PARTICULATE MATTER (PM), RESPIRATORY SYMPTOMS AND PEAK EXPIRATORY FLOW RATE AMONG WORKERS AT TWO BUS TERMINALS

by

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API	Air Pollution Index
ATS	American Thoracic Society
AED	Aerodynamic Equivalent Diameter
BMI	Body mass index
BSA	Body surface area
CEPA	Canada Environmental Protection Act
cm	Centimeter
COMEAP	Committee on Medical Effects of Air Pollutants
DPV	Diesel Powered Vehicles
DP	Dew point
DPM	Diesel Particulate Matter
DOE	Department of Environment
DEEP	Diesel Emissions Evaluation Program
DEP	Diesel Exhaust Particulate
DNA	Deoxyribonucleic acid
EEA	Energy and Environmental affair
EPA	Environmental Protection Agency
et al.,	And others
EU	European Union
GERD	Gastroesophageal Reflux Disease
GHG	Greenhouse gases
H_o	Hypothesis null

H_a	Hypothesis Alternative
HWE	Healthy Worker Effect
IARC	International Agency For Research On Cancer
IDEM	Air quality in Indiana,
LOSH	Labor Occupational Safety & Health Program
MOSTE	Ministry of Science, Technology and the Environment
MRC	Medical Research Council
OEHHA	Office Of Environmental Health Hazard Assessment
PAS	photoemission aerosol sensor
PEFR	Peak Expiratory Flow Rate
PM	Particulate Matter
PM_{10}	Particulate matter 10
$PM_{2.5}$	Particulate matter 2.5
PM_1	Particulate matter 1
$PM_{0.1}$	Particulate matter 0.1
RH	Relative humidity
SFT	Skin Fold Thickness
SMPS	Scanning Mobility Particle Sizer
TEOM	Tapered Element Oscillating Microbalance
TSP	Total suspended particulate
USEPA	United States Environmental Protection Agency
UFP	Ultrafine Particle
UK	United Kingdom

WHO	World Health Organisation
WHR	Waist Hip Ratio
$\mu g/m^3$	Microgram per meter cube
μm	Micrometer
kg	kilogram
m^2	Meter square
°C	Degree celcius
l/min	Liter per minute
%	Percent

JIRIM ZARAHAN, GEJALA PERNAFASAN DAN KADAR ALIR EKSPIRATORI PUNCAK DALAM KALANGAN PEKERJA DI DUA BUAH TERMINAL BAS.

ABSTRAK

Pekerja di terminal bas terdedah pada jirim zarahan (PM) dari ekzos bas melalui pernafasan. Satu kajian keratan rentas telah dijalankan untuk mengkaji perhubungan antara PM dengan gejala pernafasan dan pengukuran meter aliran puncak (PEFR) dalam kalangan pekerja di dua terminal bas yang berbeza; terminal bas Kota Bharu dan Pekeliling. Seramai 87 orang pekerja yang sihat telah dipilih melalui persampelan bertujuan sebagai responden. Dustmate (Turnkey, England) dan *Humidity alert II Hygro-Thermometer* (Extech, USA) telah digunakan untuk mencerap data PM, suhu, kelembapan relatif dan takat embun. Pemantauan persekitaran telah dijalankan selama lapan jam bagi tempoh dua minggu di setiap lokasi. Gejala pernafasan yang dilaporkan diperolehi melalui temubual menggunakan borang soal selidik yang telah diubahsuai daripada *Medical Research Council* (MRC) (UK). Status fungsi paru-paru pula diukur dengan menggunakan meter aliran puncak (*Philips, Netherlands*) untuk menilai tahap halangan udara dalam kalangan responden. $PM_{2.5}$ dan PM_1 adalah lebih tinggi di terminal bas Pekeliling [$PM_{2.5}$=18.4 (IQR: 14.2-24.5) $\mu g/m^3$; PM_1=6.95 (IQR: 4.9-9.6) $\mu g/m^3$] berbanding terminal bas Kota Bharu [$PM_{2.5}$=14.4 (IQR: 9.2-24.1) $\mu g/m^3$; PM_1=5.41 (IQR: 2.8-10) $\mu g/m^3$)]. Terdapat perhubungan yang signifikan antara PM ($PM_{2.5}$ dan PM_1) dengan pembolehubah meteorologi (suhu, kelembapan dan takat embun) ($p=0.001$). Gejala pernafasan yang paling tinggi dilaporkan dalam kalangan responden adalah semput ketika berada di tempat berdebu (65.5%, n=57). Kajian juga mendapati bahawa tiada perbezaan bacaan PEFR antara subjek dari kedua-dua terminal ($p>0.05$). Selain itu, tiada perkaitan antara bacaan PEFR dengan PM ($p>0.05$). Terdapat perkaitan yang sederhana antara PEFR dengan tinggi, ($p=0.001$, $r=0.469$) dan luas permukaan badan (BSA) ($p=0.001$, $r=0.446$). Pengasingan platform bas dari kaunter tiket, kedai runcit dan kedai makan adalah cara terbaik untuk mengurangkan pendedahan PM terhadap pekerja.

