PHYSICOCHEMICAL CHARACTERISTICS OF FINE AND COARSE PARTICLES IN INDOOR BUILDING

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ABSTRACT

An experimental study was conducted to investigate the physicochemical characteristics of fine and coarse particles as the major pollutants that may post risks to human health in the indoor workplace building of chemical company which located in Gebeng, Kuantan. The objectives of this study are to measure the concentration level of particles, to assess the heavy metals concentration which associated with particles, and to investigate the relationship of the concentration level of particles in the indoor and outdoor workplace building of chemical company. A walkthrough observation was conducted in order to study the layout building, to define the exposure zones for conducting sampling in the building, to obtain the basic information on the factors that may affect indoor air quality and identifying the sources of the potential contaminants. The concentration level of particles was collected by using a very fast response hand-held instrument and the heavy metal which associated with fine and coarse particles was analysed by using Inductively Coupled Plasma- Mass Spectrometry (ICP-MS). The results of concentration level of particles was compared with the WHO Guideline of Indoor Air Quality for Particulate Matter and US-EPA Standard for particulate matter. It shows that the concentration level of fine particles at location B of workplace building of chemical company is not complied with WHO Guideline of Indoor Air Quality for Particulate Matter. In addition, the concentration levels of coarse particles at three points A, B, and C are not complied with both WHO guideline and US-EPA Standard. While only the concentration level of coarse particle at location D is complied with the standard limits that stated in US-EPA guidelines. For the outdoor environment, both fine and coarse particles concentration levels are complied with the National Ambient Air Quality Standard (NAAQS). Apart from this, it was found that six heavy metals such as Al, Si, Se, Co, Ba, and Ga which associated with fine and coarse particles in the indoor and outdoor environment of the workplace building of chemical company. Some control measures were proposed in order to minimize the concentration level of fine and coarse particles in the indoor building such as removing the pollutants by houseplants, isolating the photocopier machine and printers in a good ventilation room, vacuuming cleaning frequently with correct way, exchange the filter of air condition from time to time, and conducting IAQ assessment frequently.

ABSTRAK

Satu kajian eksperimen telah dijalankan untuk menyelidik ciri-ciri fizikokimia partikel halus dan kasar yang sebagai pencemar utama dan boleh membawa risiko kepada kesihatan manusia dalam bangunan dalaman tempat kerja syarikat kimia yang terletak di Gebeng, Kuantan. Objektif kajian ini adalah untuk mengukur tahap kepekatan partikel, menilai kepekatan logam-logam yang bersama dengan partikel, dan menyelidik hubungan tahap kepekatan partikel dalam persekitaran dalaman dan luaran bangunan tempat kerja syarikat kimia. Satu pemerhatian 'Walkthrough' telah dijalankan untuk mengkaji pelan layout bangunan, menentukan pendedahan zon partikel bagi menjalankan persampelan dalam bangunan tersebut, mendapatkan maklumat asas yang mengenai factor-faktor yang boleh menjejaskan kualiti udara dalaman, dan mengenal pasti sumber bahan cemar yang berpotensi. Sebuah tangan instrument telah digunakan untuk mengumpulkan kepekatan partikel dan logam-logam yang bersama dengan partikel halus dan kasar telah dianalisis dengan menggunakan 'Inductively Coupled Plasma – Mass Spectrometry' (ICP-MS). Perbandingan keputusan tahap kepekatan partikel dilakukan dengan garis panduan Pertubuhan Kesihatan Dunia (WHO) Kualiti Udara Dalaman untuk partikel- partikel, dan 'US-EPA' standard bagi partikel-partikel. Terdapat keputusan tahap kepekatan partikel halus di lokasi B, dari bangunan tempat kerja syarikat kimia tidak mematuhi garis panduan WHO Kualiti Udara Dalaman bagi partikel-partikel. Di samping itu, terdapat tahap kepekatan partikel kasar di lokasi A, B, dan C tidak mematuhi kedua-dua garis panduan WHO dan US-EPA standard kecuali lokasi D yang mematuhi had-had yang dinyatakan dalam garis panduan 'US-EPA'. Bagi persekitaran luar bangunan, terdapat tahap kepekatan kedua-dua partikel halus dan kasar telah mematuhi 'National Ambient Air Quality Standard' (NAAQS). Selain itu, terdapat enam logam- logam seperti Al, Si, Se, Co, Ba, dan Ga yang bersma dengan partikel halus dan kasar dalam persekitaran dalaman dan luaran bangunan tempat kerja syarikat kimia. Beberapa langkah-langkah kawalan telah dicadangkan untuk mengurangkan tahap kepekatan partikel halus dan kasar dalam bangunan dalaman. Langkah- langkah berikut termasuk mengadakan houseplants untuk mengurangkan partikel, mengasingkan mesin fotokopi dan pencetak dalam sebuah bilik yang mempunyai pengudaraan yang baik, sentiasa memvakum dengan cara yang betul, menukarkan penapis penghawa dingin dari semasa ke semasa, dan menjalankan penilaian kualiti udara dalaman (IAQ) dengan kerap.

