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HEALTH RISK ASSESSMENT OF PM10 FROM AN INDUSTRIAL AREA IN TAMAN TUANKU JAAFAR, NEGERI SEMBILAN

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BY

FARAH ADLINA BINTI MOHAMMAD YAZAH

Thesis submitted in fulfilment of the requirement for the degree of Bachelor Science (Environmental and Occupational Health) from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

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ABSTRACT

HEALTH RISK ASSESSMENT OF PM_{10} FROM AN INDUSTRIAL AREA IN TAMAN TUANKU JAAFAR, NEGERI SEMBILAN

FARAH ADLINA BINTI MOHAMMAD YAZAH

Introduction: According to the World Health Organization, air pollution is a major environmental risk to health. The concern on air pollution arising from industrial processes is increasing as it can directly or indirectly affect its neighbouring populations. **Objective**: The main objective of this study is to evaluate the non-carcinogenic risk assessment of particulate matter (PM_{10}) from industrial air samples in Taman Tuanku Jaafar, Negeri Sembilan. **Methodology**: The air was sampled using a PM_{10} High-Volume Air Sampler with quartz microfibre filters which was placed on a rooftop at SMK Taman Tuanku Jaafar. Each sample was collected for 12 hours for 6 days (3 weekdays and 3 weekends) which resulted in a total of 12 samples. **Results**: The result showed that the average 24-hour PM_{10} concentration was significantly lower than the permissible value stated in the New Malaysian Ambient Air Quality Standard (MAAQS) 2020, $t(5)=-2.721, (p<0.05)$. Through statistical analysis, it has been found that there was no significant difference between the level of PM_{10} collected on weekday versus weekend, $t(4)=-0.56$ ($p>0.05$) as well as day-time versus night-time with $t(10)=-0.936$ ($p>0.05$). The estimated daily intake of PM_{10} via inhalation ranged from 0.0131 to 0.0326 mg/kg/day. The hazard quotient (HQ) was calculated based on the formula suggested by the United States Environmental Protection Agency and found to be lower than 1, which indicates that inhalation exposure towards PM_{10} in ambient air may not inflict non-cancerous effects. **Conclusion**: It is concluded that the PM_{10} concentration in the industrial air sample from Taman Tuanku Jaafar is lower than the MAAQS and pose no major implications to human health.

Keywords: Air sample, Industrial area, PM_{10}, Health risk

ABSTRAK

PENILAIAN RISIKO KESIHATAN DARIPADA PM_{10} DARI KAWASAN PERINDUSTRIAN DI TAMAN TUANKU JAAFAR, NEGERI SEMBILAN

FARAH ADLINA BINTI MOHAMMAD YAZAH

Pendahuluan: Menurut Pertubuhan Kesihatan Sedunia, pencemaran udara merupakan risiko utama terhadap kesihatan. Kerisauan terhadap pencemaran udara yang timbul dari proses perindustrian semakin meningkat kerana ia dapat mempengaruhi penduduk disekelilingnya secara langsung atau tidak langsung. **Objektif**: Objektif utama kajian ini adalah untuk menilai risiko kesihatan yang bukan karsinogenik daripada zarah (PM_{10}) dari sampel udara industri di Taman Tuanku Jaafar, Negeri Sembilan. **Metodologi**: Udara disampel menggunakan Alat Persampelan Udara Berisipadu Tinggi (PM_{10}) dengan penapis mikrofiber kuarza yang diletakkan di atas bumbung di SMK Taman Tuanku Jaafar. Setiap sampel dilakukan selama 12 jam selama 6 hari (3 hari kerja dan 3 hujung minggu) yang membawa kepada 12 jumlah sampel. **Keputusan**: Hasil kajian menunjukkan bahawa tahap purata PM_{10} (24 jam) jauh lebih rendah daripada nilai yang dibenarkan dalam Piawaian Kualiti Udara Ambien Malaysia Baharu 2020, $t(5)=-2.721,(p<0.05)$. Melalui analisis statistik, ia didapati bahawa tidak ada perbezaan yang ketara antara tahap PM_{10} yang disampel pada hari kerja berbanding hujung minggu, $t(4)=-0.56(p> 0.05)$ serta pada waktu siang berbanding waktu malam dengan $t(10)=-0.936(p> 0.05)$. Anggaran pengambilan harian PM_{10} melalui pernafasan adalah antara 0.0131 hingga 0.0326 mg/kg/hari. Nilai bahaya (HQ) dihitung berdasarkan formula yang disarankan oleh Agensi Perlindungan Alam Sekitar Amerika Syarikat dan ianya didapati lebih rendah dari nilai 1**,** yang menunjukkan bahawa pendedahan terhadap PM_{10} dalam udara ambien mungkin tidak akan menimbulkan kesan bukan karsinogenik. **Kesimpulan:** Kesimpulannya, tahap PM_{10} dalam sampel udara perindustrian dari Taman Tuanku Jaafar adalah lebih rendah daripada piawaian yang ditetapkan dan tidak akan menimbulkan implikasi besar terhadap kesihatan manusia.

Kata kunci: Sampel udara, Kawasan perindustrian, PM_{10}, Risiko kesihatan.

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LIST OF ABBREVIATIONS

WHO	World Health Organization
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
DOE	Department of Environment
DNA	Deoxyribonucleic acid
US EPA	United States Environmental Protection Agency
ATSDR	Agency for Toxic Substances and Disease Registry
MAAQS	Malaysia Ambient Air Quality Standard
HVAS	High Volume Air Sampler
EDI	Estimated Daily Intake
HQ	Hazard Quotient

CHAPTER 1

INTRODUCTION

1.1 Background

Over the years, many countries, including Malaysia, have transitioned into an industrial-based economy. An increase in the number of world population will significantly increase the demand for industrial developments. Consequently, industrial activities now produce harmful by-products such as particulate matter and chemical gases that pollute the air (Duh, Shandas, Chang & George, 2008). A rapid industrialization will deteriorate the environment and cause various problems, especially the ones that are linked to its emissions. Although pollution is controlled in Malaysia through environmental legislations and policies, such as Environmental Quality Act 1974 and Ambient Air Quality Standard 2013, the country still suffers from air pollution. Realizing the importance of air pollution, the United Nation has taken it into account in four of the Sustainable Development Goals (Griggs, Nilsson, Stevance & McCollum, 2017).

Currently, one of the many environmental risk that we are facing is air pollution (WHO, 2014) and exposure towards it has been linked with various negative health effects (Chen & Kan, 2008). The common sources of air pollution include combustion processes from motorized vehicles, burning of fuels and emissions from industrial processes. The distribution of air pollutants is influenced by emission source, type of pollutant and environmental conditions (European Environment Agency, 2016). In 2013, the International Agency for Research on Cancer (IARC) has evaluated and classified particulate matter (PM) as Group 1 carcinogen. They have also noted a direct relationship between air pollution, specifying particulate matter, with bladder cancer. Air pollution has also been associated with health conditions such as respiratory and cardiovascular diseases and cancer, with acute and chronic effects (Osornio-Vargas et al., 2003).

