

3.1. Measurement site

The National Museum of Malaysia is at the heart of the city of Kuala Lumpur located at a walking distance from KL central. The National Museum of Malaysia is also known as Muzium Negara, is a built-in Style of traditional Malay house. The impressive Malay architecture and façades beautified by two colossal murals of Italian glass mosaic, each depicting scenes of Malaysian history and craft, respectively, as illustrated in Figure 1. The surrounding can be characterised as an Urban environment which as a moderate maritime climate. The building is coupled with an HVAC system which is in operation throughout the building. All Galleries have tiled floor finishes and a painted block wall. Samples in the museum were collected between 26th July 2019 and 26th August 2019.

Figure 1: National Museum Malaysia Facades.

3.2. Particulates Matter sampling (PM2.5 & PM10)

Casella 7 Holes and Cyclone sampler head were the primary equipment used to capture total inhalable and respirable particulates samples, with each pump set to run at a flow rate of 2.0 L/min and 2.2 L/min, respectively. Mass concentration of airborne particulates calculated according to the method used by HSE (2019). Briefly, airborne particulates quantity was determined by pumping air through the filter analysed. The airflow was observed and recorded before and after each sample. The quantity of airborne particulates collected on nitrocellulose filter is determined by weighing gravimetrically using a weighing balance. The filters are weighed three times before and after sampling, and the average result is observed and recorded. The particulate matter mass concentration is determined by the gravimetric method based on the difference of measured weight. Mass concentration data were quantified for 32 days (16 weekdays and 16 weekends). The sample stations were positioned in four crucial areas of the museum building which is (i) indoor Area of Gallery A, (ii) Indoor Area of Gallery B, (iii) Inside three exhibition box each form Gallery A and B, and (iv) Lobby of the museum. Figure 2 (a) and (b) indicates the layout of the museum Gallery A, Gallery B and lobby illustrating where samples are captured. The sample was conducted for 8 hours working period (9 a.m. to 5 p.m.). A total of one hundred and twenty-eight (128) samples were collected (sixty-four (64) inhalable samples and sixty-four (64) respirable samples) for both weekdays and weekends. Results between weekdays and weekends were further compared, discussed and analysed respectively.

3.3 Microclimate sampling

Indoor microclimate data were examined for 40 days. Hobo data logger (HOBO U10-003) were placed in each of the showcases selected, and on top of one exhibition box in Gallery A and B, as illustrated in Figure 2 (a) and (b). Thermographic parameters examined are the temperature and relative humidity for both day and night. Hobo data loggers were configured to record Temperature and relative humidity at ten (10) minutes intervals.

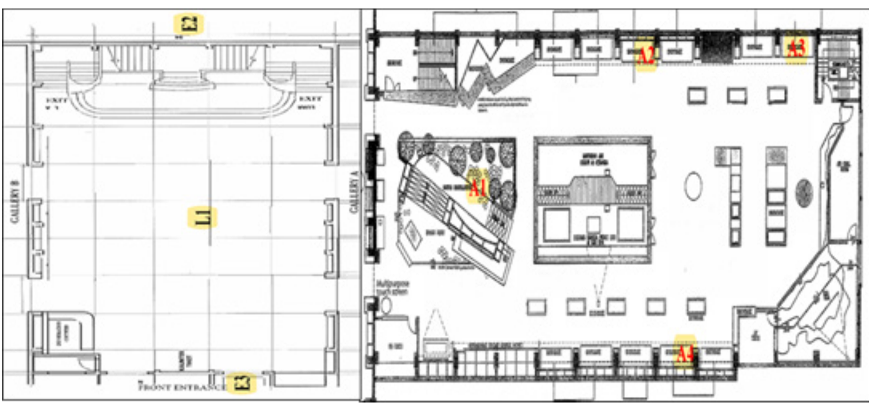


Figure 2 (a): Layout of National Museum Gallery A/Lobby, Illustrating the location of sample stations. A1: Indoor Area; A2: Ceramic Exhibition Box; A3: Metal Exhibition Box; A4: Stone Exhibition Box; L1: Lobby.