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LIST OF SYMBOLS

$PM_{2.5}$	Fine particle
PM_{10}	Coarse particle
mm	Millimeter
μm	Micrometer
%	Percentage
>	More than
<	Less than
$\mu g\ m^{-3}$	Concentration / microgram per cubic meter
R^2	Coefficient of determination
Cr	Chromium
As	Arsenic
Al	Aluminium
Si	Silicon
K	Potassium
Na	Sodium
Ca	Calcium
Mg	Magnesium
Cu	Copper
Zn	Zinc
Pb	Lead
Cd	Cadmium
Fe	Iron
Mn	Manganese
Ba	Barium
Sr	Strontium
Ni	Nickel
Se	Selenium
H+	Hydrogen ion
HNO_3	Nitric acid
HF	Hydrofluoric acid
DO	Deionized
atm	Atmospheric pressure
min	Minute
°C	Celsius
m/s	Meter per second
ppm	Part per million

LIST OF ABBREVIATIONS

PM	Particulate Matter
ICOP	Industry Code of Practice
SPSS	Statistical Package for Social Science
HVAC	Heating, Ventilation and Air Conditioning
NAAQS	National Ambient Air Quality Standard
US-EPA	United States Environmental Protection Agency
TSP	Total Suspended Particulate
PSI	Pollutant Standard Index
WHO	World Health Organization
ICP-MS	Inductive Coupled Plasma – Mass Spectrometry
RH	Relative Humidity
AED	Aerodynamic Equivalent Diameter
I/O	Indoor- to-Outdoor ratio
PEF	Peak Expiratory Flow
AQI	Air Quality Index
IAQ	Indoor Air Quality
DOSH	Department of Occupational Safety and Health
OSHA	Occupational Safety and Health Act
PEL	Permissible Exposure Limits
TWA	Time Weighted Average

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this chapter, the following sub-chapters discuss about the introduction of the research, which include background of study, research objectives, research question, research hypotheses, as well as the research expected results.

1.2 BACKGROUND OF STUDY

Indoor environment of every workplace is not only vital for the comfort of every building occupants but as well as for their health. Poor indoor air quality might impose some potential health effects and symptoms such as headache, fatigue, irritation of eyes, nose, throat and lungs. However, workers and building occupants might get well from those symptoms by removing those contaminants in the buildings where they perform their daily tasks.

No doubt, air pollutants are no longer new elements which might degrade the air quality no matter outdoor or indoor air environment. Generally, we always think that air pollution is being happened in the outdoors environment, but we never think that the air for indoor environment such as office, library, museum, and hospital could also be polluted by the sources of air pollutants. All these air pollutants might pose some relative health impacts to the health of building occupants in the building due to the daily exposure. There are several air pollutants such as Ozone, Carbon Monoxide, Particulate Matter (PM), Nitrogen Oxides, Sulphur Dioxide, and Lead. However, only particulate matter

will be focused in this study which entitled physicochemical characteristic of fine and coarse particle in indoor building.

In this study, indoor workplace building of chemical company is being chosen as the study background to conduct this research. In this workplace, there might be presence of indoor air pollutants which resulted from the sources of materials that used in the indoor building. However, particulate matter (PM) as the major air pollutants that mostly found in the indoor environment of the building. There are two types of PM that may exist in the indoor building which include $PM_{2.5}$ as fine particle and PM_{10} as coarse particle. Both of these particles might impose some health impacts to human health as well as cause damage to the building.