The Malaysian Department of Environment (DOE) has identified five primary pollutants which are sulphur dioxide (SO_2) , nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter with 10-micron (PM_{10}) size in diameter and ground-level ozone (O_3). These pollutants are responsible in causing damages to property, health and environment. Globally, about 4.2 million deaths were attributable to ambient air pollution (AAP) (WHO, 2018). Recognizing the possible risks of human exposure towards the harmful particle is important to protect a population. The aim of this study is to assess the non-carcinogenic risk of particulate matter (PM_{10}) in an industrial air sample from Taman Tuanku Jaafar, Negeri Sembilan.

1.2 Problem Statement

Industrial pollution introduces dangerous substances that move freely in the environment whilst contaminating the water, soil and air. The amount of pollutants have shown a steady increase from activities such as burning of fuels, carrying out chemical processes, and releasing toxic chemicals. In 2018, the News Straits Time had reported on the cease of operations, ordered to a factory in Taman Tuanku Jaafar industrial area due to its plastic washing processes which had caused the Simin river in Negeri Sembilan to turn blue in colour. Following this river pollution issue, there has been a need to enhance enforcement activities at the respective state. As a result of this malpractice, there is a concern regarding public health consequences which may arise from industrial activities. Although industrial emission can produce different types of pollution, the main attention will be given to air pollution as it can result in serious health complications in human.

Taman Tuanku Jaafar is an area which consists of several industrial and residential sites. With the large number of factories in the area and its close proximity to the community, there is a need to determine the concentration of particulate matter in its ambient air and the non-carcinogenic risk that is associated with it. Even though PM_{10} can be emitted from other sources such as traffic-related emission, PM_{10} from industrial activity is a major focus as its emissions can travel farther and can adversely affect its neighboring populations. Considering the impact of air pollution on human health, this study aims to assess the non-carcinogenic risk of PM_{10} in an industrial air sample from Taman Tuanku Jaafar in Negeri Sembilan.

1.3 Study Justification

Air pollution can cause severe health problems to human and it interacts mainly with living organism through inhalation. The air is inhaled inevitably by a normal adult at a rate of 12 to 18 breaths per minute in a resting state to maintain vital functions (Martini, Ober, Garrison, Welch & Hutchings, 2001). Environmental mutagens in ambient air forms DNA adducts by binding to nucleotides and initiate mutation. In a long term exposure, these mutations may lead to unregulated cell growth which will then give rise to cancer. A study by Petavratzi, Kingman and Lowndes (2005) have associated lung cancer with the tiny dust-like particles, known as particulate matter. Several studies have also emphasized on the irreversible and heritable nature of mutagenic events (Mortelmans & Zeiger, 2000; Schrader, 2003).

There is an urgent need to assess the particulate matter concentration in industrial air sample as it can affect everyone, especially those who have reduced lung function. The International Agency for Research on Cancer (IARC) (2013) confirmed that ambient air pollution is indeed a major cause of cancer. Studies on particle mass does not conclude a strong association between particles and its effect on human health (El Morabet, R., 2019). Therefore, a more in depth assessment is needed to evaluate the risk. In addition, there are limited number of study relating to the risk assessment of air samples in Malaysia, and the air quality report by the Department of Environment is insufficient to justify the safety of ambient air towards the population.

1.4 Objectives

1.4.1 General Objective

To evaluate the non-carcinogenic risk assessment of particulate matter (PM_{10}) in an industrial air sample in Taman Tuanku Jaafar, Negeri Sembilan.

1.4.2 Specific Objectives

1. To determine the level of PM_{10} in the industrial air sample and compare it with the permissible limit value in Malaysia.
2. To compare the concentration of PM_{10} collected on weekdays and weekends.
3. To compare the level of PM_{10} collected during daytime and night-time.
4. To evaluate the estimated daily intake of PM_{10} via inhalation.
5. To assess the non-carcinogenic risk of PM_{10} via inhalation.

1.4.3 Hypotheses

1. There is a significant difference in the level of PM_{10} with the permissible limit value in Malaysia.
2. There is a significant difference in the level of PM_{10} collected on weekdays and weekends.
3. There is a significant difference in the level PM_{10} collected during daytime and night-time.
4. There is a non-carcinogenic risk of PM_{10} via inhalation in Taman Tuanku Jaafar, Negeri Sembilan.

1.5 Conceptual Framework

Figure 1.1 shows the conceptual framework of the current study.