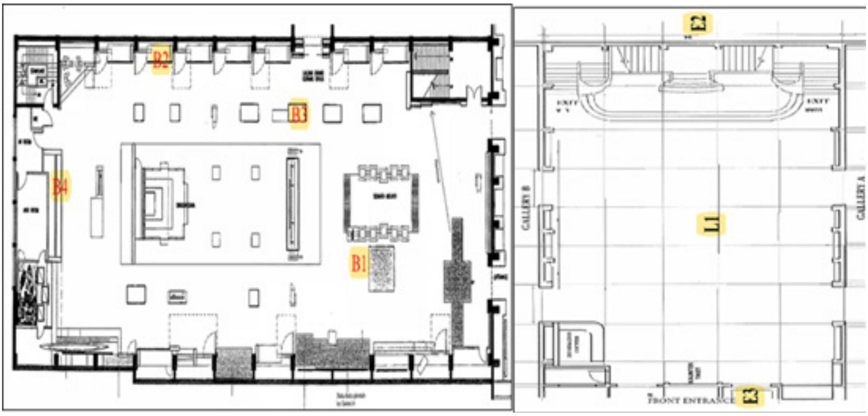


Figure 2 (b): Layout of National Museum Gallery B/Lobby, Illustrating the location of sample stations. B1: Indoor Area; B2: Glazed ceramic Exhibition Box; B3: Metal Exhibition Box; B4: Glazed ceramic Exhibition Box; L1: Lobby

4. RESULTS AND DISCUSSIONS

4.1. Evaluating the indoor microclimate parameters at the National Museum Malaysia using two different Standards

In Table 2, the risk associated with indoor microclimate condition at the National Museum Malaysia is analysed according to various guidelines from various publications. Results obtained from data logger reflecting the indoor climate for 40 days were used. Two prominent standards were used to evaluate the result obtained, namely the ASHRAE standards for Museums, Libraries and Archives, and the UNI 10829/99 of the Italian standardized body.

ASHRAE requirement for "class A" for maximum allowable short-term fluctuation of temperature and relative humidity, for general museum collections states between 15 - 25 °C ± 2 °C for T, that is between 13 °C and 27 °C, and 50 % ±5% for RH, implying a range between 45 % and 55 %, respectively. On the other hand, the Italian standard (UNI 10829/99) required a fluctuation limit between 19 – 24°C ±1.5 °C for a short-term change in T, which translates to a range between 17.5 °C and 25.5 °C, and between 50 – 64 % ± 4% for short-term change in RH, that is between 46% and 68%, as illustrated in Table 5.2. The average temperature and relative humidity for 40 days, at various locations in the National Museum, were computed and evaluated using the standards mentioned above.

ASHRAE has classified the museum based on the instigated microclimate control, and categorizes the museum into five classes of control which are the AA, A, B, C and D. The class used to evaluate microclimate results in this research is the class A, reason being that class A is the optimum for most museum as stated in the ASHRAE handbook. The Italian standard (UNI 10829/99), however, specify the ideal climate parameters for each item based on the artefacts materials. For the scope of this research, the one specifies for polychrome sculptures, painting of wood, and fabrics s used. The researcher used the category of this Italian standards because the materials are closely related to the one being studied in this research.

Table 2 shows the summary of the evaluated data from Figure 3 (a) and (b). The negative (-) values indicate measurement beyond required fluctuation limits, while the positive (+) values indicate measurements that fall within the acceptable fluctuation limits. The evaluated result shows the climate data in Gallery B were in the worst conditions when compared with the ASHRAE fluctuation limits for RH. Most of the data loggers' locations in Gallery B were beyond the acceptable limits with the location of indoor area (B1) and unglazed ceramic exhibition box (B4) falling 16 % above ASHRAE fluctuation limit for RH. The other two exhibition boxes that are glazed (B2), and metal (B3) exhibition boxes were also 14 % above the ASHRAE limits for RH. This high percentage of RH values were obviously due to the high relative humidity of the Gallery, as observed vividly by the researcher. Other researchers such as Fabbri, Pretelli, & Bonora (2019), and Camuffo et al. (2002) has also reported the same case of high relative humidity in the Museum. Although the highest evaluated result of 18 % was obtained at the indoor area of Gallery A, all other locations in that Gallery were within acceptable limits, except for ceramic exhibition box (A2) with just 5 % above ASHRAE fluctuation limits. These two locations were beyond the acceptable fluctuation limit because of the location of the data loggers. The logger at these locations was far the farthest from the main entrance of the museum, and the HVAC system was located close to this position, which makes this area cooler than other areas of the Gallery.

Furthermore, the average RH of the lobby and a ceramic exhibition box in the lobby area were 10 % above the standard fluctuation limit. Most of the average temperature obtained at all the locations in the Galleries were within permissible fluctuation range set by ASHRAE, except for indoors of Gallery B, glazed ceramic, and metal exhibition box of Gallery B which were just 1 % above the ASHRAE fluctuation limits. Additionally, the lobby and the ceramic exhibition box in the lobby area were both 3 % above the required fluctuation limitation set by ASHRAE for temperature.