PM exists as solid or liquid matter which is suspended in the air and it usually less than 0.1mm wide and can be as small as 0.00005mm in order to remain in the air. There are two main types of PM such as coarse and fine particles. Coarse particles are produced from the sources like road dust, sea spray, and construction for outdoor environment, and indoor environment includes cleaning activities, sitting down and standing up, moving documents or paper sheets and walking across the carpet as well (Salma et al., 2013). The aerodynamic diameter of course particle is less than 10 μm, which also named as PM_{10}. These particles consist of different sources and composition compared with fine particles which the aerodynamic diameter is less than 2.5 μm, $PM_{2.5}$ (Brunekreef and Forsberg, 2005). Fine particles are found in the smoke and haze which can be directly emitted from forest fires or created when the fuel is burned and react in the air from industries, power plants and automobiles. For indoor environment, fine particles produced by photocopier machine and laser printers (Tang et al., 2012). Undoubtedly, there is an existence of ultrafine particles in the air which produced by nucleation and condensation, as well as from combustion emissions (Brunekreef and Forsberg, 2005). The ultrafine particles mostly less than 0.2 μm in diameter, which are originally unstable, and increase via coagulation and condensation to bigger accumulated particles (Brunekreef and Forsberg, 2005).

There are several physicochemical characteristics of fine and coarse particles which include particles size distribution, particle mass concentrations, chemical composition of airborne particles, and toxicity of ambient inhalable particles which act as major pollutants in the atmosphere of indoor environment of the building. In view of the fact that the concentration and chemical composition of airborne particles which strongly influence the effects of PM on human health, thus it is essential to investigate the physicochemical characteristics of fine and coarse particles in the atmosphere (Lu et al., 2011) of indoor environment in order to reduce the exposure to the particles and enhance human health in indoor building. However, the toxicity of the airborne particles was discovered to be associated with heavy metals in both fine and coarse particles (Lu et al., 2008).

With the presence of the particulate matters, which are coarse and fine particles in the indoor environment, the quality of indoor air may degrade and it may impose risks and negative impacts to human health. Those particles are small enough enable to penetrate or pass through the throat and nose and then enter the lungs, which can affect the heart and lungs and cause serious health problems. The problems include more frequent asthma attacks, respiratory infection, painful breathing, and irritation of eyes, nose, throat, and lungs, as well as premature death (Fierro, 2000).

1.3 PROBLEM STATEMENT

The physicochemical characteristics of fine and coarse particles such as particle size, particle concentration level, and heavy metal which associated with both particles enable to determine the health risk posed by PM (Mills et al., 2009). The particles size of $PM_{2.5}$ and PM_{10} which exist in the atmosphere with the aerodynamic diameter less than 2.5 μm and 10 μm respectively enable the particles penetrate to the human respiratory system easily. There are numerous studies which have found that the associations between the higher concentrations level of fine and coarse particles and the potential adverse effects on human health in the indoor building (Rastogi et al., 2012). This is because high particle concentration level of PM may increase the exposure of PM to the building occupants and cause them feel uncomfortable when they carry out their tasks. In addition, the heavy metals that associated with PM might be found in the workplace

building of this chemical company due to the location of this company is situated in the industrial estate of Gebeng area, which located near to others chemical, polyplastic, and petrolchemical company and the process of silica production in this chemical company undergoes three processes by using sodium silicate and sulphuric acid. These conditions may contribute to the presence of heavy metals that associated with PM (Taner et al., 2013) and it may consist of the elements such as Silicon (Si), and Aluminum (Al) which might cause chronic effect and pose risk to the indoor building occupants of chemical company. All these show that some of the respiratory illness, respiratory effects, and irritation of the skin and eyes to the building occupants due to the excessive exposure of fine and coarse particles in their work sites, and it emphasizes that this matter is no longer a new issue to the building occupants which cannot be ignored in the indoor workplace building especially for those workers who work in the indoor building of chemical company.

1.4 RESEARCH OBJECTIVES

1.4.1 GENERAL OBJECTIVE

This study is conducted to investigate the physicochemical characteristics of fine and coarse particles as the major air pollutants in the indoor building which may pose risks to the human health in the indoor workplace building.

1.4.2 SPECIFIC OBJECTIVE

i. To measure the concentration level of fine and coarse particles in the indoor and outdoor of the workplace building.
ii. To assess the heavy metals concentration which associated with PM in the indoor and outdoor of the workplace building.
iii. To investigate the relationship of the concentration level of fine and coarse particles in the indoor and outdoor of the workplace building.