PARTICULATE MATTER (PM), RESPIRATORY SYMPTOMS AND PEAK EXPIRATORY FLOW RATE AMONG WORKERS AT TWO BUS TERMINALS

ABSTRACT

Workers at bus terminal are exposed to harmful particulate matter (PM) from bus-exhausts through inhalation. A cross sectional study was conducted to determine the association of PM with respiratory symptoms and peak expiratory flow rate (PEFR) among workers at two bus terminals; Kota Bharu and Pekeliling bus terminals. Eighty seven healthy workers were recruited as respondent from purposive sampling. Dustmate (Turnkey, England) and Humidity alert II Hygro-Thermometer (Extech, USA) were used to collect the PM, temperature, relative humidity and dew point, respectively. Environmental monitoring were conducted eight hours daily for fortnight at each locations. Reported respiratory symptoms were gathered by interview using a British Medical Research Council (MRC), UK questionnaires. The lung function status was measured using peak flow meter (Philips, Netherlands) to evaluate if there is a degree of airflow obstruction in the respondents' airways. $PM_{2.5}$ and PM_1 were higher at Pekeliling bus terminal [$PM_{2.5}$=18.4 (IQR: 14.2-24.5) $\mu g/m^3$; PM_1=6.95 (IQR: 4.9-9.6) $\mu g/m^3$] compared to Kota Bharu bus terminal [$PM_{2.5}$=14.4 (IQR: 9.2-24.1) $\mu g/m^3$; PM_1=5.41 (IQR: 2.8-10) $\mu g/m^3$)] (p= 0.001). There was significant correlation between PM ($PM_{2.5}$ and PM_1) with meteorological variables (temperature, humidity and dew point) (p=0.001). The commonest symptoms reported among the subjects was wheezing while in dusty place (65.5%, n=57). This study also found no significant different of PEFR reading between subjects from both locations ($p>0.05$). Besides, there is no correlation between PEFR readings with PM ($p>0.05$). Moderate correlation was found between PEFR reading with height (p=0.001, r=0.469) and body surface area (BSA) (p=0.001, r=0.446). Separated bus platform from ticket counter, retail shops and food stalls are the best way to reduce PM exposure among the workers.

CHAPTER 1

INTRODUCTION

Particulate matter (PM) pollution begins in the late 1800s since fossil fuels entitled as new industries. Environmental Protection Agency (EPA) was formed in 1970 to conserve public health and environment. One of the pollutants that concerned is PM. This study is focusing on association between PM, with reported respiratory symptoms and PEFR among workers at Kota Bharu and Pekeliling bus terminals.

1.1 Research background

Air pollution is not a small issues. Studies from developed and developing countries showed positive correlation between exposure to ambient air pollution and human health (Dockery et al., 1993; Schwartz, 1993; Brunekreef & Holgate, 2006; Chen, Craig & Krewski, 2008). Tragedies such as Donora smog in October 1948 and London smog in December 1952 had incapacitated the urban life. Hospitalisation and death were increased from the tragedies thus make people aware the important of air quality in life. For the past three years, there were about 3.7 million deaths worldwide associated with ambient air pollution (WHO, 2006).

Malaysia was ranked at 56th out of 116 countries that are experiencing air pollution problems (Nation Master, 2014). Motor vehicles (mobile sources), industrial and power plants (stationary sources) and open burning are the three main sources that caused air pollution in Malaysia (Afroz, Hassan & Ibrahim, 2003). Transportation remained as one of the largest greenhouse gases (GHG) emitters in Malaysia (Steven & Keat, 2012). The emission was worsening due to improper public transportation infrastructure in Malaysia which has resulted in heavy reliance on passenger vehicles.

Approximately 49% of the total GHG emissions were attributed to transportation related activities (MOSTE, 2000).

United States Environmental Protection Agency (USEPA) (2014) has listed PM as out of five harmful air pollutant to human health. Particulate matter issues are underestimated among people without knowing that 1000 micrograms/cubic meter exposed within 24 hours was significantly harmful to the health (EPA, 1971). Public places also contribute to the production of PM. Bus terminal is one of the public places which air pollution occurs. Increasing the total number of buses may generate more diesel combustion. Malaysia Energy Information Hub (n.d.) stated that 111 968 ktoe of diesel has been used by consumers in Malaysia within 12 years from the year 2000 to year 2012.

Petrol and diesel are the main activator for vehicles in Malaysia. Buses use diesel due to their turbocharged engine. There are different grades of standard diesel fuel, rated by the total number of cetane. The higher the cetane number, the more volatile the fuel, thus it is easier to ignite when it is sprayed into the hot compressed air (Deanna, 2014). Renato & Rosangela (2012) indicated that the cetane number has significant influence on PM emissions.

Euro 4M diesel is broadly used in Singapore since 2005. It releases only 50 parts per million (ppm) of sulphur content. However Malaysia uses Diesel Powered Vehicles (DPV), used Euro 2M, with 500 ppm sulphur content, which is ten times higher than Singapore diesel standards (Lim, 2014). Malaysia is still using a low quality of diesel fuel, thus might release numbers of toxic pollutants including diesel particulate matter.

International Agency for Research on Cancer (IARC) (2012), has classified diesel exhaust as carcinogenic to humans and has been listed it into group 1.

Anderson, Thundiyil and Stolbach (2012) stated that PM air pollution contributes to approximately 800,000 premature deaths each year estimates by the World Health Organisation and line up at the 13th leading cause of mortality worldwide. Particulate matter pollution correlates with the increase of hospitalisation and mortality due to cardiovascular disease (Samet, Dominici, Curriero, Coursac & Zeger, 2000; Pope et al., 2002; Pope CA et al., 2004).

Office of Environmental Health Hazard Assessment (OEHHA) (2007) conducted the assessment of diesel exhaust among workers who work around the diesel equipment such as truck drivers, railroad workers and equipment operators. It was shown that these workers were more likely to develop lung cancer than workers who were not exposed to diesel emissions. Studies found that short-term exposure to peak particle concentrations of diesel exhaust was associated with adverse health affects (Katsouyanni et al., 1997; Michaels & Kleinman, 2000; Peters et al., 2002).