For the evaluation of result with the Italian standards, all values of RH at all sample locations were observed to be within limits set by UNI 10829/99. These decent results were apparently because the Italian standard gave room for more fluctuation in RH as when compared to the ASHRAE Standard. However, the average temperature data at all locations were far beyond the worst because the Italian standard is strict to its temperature fluctuation requirement. The maximum values of 9 % above fluctuation limits set by UNI 10829/99 were recorded at the two locations in the lobby. The reason for this high temperature at the lobby area was apparently because of the infiltration of the outdoor temperature through various openings to the lobby. Also, there is a higher population of visitors in the lobby as compared to other areas in the museum; visitors release sensible heat which can be among the factors that contribute to high temperature in the lobby (Sharif-Askari & Abu-Hijleh, 2018). The higher temperature was as well observed in three locations in Gallery B, namely, indoors of Gallery B, glazed ceramic, and metal exhibition box, each measuring a value of 7 % above average required limits. No result was found to be below minimum variation limits set by both standards. From the evaluated resulted, it implies that the museum microclimate condition is in the critical state. Therefore, the museum management needs to be informed of the consequences to artefacts present, in order to put in a strategic plan to control and improve the microclimate condition of the museum to an acceptable standard.

Table 2: Average 40 Days Microclimate Data from the Various Location at the National Museum Malaysia, Analysed by ASHRAE and UNI 10829/99 Standards.

			limit					
Gallery A (A1)	15 - 25 °C ± 2 °C	+ 3 % below	50 % ±5%	- 18 % above	19 – 24°C ±1.5 °C	- 2 % above	50 – 64 % ± 4%	+ 5 % below
Ceramic Exhibition Box (A2)	15 - 25 °C ± 2 °C	+ 1 % below	50 % ±5%	- 5 % above	19 – 24°C ±1.5 °C	- 5 % above	50 – 64 % ± 4%	+ 15 % below
Metal exhibition Box (A3)	15 - 25 °C ± 2 °C	0 % with	50 % ±5%	+ 1 % below	19 – 24°C ±1.5 °C	- 6 % above	50 – 64 % ± 4%	+ 20 % below
Stone exhibition Box (A4)	15 - 25 °C ± 2 °C	+ 2% below	50 % ±5%	+ 1 % below	19 – 24°C ±1.5 °C	- 4 % above	50 – 64 % ± 4%	+ 20 % below
Gallery B (B1)	15 - 25 °C ± 2 °C	- 1 % above	50 % ±5%	- 16 % above	19 – 24°C ±1.5 °C	- 7 % above	50 – 64 % ± 4%	+ 6 % below
Glazed-ceramic Exhibition Box (B2)	15 - 25 °C ± 2 °C	- 1 % above	50 % ±5%	- 14 % above	19 – 24°C ±1.5 °C	- 7 % above	50 – 64 % ± 4%	+ 7 % below
Metal Exhibition Box (B3)	15 - 25 °C ± 2 °C	- 1 % above	50 % ±5%	- 14 % above	19 – 24°C ±1.5 °C	- 7 % above	50 – 64 % ± 4%	-+ 8 % below
Unglazed-ceramic Exhibition Box (B3)	15 - 25 °C ± 2 °C	+ 5 % below	50 % ±5%	- 16 % above	19 – 24°C ±1.5 °C	0 exact	50 – 64 % ± 4%	+ 6 % below
Lobby (L1)	15 - 25 °C ± 2 °C	- 3 % above	50 % ±5%	- 10 % above	19 – 24°C ±1.5 °C	- 9 % above		+ 11 % below
Ceramic exhibition Box (Lobby)	15 - 25 °C ± 2 °C	- 3 % above	50 % ±5%	- 10 % above	19 – 24°C ±1.5 °C	- 9 % above		+ 1 % below

Note: Positive (+) values indicate measurement that falls within the required fluctuation standard and Negative (-) implies values beyond required fluctuation standard.