1.5 RESEARCH QUESTIONS

This study is guided by the questions as follow:

i. What are the physicochemical characteristics of fine and coarse particles that contribute potential health hazards in the indoor workplace building of chemical company?
ii. What are the concentration level of PM in indoor and outdoor of the workplace building of chemical company?
iii. What are the heavy metals concentration which associated with the PM in the indoor and outdoor workplace building of chemical company?

1.6 RESEARCH HYPOTHESES

The hypotheses of this study are as follow:

H_0: There is no physicochemical characteristic of fine and coarse particles in the indoor workplace building of chemical company.

H_1: There are some physicochemical characteristics of fine and coarse particles in the indoor workplace building of chemical company.

H_0: The concentration of fine and coarse particles in the indoor workplace building of chemical company does not exceed the standard limit of guidelines.

H_1: The concentration of fine and coarse particles in the indoor workplace building of chemical company is exceeding the standard limit of guidelines.

H_0: There are no heavy metals which associated with fine and coarse particles in the indoor and outdoor workplace building of chemical company.

H_1: There are some heavy metals that might associated with fine and coarse particles in indoor and outdoor workplace building of chemical company

OPERATIONAL DEFINITION

Below are the several terms that needed to be defined:

1. **Particulate matter (PM):** A complex mixture of small particles and liquid droplets that suspended in the air which considered being one of the atmospheric pollutants that causes air pollution (Abdullahi et al., 2013). There are mainly two types of particulate matters such as coarse particle (PM_{10}) and fine particle ($PM_{2.5}$). However, there is existence of ultrafine particles which mostly less than 0.2 μm in aerodynamic diameter (Rastogi et al., 2012). PM able to impose potential health problems due to several characteristics of the particles.
2. **Physicochemical characteristics:** The physicochemical characteristics of particulate matter are used to evaluate the physical hazards and help predict possible toxicological or environment hazards and the behavior of PM. These strongly influence the effects of particles on human health (Lu et al., 2011). For example, density, particle size distribution, particle mass concentration aerodynamic equivalent diameter, and chemical composition.
3. **Particle size distribution:** Particle size distribution is an index that used to indicate the particle size of the PM that are existing in what proportions in the indoor environment of indoor building where the total amount of particle is 100% in the sample particle group which to be measured. It is based on particle number, surface area, and volume of particles (Rastogi et al., 2012) which may cause the particulate matter easy to penetrate into the respiratory tract.
4. **Aerodynamic Equivalent Diameter:** The shape, roughness, and aerodynamic drag of the fine and coarse particles which the diameter of the particles is defined as a unit- density sphere that having the same settling velocity as the particle is being measured (Morawka and Salthammer, 2003).
5. **Indoor environment:** Indoor environment refers to the interior environmental quality of a building which might affect the overall comfort, health, and environment of the building occupants (Morawka and Salthammer, 2003).
6. **Indoor air pollutants:** Indoor air pollutants are the particle pollution that able to create risk or harm to the human health and the environment, as well as causing damage to the property. There are six common types of air pollutants such as

particulate matter, ozone, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead (Marian Fierro, 2000).

7. **Particle mass concentration:** It measures the concentration level of particles where most of the number of particles is in the ultrafine range of size, which able to reach and deposit in the alveoli region of lung (Jaques and Kim, 2000).

1.8 CONCEPTUAL FRAMEWORK

Figure 1.0 illustrates the conceptual framework of this study which related to the physicochemical characteristics of fine and coarse particles with the environmental parameters, as well as some health impacts that might pose risks to indoor building occupants. From the conceptual framework, it clearly shows that the physicochemical characteristics of PM may influence the penetration of fine and coarse particles into the human respiratory system which causes the indoor air pollution and some relative health impacts to the building occupants of indoor building.

There are several physicochemical characteristics of fine and coarse particles that might pose risks to the indoor building occupants such as different particle size, particle mass concentrations, as well as heavy metals that carried on the surface of the particulate matters. The particles size and the density of particles show the physical properties of the particulate matters which have the strong dependence on size and density, by measuring their aerodynamic diameters which varying from a few nanometres to tens of micrometres (Kelly and Fussell, 2012). Particle mass concentrations illustrate the indoor concentrations of coarse and fine particles in the building which should comply with the standard limit that stated in the guidelines and references for indoor air quality. Heavy metals which associated with PM provide the information of the concentrations of the heavy metals of the PM by determining the principle components of particles and identifying the groups (cluster) of the particles (Paoletti et al., 2002).