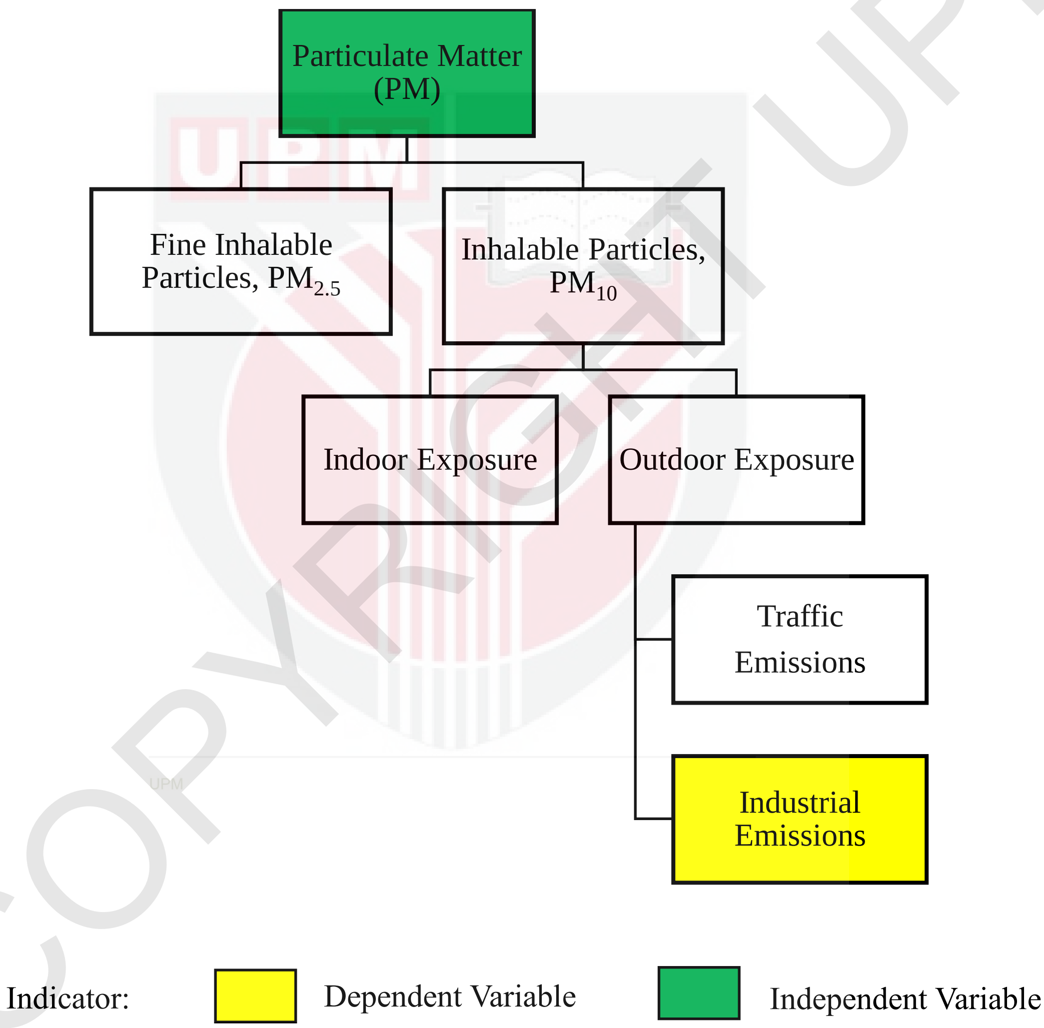


Figure 1.1: Conceptual Framework

1.6 Definition of Terms

1.6.1 Conceptual Definitions

1.6.1.1 Particulate Matter (PM_{10})

Inhalable particles with an aerodynamic diameters of 10 micrometres and smaller (US EPA, 2020).

1.6.1.2 Industrial Emissions

Industrial emissions are gas-borne pollutants that are emitted into the atmosphere from smokestacks of industrial plants.

1.6.1.3 Health Risk Assessment

Health risk assessment is the process of estimating the probability and nature of adverse health effects in humans who may be exposed to environmental contaminants (US EPA, 2016).

1.6.1.4 Non-carcinogenic Risk

Probability of a harm (non-cancerous) arising from exposure towards a chemical substance under specific conditions.

1.6.1.5 Estimated Daily Intake

The presumed daily exposure to or consumption of a nutrient or chemical residue (*Medical Dictionary*, 2009).

1.6.2 Operational Definition

1.6.2.1 Ambient Air Sample

The ambient air sample is collected using a TISCH High-Volume Air Sampler (HVAS) which uses a PM_{10} size selective inlet to collect particles with an aerodynamic diameter of 10µm or less. As the particles move through the inlet, the larger particles are trapped inside of the inlet as smaller PM_{10} particulates continue to travel through the sampler and are collected on the quartz filter paper. The ambient air sample obtained was then extracted in the laboratory.

CHAPTER 2

LITERATURE REVIEW

2.1 Industrial Air Pollution

Air pollution is one of the major and concerning environmental health issues**.** The World Health Organization (2019) has stated that seven million people worldwide had been killed by air pollution annually and it has been statistically proven that 90 out of 100 people inhale polluted air. Air might be polluted from man-made sources or they may exist as by-products of chemical reactions that occur in the atmosphere (Claxton et al., 2004). Although there have been many attempts to make the air quality better and to lessen climatic outflows in industrialized nations, air pollution is still viewed as a significant cause for adverse health effect in humans. Examples of air pollutants include organic solvents, respirable particles, aromatic amines, sulphur dioxide, carbon monoxide, and polycyclic aromatic hydrocarbons (PAHs). In 2007, Lewtas conducted a study that affirmed the dangerous mutagenic and carcinogenic properties of PAHs and their derivatives.

Living organisms take in different chemical compounds from the environment. Multiple chemical substances which include anthropogenic products are continuously emitted into the environment and are mainly destined to be in the ambient air. Chemical substances have been naturally occurring, but rapid industrialization has resulted in the use of more artificial chemicals. Based on the 2014 statistics of Pollutant Release and Transfer Registration (PRTR) from the Japanese national inventory, 80% to 90% of industrial emissions are released into the atmosphere. Not only that, the emission that was released into the air consist of Group 1 carcinogens that have been identified by the International Agency for Research on Cancer (IARC).

Although industrialization is important for the economic growth and development of a country, it can cause serious harm to its living population. Pope et al. (2002) have estimated that for each 10µg of fine particles per cubic meter, lung cancer mortality increases by 8%. This is in line with the finding from an epidemiologic study on the global burden of disease due to outdoor air pollution by Cohen et al., in 2005 that identified a positive correlation between urban air pollution and the development of lung cancer. A more severe air pollution issue will occur when industries are located closely to residential areas. This can be seen through a study on heritable mutation induction of close proximity to steel mills by Somers, Yauk, White, Parfett & Quinn in 2002 which have emphasized the need to study the genetic consequences of inhaling polluted industrial air.

2.2 Health Effects of PM_{10}

Particulate matter (PM) are tiny particles and liquid droplets that are present in the atmosphere. Based on the United States Environmental Protection Agency (US EPA), PM_{10} are inhalable particles with an aerodynamic diameter of less than and equal to 10 micrometre (see Figure 2.1). These particles can be emitted into the environment from natural sources (e.g., trees and vegetation) or anthropogenic sources (e.g., industrial processes and motor vehicle exhaust) (California Air Resource Board, 2020). However, PM_{10} such as SO_2 and NO_2 can also be formed through atmospheric chemical reactions. In Malaysia, starting from the year 2020, an area is in compliance with the 24-hour PM_{10} standard if it does not exceed 100 µg/m^3 level more than once per year on average over a three-year period (40 µg/m^3 for annual PM_{10} limit value). Ambient air quality standards takes into account the health of “sensitive” populations which include children, elderly and people with pre-existing adverse health conditions. Not only that, it also considers protection against animals, buildings and plants. (Afroz, R et.al, 2003).

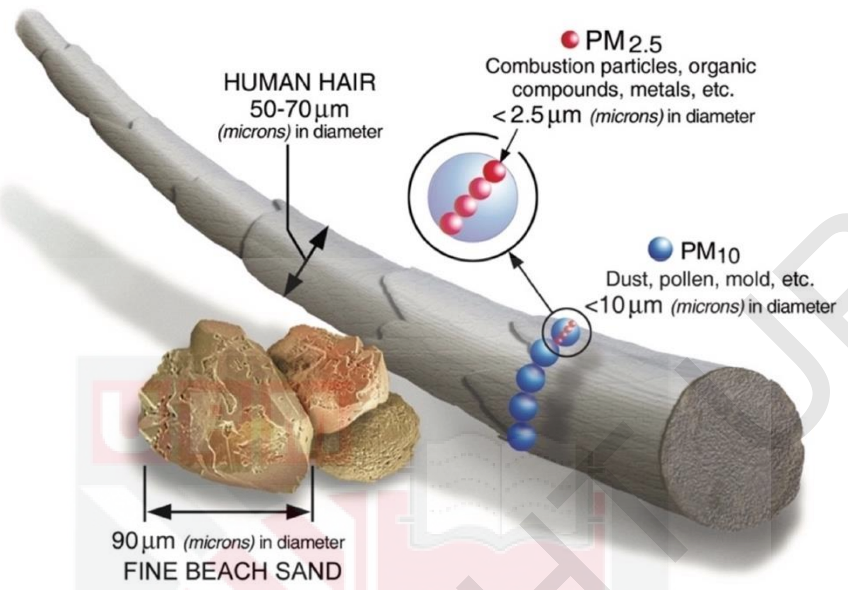


Figure 2.1: Size Comparison for Particulate Matter (PM)
(Source: USEPA)