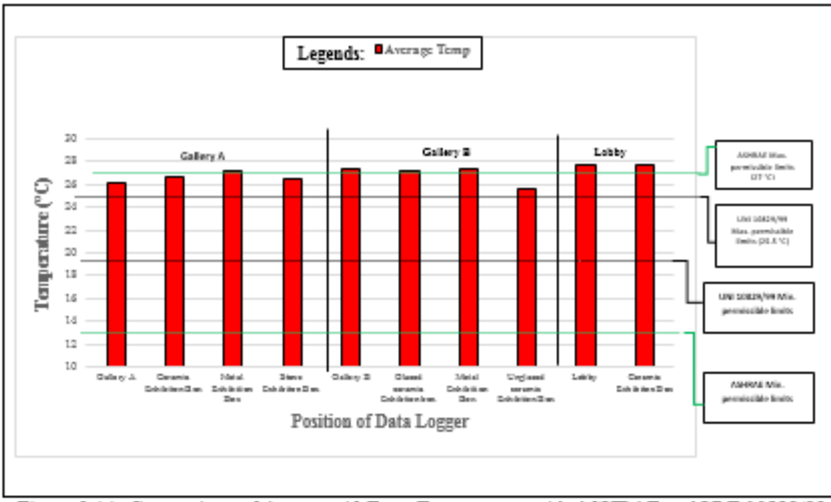


Figure 3 (a): Comparison of Average 40 Days Temperature with ASHRAE and UNI 10829/99 Standards.

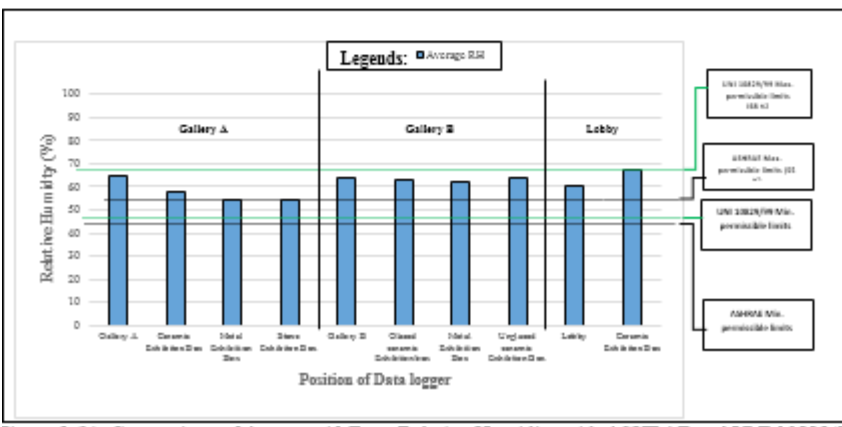


Figure 3 (b): Comparison of Average 40 Days Relative Humidity with ASHRAE and UNI 10829/99 Standards.

4.2 Relationship between Average 8 hours Temperature (T), Relative Humidity (RH) and Mass Concentrations of Total Inhalable and Respirable Particulates Observed at the National Museum Malaysia.

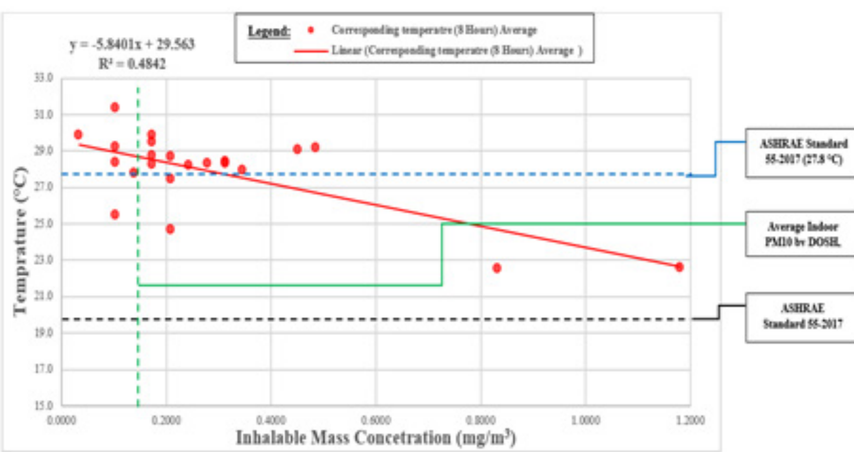
The mass concentration of ambient particulate matter in the air is governed by the climatological parameters such as temperature, relative humidity, wind velocity and wind direction (Jayamurugan et al., 2013; Kraus et al., 2017). This section tries to describe the relationship between the average 8 hours Temperature, Relative Humidity and mass concertation of total inhalable and respirable dust concentration observed in Gallery A and Gallery B during the sampling period. Other microclimates parameters such as air change rate, speed of particles deposition, the roughness of materials surfaces, and room volume were assumed to be constant. The relationship between the mass concentration of respirable (PM2.5), total inhalable (PM10), temperature (T), and relative humidity (RH) for Gallery A and B is illustrated in Figure 4 (a) - (d) and 5 (a) - (d), respectively. In total, twenty-two (22) and twenty-three (23) samples were captured for total inhalable and respirable particulate matter mass concentrations in Gallery A and B, consecutively. Mass concentration samples were captured for 8 hours for each day sampling, while their respective average 8 hours temperature and relative humidity were also measured and recorded. The analysis was made to determine the relationship between the two variables.