Apart from this, the environmental parameters that affect the movement and concentration level of fine and coarse particles which include temperature, air velocity, and relative humidity of the indoor building. The environmental parameters may influence the concentration level of fine and coarse particle in the indoor and outdoor

environment of the workplace building by infiltration. This results increasing the concentration level in the indoor building and might cause the respiratory disease to indoor building occupants.

There are several potential health impacts due to the existence of coarse and fine particles in the indoor building. Those people might suffer from several illnesses such as aggravated asthma, coughing and difficult breathing, headache, fatigue, irritation of eyes, nose, throat, and lungs, as well as decrease the lung function, due to long term exposure of coarse and fine particles in the indoor workplace building of chemical company.

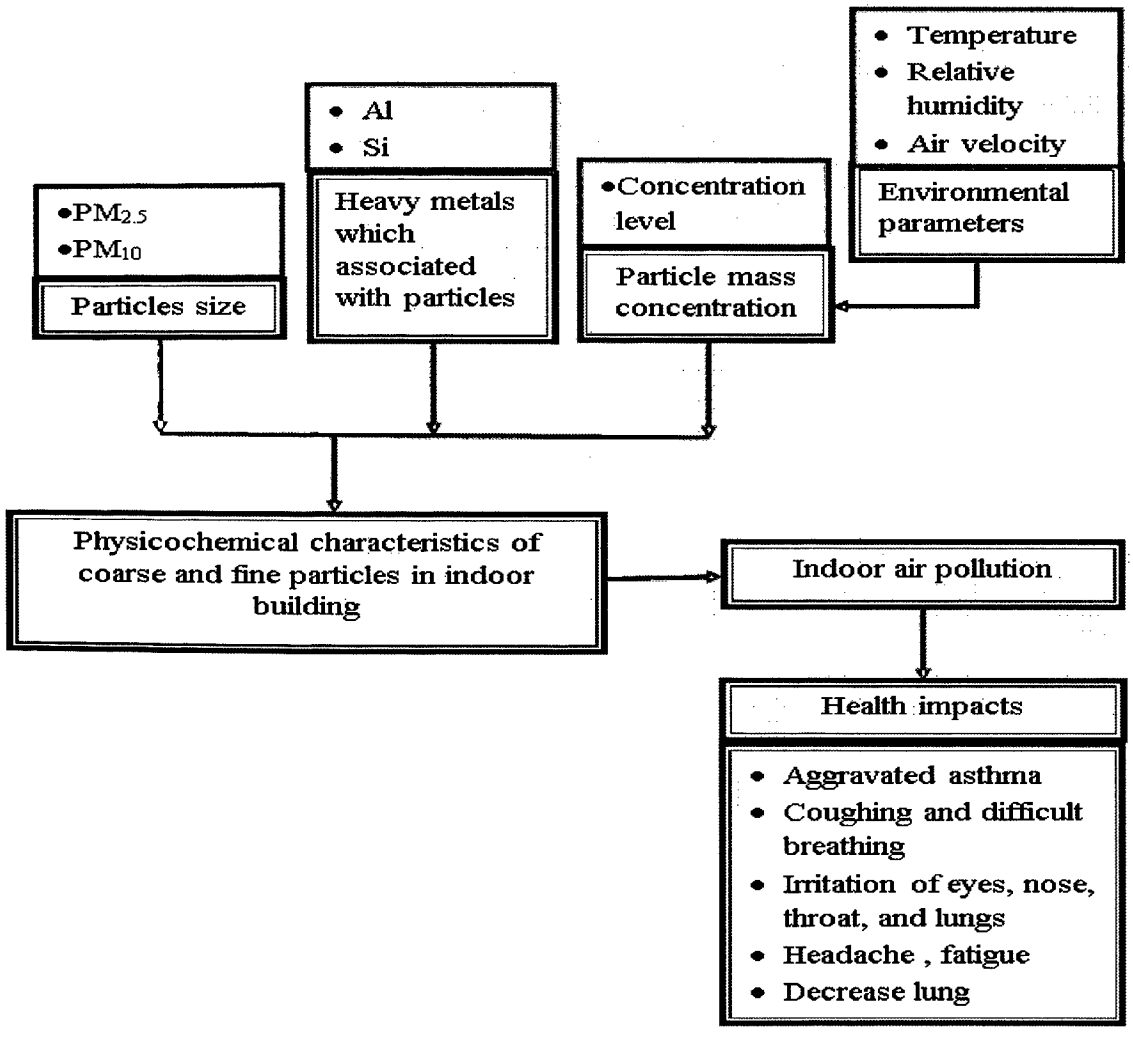

Figure 1.0: Conceptual framework of the physicochemical characteristics of coarse and fine particles and the potential health impacts to the indoor building occupants of indoor workplace building