As stated by the World Health Organization (WHO) in 2006, outdoor and indoor air pollution causes more than 2,000,000 premature deaths each year. PM_{10} particles are so tiny that when inhaled, it can penetrate deeply into the lungs. Exposure to high concentrations of PM_{10} can result in health effects ranging from acute to chronic effects (Malborough District Council, 2020). Epidemiology and laboratory research shows that ambient air pollutants contributed to respiratory diseases such as asthma and bronchitis (Ling, 2011; Chen & Kan, 2008; WHO, 2014). A study by Enger & Smith (2000) has highlighted a case of air pollution that occurred in Donora, Pennsylvania in October 1948 whereby pollutants from a zinc plant and steel mills were trapped in the valley which formed a dense fog that caused 17 fatalities and 5910 illnesses. Poor air quality has become a norm in megacities such as Seoul and Beijing that results from open burning, unregulated industries, and unmaintained powered mobiles. Hence, it causes a high rate of death in the countries (Enger & Smith, 2000).

Respiratory diseases and heart attacks are common for people who breathe in dirty air compared to matching groups in cleaner environments (Cunningham, et al 2005). In Malaysia, damages to respiratory system is the second biggest contributor (21.70%) to hospitalisation in Ministry of Health and private hospitals in 2013 (Malaysian Health Fact, 2014). During a haze episode in Malaysia in year 2005, researchers have found an increase in conjunctivitis, asthma, acute respiratory infection (ARI) cases. (Rafia et al., 2003; Norela et al., 2008). A similar incident occurred in 1997 whereby asthma and ARI cases increased by five folds from June to September (Rafia et al., 2003).

Air particulate has different effects to an exposed population, especially to the vulnerable subgroups. Children and infants are susceptible to air pollution as their respiratory, neuro and immune system are still developing until the age of six. Willhem (2008) stated that children have a greater lung capacity in relation to their body weight, which causes them to inhale more air per kilogram of body weight than adults. The higher respiratory rates increases the possibility of respiratory infections. Elderly individuals are vulnerable to air pollution as their immune system becomes less efficient. According to Poland, Ovsyannikova, Kennedy, Lambert and Kirkland (2014), with increasing age, the immune system undergoes deterioration in the ability to respond to infections and vaccination, which may give rise to morbidity and mortality due to infectious diseases. Besides that, individuals with pre-existing diseases such as asthma, fibrosis, hypertension and diabetes are also at risk of being susceptible to air pollution (Brook et al., 2010). Health risk evaluation and assessment is important to mitigate issues relating to air pollutants.

2.3 Health Risk Assessment of PM_{10}

According to the US EPA, human health risk assessment is the process of estimating the probability and nature of adverse health effects in humans who may be exposed to environmental contaminants. It is also a tool used in risk management for scientists and government officials to measure the probability of experiencing health problems for people who are in contact with toxic substances. Health problems may include cancer, irritation, or respiratory diseases. There are four steps in risk assessment process which are hazard identification, exposure assessment, dose-response assessment and risk characterization (US EPA, 2016). In hazard identification, evidence (e.g., case reports or formal studies) on health problems caused by a potential hazard is gathered. An exposure assessment estimates the amount and magnitude of exposure to an affected population. As for dose-response assessment, the association between exposure to different concentration of pollutants and its health outcomes is studied. Risk characterization is the final step of risk assessment as the result from exposure assessment and dose-response assessment will be combined to determine the likelihood that a substance can induce harm to an exposed individual or population (National Research Council, 1994).

Health risk assessment can be conducted using different tools. One of the tool has been developed by WHO European Center for Environment and Health is the Air Quality Health Impact Assessment (AirQ2.2.3) software, that has been utilized by a few scholars to determine the correlation between level of pollutants and its health implications (Fattore et al. 2011; Shakour et al. 2011). This tool uses a dose-response function that takes into account the main health parameters which are relative risk (RR) and baseline incidence (BI). The tool was proven to be effective in a study conducted by Khaniabadi et al., (2018) towards a population in Iran, to assess the health impacts of exposure towards PM_{10} and SO_2. The result showed that 4.2% of cardiovascular and 6.2% of respiratory mortality were linked to PM_{10} concentration of more than 10 μg/m^3 while 3.4% of cardiovascular and 2% respiratory death were related to SO_2 concentration of more than 10 μg/m^3. The same tool was used in a research conducted by Goudarzi et al., in 2017 to assess the risk of exposure to middle-eastern dust storms in the Iranian megacity of Kermanshah which led to thousands of hospitalizations each year due to respiratory illnesses and cardiovascular diseases.

Another commonly used health risk assessment method is adopted from US EPA which utilizes the average daily intake value and reference concentration of a specified pollutant from the Integrated Risk Information System (IRIS) to study the health implications from heavy metals exposure in factory and workshops (Fang, Yang & Xu, 2013). The assessment indicated that the hazard risk for non-carcinogenic metal in particulate matter monitored in several areas of the workshop were all above the safety level (HQ>1). Subsequently, the formula suggested by US EPA also deduced an alarming finding which indicated that children and adults breathing in particle-bound non-carcinogenic metals of PM_{10} within a school environment, particularly chromium, was far from negligible (Mohamad, Latif & Khan, 2016). Other study which has been conducted in Garfield County Colorado, where natural gas development is a major industry, has also utilized a similar method. Finding from the study, showed an increasing probability in developing cancer and non-cancerous health implications from its ambient benzene level (Coons and Walker, 2008).

CHAPTER 3

METHODOLOGY

3.1 Study Location

Ambient air was sampled at a strategic point in Sekolah Menengah Kebangsaan Taman Tuanku Jaafar (02°39.749' N, 101°59.930' E) (Garmin GPSMAP 64S) (see Figure 3.1) located in Negeri Sembilan. Taman Tuanku Jaafar is one of the major town in Negeri Sembilan which consist of multiple residential and industrialised area. The industrial area is characterized to be the main source of air pollution and the sampling site was located at approximately 1.5km (SW) from Taman Tuanku Jaafar industrial area which consisted mainly of manufacturing industries.

Figure 3.1: Aerial View of Study Location

3.2 Study Design

This is a cross-sectional study which aims to assess the mutagenic activity of industrial air samples collected in Taman Tuanku Jaafar, Negeri Sembilan. The air was sampled three times during weekdays and three time during weekends. Two air samples were taken on each sampling day which represents the daytime and night-time points. Each sample was taken for around 12 hours.