4.2.1 Relationship between Average 8 hours Temperature (T), Relative Humidity (RH) and Daily Mass Concentrations of Total Inhalable and Respirable Particulates Observed in Gallery A

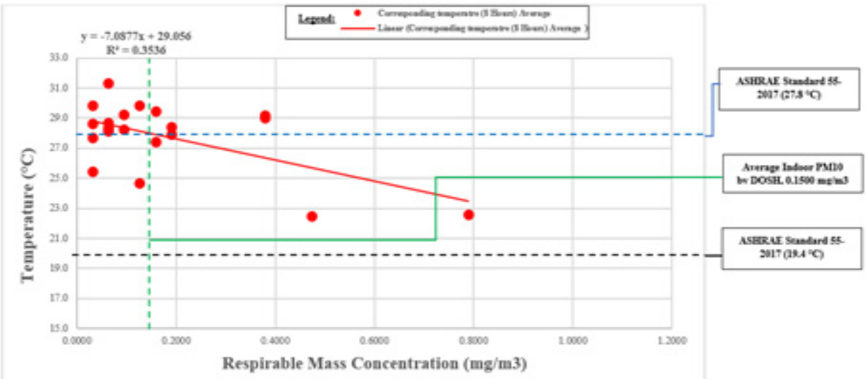
From Figure 4 (a) and (b), it is evident that there is a strong negative correlation between the temperature and the mass concentration of respirable and total inhalable particulates matter. The correlation coefficient is 0.6 and 0.7 for respirable and temperature, and total inhalable PM and temperature, respectively. That is, the lower the temperature in Gallery A, the higher the mass concentration of respirable and total inhalable PM and vice versa. The correlation can be expressed by the polynomial equation ($y = -7.0877x + 29.056$) for respirable dust concentration, and ($y = -5.8401x + 29.563$) for the total inhalable dust concentrates, with reliability coefficient of 35.36 % and 48.42 %, respectively. Kapwata et al. (2018) obtained a contradictory positive correlation result of between hourly indoor temperature and PM4 concentration in a summer and winter season. For the total inhalable dust mass concentrate, the maximum correlation of 1.1806 mg/m3 was recorded at a temperature of 22.6 °C. The lowest total inhalable dust mass concentrates of 0.0347 mg/m3 have recorded a temperature of 29.8 °C. Furthermore, the maximum value of 0.7891 mg/m3 respirable mass concentrations was observed at 22.6 °C temperature level, and minimum mass concentration value of 0.0316 mg/m3 was observed at 25.5 °C, 22.7 °C and 28.3 °C.

The relationship between the daily 8 hours mass concentration and respective relative humidity, however, shows an average positive relationship with a correlation coefficient of 0.5 for both respirable and total inhalable dust mass concentrations, as shown in Figure 4 (c) and (d). A similar result has been observed by Al-taai & Al-ghabban (2017). The correlation was expressed by polynomial equation y = 9.71x + 57.789 for respirable dust and y = 7.6233x + 57.203 for total inhalable dust mass concentrations. This relationship means that for every increase in the Relative humidity, there is an equal increase in the mass concentrations of both total inhalable and respirable dust concentrates and vice versa. Although, this result seems opposing to the one observed by Kraus et al., (2017) where a higher relative humidity gives results in a lower mass concentration of PM10.

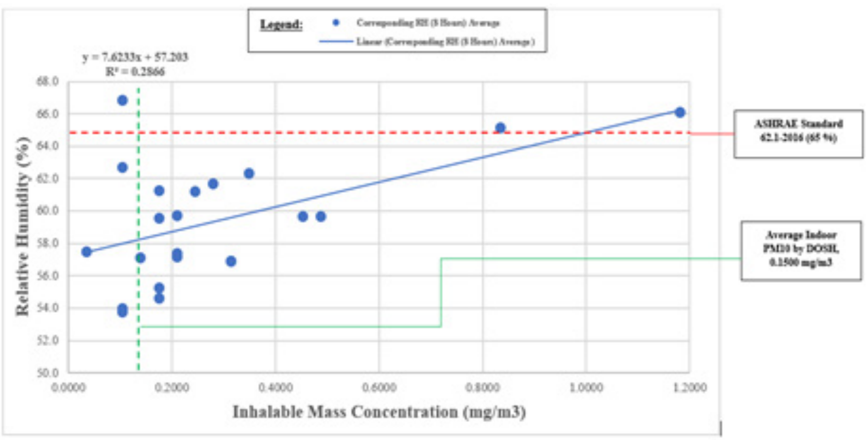
(a)



