IOP Conf. Series: Earth and Environmental Science **18** (2014) 012008 doi:10.1088/1755-1315/18/1/012008

The exposure assessment of airborne particulates matter (PM_{10} & $PM_{2.5}$) towards building occupants : A case study at KL Sentral, Kuala Lumpur, Malaysia.

S A Mohddin[1],[3] and N M Aminuddin[2]
Department of Applied Arts and Design, Kulliyyah Architecture and Environmental Design, International Islamic University Malaysia, P.O.Box 10, 50728 Kuala Lumpur.

Email : shamzani@iium.edu.my

Abstract. Airborne particulates have been recognized as a crucial pollutant of indoor air. These pollutants can contribute towards poor indoor air quality (IAQ), which may affect human health in immediate or long term. This study aims to determine the level of IAQ and the effects of particulate towards occupants of office buildings (the office buildings selected for the case study are SSM, KTMB and MRCB at KL Sentral). The objectives of study are (i) to measure the level of airborne particulates that contribute to the IAQ during working hours, (ii) to compare the level of airborne particulates with the existing guidelines and standards of IAQ in Malaysia and other Asian countries and (iii) to assess the symptoms associated with airborne particulates among the building occupants, which were achieved through primary data collection (case study or site survey, structured interview and questionnaire survey) and supported by literature reviews. The results showed that the mass concentration level of airborne particulates within the areas has exceeded the allowable limit of $0.15 mg/m^3$ by IAQ Code of Practice, 2005 of the Department of Safety and Health (DOSH), Malaysia and $0.05 mg/m^3$ by the Department of Environmental (DOE) (outdoor) of 8 hours continuous sampling. Based on the findings, the highest mass concentration values measured is $2.581 mg/m^3$ at lobby of SSM building which is the highest recorded 17 times higher from the maximum limit recommended by DOSH than the others. This is due to the nearby construction works and the high numbers of particulates are generated from various types of vehicles for transportation surrounding KL Sentral. Therefore, the development of Malaysian Ambient Air Quality Guidelines on $PM_{2.5}$ as one of the crucial parameters is highly recommended.

1.Introduction

Nowadays, people are being exposed to a variety of health risks from the surrounding indoor pollution which can affect one's health. Some of the risks are unavoidable. This study will be focused on airborne particulates which affect the occupants of office buildings. The purpose of this study is to provide an overview of the research conducted. In this paper, the items to be discussed and elaborated are the statement of the research problem, the research goals, the research hypothesis, the significance of this research, the outline methodology and the analysis and findings. The two main components in this research are the measurement of particulate matters and the assessment of the health effects in the selected buildings. The sources of air pollution can be divided into two types which are either natural or from anthropogenic sources. Furthermore, the air pollution can have direct and indirect effects on the occupants of the buildings. The effects can be both of short-term and long-term on human health.

[3] To whom any correspondence should be addressed.

2.Statement of the research problem

The air is one critical element to many living things. People may survive for two weeks without food and two days without water. However, a person may only survive for two minutes without air. In daily life, an average person consumes approximately 1kg of food, 2kg of water and 20kg of air [1]. In recent years, the air quality in Malaysia has become quite an issue. Most people are aware that outdoor air pollution can damage the environment and their health, but they may not know that Indoor Air Pollution (IAP) can also have significant effects. Besides that, a study carried out in the USA has shown that the effects of IAP are even worse when compared to the outdoor air pollution. According to the Environmental Science Engineering Program at the Harvard School of Public Health, about 4 % of deaths in the United States can be attributed to air pollution. In developed countries, an average working person spends over 90% of his or her lifetime indoors [2]. According to Shamzani [3], in Malaysia, the awareness on IAP has increased due to the direct and indirect effects towards building occupants whether short-term or long-term mainly on human health such as eye irritation threshold, throat irritation threshold, biting sensation in the nose and eye, teary eyes, lung effects, inflammation of lung (pneumonitis), edema and respiratory distress, which can all endanger to the extent of death.