1.2 Rationale of Study

Buses are well known as the most selected domestic transport by public due to its reasonable price. Therefore, bus terminals become the important facilities to travel from one place to another. The bus terminals consist of waiting platform, ticket counter, bus platform, and other facilities such as food court, toilets and grocery shop with comprise people in at each place. Those who are involved in transportation industry are highly exposed to the traffic air pollutants. They have high risk of respiratory and lung diseases due to such exposure and need to do risk assessment (Jenkins, Phillips, Mulberg & Hui, 1992).

The pollution levels at bus stations may reach up to ten times of the ambient air for yearly background and up to four times for the local background (Milan, Lidia, Maricela & Piero, 2005). In addition, researchers conducted a study in Taiwan found that ultrafine particle (UFP) levels at bus terminal are ten times higher than in the urban background in China (Yu, Hsiao & Cheng, 2011). Cities in China was listed as polluted cities in the world (Curiosity Aroused, n.d.). Therefore, this study will be able to identify the total amount of particulate matter at two bus terminal in two states. The aim of this study is to investigate whether the higher exposure of particulate matter may associate to respiratory symptoms among workers at bus terminal.

Pekeliling bus terminal is located at Jalan Tun Razak, Kuala Lumpur. Kuala Lumpur is an urban, always having problem with traffic congestion and fuel emission. Pekeliling bus terminal was chosen due to its open space criteria. As for comparison, the level of PM exposure at Kota Bharu bus terminal was measured. Kota Bharu is the capital city of Kelantan and it is the largest bus terminal in Kelantan. Hence, it comprises varies of company buses, thus enable people to use the bus services. Besides, the bus terminal have the job opportunities due to its services and high demands.

Both bus terminals are an open space, where the waiting area for the passengers are the same level with the waiting platform. A study by Yu et al. (2012) found that PM_{10}, $PM_{2.5}$, and ultrafine particle (UFP) levels on the bus platform were 1.9, 2.0, and 1.2 times higher than inside the waiting room. This showed that the open spaced bus terminal generates more PM than the closed bus terminal. Jinsart et al. (2012) found that tuk tuk and non-air-conditioned bus drivers were exposed to high level of PM due to long term exposure of diesel exhaust. They also found that $PM_{2.5}$ exposure levels of the drivers in streets of Bangkok were similar to the levels of great polluted areas of Bangkok in 1998 and 1999.

A study was conducted in Depok bus terminal, Indonesia to determine the relationship between $PM_{2.5}$ with lung function decline among bus terminal traders. At the end of the study, $PM_{2.5}$ was found to be the most influential factor for lung function decline among traders (Marpaung, 2012). Therefore, peak flow meter is the simplest tools to measure the expiratory flow rate thus to determine relationship between exposure of diesel exhaust with lung function status. Aditya & Manjinder (1997) stated that the mean peak expiratory flow rate (PEFR) of the bus drivers was less than the control group. From this finding, it can be concluded that reduction in the PEFR among the bus drivers was probably due to their continuous exposure to pollutants, which may have adverse effect to their respiratory functions. Another study by Somnath, Tarannum, Samrat, Goutam & Tamal (2011) found there was 19.08 percent difference of mean PEFR between exposed and control group. Nevertheless, sociodemographic such as age, gender, height, BMI and BSA was taken into account in this study. This is because gender, age, height, environment and ethnicity had an influence on the lung function (Anyanwu & Umeh, 1989).

Labour Occupational Safety & Health Program (LOSH) (2003) stated exposure to high concentrations of diesel exhaust may cause short-term symptoms such as irritation of eyes, nose, throat, chest tightness, wheezing, pulmonary function changes, headache, lightheadedness, heartburn and vomiting. Moreover, long term exposure to diesel exhaust may cause chronic obstructive lung disease, lung cancer, and asthma (IDEM, n.d.). Therefore, expanded levels of inhalable particulate toxins are connected to increments of mortality and morbidity rate due to cardiovascular and respiratory disease (Schwartz & Dockery, 1992; Ostro, 1993; Dockery et al., 1993; Schwartz, 1993; Dockery & Pope, 1994).

1.3 Objective

The objective of this study is divided into two; general and specific objectives.

1.3.1 General Objective:-

- To study the association of particulate matter exposure from diesel exhaust to respiratory health among workers at Kota Bharu bus terminal and Pekeliling bus terminal.

1.3.2 Specific Objective:-

a) To compare the levels of particulate matter between Kota Bharu and Pekeliling bus terminals.

b) To determine the peak expiratory flow rate readings and respiratory symptoms among workers at Kota Bharu and Pekeliling bus terminals.

c) To determine the association of respiratory symptoms among workers between Kota Bharu and Pekeliling bus terminals.

d) To determine the association between particulate matter and respiratory symptoms among workers at Kota Bharu and Pekeliling bus terminals.

e) To compare the peak Expiratory Flow Rate readings among workers between Kota Bharu and Pekeliling bus terminals.

f) To determine the association between particulate matter level and peak expiratory flow rate reading among workers between Kota Bharu and Pekeliling bus terminals.

g) To determine the association between sociodemographic factors and peak expiratory flow rate among workers at Kota Bharu and Pekeliling bus terminal.

h) To compare the peak expiratory flow rate readings between workers who had and had not reported respiratory symptoms at Kota Bharu and Pekeliling bus terminal.

