THE CHARACTERISTICS, AND SOILING DEFECTS OF AIRBORNE PARTICULATES TOWARDS INORGANIC-BASED ARTEFACTS INSIDE THE NATIONAL MUSEUM OF MALAYSIA.

BY

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ABSTRACT

Artefacts 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. As such, this research is aimed at determining the rate of soiling in order to reduce the hazardous effect caused by climatological conditions on artefacts in Gallery A and Gallery B of the National Museum, Kuala Lumpur, Malaysia. The researchers collected data for 40 days. The mass concentration of PM in terms of Respirable and Total Inhalable particles were obtained at various sample stations using Cyclone sampler heads and 7-Holes head, respectively. Average mass concentration results were subsequently analysed by comparing the weekdays and weekends results and with the Department of Safety and Health (DOSH) guideline stated in the industrial code of practice on Indoor Air Quality 2010 edition, and Department of Environment (DOE) guidelines on Ambient Air Quality (Iterim-2018). HOBO data loggers were placed at respective sample stations to determine the state of the microclimate conditions, and the possible effects on the exhibits in Gallery A and Gallery B. The obtained microclimate parameters at various stations were further evaluated by comparing with required fluctuation limits stipulated in the 2015 *ASHRAE Handbook* and Italian Standards (UNI 10829/99). Relationship between average 8 hours microclimate parameters and mass concentrations values were computed using the Pearson Correlation and Multiple Linear Regression methods. Furthermore, the elemental composition of short-term dust-fall sample were collected on artefacts at the various sampling station. The average mass concentration results at most of the sample stations were more than the required standard set by DOE and DOSH, with the highest value of 0.4688 mg/m^3 obtained at the metal and ceramic showcase at weekdays, a result 213 times above the required standard. The result of respirable dust to the total inhalable dust were 55.4 % and 59.7 % for weekdays and weekends, respectively. The microclimate results show that there is an unwanted variability in most of the sample stations during the period of this research in both Galleries. The variation can cause several damages to artefacts present in both Galleries. The temperature measured in the Museum was between 20°C and 30.5 °C and relative humidity varied from 50% and 71%, in both Galleries. Most of the temperatures and relative humidity results in Gallery A and Gallery B were also found to be beyond the acceptable fluctuation limits set by ASHRAE and the UNI 10829/99 standards. The result of correlation and regression indicates that the hygrothermal microclimate of the indoor area of Gallery A and Gallery B has a significant effect on the mass concentration of dust particulates, with Gallery A being significantly affected. A total of fourteen (14) elements (Al, Cr, Fe, Cu, Zn, Pb, Bi, Ti, Co, Ni, Si, V, Mn, and Mg) were observed, most of which are detrimental to artefacts present in the museum and mostly originates from a man-made source. The elements dominating Gallery A and B are Zn, Cr, Al, and Fe, with percentage elemental composition of 15.95 %, 9.64 %, 7.56 % and 6.55 %, respectively. Therefore, it can be concluded that the climatological conditions of Gallery A and Gallery B of the National Museum Malaysia are above required standard and urgent attention needs to be arranged to reduce the damages it can cause.