3.3 Sampling Technique

The samples were taken using a high-volume air sampler (TISCH TE-6070 PM_{10}) (Tisch Environmental Inc, United States of America) (see Figure 3.2) with a size-selective inlet (PM_{10}). Particulate matter were collected on Whatman™ quartz microfibre filters (QMA 20.3x25.4cm) (GE Healthcare Life Sciences, United Kingdom) that has been pre-fired at 500°C in a laboratory chamber furnace (Carbolite ELF116B 6L) (CARBOLITE GERO, United Kingdom) for 4 hours. The samples were taken at a flow rate of 1.08m^3/min (1080 L/min) for 12 hours, resulting in a total sampled air volume of about 777.6m^3 (normalised to standard conditions). All day-time (AM) samples were taken from 7a.m until 7p.m while the night-time (PM) samples were taken from 7p.m until 7a.m. Before each sampling runs, a new Dickson recorder chart (TE-106) (Tisch Environmental Inc, United States of America) was installed into the machine to ensure that the flow rate remains constant. The environmental condition was measured using a weather meter (Kestrel 5500) (Nielsen-Kellerman, United States of America). The quartz microfibre filters were changed manually after every cycle. The weight of the collected particulate matter on the filters was determined by weighing the filters before and after sampling (prior to weighing, 24 h conditioning at 20°C in desiccators) using the same balance (A&D Weighing GX-400 milligram scale Balance) (A&D Company, Japan). After sampling, filters were stored at −18°C.

Figure 3.2: TISCH High-Volume Air Sampler

3.4 Health Risk Assessment

Quantitative health risk assessment of non-carcinogenic risk of outdoor air inhalation was determined by using US EPA (2007) methodology. The analysis takes into account the sampled pollutant (PM_{10}) concentration and included guideline value for non-carcinogenic Reference Concentration (RfC) value.

3.4.1 Estimated Daily Intake

The Estimated Daily Intake, EDI was determined based on the generalized adult population. The formula (ATSDR 2005) to calculate the estimated daily intake is as follow:

$$EDI = (C \times IR \times AF \times F \times ED) / (BW \times AT)$$

Where,

EDI = Estimated daily intake (mg/kg body weight per day),

C = Contaminant concentration (mg/m^3),

IR = Intake rate (inhalation) (m^3/day),

AF = Bioavailability factor (unitless),

F = Frequency of exposure (days/year),

ED = Exposure duration (years),

BW = Body weight (kg) and

AT = Averaging time (non-carcinogenic) (ED X 365 days/year) (days).

The estimated daily intake was calculated with the use of the following numerical values: IR = 20 m^3/day average for an adult (EPA 1989d) ; AF = 1, with the assumption that 100% of inhaled pollution is bioavailable, F = 350 days/year, assuming that residents take an average of 2 weeks' vacation time away from their homes each year (EPA 1997) ; ED = 12 years, average duration of homeownership in the United States based on the 2018 1-year American Community Survey; BW = 70kg for average adult (EPA 1989d) and ; AT = 4380 days.

3.4.2 Non-carcinogenic Risk of Outdoor Air Inhalation

The US EPA (2007) method was used to calculate the non-carcinogenic risk value (HQ) of PM_{10} inhalation exposure. The formula is as follow:

$$HQ = EDI / RfC$$

Where,

HQ = Hazard quotient (unitless),

EDI = Estimated daily intake (mg/kg body weight per day) and,

RfC = Reference Concentration (mg/kg body weight per day).

The non-carcinogenic risk level (HQ) of inhalation exposure towards PM_{10} was calculated by comparing the estimated daily intake (EDI) to the estimated value of exposure that does not pose a threat to health, known as the Reference Concentration (RfC). The reference concentration value of PM_{10} was not available in the Integrated Risk Information System (IRIS). Therefore, the 24-hour guideline value for PM_{10} (0.1 mg/m^3) which is based on the New Malaysia Ambient Air Quality Standard (MAAQS) 2020. was used as a substitute for the reference concentration. If the HQ exceeded one, it is estimated that the level of PM_{10} in ambient air may inflict non-cancer effects to the population.

3.5 Quality Control

During the air sampling, the High Volume Air Sampler (HVAS) was located away from any obstacles to prevent restricted air flow. A Dickson recorder chart (TE-106) was placed inside the sampler to record any flow rate discrepancy. A secured electrical supply was obtained to operate the sampler and the sampler was ensured to be working properly. Filters were handled attentively using vinyl (non-powdered) gloves at all times. The filter was properly aligned on the screen so that an airtight seal was formed. A programmable timer was set at a sampling period of 12 hours, and the sampling time, weather information, and filter number was recorded. All filters were visually inspected thoroughly before being equilibrated in the conditioning environment for 24 hours before and after sampling. The conditioning environment temperature was around 20°C inside a desiccator. At the end of sampling, the filter was removed carefully by only touching the outer edge, and then folded in half, so that only surfaces with collected particles were in contact with one another. Then it was wrapped in an aluminium foil, and placed inside a clean zip lock bag. In the process of weighing the filter paper and chemical substances, the weighing scale was ensured to be calibrated. Before weighing, the filter and the weighing scale was swiftly brushed with anti-static brush to eliminate any static which may affect the balance result.

3.6 Data Analysis

All the data were analysed by using IBM SPSS (Statistic Package for Social Science) Version 26 and Microsoft Excel. The details of each statistical analysis are shown in Table 3.1.

Table 3.1: Summary of Research Objectives and Statistical Analysis

Research Objective	Statistical Analysis
1. To determine the level of PM_{10} in the air sample from industrial area and compare it with the permissible limit value in Malaysia.	One sample T-test
2. To compare the level of PM_{10} collected on weekdays and weekends.	Independent T-test
3. To compare the level of PM_{10} collected during daytime and night-time.	
4. To evaluate the estimated daily intake of PM_{10} via inhalation.	None
5. To assess the non-carcinogenic risk of PM_{10} via inhalation.	

CHAPTER 4

RESULTS

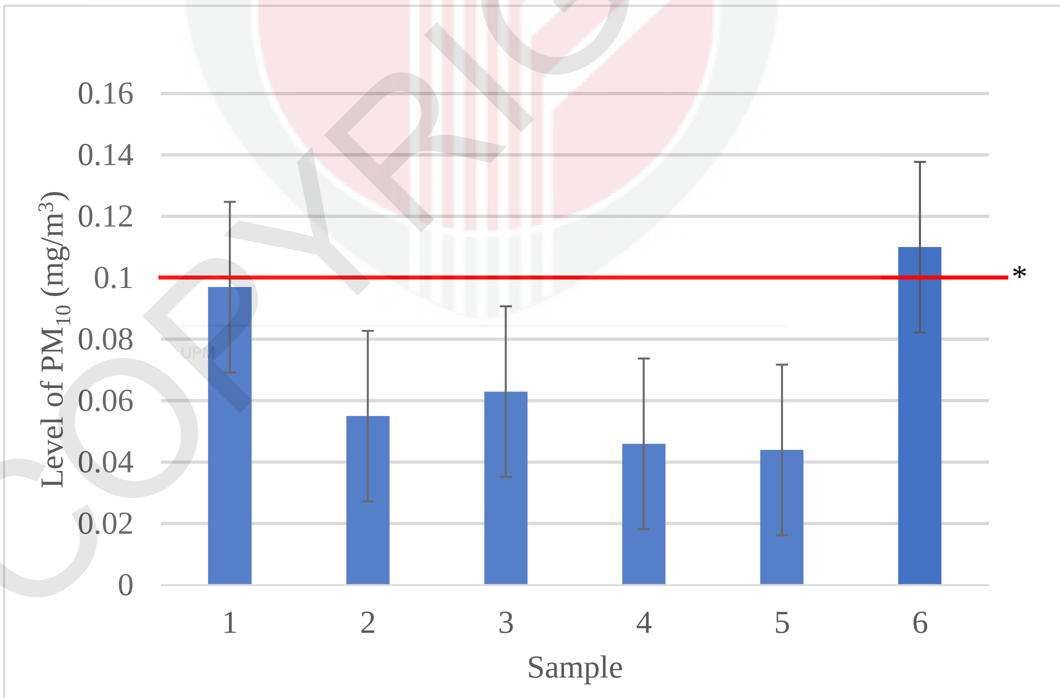
4.1 Particle Concentrations and Meteorological Conditions