(b)


Legend:
y = -7.0877x + 29.056
R² = 0.3536
ASHRAE Standard 55-2017 (27.8 °C)
Average Indoor PM10 by DOSH, 0.1500 mg/m3
ASHRAE Standard 55-2017 (19.4 °C)
Temperature (°C)
Respirable Mass Concentration (mg/m3)

(c)


Legend:
y = 7.6233x + 57.203
R² = 0.2866
ASHRAE Standard 62.1-2016 (65 %)
Average Indoor PM10 by DOSH, 0.1500 mg/m3
Relative Humidity (%)
Inhalable Mass Concentration (mg/m3)

(d)

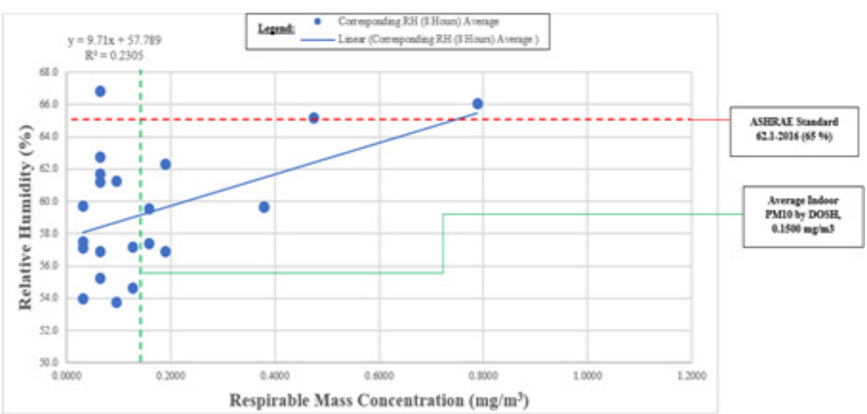

Legend:
Corresponding RH (8 Hour) Average
Linear (Corresponding RH (8 Hour) Average)
y = 9.71x + 57.789
R² = 0.2305
ASHRAE Standard 62.1-2016 (65 %)
Average Indoor PM10 by DOSH, 0.1500 mg/m3
Relative Humidity (%)
Respirable Mass Concentration (mg/m³)

Figure 4 (a) – (d): Relationship Between Daily 8 hours Average Temperature (T), Relative Humidity (RH) and Daily Mass Concentrations of Respirable and Total Inhalable Dust Observed in Gallery A of the National Museum Malaysia.

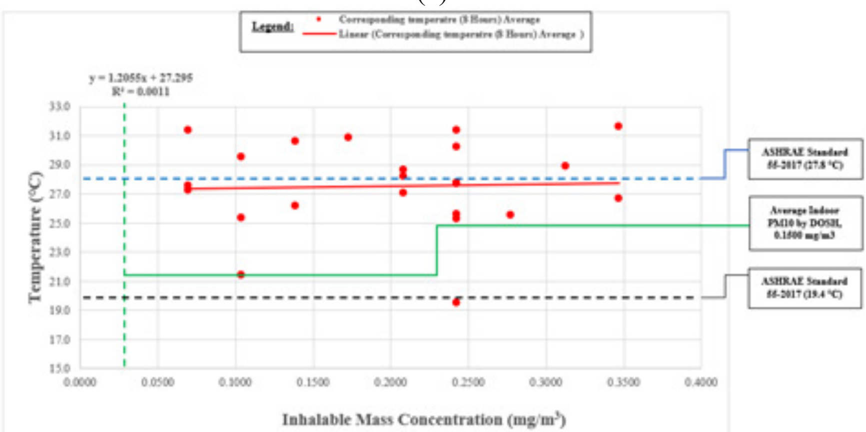
4.2.2 Relationship between Average 8 hours Temperature (T), Relative Humidity (RH) and Mass Concentrations of Total Inhalable and Respirable Particulates Observed in Gallery B

In contrary to Gallery A's results, the relationship between the mass concentration of respirable and total inhalable PM and microclimate parameters (temperature and relative humidity) observe in Gallery B, shows a weak positive and negative relationship in some cases and no relationship in some others. Figure 5 (a), for example, has almost a parallel line with a zero (0) coefficient of correlation. This result means that there exists no relationship between daily PM10 concentration and daily 8 hours average temperature in Gallery B. Kraus et al., (2017) reported the same scenario where temperature difference of an internal residential building has no significant effect on PM10. Additionally, a weak correlation coefficient of 0.2 was observed in Figure 3.8 (c), expressed with a polynomial equation y = -11.285x + 62.197. That is, an increase in relative humidity will result in a small decrease in the mass concentration of total inhalable PM and vice versa.