1.4 Hypothesis

a) First Hypothesis

- H_O: There is no significant difference in level of particulate matter at two different locations of bus terminals.
- H_A: There is significant difference in level of particulate matter at two different locations of bus terminals.

b) Second hypothesis

- H_O: There is no significant association of respiratory symptoms among workers at two bus terminals.
- H_A: There is significant association of respiratory symptoms among workers at two bus terminals.

c) **Third Hypothesis**

- H_O: There is no significant association between particulate matter and respiratory symptoms among workers at two bus terminals.

- H_A: There is significant association between particulate matter and respiratory symptoms among workers at two bus terminals.

d) **Fourth Hypothesis**

- H_O: There is no significant difference in peak expiratory flow rate readings among workers between two bus terminals.
- H_A: There is significant difference in peak expiratory flow rate readings among workers between two bus terminals.

e) **Fifth Hypothesis**

- H_O: There is no association between levels of particulate matters exposure and reduced peak expiratory flow rate readings among workers at bus terminal.
- H_A: There is association between levels of particulate matters exposure and reduced peak expiratory flow rate readings among workers at bus terminal.

f) Sixth Hypothesis

- H_O: There is no association between sociodemographic factors (gender, height, BMI, BSA) and peak expiratory flow rate among subjects at bus terminals.
- H_A: There is association between sociodemographic factors (gender, height, BMI, BSA) with peak expiratory flow rate among subjects at bus terminals.

g) Seventh Hypothesis

- H_o: There is no significant difference in peak expiratory flow rate readings among workers who had and had not reported respiratory symptoms.
- H_A: There is significant difference in peak expiratory flow rate readings among workers who had and had not reported respiratory symptoms.

1.5 Flowchart of study

Figure 1.1 below shows the research flowchart which represents the direction of this study.

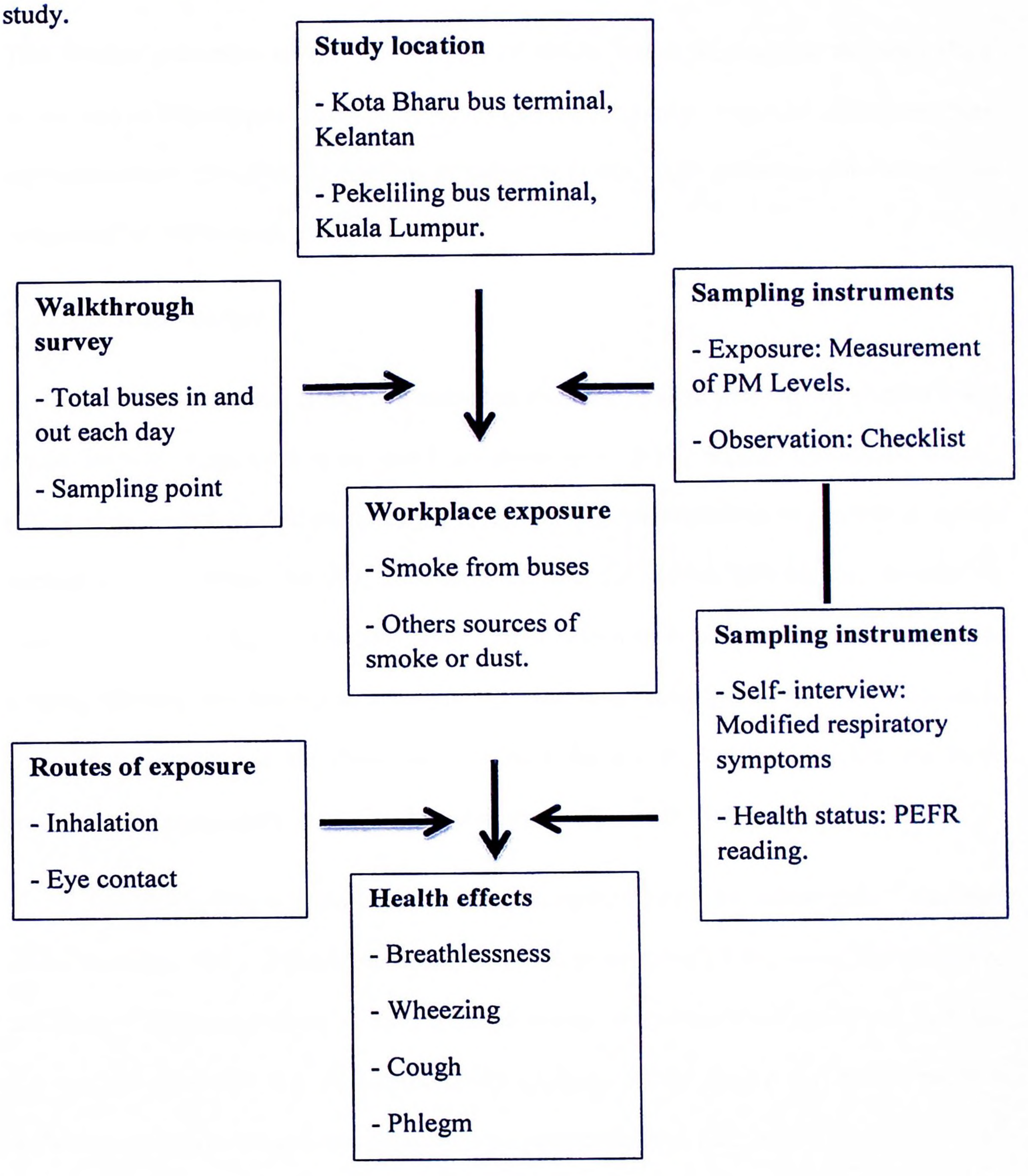

Figure 1.1: Flowchart of study.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of literature related to health problems at the workplace. At the end of this chapter, characteristics of particulate matter were also discussed. Peak expiratory flow rate (PEFR) reading of subjects is the main outcome and factors that influenced of PEFR were also elaborated.