Table 4.1 provides an overview of the meteorological conditions during a 12-hour sampling period and summarises the amount of airborne PM_{10} collected on the filters. The amount ranged from 0.003 mg/m^3 to 0.087 mg/m^3 with an average of 0.035 ± 0.024 mg/m^3. Both sample 9 and sample 2 were collected on a weekday. The sample with the lowest PM_{10} concentrations was collected from 7a.m until 7p.m while the sample with the highest PM_{10} concentration was collected from 7p.m until 7a.m. The mean (12-hour) ambient temperature varied from 25°C to 34°C and the average temperature during sampling was 29.7°C. The registered wind speeds ranged from 2 to 11 km/hr with a mean of 5.66 km/hr. As for the humidity, the highest was 93% and lowest reading was 43%. Based on the 24-hour PM_{10} concentration in Table 2, the highest reading was collected on a weekend which was 0.110 mg/m^3. In contrast to that, the lowest reading of 0.044 mg/m^3 was obtained from a weekday. The mean concentration of PM_{10} was 0.069 ± 0.028 mg/m^3.

Table 4.1: Sampling Conditions and Amount of Particulate Matter Collected

Sample	Date	Time of Day	Wind Speed (km/hr)	Ambient Temperature (°C)	Humidity (%)	PM_{10} (12 hour) (mg/m^3)	PM_{10} (24 hour) (AM+PM) (mg/m^3)
1	28.2.2020	AM	11	33	48	0.010	0.097
2	28.2.2020	PM	5	26	62	0.087	
3	29.2.2020	AM	11	34	43	0.032	0.055
4	29.2.2020	PM	2	26	76	0.023	
5	1.3.2020	AM	6	34	61	0.035	0.063
6	1.3.2020	PM	5	26	82	0.028	
7	2.3.2020	AM	10	33	66	0.015	0.046
8	2.3.2020	PM	3	28	79	0.031	
9	3.3.2020	AM	3	34	56	0.003	0.044
10	3.3.2020	PM	2	28	82	0.041	
11	7.3.2020	AM	8	30	74	0.073	0.110
12	7.3.2020	PM	2	25	93	0.037	

Figure 4.1 shows the level of PM_{10} for each sample collected as comparison to the permissible exposure limit. According to the Shapiro-Wilk normality test, the data for the concentration of PM_{10} was normally distributed. One sample T-test was used to compare mean of PM_{10} concentration (24 hour sampling period) with the 24-hour guideline value for PM_{10} (0.1 mg/m^3) which is based on the New Malaysia Ambient Air Quality Standard (MAAQS) 2020. It was found that the mean of PM_{10} concentration was significantly lower than the value set by MAAQS, $t(5)=-2.721 (p<0.05)$. However, sample 1 showed an alarming level of PM_{10} of 0.097 mg/m^3 and sample 6 exceeded the permissible limit by a slightly higher level of 0.110 mg/m^3.



*MAAQS 2020 24-Hour PM_{10} Guideline Value

Figure 4.1: Level of PM_{10} Collected for Each Sample

Figure 4.2 represents the mean level of PM_{10} collected on weekday and weekend. It was shown that the mean of PM_{10} level collected on weekend was higher (0.076 ± 0.030 mg/m^3) as compared to weekday (0.062 ± 0.030 mg/m^3). However, there was no significant difference between level of PM_{10} during weekday and weekend with $t(4)=-0.56$ ($p>0.05$). Figure 4.3 shows the mean level of PM_{10} gathered during day-time (AM) and night-time (PM). The sampling period for AM starts from 7a.m until 7p.m while the sampling period for PM starts from 7p.m until 7a.m. It was shown that the level of PM_{10} collected during night-time (0.041 ± 0.023 mg/m^3) was higher than the level of PM_{10} gathered during day-time (0.028 ± 0.025 mg/m^3). However, there was no significant difference in the PM_{10} concentration between both sampling time with $t(10)=-0.936$,($p>0.05$).