خلاصة البح

تعرض الآثار المصنوعة اليدوية باستمرار للظروف المناخية الضارة مثل التركيز العالي من الجيسمات ودرجة الحرارة غير المستقرة والرطوبة النسبية. يمكن أن تسبب هذه الظروف المناخية المعاكسة الأضرار المتنوعة من الميكانيكية والكيميائية والبيولوجية للمعارض الموجودة ومجموعات بناء التراث الثقافي في المتحف. على هذا النحو، يهدف هذا البحث إلى تحديد معدل التلوث من أجل تقليل التأثير الخطير الناجم عن الظروف المناخية على الآثار المصنوعات اليدوية في المعرض A والمعرض B بالمتحف الوطني، كوالا لامبور، ماليزيا. لقد جمع الباحثون البيانات لمدة 40 يومًا. ثم تم استخدام رؤوس عينات الإعصار ورأس 7 ثقوب للحصول على جزئيات المستنشق والاستنشاق الكلي في محطات العينات المختلفة علي التوالي، وتم تحليل متوسط نتائج تركيز الكتلة بمقارنة نتائج أيام الأسبوع وعطلات نهاية الأسبوع من إدارة الصحة والسلامة (DOSH) ووزارة البيئة (DOE). تم وضع مسجلات بيانات HOBO في محطات العينات المعنية لتحديد حالة ظروف المناخ المحلي، والتأثيرات المحتملة على المعروضات في صالتي المعرض A و B. وتم تقييم معلومات المناخ المحلي التي تم الحصول عليها في محطات مختلفة من خلال مقارنة حدود التقلب المطلوبة المنصوص عليها في دليل ASHRAE 2015 والمعايير الإيطالية (UNI 10829/99). وكذلك تم حساب العلاقة بين متوسط 8 ساعات المعلمات المناخية وقيم تركيزات الكتلة باستخدام طرق بيرسون الارتباط والانحدار الخطي المتعدد. علاوة على ذلك، تم جمع التركيب الأولي لعينة سقوط الغبار على المدى القصير في المصنوعات اليدوية في محطة أخذ العينات المختلفة ومع ذلك، أن متوسط نتائج تركيز الكتلة في معظم محطات العينات أكثر من المعيار المطلوب الذي حددته وزارة البيئة ووزارة الصحة والسلامة، مع أعلى قيمة بلغت 0.4688 ملغم / م 3 تم الحصول عليها في معرض المعادن والسيراميك في أيام الأسبوع، نتيجة 213 مرة أعلى من المعيار المطلوب. كانت نتيجة الغبار القابل للتنفس إلى إجمالي الغبار المستنشق 55.4 ٪ و 59.7 ٪ لأيام الأسبوع وعطلات نهاية الأسبوع على التوالي. تظهر نتائج المناخ المحلي أن هناك تقلبًا غير مرغوب فيه في معظم محطات العينات خلال فترة هذا البحث في كلا المعرضين، يمكن أن يسبب الاختلاف العديد من الأضرار التي لحقت القطع الأثرية الموجودة في كلي المعرضين، وكانت درجة الحرارة المقاسة في المتحف بين 20 درجة مئوية و 30.5 درجة مئوية، وكانت الرطوبة النسبية تتراوح بين 50 ٪ و 71 ٪ ، في كلا المعرضين. تم العثور على معظم درجات الحرارة والرطوبة النسبية في المعرضين A و Gallery B أيضًا على أنها تتجاوز حدود التذبذب المقبولة التي حددتها ASHRAE ومعايير UNI 10829/99، وتشير نتيجة الارتباط والانحدار إلى أن المناخ المحلي الضار للمنطقة الداخلية في المعرض A والمعرض B له تأثير كبير على تركيز كتلة جسيمات الغبار، مع تعرض المعرض A للتأثر بشكل كبير، تمت ملاحظة أربعة عشر (14) عنصرًا (Al و Cr و Fe و Cu و Zn و Pb و Bi و Ti و Co و Ni و Si و V و Mn و Mg)، معظمها ضار بالمصنوعات اليدوية الموجودة في المتحف ومعظمهم من مصدر من صنع الإنسان. العناصر التي تهيمن على المعرضين A و B هما Zn و Cr و Al و Fe، مع نسبة تكوين أولية بنسبة 15.95٪ و 9.64٪ و 7.56٪ و 6.55٪ على التوالي. لذلك، يمكن أن نستنتج أن الظروف المناخية الأكثر ملاحظة في المعرض A ومعرض B بالمتحف الوطني في ماليزيا أعلى من المستوى المطلوب، ويلزم ترتيب اهتمام عاجل لإنكار إمكانية آثاره.

APPROVAL PAGE

I certify that I have supervised and read this dissertation and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

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Supervisor

I certify that I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services Engineering.

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Abdul Razak Sapian
Dean, Kulliyyah of Architecture and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Truly, my prayer and my services of sacrifice, my life and my death are (all) for Allah, the Cherisher of the Worlds

(Q6:162)