2.1 Particulate matter

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets suspended in air which are made up of acids, organic chemicals, metals, pollen, soot, smoke or dust particles (EPA, 2013). The characteristic of particle in the air depend on size, shape, density, concentration and air motion (Silverman, Billings & First, 1971). According to Anderson et al. (2012), particulate size can be explained by its settling velocity also known as aerodynamic equivalent diameter (AED). Aerodynamic equivalent diameter, is the diameter of sphere density of 1 g cm^{-3} having the same terminal settling velocity as the particle of interest (Baron & Willeke, 2001).

Generally, PM is classified into four categories based on aerodynamic diameter of the particles. PM_{10} (coarse particles), $PM_{2.5}$ (fine particles), PM_1 (very fine particles) and $PM_{0.1}$ (UFP) are defined as having aerodynamic diameters less than 10 µm, 2.5 µm, 1.0 µm and less than 0.1 µm, respectively (Adam, 2012). Figure 2.1 shows the size differences of particles when compared to an average human hair (50-70 µm).

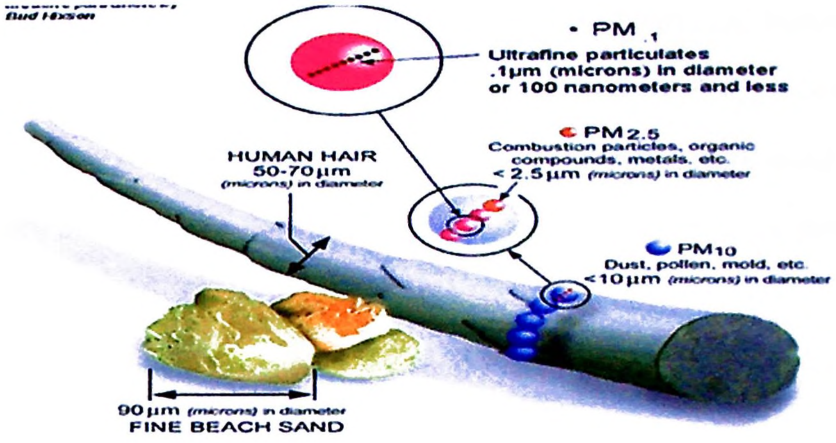

Figure 2.1: Various sizes of particulate matter
Source adapted from (USEPA, 2012)

PM is categorised as primary particles when it is directly emitted into the atmosphere. Particle also can be classified as secondary particles when it is formed by gas-to-particle conversion in the atmosphere. Sources of particles are varies. It is divided into two; natural and anthropogenic sources. Natural sources may exist from volcanoes, water mist and etc. While, anthropogenic sources may come from human activities such as smoke stacks at factories, power plants, and auto paint shops (Environmental services, 2015).

PM is formed from the slow coagulation of particles in the nuclei mode and grow when condense into other particles within the atmosphere. Few previous studies stated that PM levels in Asian countries are affected by seasonal variations (Begum, Biwas & Hopke, 2006; Gatari et al., 2006; Ho et al., 2006; Wang et al., 2008). Distribution of PM were also influenced by meteorological variables such as relative humidity, temperature and wind speed (Gebhart, Kreidenweis & Malm, 2001). On the other hand, in the atmospheric, temperature plays an important role as driven process in formation of secondary aerosols from gases to particle (Katheeri, Jallad & Omar, 2013).

Warmer temperature tends to increase the oxidation of particles, thus increasing their formation rate. According to Robertson (2006), formation of $PM_{2.5}$ increase when the temperature are high, wind velocities are low and the atmosphere conditions are stable. PM was influenced by relative humidity, by affecting hygroscopic aerosol particle. Absorption of water from a humid atmosphere increases the size of the individual particle and reduces its lifetime in the atmosphere (Nilsson, 1994). The amount of water in the atmosphere influences the rate of particle formation. When relative humidity increases, the surface area of particle expands, thus allow more precursor gases to be absorbed by incrementing concentrations of ambient particulate (Canada Environment, 2001).

There was a strong correlation between wind speed and relative humidity during sampling periods of the commuter study (Adams, Nieuwenhuijsen & Colvile, 2001). In contrast, studies conducted by Harrison, Deacon, Jones and Appleby (1997) and Zagury, Le Moullec and Momas (2000) found that there is no association or low association of PM with the meteorological factors; temperature, relative humidity and atmospheric pressure except wind speed.

A study conducted by Deacon, Derwent, Harrison, Middleton & Moorcroft (1997) found that low wind speeds was associated with increased of fine fraction mass ($PM_{2.5}$). Particles tend to have a long residence time in wet, but dry deposition have the ability to travel over long distances (Maynard & Howard, 1999). Sedimentation and precipitation expels PM_{10} from the climate for couple of hours while, $PM_{2.5}$ may stay for quite long or even a couple of weeks. These showed particles can be transported over the long distance (Zhu, Hinds, Kim, Shen & Sioutas, 2002). Very fine particles have the ability to remain longer within the atmosphere by allowing them to accumulate downwind towards other regions (CEPA, 1999).