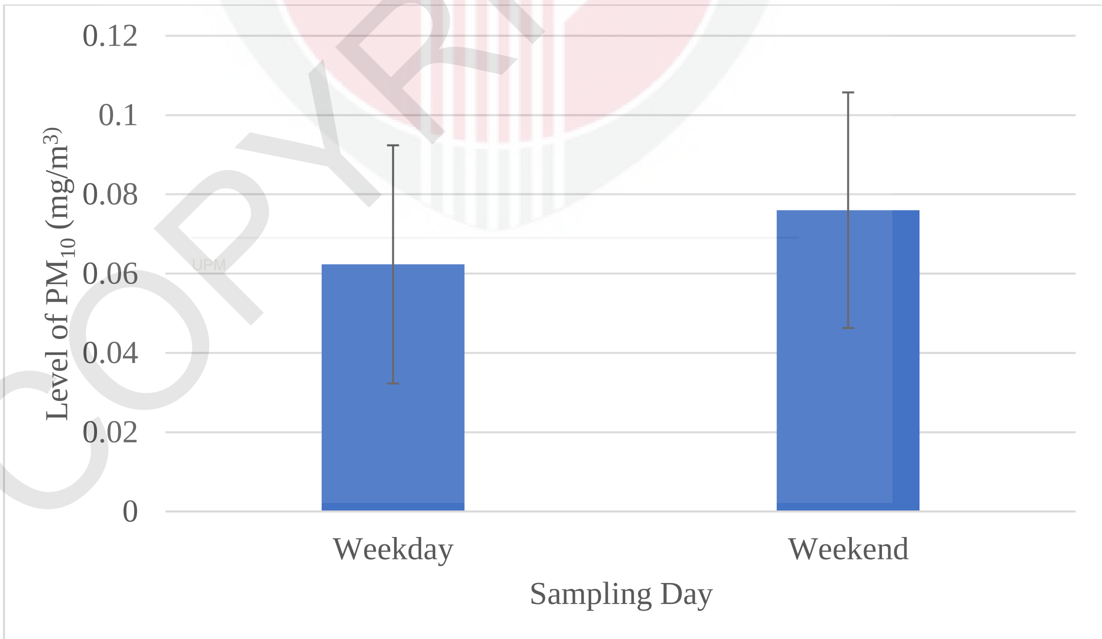


Figure 4.2: Mean Level of PM_{10} Collected on Weekday and Weekend

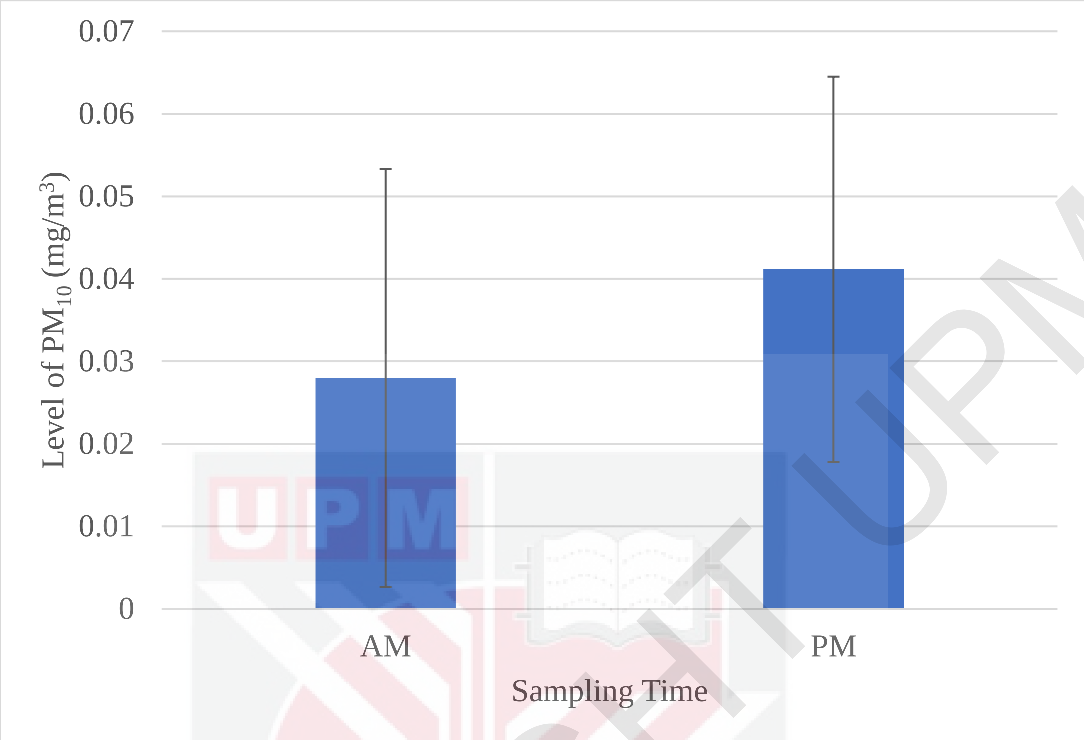


Figure 4.3: Mean Level of PM_{10} Collected During Daytime (AM) and Night-time (PM)

4.2 Estimated Daily Intake

The estimated daily intake (EDI) of PM_{10} was calculated based on the Public Health Assessment Guidance Manual from Agency for Toxic Substances and Disease Registry (ATSDR). The EDI of the general adult population in Taman Tuanku Jaafar were calculated and tabulated in Table 4.2. Variables such as PM_{10} concentration, inhalation rate, contaminant availability factor, exposure frequency, exposure duration, body weight and averaging time were taken into account to evaluate the EDI. The calculated EDI ranged from 0.0131 mg/kg/day to 0.0326 mg/kg/day.

Table 4.2: Estimated Daily Intake for 24-Hour PM_{10} Concentration

PM_{10} (mg/m^3)	**Estimated Daily Intake (EDI) (mg/kg per day)**
0.097	0.0288
0.055	0.0163
0.063	0.0187
0.046	0.0137
0.044	0.0131
0.110	0.0326

4.3 Non-carcinogenic Risk of Outdoor PM_{10}

Based on the calculated estimated daily intake rates and taking into account the reference concentration value for PM_{10} (MAAQS 2020 24-Hour PM_{10} Guideline Value), hazard quotient (HQ) values were calculated. Table 4.3 shows the HQ value for all the six (24-hour) PM_{10} concentration in Taman Tuanku Jaafar that ranges from 0.13 to 0.33. Based on this data, none of the sample calculated exceeded 1. Thus, it indicates that the estimated level of PM_{10} in ambient air may not inflict non-cancerous effects to the general adult population in Taman Tuanku Jaafar.

Table 4.3: Hazard Quotient for 24-Hour PM_{10} Concentration

PM_{10} (mg/m^3)	**Hazard Quotient (HQ)**
0.097	0.29
0.055	0.16
0.063	0.19
0.046	0.14
0.044	0.13
0.110	0.33

CHAPTER 5

DISCUSSION

5.1 Particle Concentrations and Meteorological Conditions

The sample was collected in an open area at SMK Taman Tuanku Jaafar which is located approximately 1.5km away from Taman Tuanku Jaafar industrial area. Average concentration of PM_{10} obtained in a period of 12-hours and 24 hours are 0.035 ± 0.024 mg/m^3 and 0.069 ± 0.028 mg/m^3 respectively. Both average reading did not exceed the New Malaysia Ambient Air Quality Standard (MAAQS) (2020) 24-hour guideline value for PM_{10} which is 0.1 mg/m$^{3.}$ This is in contrast with other findings which showed that industrial air sample are heavily polluted with PM_{10} particles (Ragosta et al., 2006). The low pollutant concentration in this study may be due to the fact that the industries in Malaysia are required to submit their monthly emission levels to the Department of Environment Malaysia. This helps the industries to obey the permissible limit which has been outlined in the existing national legislations.

However, when looking into Figure 4.1, sample 6 exceeded the permissible limit. On the following day, the highest day-time PM_{10} concentration was recorded which is 0.073 mg/m^3. This high level of PM_{10} may be affected by the meteorological condition in Taman Tuanku Jaafar. According to Giri, Murthy, Adhikary and Khanal

(2006), the distribution of these tiny pollutants are indeed affected by wind speed, environmental temperature and humidity. This statement has also been agreed by other researches (Alpert,*etal.*,1998; Monn, 2001) which indicated that suspended particles in ambient air is affected by wind speed, wind direction, relative humidity and precipitation. For this study, the meteorological conditions that were taken into account were wind speed, ambient temperature, and relative humidity.

When the temperature rises, it affects the movement of the air. As warm air is less dense than cooler air, it rises and traps air pollutant which causes its concentration to increase. Many studies have associated high temperature with air pollution (Ren and Tong, 2006; Stafoggia et al., 2008). Furthermore, the association has worsened effects on the vulnerable groups (Zeka et al., 2006; Zanobetti and Schwartz, 2000). In this study there was no clear relationship between relative humidity and levels of PM_{10}. However, other study have shown inversely proportional relationship between the two variables (Barmpadimos, Hueglin, Keller, Henne & Prévôt, 2011). Moisture binds to particulate matter and affect its natural deposition. The particles will become bigger and cause 'dry deposition' that reduces the ambient PM_{10} concentration (Hernandez, G., Berry, T. A., Wallis, S., & Poyner, D., 2017). As for wind speed, it acts as a transport that disperses the pollutant. Based on Table 4.1, it has been shown that as the wind speed decreases, the level of PM_{10} increases. This is line with a study by Ayanlade and Oyegbade in 2016 which also proved that wind speed has a significant influence on the particle concentration.