1.9 SIGNIFICANT OF STUDY

Nowadays, indoor air pollution is no longer a new issue in the indoor building such as office, library, museum, as well as hospital. With the presence of indoor air pollutants such as PM, the indoor building occupants might face the potential health impacts especially the respiratory diseases if the concentration level of the PM above the standard limit that stated in the guidelines and reference of indoor air quality. Therefore, it is vital to conduct this study in order to determine the concentration level of the ambient particles that exposed by the indoor building occupants of chemical company. The purpose of this finding is to investigate the physicochemical characteristics of fine and coarse particles as the major air pollutants in the indoor workplace building. Thus, the indoor building occupants able to aware on these fine and coarse particles and understand the environmental condition of that building so that they able to carry out their daily tasks and perform their jobs under good environment.

Apart from this, preventive measures can be taken by the building occupants by identifying the source of fine and coarse particles in the indoor workplace building in order to eliminate or reduce the concentration level of both particles by complying with the standard limits that stated in guidelines of particulate matter. This is to allow the building occupants to perform their tasks effectively and in the comfort zone which free from respiratory diseases that resulted via the penetration of the fine and coarse particles into human lungs.

Moreover, this study enables the building occupants realize which heavy metals that associated with PM in the indoor workplace building as the presence of heavy metals that associated with PM may consist of the elements such as Silicon (Si), and Aluminum (Al) which might cause chronic effect and pose risk to the indoor building occupants of chemical company if they expose to such particles from time to time (Taner et al., 2013). Therefore, corrective measure can be taken in order to ensure the safety and health of indoor building occupants.

Furthermore, this study can be used as a reference in the future studies which related to the fine and coarse particles in the indoor building. This is to allow the

researchers conduct more studies related to fine and coarse particles in the indoor building in order to increase the awareness of the building occupants in the indoor environment towards the indoor air pollutants especially the presence of heavy metals that associated with fine and coarse particles in the indoor workplace building and to ensure the concentration levels of the fine and coarse particles are complied with the standard limit that stated in the guidelines and references for indoor air quality.

1.10 SCOPE OF STUDY

This study is to measure the physicochemical characteristics of fine and coarse particles in the indoor building. This study was conducted in the indoor and outdoor environment of workplace building of a chemical company that located in Gebeng, Kuantan, where the building occupants might expose to the fine and coarse particulate matters. In this study, data collection was conducted in different areas of indoor and outdoor workplace building of the chemical company in order to identify the areas which consist of high concentration level of fine and coarse particles.

Preliminary walkthrough observation was conducted to study the layout of the workplace building, to define exposure zones for the sampling in the building (Chen et al., 2006) that contribute the potential health hazards to the building occupants. This was conducted in order to identify the source and pathways of fine and coarse particles in that building, as well as to obtain basic information on the factors that may affect indoor air quality and identifying potential contaminants and their sources (DOSH Malaysia, 2010).

After collecting those data related to the physicochemical characteristics of fine and coarse particles, analysis of data was carried out by using Excel and SPSS (v.20) software. The data for the particle mass concentration was analyzed by Excel (Lu et al., 2011) and compared by referring to the guidelines and references for indoor air quality to verify whether the concentration level of the particle in the indoor building is under or above the standard limits. Apart from this, SPSS (v.20) software was utilized to perform statistical analysis of the experimental data such as principle component analysis in order to identify the possible heavy metal associated with the fine and coarse particles (Taner et al., 2013) in the indoor building.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, experimental studies which related to the physicochemical characteristics of fine and coarse particles in the indoor building will be studied. There are four subsections that will be discussed and focused on this study which include particulate matters, physicochemical characteristics of fine and coarse particles in indoor environment of indoor workplace building, factors that affecting the transportation of fine and coarse particles in indoor environment, and the health impacts due to the presence of particulate matters in the indoor workplace building.