Morphological characteristics of the particles and chemical composition are paramount factors in determining adverse health effects (Walgraeve, Demeestere, Dewulf, Zimmermann & Langenhove, 2010). *In vitro* toxicological research conducted found that, PM induces several types of adverse cellular effects, including cytotoxicity, mutagenicity, DNA damage and stimulation of pro-inflammatory cytokine production. Besides, the pro-inflammatory response was highest for fine PM collected at traffic locations (Steenhof et al., 2011).

2.1.1 Total Suspended Particulate

Total suspended particulate (TSP) range in size from 0.001 to 500 micrometre and depends on their size and other properties which suspended in the air for a few seconds or continually (European Environmental Agency, 2011). Power stations, construction activities, incineration and vehicles are source of TSP. A study conducted in India found that the TSP in Delhi comprised mainly from vehicular pollutants with 62 percent (Srivastava, Gupta & Jain, 2008).

Yuyu, Ebenstein, Greenstone & Hongbin (2013) conducted a study in China. They found that the TSP concentrations was 184 $\mu g/m^3$ and 55 percent higher in the North and there was reductions in life expectancies of 5.52 years in the North due to elevated rates of cardiorespiratory mortality. Frequency of cough was found to be correlated with the average of one day mean concentrations of TSP, the sulphate fraction of TSP and sulphur dioxide concentrations during the early year of the health examination among preadolescent children at six cities in the eastern and mid-Western United States (Ware et al., 1986).

2.1.2 Particulate Matter 10

PM_{10} are particle pollution which are emitted and formed in the atmosphere when other pollutants react (EEA, 2011). Coarse particle is classified as small particle with sizes ranges from 2.5 μm to 10 μm (USEPA, 2013). Inhalable coarse particulate matter can enter the trachea or deposited in the bronchi. The effect of atmospheric temperature on PM_{10} levels is very conspicuous with the seasonal variation. These particles are aggravated to airways disease, reduced the lung function, and rose of cardiovascular mortality (Samet, Zeger and Berhane, 1995; Peter et al., 1996).

2.1.3 Particulate Matter 2.5

Fine particles are particle with size less than 2.5 μm. It can reach to the alveoli in the lungs and can produce a deleterious effect. Studies conducted by USEPA (2004) and WHO (2005) found an association of adverse and severe health fallout with exposure to ambient air PM (less than 2.5 μm in aerodynamic diameter) among susceptible sub-populations; infants, elderly and subjects with cardiopulmonary diseases.

The World Bank Group (1999) stated that fine particulates can reach the thoracic regions of the respiratory tract, or lower. They are responsible for most of the excess mortality and morbidity associated with high levels of exposure to particulates. Fine and UFP act like a gas and penetrates the indoors from outside air, then penetrate deep into the lungs. Fine particles also have a greater accumulated surface area. It can adsorb toxic combustion products, metals and atmospheric air toxics by carrying deep into the lung.

2.1.4 Diesel exhaust emission

Engine exhaust consists primarily of nitrogen, oxygen, water vapour, and carbon dioxide, with minor elements of carbon monoxide, hydrocarbons, nitrogen oxide, and PM (Maricq, 2007). Generally, diesel engine is different from petrol engine because it produces large amount of nitrogen oxides and aldehydes but generates less carbon monoxide (Sydbom et al., 2001). Type and age of the vehicle, driving patterns, road conditions, engine lubricant, type of emissions control, and the extent of regular inspection and maintenance are the factors that affecting vehicle emissions (Ding, Chan, Ke & Wang, 2014).

Diesel particulates is defined as solid or liquid matter that is collected on an absolute filter in a diluted exhaust stream at temperatures equal to or less than 52°C. This definition was engaged to ensure that the measured particulate samples are typical of diesel-derived atmospheric particulate (Keskinena & Ronkko, 2010). Even though the modern engine technologies assist in reducing the particle mass emissions from buses but the ultrafine particle number emissions still rise (Johnson & Baumgard, 1996; Kittelson, Watts & Arnold, 1999; Ntziachristos & Samaras, 2003).

Diesel particulate matter constitutes of respirable dust due to its submicron aerosol. Many studies agreed that the aerodynamic diameters for diesel exhaust particles are between 0.1 μm to 0.25 μm (Dolan et al., 1980; Groblicki, 1979; Williams, 1982). About ninety percent of the particulates constitute in diesel exhaust are fine particles (Energy and Environmental Affair, 2014). Small size of diesel particulate matter not only can penetrate the deepest part of the lung but also not easily removed from the air stream. Gulliver & Briggs (2004) stated that road traffic is the major source of fine particle, due to the direct emission from diesel vehicles or indirect emission from the formation of secondary particulates in the air.

2.1.5 Ambient air quality guideline

Particulate matter is not safe at any exposure level. There is no threshold concentration which any danger to human health (Morawska, Moore & Ristovski, 2004). Environmental Protection Agency (EPA) guidelines on air quality normally based on 24 hours or annual exposures. The peak exposures (1 hour or less in term) are the most applicable to human wellbeing and fuel thus manifest of existing respiratory conditions, such as asthma (Michaels & Kleinman, 2000).

According to Bedada et al. (2007), the ambient of $PM_{2.5}$ background concentrations are below 16 $\mu g/m^3$. The recommended values for annual and 24-hour mean concentrations are 0.020 mg/m^3 and 0.050 mg/m^3 for PM_{10} and 0.010 mg/m^3 and 0.025 mg/m^3 for $PM_{2.5}$ (WHO, 2006). However, World Health Organisation (WHO) does not highlighted the specific guideline for PM_1, but the recommended mean concentration value should be less than 0.025 mg/m^3 for short term exposure. The recommended values of PM from WHO is applicable to open air, which were based on certain cities in the world but not from the workplace. The health risk of PM depends on the air trade and the span of the work environment, as well as the methods of spreading, structures and sorts of PM.