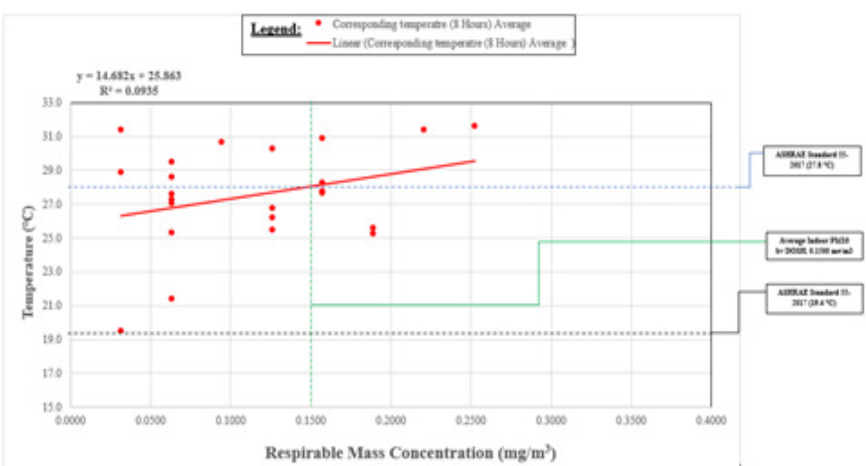
A weak positive relationship of 0.3 was observed between respirable particulates (PM2.5) mass concentration and temperature of in Gallery B, as illustrated in Figure 5 (b) represented with a polynomial equation y = 14.268x + 61.953, which means that a slight increase in temperature resulted in a small increase in the respirable mass concentration and vice versa. At the same time, a weak negative correlation coefficient of 0.3 was observed between PM2.5 and relative humidity, expressed with equation y = -17.602x + 61.953, in Figure 5 (d).

In addition to the correlation analysis, most of the values obtained were observed to be above the required standards of 0.150 mg/m3 set by DOSH for indoor air quality requirement, as described in Figure 4 (a) - (d) and 5 (a) - (d). Detailed analysis of the comparison of result with DOSH requirement has been discussed in another publication. The result of this experimental measurement also indicates the hygrothermal microclimate of the indoor area of Gallery A and Gallery B has a significant effect on mass concentration of dust particulates (Jayamurugan et al., 2013; Kraus & Šenitková, 2017), with Gallery A measurements being the most significant.

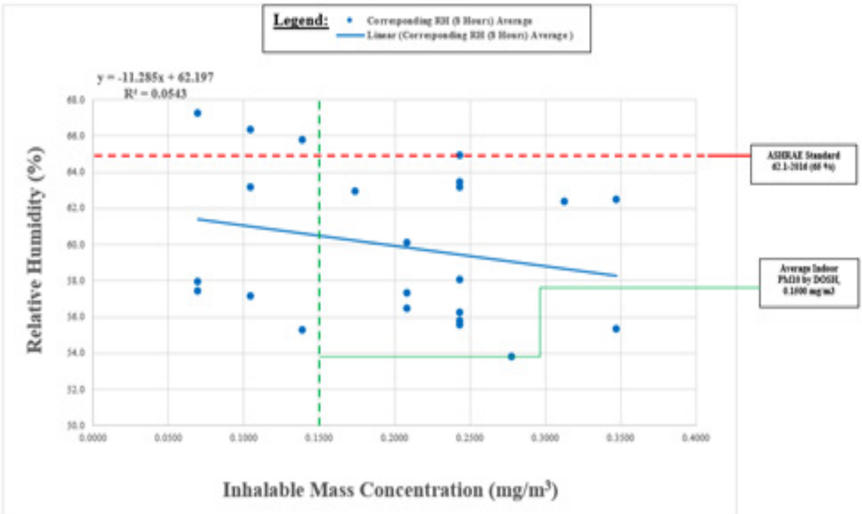
(a)



(b)



(c)


Legend:
Corresponding RH (8 Hours) Average
Linear (Corresponding RH (8 Hours) Average)
y = -11.285x + 62.197
R² = 0.0543
Relative Humidity (%)
Inhalable Mass Concentration (mg/m³)
ASHRAE Standard 62.1-2016 (65 %)
Average Indoor PM10 by DOSH, 0.1500 mg/m3