Interestingly, there was no major difference between the mean level of PM_{10} collected during day-time (7a.m to 7p.m) versus night-time (7p.m to 7a.m). The result in Figure 4.3 shows that the particulate level during night time was still slightly higher compared to day-time. This may be due to the fact that in Malaysia, heavy-duty industrial trucks are encouraged to operate during night time. Wang (2018) have conducted a study on vehicle emission and found that large trucks are a major source of black carbon emission. Likewise, through statistical analysis, there was no significant difference for the average PM_{10} collected during weekday and weekend. As shown in Figure 4.2, the average level of PM_{10} was higher on weekend compared to weekday, with only 0.0137 mg/m^3 difference. This is because industries in Malaysia usually operates seven days per week which results in an indistinguishable average daily emission.

5.2 Health Risk Assessment

The health risk assessment consist of the estimated daily intake (EDI) of PM_{10} for the general adult population and the non-carcinogenic hazard quotient. The result showed that the average estimated daily intake was 0.0205 kg/mg/day. The highest EDI calculated was 0.0326 mg/kg/day. Although the value obtained was low, it might not be safe for the susceptible groups. Children have higher breathing rates compared to adults at rest (Lockett, 2019). This allows more air to pass through their lungs. A study on healthy infants by Wiriya, Prapamontol & Chantara (2013) showed positive association between increased respiratory symptoms and moderate levels of air pollution. In cases of elderly, this subgroup is vulnerable to even low level of particulates because they have a higher prevalence of underlying diseases that aggravates the effects of air pollution (Simoni et al., 2003).

Based on the estimated daily intake, and taking into account the reference concentration of PM_{10}, hazard quotient (HQ) values were calculated. This study focuses on non-carcinogenic health effects, whereby the allowed non-carcinogenic risk is when HQ is less than 1. In this study, the highest HQ obtained was 0.33 which is equivalent to one third of the allowed value. Since the hazard quotient obtained is in the safe range, it signifies that the risk is negligible. Current practices in controlling the PM_{10} level can be maintained. However it should be noted that constant monitoring should still be carried out since particulate matter is considered to be Group 1 carcinogen by the International Agency for Research on Cancer (IARC). Not only that, the calculation was based solely on the general adult population. Infants and children are more likely to be at risk (HQ>1) from exposure towards PM_{10} (Morakinyo, Adebowale, Mokgobu & Mukhola, 2017).

CHAPTER 6

CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

6.1 Conclusion

This study showed that the PM_{10} concentration in air sample from Taman Tuanku Jaafar industrial area was below the national guideline value. This indicates that there is a low possibility of acquiring adverse health effects from inhaling the particulate matter in the area. Independent T-test analysis of the result obtained also proved that there is no significant difference between the PM_{10} concentration collected during day-time versus night time, and weekday versus weekend. The hazard quotient was lower than the acceptable value which means that the risk of non-cancerous effects to the population is negligible. However, future studies on the effects of air pollution should still be carried out as it is a rising threat to human health, especially to the vulnerable groups such as children, elderly and those with pre-existing respiratory diseases.

6.2 Limitations

I acknowledge several limitations in this research. First of all, the number of sampling point is insufficient. This makes it difficult to associate the PM_{10} concentration with industrial activities. Moreover, the reference concentration value for PM_{10} in general was unavailable in the Integrated Risk Information System (IRIS). Due to this limitation, it may effect actual EDI value that has been calculated. Last but not least, this study only assess the health risk on general adult population. The assessment should should take into account the risk for susceptible groups as they experience more complication from exposure to air pollution.

6.3 Recommendations

Future studies should conduct chemical characterization test to assess the interaction between each pollutant and its health effects. This is because each pollutant is unique and has its own mode of action towards the human health. Next, the number of sampling points could be increased to ensure validity in the result of exposure towards specific pollutant. In relation to that, the exact source of pollutant can also be determined. Lastly, health risk on vulnerable subgroup should be carried out in order to fully cater for the whole population.

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APPENDICES

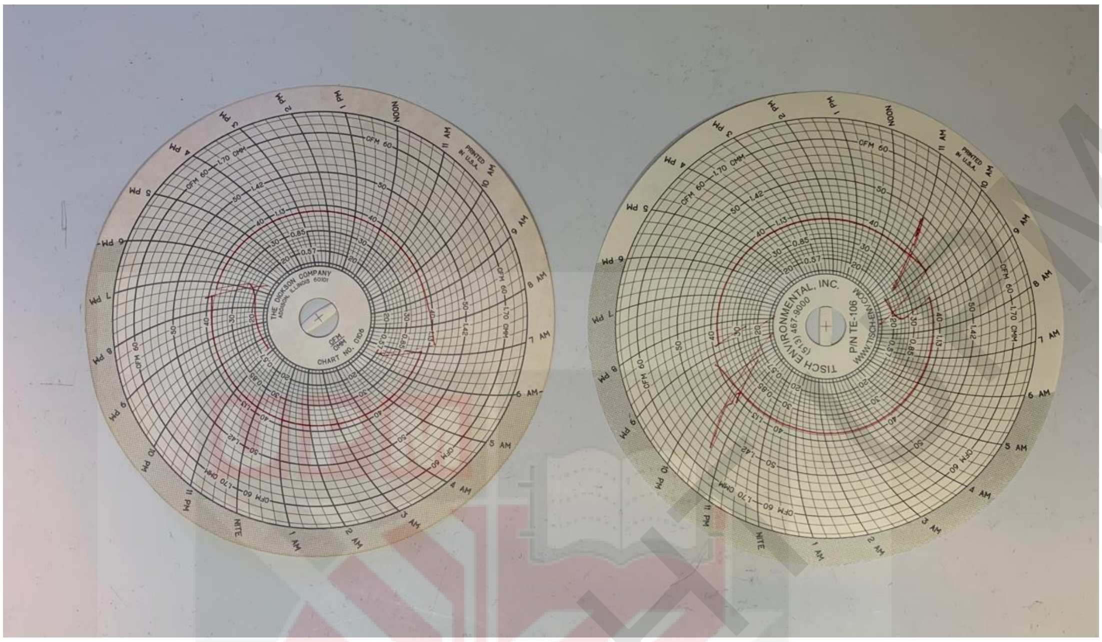

Figure 7.1: Flow Rate Reading on Dickson Recorder Chart (TE-106)

Figure 7.2: Wrapped Filter Paper in a Zip Lock Bag

Figure 7.4: Manual Filter Paper Exchange Process for HVAS