2.2 PARTICULATE MATTER

Particulate matter (PM) is the complex mixture of small solid particles and different sizes of liquid droplets that suspended in the air which considered being one of the atmospheric pollutants that display as a broad class of chemically and physically multiple substances and cause air pollution no matter in indoor or outdoor building (Abdullahi et al., 2013). There are three types of PM which classified according to the size of the particles such as coarse, fine and ultrafine particulate matters. However, the main types of PM that mostly exist in the atmosphere in the indoor building are fine and coarse particles with the aerodynamic diameter of 2.5μm or less and 10μm or less respectively. In addition, particulate pollution includes emission directly from natural and man-made sources. It consists of primary particles that released directly from their source or secondary particles which formed within the atmosphere as a result of chemical reactions (Abdullahi et al., 2013). The most vital difference of particulate pollution is

based on the ways of the particles are brought into the atmosphere (Kelly and Fussell, 2012).

2.2.1 Fine Particulate Matter

Fine PM which known as $PM_{2.5}$ indicates that the particles exist with the aerodynamic diameter of 2.5μm or less. It also known as respirable particles as it possess the ability to penetrate into the alveolar gas exchange region of the lungs than coarse particles (Kelly and Fussell, 2012). Fine PM mainly formed from chemical reactions in the atmosphere and via fuel combustion such as motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes which encompass grown by coagulation and condensation (Kelly and Fussell, 2012). For indoor environment, fine particles might produce from photocopier machine, and the laser printers as well (Tang et al., 2012).

Fine PM is smaller particle which able to pass through the smaller airways, travel into respiratory system via inhalation. When inhalation take places, fine particles able to stick to the sides of the airway or travel deeper into the lungs via mouth or nose. As a result of short periods and longer periods exposure to this fine particles, human might face several serious health effects such as aggravated asthma, acute respiratory symptoms, decreasing in lung function, and premature death if in worst condition. People who considered being the most sensitive towards those health effects when expose to fine PM include children, elderly people, people with asthma, cardiovascular or lung disease. Additionally, fine PM is responsible for environmental effects which include corrosion, soiling, damage to vegetation and reduced visibility.

2.2.2 Coarse Particulate Matter

Coarse PM is large particle which consists of particles having aerodynamic diameters between 2.5μm and 10μm. These particles are known as PM_{10}, it indicates those PM which having a diameter of 10μm or less. It also termed as thoracic particles due to they able to pass through the nose and throat and penetrate beyond the larynx to deposit along the airways in the thorax (Kelly and Fussell, 2012). Coarse particles

primarily come from road dust, agriculture dust, river beds, construction sites, mining operations, sand, and non-exhaust vehicle emissions like tire rubber for outdoor environment, as well as human activities for indoor environment. The indoor human activities which will create coarse particles include cleaning activities, sitting down and standing up, moving documents or paper sheets and walking across the carpet as well (Salma et al., 2013). Besides that, this class of PM also includes biological substances such as pollen, fungi, mold, and spores, toxic substances such as endotoxins which released by some bacteria and other plant parts as well (Kelly and Fussell, 2012). In addition, these particles are frequently embedded with toxic substances include organic hydrocarbons, metals such as lead, as well as pesticides.

By exposure to this coarse particle in long term and short term periods, it might pose risks to human health no matter in indoor or outdoor environment of a building. By breathing in the air along with coarse particles that presence in the ambient air, this might lead to increase the use of medication and frequently visit to hospital due to the health effects that caused by coarse PM. These adverse health impacts include coughing, wheezing, shortness of breath, aggravated asthma, lung damage, as well as the premature death for those individuals who existing with heart or lung diseases.

2.2.3 Source of Particulate Matter

There are several sources which directly release or form the fine and coarse particles in the atmosphere by chemical reactions. According to the study which conducted by Kelly and Fussell (2012), primary sources are released directly into the atmosphere from the source include road transport, stationary combustion, industrial processes, wind carrying soils and the generation of marine aerosol particles by bursting of air bubbles in breaking waves. However, secondary sources are formed within the atmosphere due to chemical reactions such as sulphates from power generation and industrial combustion process, and nitrogen dioxide from road transport and power generation. Both fine and coarse particles generally emissions from both natural and man-made sources and they enclose a range of chemical compounds which able to be used for the identification of the source (Abdullahi et al., 2013). The natural sources include wind-blown dust, sea salt, volcanic ash, pollens, fungal spores, soil particles, the products of