Furthermore, Wargocki et. al. [4] in his study has recommended maintaining the indoor air quality at a high level by controlling the indoor air pollution sources and ensuring adequate ventilation to promote human comfort, health and productivity in the building. This study is supported in an experiment of another further study by them which has shown that by improving IAQ in an office building it will improve the performance of typical office work such as typing, arithmetical calculations and proof-reading. The results of these studies indicated that the performance of office work may improve by 5 percent when the air quality is improved. It is expected that a new regulation will specify what constitutes good indoor air quality in the workplace. If we refer to the Malaysia Act 514, Occupational Safety and Health Act 1994, Part IV – General Duties of Employers and Self-employed Persons [5], it only requires employers to maintain good air quality, but does not provide specific standards or measures of quality to be achieved or maintained. Even in the latest Code of Practice on Indoor Air Quality [6] by Department of Safety and Health (DOSH) under the Malaysian Ministry of Human Resources the details are not spelled out. As a guideline, the documents do not enforce the industry to comply but they only serve as guidance for the industry to voluntarily improve their offices' IAQ.

3.Indoor air pollution (IAP) and airborne particulates

Indoor air pollution (IAP) can be defined as gas, chemical and particles that enter the atmosphere of a structure which can make the air unhealthy and cause short and long term illness, breathing problems and allergies [7]. These pollutant agents may harm those people who spend a lot of the time indoor compare to people that spent more time outside. For the purpose of this research, the case study will be conducted to understand the effect of indoor air pollution in non-residential building i.e. office building. Air can be contaminated by a range of very different particulates such as dust, pollen, soot, smoke, and liquid droplets. Many of them can harm our health, especially very small particulates that can enter deep into the lungs [8]. Particulates matter (PM) is the sum of all solid and liquid particulates suspended in the air, many of which are hazardous. These particulates come in many different range of size such as coarse, fine and ultra-fine. They also vary in composition and origin. Particulates are either directly emitted into the air by sources such as combustion process and windblown dust, or formed in the atmosphere by transformation of emitted gases such as SO_2.

4.The effects of airborne particulates towards human health

Small particulates of concern include "inhalable coarse particulates" (such as those found near roadways and dusty industries), which are larger than 2.5 micrometers and smaller than 10 micrometers in diameter; and "fine particulates (such as those found in smoke and haze), which are 2.5 micrometers in diameter and smaller [9]. The major source of fine particulates ($PM_{2.5}$) throughout the world today is the human combustion of fossil fuels from a variety of activities (e.g. industry, traffic, and power generation). Biomass burning, heating, cooking, indoor activities and nonhuman sources (e.g. fires) may also be relevant sources, particularly in certain regions. Many aspects of air pollution play a role in the characteristics of population- and individual-level exposures. Pollutants vary on multiple time scales, with emission rates, weather patterns, and diurnal/seasonal cycles in solar radiation and temperature having the greatest impact on concentrations [10][11]. Particulates pollution - especially fine particulates - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particulates pollution exposure to a variety of problems, including: increased respiratory symptoms (such as irritation of the airways, coughing, or difficulty in breathing), decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease. People with heart or lung diseases, children and older adults are the most likely to be affected by particle pollution exposure. However, even if you are healthy, you may experience temporary symptoms from exposure to elevated levels of particulates pollution.

5. Sampling techniques and equipment

The sampling were conducted at ten (10) selected sampling points where five (5) are placed indoors, three (3) are placed in the lobby and two (2) are placed in outdoor areas. The buildings selected are SSM, KTMB and MRCB KL Sentral, Kuala Lumpur. The first building which is SSM office building, the equipments were located at Lobby (Ground Floor) and Office area (Level 17). Meanwhile, for the second selected building is MRCB Office building, the equipments were placed at the Lobby and Office area at Level 4. Another two (2) sampling points were located at Commercial areas which are the Main Entrance (Level 2) and Centre of KL Sentral (Level 1). KTMB building is within KL Sentral but their management and operations are separated from the MRCB building. KTMB is responsible to make sure their buildings are safe and healthy to user or occupants. There are two (2) sampling points which are Platform Komuter (Line 1 – 4) and Platform Inter-City were selected to locate the equipments during working hours. There are two (2) types of sampling head used in sampling airborne particulates i.e. inhalable particulates and respirable particulates. For the purpose of this research, the sampling devices used for measuring the dust existence are 7 Holes Sampler (Total Inhalable Dust Sampler) and Cyclone Sampler (Respirable Sampling Heads***)***. Basically, these equipments are practically used for personal air sampling. However, for this case study, the equipments are located at fixed selected sampling points for assessing emission within 8 hours.