In 1990 Canadian Committee issued a guideline exposure to Diesel Particulate Matter (DPM) should not be more than 1.5 mg/m^3 over a normal 8-hour shift. The WHO has entrenched limits of PM_{10} and $PM_{2.5}$ concentrations which are legally necessary in the European Union (EU) since January 2005 (PM_{10}) and since 2010 ($PM_{2.5}$) proportionately. Mean 24 hour for PM_{10} concentration and $PM_{2.5}$ concentration respectively to not exceed 50 $\mu g/m^3$ and 25 $\mu g/m^3$. While, mean annual PM_{10} concentration and $PM_{2.5}$ concentration respectively not exceed 20 $\mu g/m^3$ and 10 $\mu g/m^3$ (Gerber, Bohn, Groneberg, Schulze & Bundschuh, 2014). National ambient air quality (NAAQS) for outdoor air pollutants as established by the EPA recommended the level for PM_{10} for 24 hours were 150 $\mu g/m^3$. $PM_{2.5}$ and TSP were 35 $\mu g/m^3$ and 260 $\mu g/m^3$, respectively (USEPA, 2015). These recommended levels are followed by the Malaysian as well.

2.2 Respiratory system

Lungs is vital organ for human. Lungs are located in the right and the left chest cavity of human. It is protected by the ribs. The right lungs detached of three lobes while left lungs branched of two lobes. These lobes are filled with sponge-like tissue. Lungs is connected by bronchial tree which plays important role in supply the lungs with air. Grape clusters shape with air-filled sacs known as alveoli are located inside the lung. (George, 2013).

Human can easily get sick by inhaling the harmful airborne particle such as dust, soot, mold, fungi, bacteria or other pollutants. Lungs have the ability to protect themselves from toxic effects. As human breathes, large particles of pollutants cannot enter the lungs due to filtration processes and if the pollutants get into the lung, it will get tightened in a thin layer of mucus that lines the inside of the breathing tubes. This mucous will clear away the pollutants toward the mouth by cilia that lined the breathing tubes. Cilia move mucous from the lungs upward toward the throat to the epiglottis. The epiglottis is the gate, which opens let on the mucous to be swallowed. If individual has problem related to respiratory system, spitting up sputum will occur (American Lung Association, 2013).

Squadrito, Cueto & Dellinger (2001) stated that the particle size is a vital factor in determining the region of the respiratory tract that is potentially affected such as nasopharyngeal, lung or alveolar. Particles with 10 micrometers in diameter or smaller have ability to pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs, thus trigger serious health effects (Sylvain, 2008). Figure 2.2 shows sizes of particles that can be inhaled into the human respiratory tract.

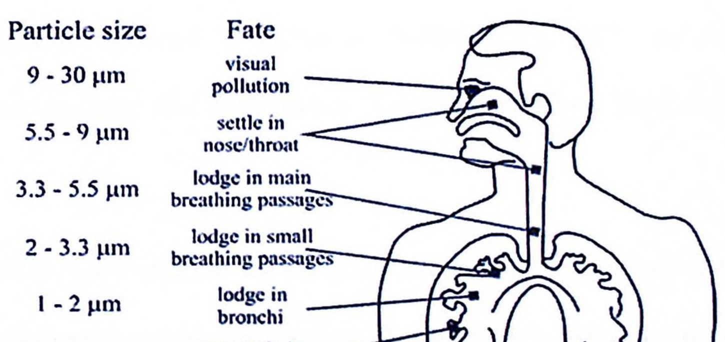

Figure 2.2: Sizes of particles that can be inhaled into the human respiratory tract

Source adapted from David, Geoff & Tony (2011).

2.3 Diesel exhausts particulate and respiratory effects

The particles size of 2.5 μm are able to deposite deep in the lungs. Hence, contribute to respiratory and cardiovascular problem. Few studies were conducted to determine the association between fine particulate matter of air pollution and cardiovascular disease, had shown positive association between the exposure and health effect (Brook et al., 2004; Pope & Dockery, 2006; Brook, 2008; Sun, Hong & Wold, 2010). Continuous exposures to ambient PM levels were associated with variety of primarily cardio-pulmonary health effects (Pope et al., 2004).

$PM_{0.1}$ (ultra-fine particles) is more harmful than the large particle. It may penetrate into the bloodstream. It can accumulate to form particles in the size range of $PM_{2.5}$. Particulate matters cause reduction of lung functions, lung cancer and emphysema. As compared to mineral dust, DPM is not settling on the ground under forces of gravity but still remains as airborne. Furthermore, DPM emitted from the vehicles will also contaminate the workplaces (Diesel Emissions Evaluation Program, 2001).

Previous studies proved that diesel particulates stimulate the allergenicity to other agents both in animals and humans (Von Mutius, 2000; Diaz, Penichet & Saxon, 2000; Heo, Saxon & Hankinson, 2001; Hashimoto et al., 2001; Hauser et al., 2003). Exposure to ambient concentrations of DEP provokes an inflammatory reaction to the airways of normal subjects, which is characterised by influx of activated neutrophils (Julia et al.,2000). These carcinogenic is proved to cause lung cancer by altering the genes (DNA) inside the lung cells, thus causes the cells to grow faster. As the cancer develops, the cancer cells produce chemicals to form new blood vessels to nearby. These blood vessels nourish the cancer cells, which continue to grow and form a large tumour (American Cancer Society, 2014).