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LIST OF ABBREVIATION

$(NH_4)_2SO_4$	Ammonium Sulfate
Al	Aluminium
As	Arsenic
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation System
Be	Beryllium
Bi	Bismuth
BTEX	Benzene, toluene, ethylbenzene and xylene
$C_6H_{15}NO$	Diethylamino-ethanol
CCN	Cloud condensation nuclei
Cd	Cadmium
CFCs	Chlorofluorocarbons
CH_4	Methane
Cl	Chlorine
CO	Carbon Monoxide
Co	Cobalt
CO_2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
Cr	Chromium
Cu	Copper
DOE	Department of Environment
DOMM	Department of Museum Malaysia
DOSH	Department of Occupational Safety and Health
DSMP	Department of Statistics Malaysia Press
EC	Elemental Carbon
EKC	Environmental Kuznets curve
ESL	Estimated service life
Fe	Iron
H_2O_2	Hydrogen peroxide
H_2S	Hydrogen sulfide
HCHO	Formaldehyde
HD	Higgins-Dewell
Hg	Mercury
HSE	Health and Safety Executive
HVAC	Heating, ventilation and air conditioning system
IAQ	Indoor Air Quality
IIUM	International Islamic University Malaysia
IR	Infrared light
K	Potassium
KAED	Kulliyyah of Architecture and Environmental Design
KOE	Kulliyyah of Engineering
L	Lead
MAAQS	Malaysian Ambient Air Quality Standard
MCE	Mixed Cellulose Ester

MCI	Minor Cost Initiative
MDF	Medium-density fibreboard
Mg	Magnesium
MJCI	Major Cost Initiative
Mn	Manganese
MONRE	Ministry of Natural Resources and Environment
N_2O	Nitrous oxide
N_2O	Nitrous oxide
N_2O_3	Nitrogen trioxide
N_2O_5	Nitrogen pentoxide
Na	Sodium
NH_4	Ammonium
Ni	Nickel
NIOSH	National Institute of Occupational Safety and Health
NO	Nitric oxide
NO_2	Nitrogen Dioxide
NO_3	Nitrate
O_3	Ground-level ozone
OC	Organic compounds
ODS	Ozone depletion substances
PAHs	Polycyclic aromatic hydrocarbons
Pb	Lead
PDA	Personal Digital Assistant
PEC	Particulate Elemental component
PM	Particulate matter
$PM_{0.1}$	Particles smaller than 0.1µm
PM_{10}	Particles with an aerodynamic diameter greater than 2.5 µm
$PM_{2.5}$	Particulates with an aerodynamic diameter smaller than 2.5 µm
PVC	Polyvinyl Chloride
QoL	Quality of life
RH	Relative humidity
S	Sulfur
SBS	Sick Building Syndrome
SDD	Silicon Drift Detector
Se	Selenium
Si	Silicon
SO_2	Sulphur Dioxide
SO_4	Sulphuric acid
T	Temperature
Ti	Titanium
TSP	Total Suspended Particulate
USEPA	United States, Environmental Protection Agency
UV	Ultraviolet
UV-B	Ultraviolet type B
V	Vanadium
VOCs	Volatile organic compounds
WHO	World Health Organisation

XRD	X-ray diffraction
XRF	X-ray Fluorescence
ZCI	Zero Cost Initiative
Zn	Zinc

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Air pollution occurs virtually through every stage of our modern life. The manners in which we build our cities, the waste remaining from manufactured goods, combustion process in automobiles and machines, and burning of fossil fuel used in generating energy to heat up and light-up the places we work, live and play all constitute an enormous amount of harmful emission to the atmosphere. These emissions do not only pose a threat to human health but also damages artefacts in buildings such as museums, historic houses, libraries and other institution housing cultural or natural collection (Cassar, 2013; Shamzani, Nur Baiti, & Rashidi, 2018).

The problem of airborne particulates is not something new, and complaints can be traced back to the investigation done by Faraday and Eastlake's on-air pollution in the National Gallery of London which results to the soiling of artefacts. Soiling of objects refers to a phenomenon when dark deposits build up on the surface of artefacts and disturb the value of the colour or form, increasing acidity and damaging the fibre of the attached part (Cassar, 2013; Fall *et al*., 2003; Heritage, 2012).

Several health effects have been linked to exposure to airborne particles when been inhaled by building occupants. Among them are increasing respiratory symptoms such as cough, sneezing, shortness of breath, and asthma attack, as well as chronic obstructive pulmonary disease (COPD), cardiovascular disease, and lung cancer (Pluschke & Schleibinger, 2018; Salthammer & Morawska, 2003)

Because of the impact mentioned above of airborne particles toward museums artefacts and human health, this dissertation thus presents a case study approach by identifying the particulate matter (PM) from airborne particle dispersed from various sources at the National Museum in Kuala Lumpur, Malaysia. This dissertation further compares the mass concentration of airborne particulate (mg/m^3) and illustrates the effect of airborne particulates toward human and artefacts. The ratio of respirable dust towards total inhalable dust (%) is compared with the standard emission PMs Guideline by Department of Environment (DOE) and Department of Occupational Safety and Health (DOSH). Elemental composition of settled dust was observed using the portable XRF, and particle number and size distribution and discussion on sight analysis and distributions.