6.Results of mass concentration of 8 hours airborne particulates sampling in the office building: SSM, MRCB And KTMB , KL Sentral.

Basically, the mass concentration gathered from 7 Hole Sampler should be higher than the cyclone samples as suggested by Shamzani [3], who stated that the Cyclone as known as Respirable Dust Sampler produces airborne mass concentration which results in excess of other instruments, which links to high shear forces generated within the instruments, breaking up particle aggregates and increasing the mass of respirable dust. The results shown in Figure 5 and 6 indicate the overall particulates level inside and outside the buildings using 7 Holes sampler and Cyclone sampler. Referring to the recommended contaminants limitation outlined in the *Code of Practice of Indoor Air Quality [6]* by DOSH, the maximum limit of respirable particulate (PM_{10}) indoor is 0.15 mg/m^3. As illustrated in the Figure 5, it is obvious that all results exceeded the maximum limitation. The lobby acts as the intermediate area of outdoor and indoor. As shown, the lobby of SSM building obtained the highest scores 2.581 mg/m^3 compared to others. The results show that it higher by 17 times from the maximum limit recommended by DOSH. This is equivalent to 1621% increase from the limitation. This situation happened due to the great number of users or occupants going in and out of the building during an event on Day 3 which is during the launching of My Corporate Identity (MyCoID) system. This movement will bring the outdoor source (pollutants especially particulates) into the Lobby area.

Meanwhile, the guideline given by DOE [12] for the ambient (outdoor) air quality on particulate matter (PM_{10}) is 0.15mg/m^3, for a period of 24 hours. In addition, through calculation based on guideline, ambient air quality for particulate matter (PM_{10}) is 0.05mg/m^3 is for a period of 8 hours. The second highest result of mean mass concentration is accumulated from the 7 Hole sampler which is 1.968 mg/m^3 obtained from Main Entrance (Level 2) which is located outside the building that is increased 3835% equivalent to 39 times from the limitation. This is due to the pollutants (i.e. smoke) generated from motor vehicles or public transportation like buses (rapid KL), taxis and airport limousines that depart or fetch the passenger at this point. According to Environment Quality Act

1974 (Act 127) – Environment Quality (Control of Emission from Petrol Engines) Regulation, DOE [13] as stated in Regulation 16 motor engines are to stop running in a closed area. It means no person shall allow the engine of any motor vehicle to run while the motor vehicle is stationary for more than 3 minutes in an enclosed or a partially enclosed parking area or any terminus. However, drivers do not follow this regulation and let their vehicle to run while waiting for passengers. In addition, there are construction activities adjacent to this area (about 200m) which might be considered as one of the factors influencing the results.