2.4 Respiratory symptoms

Wheezing, shortness breath, cough and phlegm are the common symptoms among if are exposed to pollutants.

2.4.1 Wheezing

Wheezing is a shrieking sound that can be made while breathing, which probably a side effect of a congestive heart disappointment sickness or different causes or conditions (WebMD, 2014). Wheezing happens due to localised or diffuse airway narrowing or obstruction from the level of the larynx to the small bronchi. Wheezes are accepted to be produced by motions or vibrations of almost shut airways dividers. Air going through a narrowed portion of an airway at high velocity produces decreased gas pressure and stream in the constricted region (Henry, 1990).

There are few causes that may lead to the narrow airways including bronchospasm; which is the muscle inside the coating of the airways contracts and has an impact of contracting the airways. Secondly is due to the swollen lining of the airways. People tend to have narrowing airways when there is a lot of secretion such as bodily fluid in the airways. Next is a strange development in the airways including a tumour (Kenny, 2012). Henry (1990) agreed that the airway narrowing may be brought by bronchoconstriction, mucosal edema, outside pressure, or incomplete obstruction by a tumour, remote body, or industrious discharges. The sound is more undoubtedly when it is breathe out and breathe in.

2.4.2 Breathlessness

Breathlessness or known as dyspneoa is an upsetting impression of uncomfortable, rapid or difficult breathing (York & White, 2013). Breathlessness is associated with different physiological, mental, social, and environmental elements and may also affect auxiliary mental and behavioural reactions (ATS, 2012). The pathogenesis of dyspneoa is multifactorial and incorporates with few components; element lung hyperinflation, expanded ventilatory interest in respect to limit, anomalies in gas trade, including hypoxemia and hypercapnia, inspiratory muscle shortcoming, and psychological and mental impacts (Andrew, 2006).

Few fundamental can make somebody feel short of breath. Firstly, there is a decreased of oxygen level in the circulation system. Secondly, breathlessness occurs when the levels of carbon dioxide in the circulation system increased. Thirdly, when the dyspneoa happen capacity of the lung to expand is decreased. When there is increasing workload correlated with normal breathing, people tend to feel breathlessness (ATS, 2012). Majority of the Potroom workers complained of breathlessness which was associated with the workplace or weather changes while dyspneoa when climbing stairs or walking up the inclines. Even though the prevalence of individual respiratory symptoms reported was high, but it was not associated with ventilator impairments (Ljiljana, 2008).

2.4.3 Cough

Cough is defined as a protective reflex activity to pass airways of bodily fluid and irritants including dust and smoke (National Health Service, 2013). The sound of a cough is because of vibration of the large airways and laryngeal structures amid turbulent stream in expiration (Korpas, Sadlonova, Salat & Masarova, 1987; Hashimoto et al., 2003). Factors influenced cough are acute infections, chronic infections, airway diseases, parenchymal diseases, tumours, cardiovascular diseases, drugs, foreign bodies and irritation of external auditory meatus (Kian & Ian, 2008).

Cough is divided into three; acute, sub-acute and chronic cough. The types of cough are classified based on the period of cough. Acute cough is defined less than three weeks (upper respiratory infections) while sub-acute cough is defined as lasting three to eight weeks (post infections following viral infections). Chronic cough last for more than eight weeks (chronic obstructive lung disease/bronchogenic carcinoma) (Irwin, Baumann, Bolser, Boulet, Braman & Brightling, 2006; mDhil, 2014). Chronic cough is also associated with cigarette smoking (Barbee, Halonen, Kaltenborn & Burrows, 1991; Cullinan, 1992; Cerveri, Accordini et al., 2003; Coultas, Mapel, Gagnon & Lydick, 2001).

Those who are regularly waking up at early morning with cough may be caused by smoking, asthma, Gastroesophageal Reflux Disease (GERD) and Post Nasal Drainage (Buzzle, n.d.). Cough is an important symptom in identifying chronic airway diseases such as asthma and chronic obstructive pulmonary disease, fibrosis lung disease, and cancer.

2.4.4 Phlegm

Phlegm is a mucous-like substance produced by the lower airways (such as the lungs). The respiratory system leading to the lungs produces mucous that streams out of or clogs up nose (Madeline & Lindsey, 2010). Cilia play an important role in trapping the large pieces of debris and waft them out from the airways. The reflexes of sneezing and coughing help to expel particles from the respiratory system and the production of mucous keeps the tissues moist and helps to trap small particles of foreign matter. It is normal in production of mucous to avoid airways become dry and malfunctions. However, excessive production of mucous and changes in nature may trigger cough and expectorate mucous as sputum (mucous that is coughed up from the lower airways). Sputum expectoration is not normal and there is always an underlying pathological cause (Richardson, 2003).

Various studies indicated the relationship of side effects with decreased of lung capacity. Manifestations of cough and phlegm were discovered to be connected with obstructive pattern instead of wheeze or phlegm (Hasnain, Khan, Saleem & Waqar, 2007).

2.5 Peak Expiratory flow rate and factors influencing its measurements.

Peak flow meter was discovered in 1949 by a bioengineer in Llandough, Pernanth. Then in 1970 a miniature version was set up to make it use friendly to patient. Today, peak flow meter is widely used not only to monitor asthmatic patients, but has been used to measure pulmonary function, to assess the ventilator capacity of normal people, indicator of person's health, and follow up for respiratory diseases (Yap et al.,