(d)

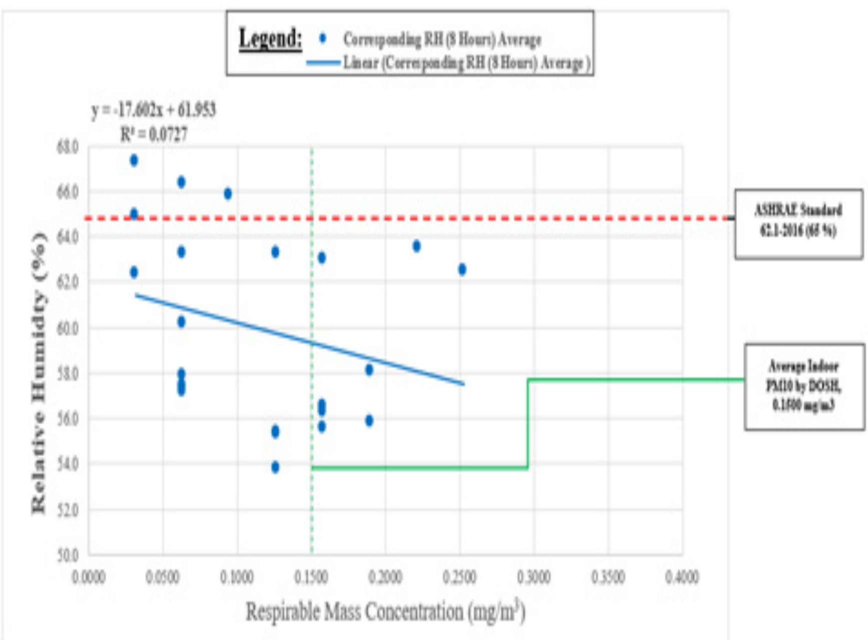

Legend:
Corresponding RH (8 Hours) Average
Linear (Corresponding RH (8 Hours) Average)
y = -17.602x + 61.953
R² = 0.0727
68.0
66.0
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
0.0000
0.0500
0.1000
0.1500
0.2000
0.2500
0.3000
0.3500
0.4000
Relative Humidity (%)
Respirable Mass Concentration (mg/m³)
ASHRAE Standard 62.1-2016 (65 %)
Average Indoor PM10 by DOSH, 0.1500 mg/m3

Figure 3.8 (a) – (d) Relationship Between Daily 8 hours Average Temperature (T), Relative Humidity (RH) and Daily Mass Concentrations of Respirable and Total Inhalable Particulates Observed in Gallery A of the National Museum Malaysia.

5. CONCLUSIONS

The mass concentration of ambient particulates matter is governed by the climatological conditions such as temperature, relative humidity, wind velocity and direction. This research evaluates the microclimate condition and describes the relationship between the average 8 hours airborne particulates sampled at the museum and the average 8 hours temperature and relative humidity of their respective locations. The evaluation of result with the ASHRAE and UNI 10829/99 standards shows that most of the data obtained were beyond the standard fluctuation limits set by both standards. When compared with the ASHRAE standard for RH, the indoor area and the unglazed ceramic exhibition box were at maximum with value 16 % above the standard. As observed by the researcher, this high relative humidity is a result of the condition of the Gallery; the gallery has some part of it ducting system leaking in that area, which makes the RH high. Other locations in both Galleries were in acceptable limit except for the indoor area of Gallery A with 18 % above the ASHRAE standard. The UNI 10829/99 shows a decent evaluation of the result obtained for relative humidity at all locations. The temperature result was, however, at critical state due to many reasons. Among the reasons are the infiltration from outdoor temperature and high population of visitors in the museum. The findings of this study show that the microclimate level of the museum is in a dangerous state which can be detrimental to artefacts present in the museum. The museum management should, therefore, be enlightened as to its consequences in order to control and improve the climatic condition to an acceptable standard.

In Gallery A, the result shows that there is a strong negative correlation of 0.7 and 0.6 between temperature and the mass concentration of total inhalable, and temperature and mass concentration of respirable particulate matter, respectively. A positive correlation coefficient of 0.5 was as well observed between the mass concentration of total inhalable and respirable particulate and relative humidity in Gallery A. The result in Gallery B is opposing with to that of Gallery A, with the relationship of both temperature and relative humidity with the mass concentration of total inhalable and respirable particulates resulting to a weak relationship in most of the cases. This research ended up by affirming the fact that the hygrothermal microclimate of the indoor area of Gallery A has more effect on the mass concentration of dust particulates when compared to that of Gallery B.

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