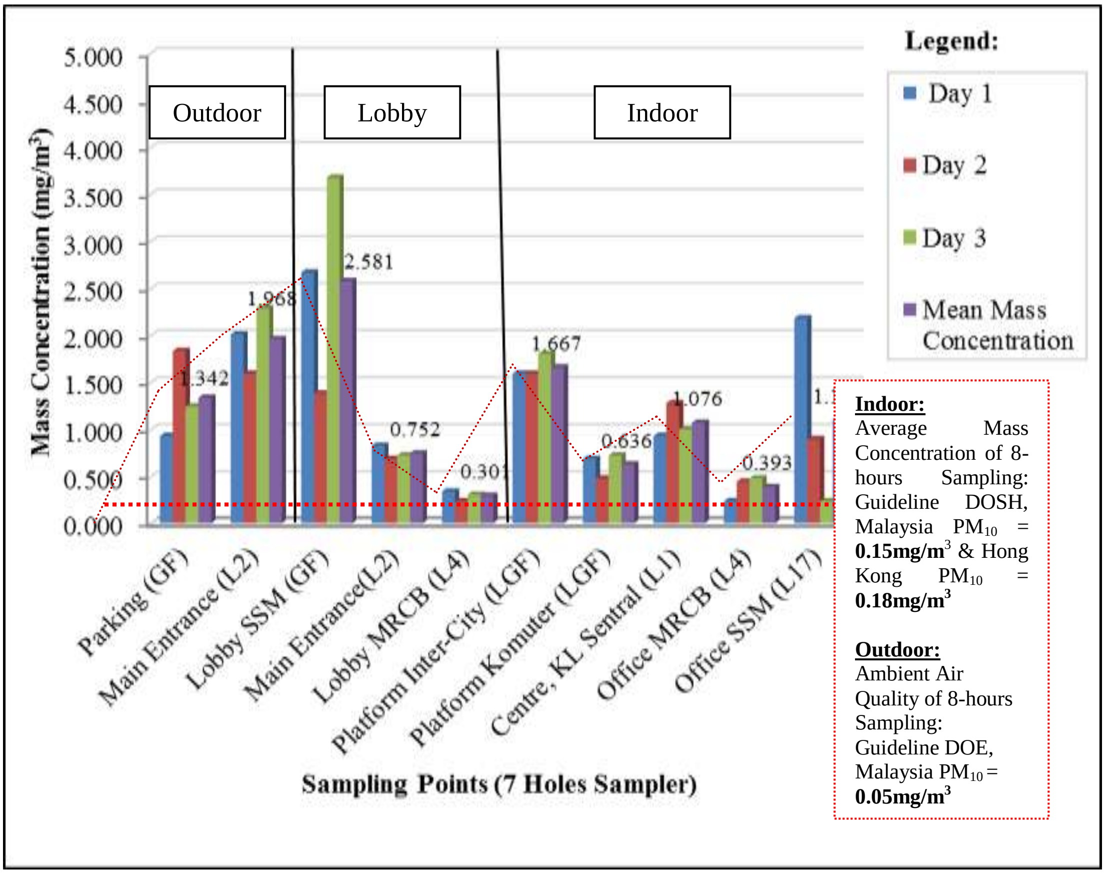

Figure 1. Comparison of mass concentration of 8 hours airborne particulates sampling between ssm, mrcb and ktm using 7 hole sampler.

Meanwhile, for Main Entrance (Level 2 – Lobby) the results is 0.752 mg/m3 which is lower than the results of outdoor area but still increase 5 times from the maximum limitation (401%). It is because the penetration of outdoor pollutants can be reduced when entrance door is automatically open or closed. The next area which has the third highest mean mass concentration score of 1.667mg/m^3 (shown increase 11 times from the maximum limitation equal to 1011%) is the Platform Inter-City, KTM. This area is an enclosed area located at ground floor. Based on researcher experience and observation, the condition at this area very stuffy and unhealthy because smoke and heat generated from the train was trapped in it for 30 minutes to an hour. The train will normally will stop at this platform about 30 minutes to 1 hour to collect passengers. It became worse when the train used diesel as their fossil fuel which released more black smoke, dust or particles compared to the train using electricity for power (i.e. the result obtained from Platform Commuter is 0.636 mg/m^3 which is 4 times increased alike 324% from the maximum limitation) .