1.2 STATEMENT OF THE PROBLEM

Different researchers have proposed several definitions of air pollution. However, in a general term, air pollution refers to the presence in the outdoor or indoor atmosphere one or more contaminants or mixtures of contaminants. Thereof in such quantities, and of such duration as may be or may tend to be hazardous to human, animals, plant, and property or which interfere with the satisfaction of life or property or the conduct of business. The cause of these contaminants are several human activities, including industrial process and driving motor vehicles, or natural events such as bushfires and windstorms.

Interestingly, airborne contaminants vary from country to country depending on varieties of factors such as climatic condition, population, the kinds of industries available and type of fuel burned. The Primary contaminants in Malaysia atmosphere as highlighted by the DOE, (2015) are Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), PM_{10}, Total Suspended Particulate (TSP), Lead (L), and Ground-level Ozone (O_3). Moreover, the primary sources of air pollution in Malaysia are industry, development activities, motor vehicles, power generation, land clearing, and open burning and forest fire.

The Department of Statistics Malaysia Press (DSMP) release compendium of environment statistics in 2018. It presents the statistics of the pollutant from various sources to the atmosphere in Malaysia to be 3.2 million tonnes, with the latest report for 2017, as illustrated in Figure 1.1. Motor vehicles emitted 2.3 million tonnes (70.4%) of contaminants, which is the most significant from all sources. Hence, the various means of transportation such as cars, trucks, train, ships, planes and other vehicles produce carbon dioxide to the atmosphere by combustion of fuel in the internal engines. Other sources of air pollution are power plant (24.50%), industries (2.90%) and Others (2.10%).

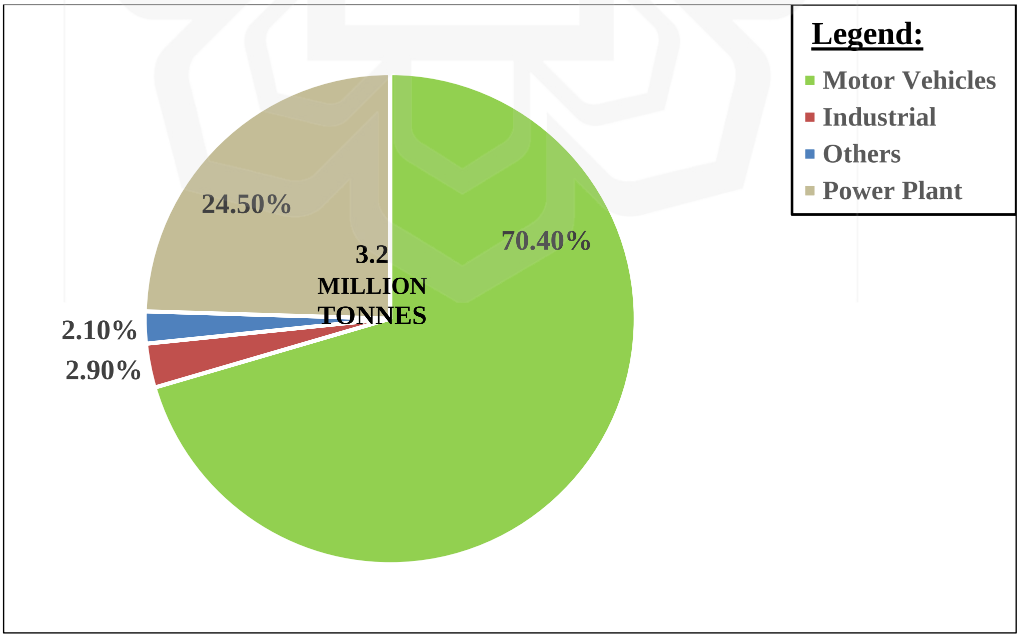

Figure 1.1: Contribution of Pollution in Malaysia.
Source. Mei Kei, (2018)