Although MRCB building obtained the lowest score compared to others, the results were still beyond the maximum limits recommended by DOSH. The Lobby and Office MRCB are located at Level 4, so the pollutants need to travel a long way and need to go through a few openings (i.e. doors) before entering the building. During the site survey, the entrance door is open sometimes and closed during lunch and at the end of the working hours. This situation may influence the results because the pollutants have easy access to the Lobby and Office. Their readings are 0.301 mg/m^3 for the Lobby and 0.393 mg/m^3 for the Office of MRCB building both increase almost 3 times (101%) from the maximum limitation. As mentioned before, the mass concentration collected using the 7-Hole Sampler should be higher than the Cyclone Sampler. It is proven that this statement is relevant because by referring to Figure 6, obviously all the readings are lower than the 7 Holes Sampler but exceed the maximum limit of respirable particulate indoor mentioned by DOSH which is 0.15 mg/m^3. The Lobby of SSM building scored the highest average mass concentration of airborne particulate reading with 0.863 mg/m^3 when compared to others (increase almost 6 times from the maximum limitation recommended and equivalent to 475%). This is due to a MyCoID event which was held at Level 4 in that building.

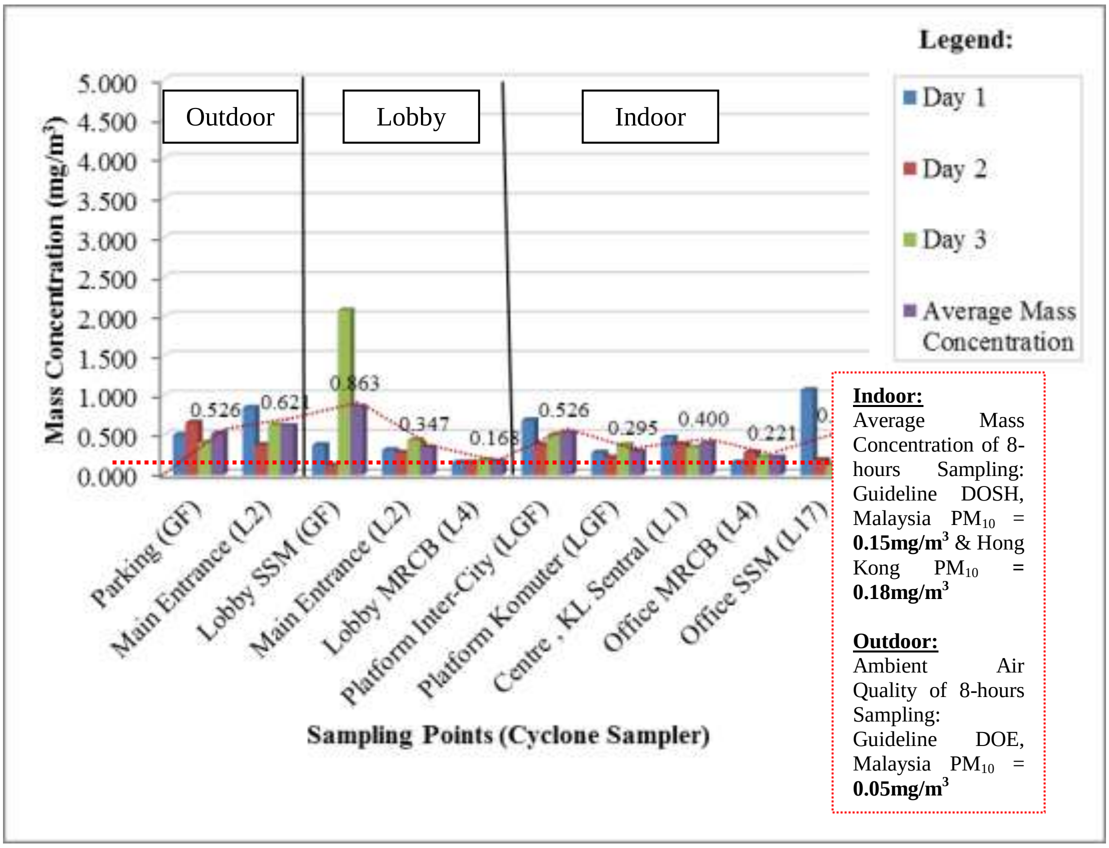

Figure 2. Comparison of mass concentration of 8 hours airborne particulates between ssm, mrcb and ktm using cyclone sampler.

The second highest is 0.621 mg/m^3 which came from the Main Entrance (Level 2) measured outdoor which has increased 4 times from the maximum limitation which equals to 314%. This is followed by Platform Inter-City and Parking at Ground Floor which both gained 0.526 mg/m^3. It is increase by almost 4 times from the maximum limitation recommended and equivalent to 251%. These are very critical areas because all users or the public are exposed to the unhealthy environment. Based on the researcher's observation, most of the users or the public do not cover their nose or mouth while waiting for the bus, taxi or train. These areas are enclosed areas and they are lack of good ventilation of air. Smoke generated from motor vehicles or trains will produce particles or dust. Respirable dust will affect human's respiratory that can cause asthma, lung cancer and other related illness. Meanwhile, the mean mass concentration of airborne particulates at Lobby MRCB can be considered as the lowest reading of only 0.168 mg/m^3 which is close to the guideline provided by DOSH but shown increment 12% from the maximum limitation. Figure 6 also highlighted the trend movements of airborne particulates were arranged from the lowest to highest floor. This trend has shown that the mass concentration value are more stable as compared to 7 Hole sampler except increasing of reading from outdoor to the Lobby SSM when airborne particulates travel through openings to enter the building.

7.Conclusion

Therefore, based on the findings gathered, it can be concluded that the level of respirable and inhalable dust in the selected office building i.e. SSM, KTMB and MRCB KL Sental is very high based on the three (3) Malaysia guidelines which are from DOSH and Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places, Hong Kong : IAQ Objectives for Office Buildings and Public Places. The Hong Kong guidelines shows that a good IAQ of indoor for respirable particulate (PM_{10}) is 0.18 mg/m^3 for an average period of 8-hours and 0.02 mg/m^3 for excellent IAQ. As the mass concentration value for respirable particulates are getting higher, this situation may create high risk of exposure to airborne particulates in office building that affect directly towards the occupants of building. The building services division for each building needs to overcome the problems and take action to develop awareness among staff about the safety and health in office building especially on airborne particulates.

References

[1] Yuanhui Zhang 2005 Indoor Air Quality Engineering *CRC Press LLC*

[2] Hays S M, Gobbell R V and Ganick N R 1995 Indoor Air Quality Solutions and Strategie *Mc Graw-Hill*

[3] Shamzani Affendy Mohd Din 2007 Collection and Physical Characterisations of Airborne Particulates *Doctor of Philosophy Thesis. United Kingdom. Cardiff University* 139

[4] Wargocki P, Wyon D P, Sundell J, Clausen G & Fanger P O 2010 The Effects of Outdoor air supply rate in an office on perceived air quality, sick building syndrome (SBS) symptoms and productivity

[5] Malaysia Act 514 1994 Occupational Safety and Health Act 1994, Part IV – General Duties of Employers and Self-employed Persons.

[6] DOSH 2005 Code of Practice of Indoor Air Quality *Department of Safety & Health, Ministry of Human Resource Malaysia.*

[7] Morawska L and Salthammer T 2004 Indoor Environment: Airborne Particle and Settled Dust *Wiley-VCH Verlag GmbH & Co. KGaA, Weinhelim*

[8] Green fact Glossary 2010 How are particles form? (Retrieved October 3, 2010)

[9] Daniel A Vallero 2010 Environmental Biotechnology: A Biosystems Approach - Antibiotic Resistance and Dual Use *Elsevier Academic Press, Amsterdam, The Netherlands*

[10] Brook et al. 2010 Particulate Matter Air Pollution and Cardiovascular Disease *Circulation 2352*

[11] Rafiah Afroz, Mohd Nasir Hassan and Noor Akma Ibrahim 2003 Review of Air Pollution and Health impacts in Malaysia *Environmental Research* **92** 71-77.

[12] DOE: Department of Environment, Government of Malaysia 2011 Environment Quality Act 1974 (Act 127) **-** Environment Quality (Control of Emission from petrol Engines) Regulation